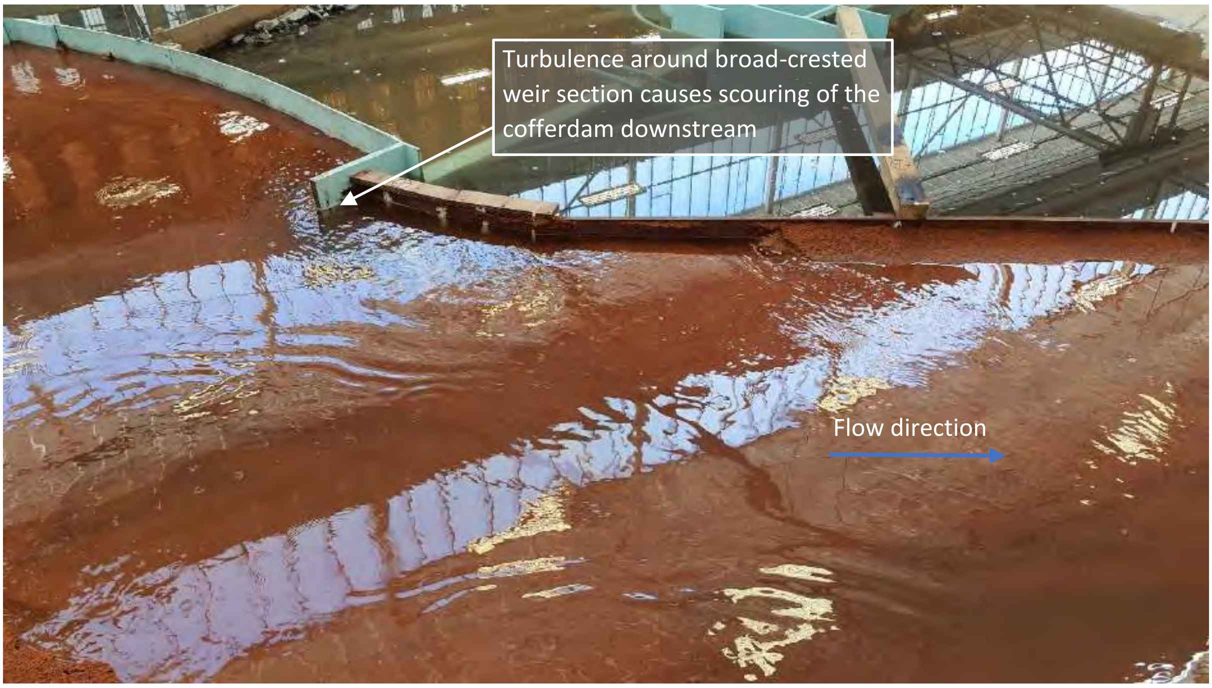

Figure 10-22: Observed scour against the downstream cofferdam during the Q5 year flood

Figure 10-23: Scour around the right bank guide wall, a) upstream and b) downstream, after the Q5 flood

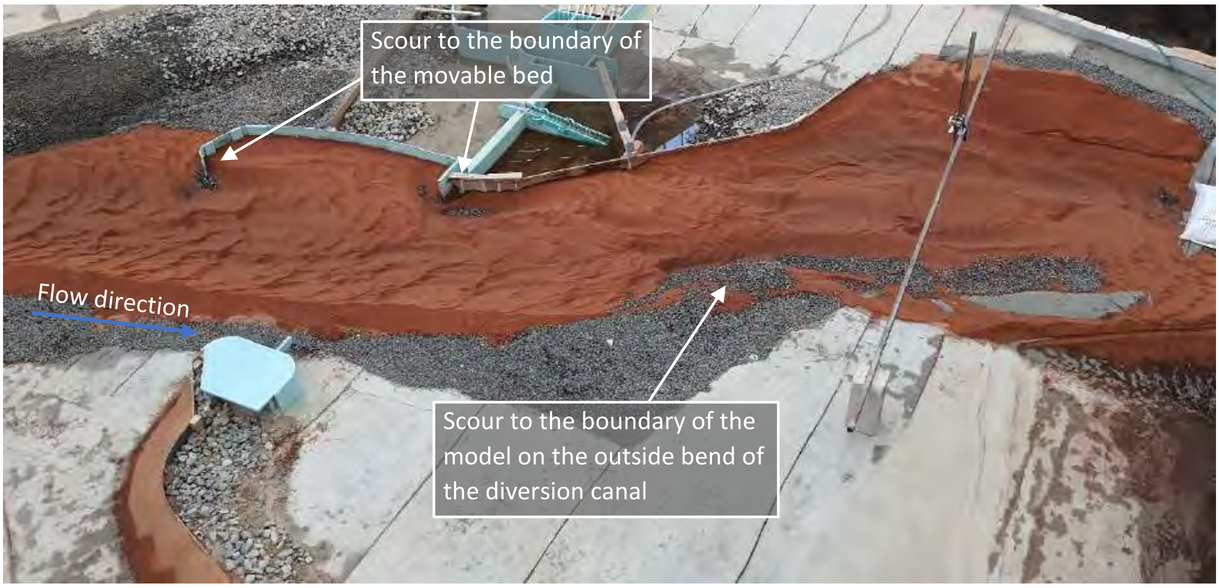

Figure 10-24: Movable bed of the diversion canal after the Q5 year flood

10-year ARI flood

The scour locations against the right bank guide wall and downstream of the bend in the diversion canal have been made deeper to bedrock level and filled with movable bed material for the Q10 year flood. Figures 10-25 to 10-27 show the results of the movable bed for the Q10 year flood. Figure-10-25 shows the turbulence against the right bank guide wall, the straight path that the flow follows at the bend in the diversion canal can also be seen. The extent of the scour of the diversion canal after the Q10 year flood is shown in Figure 10-26. Around the right bank guide wall the upstream and downstream sections have scoured locally to bedrock. The cofferdam downstream has been eroded away to the water level and deposition occurred against the left bank of the diversion canal. The diversion canal has formed a new straight channel at the bend location that flows back to the main channel of the Berg River. The inlet section is shown in Figure 10-27, the shaped inlet worked well for the Q10 year flood. Apart from the local scour around the right bank guide wall, the diversion canal has not scoured to bedrock, instead the diversion canal has become wider with each test carried out.

Figure 10-25: Modified option C layout during the Q10 flood

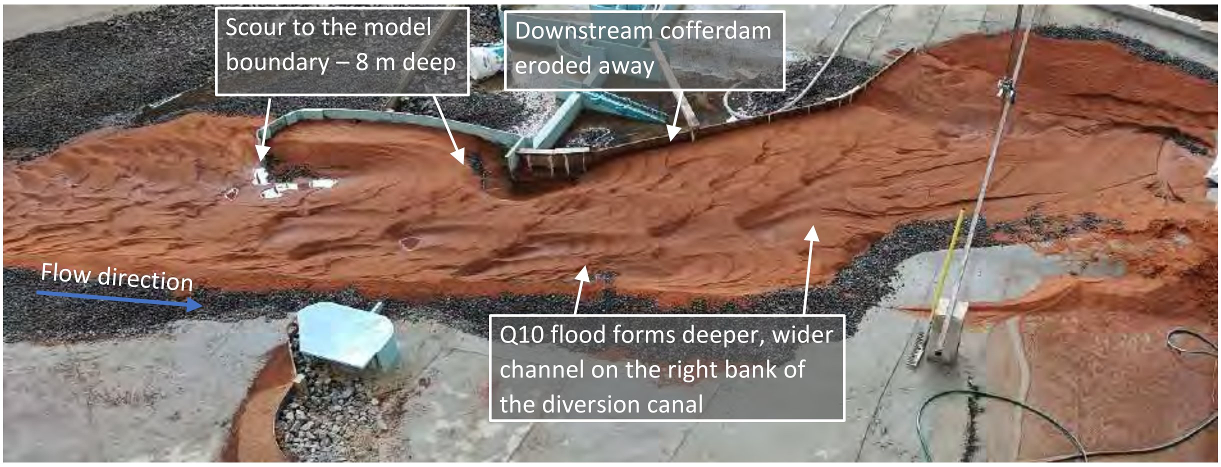

Figure 10-26: Result of the Q10 flood with the movable bed of the modified option C layout of the diversion canal

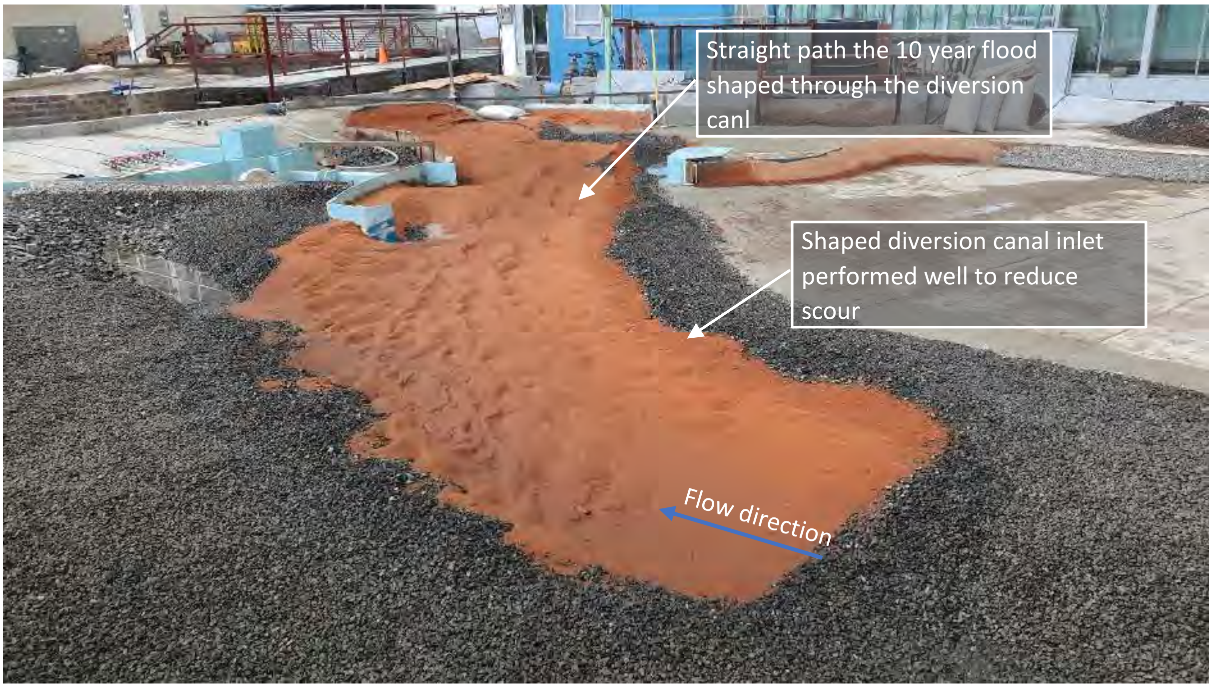

Figure 10-27: Downstream view of the diversion canal inlet after the Q10 flood

10.6 Summary of temporary works model test results

The investigation of the proposed temporary works has been carried out through a desktop study of four possible options for constructing the temporary works for the construction of the abstraction works, pumpstation, fishway-canoe chute and weir. Options A and C were further investigated by evaluating the practicality of construction in the available area between the components of the abstraction works. Option C was tested in the 1:40 scale physical model that was used to optimise the design of the abstraction works and weir, the final proposed layout for the temporary works Option C is illustrated in Figure 10-13. The findings and recommendations of this study on the selected temporary works were made to guide the contractor to decide on the acceptable risk during construction. The following findings and recommendations are made:

- A 20 m wide (bottom width) trapezoidal (1:2.5 (V:H)) diversion canal that is excavated through the right bank floodplain is suitable to convey the 10-year ARI-flood (533 m^3/s) safely around the construction area of the abstraction works on the left bank.
- The diversion canal inlet is at 47.3 masl with a bed slope of 1:1000 (V:H), the canal must return to the main river channel bed invert level to prevent retrogressive erosion.
- Upstream, a cofferdam is required with a crest level of 54.7 masl.
- Downstream, a cofferdam is required to have a crest elevation of 54.6 masl.
- The final layout of the upstream cofferdam will depend on the construction of the left bank flank wall.
- A 40 m wide inlet that contracts over a length of 30 m to 20m is recommended to guide the flow into the diversion canal.
- On the right bank, a long radius bend to connect the diversion canal to the main channel of the river, this bend has proved to be effective in guiding the flow into the diversion canal with minimal erosion of the right bank.
- Suitable erosion protection measures must be investigated by the contractor. The recorded water levels and flow velocities from this study could be used to design suitable erosion protection measures for the coffer dams and diversion canal banks.

11. Fishway-canoe chute design

The proposed combined fishway-canoe chute design was tested as a separate physical model in a 1 m wide glass flume with a 1:15 scale model. A larger model scale was selected to test the functioning of the proposed fishway-canoe chute to limit the scale effects. The fishway-canoe chute was developed specifically for the BRVAS to promote the migration of the indigenous potamodromous Berg-Breede River Whitefish (*Pseudobarbus capensis)* which would be negatively affected by the construction of a weir in the Berg River. A canoe chute was incorporated into the design to serve the annual Berg River canoe marathon held between Paarl and Velddrif. The typical kayaks that were considered for the design of the fishway-canoe chute is a K1- and a K2-kayak, which is typically used in the annual Berg River Marathon. This section describes the design of the fishway-canoe chute and the findings of the physical model. Two fishway-canoe chute options were tested, the main difference between the two options were the baffle shape and step configuration. Option A consisted of straight side baffles and Option B made use of rounded side baffles, while other differences of each design are described in Sections 11.1 and 11.2.

Table 11-1 indicates the observed river discharge exceedance as percentage of time based on the Hermon flow gauging station of DWS (exceedance data provided by DWS). The river discharge is seldom exceeded during winter for a fishway-canoe chute head (H) of 1.0 m at a river discharge of 46 m^3/s. This makes the chute safe for canoeists and for fish without spillage over the sides of the chute for most of the time during the winter design months.

The proposed fishway-canoe chute design is enclosed in **Appendix A2**. Figures 11-1 to 11-3 show the fishway-canoe chute model at 1:15 scale setup in the flume as well as with flow.

Table 11-1: Percentage exceedance of low flow discharges during winter

Head at fishway-canoe chute (H in m)	Q river (m^3/s)	Q fishway-canoe chute (m^3/s)	% Exceedance Winter Jun to Sep			
			Jun	**Jul**	**Aug**	**Sep**
0.3	1.0	1.0	99%	99%	100%	100%
0.4	2.6	1.5	94%	97%	100%	99%
0.5	5.1	2.1	80%	92%	96%	93%
0.6	8.3	2.8	65%	80%	86%	75%
0.8	23.3	4.3	30%	50%	40%	30%
1.0	45.8	5.9	2%	3%	3%	2%
1.2	73.5	7.8	1%	2%	3%	1%
1.5	123.0	10.9	1%	1%	1%	1%

11.1 Characteristics of the fishway-canoe chute – Option A

A concept combination canoe chute-fishway was designed as part of this study based on discussions with DWS and fishway expert Dr Anton Bok. The fishway-canoe chute incorporated unique design features to develop a chute suitable for both fish migration upstream and downstream travel of canoeists, the design features described is shown in Figure 11-1. Side baffles were used to create small resting zones downstream of each baffle for fish migration, these baffles were placed at an angle (facing downstream) to prevent the canoe from being trapped by the side baffles in the event of the bow of the kayak contacting a baffle. Chevron floor “weirs” assisted in creating roughness in the chute and creating a pool upstream of each chevron weir to create additional flow depth. The angle of the chevron weirs created more roughness towards the sides of the chute where fish migration will typically take place, while allowing the flow down the centre of the chute to be more favourable for canoe passage. A combination of steps and sloped bed sections was used in the middle section of the chute, the motivation for the sloped sections was to protect the keel of the kayaks from the chevron floor weirs and the steps creating the required roughness and flow depth for fish migration.

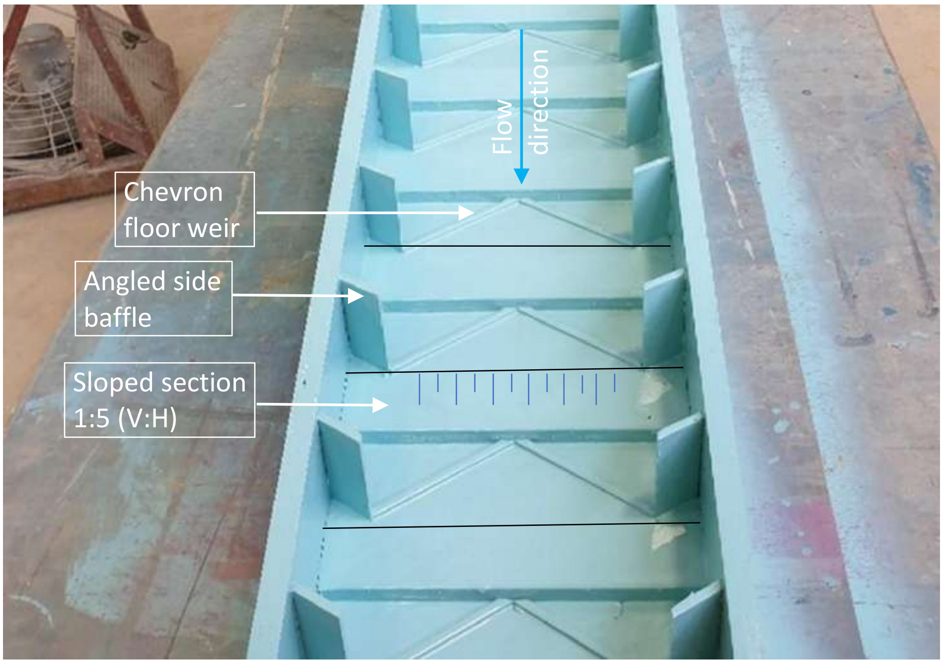

Figure 11-1: Fishway-canoe chute design features for Option A

The proposed combined fishway-canoe chute (refer Figure 11-2) has the following characteristics:

a) 3 m wide canoe chute with dividing walls upstream to guide the fish, canoes and for flow measurement.
b) To be constructed on the Crump weir low notch, with the crest level 0.3 m lower than the low notch of the weir, to the left bank side of the dividing wall between the 20 m and 40 m long weir notches. The 17 m long low-notch and the 3 m long fishway-canoe chute opening make up the 20 m long low-notch Crump weir.
c) The crest of the Crump weir at the chute is at 51.3 masl. At a river discharge of 5 m^3/s the tailwater level is about 48 masl, which results in a 3.3 m drop from the crest of the weir to the downstream water level, or a 3.8 m head difference from the upstream to downstream water levels. The fishway-canoe chute is currently designed to be 35.75 m in length to provide safe flow patterns for canoeists through the unstable jump at the downstream end of the chute.
d) 0.5 m wide baffles for fish are placed on the left- and right-bank sides of the canoe chute, at 45 degree angles to the flow direction. The baffles create small resting zones behind them for fish migrating upstream.
e) Downstream of the crest the total width of the canoe chute is 4 m, including the baffles on the sides.
f) Chevron shaped floor “weirs” are included in the canoe chute not too high so that the keels of the canoes going down the centre of the chute cannot hit them.
g) The combined canoe chute-fishway has a 1:5 (V:H) general longitudinal slope.

h) Fish resting pools are added on the sides of the fishway-canoe chute to provide an area with low levels of turbulence and velocity for migrating fish to recover before swimming upstream, initially, one resting pool on each side was proposed and tested in the physical model.

i) The crest of the canoe chute has a Crump shape like the rest of the weir for DWS flow measurement. The canoe chute-fishway starts 0.75 m downstream of the crest and at an elevation 0.15 m lower not to affect flow measurement.

The initial designed fishway-canoe chute was tested and modified at a scale of 1:15 in a flume and the modified version was then included in the 3D 1:40 scale movable bed physical model. Some minor changes were made to the initial design of the fishway-canoe chute during the tests such as:

- Changing the baffle orientation from a 60-degree to a 45-degree angle to be safer for canoeists without affecting the fish swimming routes.
- Lowering the floor levels immediately downstream of the baffles on the sides of the chute to increase the flow depth and to improve resting conditions for fish.
- Raising the height of the chevron shaped weirs to 150 mm to increase the flow depth near the baffles while still safe for the canoeists.
- A second set of large pools for fish to rest at every 2 m drop i.e., at 10 m intervals along the chute is recommended. It was found that the resting pools do not influence the flow in the chute of the fishway-canoe chute and the additional proposed resting pools were not added in subsequent tests.

Figure 11-2: Fishway-canoe chute model viewed from upstream (no flow)

Figure 11-3: Fishway-canoe chute model at a discharge of about 8 m^3/s in the chute (H = 1.2m) viewed from upstream

Figure 11-4 shows the observed flow depths measured along the centre of the chute (solid lines, location 1 indicated in Figure 11-7) and in line with the edges of the side baffles (dotted lines, location 2 in Figure 11-7). At H = 0.3 m the river discharge is only 1 m^3/s and the flow depth near the side baffles as shallow as 0.1 m deep.

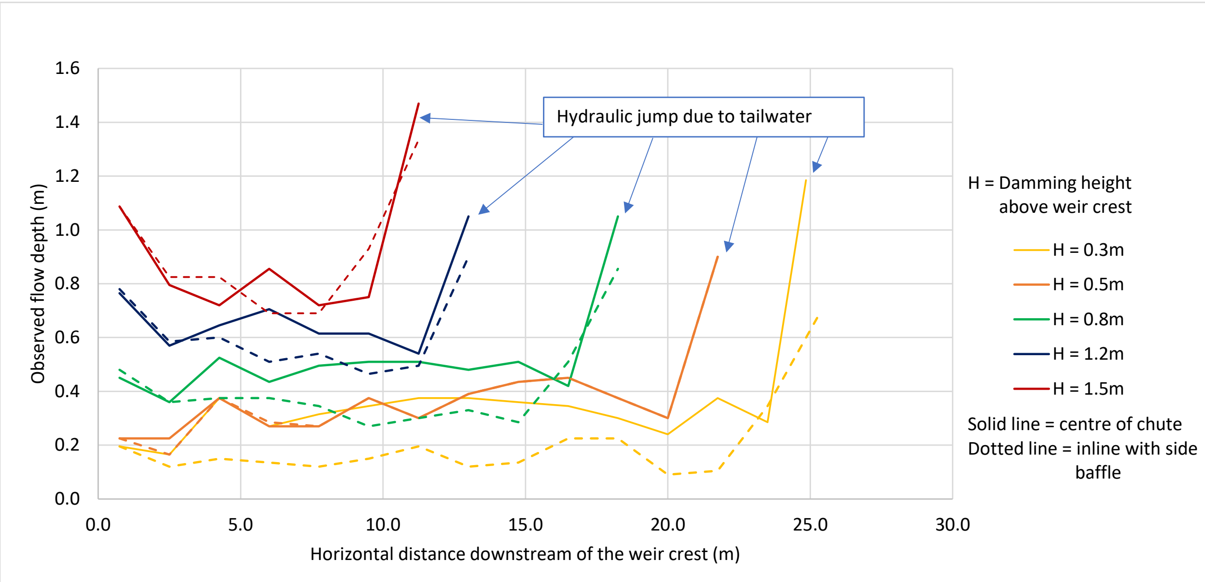

Figure 11-4 Observed flow depths at the center of the chute (solid lines) and in line with the baffles (dotted lines); zero distance on x-axis is at the Crump weir crest

Figure 11-5 indicates the observed flow depths at the 150 mm high chevron weirs on the floor where the flow is at its shallowest on the crests of these small weirs. At H = 0.5 m the river discharge is

5.1 m^3/s and the chute discharge 2.1 m^3/s (Table 11-2), with a minimum flow depth on the chute of 0.11 m. At H = 0.8 m the river discharge is 23.3 m^3/s, a small flood, and the flow depths on the chute are deeper than 0.3 m.

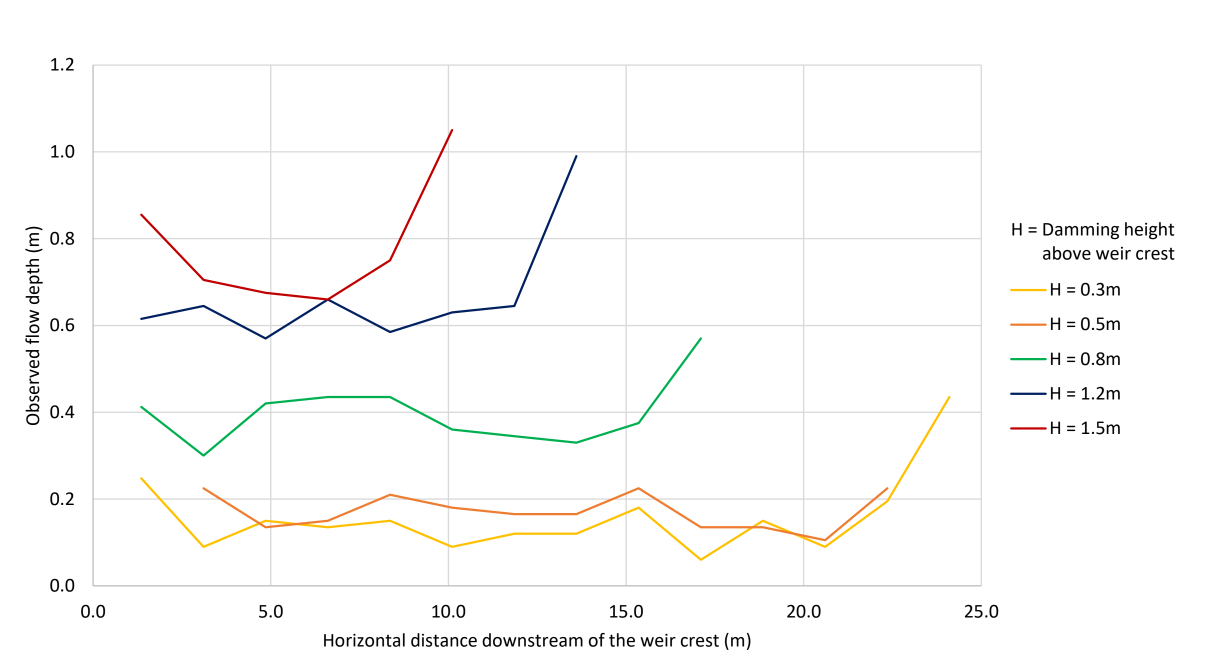

Figure 11-5: Flow depth at the 150mm high chevron-shaped weirs (location 4 in Figure 11-7)

Figure 11-6 shows the observed flow depths inside the side baffles (location 3 in Figure 11-7). The minimum flow depth at a low river discharge of 1 m^3/s is > 0.3 m. The solid black line at the top of the graph indicates the proposed top of the side walls of the chute, while the dotted blue line indicates a proposed concrete wall above the water and minimum 0.3 m high at the upper chute, along the edges of the baffles, to help canoeists navigate down the chute.

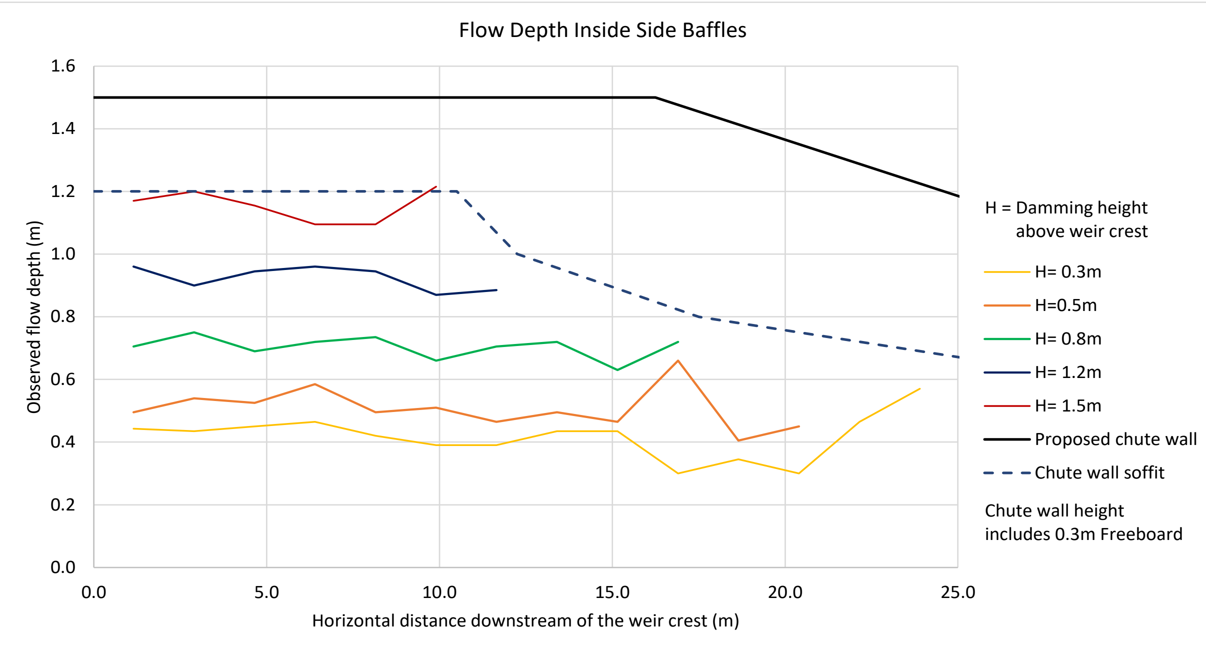

Figure 11-6: Flow depth inside side baffles

Table 11-2 shows data for the observed water depths in the larger resting pools (located every 10 m down the chute in the final proposed design). Table 11-3 indicates the observed water surface flow velocities around the edges of the side baffles (location 5 in Figure 11-7). The maximum flow velocity was recorded at 4.3 m/s (average of three measurements), at H = 1.2 m and river discharge of 73.5 m^3/s. (The current scenario 2-year flood in the Berg River is 182 m^3/s, with a 1- year flood peak of about 90 m^3/s).

Table 11-2: River discharges, tailwater levels and observed resting pool depths

H (m)	Calculated River Discharge (m^3/s)	Observed Chute Discharge (m^3/s)	Simulated Tailwater (masl)	Observed Resting Pool Depth (m)
0.3	1.0	1.0	47.0	0.375
0.5	5.1	2.1	48.0	0.405
0.8	23.3	4.3	49.0	0.600
1.2	73.5	7.8	50.1	-
1.5	123.0	10.9	50.8	-

Table 11-3: Measured flow velocities around the side baffles on the sides of the canoe chute

Damming height above weir crest (m)	H = 0.5m	H= 0.8m	H= 1.2m	H = 1.5m
Average (m/s)*	2.1	1.7	4.3	2.3

* Based on the average flow velocity of three tests taken around baffle 5, variation in local currents due to turbulence caused velocities to fluctuate

Figure 11-8 indicates the observed chute centreline water levels, which is more important to canoeists.

The design of the fishway-canoe chute tested in the physical model and the proposed design is shown in **Appendix A2**. For the safety of canoeists vertical concrete walls could be added along the side baffles, above the observed water levels on the chute. It is also proposed that the gap below these walls, where the fish should be able to pass, should be fitted with 16 mm round bars running longitudinally at the 1:5 (V:H) slope of the chute, without vertical support bars. The required gap between these bars should be determined by the fish and kayak requirements. For kayaks it is proposed that the maximum gap between the bars is 150 mm (to be confirmed by kayak designs and fish requirements).

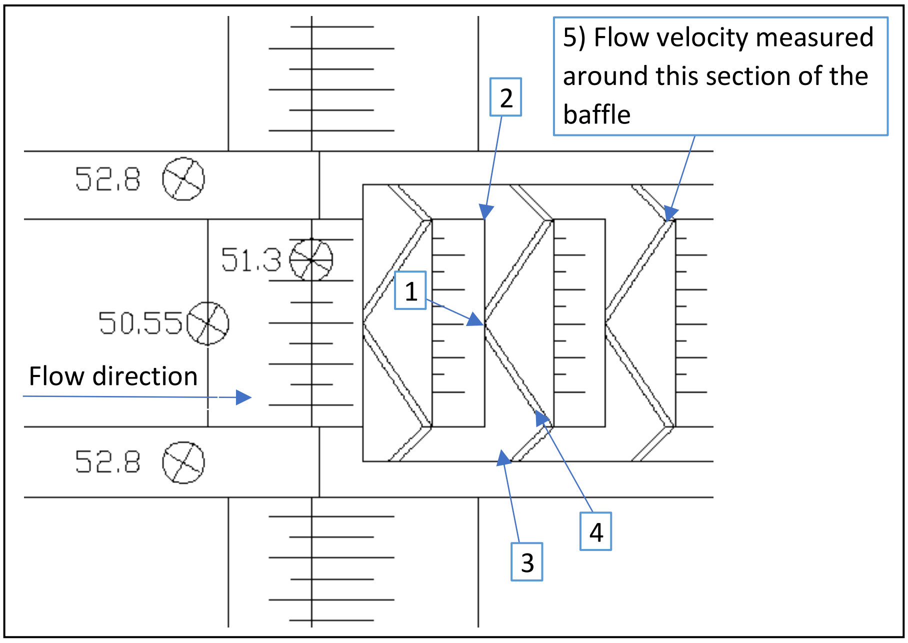

Figure 11-7: Locations where measurements were taken during the 1:15 model tests

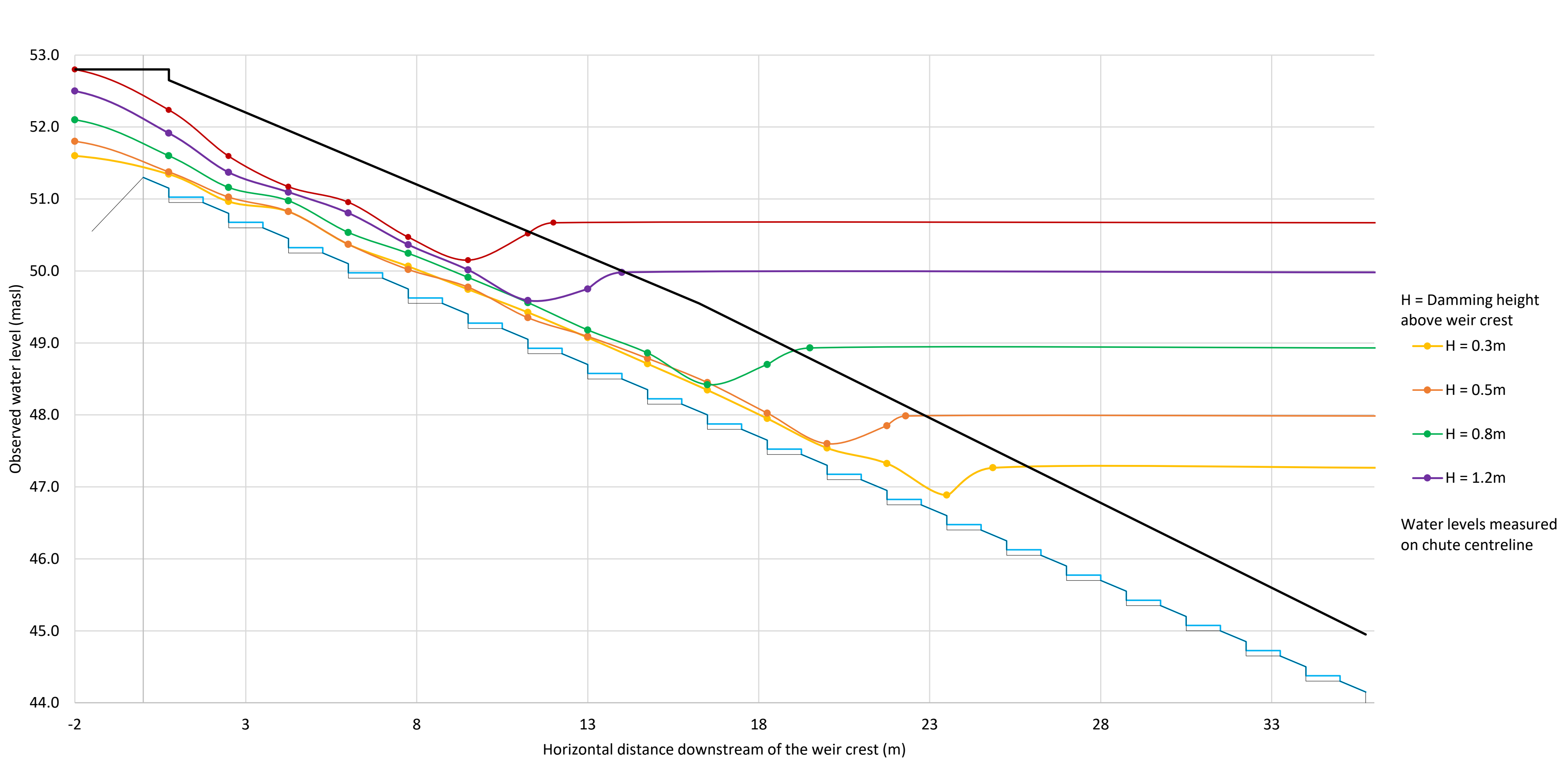

Figure 11-8: Longitudinal section of water levels on the fishway-canoe chute, measured at location 1 (Figure 11-7)

11.2 Characteristics of the fishway-canoe chute – Option B

Option B was adapted from the design and test results of Option A after consultations with experienced canoeists to address the safety concerns of the canoeists. There was a possibility that a kayak could become lodged sideways between the baffles as shown in Figure 11-9, due to the spacing of the side baffles. There was also a possibility of a kayak breaking if the bow collided with the baffles due to the sharp approach angle and the high flow velocity experienced in the chute at higher flows.

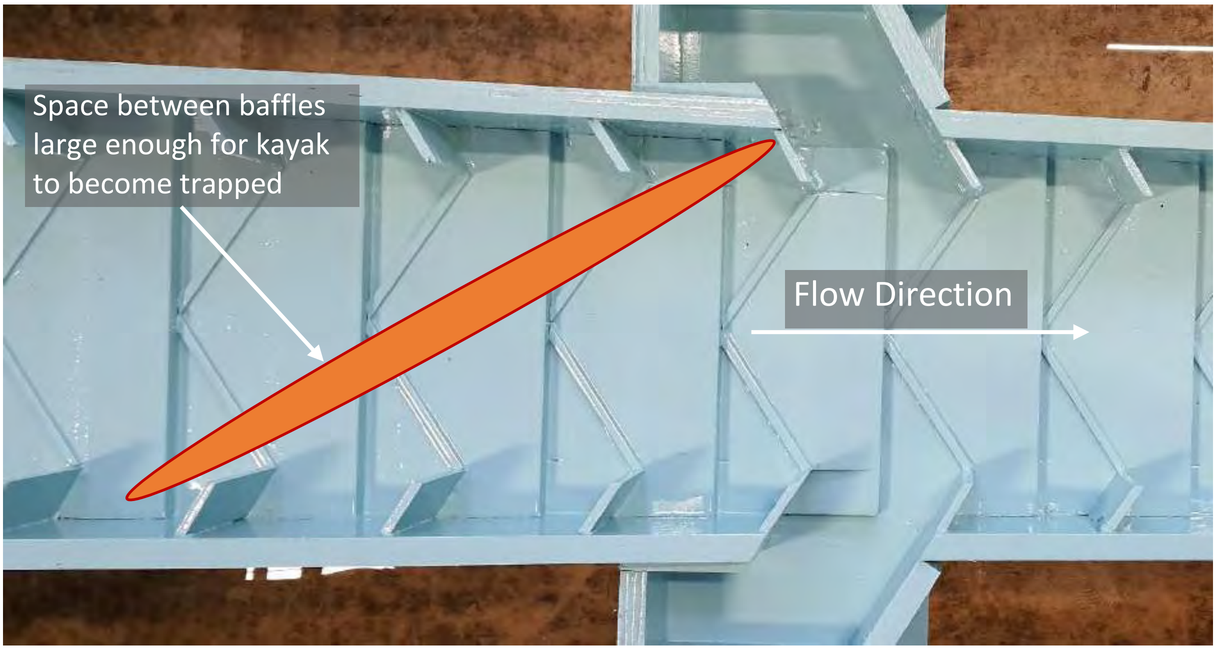

Figure 11-9: Illustration of the risk of a kayak being lodged between baffles in Option A of the fishway-canoe chute design

Other safety concerns and recommendations made by the canoeists were also addressed in the modified design. The following are some of the key hydraulic design changes made to the original design to better promote the safe passage of canoeists:

- Canoe chute Crump weir crest at 51.3 masl (0.3 m below the 17 m long low notch of the Crump weir).
- 1 m x 0.2 m (L x H) chute steps that form a 1:5 (V:H) slope.
- 0.2 x 0.2 m horizontal chevron-shaped floor weirs with a rounded upstream edge (0.1 m radius to reduce risk of injury in the event of a canoeist hitting the chevron floor weirs.
- The area between the upstream step and the chevron weir was filled in up to 0.3 m from the upstream step to prevent feet or limbs from getting stuck in the event of a canoeist capsizing whilst navigating the chute.
- Side baffles with 1 m radius, starting at the downstream end of each step and extending upstream to the chute sidewall to reduce the approach angle of the kayak with the baffle.
- Resting pools on either side of the fishway-canoe chute with access at steps 9 and 10. Resting pools will be located at intervals of 10 m along the final fishway-canoe chute).
- Upstream water heads tested: 0.3m, 0.5m, 0.8m, 1.2m and 1.5m (latter at top of dividing walls).
- Dividing walls extended to the final design height of 1.5m above the chute Crump weir crest (52.8masl).

Figure 11-10 shows the fishway-canoe chute tested in the hydraulics laboratory at a 1:15 scale. Only the first 15 steps (15m) were constructed and tested. The purpose of the tests was to test the hydraulic performance on the steps of the fishway-canoe chute, for this reason, the tailwater levels in the tests did not reflect the calculated tailwater levels expected downstream of the abstraction works.

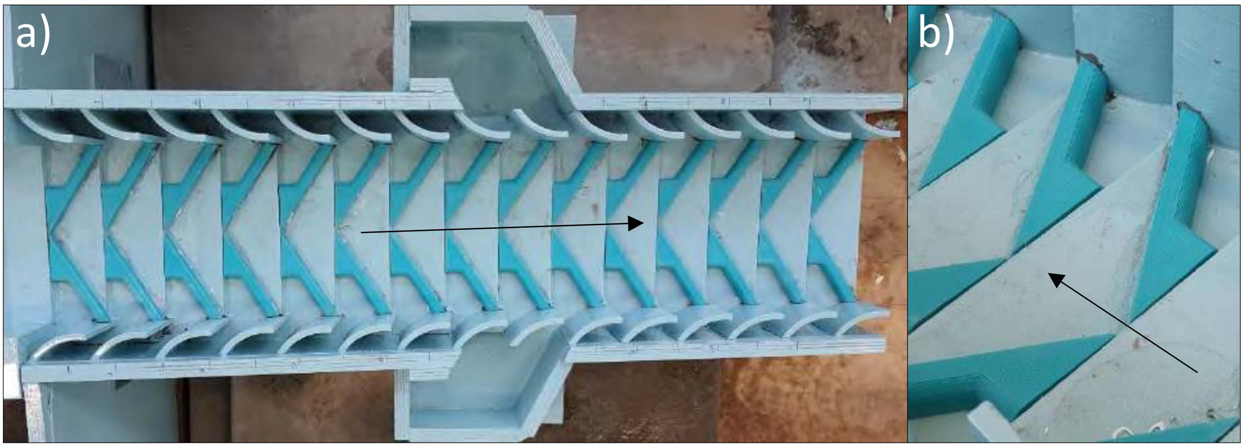

Figure 11-10: a) 1:15 scale model of the modified fishway-canoe chute constructed in the hydraulics laboratory, b) close-up view of the filled area and upstream radius of the chevron weir

Figure 11-11 shows the location of each measurement that was taken. Point 4 refers to the maximum observed water level against the baffle.

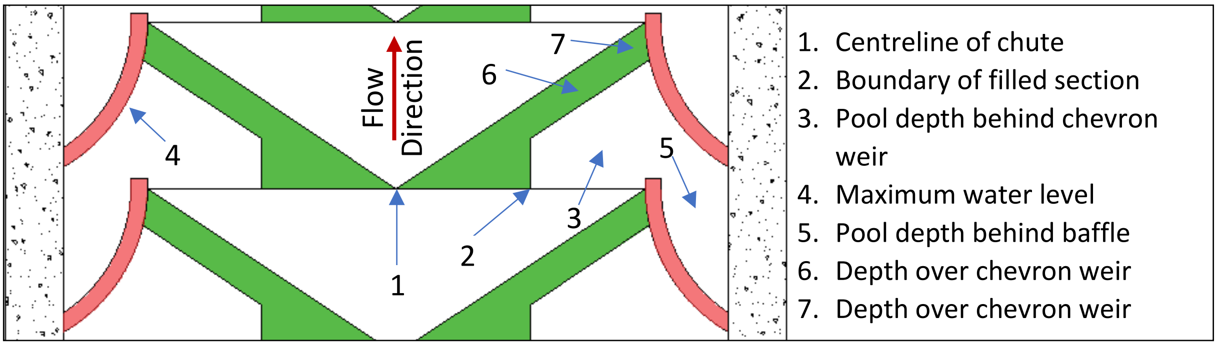

Figure 11-11: Measurement locations in physical model tests

Table 11-4 shows the water levels that were tested and the corresponding flow rate over the chute, river discharge and simulated tailwater levels. Tailwater was not used during the tests for the modified fishway-canoe chute to test steps 1 to 10 for each water level. The resting pool depth observed for each test is also shown in Table 11-4.

Table 11-4: River discharges, tailwater levels and observed resting pool water depths

Upstream Head H (m)	Calculated River Discharge (m^3/s)	Observed Chute Discharge (m^3/s)	Simulated Tailwater (masl)	Observed Resting Pool Depth (m)
0.3	1.0	1.0	47.0	0.47
0.5	5.1	2.1	48.0	0.51
0.8	23.3	4.3	49.0	0.68
1.2	73.5	7.8	50.1	0.86
1.5	123.0	10.9	50.8	1.00

Figure 11-12 indicates the observed flow depths in the centre of the chute (location 1) and at the boundary of the filled-in section (location 2). The flow depths recorded in this location is of interest to the canoeists. Flow depths recorded at location 2 is typically lower than in the centre of the chute due to the flow spreading to the pool created by the chevron weir. H = 0.3m corresponds to a river and fishway-canoe chute flow of only 1m³/s which is the minimum limit for kayak passage. A river flow of 1m³/s would be too low for a kayak to navigate the river. However, the shape of the chevron weir would still focus the flow towards the centre of the chute which is beneficial for ensuring that the kayak is pulled towards the centre of the chute. The typical winter canoeing discharges in the river are between 5 m³/s (H=0.5 m) and 74 m³/s (H=1.2 m).

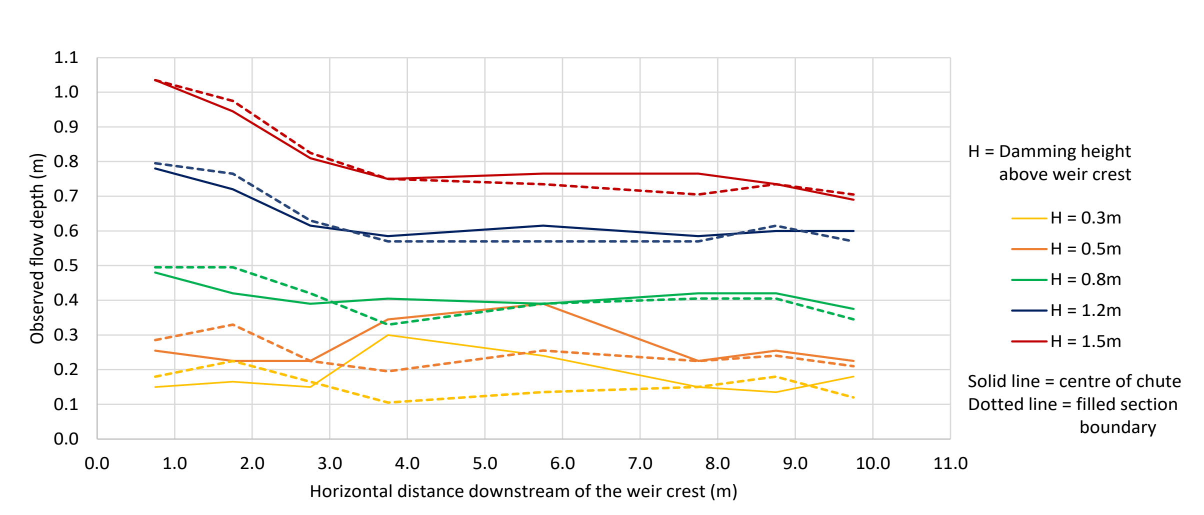

Figure 11-12: Observed flow depths in the centre of the chute (location 1) and on the boundary of the filled section (location 2)

Figure 11-13 illustrates the function of the chevron weirs where the water level over the chevron weirs at the baffles (location 7) is higher than in the centre of the chute (location 1). The higher flow depth is attributed to the flow around the baffles and the chevron weirs create a triangular section when viewed from upstream. As the discharge increases the effect of the chevron weirs and baffles becomes less pronounced and the difference in water level is reduced.

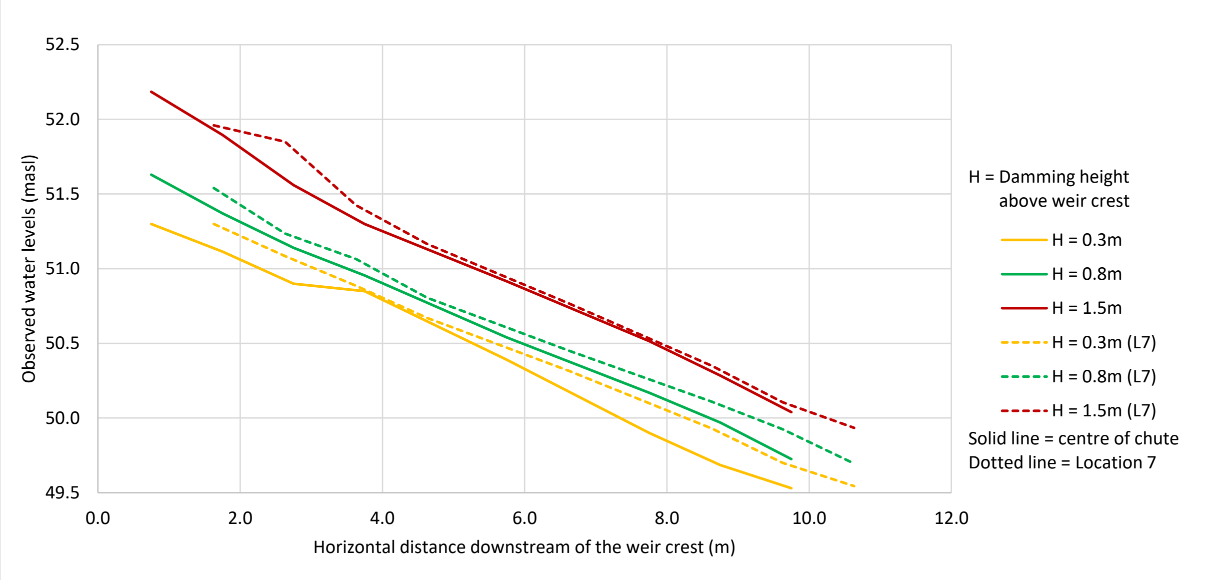

Figure 11-13: Observed water levels at the centre of the chute (location 1) and the boundary between the baffle and chevron weirs (location 7)

Figure 11-14 indicates the flow depths observed over the 0.2 m high chevron floor weirs. The flow depth over the chevron weirs will be the minimum flow depth in the chute, but each weir is only 0.2m wide. The minimum flow depth over the chevron weirs is 0.1m at a discharge of 1m³/s. At H = 0.8 m the river discharge is 23.3 m³/s (Table 11-4), a small flood, and the minimum flow depth is increased to 0.23 m.

