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Nidelva River bank modification report.

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Report

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Report

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FOREWORDS

The report is part of the Samfunnets plans for expanison. These plans include a filling into Nidelva to secure the slope between Upper Bakklandet – Lower Singsaker. The objective of this study is to estimate changes in flowpattern, flow velocities, flood level and possible changes in erosion risk due to the geometry modification, stated in document code 418290-RIG-NOT-002, Multiconsult.

Thanks to Ingebrigt Bævre, Orvedal Kjartan at NVE and Knut Alfredsen for providing data for this report.

Contents

Figures & Tables

I. INTRODUCTION

1.1. Description of the task

The report is part of the Samfunnets plans for expanison. These plans include a filling into Nidelva to secure the slope between Upper Bakklandet – Lower Singsaker. The objective of this study is to estimate changes in flowpattern, flow velocities, flood level and possible changes in erosion risk due to the geometry modification, stated in document code 418290-RIG-NOT-002, Multiconsult.

For this purpose the River Analysis System HEC-RAS is used.

1.2. Description of the waterway and modification work

The river bank modification will be started from downstream Elgeseter bru and length up to 300m. The design was consulted by Multiconsult and are displayed as below:

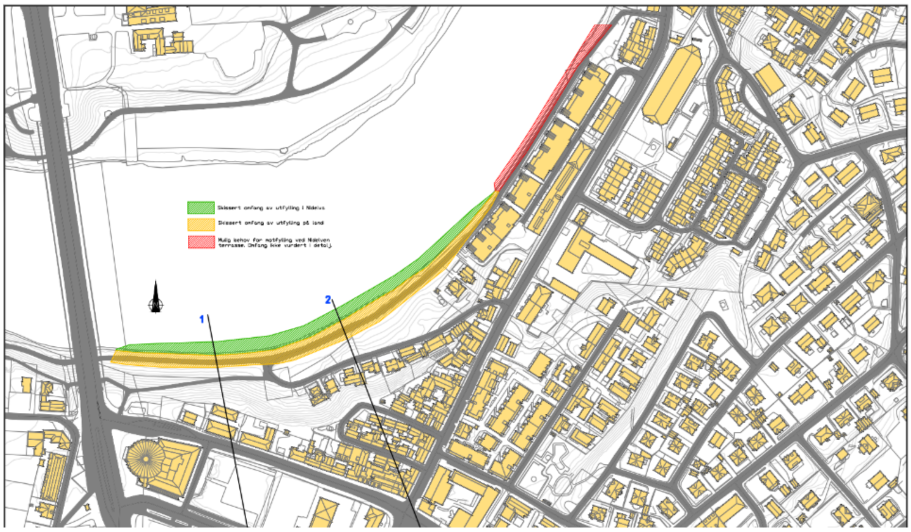


Figure 1: Riverbank design (Gylland, Feb 2017)

The filling will begin from -2.61m depth in profile 1 and -2.63m in profile 2 and extend up to 7m towards the river bed. Those parameters were used later in Hec-Ras to simulate the river flow after the modification.

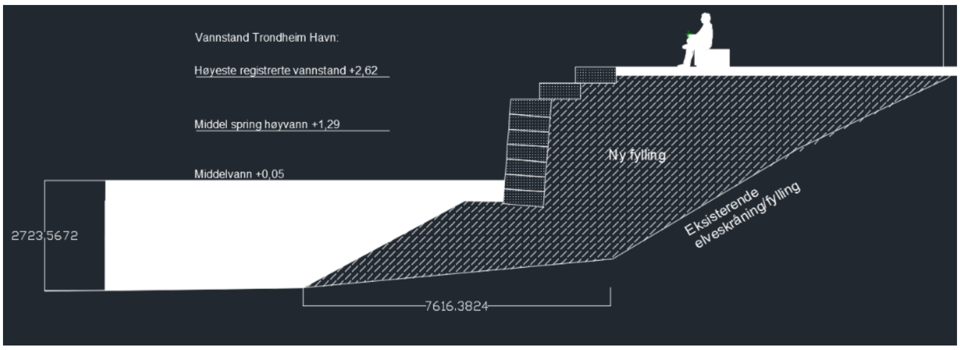


Figure 2: Cross section 1 profile

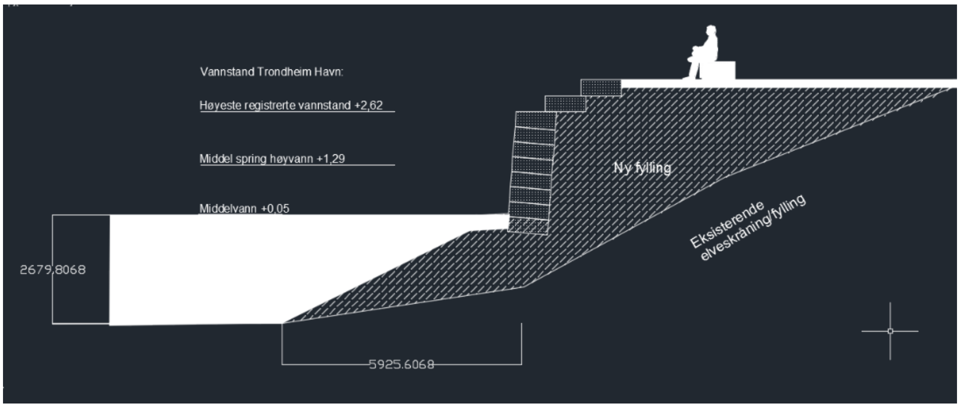


Figure 3: Cross section 2 profile

II. METHODOLOGY

HecRas was used to answer the question how river bank modification at Elgeseter Bru effects the water level and velocites. The model was built from downstream Sluppen bru to Trondheim havn, while the area of interest is from upstream Elgseter bru to about 300m downstream Elgeseter bru, or from cross section 25 → 28 in fig 4.