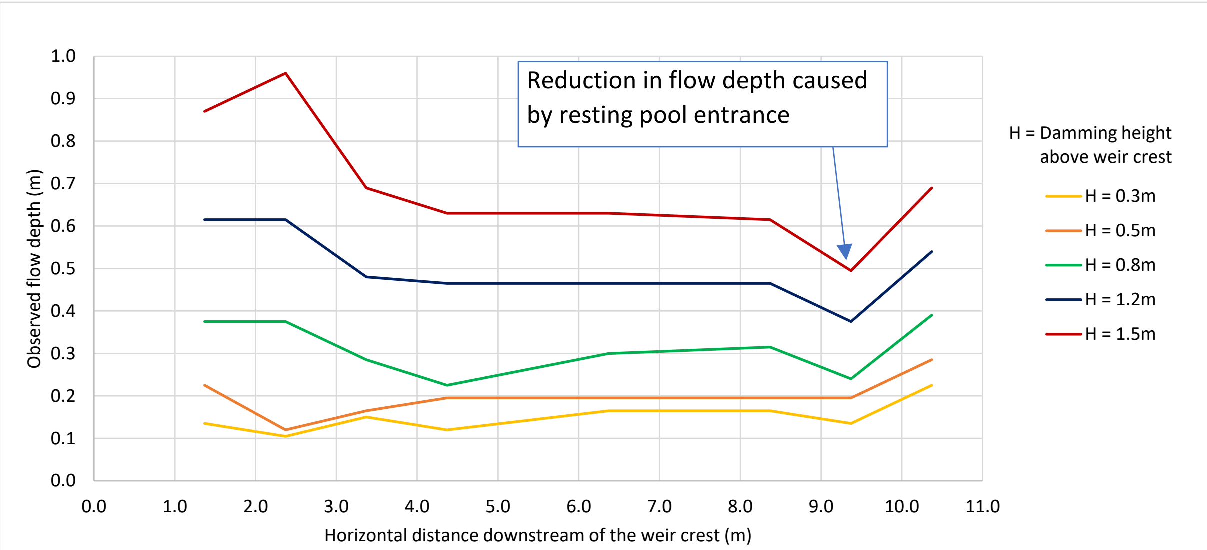

Figure 11-14: Observed flow depth over chevron weir (location 6)

The observed flow depths in the side baffles are shown in Figure 11-15, deeper flows are recorded in this location due to the damming caused by the chevron floor weirs. The flow inside the baffles has low levels of turbulence when compared to the design previously tested. The increase in depth at 8.8 m is due to the resting pool which is 0.2 m lower at step 9 (8.8 m). Figure 11-16 shows the difference in the flow behind the side baffles for a) the previous model tested and b) the modified fishway-canoe chute, the discharge in the chute is 4.3 m³/s and the river discharge 23.3 m³/s.

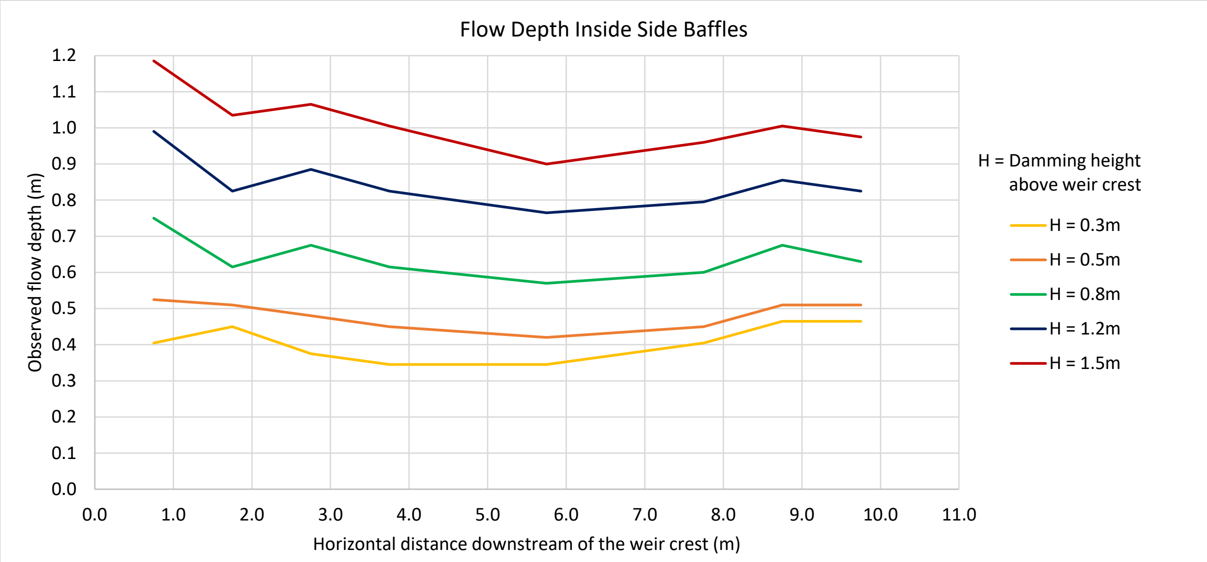

Figure 11-15: Observed flow depth behind 1 m radius baffle (location 5)

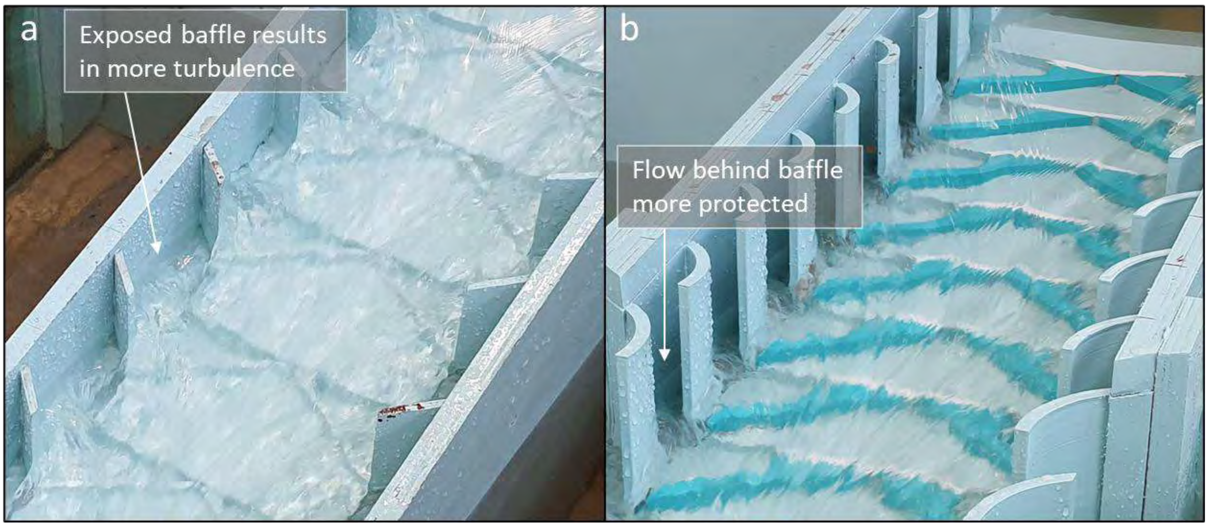

Figure 11-16: Comparison of turbulence between angled baffles and 1m radius baffles

Figure 11-17 illustrates the proposed wall height for the fishway-canoe chute, the height was determined by comparing the maximum observed flow depths on the side against the side baffle (location 4) and behind the baffle (location 5) from the modified chute (solid lines) for the first 10 m to the maximum flow depths observed in the previous design (dotted lines) where the full length of the fishway-canoe chute was tested with the correct tailwater levels. The maximum flow depths are for the modified chute (solid lines) are lower than the previously observed flow depths (dotted lines) and it would be a safe assumption that the flow depths for the modified chute will remain lower than the previous design that was tested if extended to the full length of the chute.

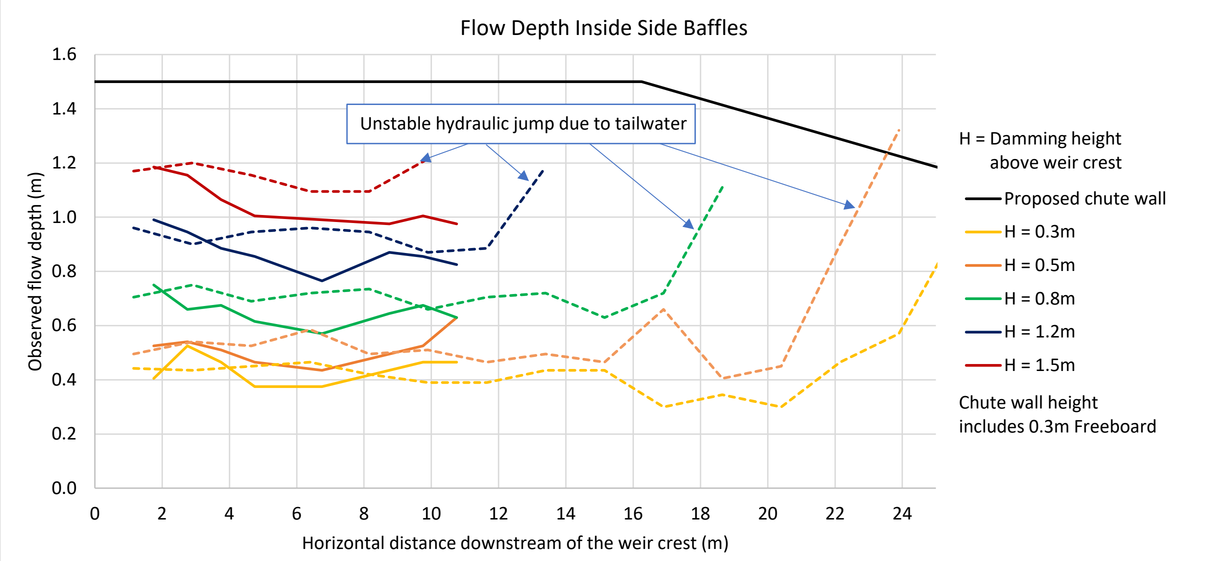

Figure 11-17: Proposed wall height based on maximum observed flow depths (max between location 4 & 5) and the maximum flow depths against the angled side baffle from the previous design

Table 11-5 indicates the observed water flow velocities observed over the chevron floor baffle around the edges of the side baffles for the modified fishway-canoe chute. The flow velocity over the floor weir is of importance for fish migration and the velocity in this location will be the highest velocity that the fish will need to swim against in the fishway-canoe chute. These observations were made using a pitot tube placed on the floor of the chevron floor weir and represents the velocity 51mm (in prototype) above the weir and away from the side baffle. Figure 11-18 shows the model setup used to measure the flow velocity. The observed velocities over the floor weir are within the acceptable range for fish migration. The estimated maximum burst speed of adult Whitefish is at least 2.5 m/s (approximately 10 x body length) which is considered to be conservative. The maximum observed velocity is 2.6 m/s at H = 1.5 m, river discharge 123 m^3/s which is slightly larger than a 1-year ARI flood (90 m^3/s).

Surface flow velocities in the centre of the chute were also observed and are shown in Table 11-5, these velocities are of interest to canoeists navigating the chute. The surface flow velocities were observed by means of small wooden blocks floating on the surface and the average velocity were calculated over 6 steps.

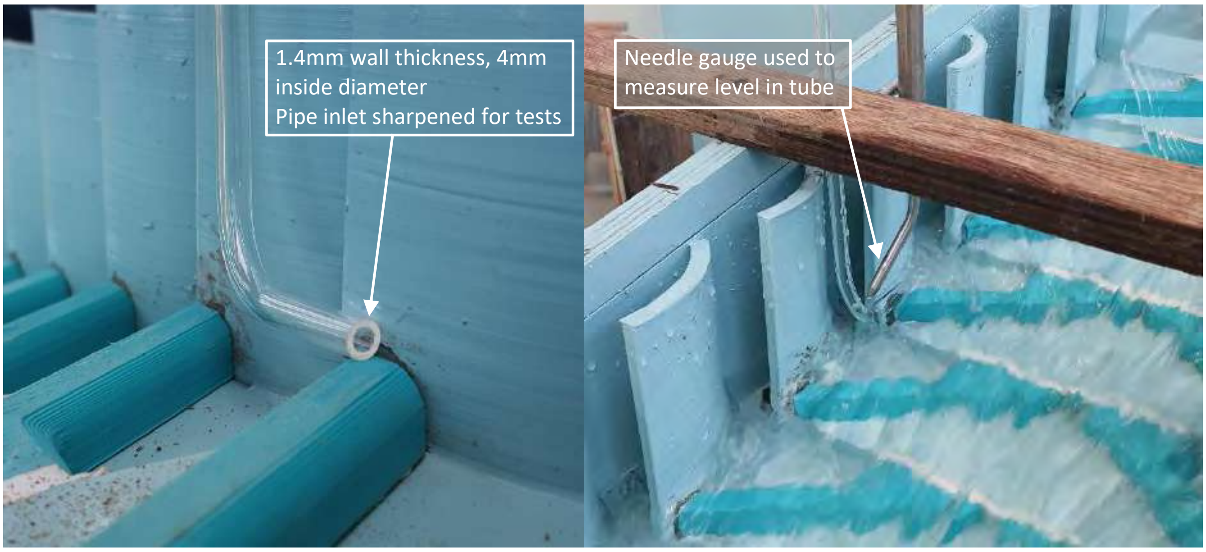

Figure 11-18: Pitot tube setup for measuring flow velocity over chevron floor weir

Table 11-5: Measured water flow velocities around the side baffles on the sides and at the centre of the canoe chute

Damming height above weir crest (m)	Method of Measurement	H = 0.3m	H = 0.5m	H= 0.8m	H= 1.2m	H = 1.5m
Fish: Bottom flow velocity over weir at baffle (m/s)	Pitot tube	1.0	1.3	2.3	2.4	2.6
Canoes: Surface flow velocity at centre of the chute (m/s)	Floats	4.2	4.9	5.3	6.2	6.6

Figure A2-2 shows the initial design as constructed and tested in the 1:15 model, while Figure A2-3 and A2-4 shows the modified design with 1m radius side baffles and 0.2m high chevron floor weirs. For the safety of the canoeists, the 1m radius baffle design is preferred, the curved design of the side baffles provides a reduced approach angle if a kayak hits the baffle and the reduced access area into the baffle will prevent a standard K1 and K2 kayak from becoming lodged between the baffles.

Initially, the design allowed for access to the resting pool through two baffles (steps 9 and 10), but high turbulence and currents were observed during the higher flows. As shown in Figure 11-19a, the inflow at the upstream baffle results in turbulent flow not suitable for a resting pool, while Figure 11-19b shows that the flow in the resting pool is less turbulent with only one opening to the resting pool. The chute discharge was 7.82 m^3/s at H = 1.2m.

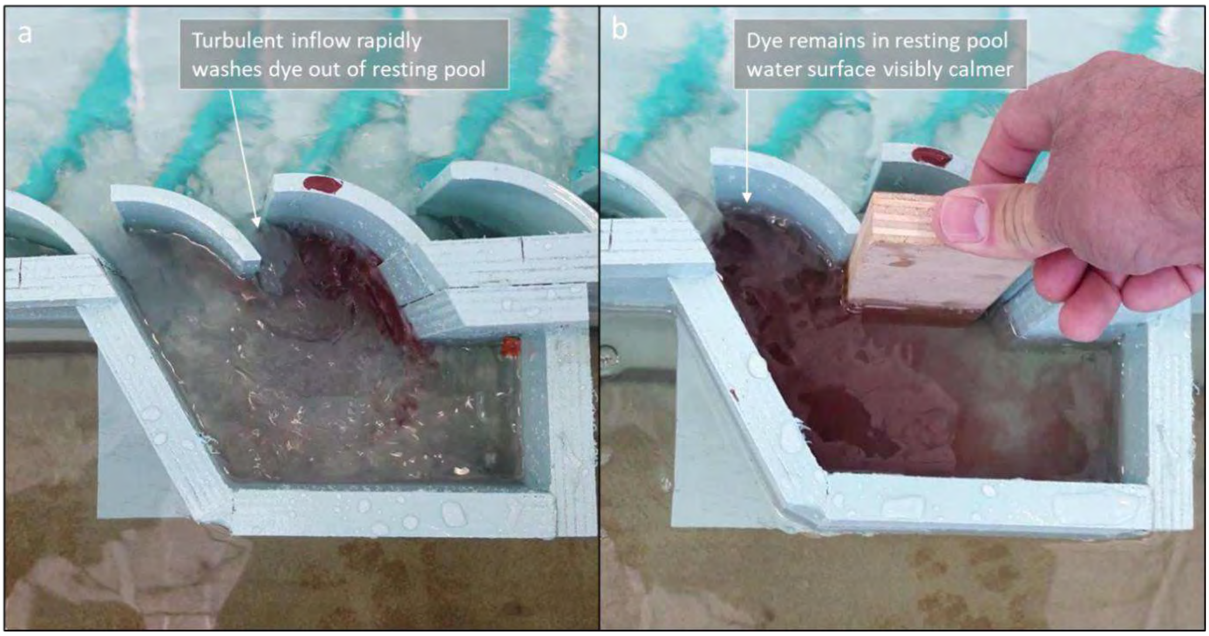

Figure 11-19: Resting pool with two openings compared to resting pool with one opening, H = 1.2m

This modified chute design aims to improve the fishway-canoe chute design by reducing the flow velocities in the chute in the centre and around the baffles, increasing the flow depth for better fish migration, improving safety and improving the self-scouring potential of the resting pools.

12. Proposed operation of the river abstraction works

12.1 Guidelines for normal operation and flushing operation

The proposed abstraction works will be self-scouring at the intake openings (boulder trap gate closed) during floods larger than 424 m^3/s (i.e. Q5cc) and secondary currents will keep the intake open. The intake openings between the boulder and gravel trap is under water and generally debris would not reach the trashracks. The radial gates are normally all closed and should not be opened during large floods. Flushing of the boulder and gravel traps by opening the radial gates should only be done to clean the traps and therefore the intake area, and not for the removal of the sediment upstream of weir. Sedimentation to say within 0.5 m of the weir crest is expected to occur during the first flood season and should not impact on the operation of the abstraction works. The boulder trap must be flushed first, manually by opening the radial gate, followed by flushing both gravel trap canals at the same time by opening both gravel trap gates simultaneously. The boulder trap should be flushed before the gravel trap is flushed to prevent coarse sediment from entering the gravel trap. The boulder trap and gravel trap should not be flushed continuously because this will impact on the low flow ecology due to elevated base flow sediment concentrations. Gravel and boulder trap flushing should be done during small floods or at the end of large floods. The model tests indicated that boulder and gravel traps can be flushed from low small floods of 10 m^3/s up to the Q5cc flood by opening the gates, but works best under free outflow supercritical conditions with the hydraulic jump forming downstream the traps when flushing. The tailwater level should be low enough (lower than upstream levels) so that free outflow conditions occur for maximum flushing efficiency of the sediment. Flushing should only be done for short periods of time (20 to 30 minutes). Typically, the boulder trap takes longer to flush than the gravel traps because it deals with coarser deposits.

The opening of the radial gates should be operated manually, after switching off the duty pumps. The stage-discharge rating curves of Figure 9.38 can be used to establish the telemetry for the weir to measure the river discharge and to establish operating rules for flushing. A summary of the upstream water levels is given in Table 12-1, measured approximately 6 m upstream of the weir.

Table 12-1: Stage-discharge rating, telemetry and proposed cleaning operation

Flood recurrence interval (years)	Flood peak including climate change (m^3/s)	Water level upstream of the low notch Crump weir (masl)	Water level upstream of the high notch Crump weir (masl)	Downstream tailwater level (masl)	Proposed cleaning operation
	10	51.94	51.94	48.36	Flush
	50	52.22	52.34	49.68	Flush
1	100	52.46	52.5	50.52	Flush
2	210	53.10	52.94	51.71	Flush
5	424	54.06	54.06	53.23	Self-scour / flush at end
10	613	54.68	54.66	54.13	Self-scour / flush at end
20	830	55.54	55.52	54.94	Self-scour / flush at end
50	1169	56.58	56.56	55.91	Self-scour / flush at end
100	1468	57.22	57.18	56.37	Self-scour

It is important that the pipeline between the river abstraction works and Voëlvlei Dam is operated at a high flow velocity, or flushed from time to time at a velocity of 3 m/s or cleaned mechanically from time to time to remove silt deposition which could affect the hydraulic roughness and friction losses.

The trashracks could be cleaned by flushing the gravel trap near the end of a flood which will drain the pump bays by reversing the flow or by raising the trashracks for cleaning. The trashracks vertical gates should be closed during flushing of the gravel trap to ensure the flushed sediment does not escape into the hoppers.

Flow will be abstracted only during the wet winter months of the year (June to September) and should not abstract the minimum Environmental Water Requirement (EWR) (considered to be in the order of 1 m^3/s but the EWR discharge does not have to be fixed per month and could also be revised from time to time and should be confirmed by environmental studies).

The boulder trap should be flushed weekly and after each storm event for 30 minutes (the time should be measured from when the gate is completely open). The boulder trap should therefore be flushed more frequently if there is more than one storm event per week, followed by flushing the gravel trap canals for 20 minutes (from when the gate is completely open). During the remaining summer months of the year (October to May), the intake and trashracks should be closed permanently with the vertical gates. The boulder trap should still be flushed weekly for 20-30 minutes, preferably after storm events should they occur during the summer months. The same applies to the gravel trap. At the start of the abstraction season in June, the boulder trap should be flushed followed by the gravel traps, one at a time. All the gates should be inspected for leakage and repaired before the abstraction season starts.

The hoppers are cleaned by the jet pumps. They should operate at least once per week to prevent sediment consolidation. During summer when the pumpstation is not operating the vertical gates at the intakes to the hoppers should be closed. Stemming fork sensors could be installed in the hoppers to measure when the jet pumps should be activated.

12.2 Sediment loads

The impact of the weir construction at the BRVAS site on the downstream sediment supply and movement is considered negligible. Initially, the increase in water levels would cause the upstream reach of the river to silt up. However, within the first one or two flood seasons, the river would achieve a new morphological equilibrium. Therefore, the weir would have no long-term effect on the Berg River sediment load or ecology.

The sources of sediment returned to the river are as follows:

a) One boulder trap at the abstraction works. Sediment to be flushed during small floods in the river. Flushing cleans the intake areas of the abstraction works and not the deposited sediment upstream of the weir which should be allowed to reach an equilibrium condition. The storage upstream of the weir is not required for operation of the abstraction works. The sediment is non-cohesive bed load, consisting of sand, gravel, cobbles and boulders.

b) Two gravel traps at the abstraction works. Sediment to be flushed during high flow periods in the river. The sediment is non-cohesive bed load, consisting of sand and gravel.

Flushing of sediments that deposited at the boulder and gravel traps would ensure that the trapped sediment is returned to Berg River. To minimize the impact of the abstraction works on the river downstream and to assist restoration of the sediment balance, flushing should be of a short duration (less than 30 minutes) and only during small floods (not under normal or low river flow conditions).

The locally increased sediment concentrations in the river during the small floods would have minimal ecological impact.

The boulder trap and gravel traps should be able to trap sediments as fine as 0.6 mm while the rest of the coarse sand non-cohesive sediment fraction should be removed by the two hoppers. Some sand and possible also coarser particles are expected to be pumped by the duty pumps at the river from time to time if the hoppers are not operated properly. The low lift pumps should therefore be able to handle sediment sizes of at least 100 mm in diameter (2 x trashrack openings of 50 mm to allow for sediment shape).

The predicted mean annual sediment load for the Berg River at the proposed BRVAS abstraction works is 54 674 t/a. The sediment load was determined by the empirical sediment yield prediction methodology for Region 8 (WRC, 2012) with a 90% confidence band and is in agreement with the 53 259 t/a sediment yield quoted in the Berg River study by Van der Walt (2005) for the post-dam scenario (Berg River Dam and Wemmershoek Dam).

Van der Walt (2005) also determined the sediment load-discharge rating curve in Figure 12-1 based on his 2003/2004 winter sampling at the G1H013 station gauge (the same gauge for the flood hydrology analysis). The relationship determined for the proposed BRVAS site, given below, was calibrated against the sediment load-discharge rating of Figure 12-1:

$$Qs = 0.0035Q^{1.8568}$$

where Qs is the sediment load (g/s) and Q is river discharge (m^3/s). The relationship was applied to the 15-year daily flow record from 2000 to 2015 in Figure 12-2 to determine the sediment mass balance for the BRVAS abstraction works. It is estimated that the bed load makes up 15 % of the total sediment load Qs during floods. The bed load could be deposited in the boulder trap, gravel trap and hoppers during normal operation of the abstraction works.

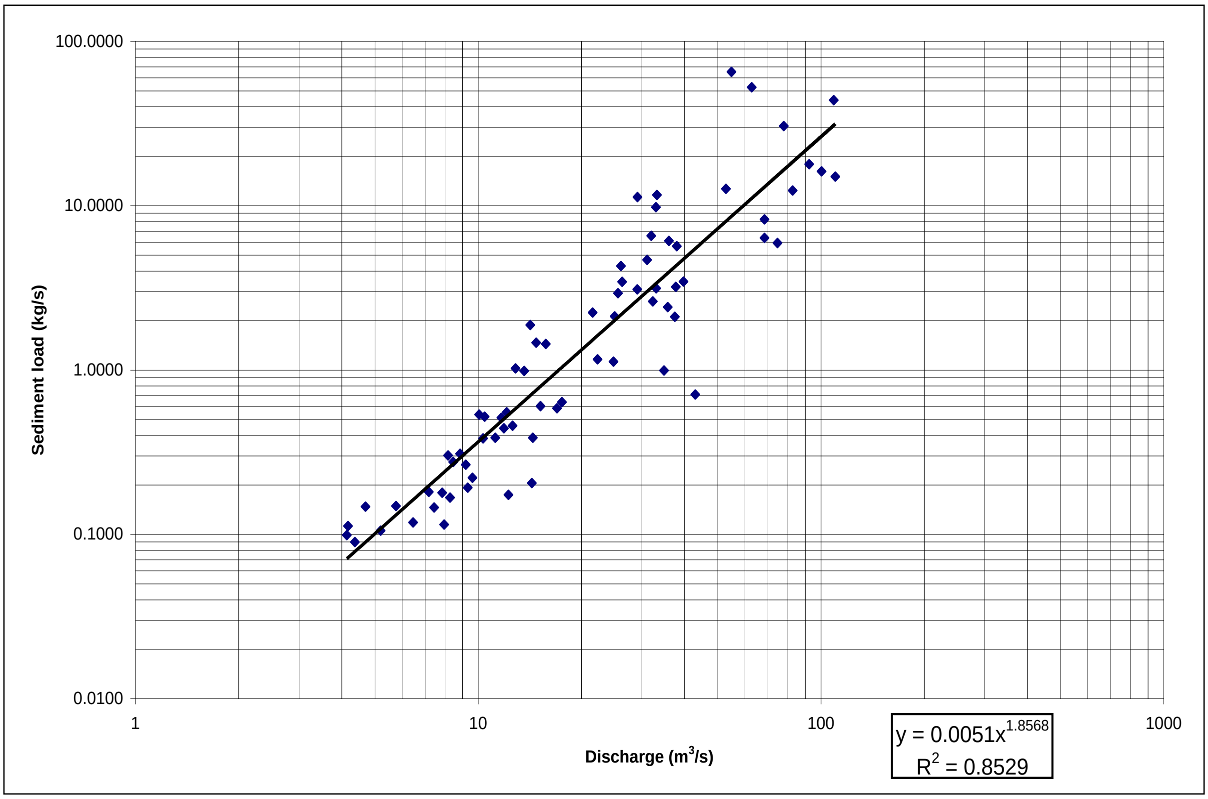

Figure 12-1: Sediment load-discharge rating curve at station gauge G1H013 (van der Walt, 2005)

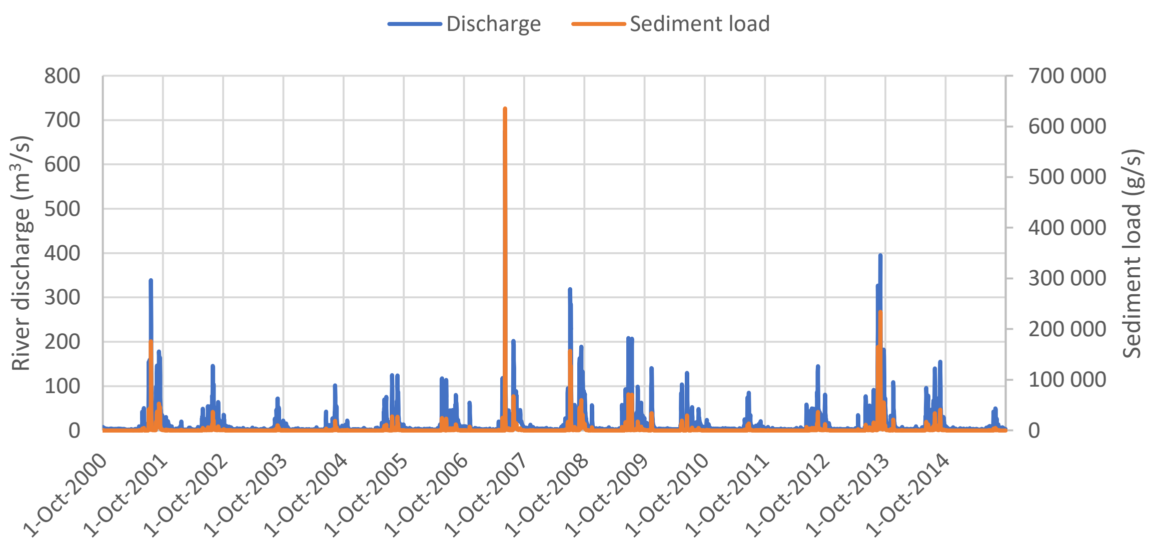

Figure 12-2: Sediment loads expected at the proposed BRVAS site for a 15-year flow record

Cohesive sediment or washload that is removed by the abstraction works at the BRVAS site will not have a negative impact on the downstream river reaches. Cohesive sediment has no effect on erosion and a reduction in washload may actually be good to counter the land degradation and climate change impacts. Therefore, only the non-cohesive sediment load will have a negative impact on the river. None of the cohesive sediment fractions are trapped at the BRVAS weir thus its abstraction works would not interrupt the natural flow of sediment to the coast related to coastal beach stability.

Tables 12-2 and 12-3 summarize the sediment loads for the future scenario with the abstraction works based on a pump discharge of 4 m^3/s and 6 m^3/s respectively. For the 6 m^3/s pump discharge, the total reduction in the cohesive sediment load at the site will be 6.7% (compared to the river upstream of the site) while the reduction in total sediment load will only be 6.4% (which is mostly composed of washload or cohesive sediment). Of the sediment abstracted by the pumps, 10.3% would be non-cohesive (but smaller than 0.3 mm).

Table 12-2: Sediment load for the future scenario with abstraction works only removing cohesive sediment (ton/annum) for a pump discharge of 4 m^3/s

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	**Total Sediment Load**
	Fraction 1 0.9 mm	Fraction 2 0.21 mm	Fraction 3 0.075 mm			
Sediment in river upstream of the site	2 870	2 870	2 460	8 201	46 473	**54 674**
Sediment trapped by boulder trap, gravel traps and hoppers	130	0	0	130	0	**130**
Sediment load abstracted by pumps	0	130	111	242	2 105	**2 347**
Downstream of site after flushing	2 870	2 740	2 349	7 960	44 367	**52 327**

Table 12-3: Sediment load for the future scenario with abstraction works only removing cohesive sediment (ton/annum) for a pump discharge of 6 m^3/s

	Coarse Non-Cohesive Sediment			Total Non-Cohesive Sediment	Total Cohesive Sediment	**Total Sediment Load**
	Fraction 1 0.9 mm	Fraction 2 0.21 mm	Fraction 3 0.075 mm			
Sediment in river upstream of the site	2 870	2 870	2 460	8 201	46 473	**54 674**
Sediment trapped by boulder trap, gravel traps and hoppers	193	0	0	193	0	**193**
Sediment load abstracted by pumps	0	193	166	359	3 130	**3 489**
Downstream of site after flushing	2 870	2 677	2 295	7 842	43 343	**51 185**

12.3 Appropriate pump selection for possible sediment abstraction

Provisional duty pumps and motive pumps to drive the jet pumps were selected to enable the appropriate sizing of the pump bays and hoppers and shown in **Appendix B**. The recommendation also carefully considers the choice of an appropriate 1 or 1.5 m^3/s of raw water pumps for pumping raw river water with some possible sediment and debris content. The choice is between a pump with a higher pump efficiency but with consequent smaller tolerances (i.e. smaller free-passage size) versus a more robust pump that is designed to handle abrasive sediment and stringy type debris with consequent larger free-passage size and lower efficiency. The provisional submersible sewerage type pump that is given in **Appendix B** was selected for a free passage of 180 mm and an efficiency between 82% and 84%.

For a remotely located pump station that is not in constant use but mostly during floods a submersible pump has the following advantages:

a) The pump and motor system is integrated with embedded monitoring and operating control instrumentation to protect the pump and motor and to enable operating at the best efficiency at all design river water levels by means of variable speed drives (usually by VFD). See duty curves in **Appendix B** of the provisionally selected pump at different speeds.

b) It can operate in both dry well and wet well mode. In dry well mode an integrated cooling jacket is provided. If a dry well mode is selected it can still operate in the unlikely event that the dry well becomes flooded during an extreme flood (electrical switch gear and control units must be located above extreme flood levels).

c) Since the pump and motor system is integrated the unit can be removed and transported to a competent workshop for maintenance and repair avoiding on site repair/maintenance.

d) Pumps-motor units malfunctioning, can be replaced relatively quickly with a unit in storage.

Particles of 50x50x100 mm which may pass through the trashracks can be handled by the proposed pumps because the pumps have a free passage of 180 mm. Although it is unlikely that the pump will have to deal with such large particles because they will be settled out by the sediment traps and hoppers. Furthermore, it is unlikely that floating particles and debris will pass through the trashracks to the hoppers because the intakes and trashracks are located below the MOL and will therefore always be submerged. Floating debris can be removed after floods by raising the trashracks and flushing of the gravel traps.

The openings of the trashracks cannot be made smaller since it will affect the intake velocities and the weir will have to be raised to increase the flow area at the screen. In some designs fine screens could be added downstream of the hoppers and short pump canals could be added so that the screens do not affect the pump intake hydraulics. The pump canals may need flushing jets to flush sediment back to the hoppers underwater. The duty pump discharge of the BRVAS scheme will require larger openings of the fine screen than at the trashracks and therefore it is not an option to install fine screens. Screening with small screens requires constant monitoring which will probably not occur 24/7 in future; the design should cater for the worst case scenario with minimum maintenance. Fine screens are not proposed at the BRVAS abstraction works.

13. Conclusions and Recommendations

Stellenbosch University was appointed to carry out a 1:40 scale physical hydraulic model study of the proposed abstraction works and weir on the Berg River for the Voëlvlei Dam water augmentation scheme. A 2D hydrodynamic numerical model (Mike21C of the DHI Group) was used in a hybrid approach with the physical model design and tests as follows:

a) The calibrated numerical model was used to simulate the tailwater levels for the physical model

b) The numerical model was used to quickly evaluate various hydraulic scenarios with movable bed conditions, before optimization of the most feasible design in the laboratory. The numerical model is therefore not there to replace the physical model; the physical model results will always be more reliable.

c) The numerical model was used to simulate the long term (15 year) river morphology upstream and downstream of the weir site and associated flood levels due to sediment deposition and scour.

d) The numerical model was also used to simulate the current development scenario floodlines as well as the post-weir flood levels upstream of the physical model domain.

The concept hydraulic design of the feasibility study by ASP (2012) was reviewed and optimized through several iterations by addressing the following:

- The flood hydrology, topographical and underwater survey as well as sediment sampling was updated as almost 10 years have passed since the feasibility study.
- The orientation and location of the abstraction works and weir on the river bed was adjusted for improved secondary currents and self-scour conditions of the intake (Option B2 – refer Figure 9-16 and **Appendix A**). The abstraction site is not ideal given the relatively low flow velocities due to the small river slope and relatively wide floodplain flow.
- Initially long berms (flood levees) along the left and right banks of the river were proposed to help constrict the wide floodplain flow and to improve flow velocities (Option A). This is the same approach followed at the Berg River Dam Supplement Scheme. However, the berms were not part of the approved EIA for the abstraction works. Obtaining approval for the berms may result in unacceptable delays and therefore Option B2 is recommended. Option B2 instead includes a guide wall separating the Crump weirs from the broad crested weir to better constrict the floodplain flow for floods smaller than the 50-year flood. Velocities in the order of 2.2 m/s during the 50-year flood suggest that self-scour at the intake can be expected.
- The Crump weir was designed based on the DWS requirements for accurate flow measurements. The length of the Crump weir was shortened and the height of the broad crested weir was raised to impose flow with higher velocities at the site. The weir was raised by 3.4 m to a new MOL of 51.3 masl (coinciding with the crest of the Crump weir of the fishway-canoe chute). The low notch and high notch Crump weirs are each successively 0.3 m higher than the fishway-canoe chute weir, separated by dividing walls for flow measurement. The low Crump weir at the fishway-canoe chute has a design head of 1.5 m for a design discharge for flow measurement of 123 m^3/s. The MOL = 51.6 masl.
- The raised weir produces headwater levels that exceed the tailwater levels for floods smaller than the 100-year flood. Therefore, the boulder trap and two gravel traps can be cleaned and flushed efficiently during small floods (<Q5cc) or at the end of large floods (< Q100cc) as indicated by the physical modelling. The boulder trap must be flushed first followed by flushing

both gravel trap canals at the same time by opening both gravel trap gates simultaneously. Flushing should only be done for short periods of time (20 to 30minutes). Guidelines for normal operation (June to September) and flushing operation of the sediment traps by raising the gates are given in Section 12.1.

- The fixed bed tests were complimented with movable bed tests to evaluate the sediment scour and deposition at the weir. Geotechnical information (DWS, 2012) indicated that bedrock is available at the proposed site and therefore no additional energy protection or erosion protection is required at the Crump weir if the weir is founded on solid rock. The movable bed tests showed that the riverbed at the weir would scour to the bedrock level. The movable bed tests also showed that sufficient self-scour would take place at the intakes for floods greater than the 5-year flood without opening the radial gates at the traps.
- Water levels were measured to optimize the structure heights and to determine the stage-discharge rating curves as well as floodlines for the BRVAS weir. The right bank berm was designed to prevent spilling up to the RMF of 61.2 masl. The broad crested weir and guide wall elevation of 57.0 masl coincides with the Q50cc flood. The level of the top of the intake structures and flank wall is 58.48 masl i.e. the Q100cc flood level plus an additional 0.5 m for freeboard against wave action.
- A concept combination fishway-canoe chute was designed as part of this study based on discussions with DWS, professional canoeists, and fishway expert Dr Anton Bok. The design was tested and optimized in the 1:40 scale physical model as well as at a scale of 1:15 in a flume. The fishway-canoe chute has a 1:5 longitudinal slope with baffles to help create pools with lower velocities for fish to swim upstream while the unique chevron shape of the stepped weirs ensure that canoes always descend along the centre of the chute.

The hydraulic drawings for the final proposed abstraction works and weir design (Option B2) are given in **Appendix A** while the floodlines for the 50-year and 100-year floods with and without the final (Option B2) abstraction works, as well as the proposed expropriation line, are given in **Appendix F**. The floodlines with the weir and abstraction works indicate that a saddle berm is required to the east of the proposed berm at the right bank side of the proposed weir.

14. References

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Appendix A1: River abstraction works drawings and weir

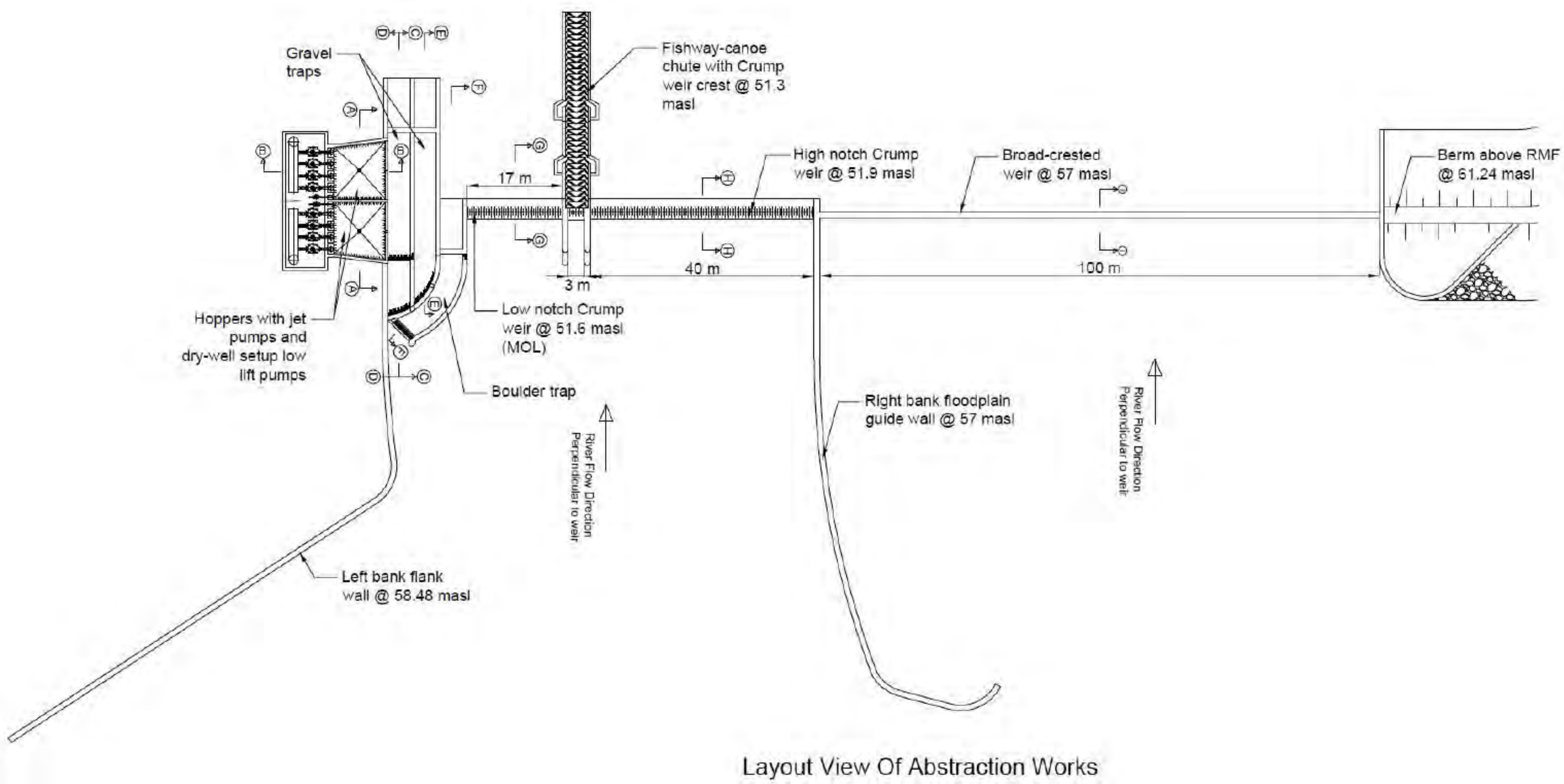


Figure A1-1: Proposed BRVAS abstraction works and weir plan layout with concrete side walls to guide the approach flow (refer to CAD dwg for details)

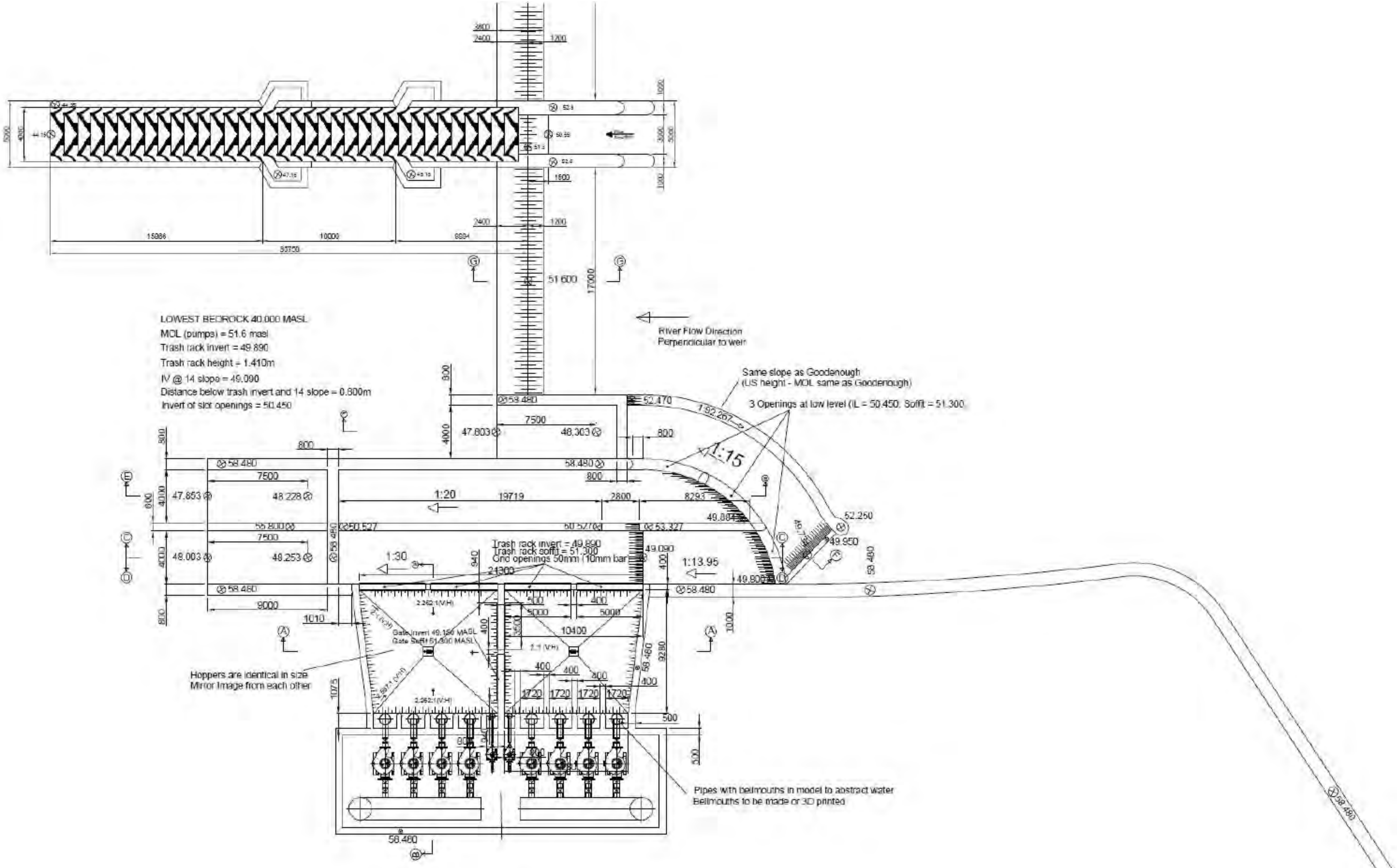


Figure A1-2: Proposed BRVAS abstraction works and weir plan layout

Figure A1-3: Proposed BRVAS weir sections at the weir viewed looking downstream

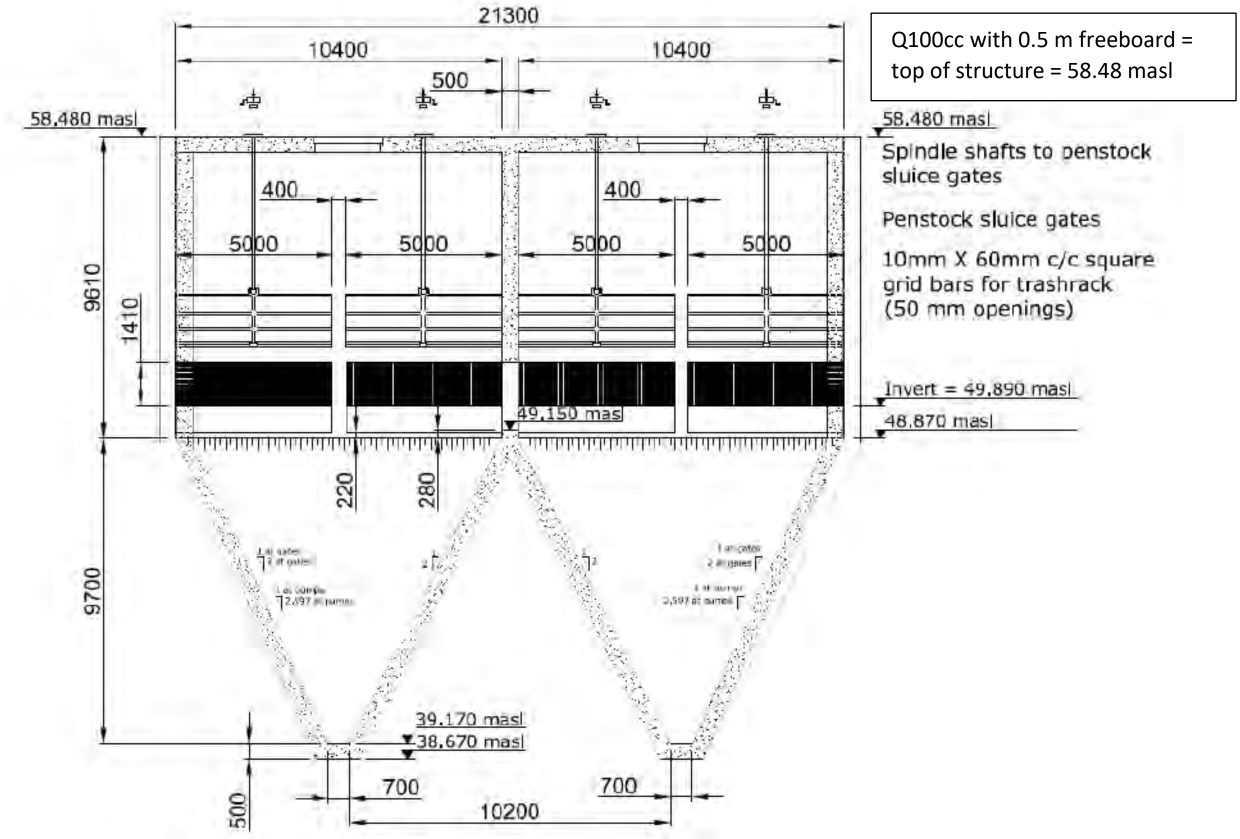


Figure A1-4: Proposed BRVAS abstraction works section A-A

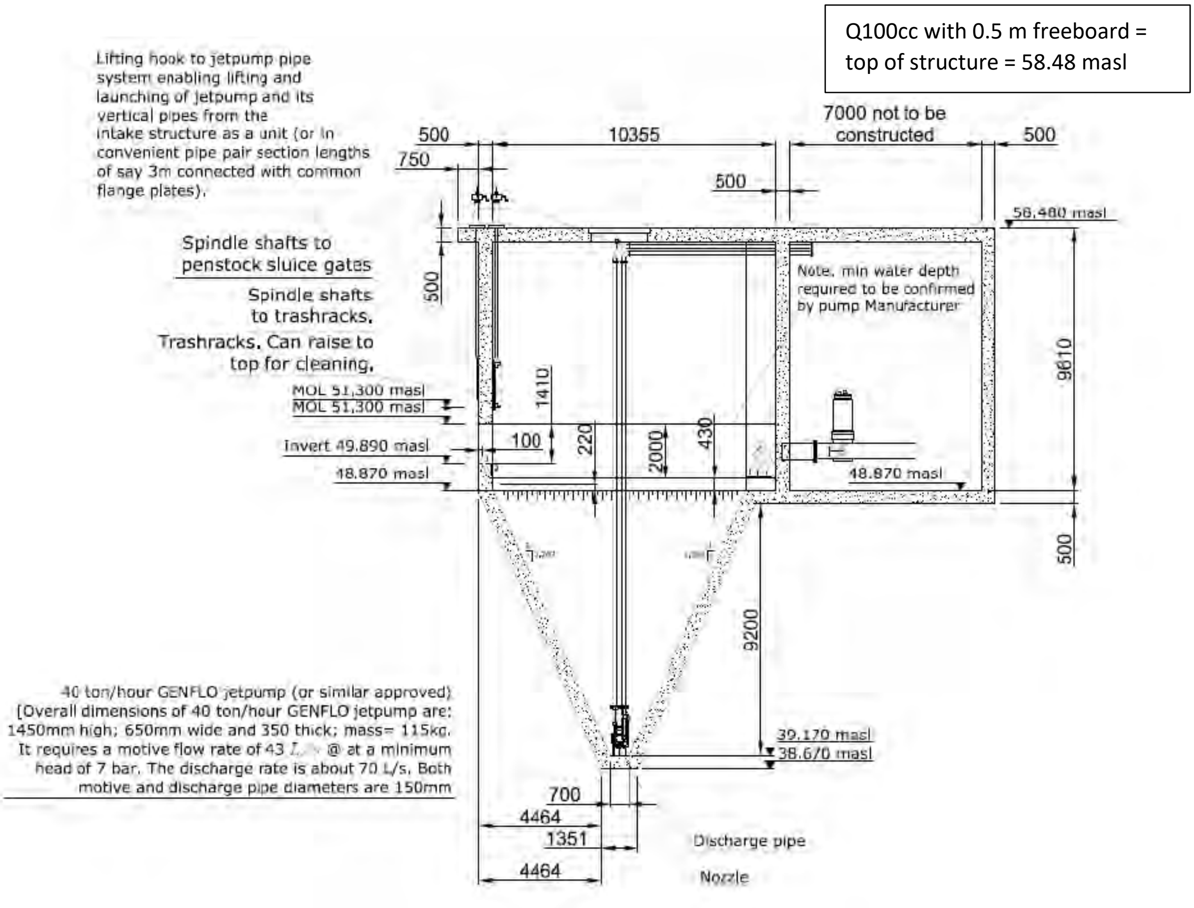


Figure A1-5: Proposed BRVAS abstraction works section B-B

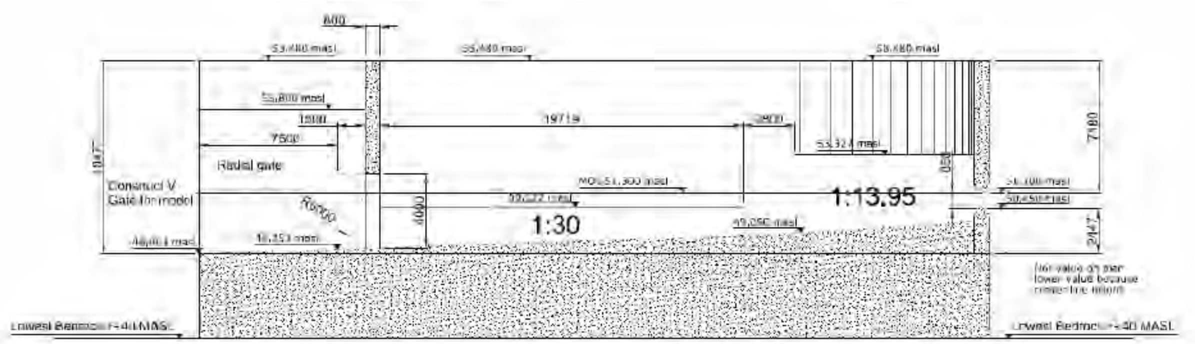


Figure A1-6: Proposed BRVAS abstraction works section C-C (Gravel trap left bank trap)