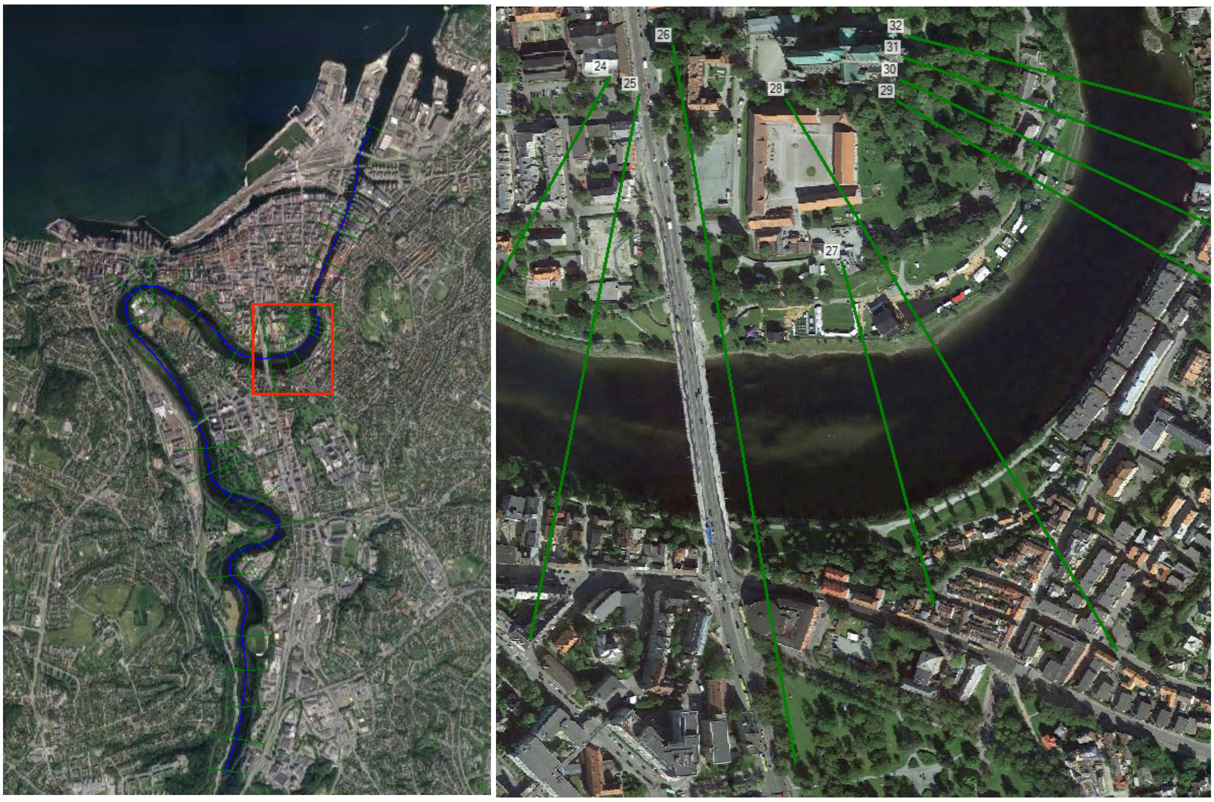
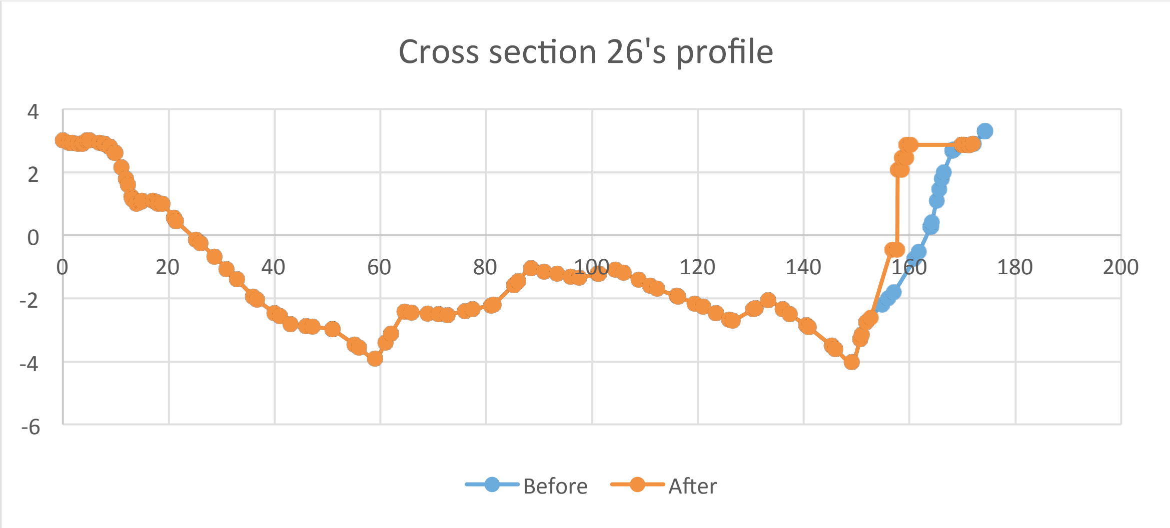
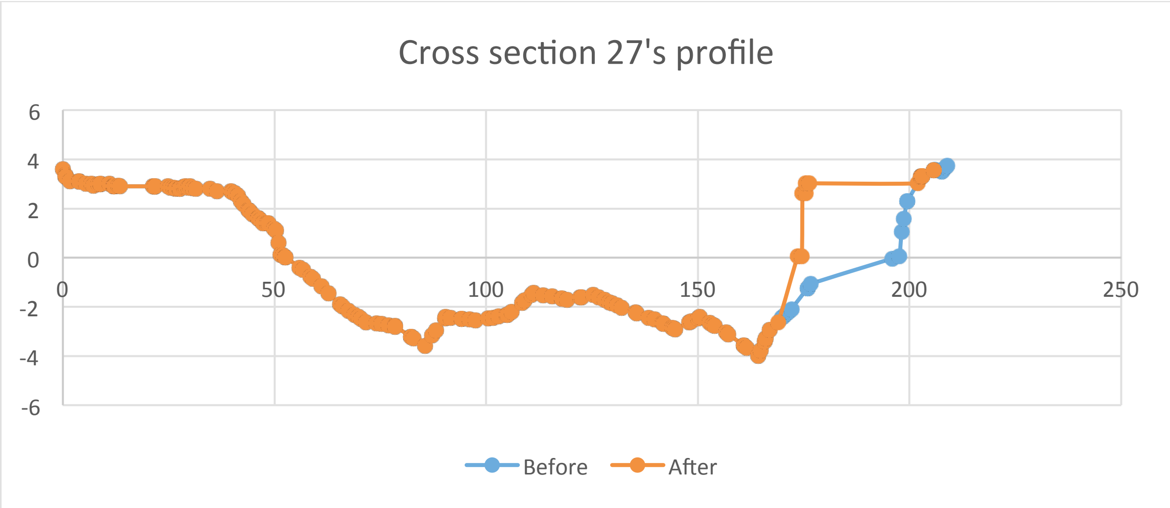


Figure 4: Hec-Ras model setup location

The model's geometry was built from Digital Elevation Map (DEM 1m laser dataset), downloaded from Hoydedata.no. River Cross sections profiles and flow data was provided by NVE and NTNU in various measurement campaigns. The model was calibrated using observed flood data to simulate the river flow before filling work.

After that, the geometry was adjusted to simulate the impact of the modification. 3 cross sections' parameters were changed to adapt to new geometry profile and are displayed as below:





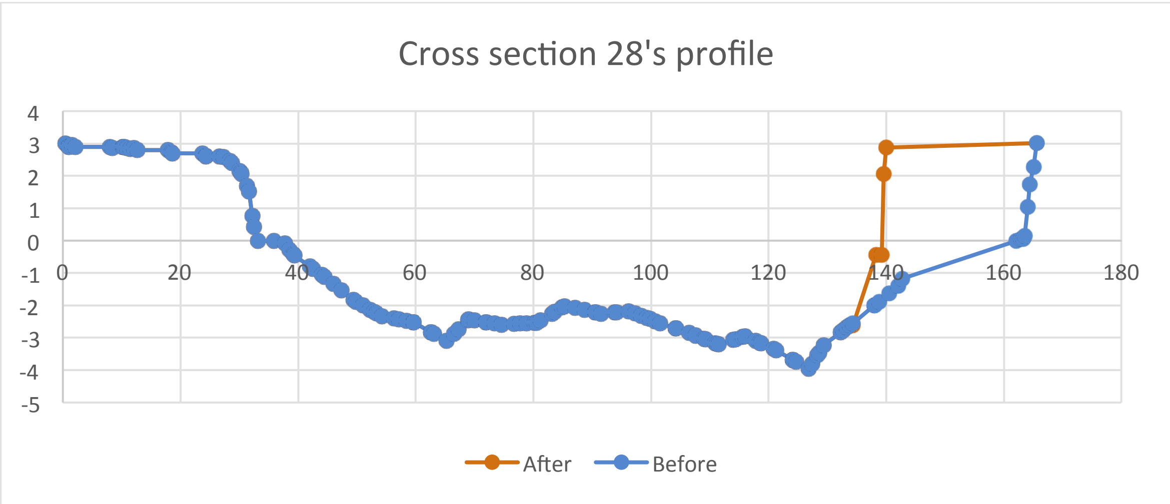


Figure 5: Geometry profiles for Filling work

Two scenarios were used to estimate flow changes after new geometry profile: daily hydropower peaking with low/medium tide water level and flood with return period of 500 years. Both scenarios were tested with low and average tide water level. Low tide is used to estimate maximum water velocity at the interested area, and from that the potential erosion at the river bed. Similarly, average tide water level is used for estimating flood level and to simulate normal river conditions. The downstream and upstream boundary condition setups are described as table below[1]:

Scenario no.	Describe	Upstream boundary condition	Downstream boundary condition
1	Hydropeaking with low/average tide water level	Normal depth Slope= 0.001, $Q = 140m^3/s$	Known water stage 0.73m (low tide) and 1.65m (average tide)
2	Flood with repeat interval 500 years, low/average tide water level	Normal depth Slope= 0.001, $Q_{500} = 955m^3/s$	

Table 1: Simulation scenarios

III. RESULTS & DISCUSSIONS

3.1. Calibration results

Calibration results between observed and simulated flow data are displayed as figure below. The X-axis is river length [m] and Y-axis is water elevation [m].