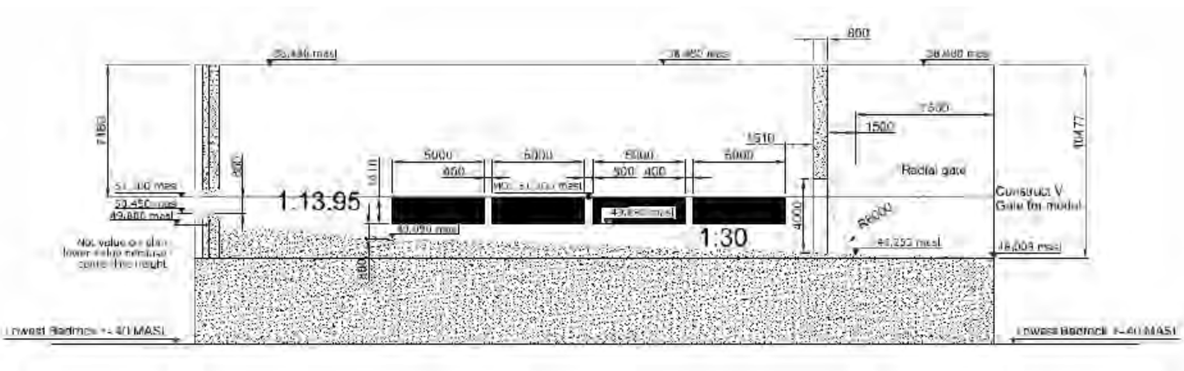


Figure A1-7: Proposed BRVAS abstraction works section D-D (Gravel trap left bank trap)

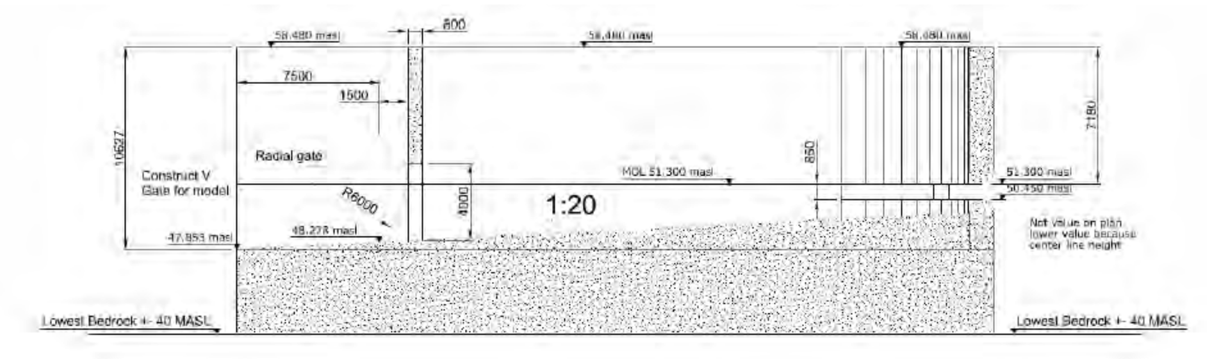


Figure A1-8: Proposed BRVAS abstraction works section E-E (Gravel trap right bank trap)

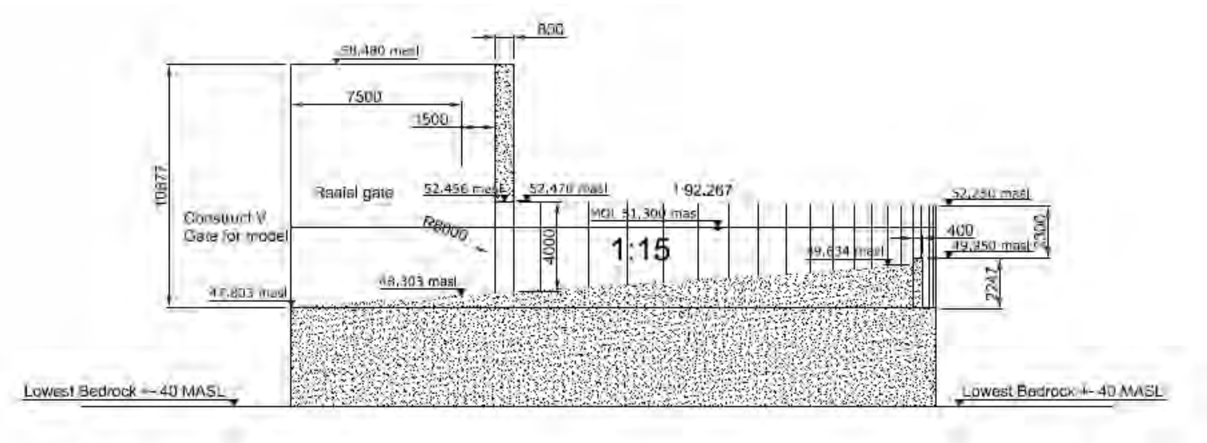


Figure A1-9: Proposed BRVAS abstraction works section F-F (Boulder trap)

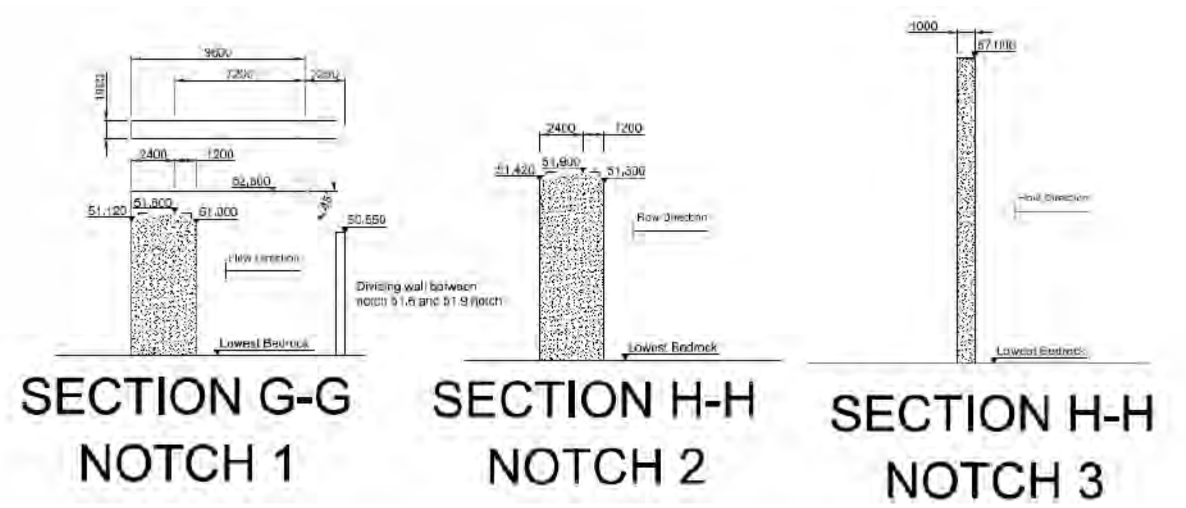


Figure A1-10: Proposed BRVAS abstraction works section G-G and H-H (Weir Cross Sections)

Appendix A2: Fishway-canoe chute hydraulic design drawings

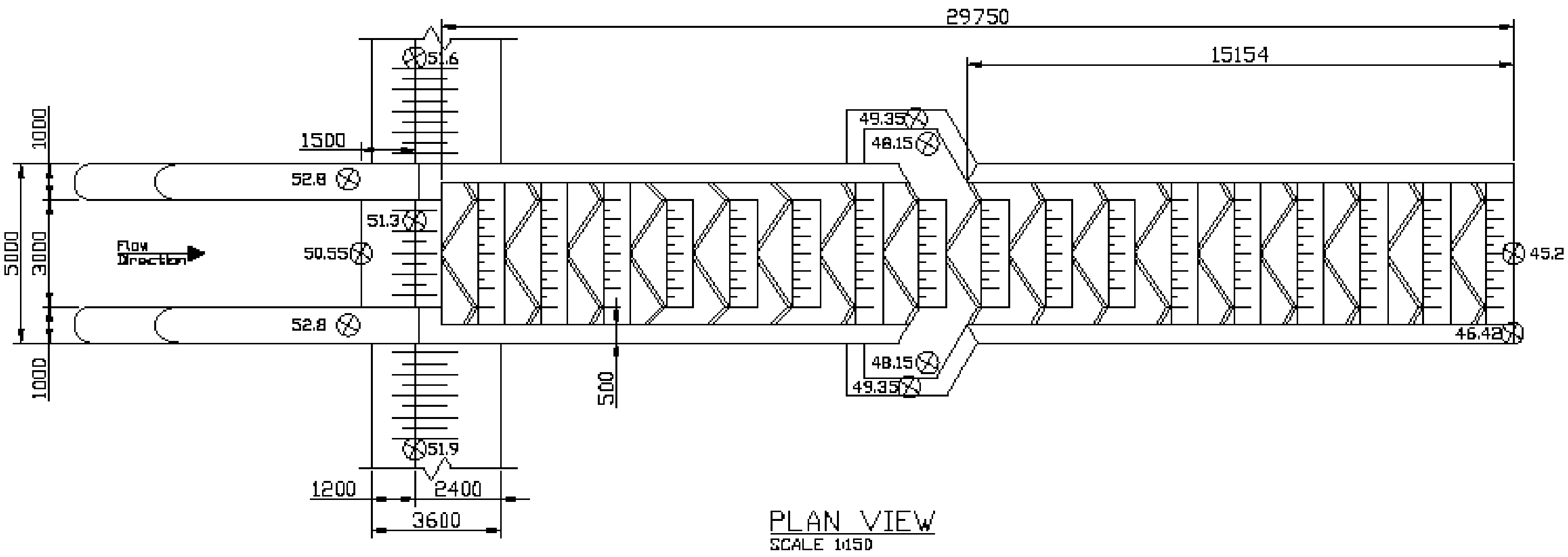


Figure A2-1: Plan layout drawing of the fishway-canoe chute as tested in the 1:15 scale model tests

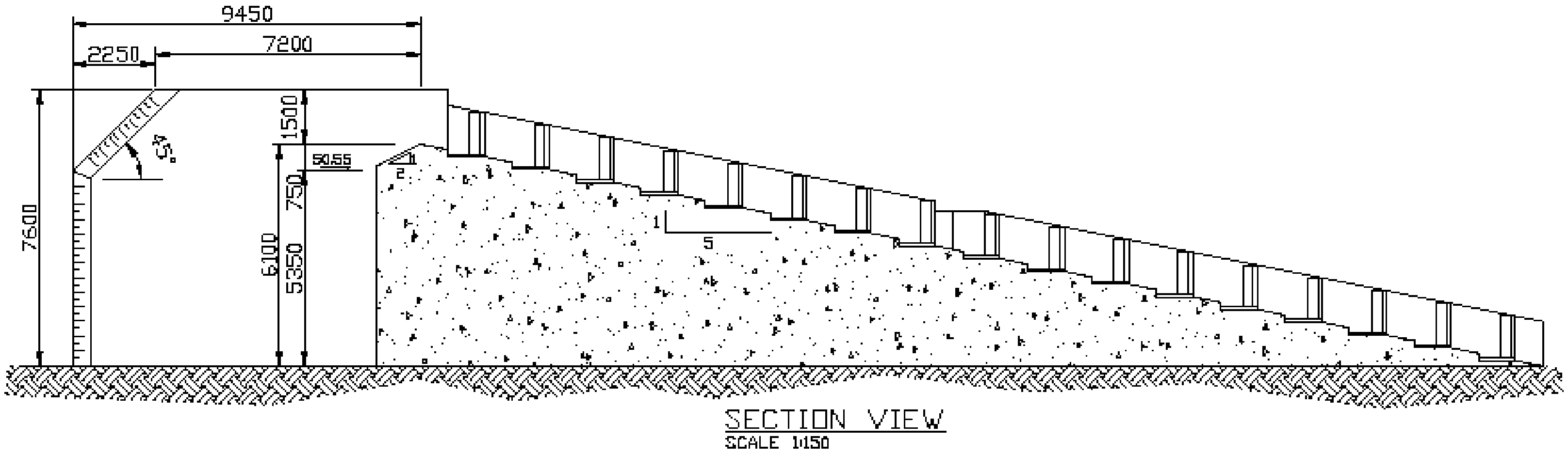


Figure A2-2: Elevation drawing of the fishway-canoe chute as tested in the 1:15 scale model tests

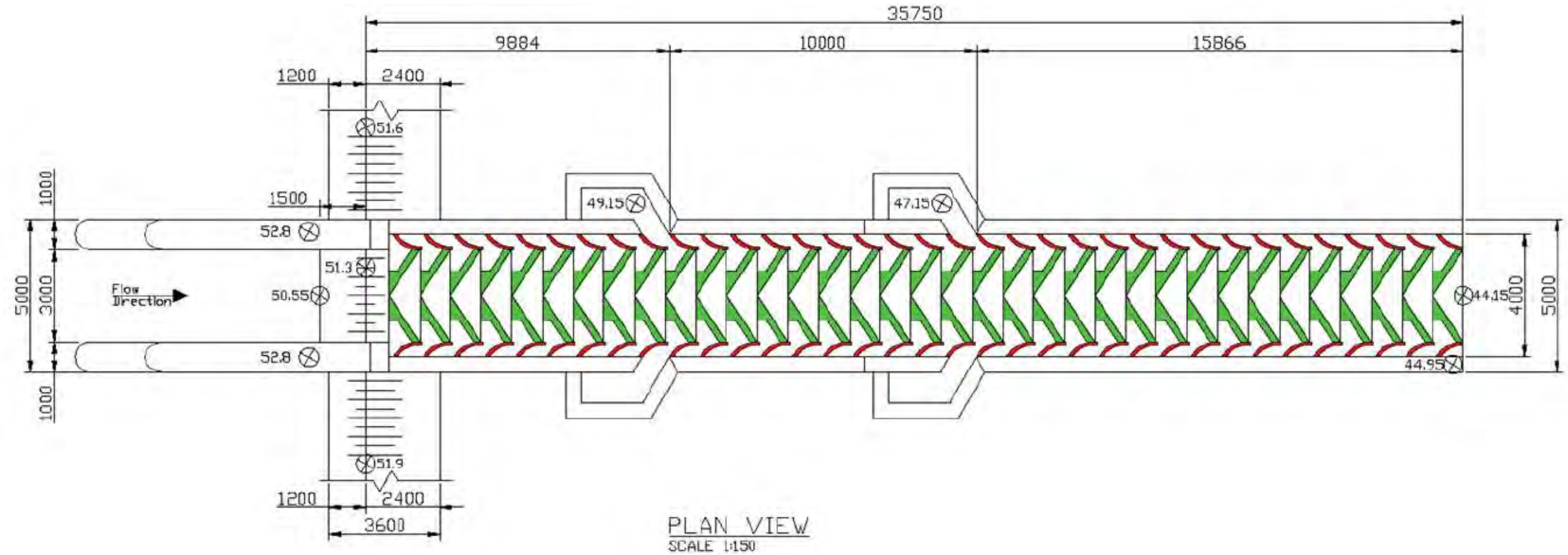


Figure A2-3: Plan layout of the proposed fishway-canoe chute with 1m radius baffles

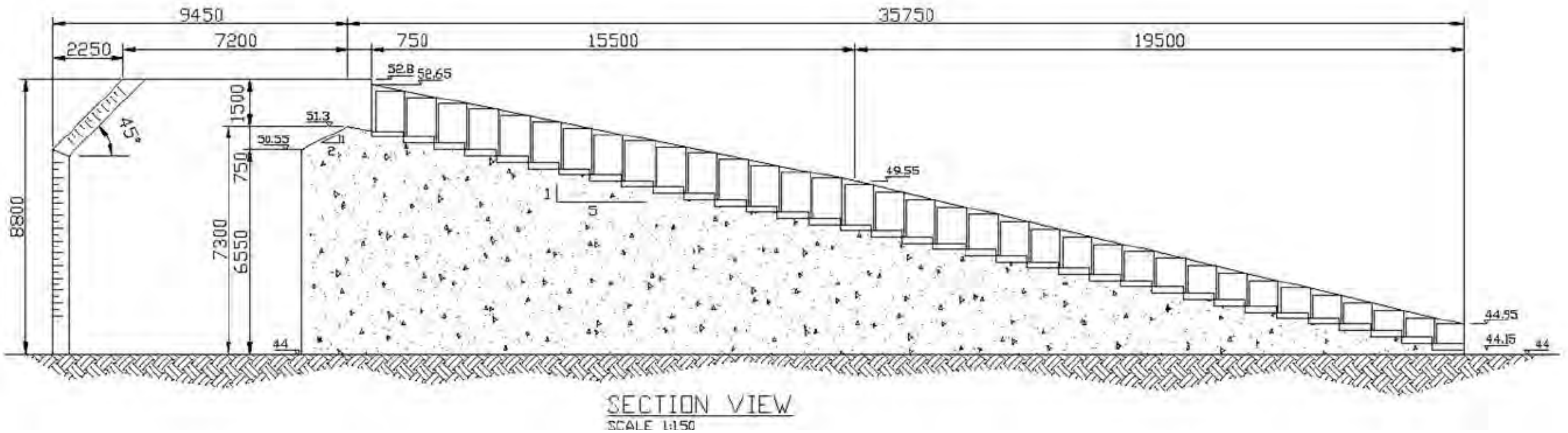


Figure A2-4: Section view of the proposed fishway-canoe chute with 1 m radius baffles

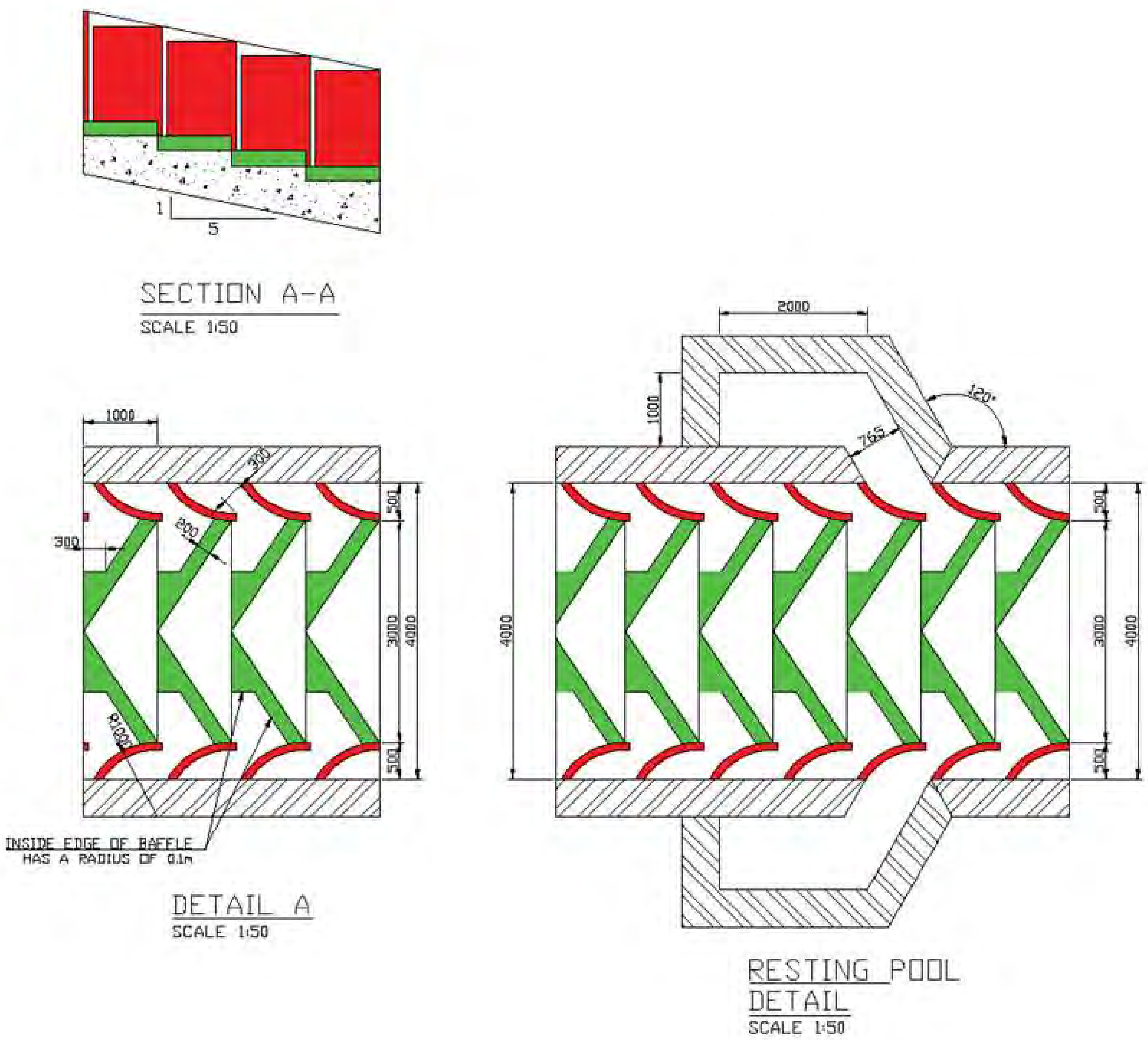
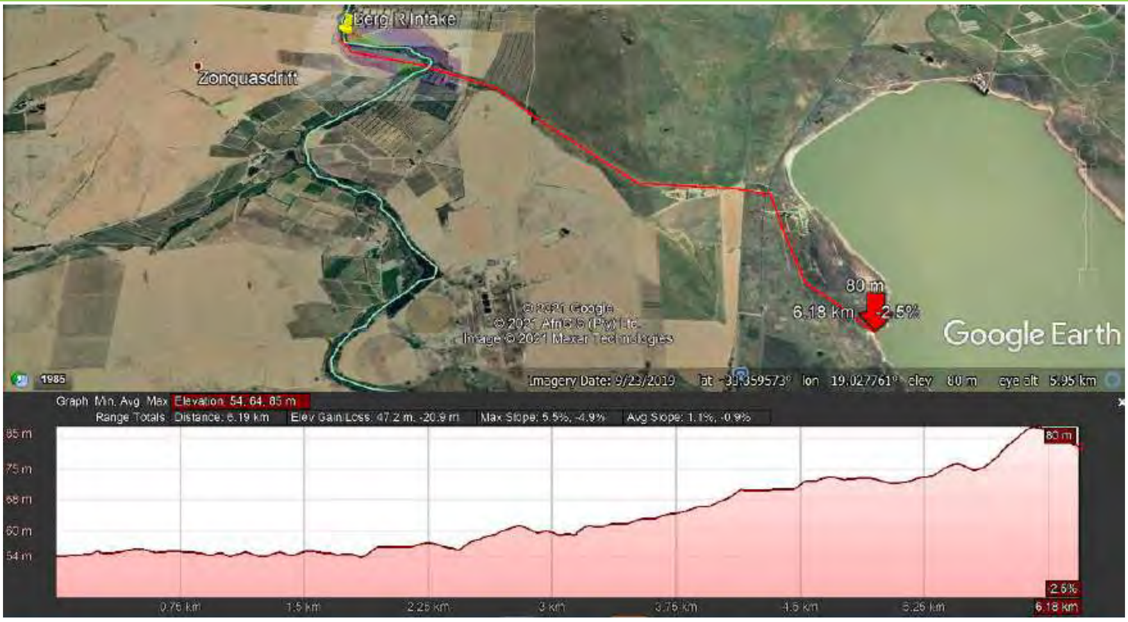


Figure A2-5: Detail drawings of proposed fishway-canoe chute

Appendix B: Provisional duty pump selection

BRVAS: BERG RIVER INTAKE: PROVISIONAL PUMP SELECTION FOR 6 X 1 m³/s



Assumptions:

Max static head	31	m
Pipe length	6200	m
Pipe dia.	1.7	m
Max vel.	2.7	m/s
Unit friction loss	0.2	m/100m
Tot friction loss	12.4	m
Minor losses (7%)	0.87	m
Total head loss	13.27	m
Max total pump head	44.27	m

Submergence required to prevent air entrainment:

Standards applied:

American National Standard for Pump Intake Design, ANSI/HI 9.8-1998, Hydraulic Institute, New Jersey, December, 1998.

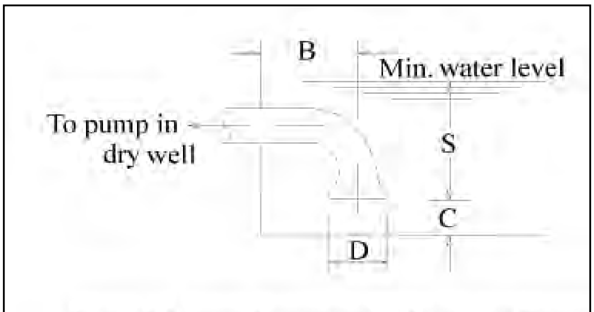


Figure 9-9. Sump dimensions for dry pit installation

The minimum submergence, S, required to prevent strong air core vortices is based in part on a dimensionless flow parameter, the Froude number, defined as:

$$F_D = V/(gD)^{0.5} \qquad (9.8.2.1\text{-}1)$$

Where:

F_D = Froude number (dimensionless)

V = Velocity at suction inlet = Flow/Area, based on D

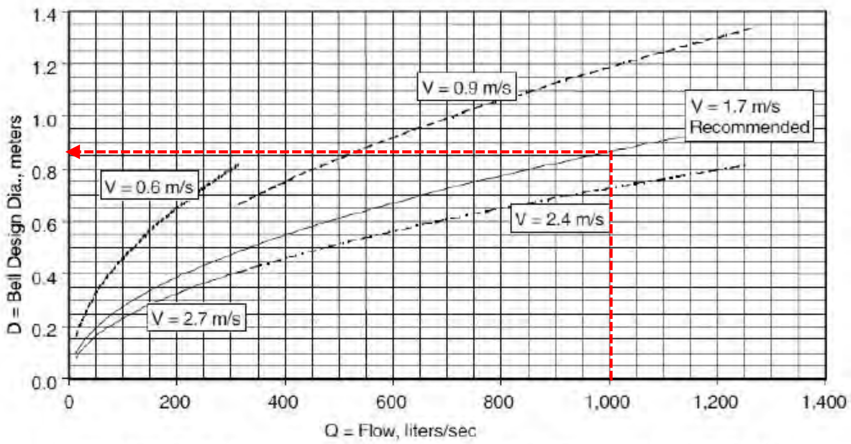
D = Outside diameter of bell or pipe inlet

g = gravitational acceleration

Consistent units must be used for V, D and g so that F_D is dimensionless. The minimum submergence, S, shall be calculated from (Hecker, G.E., 1987),

$$S = D(1+2.3F_D) \qquad (9.8.2.1\text{-}2)$$

where the units of S are those used for D. Section



V = Average bell velocity, m/s Q = flow, l/s D = Outside Bell Diameter, m = $[Q/(785V)]^{0.5}$

Figure 9.8.25A — Recommended inlet bell design diameter (OD)

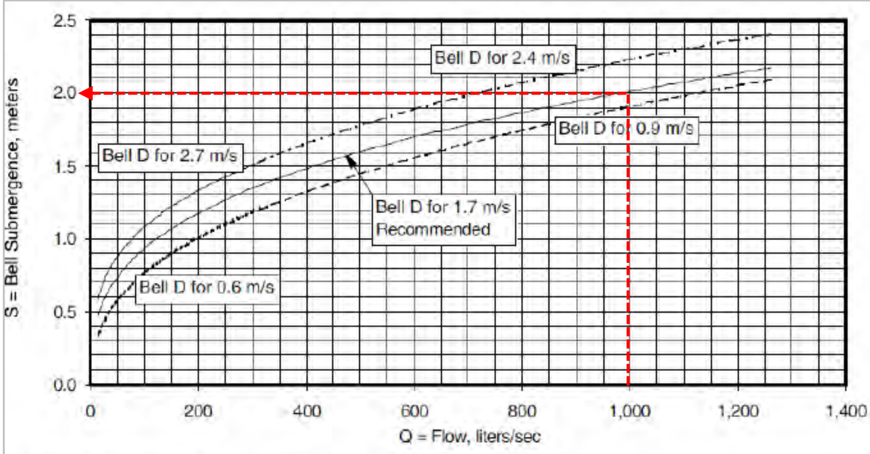
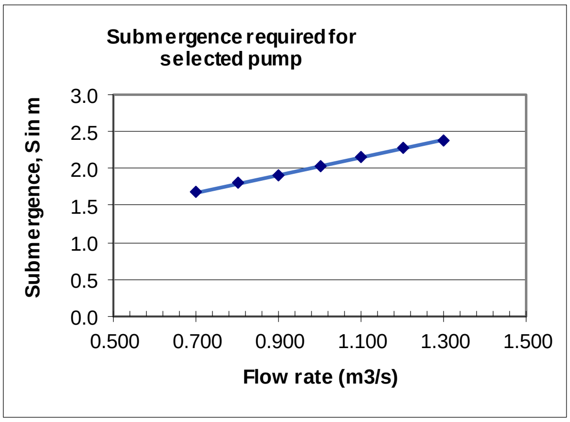


Figure 9.8.26A — Recommended minimum submergence to minimize free surface vortices

Qp	D (Bellmouth)	S
m³/s	From Fig 9.8.25A of ANSI-HI-98	(m)
0.700	0.86	1.68
0.800	0.86	1.80
0.900	0.86	1.92
1.000	0.86	2.03
1.100	0.86	2.15
1.200	0.86	2.27
1.300	0.86	2.38



Select Submergence = 2 m

Net Positive Suction Head (NPSH) available vs required:

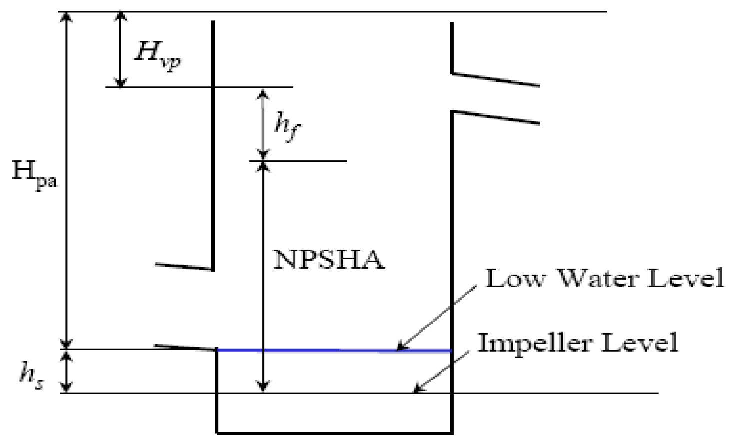


Figure 8-12. Net positive suction head available

8.3.4 Net Positive Suction Head Available

Net positive suction head available (NPSHA) is the head available above vapor pressure head to move a liquid into the impeller unit of the pump. It is necessary to ensure that the NPSHA exceeds the NPSHR to prevent cavitation. The following equation is used to compute NPHSA.

$$NPSHA = H_{pa} + H_s - h_f - H_{vp} \quad (8\text{-}11)$$

where:

H_{pa}	=	the atmospheric pressure head on the surface of the liquid in the sump – m (ft).
H_s	=	static suction head of liquid. This is height of the surface of the liquid above the centerline of the pump impeller – m (ft)
h_f	=	total friction losses in the suction line – m (ft)
H_{vp}	=	the vapor pressure head of the liquid at the operating temperature – m (ft)

Parameter	Quantity	unit	Remark
Elevation of intake	50	m MSL	
Atmosperic head (Hpa)	10.3	m H2O	
Vapour pressure of water at 20°C (Hvp)	0.24	m H2O	
Friction head loss incl fall through screens	*0.15*	m	CHECK (assumed 0.15m, to confirm)
Submergence (S) at intake level of pump - from ANSI	**2.0**	m	Based on ANSI/HI 9.8
Submergence of impellor intake face (S-1.38m), (Hs)	1.38	m	See dimensions of selected pump
NPSHavailable= Hpa + Hs - hf - Hvp	11.3	m	
NPSHrequired from pump curves	4	m	See selected pump's curves
NPSHavailable / NPSHrequired	2.8	> 1.3; OK	

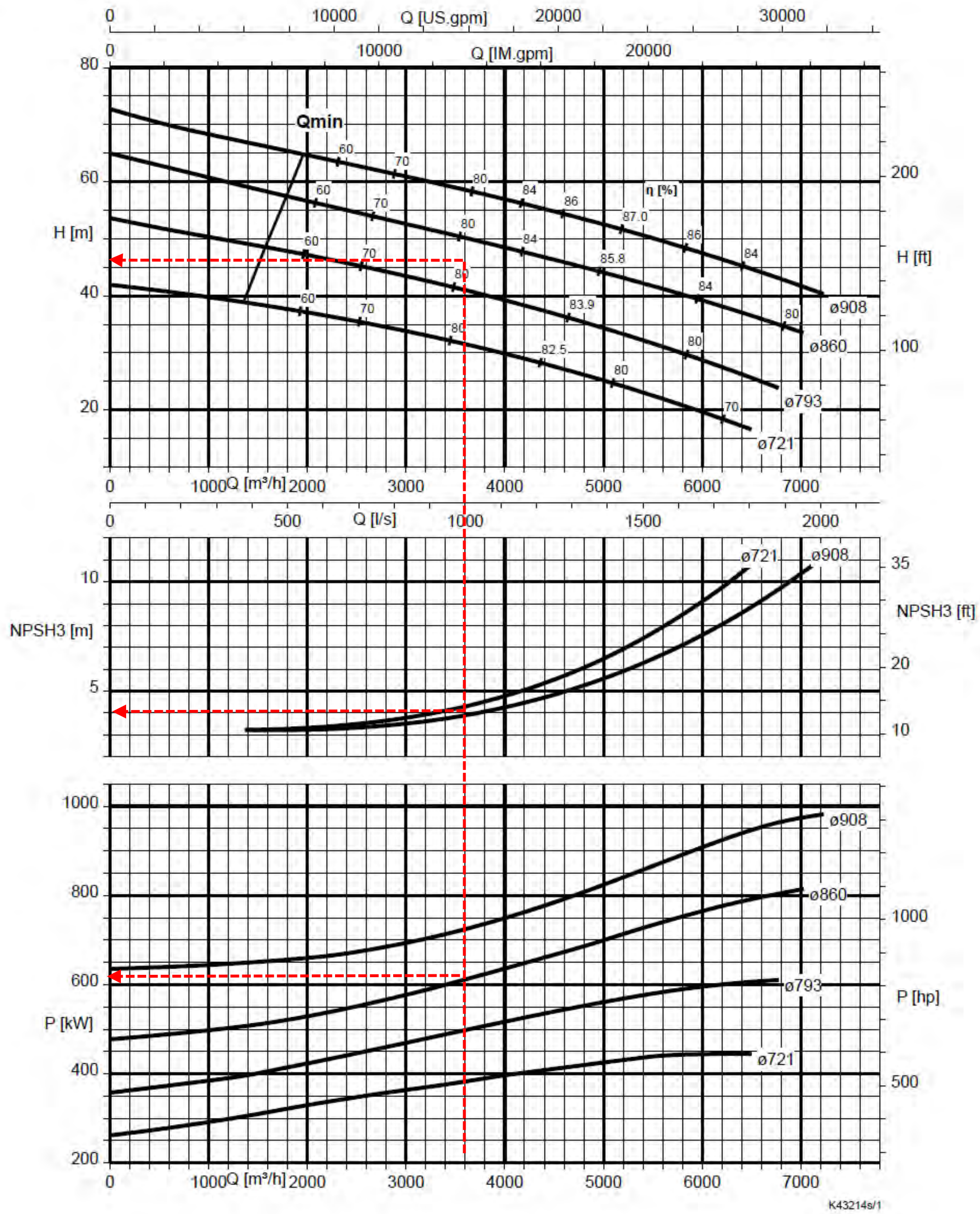
Provisional selected pump: Pump duty point, required NPSH & motor power:

KSB

Waste Water
Submersible Motor Pump

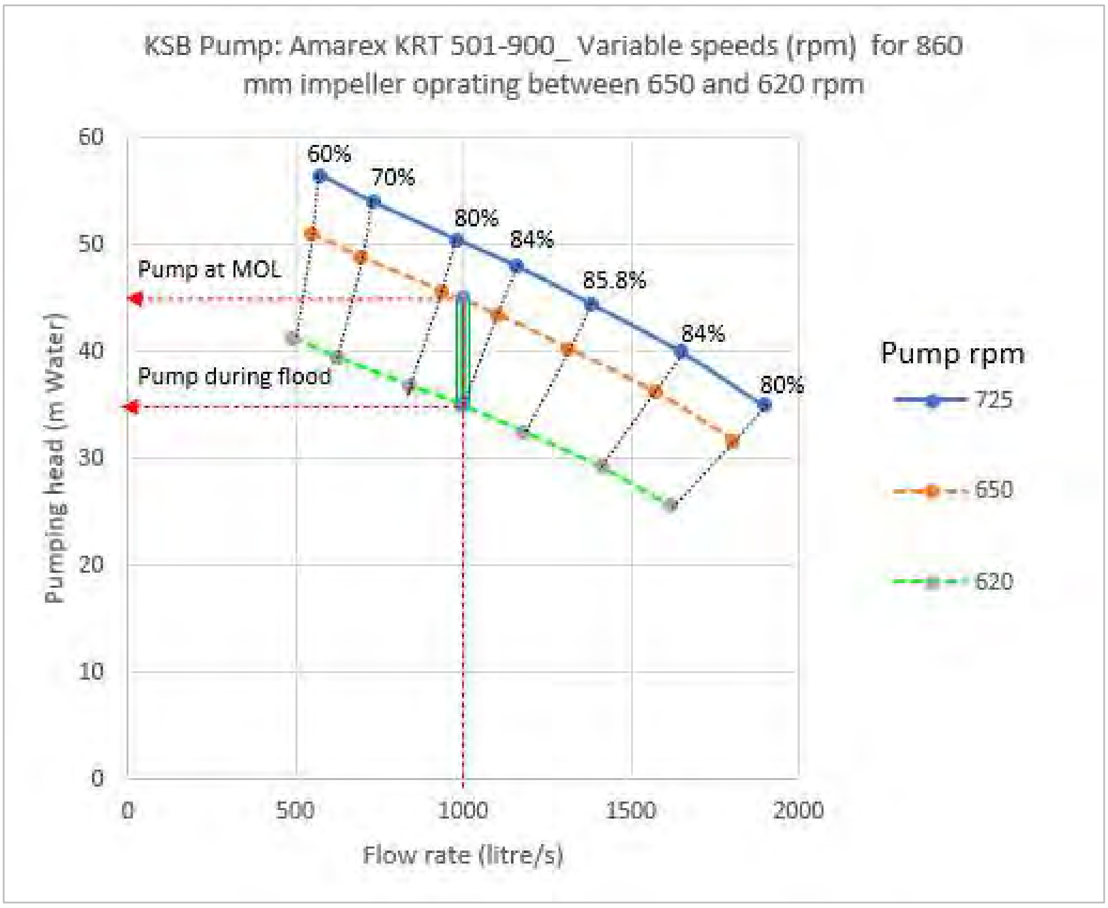
Amarex KRT K 501-900, n = 725 rpm

Characteristic curves to ISO 9906 Class 3B, below 10 kW to § 4.4.2. n = nominal speed



Free passage = 180 mm

Variable speed (VFD) analysis for river water level variation of provisional pump selected:



Provisional pump selection - Pump dimensions

KSB

Waste Water
Submersible Motor Pump

General arrangement drawing D1, dry, vertical, on concrete bases, pump casing with integrally cast feet, motor version N

D1)

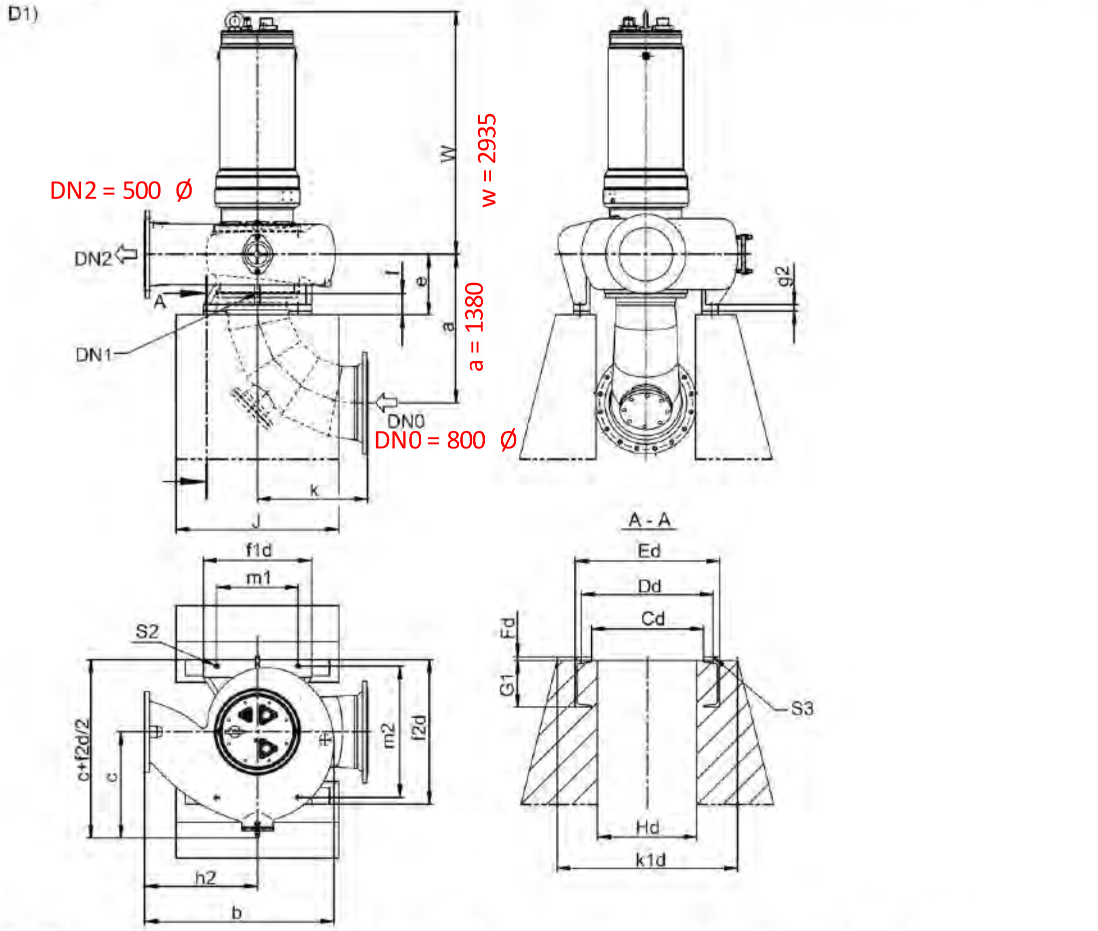


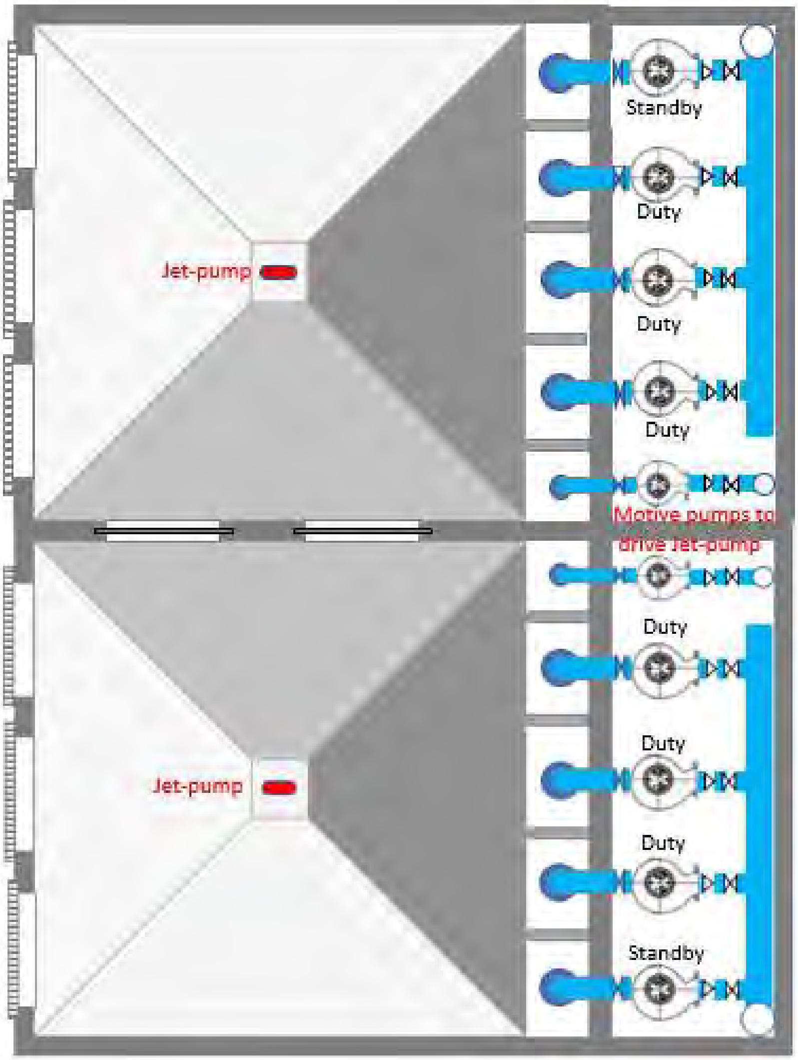
Fig. 28: General arrangement drawing D1, dry, vertical, on concrete bases, pump casing with integrally cast feet, motor version N

501-900, installation type D

501-900, installation type D

Size	Impeller type 50 Hz	Impeller type 60 Hz	Motor	Figure see page	DN0	DN1	DN2	a [mm]	a ASME [mm]	b [mm]	c [mm]	Td [mm]	e [mm]	e ASME [mm]	h2 [mm]	h2 ASME [mm]	i [mm]	f1d [mm]	f2d [mm]	k [mm]	m1 [mm]	m2 [mm]	g2 [mm]	s2 [mm]	s3 [mm]	w [mm]	Cd [mm]	Dd [mm]	Ed [mm]	Fd [mm]	G1 [mm]	Hd [mm]	J [mm]	Md [mm]	k1d [mm]	LT [mm]	x4 [mm]	Weight of the pump set [kg]	Weight of the suction elbow [kg]
501-900	K	–	260 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2420	1100	1280	1400	30	300	950	1600	800	1800	-	-	5450	184
501-900	K	–	300 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2420	1100	1280	1400	30	300	950	1600	800	1800	-	-	5700	184
501-900	K	–	350 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2640	1100	1280	1400	30	300	950	1600	800	1800	-	-	5952	184
501-900	K	–	460 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2636	1100	1280	1400	30	300	950	1600	800	1800	-	-	6702	184
501-900	K	–	530 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2635	1100	1280	1400	30	300	950	1600	800	1800	-	-	6938	184
501-900	K	–	580 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2635	1100	1280	1400	30	300	950	1600	800	1800	-	-	7258	184
501-900	K	–	630 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2935	1100	1280	1400	30	300	950	1600	800	1800	-	-	7923	184
501-900	K	–	690 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2935	1100	1280	1400	30	300	950	1600	800	1800	-	-	8203	184
501-900	K	–	760 8	36	800	600	500	1380	1625	1970	900	1575	400	400	1200	500	20	1100	1400	1000	830	1280	45	35	30	2935	1100	1280	1400	30	300	950	1600	800	1800	-	-	8463	184

Provisional schematic layout of pumpstation and hoppers: Eight 1 m³/s pumps and two motive pumps to drive two jet-pumps



NOTES:

1. Motive water to drive jet-pumps must pass through a filter for fluidization water
2. Assume jet-pump specification the same as for Thukela new intake (i.e. 40 t/hr)

Appendix C: Flood hydrology of the BRVAS abstraction site

The preliminary study of ASP (2012) derived flood peaks for the Berg River Voëlvlei Augmentation Scheme but the probabilistic flood hydrology analysis had to be updated with more recent data and a corrected catchment area. Flood peak data was obtained from the Department of Water and Sanitation (DWS) gauging station G1H013 at Drieheuvels for the period 1964 to 2011 for the ASP (2012) study and for the period 1964 to 2020 for this study. The catchment area at the gauging station is 2 934 km^2 while the proposed abstraction works site has a catchment area of 1 527 km^2. The observed flood peaks at G1H013 were scaled to those for the BRVAS site (given in Table C.3) by using the square root of the catchment ratio. The station G1H079 may be located closer to the proposed site but has a 10-year record of floods exceeding the maximum gauge level (discharge table limit) by several meters. Note that the Berg River Dam, which was commissioned in 2008, has an estimated flood attenuation factor of 10-15 % at the site but was not taken into account to be conservative.

Based on TR137 (Kovacs, 1988) the largest historical flood on record occurred on 18 May 1954 at gauging station G1M07 (Old Number) near Wellington with a flood peak of 2 130 m^3/s. However, according to the DWA database, a flood peak of only 771 m^3/s was recorded at G1H007 for the same date (catchment area 713 m^2). This was not a localized flood since at G1H002 (at Vier en Twintig River station with catchment area 187 m^2) the flood peaked at 633 m^3/s on the following day on a tributary of the Berg River (downstream of the proposed site as shown in Figure C-1). A flood peak of 1 128 m^3/s would have been observed at the proposed BRVAS site if the corresponding flood at the G1H007 station is scaled. The extreme historic peak flood of 1 128 m^3/s at G1H007 was therefore considered in the probabilistic analysis.

Table C.1 shows the flood peaks at the BRVAS site used in the probabilistic flood analysis while Table C.2 and Figure C-2 show the results. The ASP Tech (2012) study identified the LP3 as the most conservative distribution, but for the updated study with an extended flood peak record, the proposed distribution that gives conservatively high flood peaks during major floods is the LN distribution. The 100-year flood based on this distribution is about 1 276 m^3/s.

In particular, the LN distribution for the 10 000-year flood compares well with the Regional Maximum Flood (RMF) of 3 908 m^3/s based on the K5 Kovacs region (TR137 Empirical Method). The RMF may be used to determine the Safety Evaluation Flood (SEF) for a Category 2 dam. The 50, 100 and 200-year flood peaks based on the RMF are given in Table C.3, however, flood peaks based on empirical methods only offer conservatively high benchmark values and are generally overestimating the annual recurrence interval extreme flood peaks in South Africa.

The results from the unit hydrograph deterministic method were revised for a catchment area of 1 527 km^2 and are shown in Table C.4, which compare well with the proposed flood peaks. Typically the probabilistic analysis is considered more accurate than the other methods because it is based on historical floods and in this case a relatively long record.

Table C.5 shows the proposed flood peaks including a 15% increase which was incorporated to account for the impact of climate change on future flood peaks. This is in agreement with the standard 15% approach by the City of Cape Town and with the DEA (2014) study of five (5) climate models for South Africa. An increase of 0 to 50% is projected for the year 2100 relative to the current 100-year flood for a structure with a medium risk global warming category that is located in the vicinity of the Voëlvlei Dam (refer to Figure C-3). The upper range of 50% is considered over-conservatively high particularly because flood attenuation of the Berg River Dam was not taken into account.

Note that the ASP Tech (2012) study designed the abstraction works for a final theoretical 100-year flood peak of 1 500 m^3/s which is near identical to the flood peak of 1 468 m^3/s that was calculated in this study for the 100-year flood but it includes future climate change impacts.

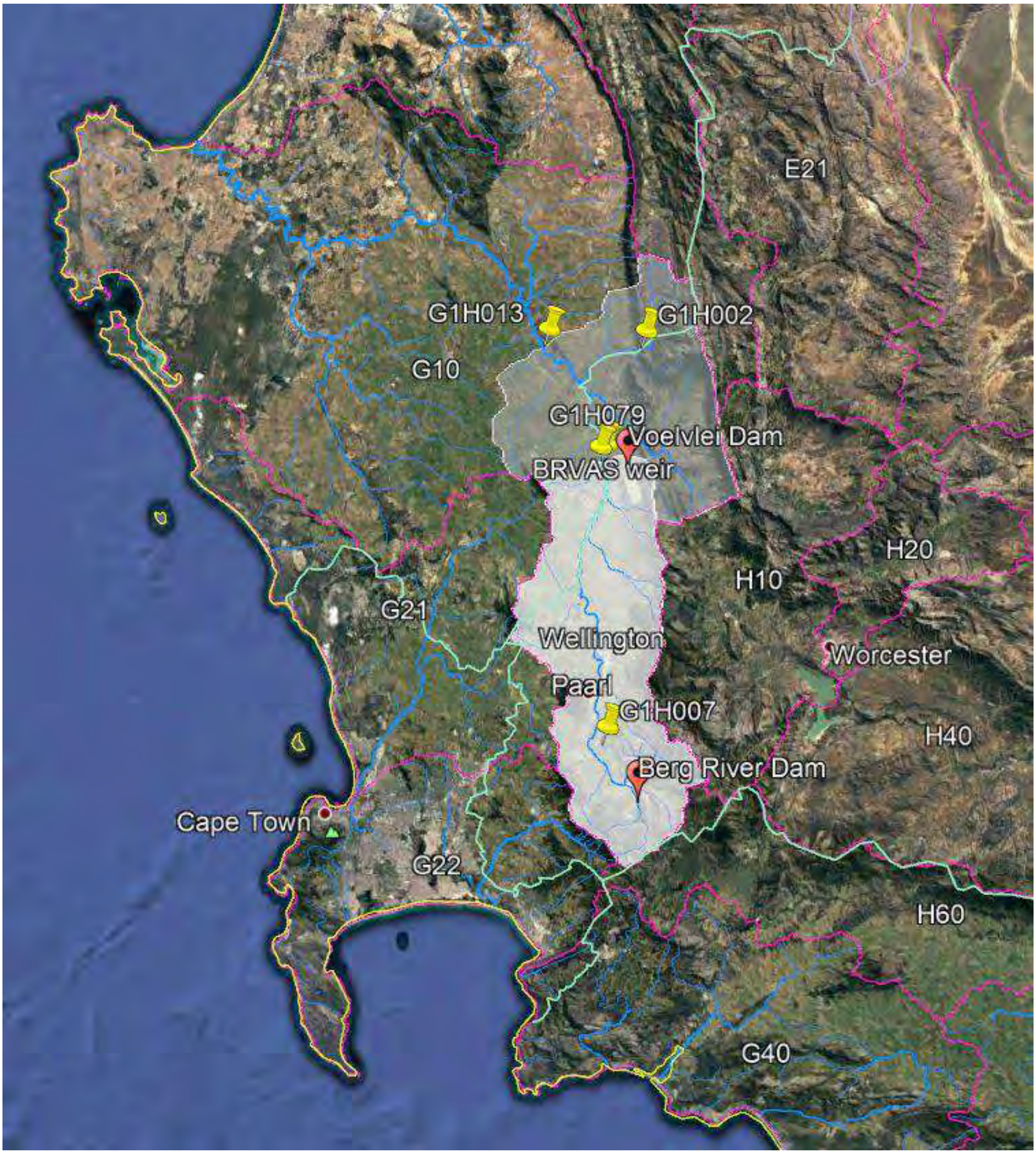


Figure C-1: Catchment areas for the proposed BRVAS site and for the flow gauging station G1H013, as well as locations of relevant DWS river gauging stations

Table C.1: Observed flood peaks scaled to the BRVAS site

Year	Flood peak (m^3/s)	Year	Flood peak (m^3/s)
1953 / 1954	1 128*	1994 / 1995	128
1964 / 1965	60	1995 / 1996	384
1965 / 1966	109	1996 / 1997	247
1966 / 1967	321	1997 / 1998	136
1967 / 1968	147	1998 / 1999	174
1968 / 1969	97	1999 / 2000	95
1969 / 1970	74	2000 / 2001	422
1970 / 1971	106	2001 / 2002	158
1971 / 1972	39	2002 / 2003	97
1972 / 1973	134	2003 / 2004	108
1973 / 1974	267	2004 / 2005	147
1974 / 1975	147	2005 / 2006	158
1975 / 1976	242	2006 / 2007	938
1976 / 1977	500	2007 / 2008	480
1977 / 1978	70	2008 / 2009	266
1978 / 1979	130	2009 / 2010	158
1979 / 1980	107	2010 / 2011	121
1980 / 1981	428	2011 / 2012	157
1981 / 1982	84	2012 / 2013	444
1982 / 1983	350	2013 / 2014	164
1983 / 1984	606	2014 / 2015	65
1984 / 1985	283	2015 / 2016	246
1985 / 1986	245	2016 / 2017	11
1986 / 1987	215	2017 / 2018	214
1987 / 1988	131	2018 / 2019	97
1988 / 1989	226	2019 / 2020	41
1989 / 1990	298		
1990 / 1991	467		
1991 / 1992	455		
1992 / 1993	699		
1993 / 1994	459		

**Historical flood peak*

Table C.2: Probabilistic analysis results at the BRVAS site

Exceed. Prob.	Recurrence interval (years)	LN	LP3	GEV_{MM^*}	$GEV_{PWM^{**}}$	Proposed this study	ASP Tech probabilistic (2012)
		Q (m³/s)	Q (m³/s)	Q (m³/s)	Q (m³/s)	Q (m³/s)	Q (m³/s)
0.5	2	182	193	204	193	182	223
0.2	5	369	373	382	354	369	403
0.1	10	533	510	514	488	533	551
0.05	20	722	649	650	643	722	715
0.02	50	1016	839	844	889	1016	959
0.01	**100**	**1276**	**985**	**1003**	**1115**	**1276**	**1168**
0.005	200	1572	1134	1174	1382	1572	1400

**MM = Method of Moment; **PWM = Probability Weighted Moment*

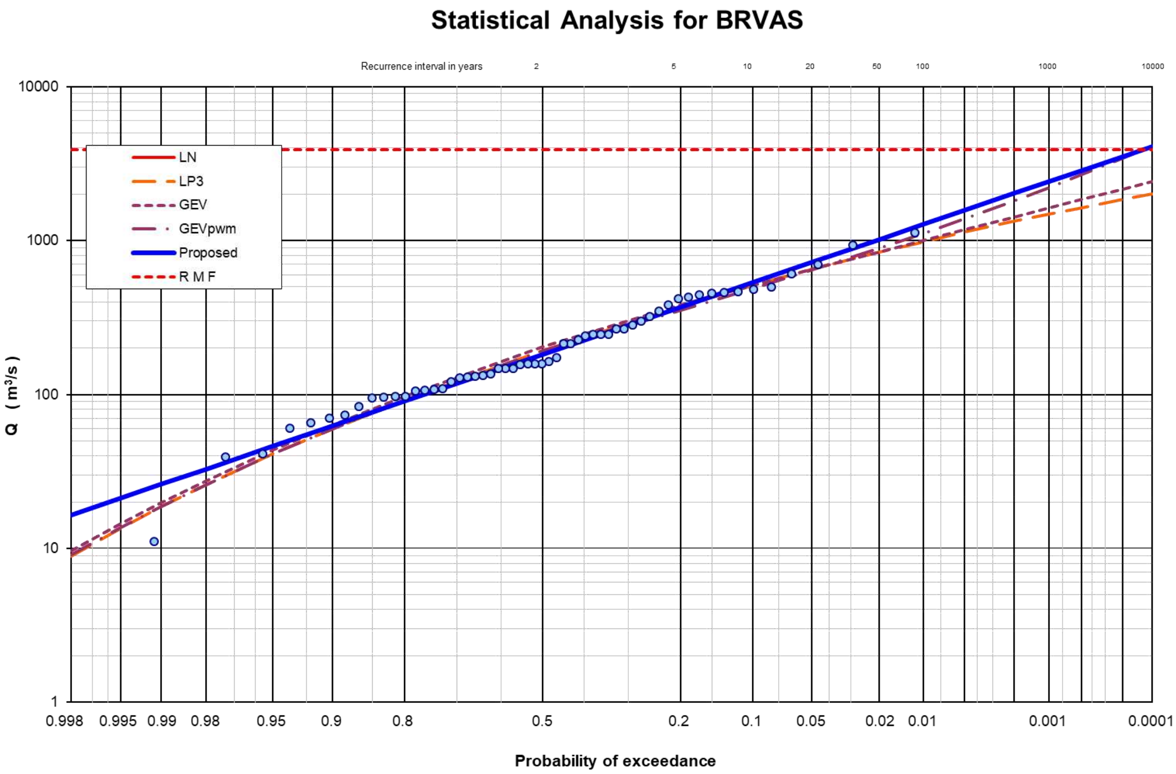


Figure C-2: Probabilistic results plotted graphically at the BRVAS site

Table C.3: Flood peaks based on the Kovacs empirical method with RMF = 3 908 m^3/s for K5 region

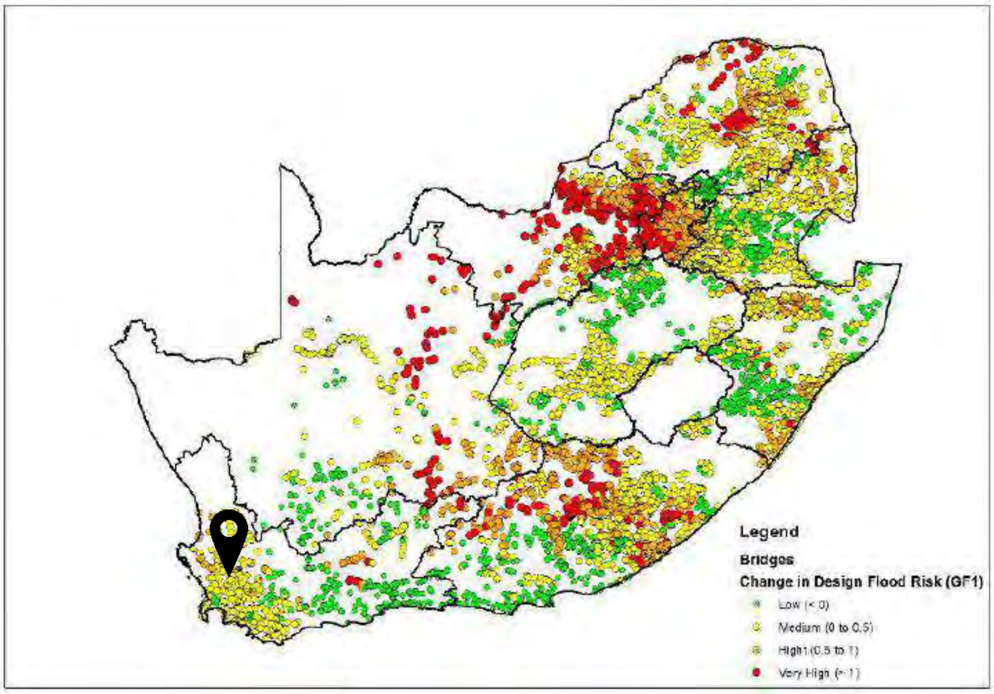
Flood recurrence interval (years)	Kovacs Flood peak (m^3/s)
50	2 116
100	2 587
200	3 058

Table C.4: Flood peaks based on the unit hydrograph method

Flood recurrence interval (years)	Flood peak (m^3/s)
50	833
100	1 039
200	1 177

Table C.5: Proposed flood peaks for current and future scenarios at the abstraction works site

Flood recurrence interval (years)	Flood peak for current scenario (m^3/s)	Flood peak for future scenario including climate change (m^3/s)
2	182	210
5	369	424
10	533	613
20	722	830
50	1 016	1 169
100	**1 276**	**1 468**
200	1 572	1 808



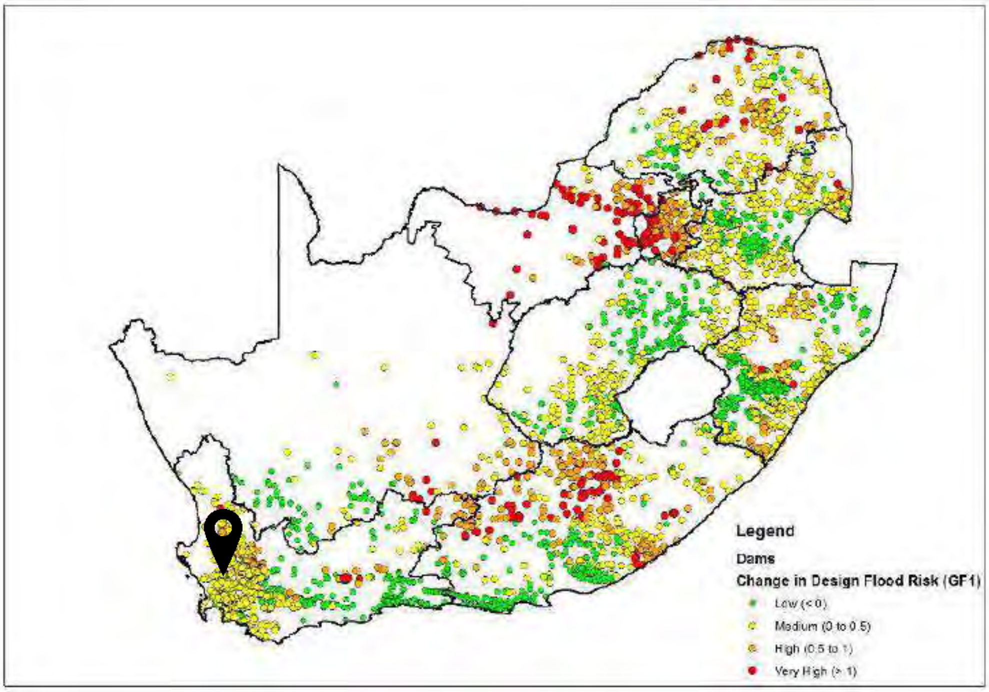


Figure C-3: Relative risk and change for the 100-year design flood: Bridges (top) and dams (bottom) (DEA LTAS Report No3, 2014)

Figure C-4 shows the hourly flood hydrographs at the abstraction site for the different recurrence intervals (including climate change and the RMF) based on the largest flood hydrograph to date that was observed on 7 June 2007 at the G1H013 gauging station.

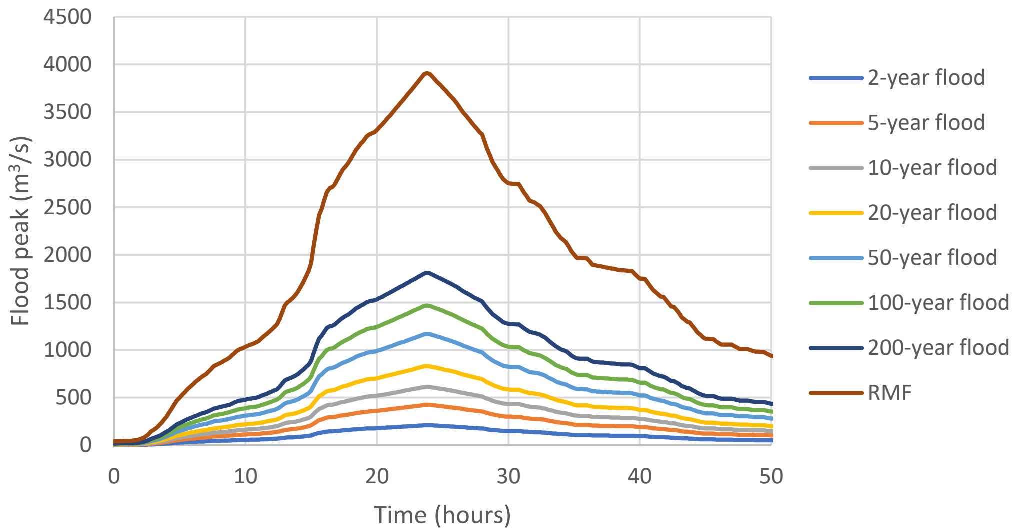


Figure C-4: Proposed flood hydrographs for the different recurrence intervals based on the 2007 historical flood

References

Kovacs. 1988. *Regional maximum flood determination in southern Africa*. Technical Report 137, Department of Water Affairs.

ASP Technology. 2012. *Hydraulic design of the proposed Berg River Abstraction Works at Voëlvlei Dam*. Report for the Western Cape Future Schemes Feasibility Study.

Department of Environmental Affairs, 2014. *LTAS Report No3 on Climate Change Adaption: Perspective for Disaster Rick Reduction and Management in South Africa*.

Appendix D1: Hydrodynamic modelling of the Berg River flow patterns near the proposed BRVAS abstraction works and site based on the 2012 survey

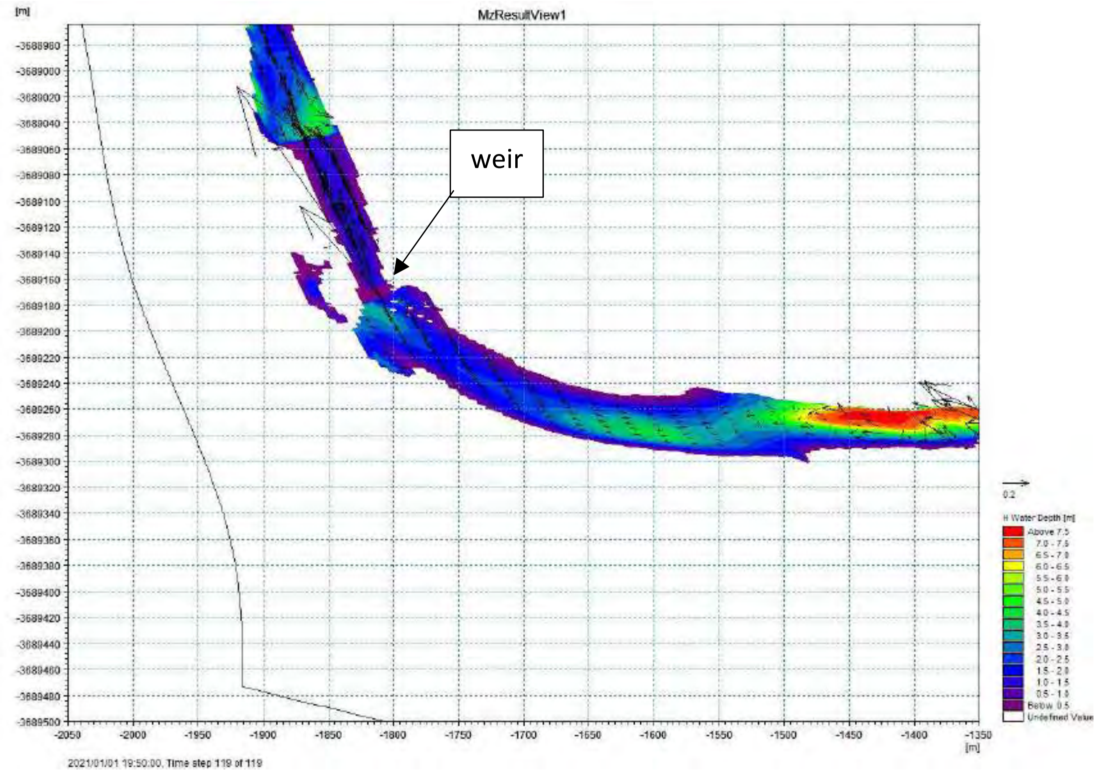


Figure D1-1: Simulated water depths at a river discharge of 5 m^3/s with the proposed weir and abstraction works

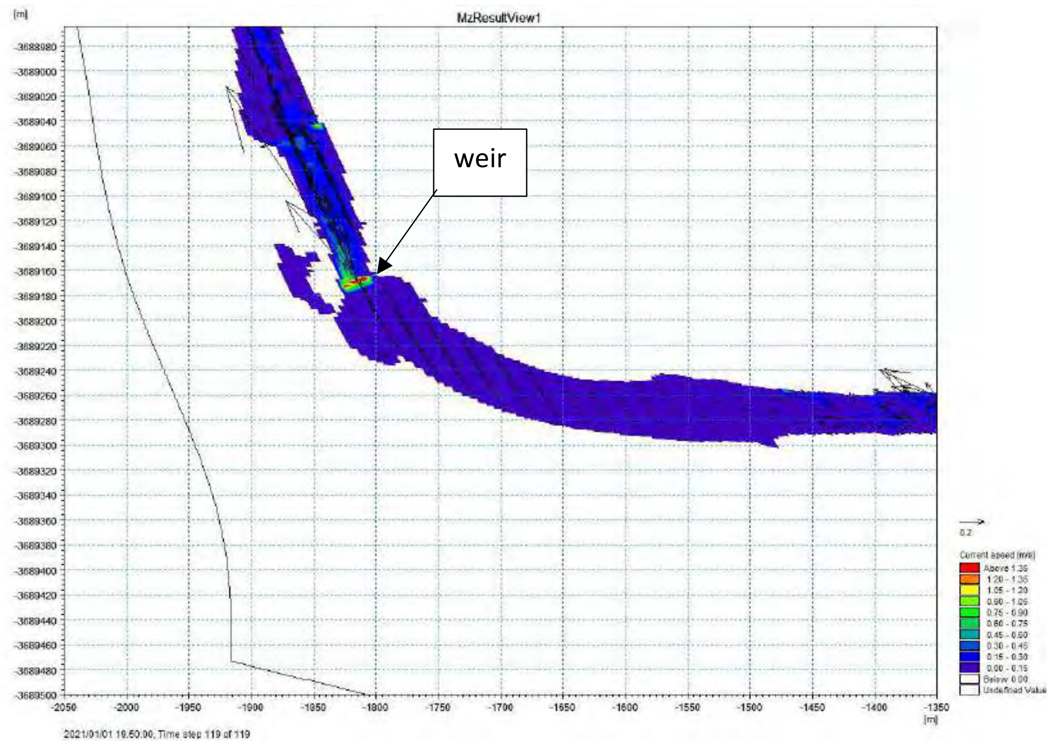


Figure D1-2: Simulated flow velocities at a river discharge of 5 m^3/s with the proposed weir and abstraction works

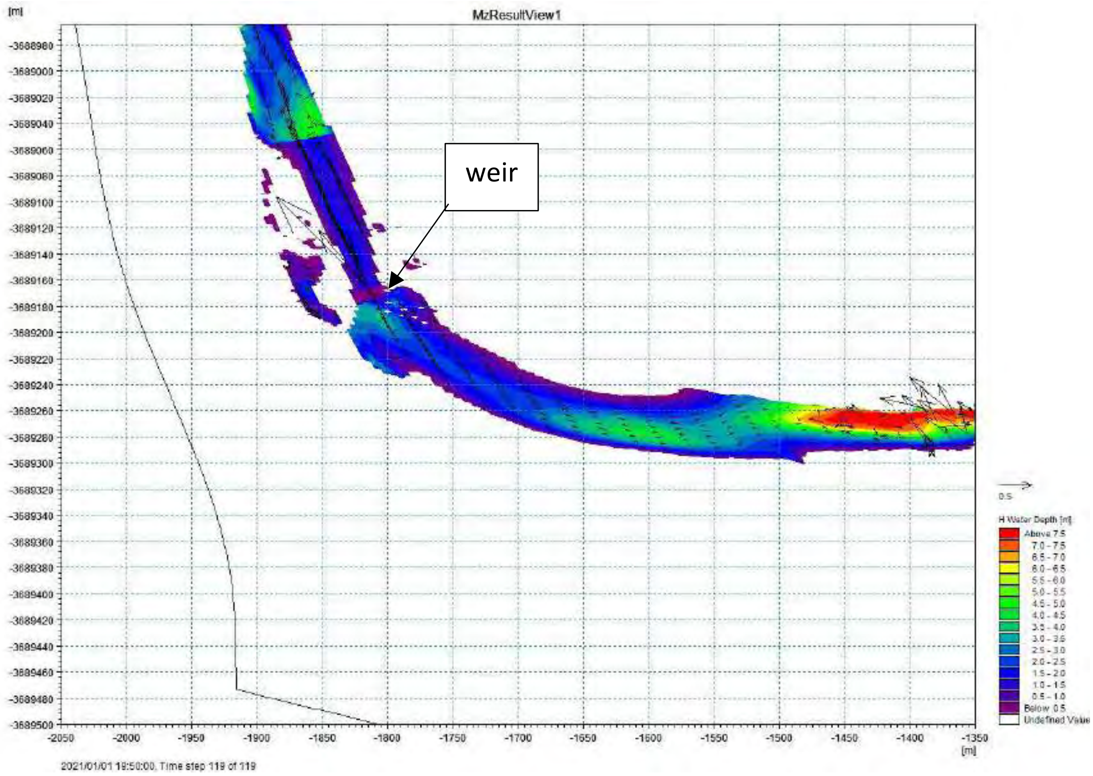


Figure D1-3: Simulated water depths at a river discharge of 10 m^3/s with the proposed weir and abstraction works

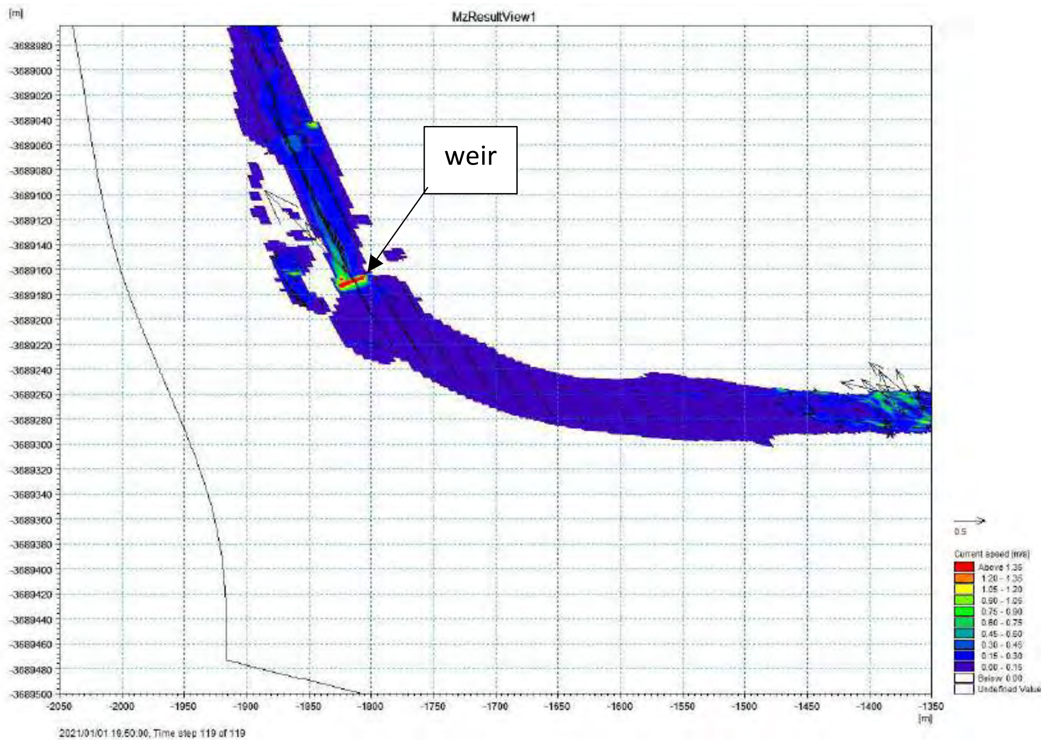


Figure D1-4: Simulated flow velocities at a river discharge of 10 m^3/s with the proposed weir and abstraction works

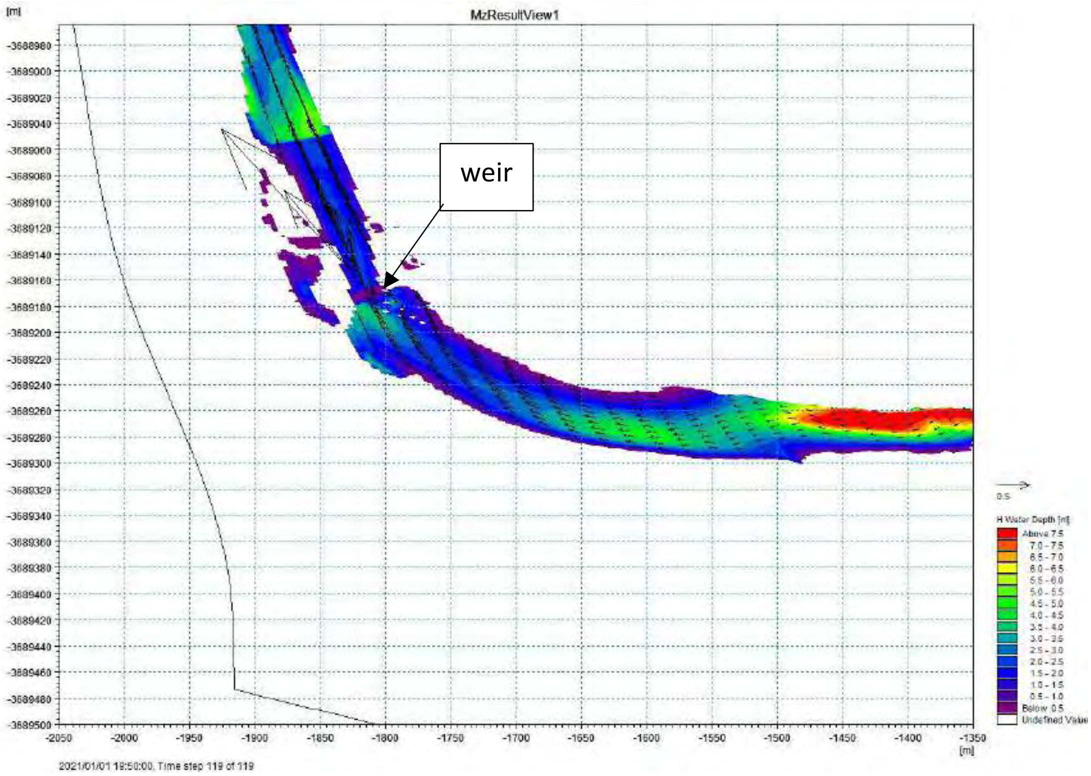


Figure D1-5: Simulated water depths at a river discharge of 25 m^3/s with the proposed weir and abstraction works

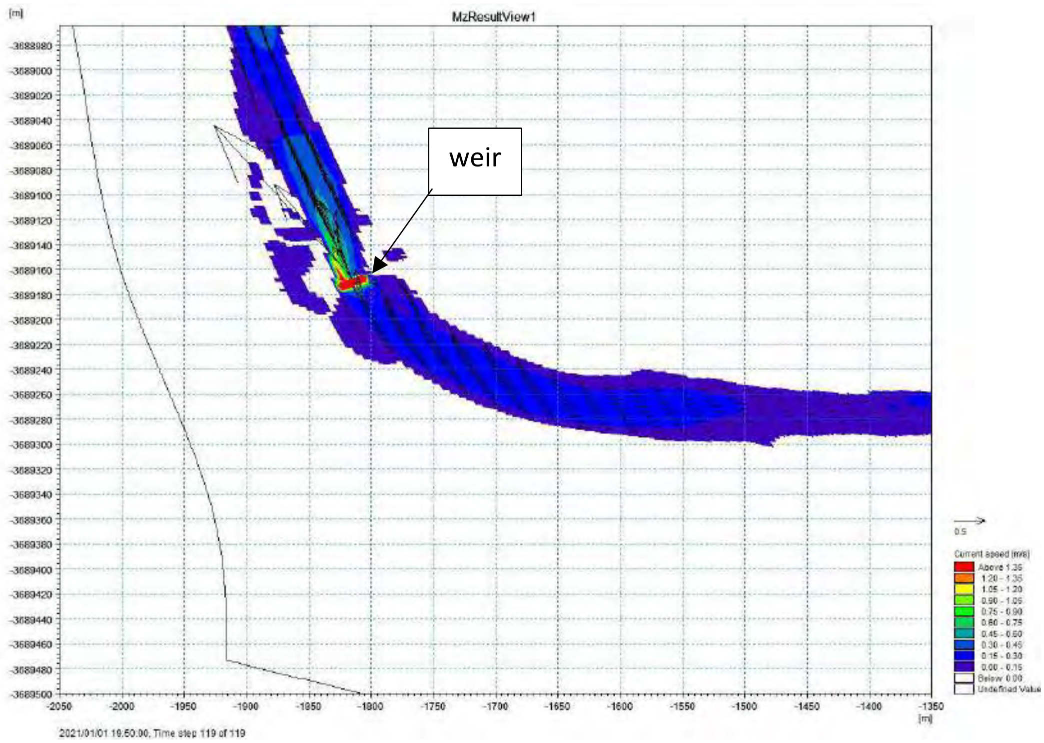


Figure D1-6: Simulated flow velocities at a river discharge of 25 m^3/s with the proposed weir and abstraction works

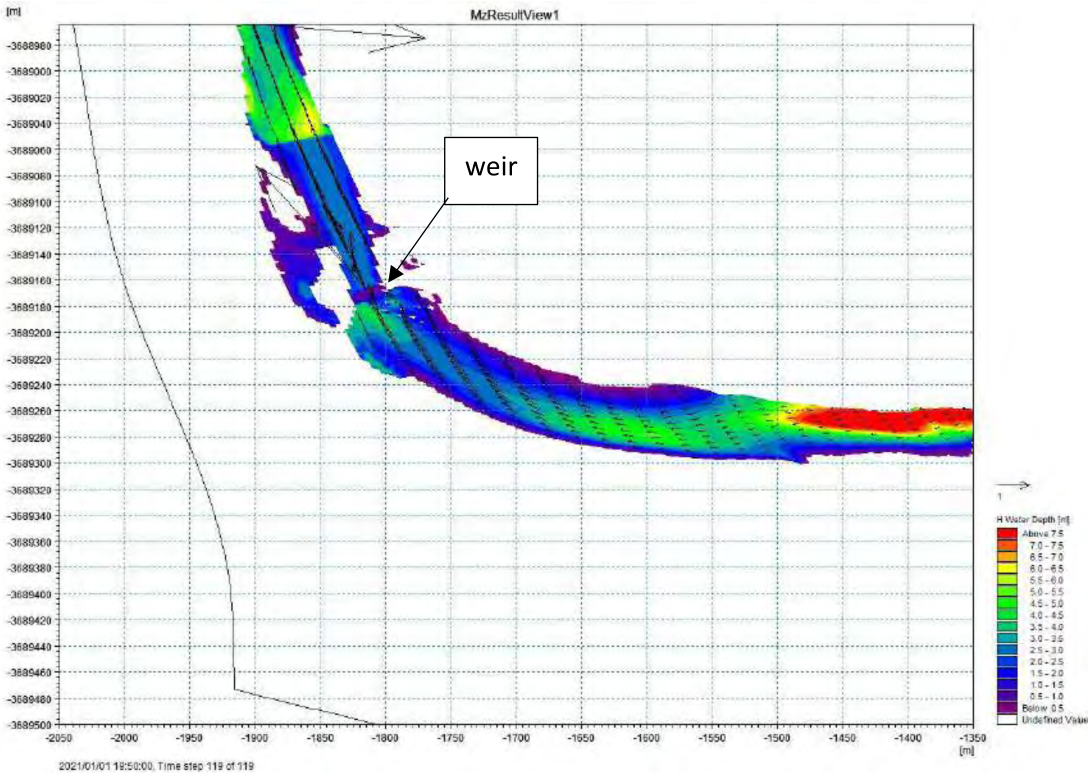


Figure D1-7: Simulated water depths at a river discharge of 50 m³/s with the proposed weir and abstraction works

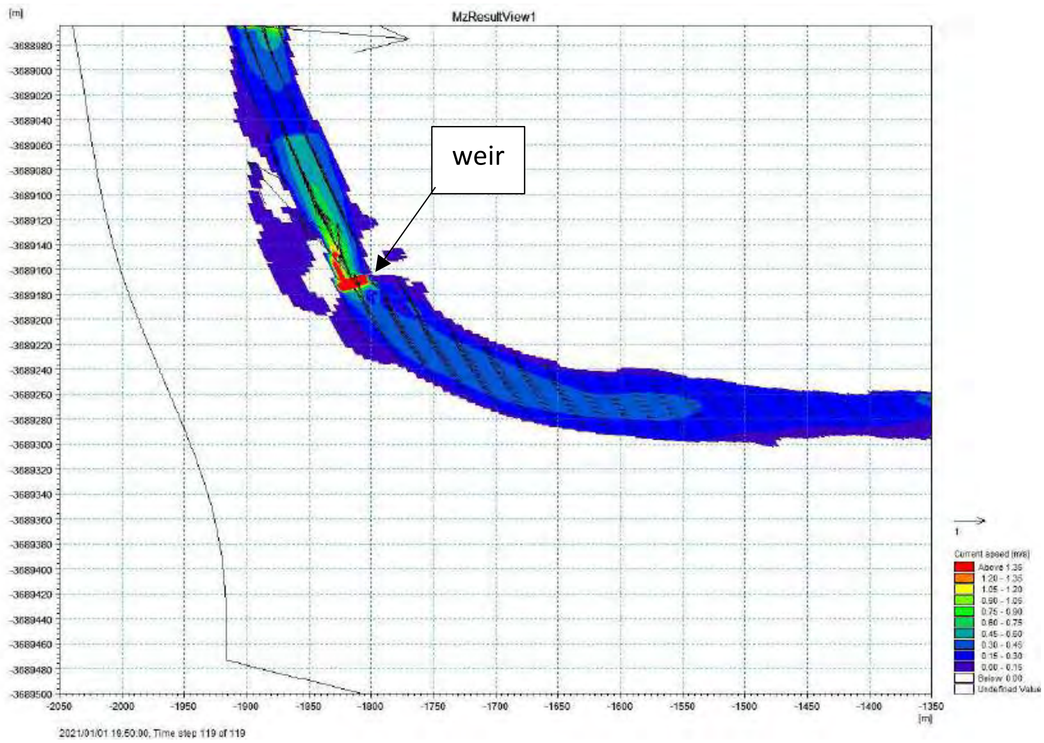


Figure D1-8: Simulated flow velocities at a river discharge of 50 m³/s with the proposed weir and abstraction works

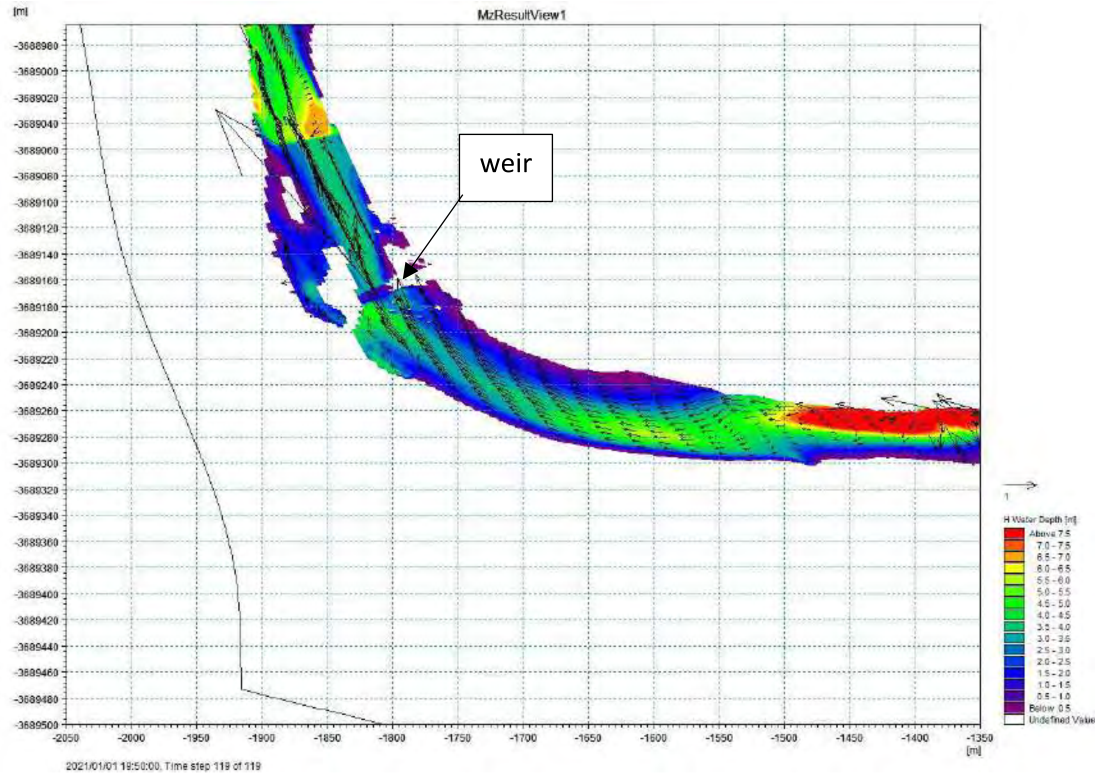


Figure D1-9: Simulated water depths at a river discharge of 100 m³/s with the proposed weir and abstraction works

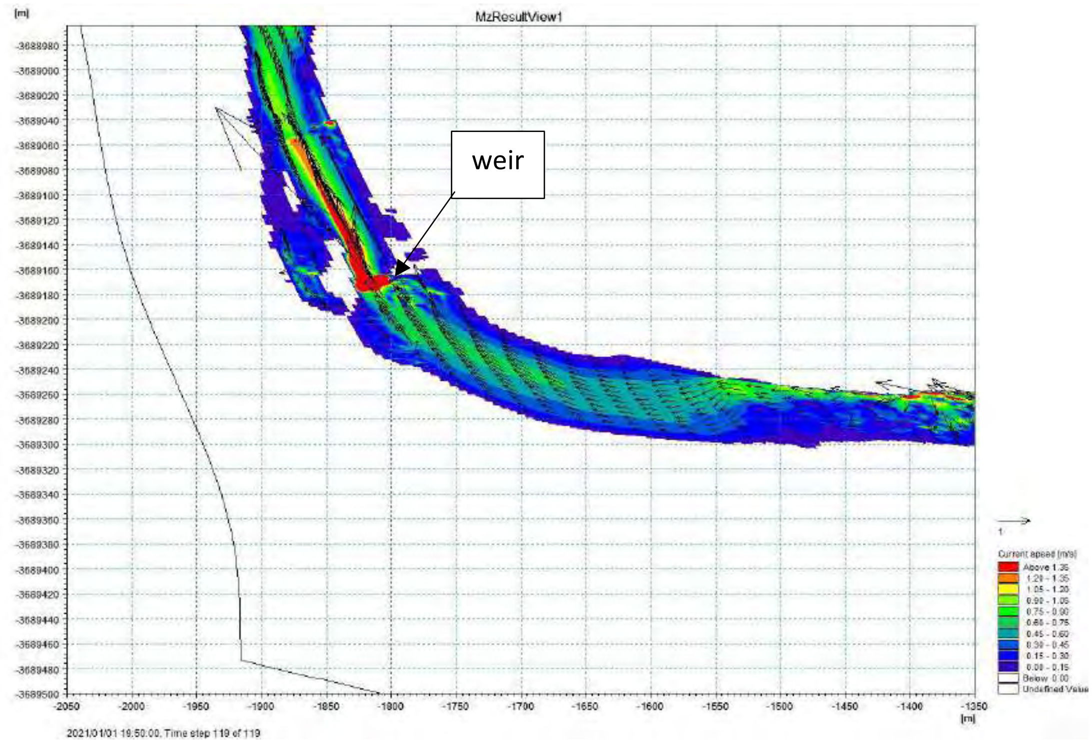


Figure D1-10: Simulated flow velocities at a river discharge of 100 m³/s with the proposed weir and abstraction works