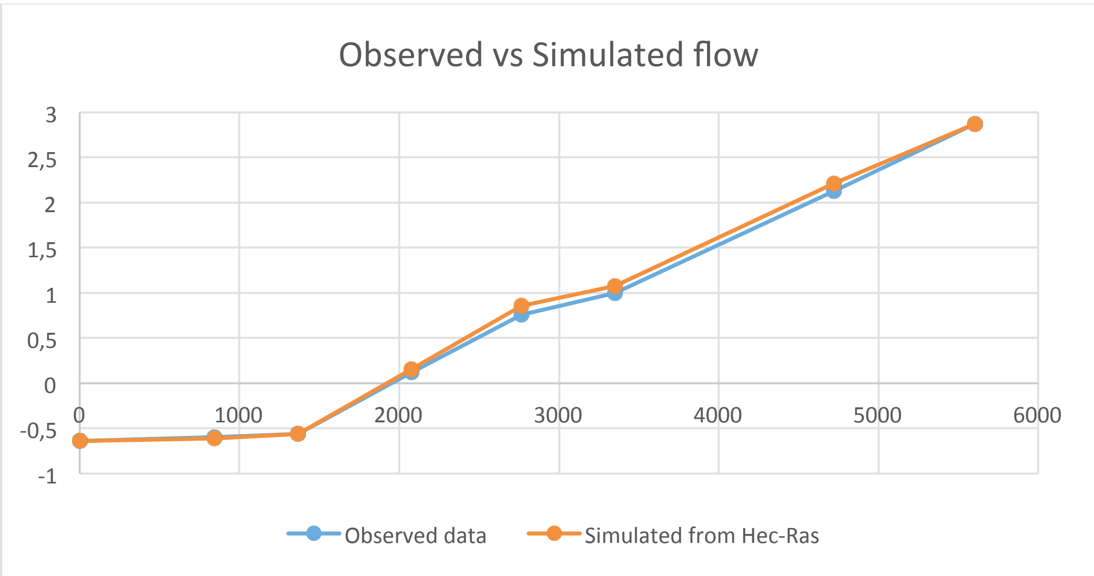


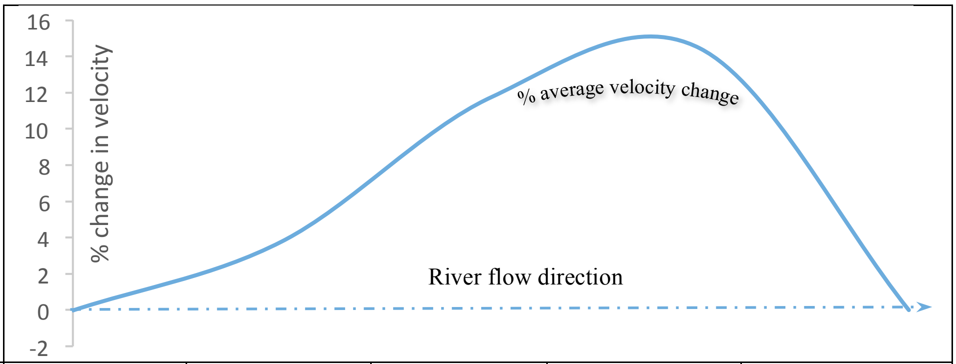
Figure 6: Hec-Ras calibration result

Maximum deviation between observed and simulated water surface elevation are 9.6 cm and 0.1 cm respectively, Nash-Sutcliffe Efficiency value $R^2 = 0.999$. This indicates that the model is able to simulate the flow conditions at this strech in Nidelva and can be used for further analysis of profile changes.

[1] The data was taken from (Karverket, 2018), (Bævre, 6/2001) and (Tor Haakon Bakken, 2016)

3.2. Effect of modification work on river velocity

Average velocity channel changes under average tide water level

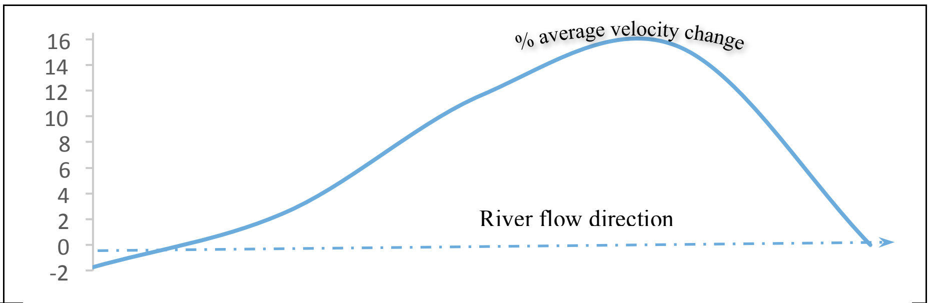


Q = 140 m^3/s

River cross section	25	26	27	28	29
Velocity channel before	0.39	0.26	0.26	0.29	0.32
Velocity channel after	0.39	0.27	0.29	0.33	0.32
% change	-0.028	3.786	11.736	**14.445**	0
Q = 955 m^3/s					
Velocity channel before	2.32	1.55	1.59	1.79	2.09
Velocity channel after	2.29	1.60	1.79	2.08	2.09
% change	-1.08	3.209	12.622	**16.232**	0

Table 2: Velocity changes under normal tide water surface elevation

Average velocity channel changes under low tide water level



Q = 140 m^3/s

River cross section	25	26	27	28	29
Velocity channel before	0.53	0.34	0.35	0.38	0.42
Velocity channel after	0.53	0.35	0.38	0.43	0.42
% change	-0.1	3.5	9.8	**12.0**	0
Q = 955 m^3/s					
Velocity channel before	2.74	1.80	1.87	2.14	2.56
Velocity channel after	2.69	1.85	2.09	2.47	2.56
% change	-1.8	2.6	11.7	**15.5**	0

Table 3: Velocity changes under low tide water surface elevation

Following table above, the water velocity is slowed down a little bit at cross section 25 (before the modification work), increase gradually until cross section 28 (at the end of the filling) and return back to normal stage at nearest downstream cross section. Having up to 16% in velocity change indicates that there may be erosion problem at the river bed, and so this need to be investigated further to identify potential erosion area and propose mitigation work.

Velocity distribution over cross section after modification work

The purpose of velocity distribution mapping is to identify the possible erosion area in the river and to visualize how the velocity changes along the filling area. A total of 45 subsections were divided in each cross section: 5 subsections for each overbank and 35 for main channel.