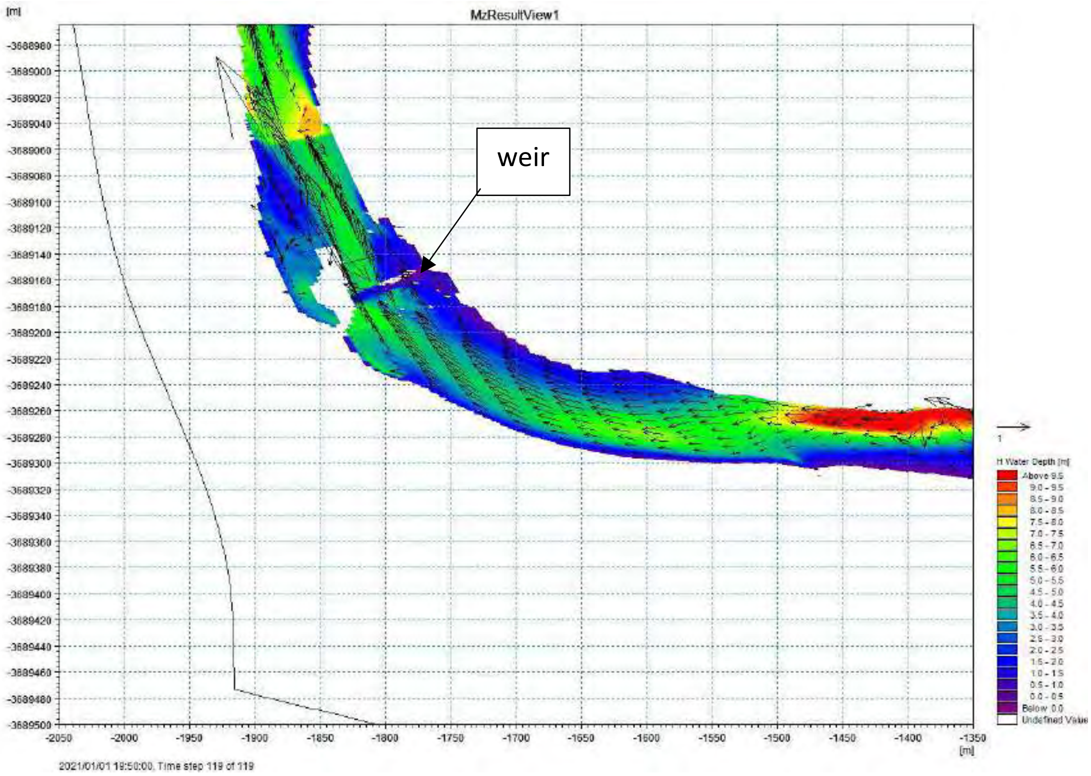


Figure D1-11: Simulated water depths at a river discharge of 210 m³/s (Q2) with the proposed weir and abstraction works

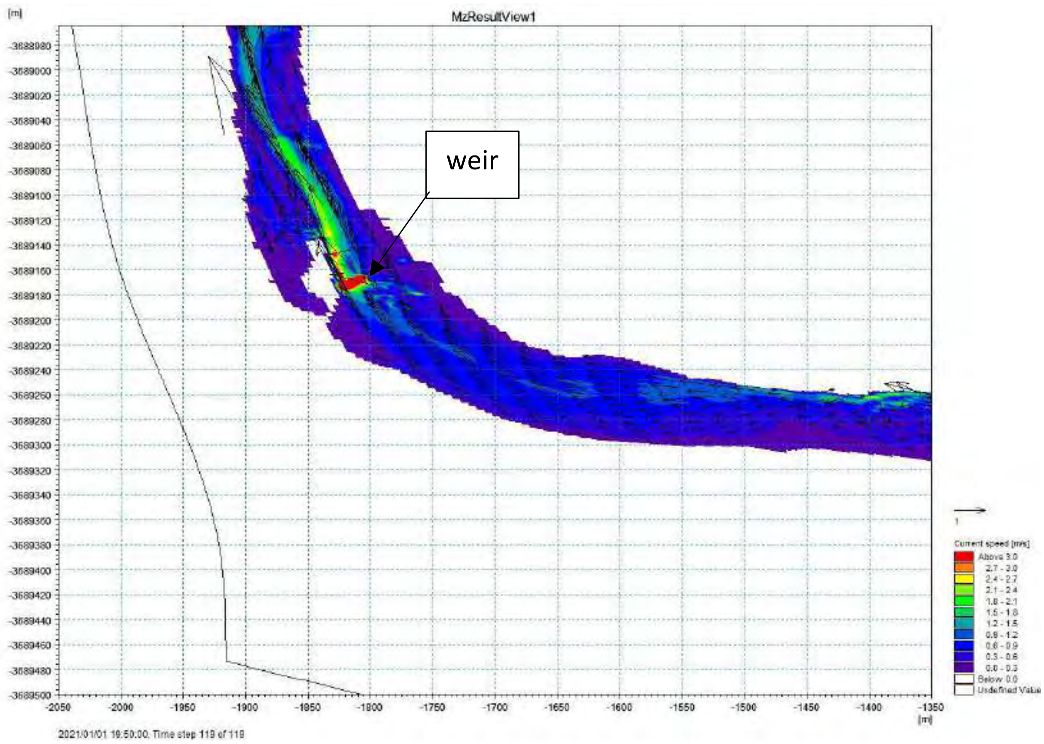


Figure D1-12: Simulated flow velocities at a river discharge of 210 m³/s (Q2) with the proposed weir and abstraction works

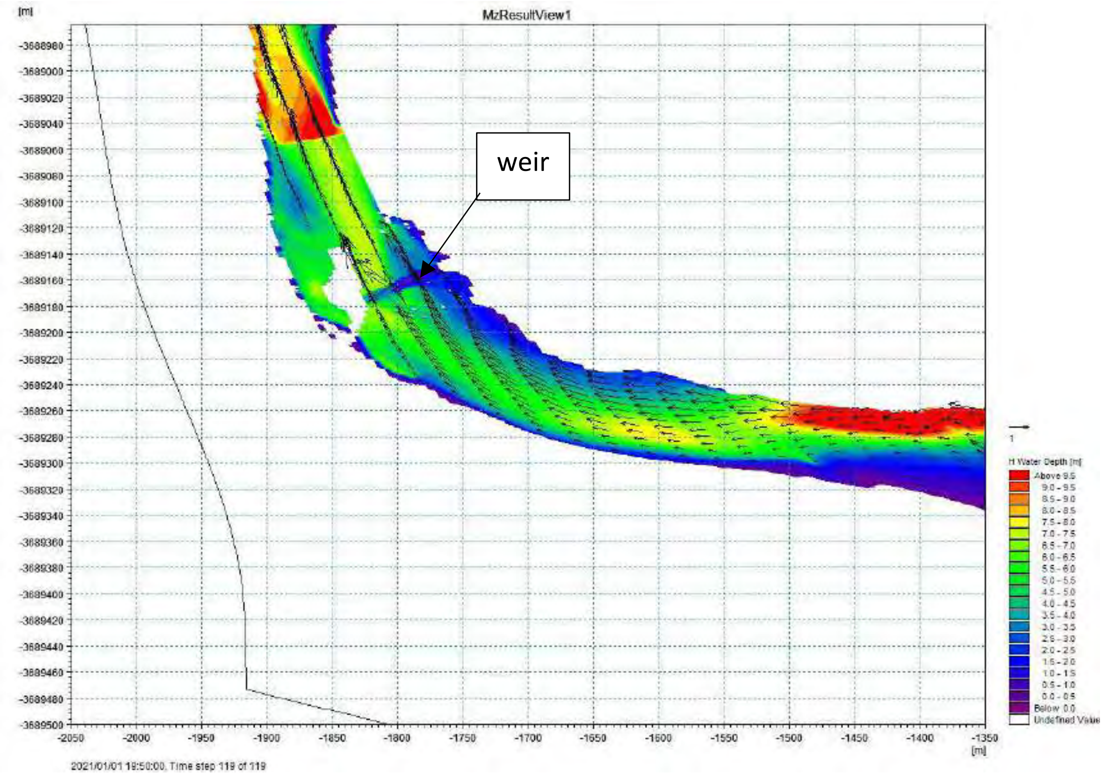


Figure D1-13: Simulated water depths at a river discharge of 424 m^3/s (Q5) with the proposed weir and abstraction works

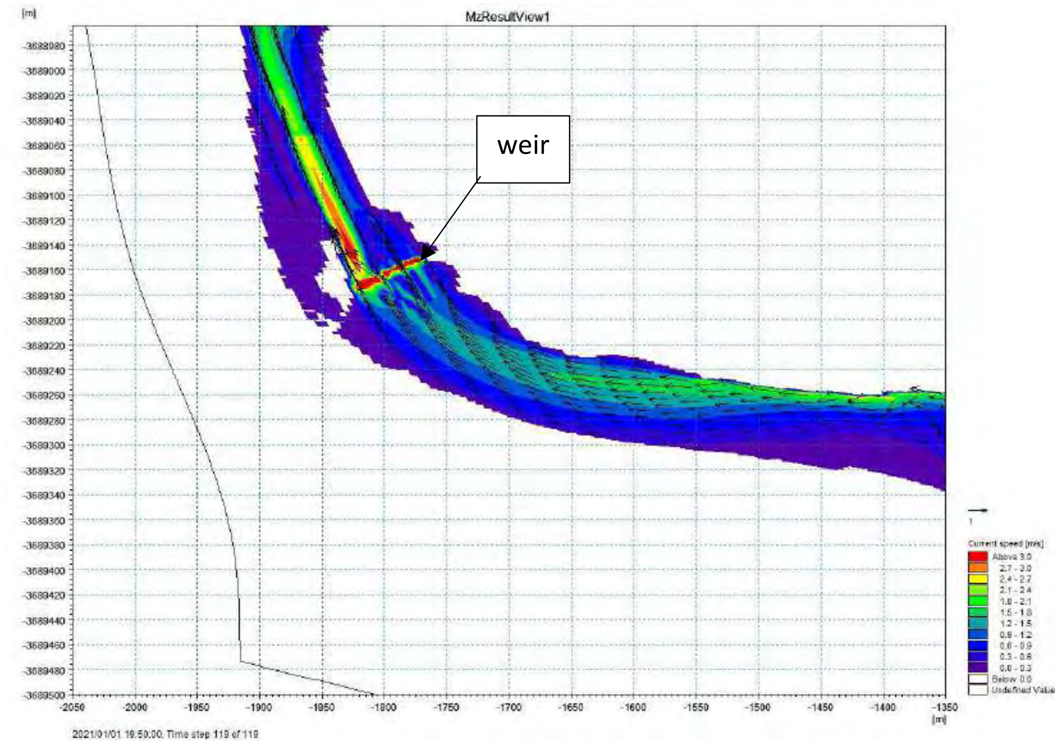


Figure D1-14: Simulated flow velocities at a river discharge of 424 m^3/s (Q5) with the proposed weir and abstraction works

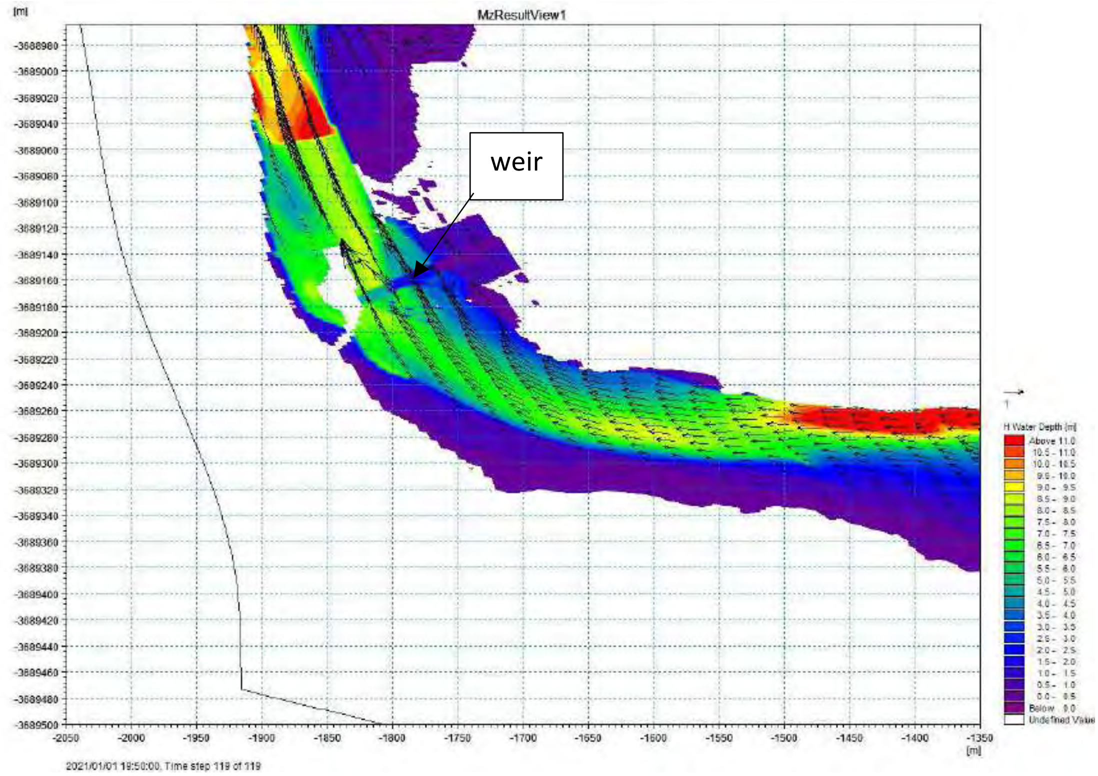


Figure D1-15: Simulated water depths at a river discharge of 613 m³/s (Q10) with the proposed weir and abstraction works

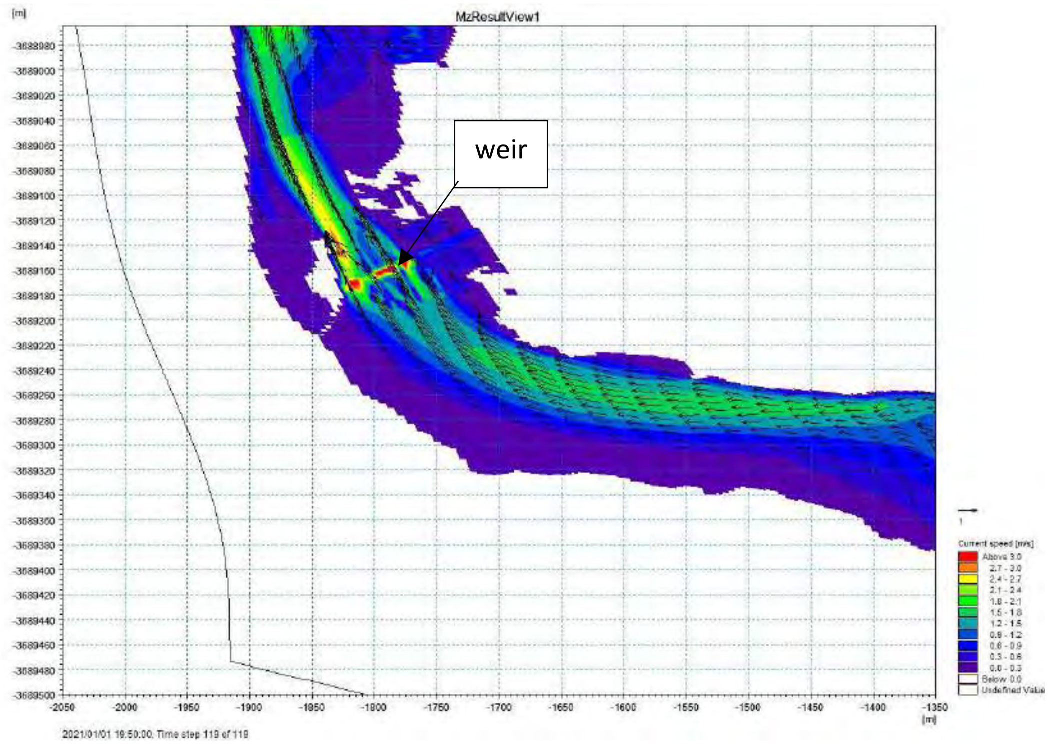


Figure D1-16: Simulated flow velocities at a river discharge of 613 m³/s (Q10) with the proposed weir and abstraction works

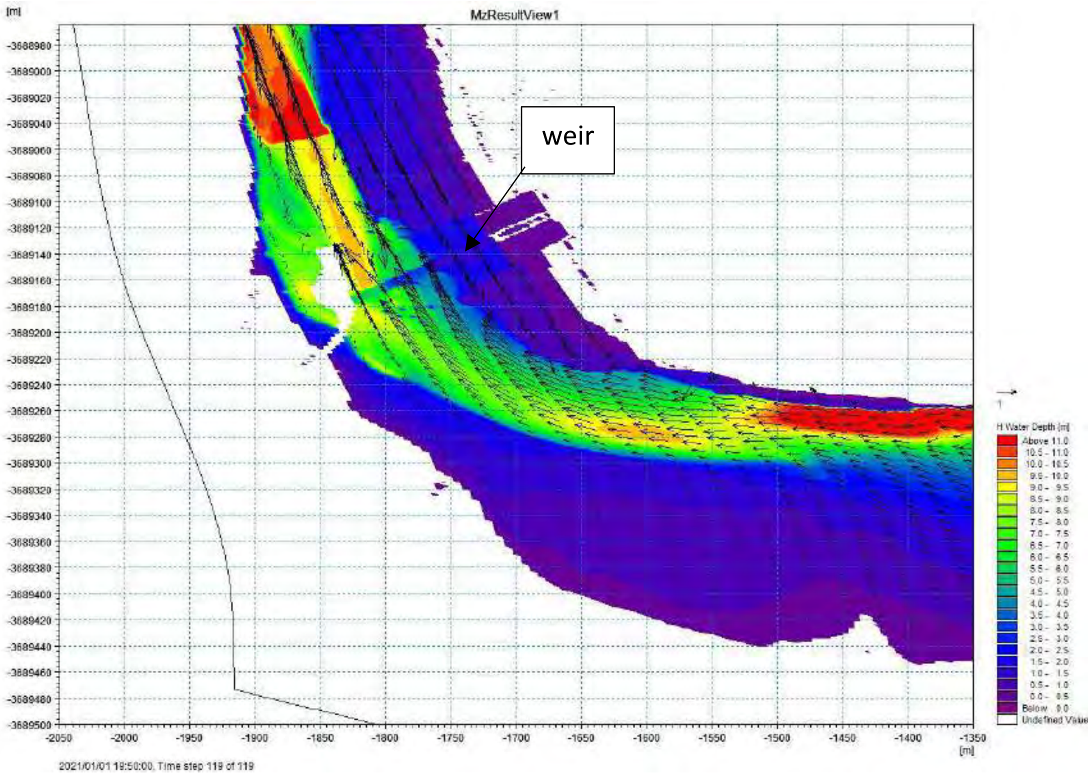


Figure D1-17: Simulated water depths at a river discharge of 830 m³/s (Q20) with the proposed weir and abstraction works

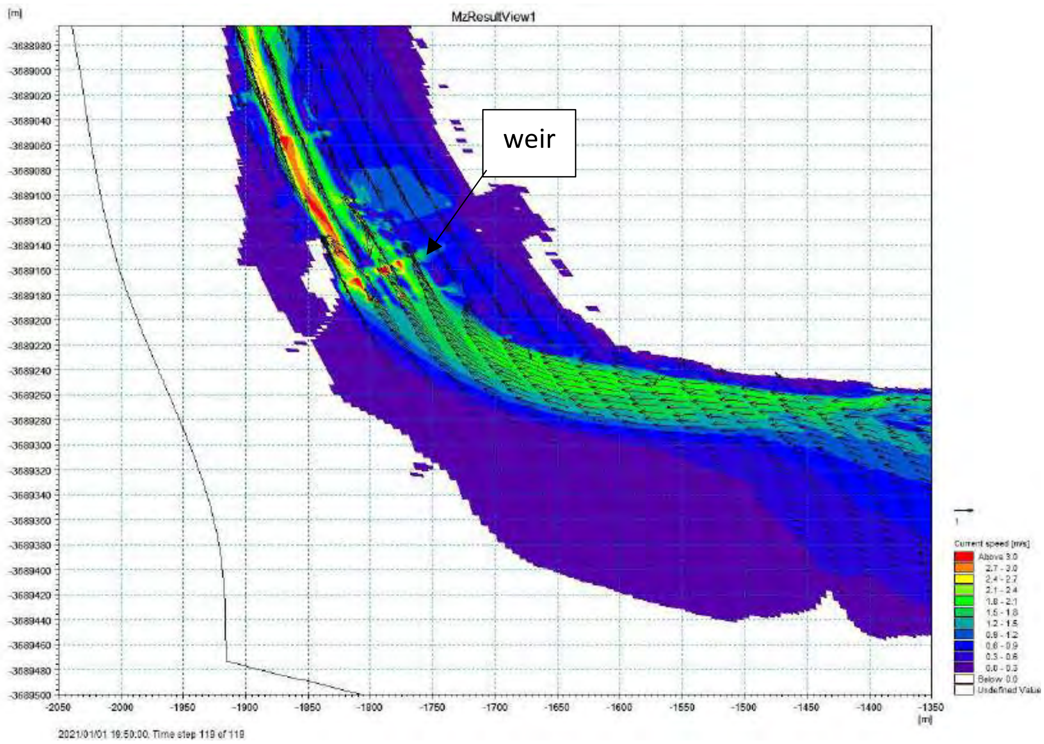


Figure D1-18: Simulated flow velocities at a river discharge of 830 m³/s (Q20) with the proposed weir and abstraction works

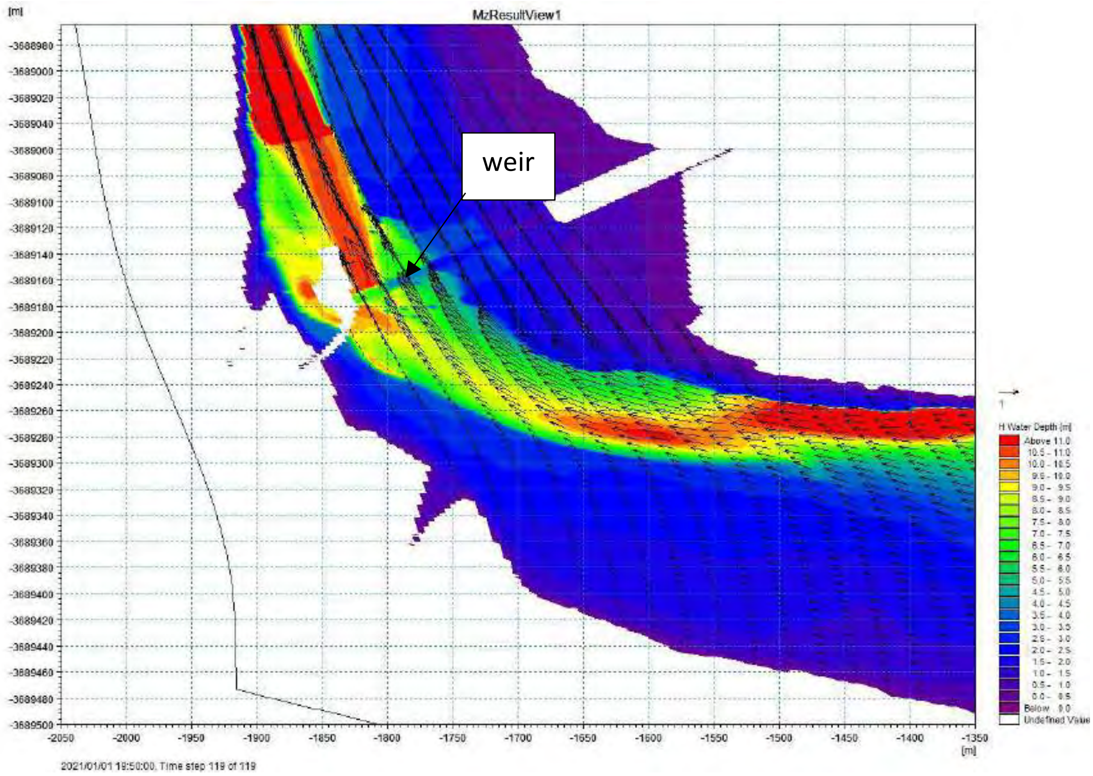


Figure D1-19: Simulated water depths at a river discharge of 1169 m^3/s (Q50) with the proposed weir and abstraction works

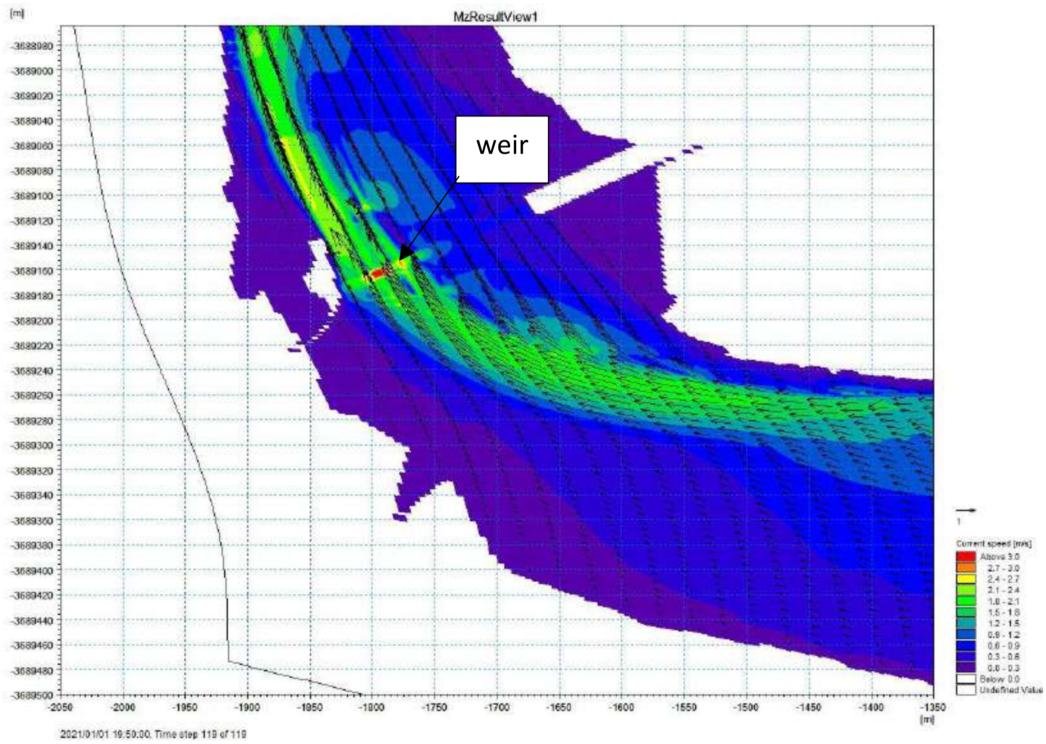


Figure D1-20: Simulated flow velocities at a river discharge of 1169 m^3/s (Q50) with the proposed weir and abstraction works

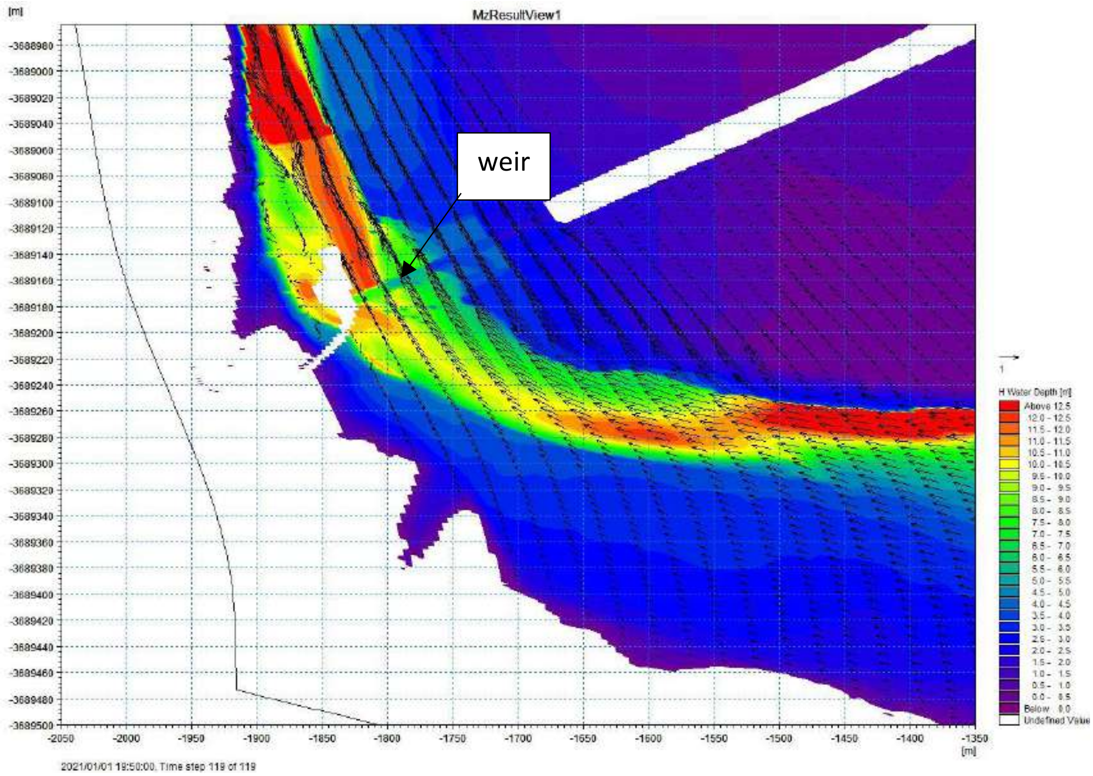


Figure D1-21: Simulated water depths at a river discharge of 1468 m^3/s (Q100) with the proposed weir and abstraction works

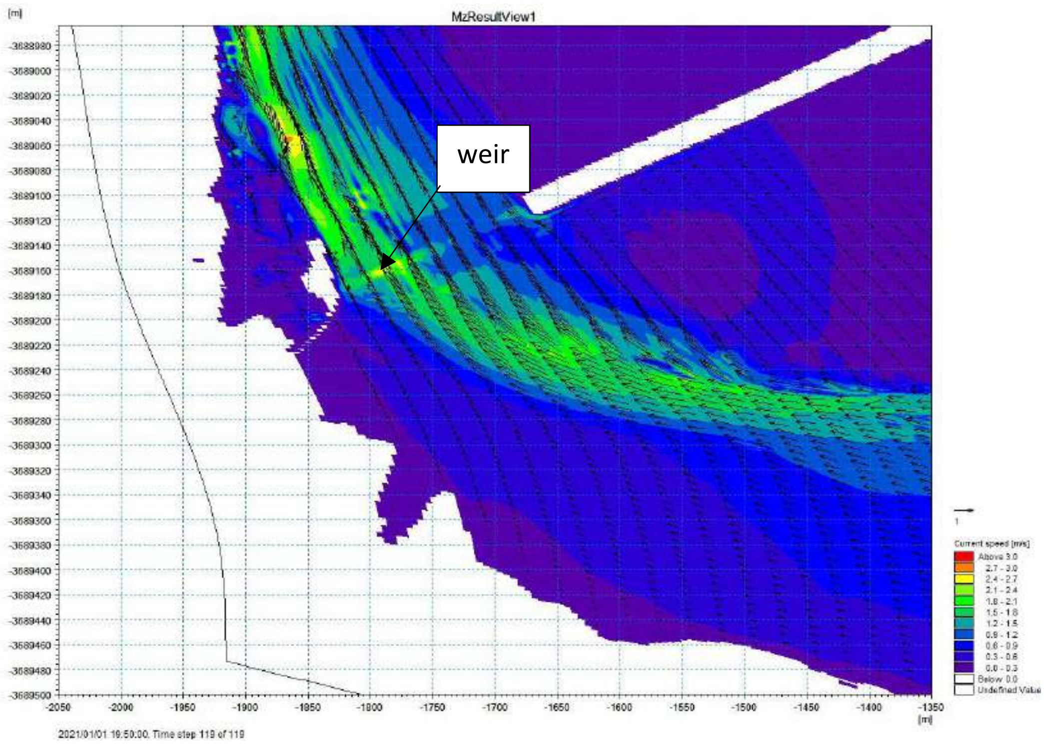


Figure D1-22: Simulated flow velocities at a river discharge of 1468 m^3/s (Q100) with the proposed weir and abstraction works

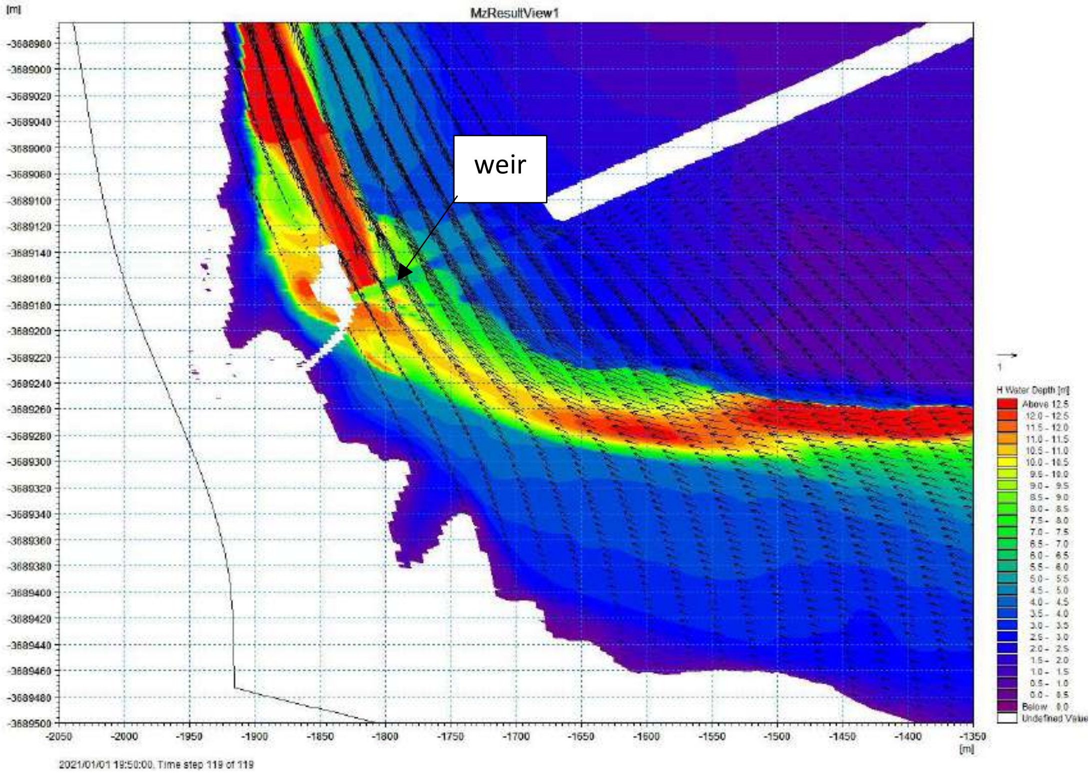


Figure D1-23: Simulated water depths at a river discharge of 1808 m³/s (Q200) with the proposed weir and abstraction works

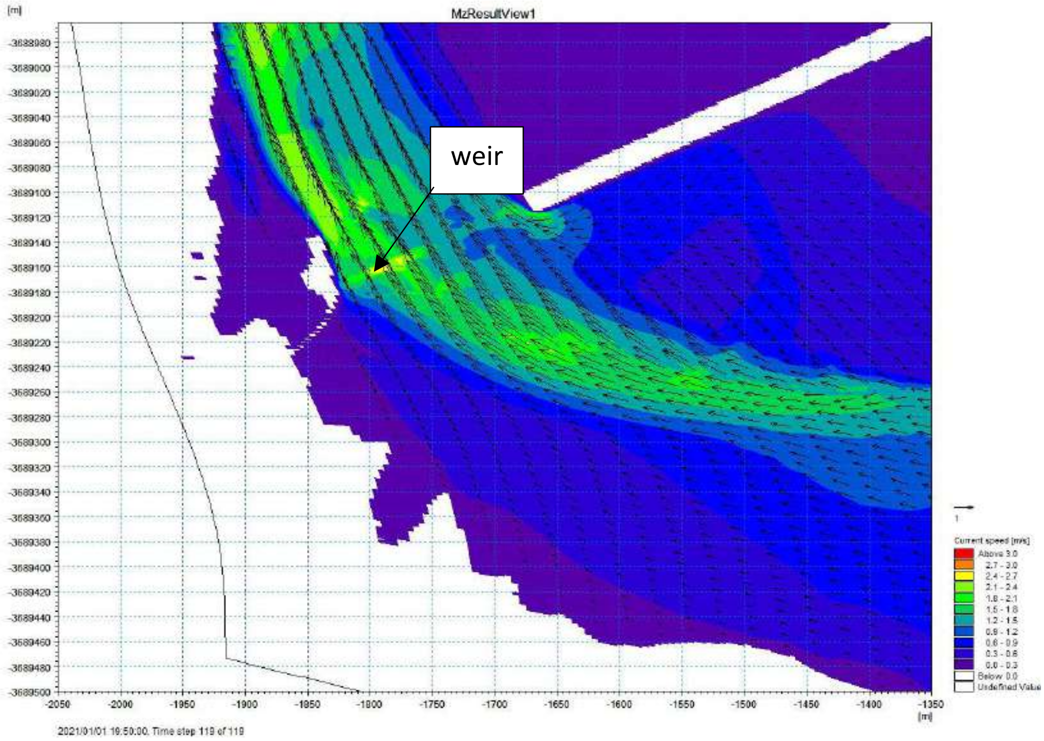


Figure D1-24: Simulated flow velocities at a river discharge of 1808 m³/s (Q200) with the proposed weir and abstraction works

Appendix D2: Hydrodynamic modelling of the Berg River flow patterns and bed levels near the proposed BRVAS abstraction works and site based on the updated 2021 survey

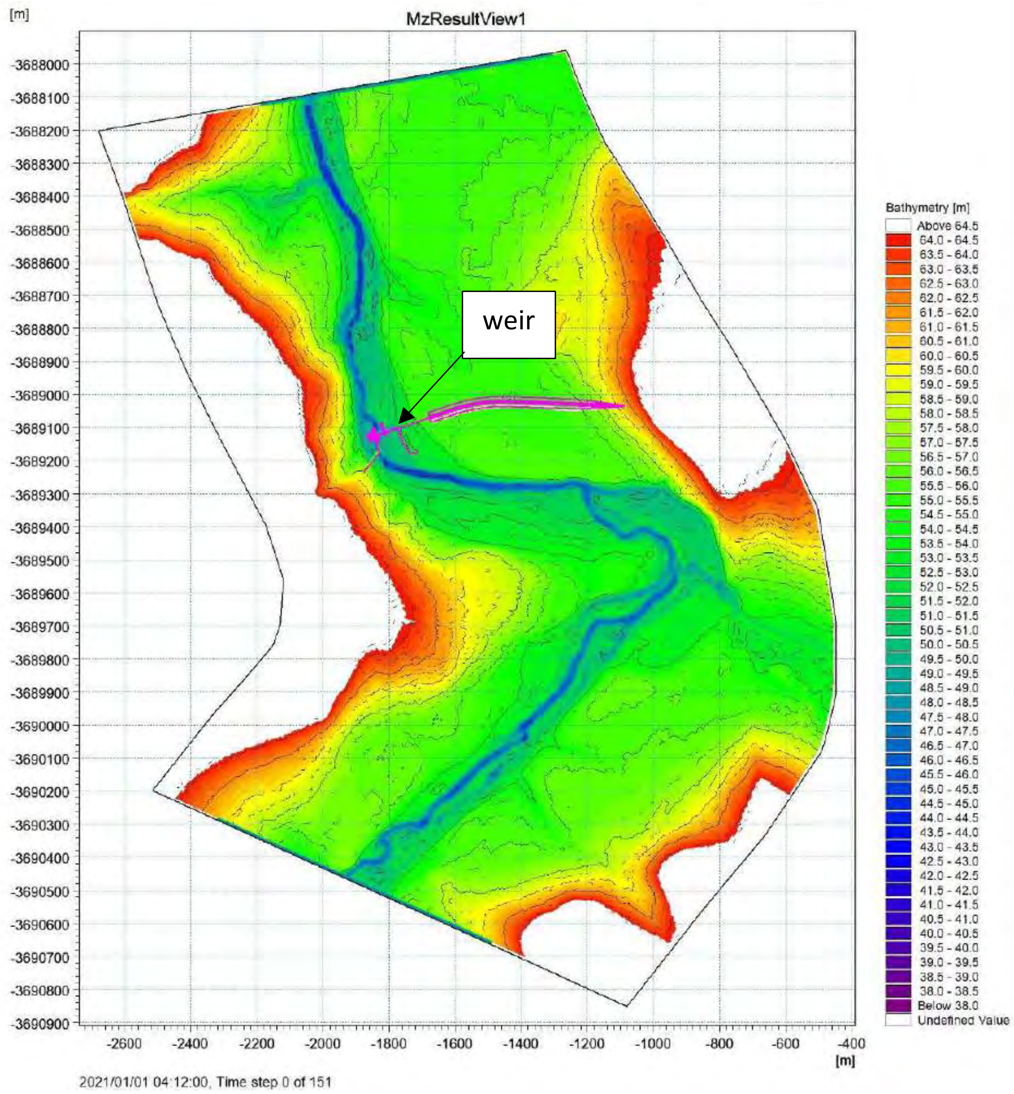


Figure D2-1: Bathymetry used in the Mike 21C model (masl) with the proposed abstraction works and weir added (Option B2)

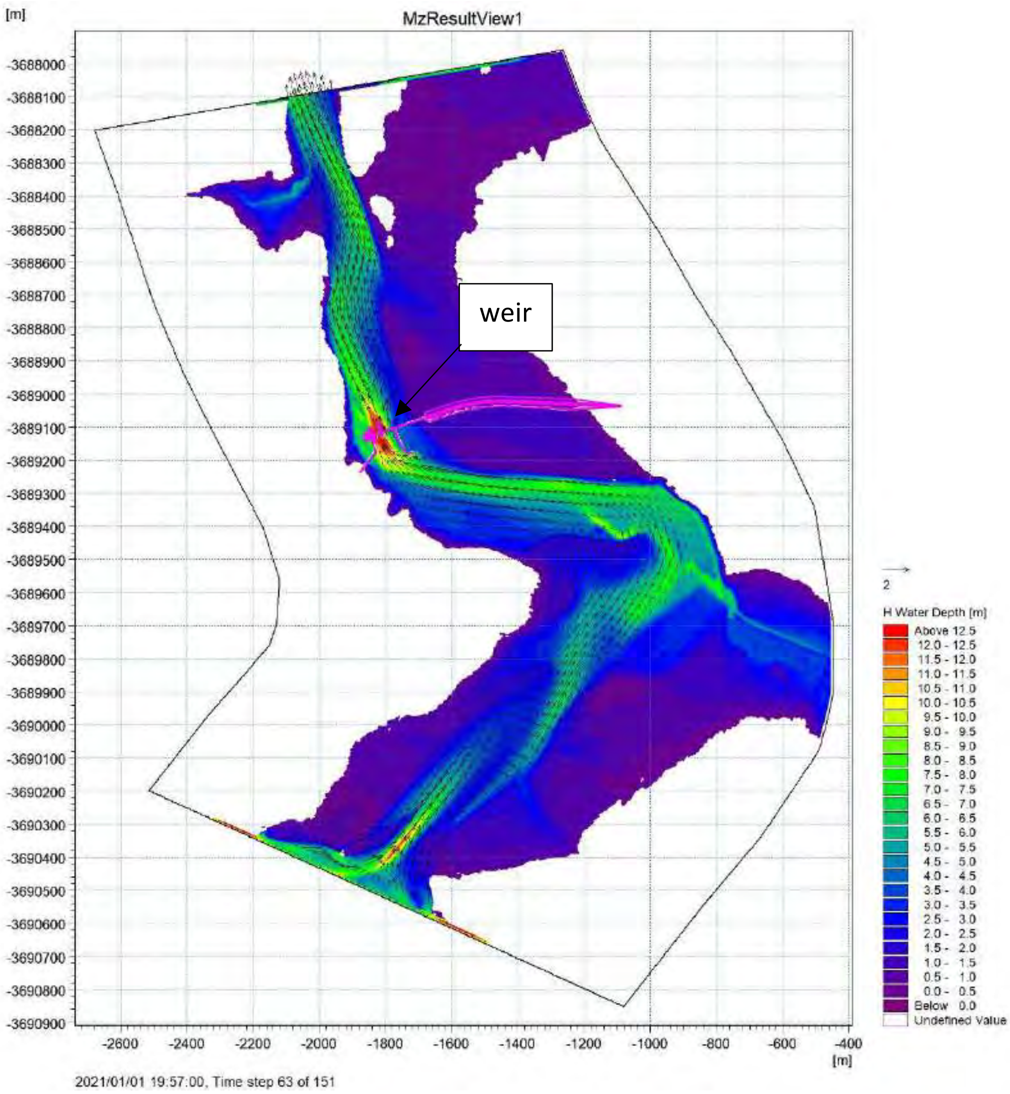


Figure D2-2: Simulated maximum flow depths with velocity vectors at the peak of the 50 year flood (current scenario)

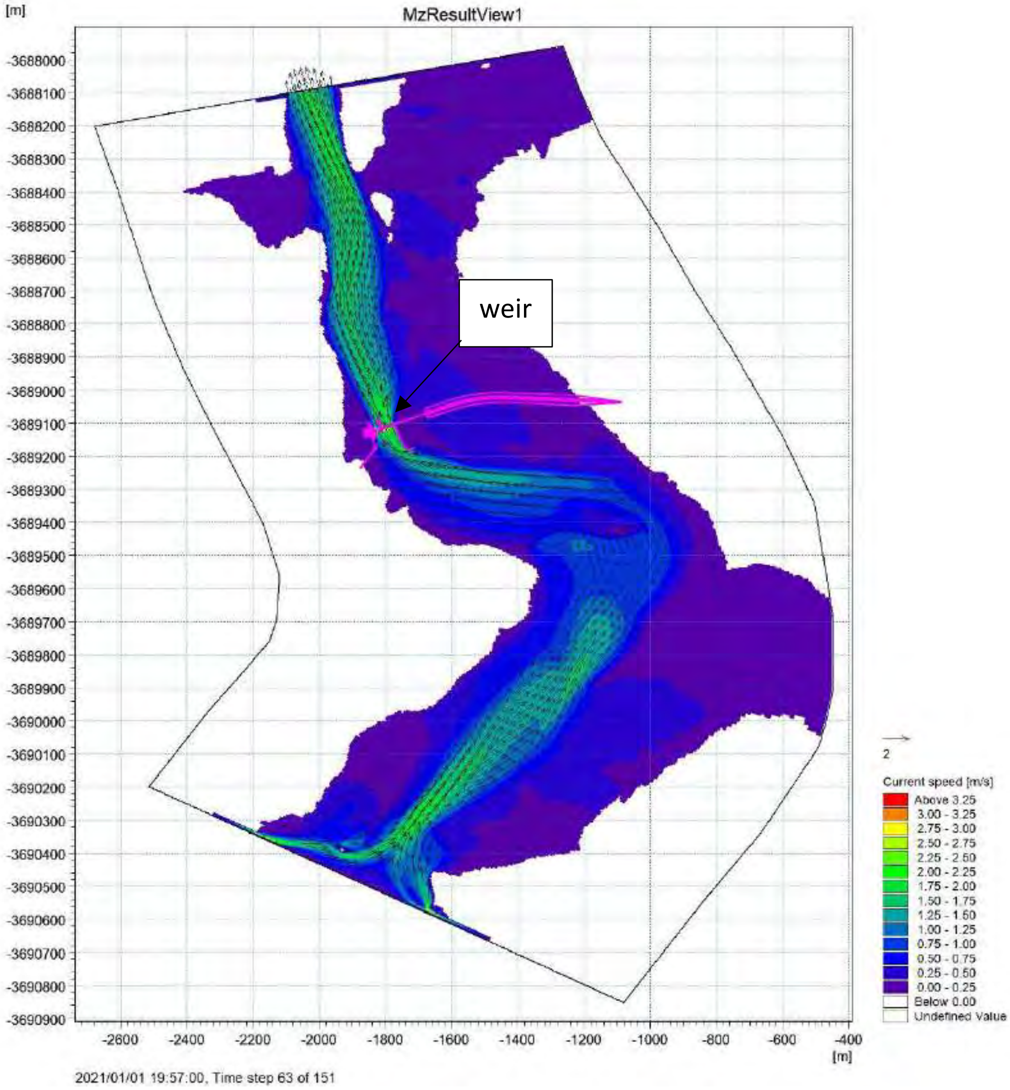


Figure D2-3: Simulated maximum flow velocities with velocity vectors at the peak of the 50 year flood (current scenario)

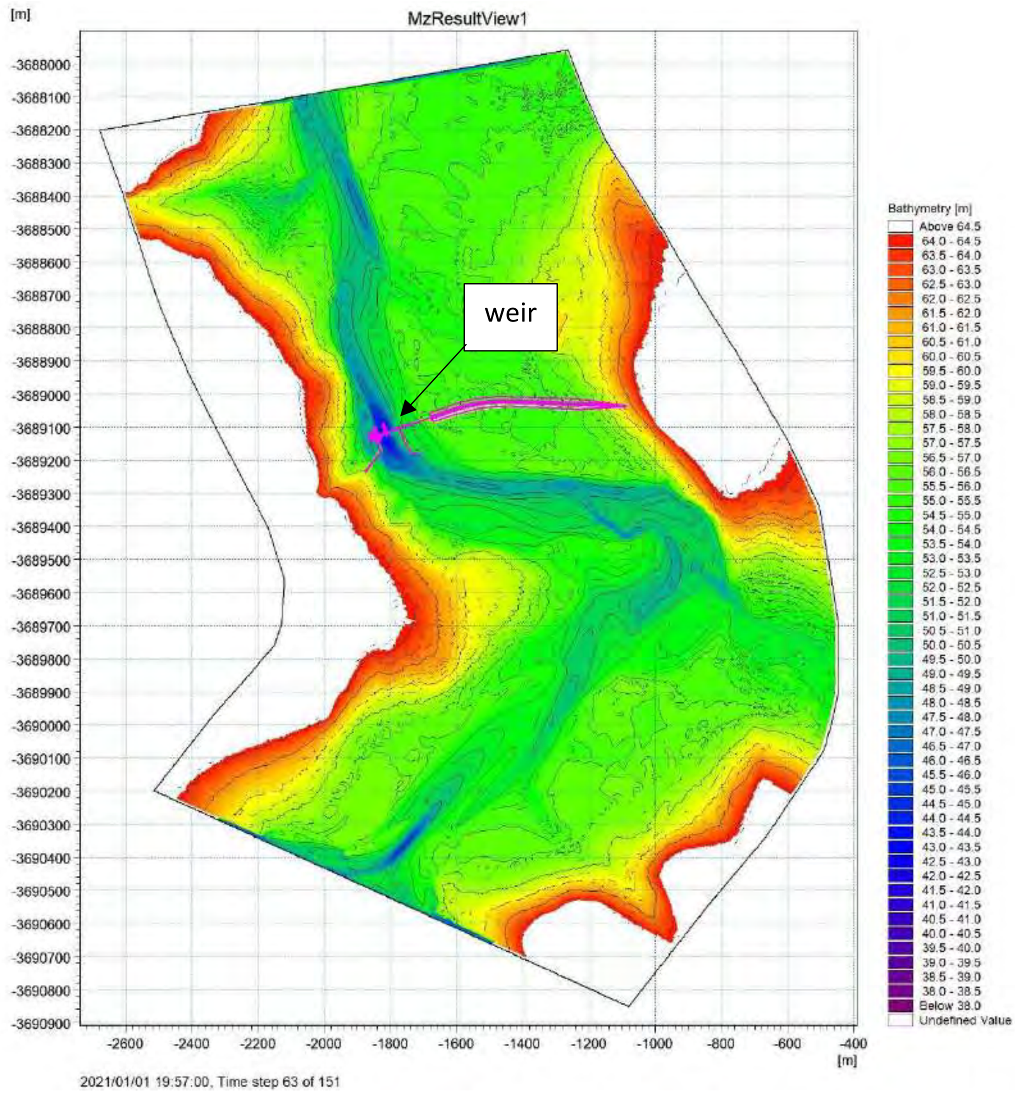


Figure D2-4: Simulated bed levels at the peak of the 50 year flood (current scenario)