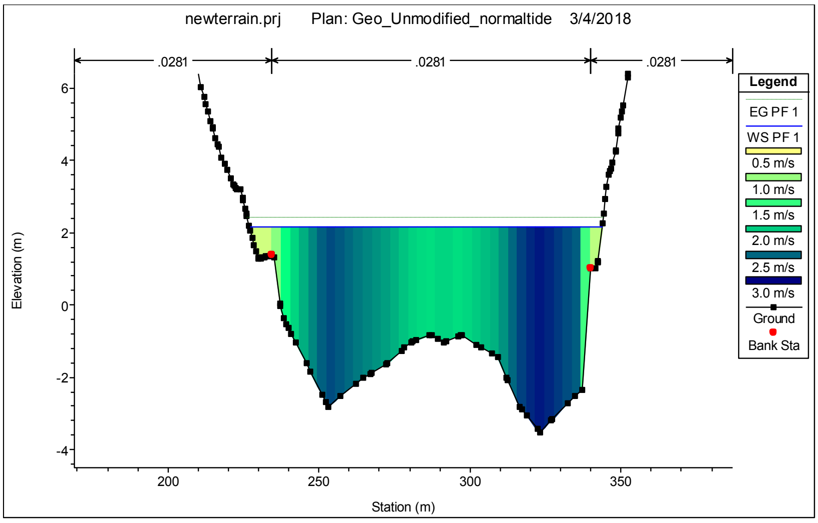


Figure 7: Example of Cross-sectional velocity distribution

After that, the velocity distribution was compared as illustrated in

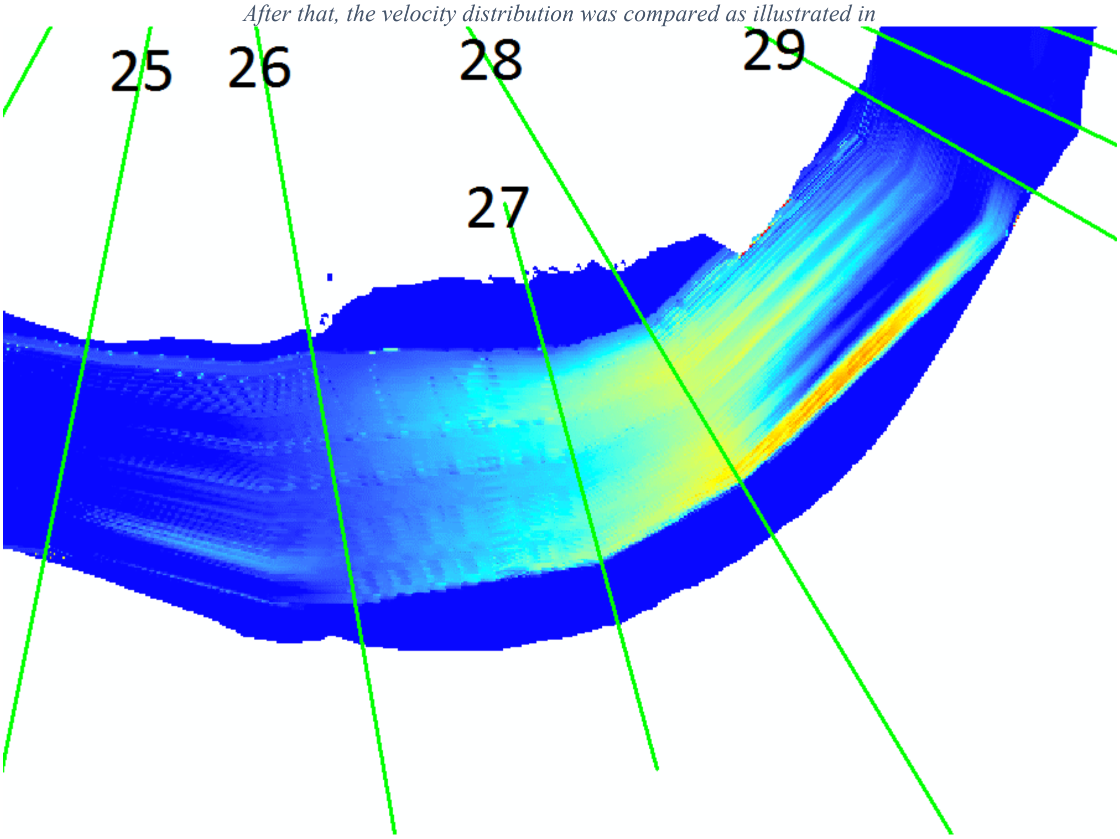


Figure 8. The largest changes are at profile 27 and 28 and are given in table 4 below:

Scenario	Tide level	Profile 27		Profile 28	
		Before	After	Before	After
Scenario 1; q=140m3/s	Low	0.44	0.47	0.49	0.53
Scenario 1; q=140m3/s	Average	0.32	0.35	0.36	0.4
Scenario 2; q=955 m3/s	Low	2.22	2.52	2.65	2.98
Scenario 2; q=955 m3/s	Average	1.91	2.11	2.17	2.46

Table 4: Maximum increase in velocities in the two scenarios and at different tide water level.

where the max velocities increased from 0.44 → 0.47 and 0.49 → 0.53 at profile 27 and 28 respectively at low tide in scenario 1. Similarly, at low tide scenario 2, the velocity increase from 2.22 → 2.52 and from 2.65 → 2.98. Details velocity table is given in appendix 2. Generally, water velocity in average tide condition is lower than in low tide condition for both scenarios.

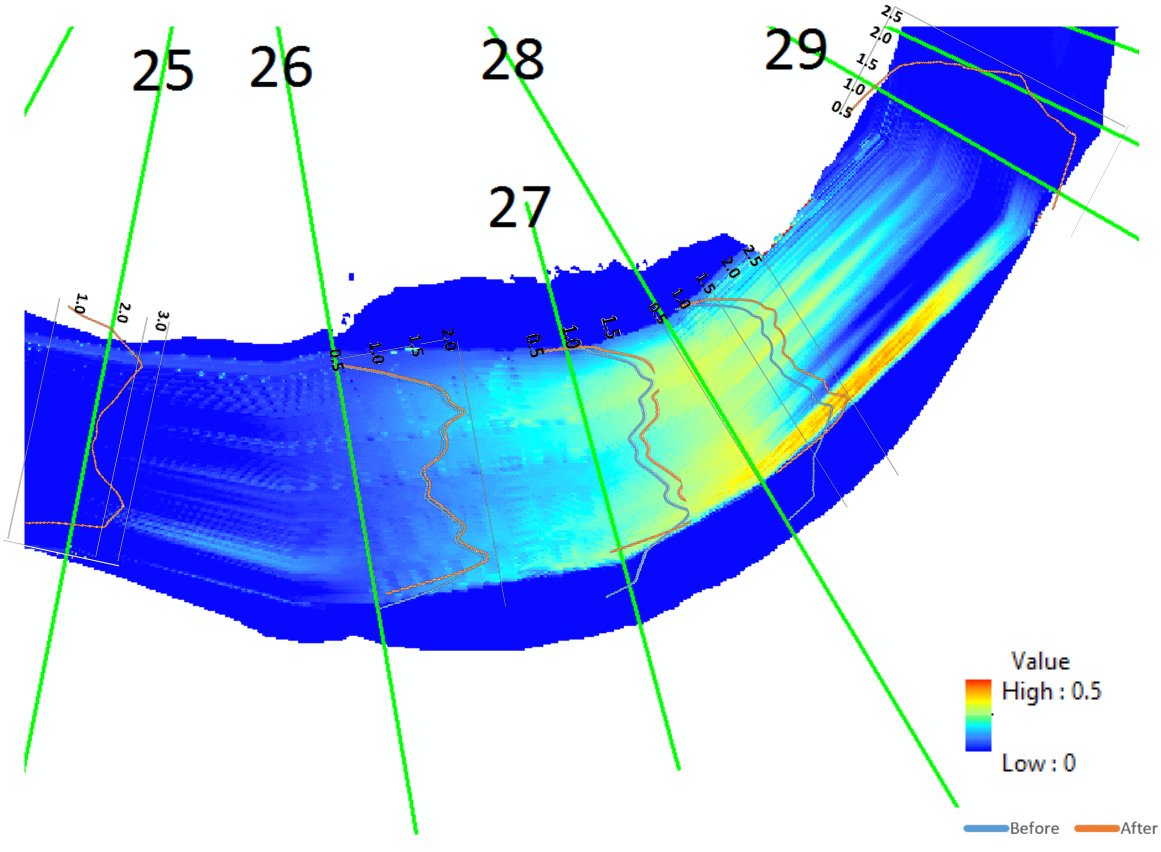


Figure 8: Velocity (lines) before and after filling and change in velocity (map) due to the filling.