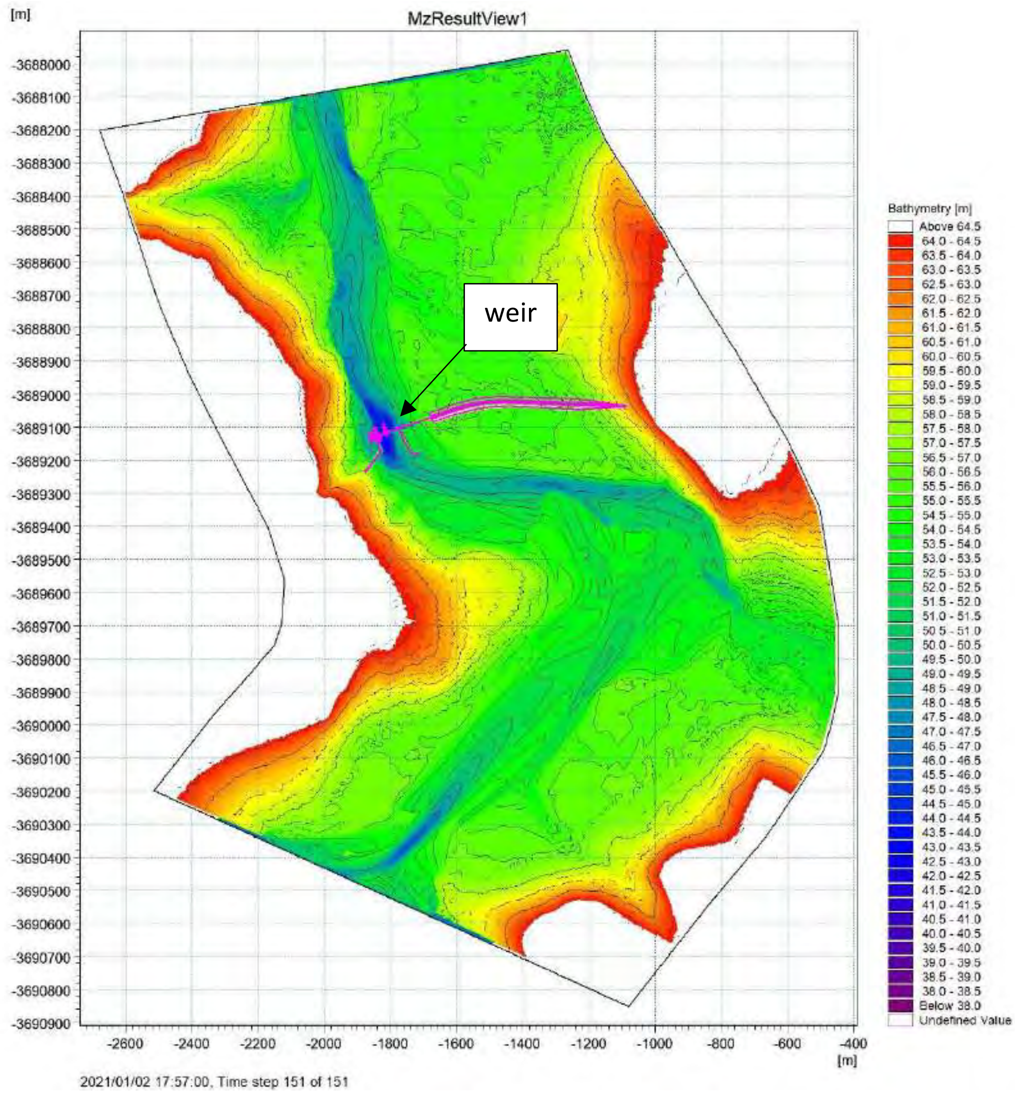


Figure D2-5: Simulated bed levels at the end of the 50 year flood (current scenario)

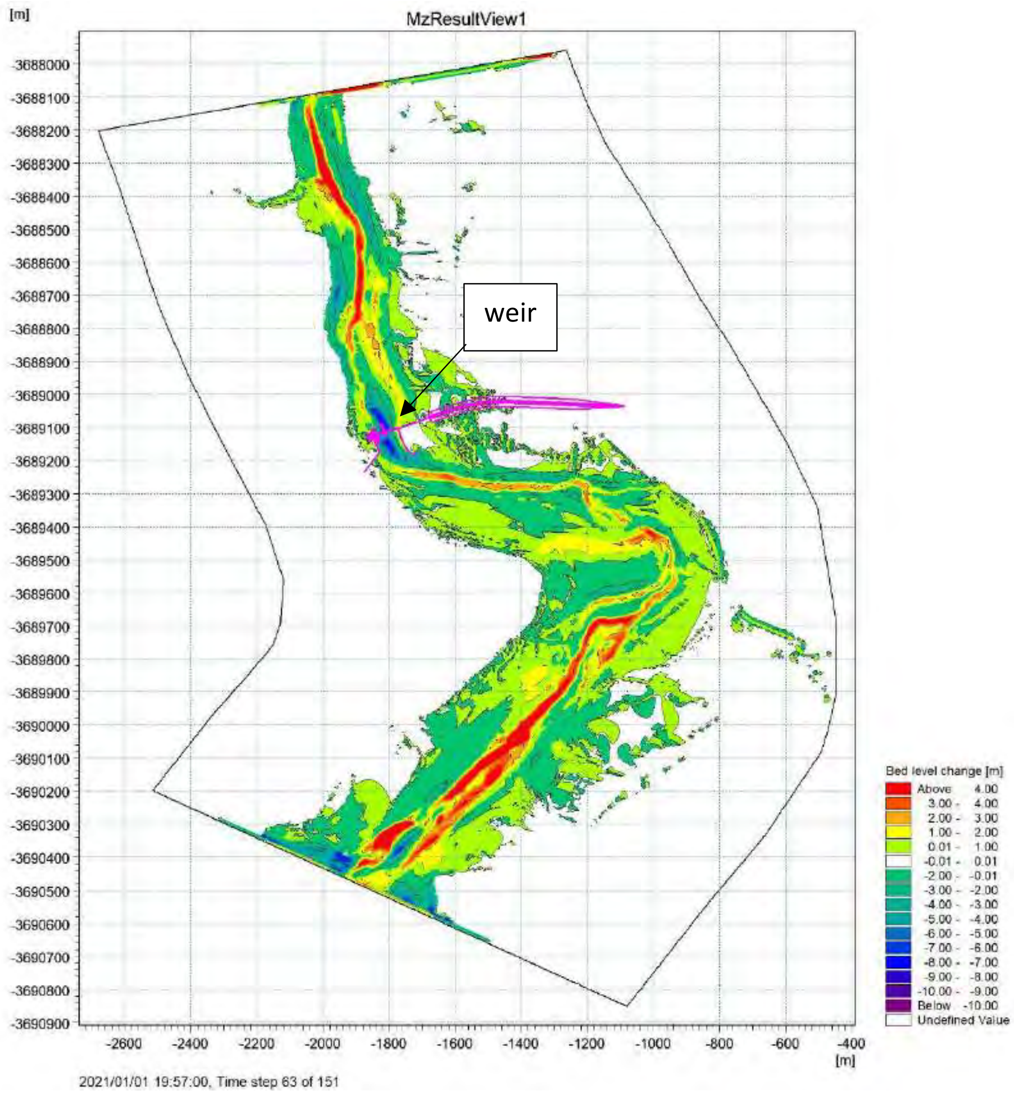


Figure D2-6: Simulated bed level change at the peak of the 50 year flood (current scenario)

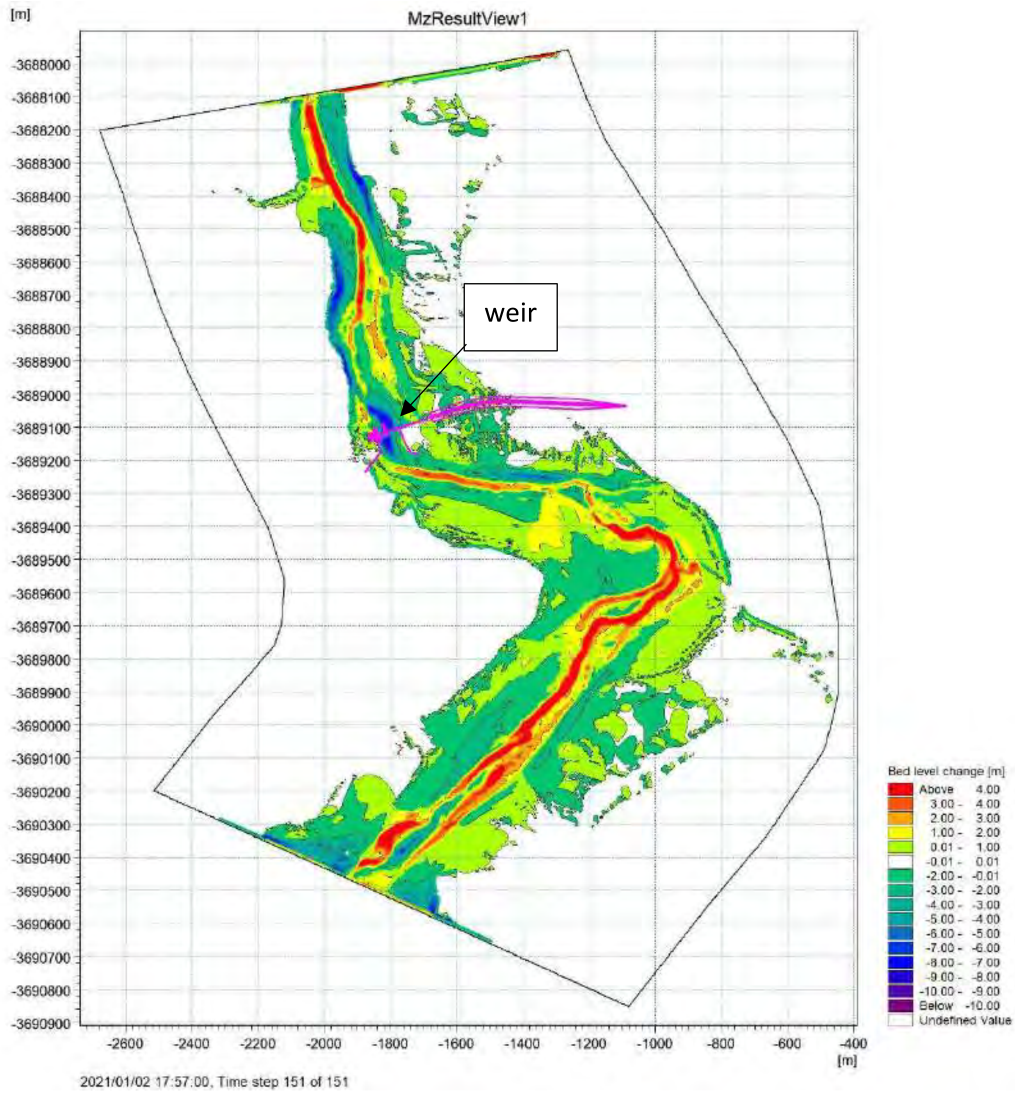


Figure D2-7: Simulated bed level change at the end of the 50 year flood (current scenario)

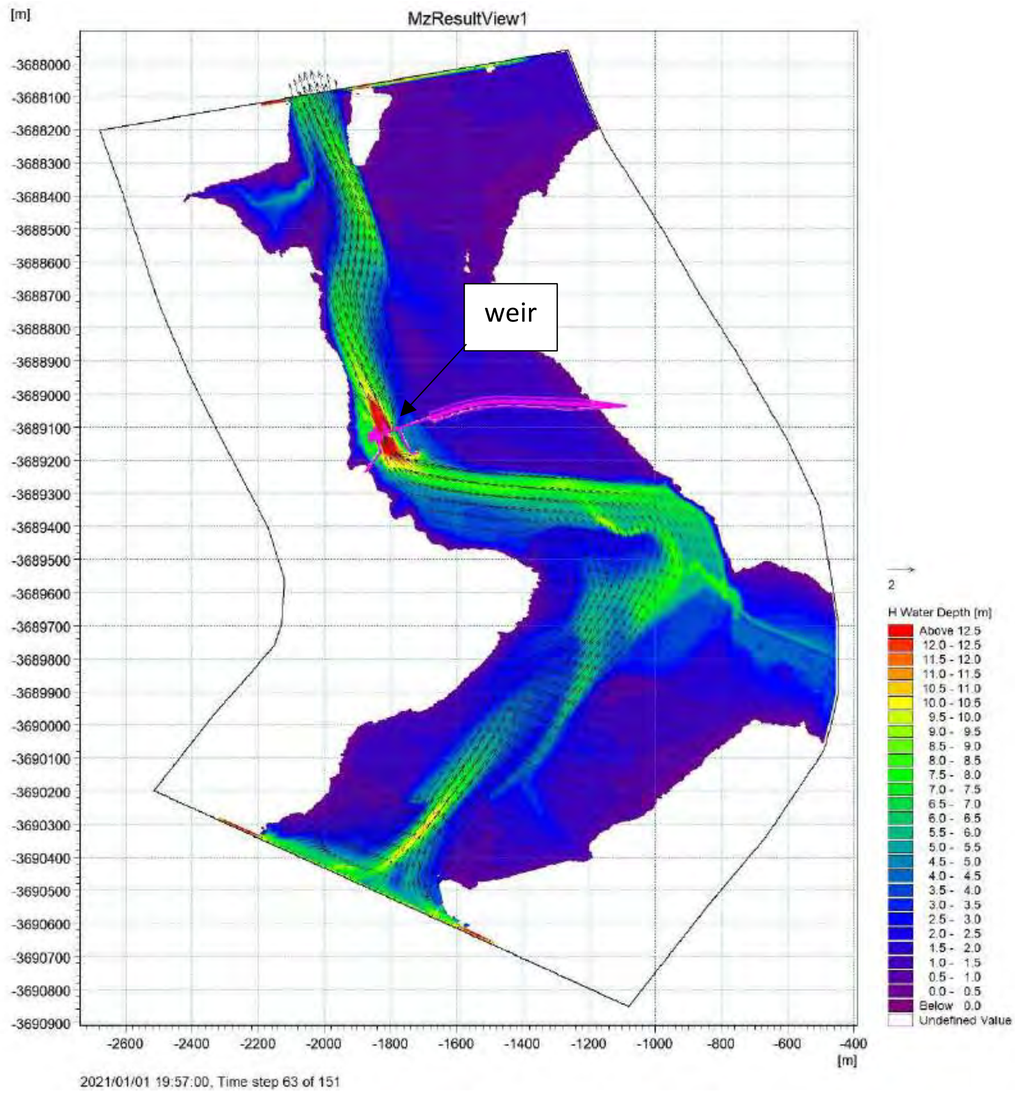


Figure D2-8: Simulated maximum flow depths with velocity vectors at the peak of the 100 year flood (current scenario)

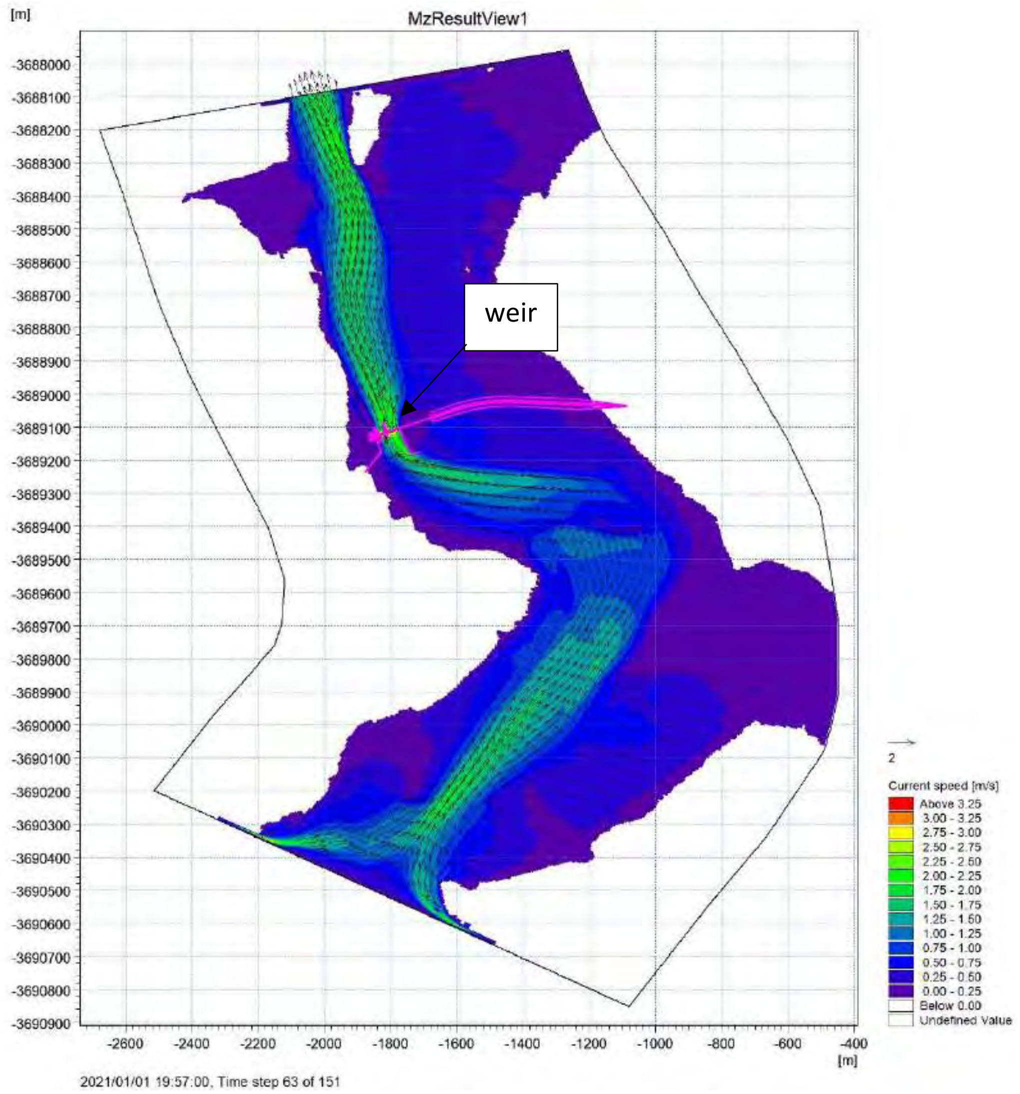


Figure D2-9: Simulated maximum flow velocities with velocity vectors at the peak of the 100 year flood (current scenario)

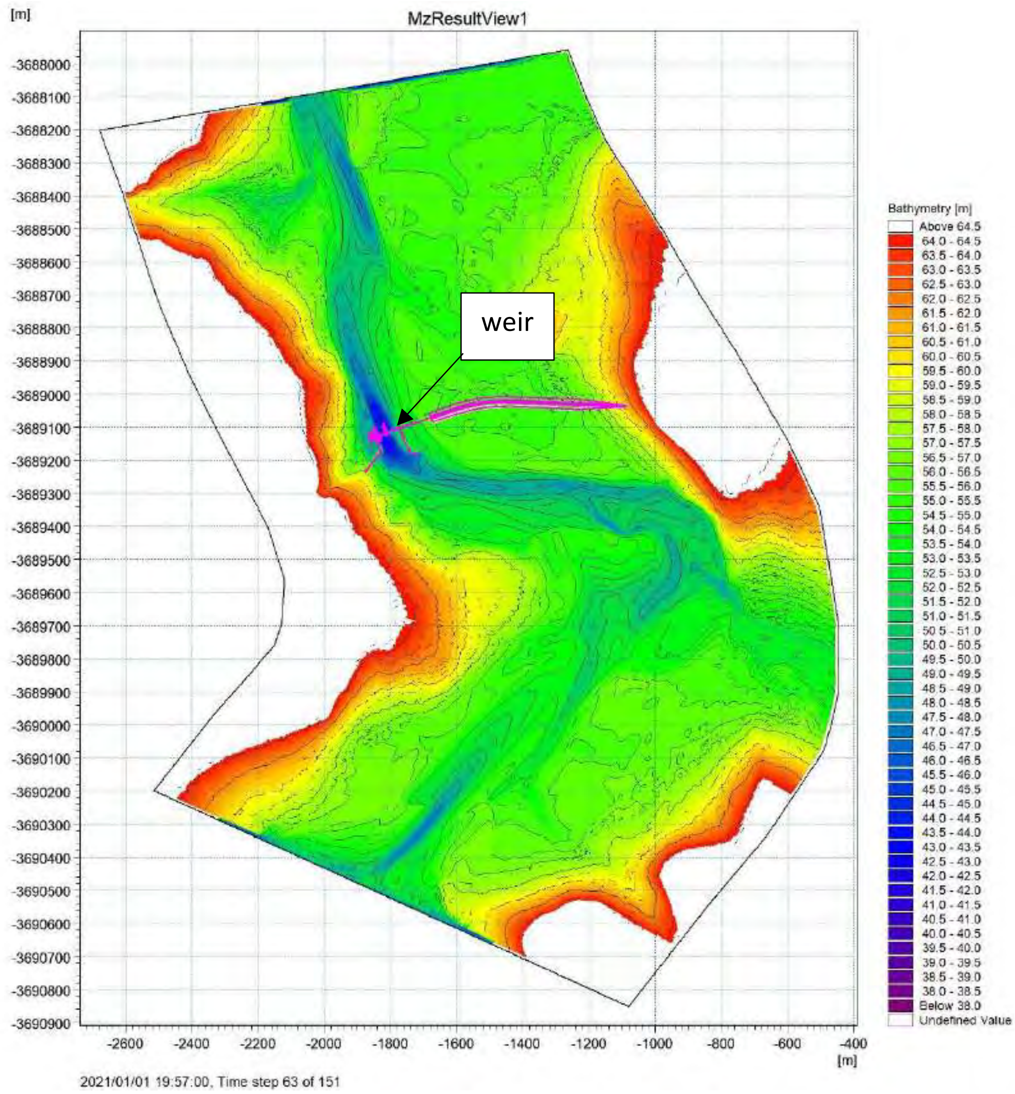


Figure D2-10: Simulated bed levels at the peak of the 100 year flood (current scenario)

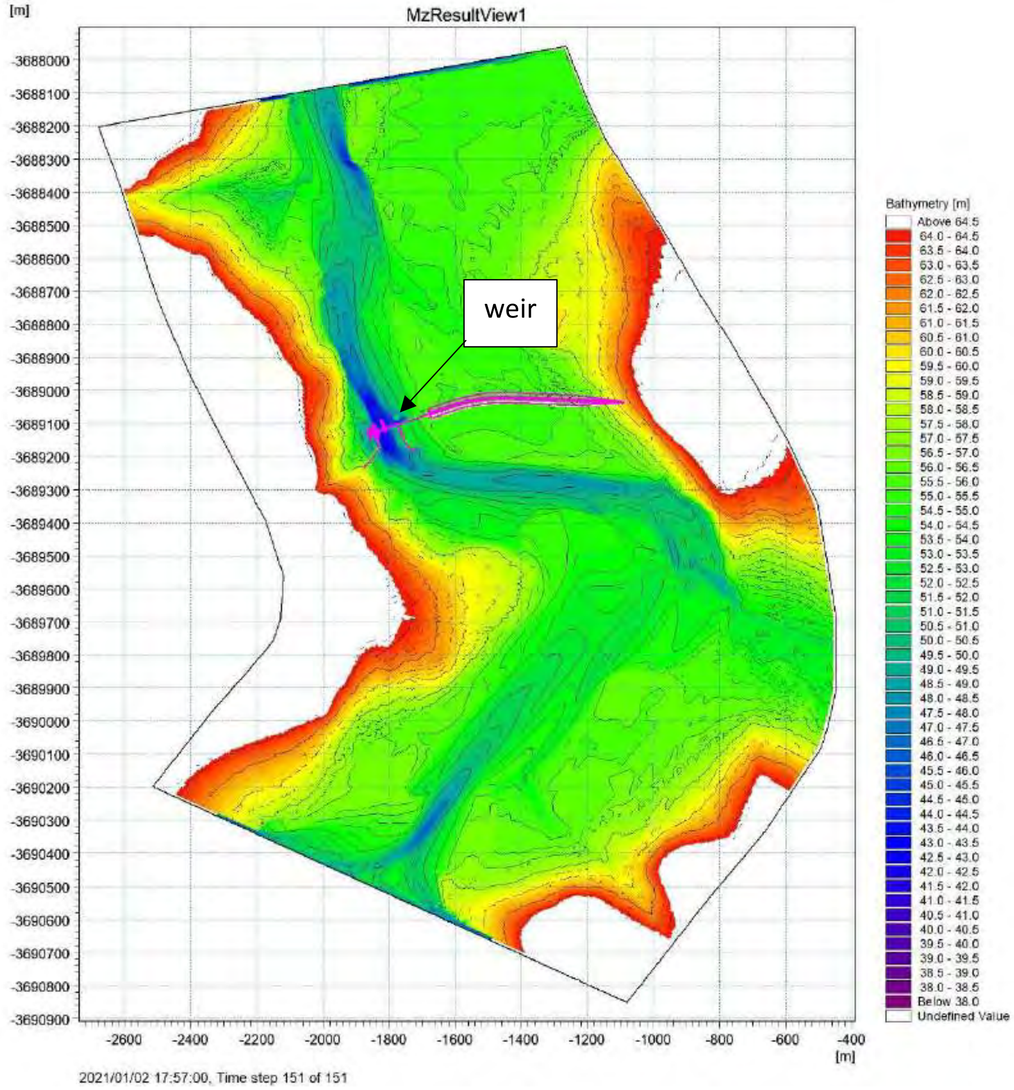


Figure D2-11: Simulated bed levels at the end of the 100 year flood (current scenario)

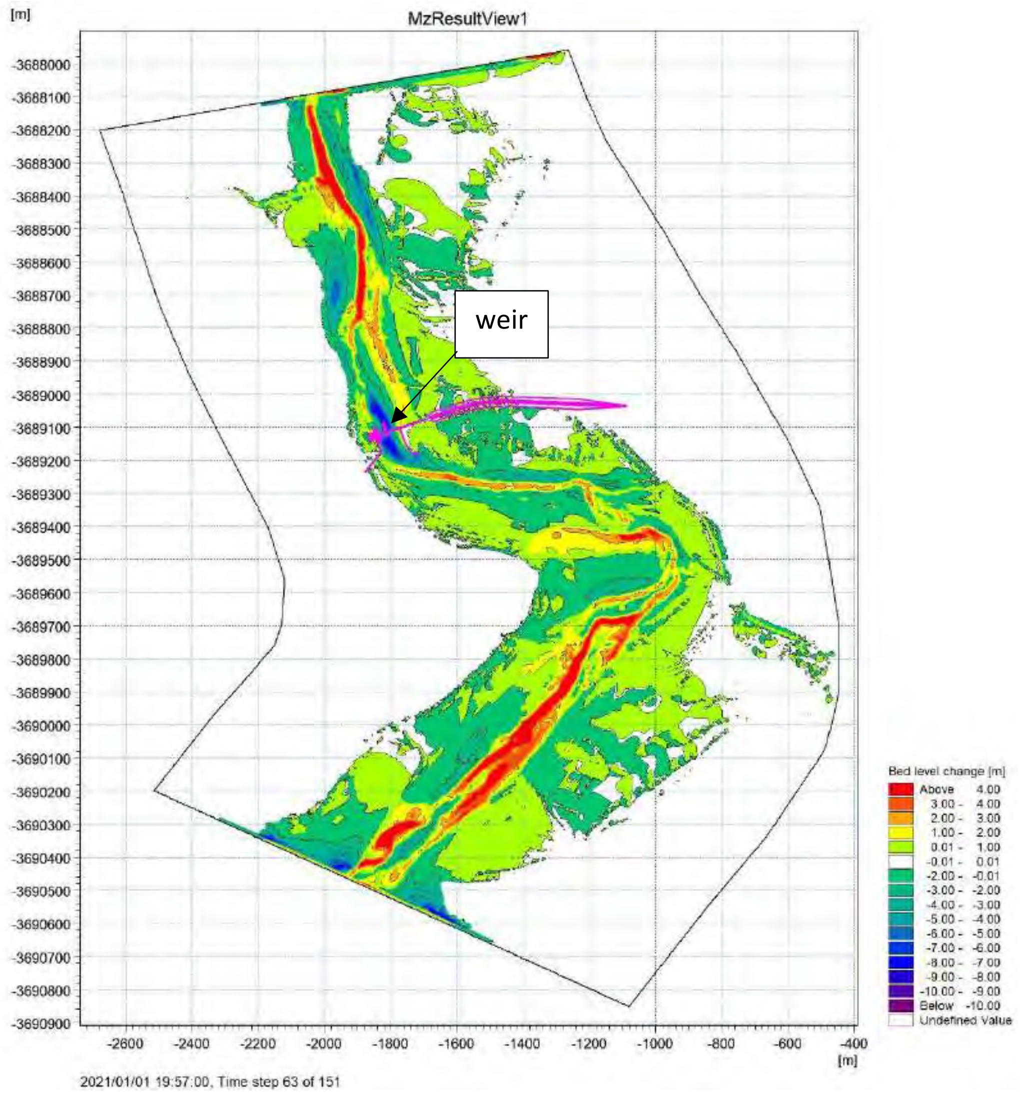


Figure D2-12: Simulated bed level change at the peak of the 100 year flood (current scenario)

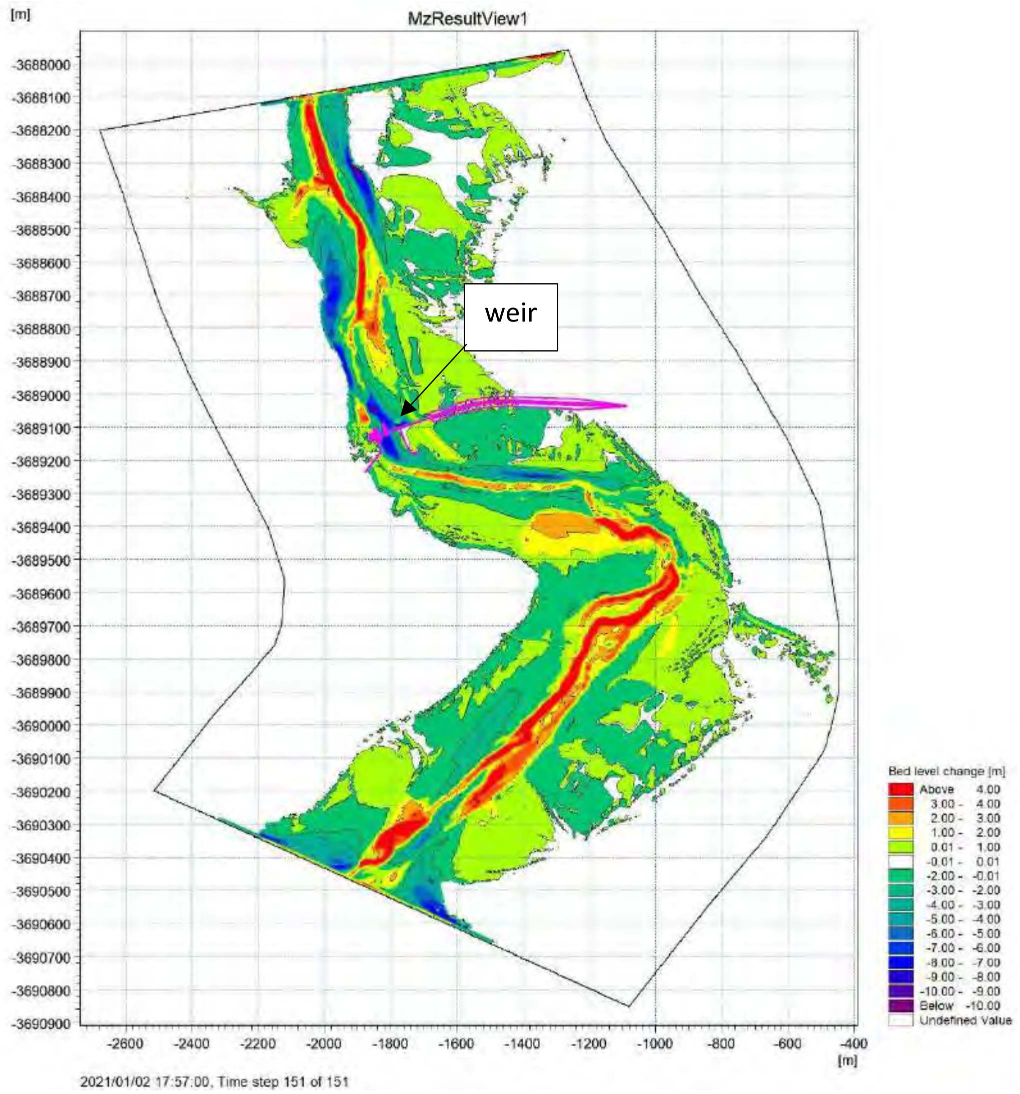


Figure D2-13: Simulated bed level change at the end of the 100 year flood (current scenario)

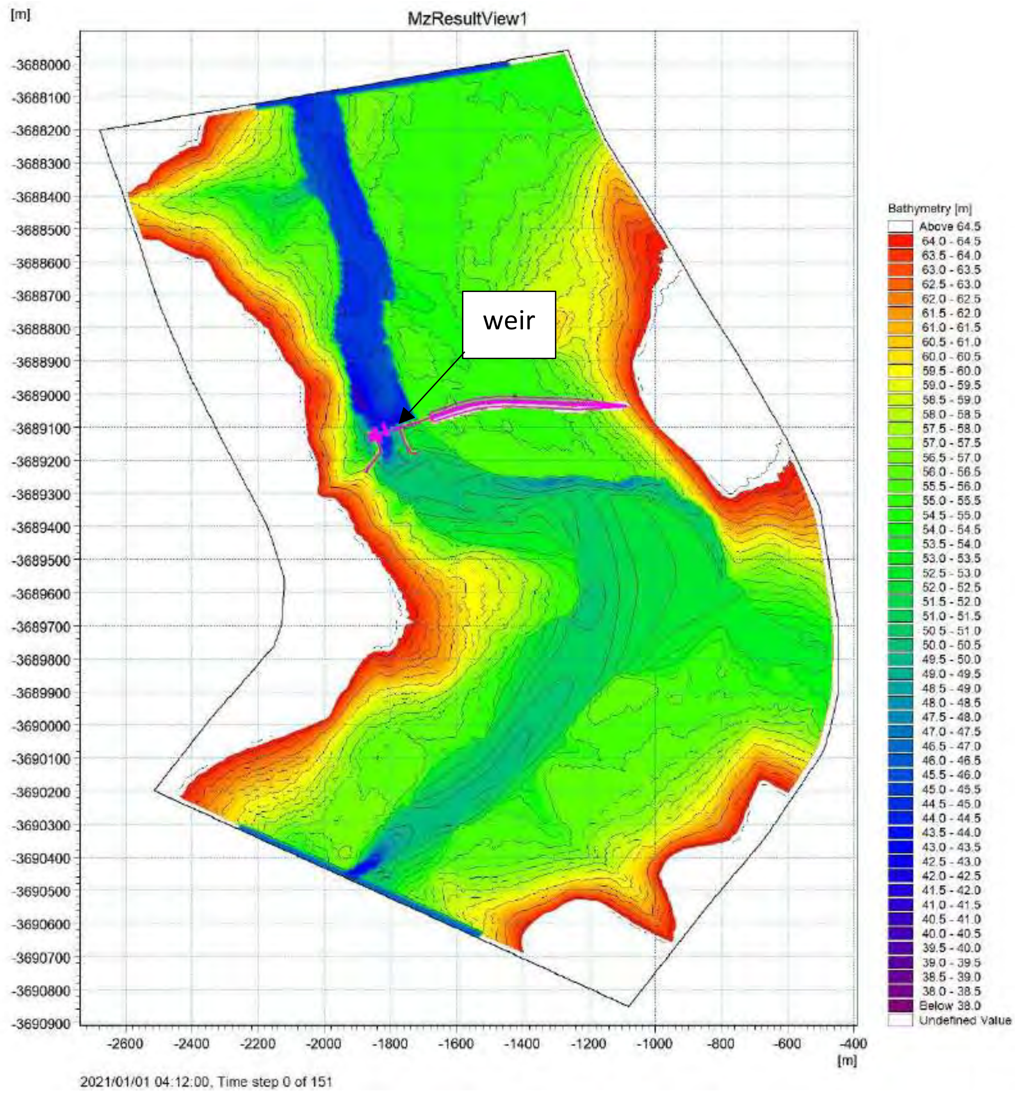


Figure D2-14: Initial bed level (masl) with the proposed abstraction works and weir (Option B2) (future scenario)

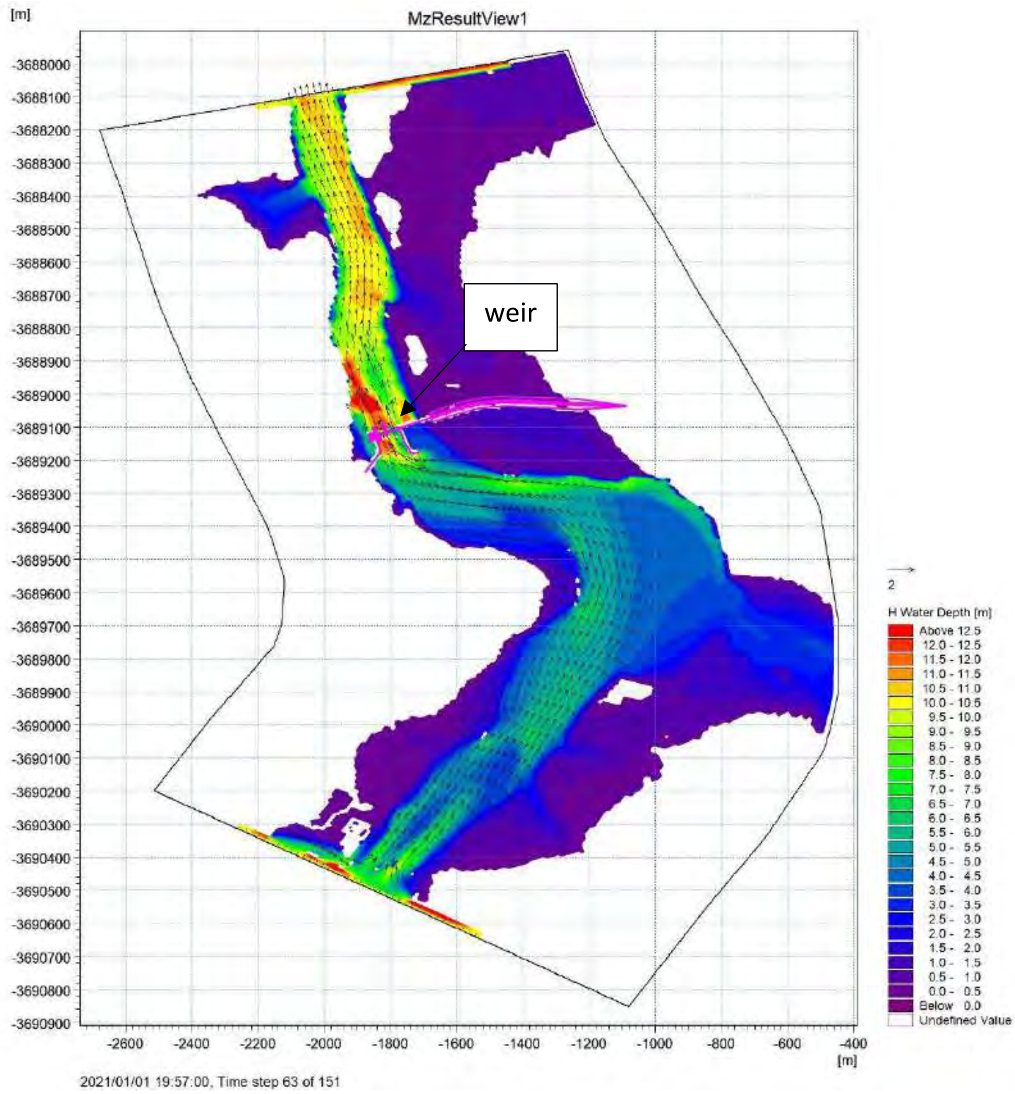


Figure D2-15: Simulated maximum flow depths with velocity vectors at the peak of the 50 year flood (future scenario)

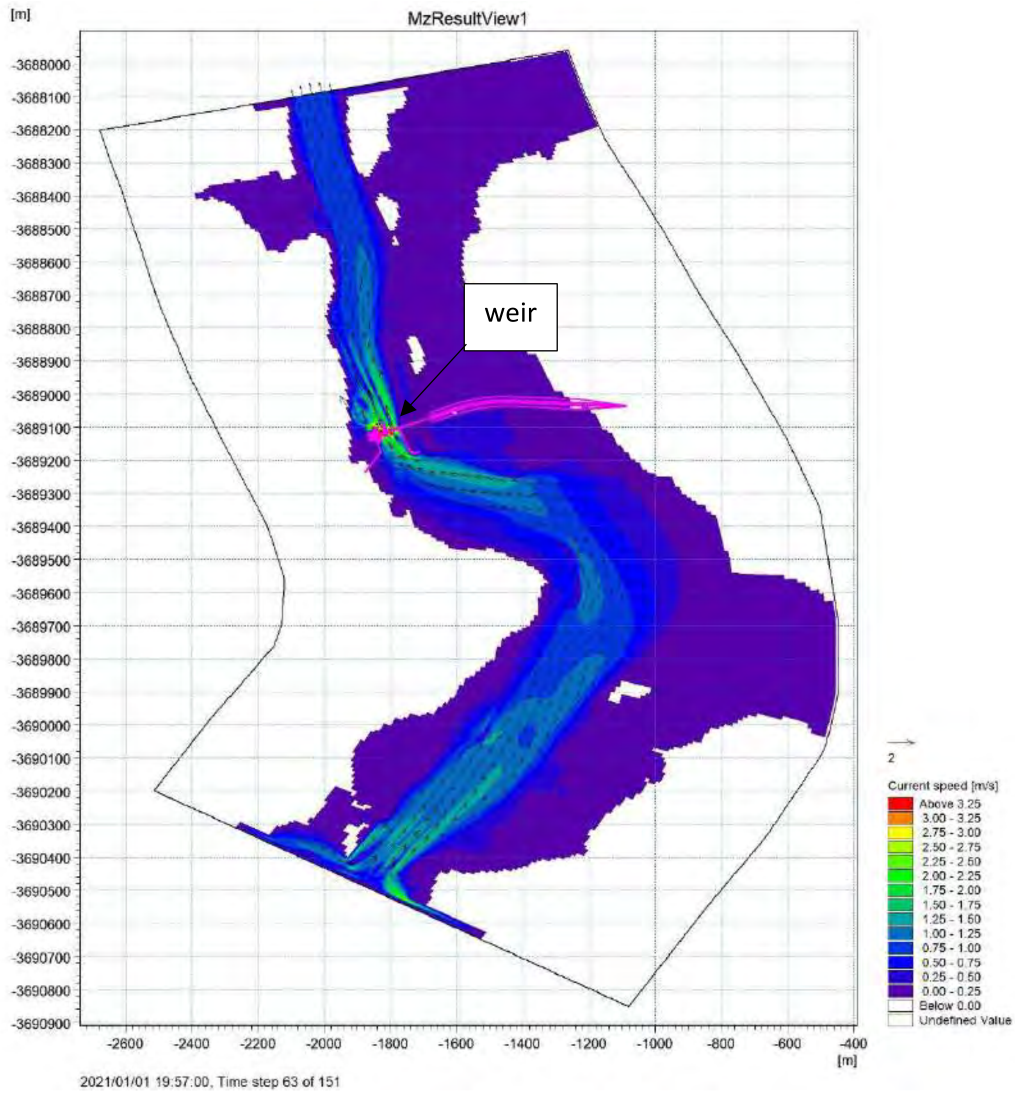


Figure D2-16: Simulated maximum flow velocities with velocity vectors at the peak of the 50 year flood (future scenario)

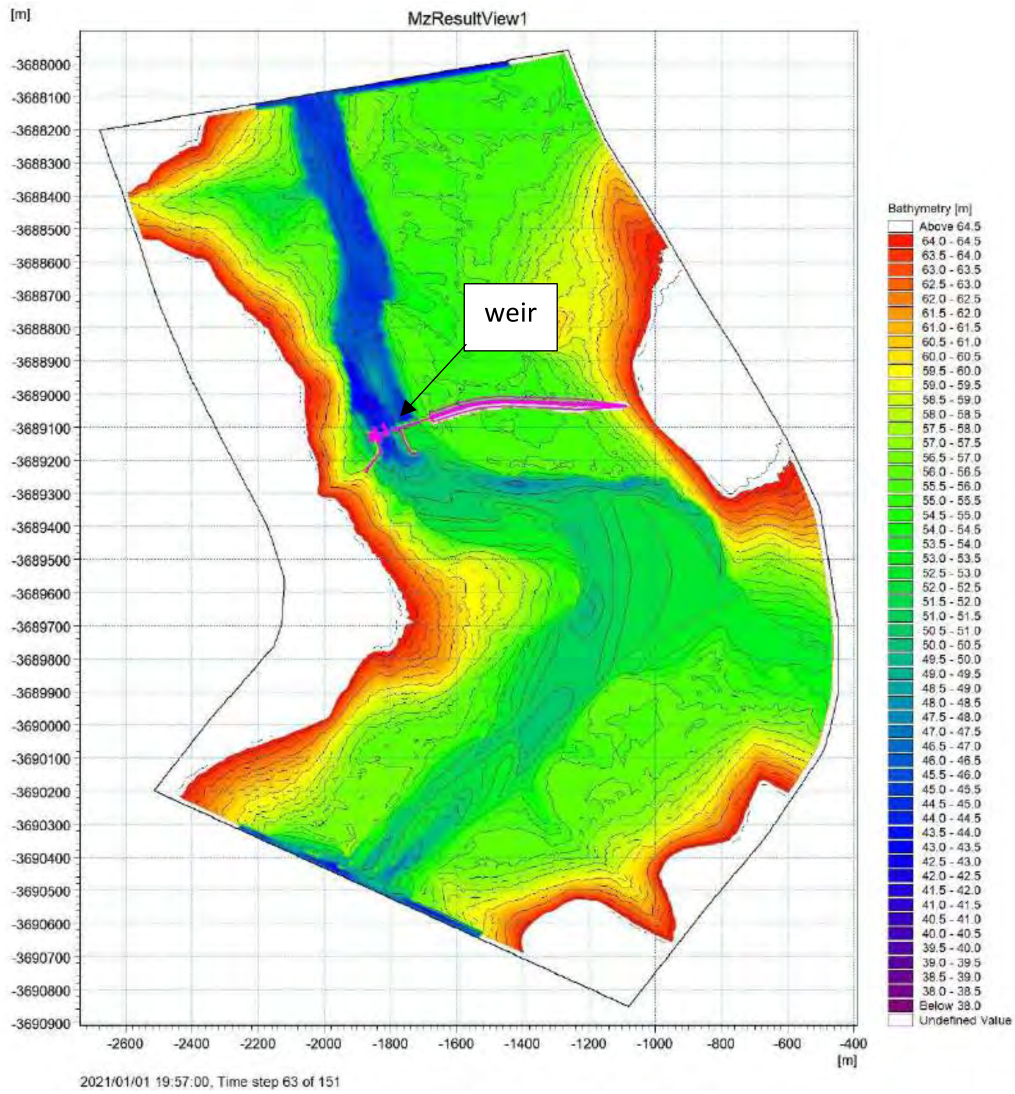


Figure D2-17: Simulated bed levels at the peak of the 50 year flood (future scenario)

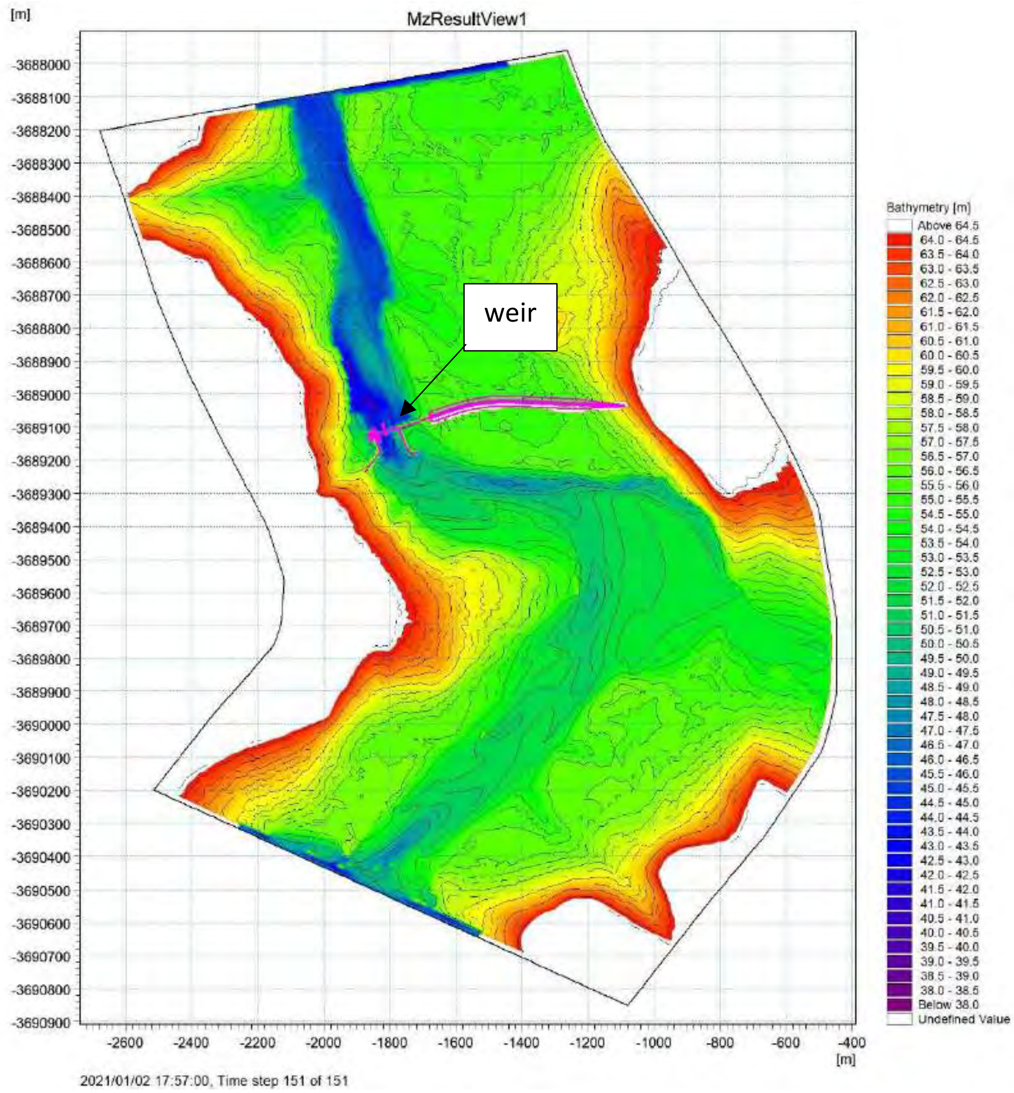


Figure D2-18: Simulated bed levels at the end of the 50 year flood (future scenario)

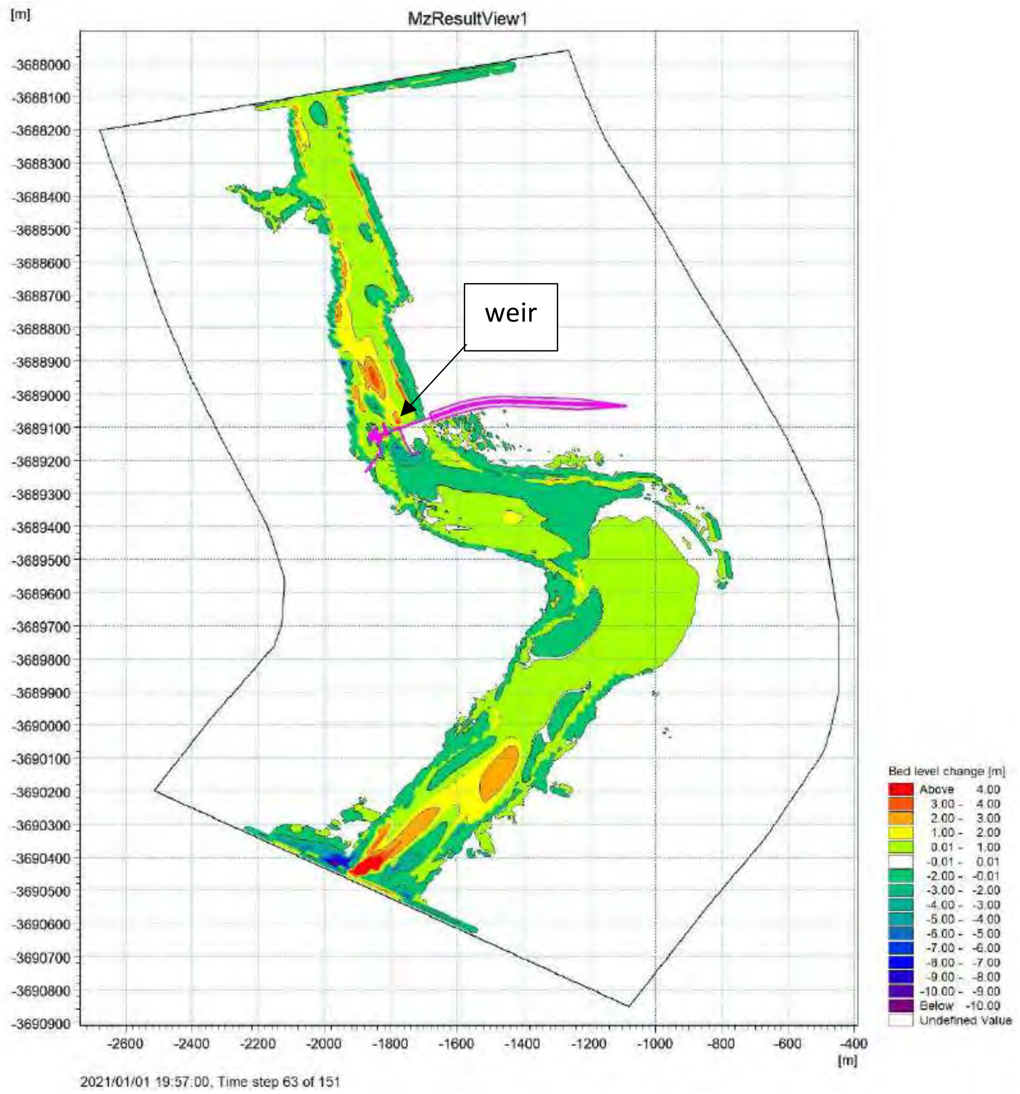


Figure D2-19: Simulated bed level change at the peak of the 50 year flood (future scenario)

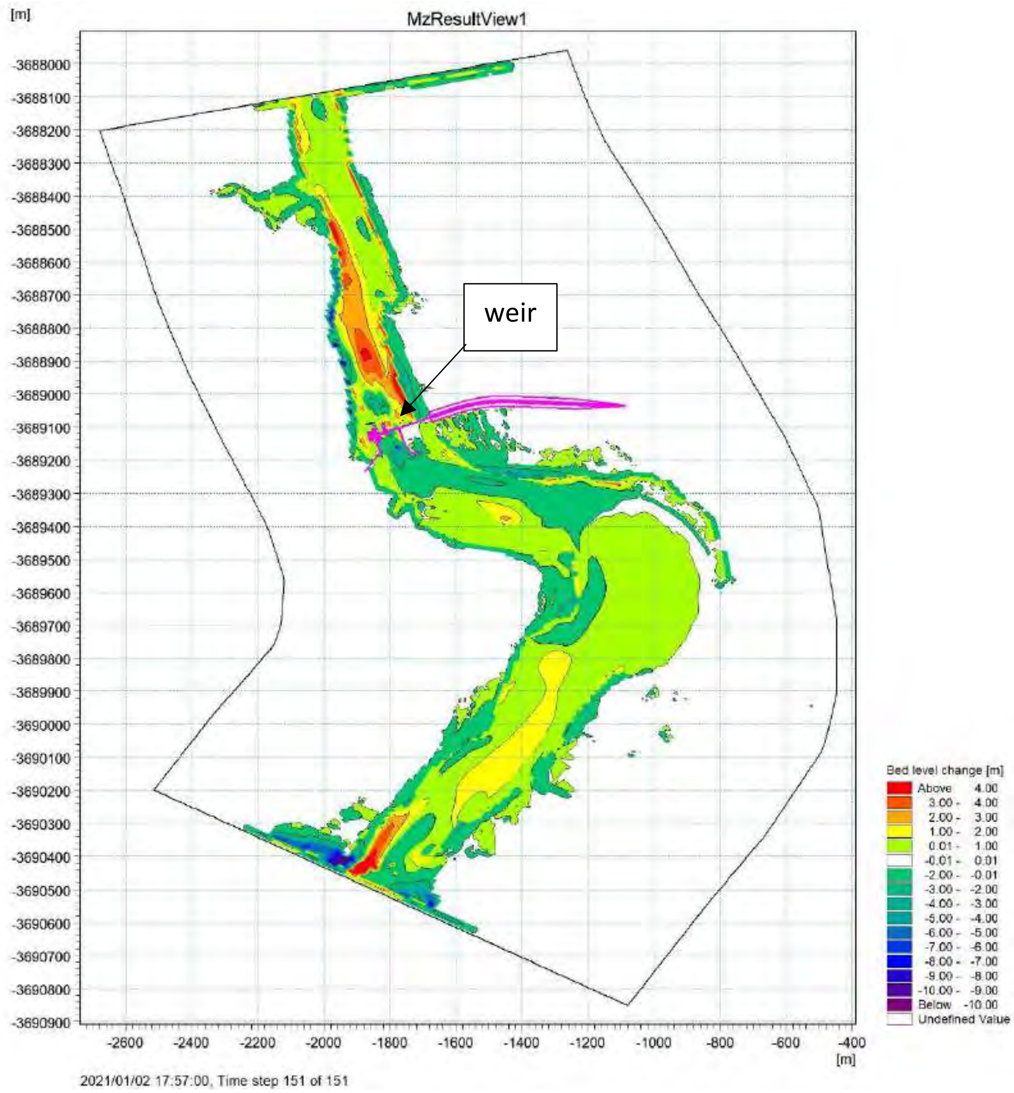


Figure D2-20: Simulated bed level change at the end of the 50 year flood (future scenario)

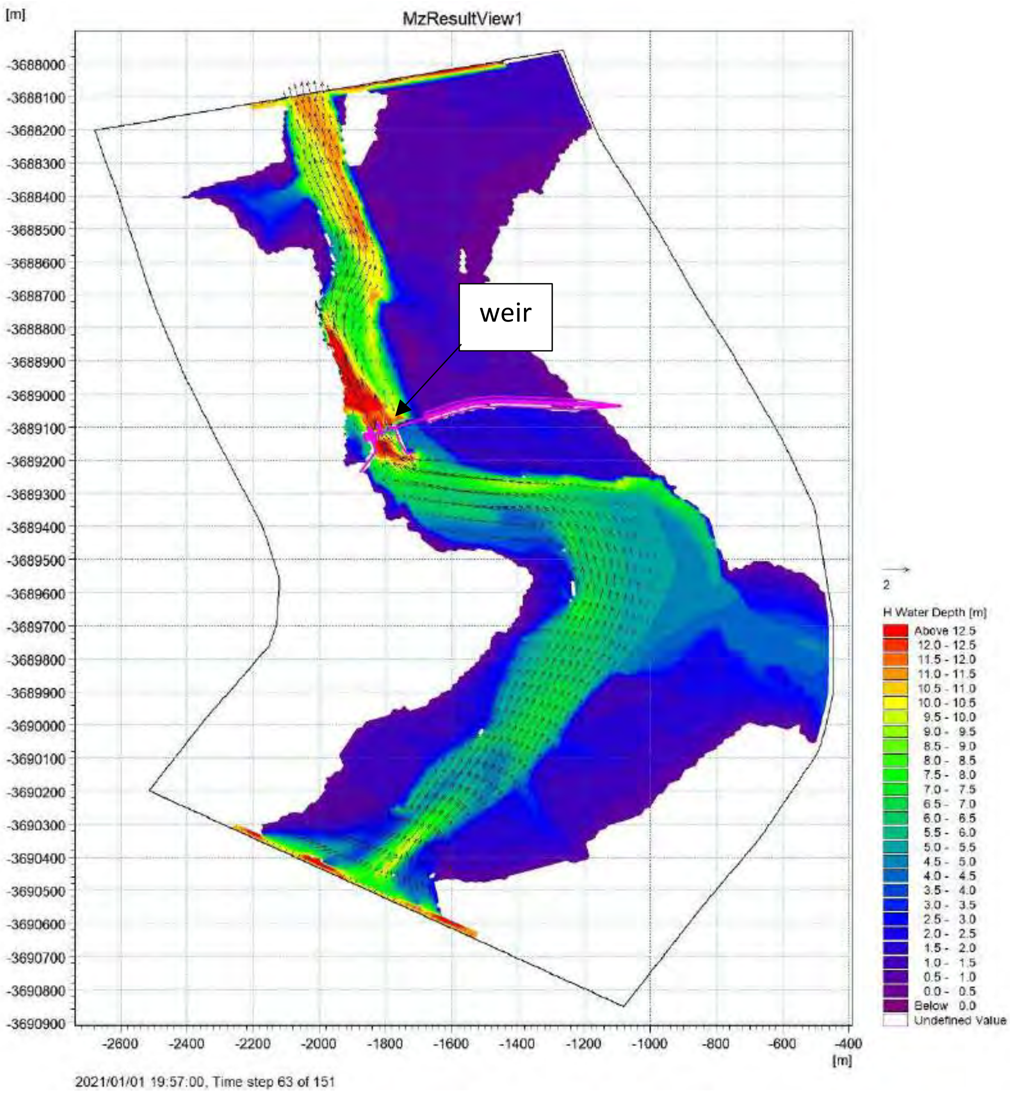


Figure D2-21: Simulated maximum flow depths with velocity vectors at the peak of the 100 year flood (future scenario)

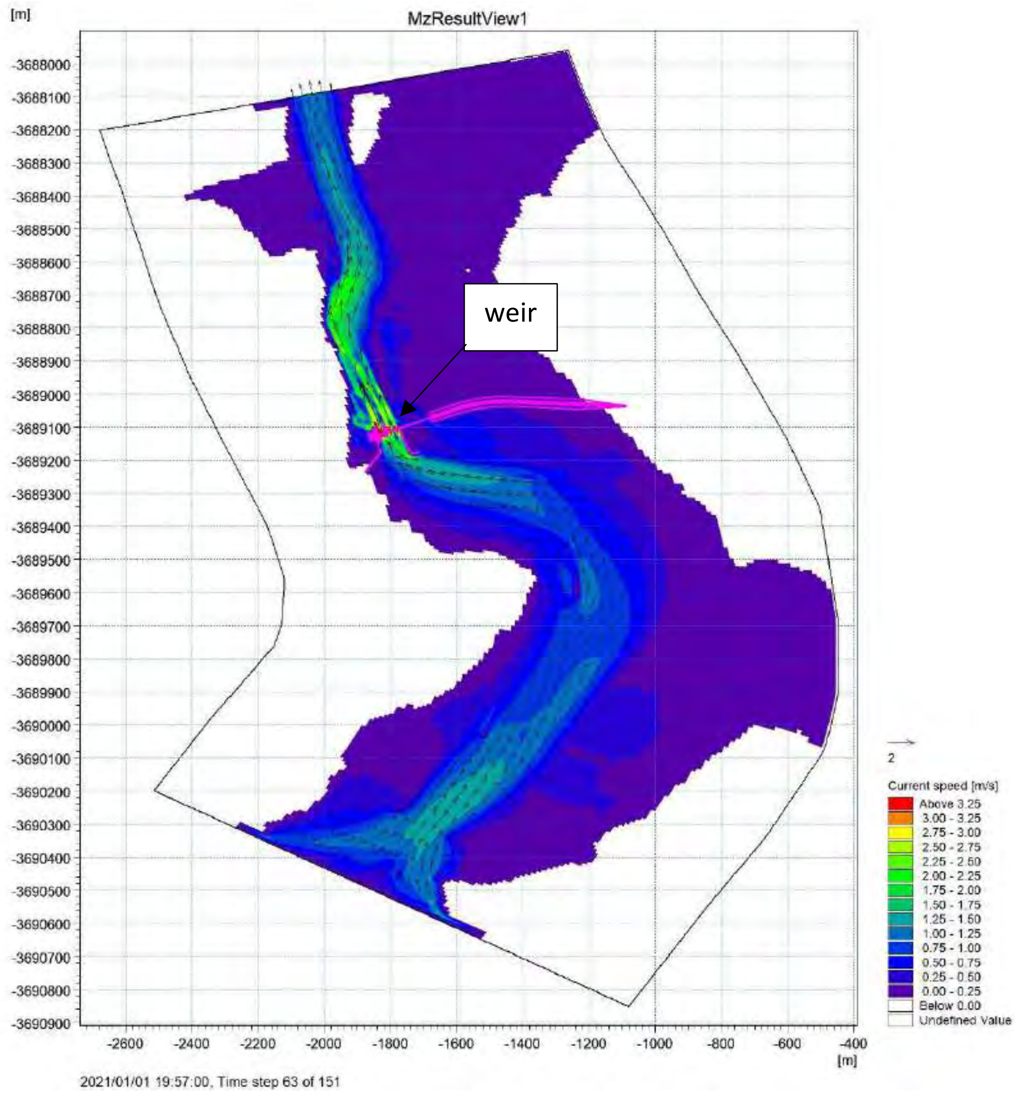


Figure D2-22: Simulated maximum flow velocities with velocity vectors at the peak of the 100 year flood (future scenario)

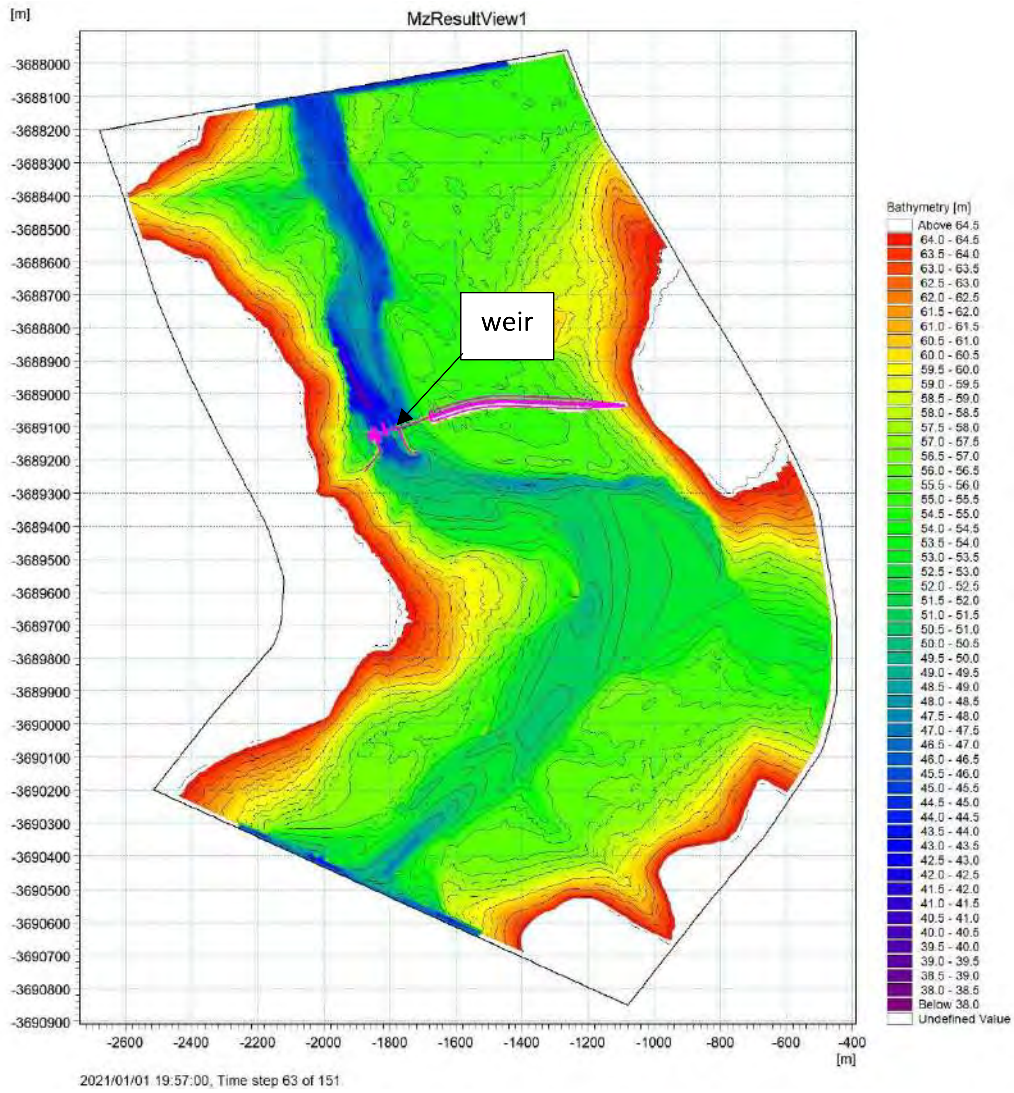


Figure D2-23: Simulated bed levels at the peak of the 100 year flood (future scenario)

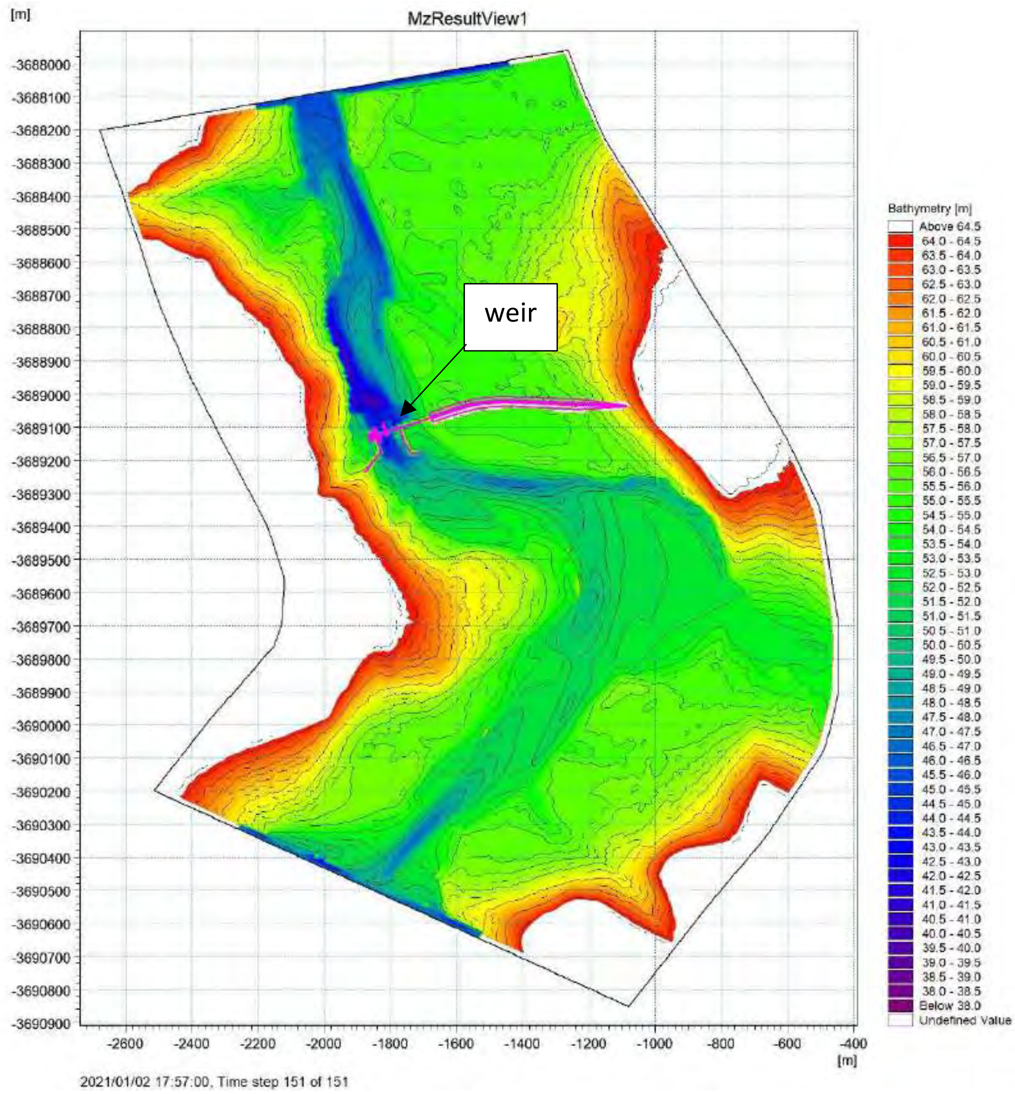


Figure D2-24: Simulated bed levels at the end of the 100 year flood (future scenario)

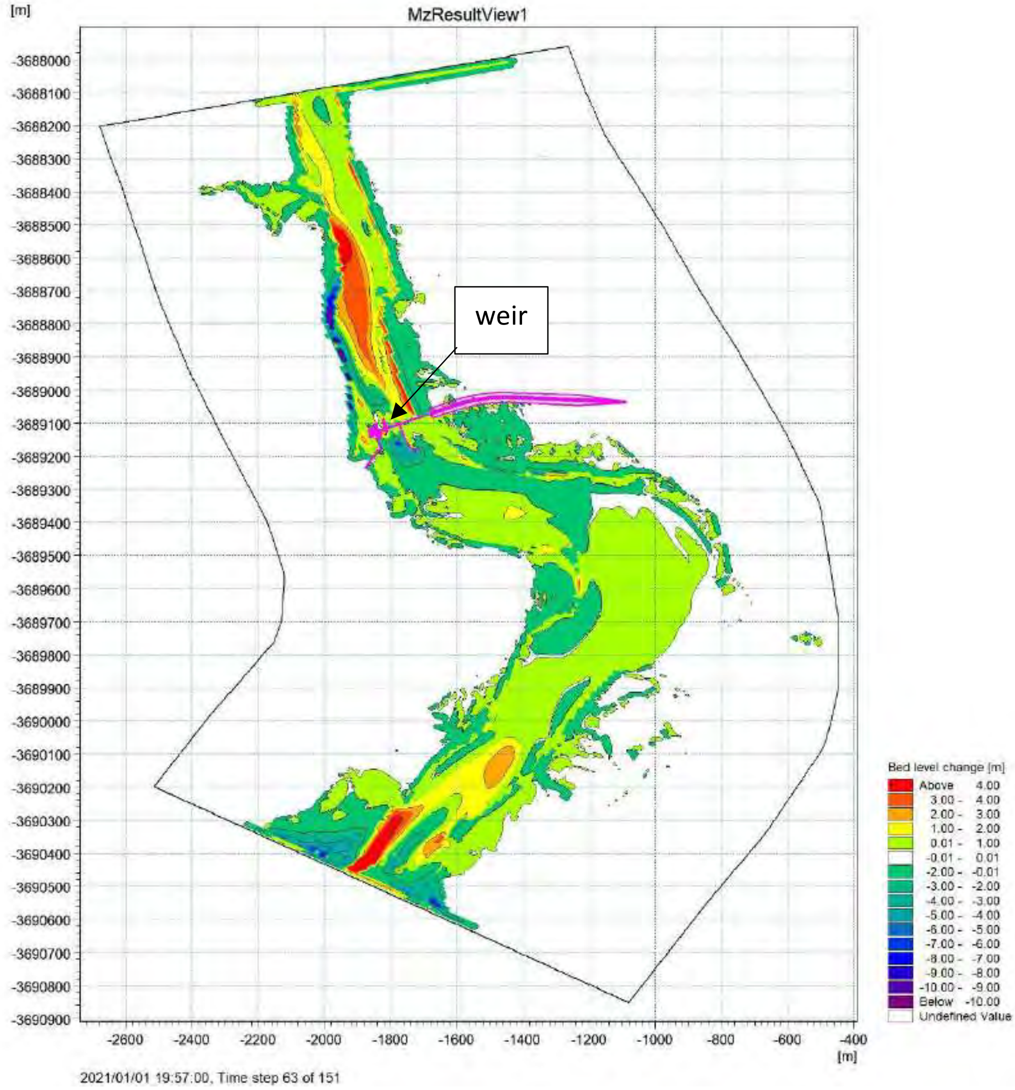


Figure D2-25: Simulated bed level change at the peak of the 100 year flood (future scenario)

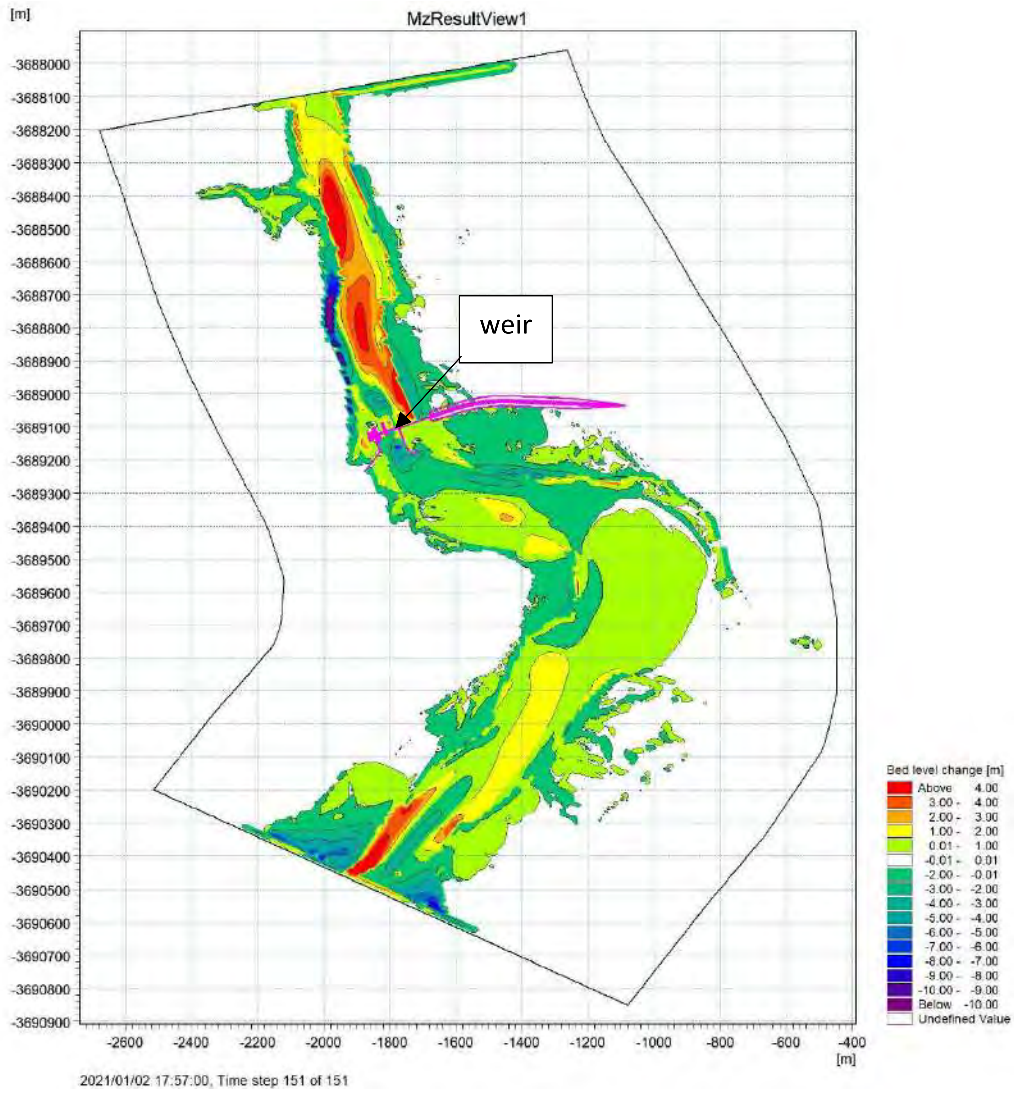


Figure D2-26: Simulated bed level change at the end of the 100 year flood (current scenario)

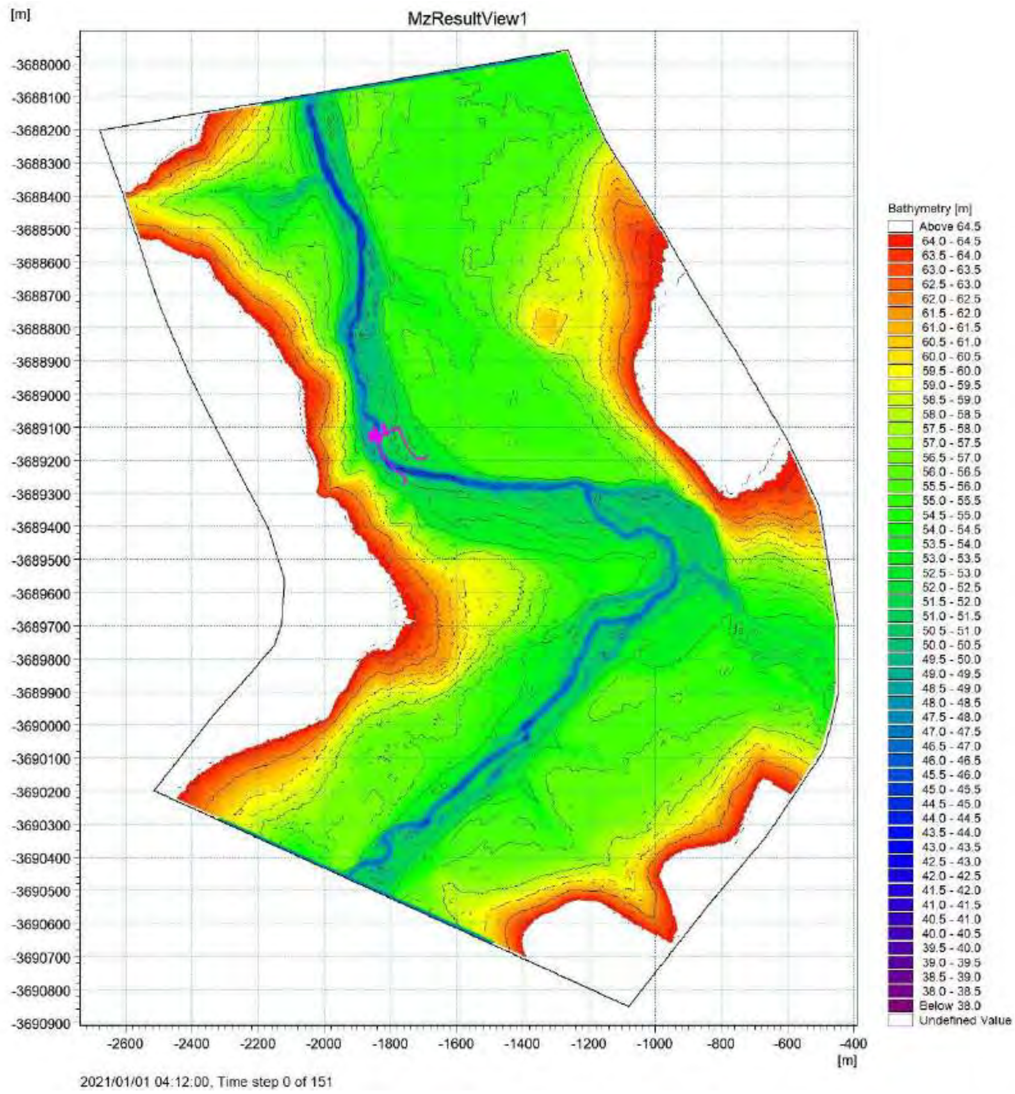


Figure D2-27: Bathymetry used in the Mike 21C model (masl) without abstraction works and weir

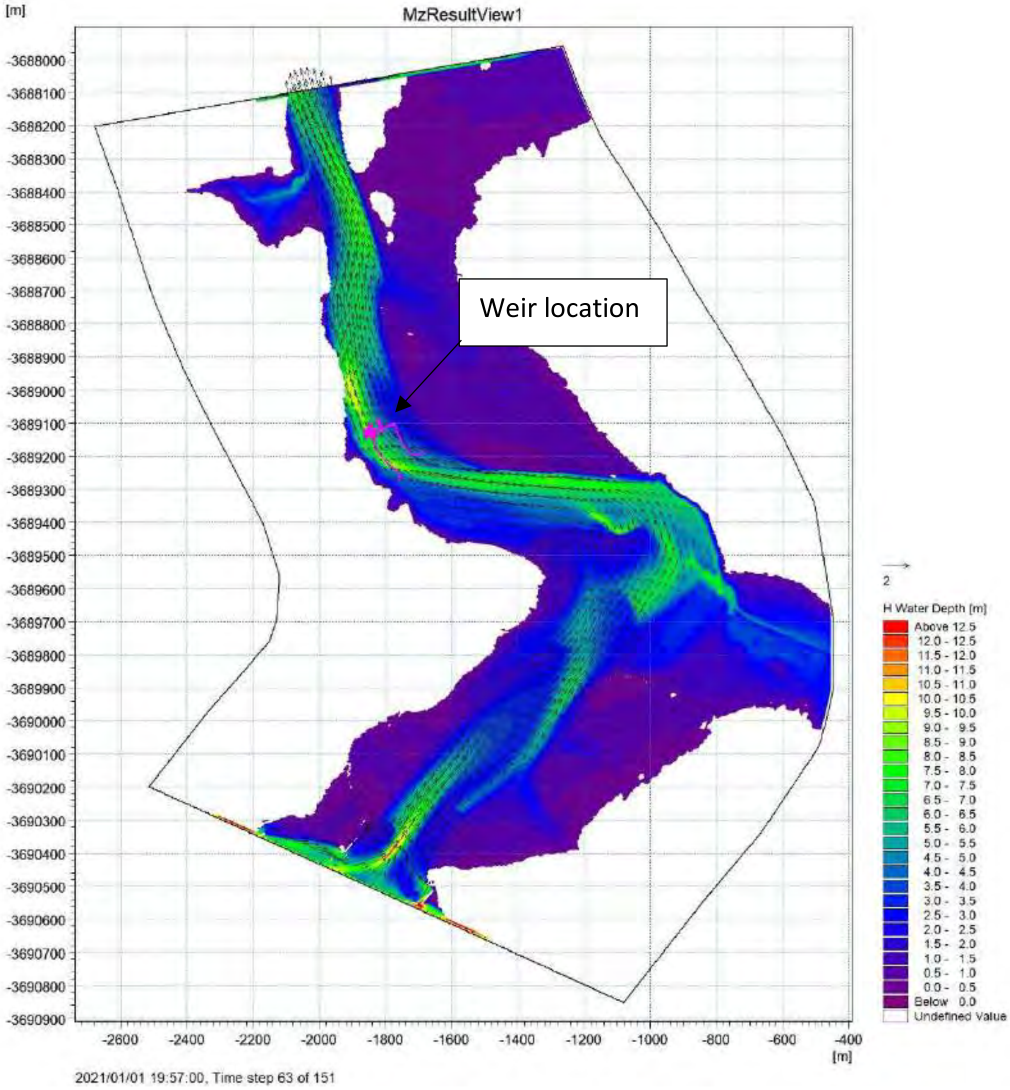


Figure D2-28: Simulated maximum flow depths with velocity vectors at the peak of the 50 year flood (without weir and abstraction works)

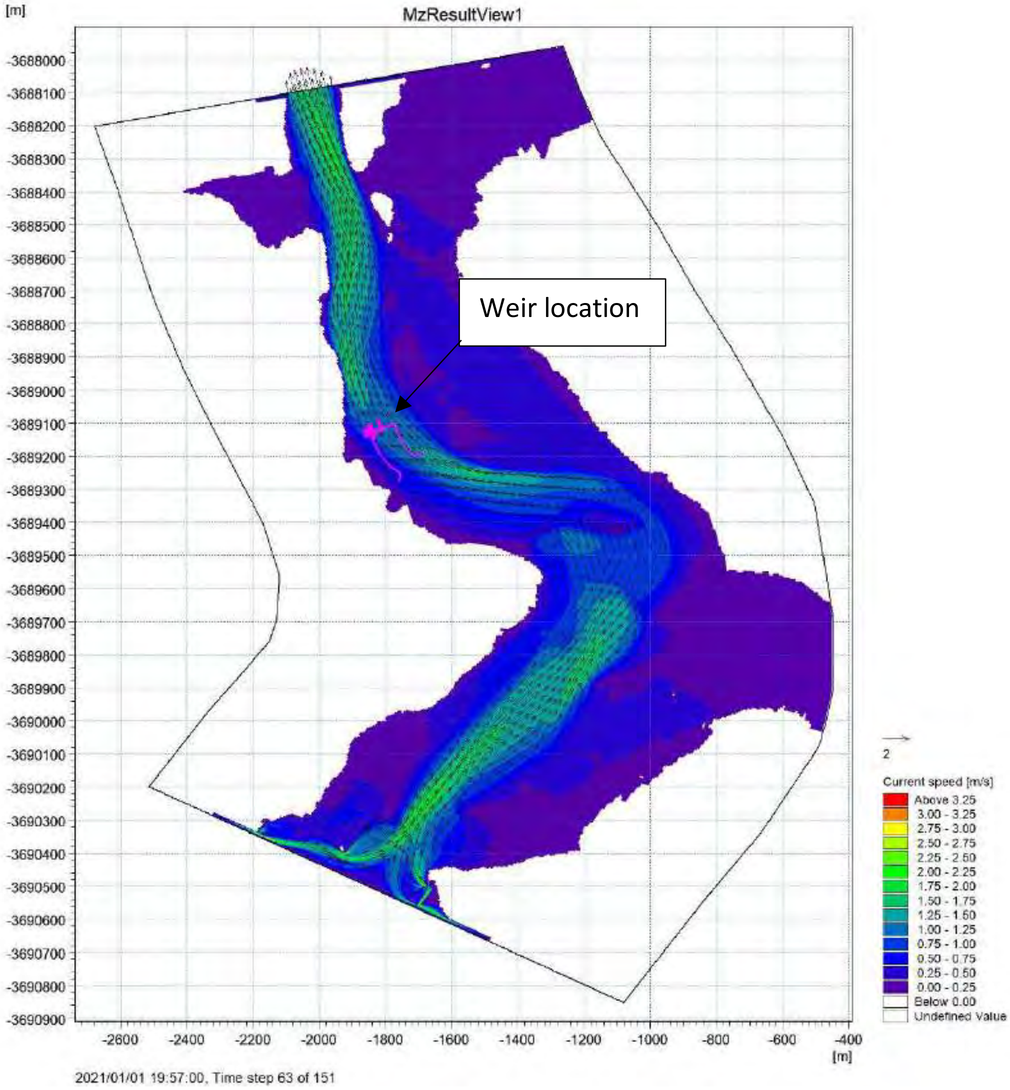


Figure D2-29: Simulated maximum flow velocities with velocity vectors at the peak of the 50 year flood (without weir and abstraction works)

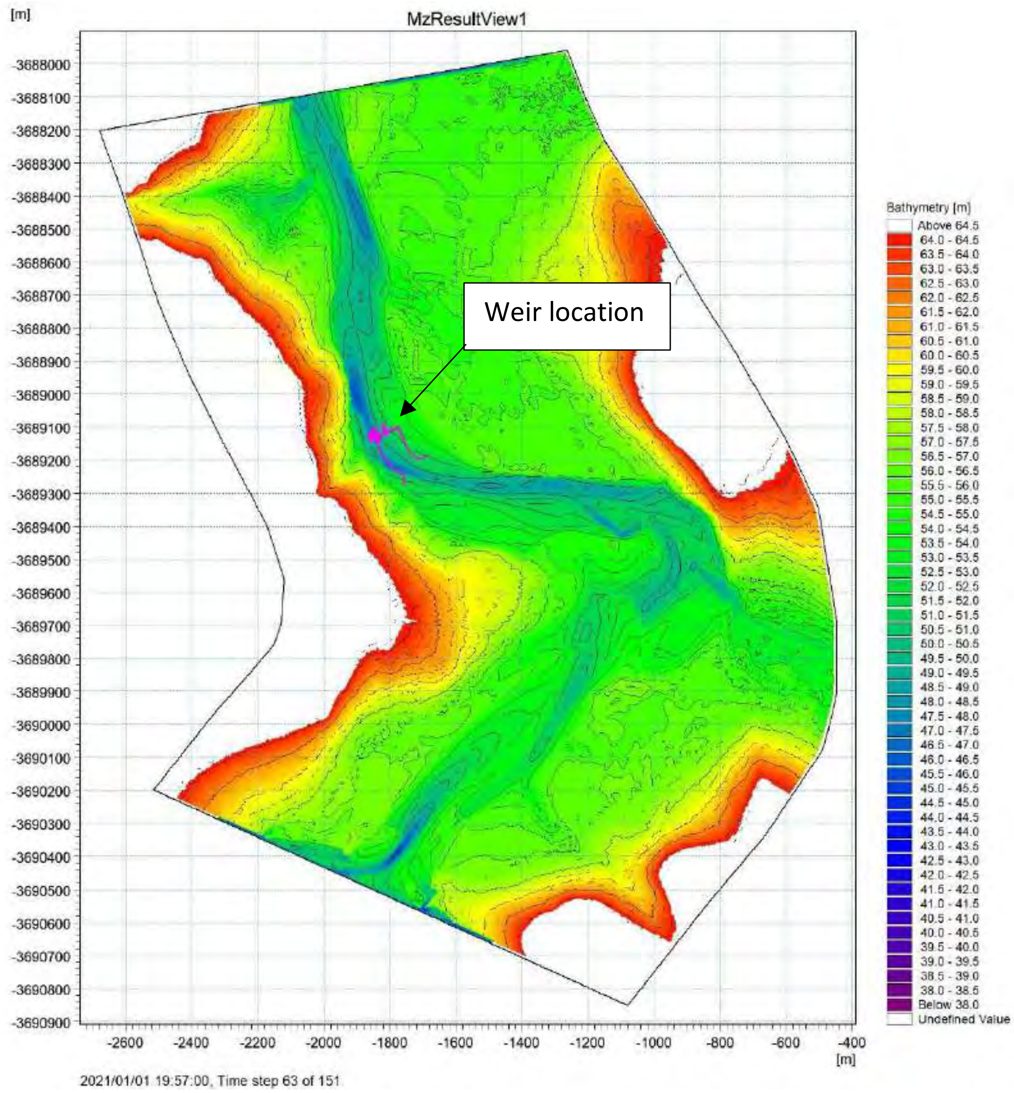


Figure D2-30: Simulated bed levels at the peak of the 50 year flood (without weir and abstraction works)

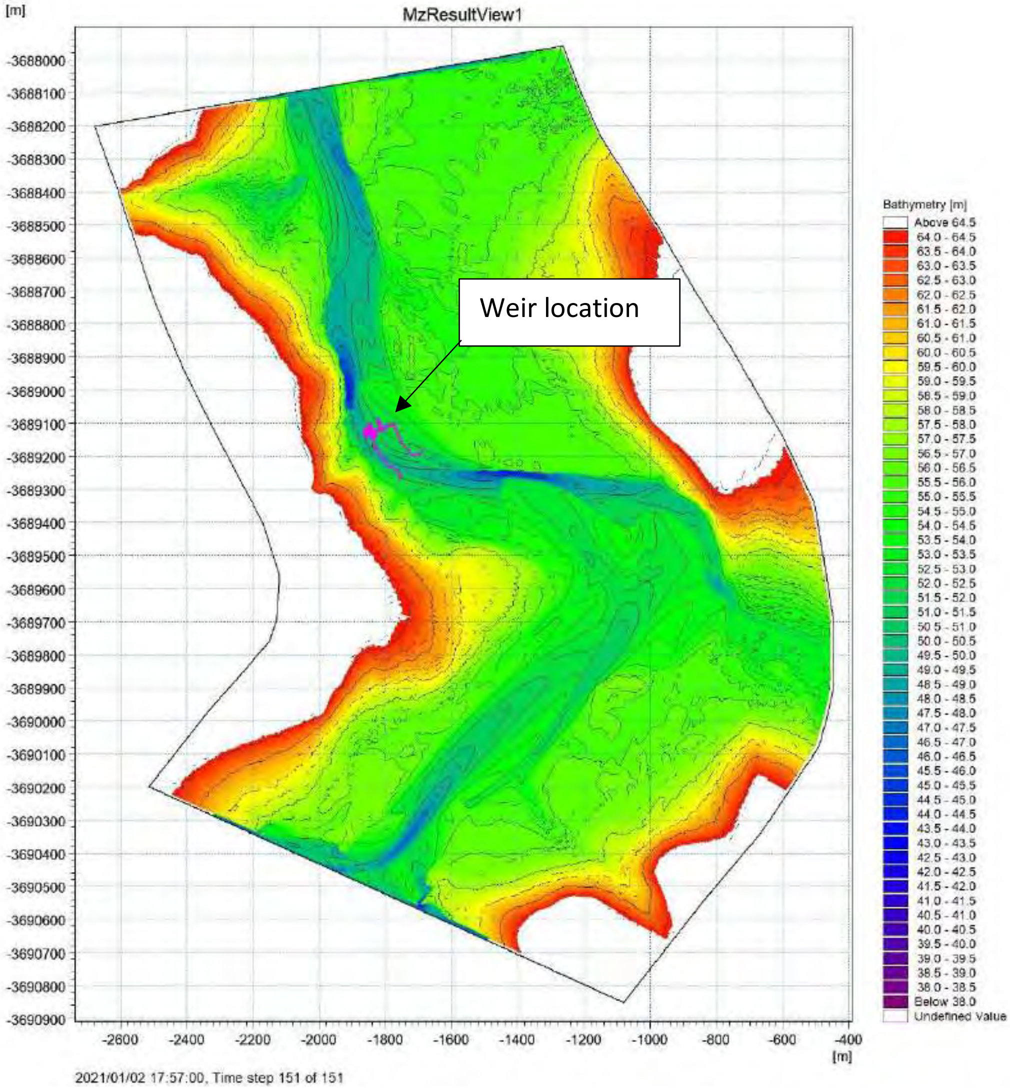


Figure D2-31: Simulated bed levels at the end of the 50 year flood (without weir and abstraction works)

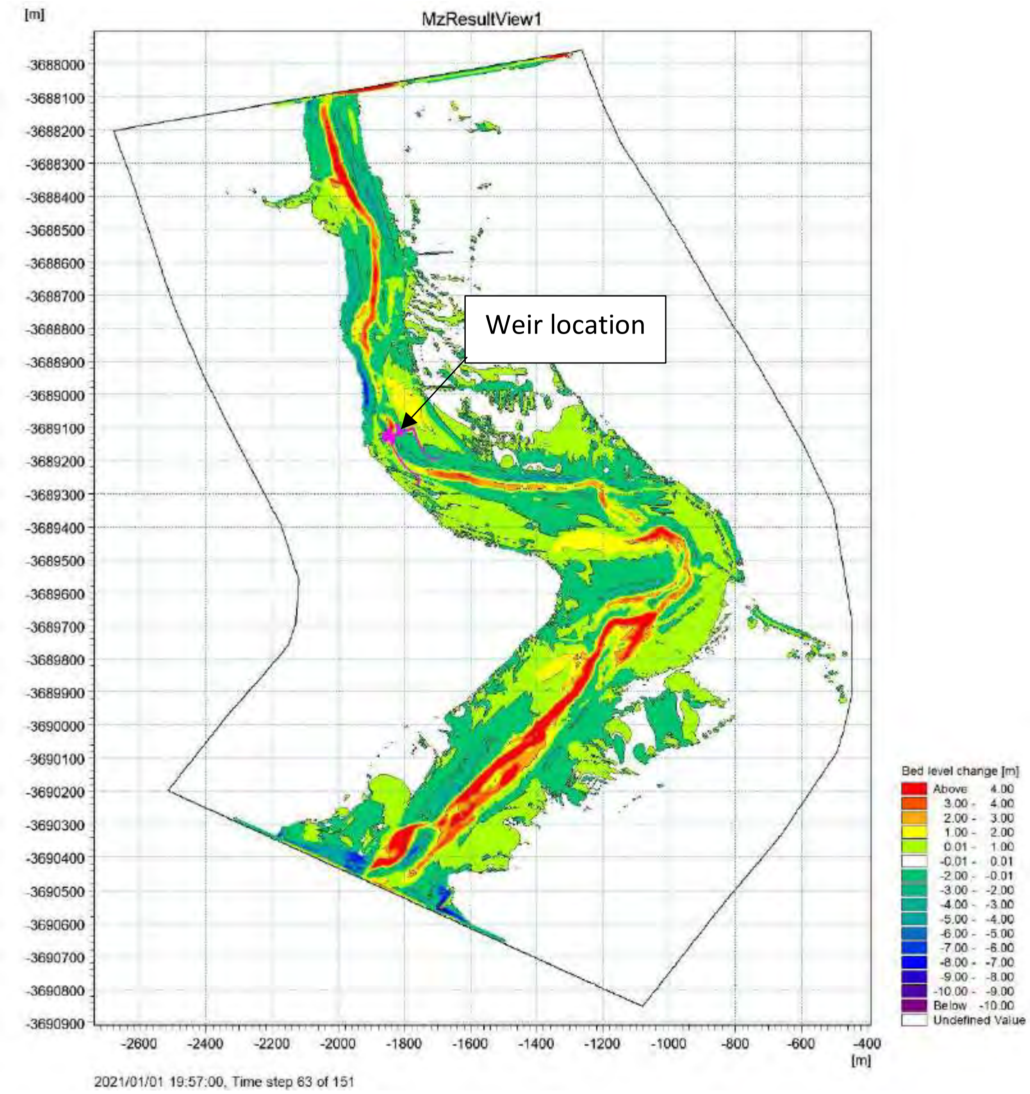


Figure D2-32: Simulated bed level change at the peak of the 50 year flood (without weir and abstraction works)