3.3. River bed protection proposal

This report uses Shield Diagram (Ponce, 1989) to calculate required mean diameter for shield layer in the river bed using following equations:

$$\tau_{c*} = \tau_{b*} = \frac{\tau_b}{(\rho_s - \rho_f)gD} \#(1)$$

$$\tau_b = \rho_f ghS \#(2)$$

In which:

τ_{b*}	dimensionless shear stress (Shields parameter)
τ_{c*}	dimensionless critical shear stress
τ_b	river bed shear stress [N/m^2]
D	mean particle diameter [m]
ρ_s	density of particle [kg/m^3]
ρ_f	density of water [kg/m^3]
g	gravity acceleration [m/s^2]
h	water depth [m] (includes water stage and min channel elevation)

For safety reason, min channel elevation and average river slope S = 0.001 were used for calculation instead of local slope S = 0.00073 (from cross section 25-28).

The calculation used scenario 1, Q = 140m^3/s under normal tide condition. The parameters are displayed as table 5:

Cross section	27	28
Water stage elevation [m]	1.66	1.66
Min channel elevation [m]	-4.0	-3.97
Dimensionless critical shear stress	0.06	0.06
Density of particles [kg/m^3]	2650	2650
Bottom slope	Use river slope S = 0.001	
Bed shear stress calculated from equation (2) [N/m^2]	56.6	56.3
Calculated d_{50} [mm]	**57**	**57**

Table 5: Proposed shield layer for river bed protection

Priliminary estimates indicates a layer of stone with mean diameter of at least 57 mm is recommended for river bed protection under considered conditions. However, the final decision should be made after performing a field investigation to determine nature grain size distribution at the area and compare with recommended d_{50}.

Figure 9: Area of highest changes in velocity and of potential interest for investigations related to erosion potential

3.4. Floodplain mapping for Q500 after geometry modification

Not any significant change was recognized in floodplain mapping and water level after the modification work compare with NVE's report (Bævre, 6/2001) (right side of figure 10) for the flood with return period 500 years. This means that the filling work have minor effect on flood level downstream and upstream Elgeseter Bru.

Cross section	Water elevation before [m]	Water elevation after [m]	Increased water level [cm]
25	2.15	2.19	4.1
26	2.18	2.21	2.9
27	2.12	2.11	-0.8

Table 6: Changes in water surface elevation

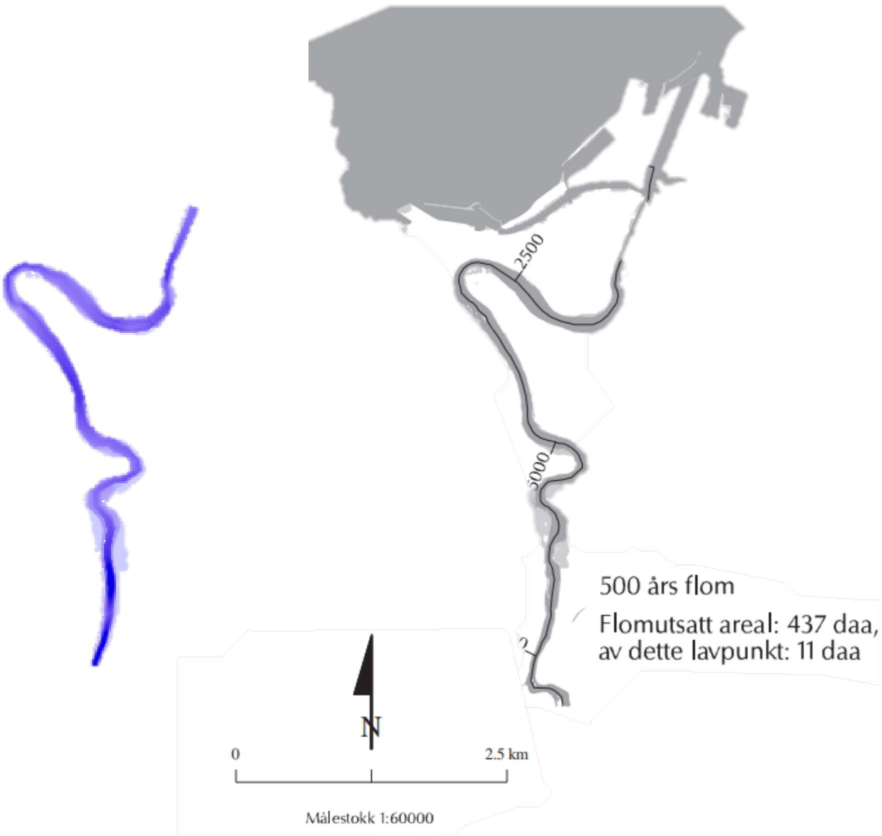


Figure 10: Floodplain mapping result

References

Bævre, I. (6/2001). *Flomsonekart - Delprosjekt Trondheim.* NVE - Norges vassdrags- og energidirektorat.

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Karverket. (2018). *Tide Tables for the Norwegian Coast and Svalbard.* Kartverket - The Norwegian Mapping Authority.

Ponce, V. M. (1989). *Engineering Hydrology: Principles and Practices, page 549 - 552.* Prentice Hall.

Tor Haakon Bakken, T. K. (2016). Simulation of river water temperatures during various hydro-peaking regimes. *Journal of Applied Water Engineering and Research*.

APPENDIX 1

Manning's number table

	River Station	Frctn (n/K)	n #1	n #2	n #3
1	7780.727	n	0.037	0.037	0.037
2	7527.504	n	0.037	0.037	0.037
3	7282.508	n	0.037	0.037	0.037
4	7003.064	n	0.0303	0.0303	0.0303
5	6735.69	n	0.0315	0.0315	0.0315
6	6235.858	n	0.0303	0.0303	0.0303
7	6006.047	n	0.0303	0.0303	0.0303
8	5837.81	n	0.0303	0.0303	0.0303
9	5603.116	n	0.0238	0.0238	0.0238
10	5361.917	n	0.0238	0.0238	0.0238
11	5150.524	n	0.0238	0.0238	0.0238
12	4916.598	n	0.0257	0.0257	0.0257
13	4721.334	n	0.0588	0.0588	0.0588
14	4504.879	n	0.0246	0.0246	0.0246
15	3957.328	n	0.0246	0.0246	0.0246
16	3884.048	n	0.0246	0.0246	0.0246
17	3725.373	n	0.0246	0.0246	0.0246
18	3598.078	n	0.0246	0.0246	0.0246
19	3351.142	n	0.0314	0.0314	0.0314
20	3271.093	n	0.0314	0.0314	0.0314
21	3173.824	n	0.0324	0.0324	0.0324
22	2966.22	n	0.0324	0.0324	0.0324
23	2765.339	n	0.0281	0.0281	0.0281
24	2544.777	n	0.0281	0.0281	0.0281
25	2343.476	n	0.0281	0.0281	0.0281
26	2223.258	n	0.0281	0.0281	0.0281
27	2076.534	n	0.0332	0.0332	0.0332
28	1949.921	n	0.0332	0.0332	0.0332
29	1883.047	n	0.0286	0.0286	0.0286
30	1682.236	n	0.0286	0.0286	0.0286
31	1641.35*	n	0.0286	0.0286	0.0286
32	1600.47*	n	0.0286	0.0286	0.0286
33	1559.582	n	0.0286	0.0286	0.0286
34	1449.102	n	0.0286	0.0286	0.0286
35	1409.818	n	0.0222	0.0222	0.0222
36	1366.38	n	0.03267	0.03267	0.03267
37	1096.673	n	0.03267	0.03267	0.03267
38	842.5486	n	0.028908	0.028908	0.028908
39	706.7225	n	0.028908	0.028908	0.028908
40	1	n	0.028908	0.028908	0.028908

APPENDIX 2

Velocity distribution cross section 27, low tide level condition, Q = 140 m^3/s

Q = 140 m^3/s										
	Before					After				
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	66.89	83.61	0.11		LOB	66.89	83.61	0.12
2	Chan	83.61	87.7	0.16		Chan	83.61	87.7	0.18
3	Chan	87.7	91.79	0.22		Chan	87.7	91.79	0.24
4	Chan	91.79	95.89	0.28		Chan	91.79	95.89	0.3
5	Chan	95.89	99.98	0.33		Chan	95.89	99.98	0.36
6	Chan	99.98	104.07	0.37		Chan	99.98	104.07	0.39
7	Chan	104.07	108.16	0.38		Chan	104.07	108.16	0.41
8	Chan	108.16	112.25	0.39		Chan	108.16	112.25	0.42
9	Chan	112.25	116.35	**0.42**		Chan	112.25	116.35	**0.45**
10	Chan	116.35	120.44	0.4		Chan	116.35	120.44	0.43
11	Chan	120.44	124.53	0.36		Chan	120.44	124.53	0.39
12	Chan	124.53	128.62	0.37		Chan	124.53	128.62	0.39
13	Chan	128.62	132.71	0.36		Chan	128.62	132.71	0.39
14	Chan	132.71	136.81	0.35		Chan	132.71	136.81	0.38
15	Chan	136.81	140.9	0.32		Chan	136.81	140.9	0.34
16	Chan	140.9	144.99	0.28		Chan	140.9	144.99	0.31
17	Chan	144.99	149.08	0.29		Chan	144.99	149.08	0.32
18	Chan	149.08	153.17	0.3		Chan	149.08	153.17	0.32
19	Chan	153.17	157.27	0.29		Chan	153.17	157.27	0.31
20	Chan	157.27	161.36	0.31		Chan	157.27	161.36	0.33
21	Chan	161.36	165.45	0.33		Chan	161.36	165.45	0.35
22	Chan	165.45	169.54	0.35		Chan	165.45	169.54	0.38
23	Chan	169.54	173.63	0.37		Chan	169.54	173.63	0.4
24	Chan	173.63	177.73	0.39		Chan	173.63	177.73	0.42
25	Chan	177.73	181.82	0.37		Chan	177.73	181.82	0.4
26	Chan	181.82	185.91	0.38		Chan	181.82	185.91	0.4
27	Chan	185.91	190	0.41		Chan	185.91	190	0.44
28	Chan	190	194.09	**0.44**		Chan	190	194.09	**0.47**
29	Chan	194.09	198.19	0.43		Chan	194.09	198.19	0.46
30	Chan	198.19	202.28	0.37		Chan	198.19	202.28	0.35
31	Chan	202.28	206.37	0.31		Chan	202.28	206.37	0.16
32	Chan	206.37	210.46	0.25					
33	Chan	210.46	214.55	0.22					
34	Chan	214.55	218.65	0.2					
35	Chan	218.65	222.74	0.18					
36	Chan	222.74	226.83	0.15					
37	ROB	226.83	243.97	0.12					

Velocity distribution Cross section 28, low tide level condition, Q = 140 m^3/s

Q = 140 m^3/s									
	Before					After			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	195.18	243.97	0.14		LOB	195.18	243.97	0.15
2	Chan	243.97	247.6	0.17		Chan	243.97	247.6	0.18
3	Chan	247.6	251.23	0.23		Chan	247.6	251.23	0.25
4	Chan	251.23	254.86	0.28		Chan	251.23	254.86	0.3
5	Chan	254.86	258.49	0.33		Chan	254.86	258.49	0.35
6	Chan	258.49	262.12	0.36		Chan	258.49	262.12	0.39
7	Chan	262.12	265.75	0.39		Chan	262.12	265.75	0.42
8	Chan	265.75	269.38	0.4		Chan	265.75	269.38	0.43
9	Chan	269.38	273.01	**0.42**		Chan	269.38	273.01	**0.46**
10	Chan	273.01	276.64	**0.42**		Chan	273.01	276.64	0.45
11	Chan	276.64	280.27	0.39		Chan	276.64	280.27	0.42
12	Chan	280.27	283.9	0.4		Chan	280.27	283.9	0.43
13	Chan	283.9	287.53	0.4		Chan	283.9	287.53	0.43
14	Chan	287.53	291.16	0.39		Chan	287.53	291.16	0.42
15	Chan	291.16	294.79	0.36		Chan	291.16	294.79	0.39
16	Chan	294.79	298.42	0.36		Chan	294.79	298.42	0.4
17	Chan	298.42	302.05	0.37		Chan	298.42	302.05	0.4
18	Chan	302.05	305.68	0.37		Chan	302.05	305.68	0.4
19	Chan	305.68	309.32	0.39		Chan	305.68	309.32	0.42
20	Chan	309.32	312.95	0.41		Chan	309.32	312.95	0.44
21	Chan	312.95	316.58	0.42		Chan	312.95	316.58	0.46
22	Chan	316.58	320.21	0.44		Chan	316.58	320.21	0.48
23	Chan	320.21	323.84	0.44		Chan	320.21	323.84	0.48
24	Chan	323.84	327.47	0.44		Chan	323.84	327.47	0.48
25	Chan	327.47	331.1	0.46		Chan	327.47	331.1	0.5
26	Chan	331.1	334.73	**0.49**		Chan	331.1	334.73	**0.53**
27	Chan	334.73	338.36	0.46		Chan	334.73	338.36	0.5
28	Chan	338.36	341.99	0.42		Chan	338.36	341.99	0.45
29	Chan	341.99	345.62	0.38		Chan	341.99	345.62	0.34
30	Chan	345.62	349.25	0.33		Chan	345.62	349.25	0.16
31	Chan	349.25	352.88	0.28					
32	Chan	352.88	356.51	0.25					
33	Chan	356.51	360.14	0.23					
34	Chan	360.14	363.77	0.21					
35	Chan	363.77	367.4	0.18					
36	Chan	367.4	371.03	0.16					
37	ROB	371.03	410.61	0.1					

Velocity distribution Cross section 27, normal tide level condition, Q = 140 m^3/s

Q = 140 m^3/s									
	Before					Cross section 28			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	66.89	83.61	0.08		LOB	66.89	83.61	0.08
2	Chan	83.61	87.7	0.16		Chan	83.61	87.7	0.18
3	Chan	87.7	91.79	0.19		Chan	87.7	91.79	0.21
4	Chan	91.79	95.89	0.23		Chan	91.79	95.89	0.25
5	Chan	95.89	99.98	0.26		Chan	95.89	99.98	0.28
6	Chan	99.98	104.07	0.28		Chan	99.98	104.07	0.3
7	Chan	104.07	108.16	0.28		Chan	104.07	108.16	0.31
8	Chan	108.16	112.25	0.29		Chan	108.16	112.25	0.32
9	Chan	112.25	116.35	**0.31**		Chan	112.25	116.35	**0.34**
10	Chan	116.35	120.44	0.3		Chan	116.35	120.44	0.33
11	Chan	120.44	124.53	0.27		Chan	120.44	124.53	0.3
12	Chan	124.53	128.62	0.28		Chan	124.53	128.62	0.3
13	Chan	128.62	132.71	0.27		Chan	128.62	132.71	0.3
14	Chan	132.71	136.81	0.27		Chan	132.71	136.81	0.29
15	Chan	136.81	140.9	0.25		Chan	136.81	140.9	0.27
16	Chan	140.9	144.99	0.23		Chan	140.9	144.99	0.25
17	Chan	144.99	149.08	0.23		Chan	144.99	149.08	0.26
18	Chan	149.08	153.17	0.24		Chan	149.08	153.17	0.26
19	Chan	153.17	157.27	0.23		Chan	153.17	157.27	0.25
20	Chan	157.27	161.36	0.24		Chan	157.27	161.36	0.26
21	Chan	161.36	165.45	0.25		Chan	161.36	165.45	0.28
22	Chan	165.45	169.54	0.27		Chan	165.45	169.54	0.29
23	Chan	169.54	173.63	0.28		Chan	169.54	173.63	0.31
24	Chan	173.63	177.73	0.29		Chan	173.63	177.73	0.32
25	Chan	177.73	181.82	0.28		Chan	177.73	181.82	0.3
26	Chan	181.82	185.91	0.28		Chan	181.82	185.91	0.31
27	Chan	185.91	190	0.3		Chan	185.91	190	0.33
28	Chan	190	194.09	**0.32**		Chan	190	194.09	**0.35**
29	Chan	194.09	198.19	0.31		Chan	194.09	198.19	0.34
30	Chan	198.19	202.28	0.27		Chan	198.19	202.28	0.27
31	Chan	202.28	206.37	0.24		Chan	202.28	206.37	0.14
32	Chan	206.37	210.46	0.21					
33	Chan	210.46	214.55	0.19					
34	Chan	214.55	218.65	0.18					
35	Chan	218.65	222.74	0.17					
36	Chan	222.74	226.83	0.16					
37	ROB	226.83	243.97	0.11					

Velocity distribution Cross section 28, normal tide level condition, Q = 140 m^3/s

Q = 140 m^3/s									
	Before					Before			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	195.18	243.97	0.13		LOB	195.18	243.97	0.15
2	Chan	243.97	247.6	0.17		Chan	243.97	247.6	0.19
3	Chan	247.6	251.23	0.21		Chan	247.6	251.23	0.23
4	Chan	251.23	254.86	0.23		Chan	251.23	254.86	0.26
5	Chan	254.86	258.49	0.26		Chan	254.86	258.49	0.29
6	Chan	258.49	262.12	0.28		Chan	258.49	262.12	0.31
7	Chan	262.12	265.75	0.29		Chan	262.12	265.75	0.33
8	Chan	265.75	269.38	0.3		Chan	265.75	269.38	0.34
9	Chan	269.38	273.01	**0.32**		Chan	269.38	273.01	**0.35**
10	Chan	273.01	276.64	0.31		Chan	273.01	276.64	**0.35**
11	Chan	276.64	280.27	0.3		Chan	276.64	280.27	0.33
12	Chan	280.27	283.9	0.3		Chan	280.27	283.9	0.34
13	Chan	283.9	287.53	0.3		Chan	283.9	287.53	0.34
14	Chan	287.53	291.16	0.3		Chan	287.53	291.16	0.33
15	Chan	291.16	294.79	0.28		Chan	291.16	294.79	0.31
16	Chan	294.79	298.42	0.28		Chan	294.79	298.42	0.31
17	Chan	298.42	302.05	0.29		Chan	298.42	302.05	0.32
18	Chan	302.05	305.68	0.29		Chan	302.05	305.68	0.32
19	Chan	305.68	309.32	0.29		Chan	305.68	309.32	0.33
20	Chan	309.32	312.95	0.31		Chan	309.32	312.95	0.34
21	Chan	312.95	316.58	0.32		Chan	312.95	316.58	0.35
22	Chan	316.58	320.21	0.33		Chan	316.58	320.21	0.37
23	Chan	320.21	323.84	0.33		Chan	320.21	323.84	0.36
24	Chan	323.84	327.47	0.33		Chan	323.84	327.47	0.36
25	Chan	327.47	331.1	0.34		Chan	327.47	331.1	0.38
26	Chan	331.1	334.73	**0.36**		Chan	331.1	334.73	**0.4**
27	Chan	334.73	338.36	0.34		Chan	334.73	338.36	0.38
28	Chan	338.36	341.99	0.31		Chan	338.36	341.99	0.35
29	Chan	341.99	345.62	0.29		Chan	341.99	345.62	0.27
30	Chan	345.62	349.25	0.26		Chan	345.62	349.25	0.13
31	Chan	349.25	352.88	0.23					
32	Chan	352.88	356.51	0.22					
33	Chan	356.51	360.14	0.21					
34	Chan	360.14	363.77	0.19					
35	Chan	363.77	367.4	0.18					
36	Chan	367.4	371.03	0.17					
37	ROB	371.03	410.61	0.09					

Velocity distribution Cross section 27, low tide level condition, Q = 955 m^3/s

Q = 955 m^3/s									
	Before					After			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	66.89	83.61	0.52		LOB	66.89	83.61	0.57
2	Chan	83.61	87.7	1.12		Chan	83.61	87.7	1.23
3	Chan	87.7	91.79	1.35		Chan	87.7	91.79	1.48
4	Chan	91.79	95.89	1.6		Chan	91.79	95.89	1.75
5	Chan	95.89	99.98	1.82		Chan	95.89	99.98	1.99
6	Chan	99.98	104.07	1.97		Chan	99.98	104.07	2.16
7	Chan	104.07	108.16	2.03		Chan	104.07	108.16	2.22
8	Chan	108.16	112.25	2.09		Chan	108.16	112.25	2.28
9	Chan	112.25	116.35	**2.22**		Chan	112.25	116.35	**2.43**
10	Chan	116.35	120.44	2.13		Chan	116.35	120.44	2.33
11	Chan	120.44	124.53	1.95		Chan	120.44	124.53	2.13
12	Chan	124.53	128.62	1.97		Chan	124.53	128.62	2.15
13	Chan	128.62	132.71	1.96		Chan	128.62	132.71	2.14
14	Chan	132.71	136.81	1.92		Chan	132.71	136.81	2.1
15	Chan	136.81	140.9	1.76		Chan	136.81	140.9	1.92
16	Chan	140.9	144.99	1.62		Chan	140.9	144.99	1.77
17	Chan	144.99	149.08	1.66		Chan	144.99	149.08	1.81
18	Chan	149.08	153.17	1.68		Chan	149.08	153.17	1.84
19	Chan	153.17	157.27	1.64		Chan	153.17	157.27	1.8
20	Chan	157.27	161.36	1.71		Chan	157.27	161.36	1.87
21	Chan	161.36	165.45	1.81		Chan	161.36	165.45	1.98
22	Chan	165.45	169.54	1.9		Chan	165.45	169.54	2.08
23	Chan	169.54	173.63	2		Chan	169.54	173.63	2.18
24	Chan	173.63	177.73	2.07		Chan	173.63	177.73	2.26
25	Chan	177.73	181.82	1.98		Chan	177.73	181.82	2.17
26	Chan	181.82	185.91	2.01		Chan	181.82	185.91	2.2
27	Chan	185.91	190	2.15		Chan	185.91	190	2.35
28	Chan	190	194.09	2.3		Chan	190	194.09	**2.52**
29	Chan	194.09	198.19	**2.22**		Chan	194.09	198.19	2.43
30	Chan	198.19	202.28	1.97		Chan	198.19	202.28	1.95
31	Chan	202.28	206.37	1.7		Chan	202.28	206.37	0.99
32	Chan	206.37	210.46	1.45					
33	Chan	210.46	214.55	1.36					
34	Chan	214.55	218.65	1.27					
35	Chan	218.65	222.74	1.18					
36	Chan	222.74	226.83	1.09					
37	ROB	226.83	243.97	0.76					

Velocity distribution Cross section 28, low tide level condition, Q = 955 m^3/s

Q = 955 m^3/s									
	Before					After			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	195.18	243.97	0.96		LOB	195.18	243.97	1.05
2	Chan	243.97	247.6	1.19		Chan	243.97	247.6	1.32
3	Chan	247.6	251.23	1.46		Chan	247.6	251.23	1.62
4	Chan	251.23	254.86	1.67		Chan	251.23	254.86	1.86
5	Chan	254.86	258.49	1.88		Chan	254.86	258.49	2.11
6	Chan	258.49	262.12	2.06		Chan	258.49	262.12	2.31
7	Chan	262.12	265.75	2.16		Chan	262.12	265.75	2.42
8	Chan	265.75	269.38	2.22		Chan	265.75	269.38	2.48
9	Chan	269.38	273.01	**2.34**		Chan	269.38	273.01	**2.62**
10	Chan	273.01	276.64	2.3		Chan	273.01	276.64	2.58
11	Chan	276.64	280.27	2.19		Chan	276.64	280.27	2.46
12	Chan	280.27	283.9	2.23		Chan	280.27	283.9	2.5
13	Chan	283.9	287.53	2.23		Chan	283.9	287.53	2.5
14	Chan	287.53	291.16	2.17		Chan	287.53	291.16	2.44
15	Chan	291.16	294.79	2.05		Chan	291.16	294.79	2.29
16	Chan	294.79	298.42	2.07		Chan	294.79	298.42	2.31
17	Chan	298.42	302.05	2.1		Chan	298.42	302.05	2.35
18	Chan	302.05	305.68	2.09		Chan	302.05	305.68	2.34
19	Chan	305.68	309.32	2.16		Chan	305.68	309.32	2.42
20	Chan	309.32	312.95	2.26		Chan	309.32	312.95	2.53
21	Chan	312.95	316.58	2.34		Chan	312.95	316.58	2.63
22	Chan	316.58	320.21	2.43		Chan	316.58	320.21	2.73
23	Chan	320.21	323.84	2.41		Chan	320.21	323.84	2.71
24	Chan	323.84	327.47	2.41		Chan	323.84	327.47	2.71
25	Chan	327.47	331.1	2.52		Chan	327.47	331.1	2.84
26	Chan	331.1	334.73	**2.65**		Chan	331.1	334.73	**2.98**
27	Chan	334.73	338.36	2.51		Chan	334.73	338.36	2.82
28	Chan	338.36	341.99	2.32		Chan	338.36	341.99	2.6
29	Chan	341.99	345.62	2.13		Chan	341.99	345.62	2
30	Chan	345.62	349.25	1.92		Chan	345.62	349.25	0.96
31	Chan	349.25	352.88	1.68		Chan			
32	Chan	352.88	356.51	1.56		Chan			
33	Chan	356.51	360.14	1.46		Chan			
34	Chan	360.14	363.77	1.36		Chan			
35	Chan	363.77	367.4	1.25		Chan			
36	Chan	367.4	371.03	1.14		Chan			

37	ROB	371.03	410.61	0.65		ROB			

Velocity distribution Cross section 27, normal tide level condition, Q = 955 m^3/s

Q = 955 m^3/s									
	Before					After			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	66.89	83.61	0.53		LOB	66.89	83.61	0.59
2	Chan	83.61	87.7	1.06		Chan	83.61	87.7	1.17
3	Chan	87.7	91.79	1.22		Chan	87.7	91.79	1.35
4	Chan	91.79	95.89	1.39		Chan	91.79	95.89	1.54
5	Chan	95.89	99.98	1.55		Chan	95.89	99.98	1.72
6	Chan	99.98	104.07	1.67		Chan	99.98	104.07	1.84
7	Chan	104.07	108.16	1.71		Chan	104.07	108.16	1.89
8	Chan	108.16	112.25	1.75		Chan	108.16	112.25	1.93
9	Chan	112.25	116.35	**1.85**		Chan	112.25	116.35	**2.04**
10	Chan	116.35	120.44	1.78		Chan	116.35	120.44	1.97
11	Chan	120.44	124.53	1.65		Chan	120.44	124.53	1.82
12	Chan	124.53	128.62	1.66		Chan	124.53	128.62	1.84
13	Chan	128.62	132.71	1.66		Chan	128.62	132.71	1.83
14	Chan	132.71	136.81	1.63		Chan	132.71	136.81	1.8
15	Chan	136.81	140.9	1.51		Chan	136.81	140.9	1.67
16	Chan	140.9	144.99	1.41		Chan	140.9	144.99	1.56
17	Chan	144.99	149.08	1.44		Chan	144.99	149.08	1.59
18	Chan	149.08	153.17	1.46		Chan	149.08	153.17	1.61
19	Chan	153.17	157.27	1.43		Chan	153.17	157.27	1.58
20	Chan	157.27	161.36	1.47		Chan	157.27	161.36	1.63
21	Chan	161.36	165.45	1.55		Chan	161.36	165.45	1.71
22	Chan	165.45	169.54	1.62		Chan	165.45	169.54	1.79
23	Chan	169.54	173.63	1.68		Chan	169.54	173.63	1.86
24	Chan	173.63	177.73	1.73		Chan	173.63	177.73	1.92
25	Chan	177.73	181.82	1.67		Chan	177.73	181.82	1.85
26	Chan	181.82	185.91	1.69		Chan	181.82	185.91	1.87
27	Chan	185.91	190	1.79		Chan	185.91	190	1.98
28	Chan	190	194.09	**1.91**		Chan	190	194.09	**2.11**
29	Chan	194.09	198.19	1.84		Chan	194.09	198.19	2.04
30	Chan	198.19	202.28	1.66		Chan	198.19	202.28	1.68
31	Chan	202.28	206.37	1.47		Chan	202.28	206.37	0.86
32	Chan	206.37	210.46	1.29					
33	Chan	210.46	214.55	1.22					
34	Chan	214.55	218.65	1.16					
35	Chan	218.65	222.74	1.1					

36	Chan	222.74	226.83	1.03					
37	ROB	226.83	243.97	0.67					

Velocity distribution Cross section 28, normal tide level condition, Q = 955 m^3/s

Q = 955 m^3/s									
	Before					After			
	Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)		Pos	Left Sta (m)	Right Sta (m)	Velocity (m/s)
1	LOB	195.18	243.97	0.82		LOB	195.18	243.97	0.92
2	Chan	243.97	247.6	1.14		Chan	243.97	247.6	1.28
3	Chan	247.6	251.23	1.32		Chan	247.6	251.23	1.49
4	Chan	251.23	254.86	1.47		Chan	251.23	254.86	1.66
5	Chan	254.86	258.49	1.62		Chan	254.86	258.49	1.83
6	Chan	258.49	262.12	1.74		Chan	258.49	262.12	1.97
7	Chan	262.12	265.75	1.82		Chan	262.12	265.75	2.06
8	Chan	265.75	269.38	1.86		Chan	265.75	269.38	2.1
9	Chan	269.38	273.01	**1.94**		Chan	269.38	273.01	**2.2**
10	Chan	273.01	276.64	1.91		Chan	273.01	276.64	2.17
11	Chan	276.64	280.27	1.84		Chan	276.64	280.27	2.08
12	Chan	280.27	283.9	1.87		Chan	280.27	283.9	2.11
13	Chan	283.9	287.53	1.87		Chan	283.9	287.53	2.11
14	Chan	287.53	291.16	1.82		Chan	287.53	291.16	2.07
15	Chan	291.16	294.79	1.73		Chan	291.16	294.79	1.96
16	Chan	294.79	298.42	1.75		Chan	294.79	298.42	1.98
17	Chan	298.42	302.05	1.77		Chan	298.42	302.05	2.01
18	Chan	302.05	305.68	1.77		Chan	302.05	305.68	2
19	Chan	305.68	309.32	1.82		Chan	305.68	309.32	2.06
20	Chan	309.32	312.95	1.88		Chan	309.32	312.95	2.14
21	Chan	312.95	316.58	1.95		Chan	312.95	316.58	2.2
22	Chan	316.58	320.21	2.01		Chan	316.58	320.21	2.28
23	Chan	320.21	323.84	2		Chan	320.21	323.84	2.26
24	Chan	323.84	327.47	2		Chan	323.84	327.47	2.26
25	Chan	327.47	331.1	2.08		Chan	327.47	331.1	2.36
26	Chan	331.1	334.73	**2.17**		Chan	331.1	334.73	**2.46**
27	Chan	334.73	338.36	2.06		Chan	334.73	338.36	2.34
28	Chan	338.36	341.99	1.93		Chan	338.36	341.99	2.18
29	Chan	341.99	345.62	1.79		Chan	341.99	345.62	1.73
30	Chan	345.62	349.25	1.64		Chan	345.62	349.25	0.81
31	Chan	349.25	352.88	1.47					
32	Chan	352.88	356.51	1.4					
33	Chan	356.51	360.14	1.33					
34	Chan	360.14	363.77	1.26					

35	Chan	363.77	367.4	1.18					
36	Chan	367.4	371.03	1.11					
37	ROB	371.03	410.61	0.57					