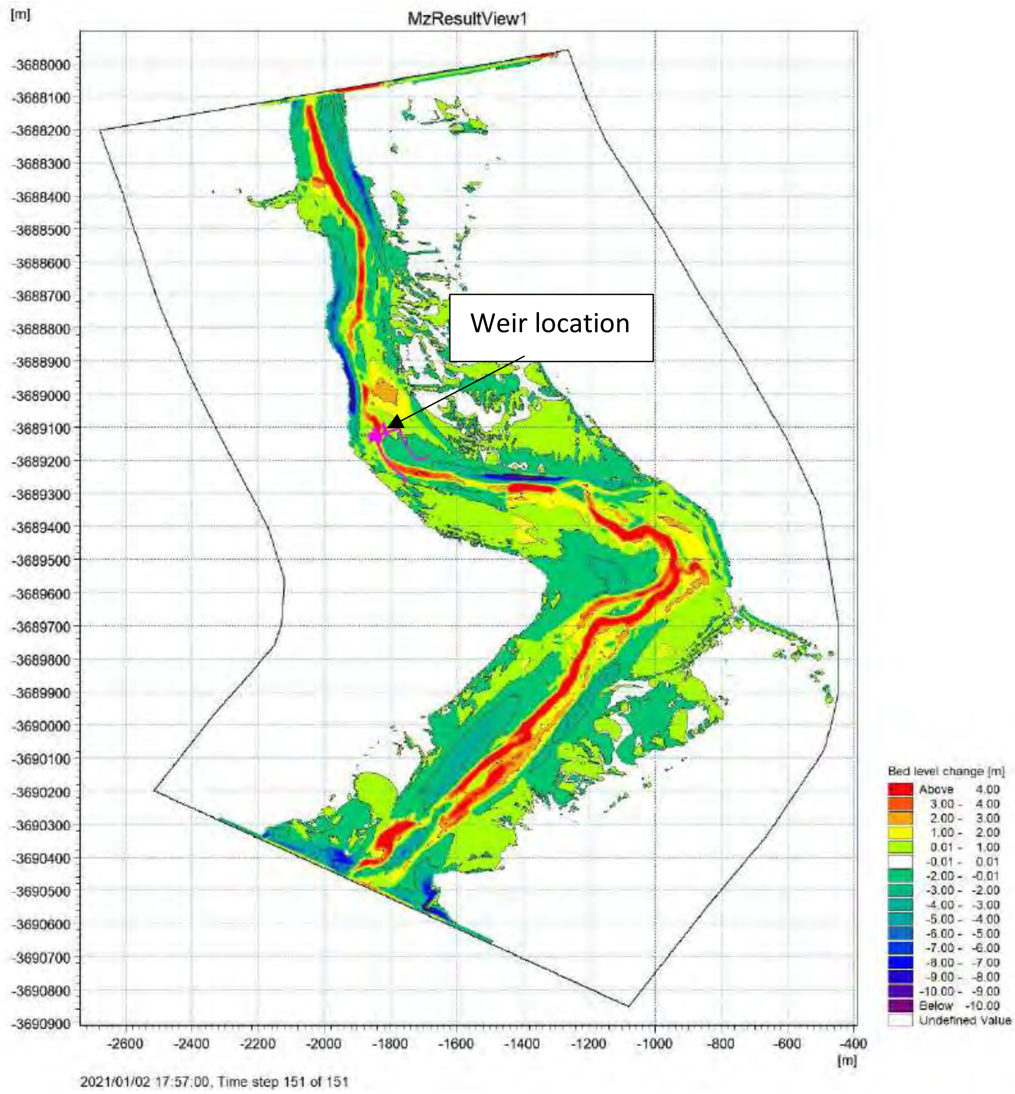


Figure D2-33: Simulated bed level change at the end of the 50 year flood (without weir and abstraction works)

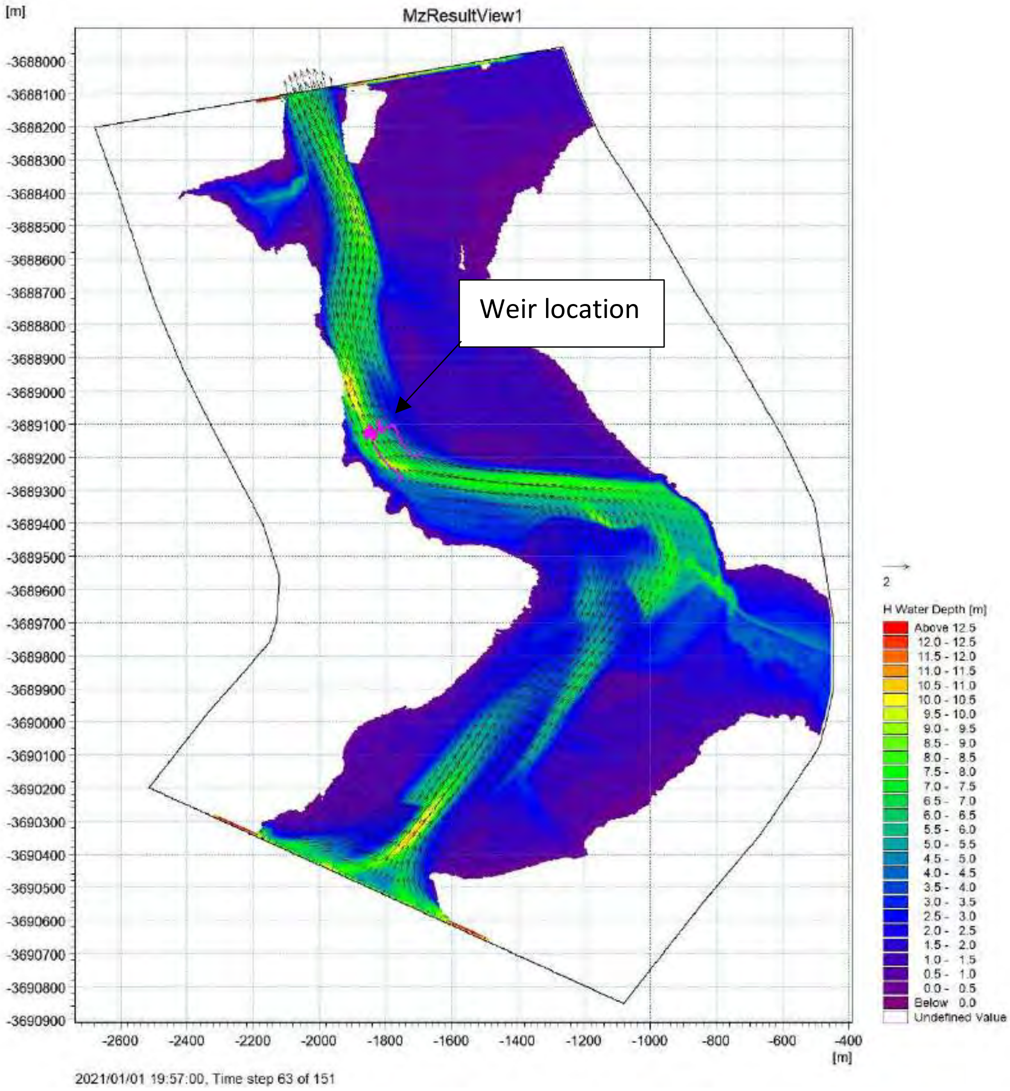


Figure D2-34: Simulated maximum flow depths with velocity vectors at the peak of the 100 year flood (without weir and abstraction works)

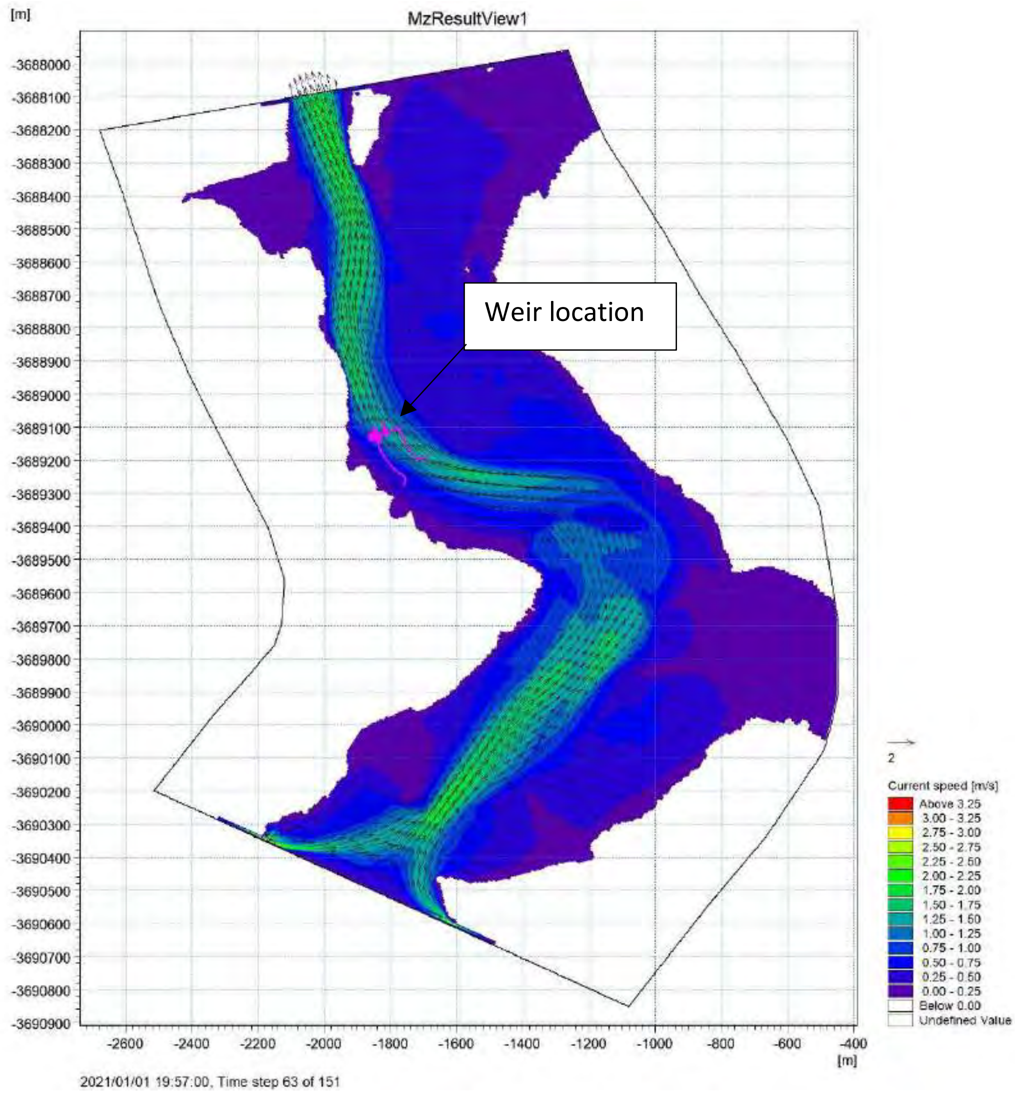


Figure D2-35: Simulated maximum flow velocities with velocity vectors at the peak of the 100 year flood (without weir and abstraction works)

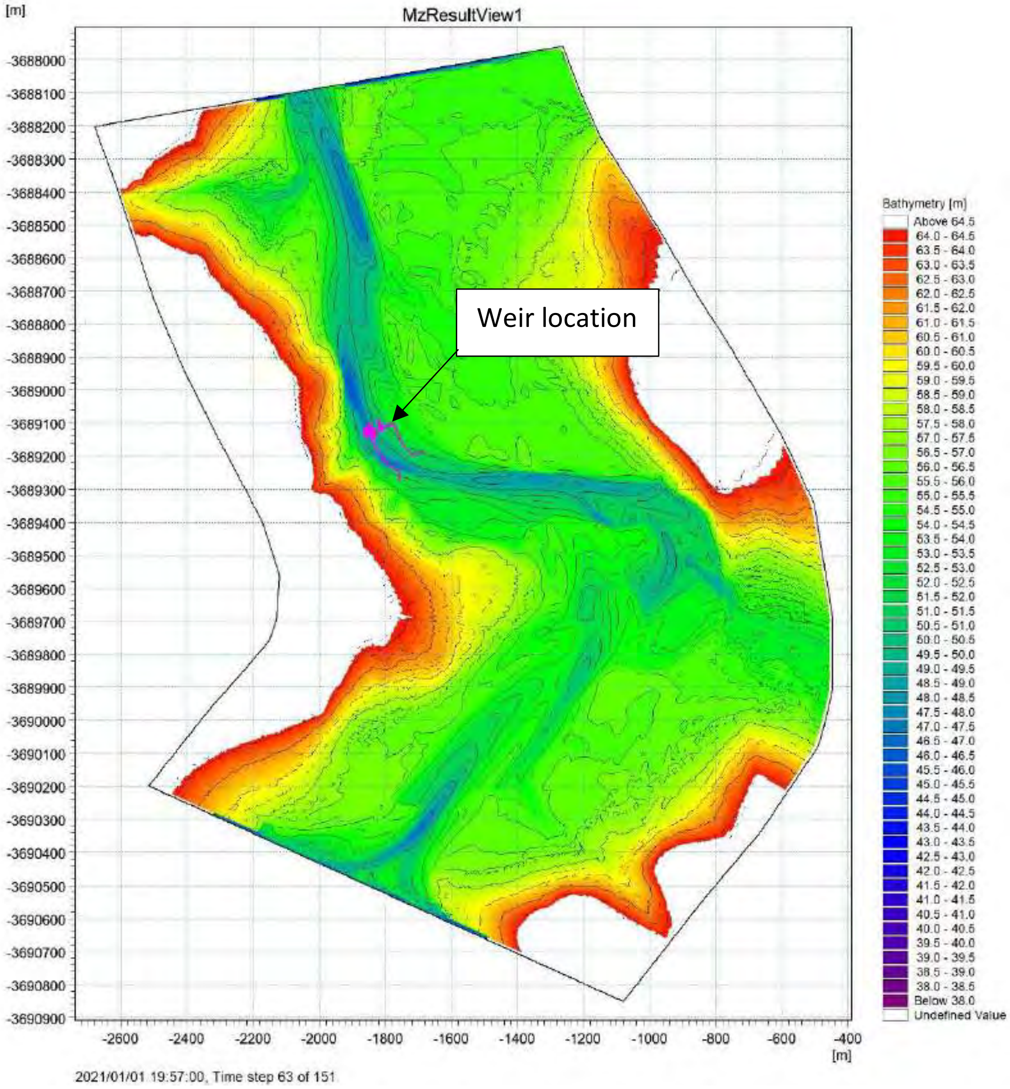


Figure D2-36: Simulated bed levels at the peak of the 100 year flood (without weir and abstraction works)

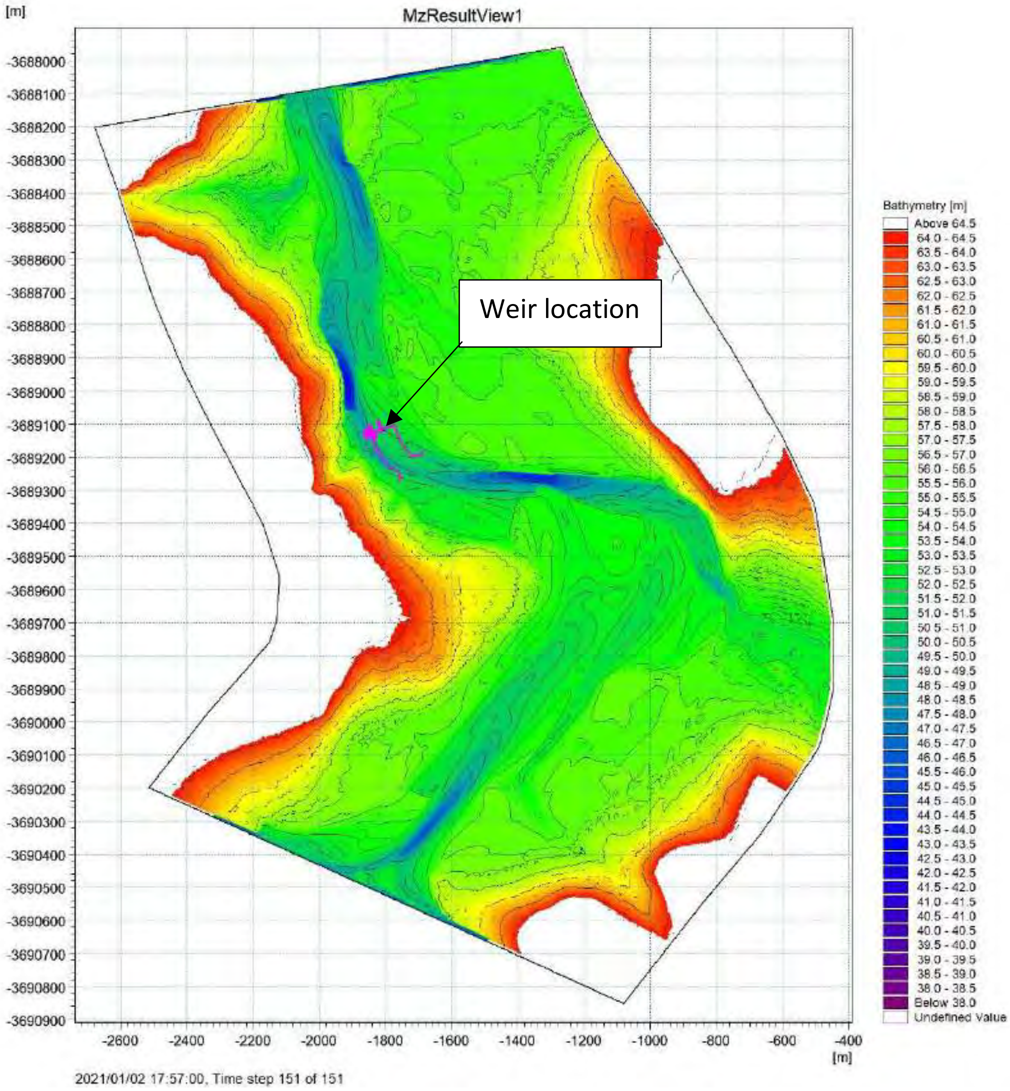


Figure D2-37: Simulated bed levels at the end of the 100 year flood (without weir and abstraction works)

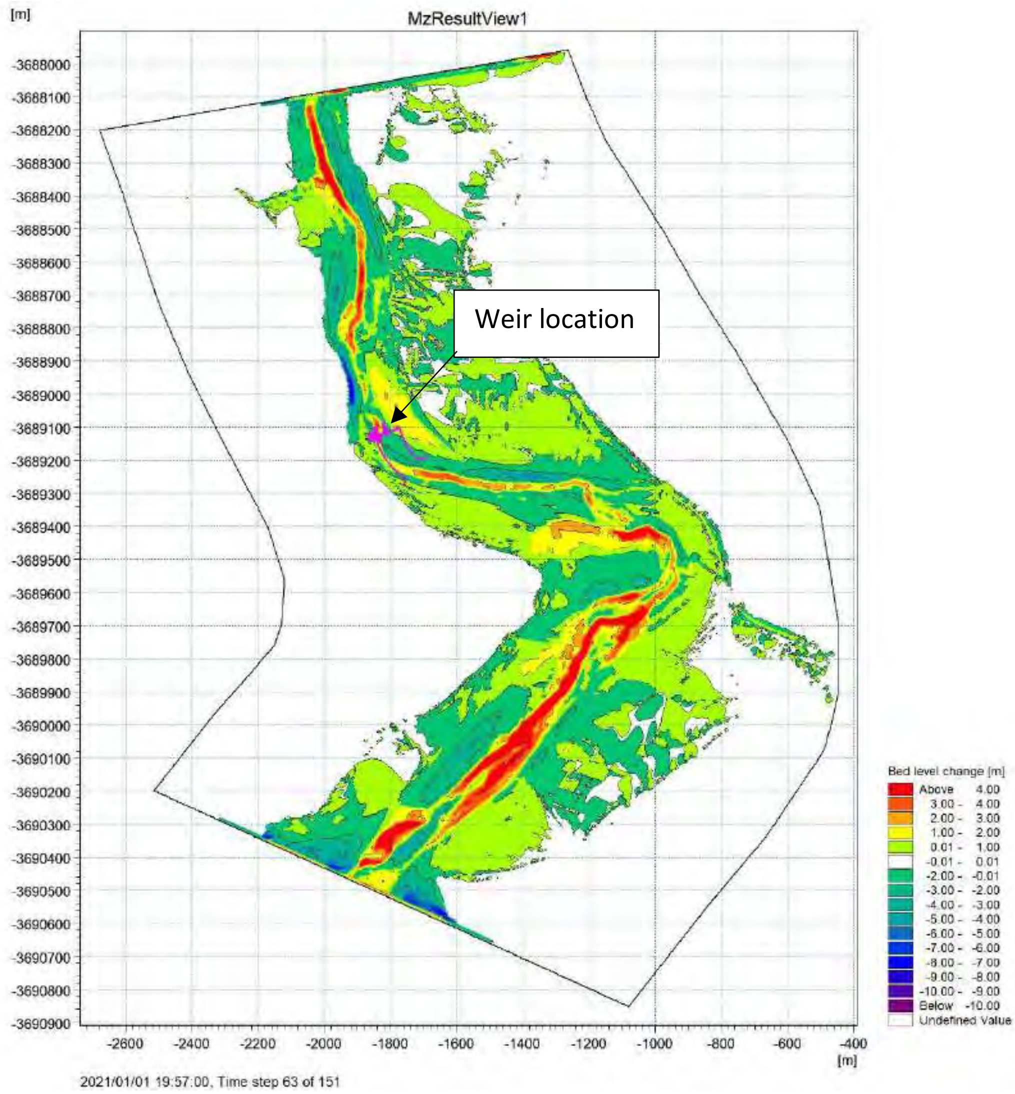


Figure D2-38: Simulated bed level change at the peak of the 100 year flood (without weir and abstraction works)

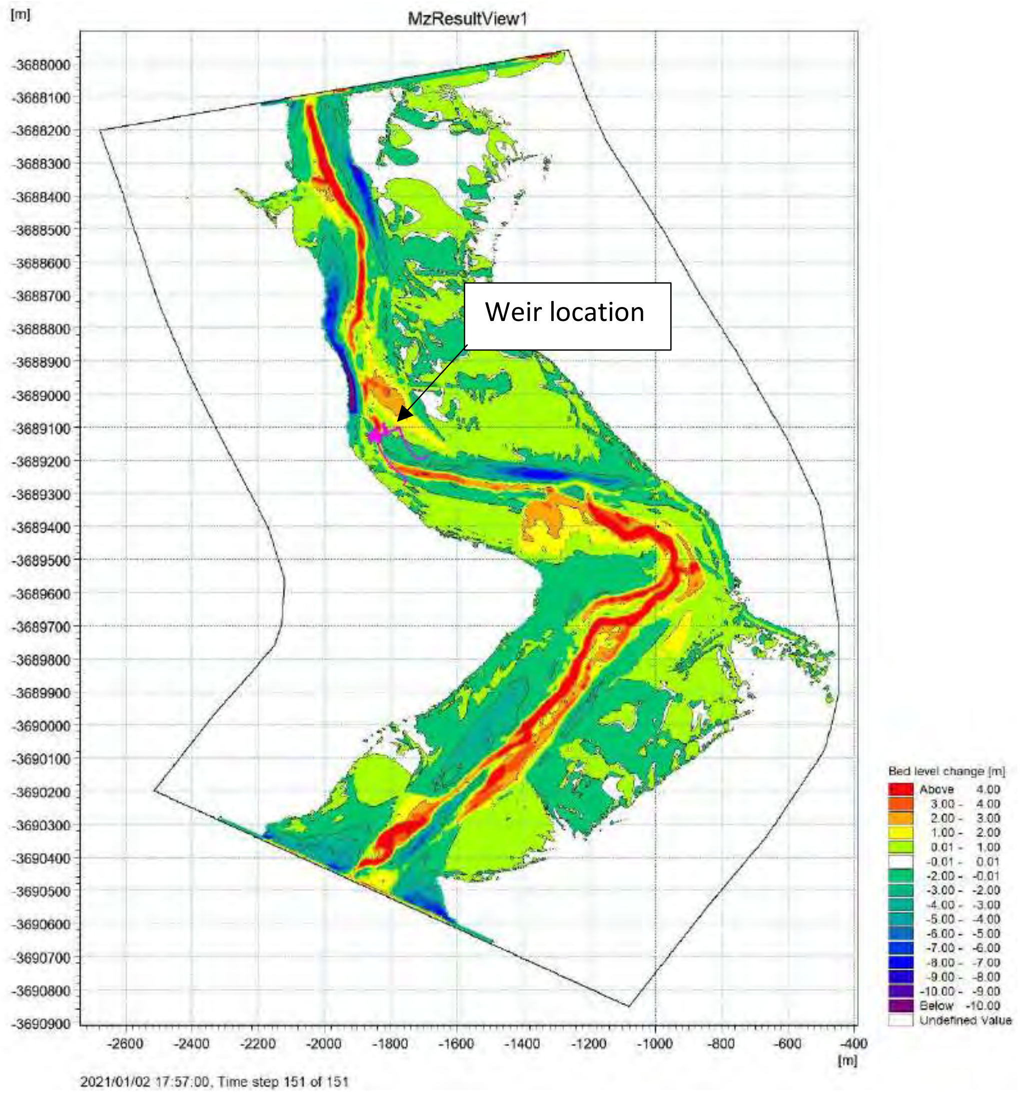


Figure D2-39: Simulated bed level change at the end of the 100 year flood (without weir and abstraction works)

Appendix E: Bed sediment grading analysis of the Berg River main channel and floodplain

Sample Name	Bergrivier BG 1
Date	2021/04/16
Container	1
Wet Mass	65
Dry Mass	65

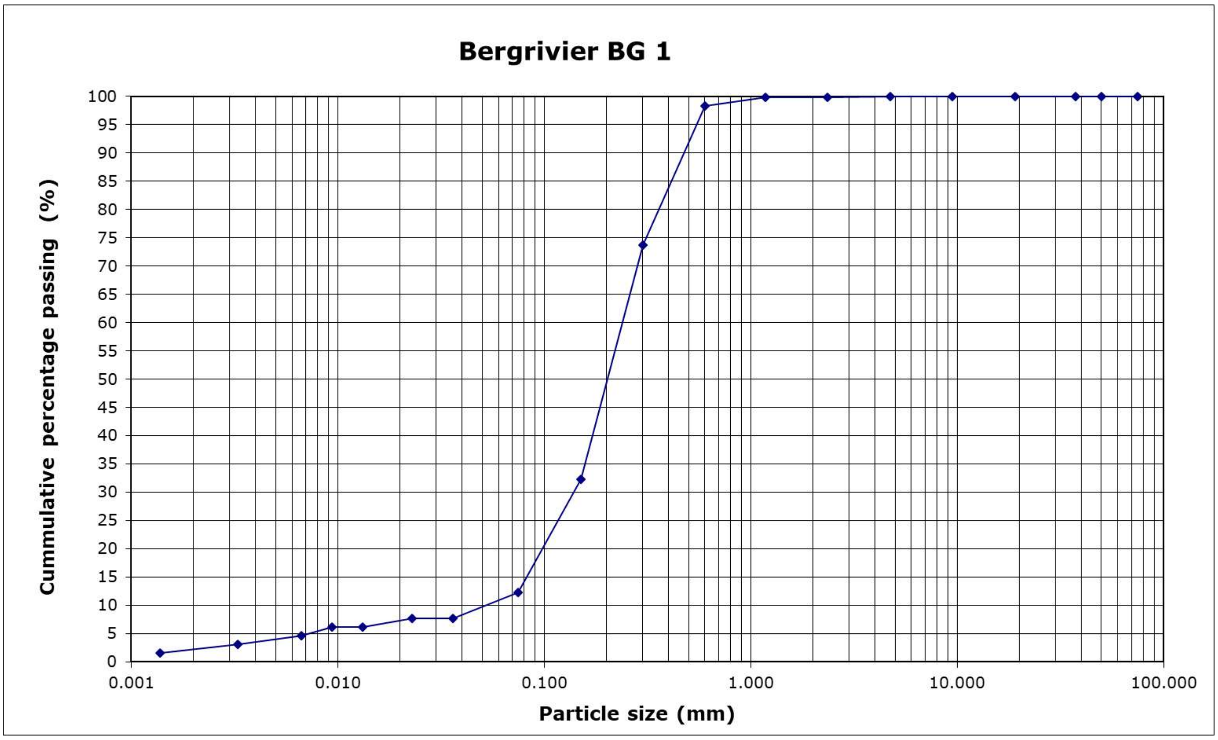
	Airdry	Dry
Total Mass	661	661.00
Container Mass	65	65.00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75.00		0.00	100.00
50.00		0.00	100.00
37.50		0.00	100.00
19.00		0.00	100.00
9.50		0.00	100.00
4.75		0.00	100.00
2.36	1	0.15	99.85
<2.36	660.00	99.85	0.00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	10	22	5.00
5	10	22	5.00
15	9	22	4.00
30	9	22	4.00
60	8	22	3.00
250	7	22	2.00
1440	6	22	1.00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	16
0.30-0.150	27
0.150-0.075	13
<0.075	8.00

Unit	% Concentration	Diameter (mm)
mm	100.00	75
mm	100.00	50
mm	100.00	37.5
mm	100.00	19
mm	100.00	9.5
mm	100.00	4.75
mm	99.85	2.36
mm	99.85	1.18
mm	98.31	0.6
mm	73.73	0.3
mm	32.26	0.15
mm	12.29	0.075
mm	7.68	0.0361
mm	7.68	0.0228
mm	6.14	0.0132
mm	6.14	0.0094
mm	4.61	0.0067
mm	3.07	0.0033
mm	1.54	0.0014



Sample Name	Bergrivier BG 2
Date	2021/04/16
Container	2
Wet Mass	65
Dry Mass	65

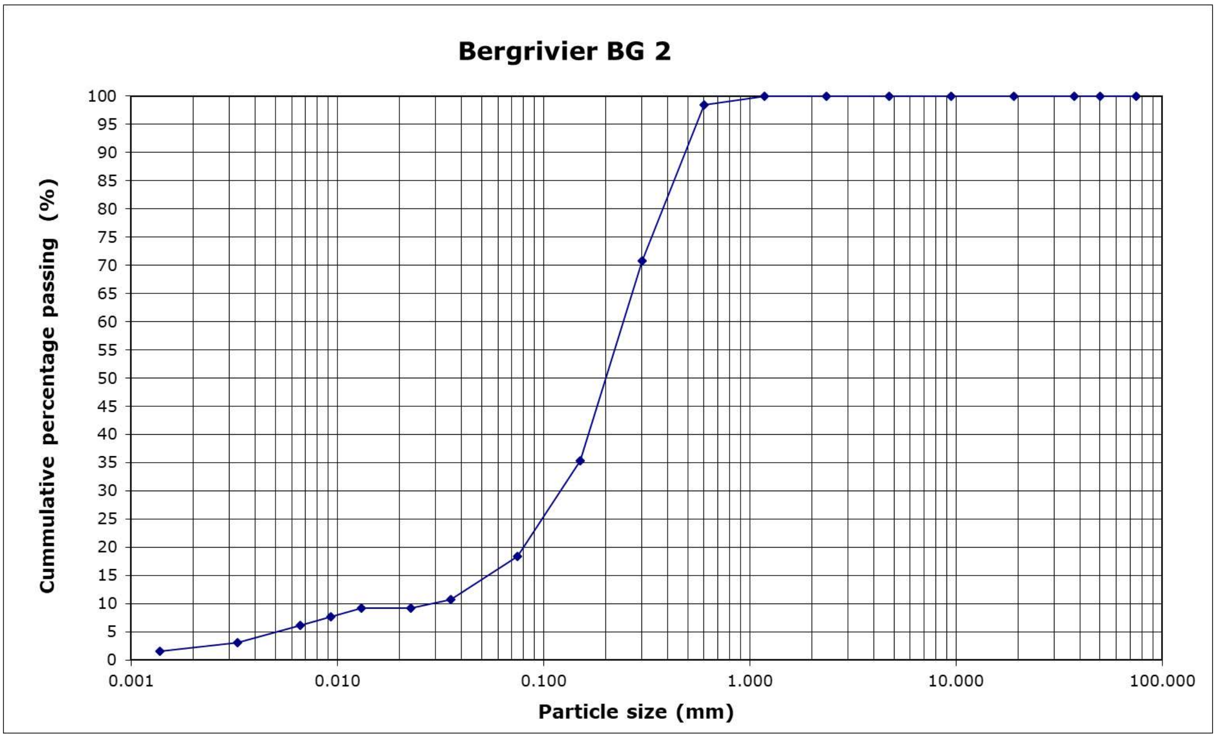
	Airdry	Dry
Total Mass	520	520,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	520,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	12	22	7,00
5	11	22	6,00
15	11	22	6,00
30	10	22	5,00
60	9	22	4,00
250	7	22	2,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	18
0.30-0.150	23
0.150-0.075	11
<0.075	12,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	70,77	0,3
mm	35,38	0,15
mm	18,46	0,075
mm	10,77	0,0356
mm	9,23	0,0227
mm	9,23	0,0131
mm	7,69	0,0093
mm	6,15	0,0066
mm	3,08	0,0033
mm	1,54	0,0014



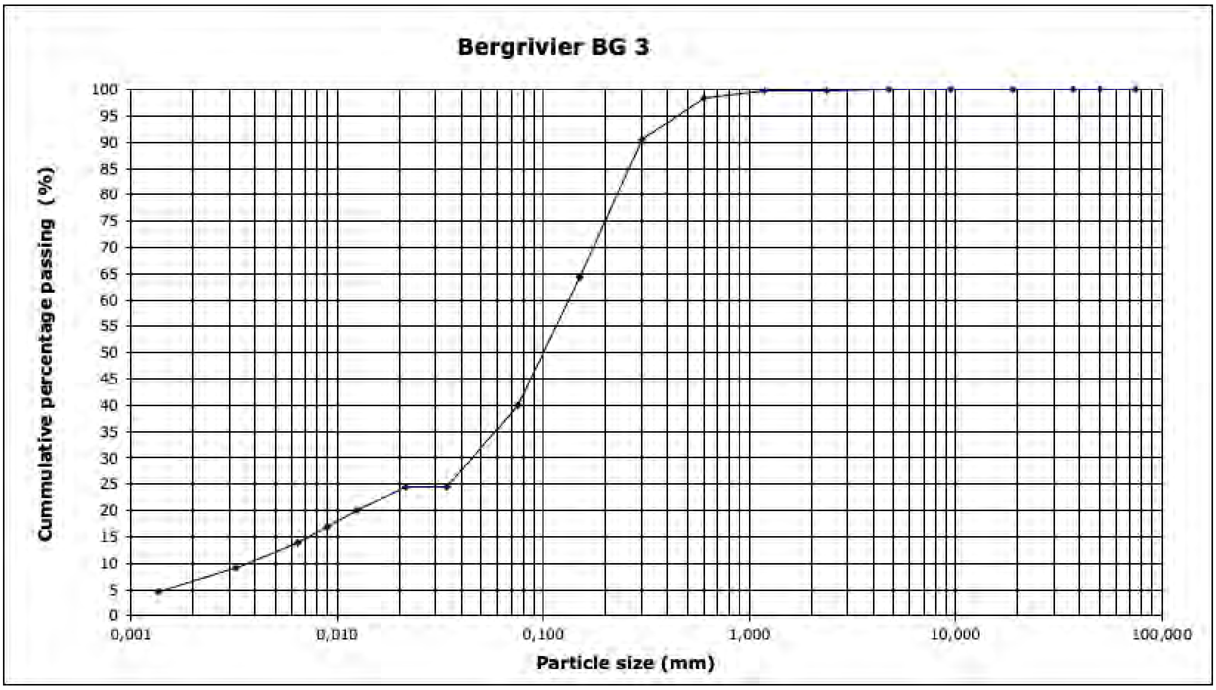
Sample Name	Bergrivier BG 3	
Date	2021/04/16	
Container	3	
Wet Mass	65	
Dry Mass	65	
	Airdry	Dry
Total Mass	527	527,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	1	0,19	99,81
<2.36	526,00	99,81	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	21	22	16,00
5	21	22	16,00
15	18	22	13,00
30	16	22	11,00
60	14	22	9,00
250	11	22	6,00
1440	8	22	3,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	5
0.30-0.150	17
0.150-0.075	16
<0.075	26,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	99,81	2,36
mm	99,81	1,18
mm	98,27	0,6
mm	90,60	0,3
mm	64,49	0,15
mm	39,92	0,075
mm	24,57	0,0338
mm	24,57	0,0214
mm	19,96	0,0125
mm	16,89	0,0090
mm	13,82	0,0064
mm	9,21	0,0032
mm	4,61	0,0014



Sample Name	Bergrivier BG 4
Date	2021/04/16
Container	4
Wet Mass	66
Dry Mass	66

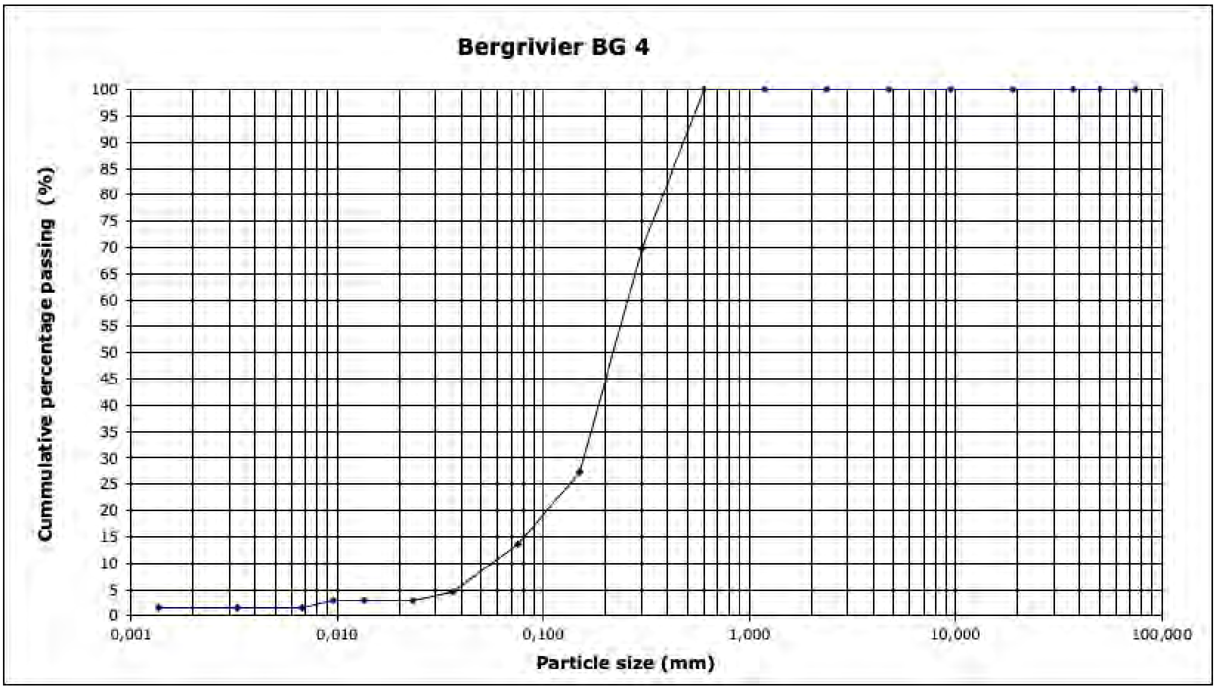
	Airdry	Dry
Total Mass	449	449,00
Container Mass	66	66,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	449,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	8	22	3,00
5	7	22	2,00
15	7	22	2,00
30	7	22	2,00
60	6	22	1,00
250	6	22	1,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	0
0.60-0.30	20
0.30-0.150	28
0.150-0.075	9
<0.075	9,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	100,00	0,6
mm	69,70	0,3
mm	27,27	0,15
mm	13,64	0,075
mm	4,55	0,0365
mm	3,03	0,0232
mm	3,03	0,0134
mm	3,03	0,0095
mm	1,52	0,0067
mm	1,52	0,0033
mm	1,52	0,0014



Sample Name	Bergrivier BG 5
Date	2021/04/16
Container	5
Wet Mass	65
Dry Mass	65

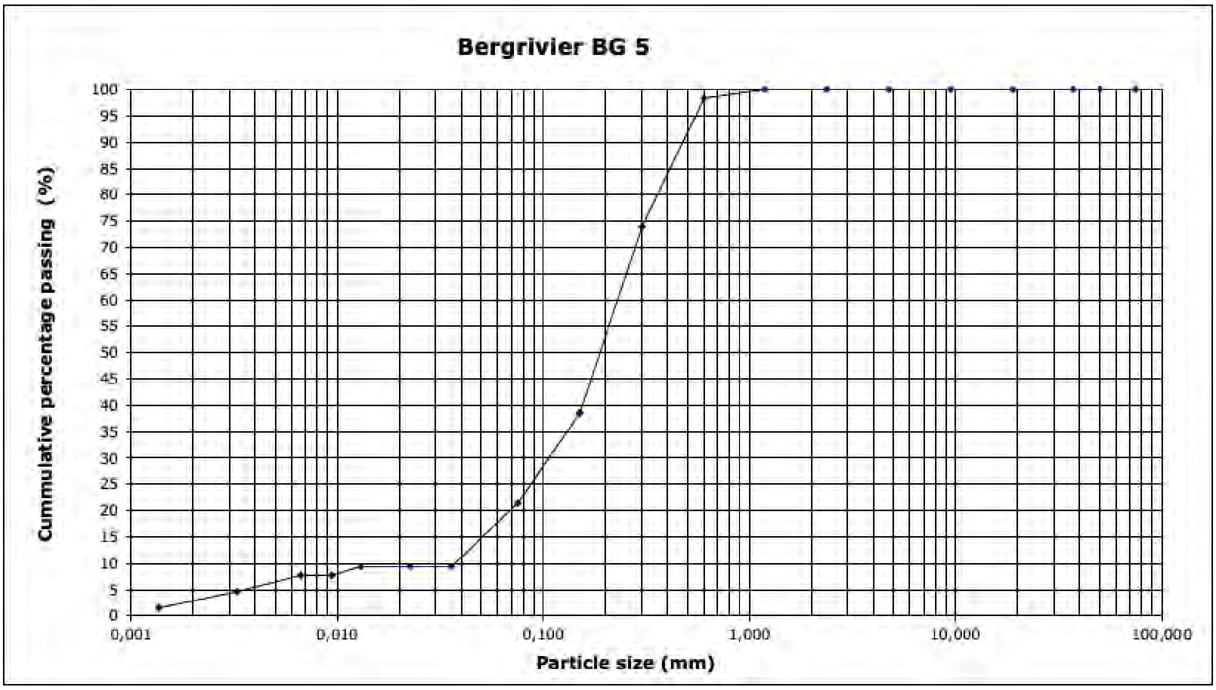
	Airdry	Dry
Total Mass	509	509,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	509,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	11	22	6,00
5	11	22	6,00
15	11	22	6,00
30	10	22	5,00
60	10	22	5,00
250	8	22	3,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	16
0.30-0.150	23
0.150-0.075	11
<0.075	14,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	73,85	0,3
mm	38,46	0,15
mm	21,54	0,075
mm	9,23	0,0359
mm	9,23	0,0227
mm	9,23	0,0131
mm	7,69	0,0093
mm	7,69	0,0066
mm	4,62	0,0033
mm	1,54	0,0014



Sample Name	Bergrivier BG 6
Date	2021/04/16
Container	6
Wet Mass	65
Dry Mass	65

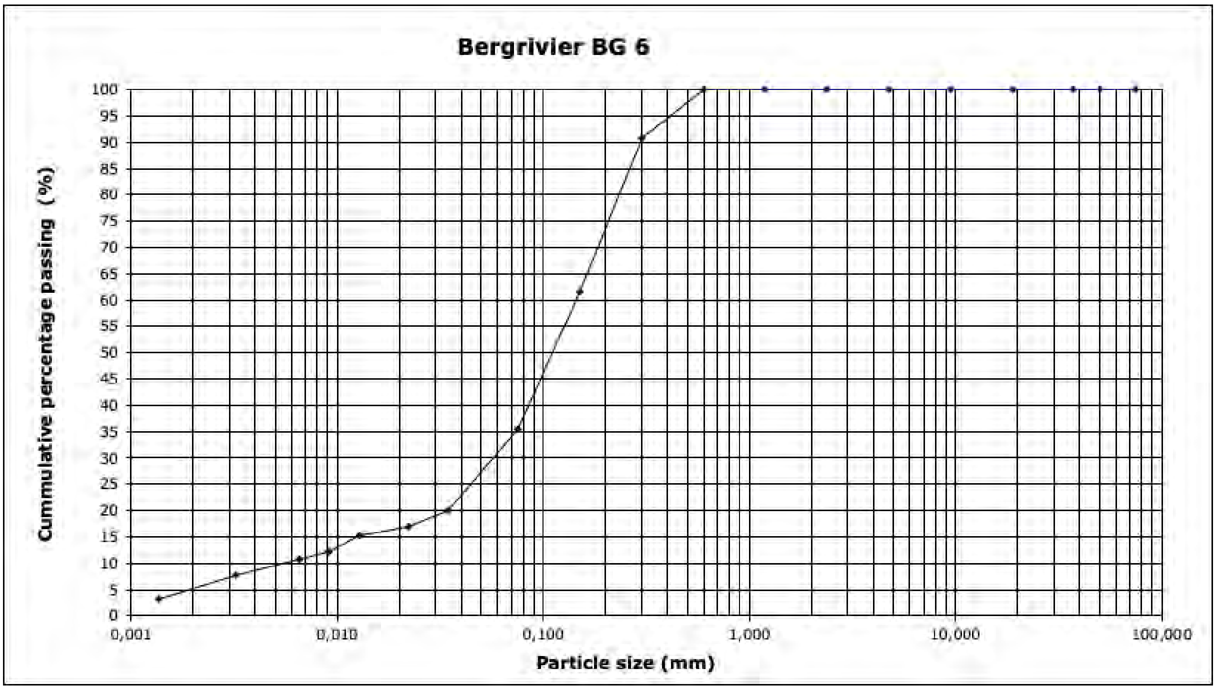
	Airdry	Dry
Total Mass	547	547,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	547,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	18	22	13,00
5	16	22	11,00
15	15	22	10,00
30	13	22	8,00
60	12	22	7,00
250	10	22	5,00
1440	7	22	2,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	0
0.60-0.30	6
0.30-0.150	19
0.150-0.075	17
<0.075	23,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	100,00	0,6
mm	90,77	0,3
mm	61,54	0,15
mm	35,38	0,075
mm	20,00	0,0343
mm	16,92	0,0220
mm	15,38	0,0128
mm	12,31	0,0092
mm	10,77	0,0065
mm	7,69	0,0032
mm	3,08	0,0014



Sample Name	Bergrivier BG 7
Date	2021/04/16
Container	7
Wet Mass	66
Dry Mass	66

	Airdry	Dry
Total Mass	901	901,00
Container Mass	66	66,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	901,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	17	22	12,00
5	15	22	10,00
15	14	22	9,00
30	12	22	7,00
60	11	22	6,00
250	10	22	5,00
1440	7	22	2,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	7
0.30-0.150	16
0.150-0.075	18
<0.075	24,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,48	0,6
mm	87,88	0,3
mm	63,64	0,15
mm	36,36	0,075
mm	18,18	0,0346
mm	15,15	0,0221
mm	13,64	0,0129
mm	10,61	0,0092
mm	9,09	0,0065
mm	7,58	0,0032
mm	3,03	0,0014

Temp °C
16
17
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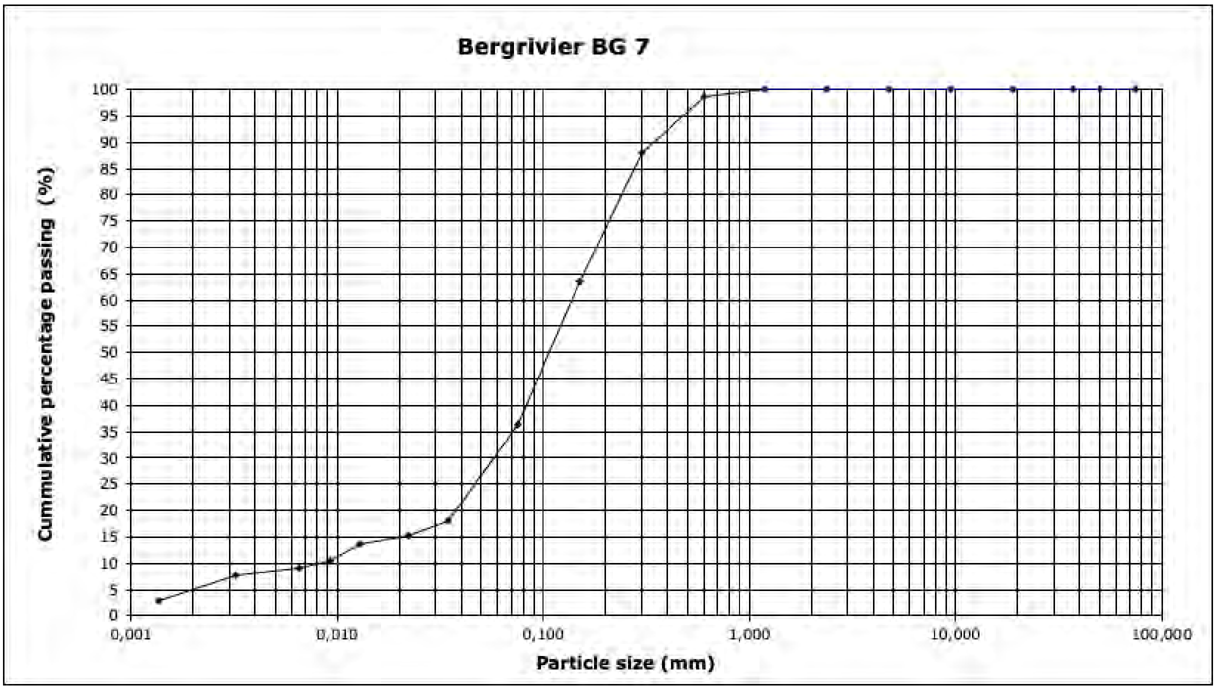


Sample Name	Bergrivier BG 8
Date	2021/04/16
Container	8
Wet Mass	65
Dry Mass	65

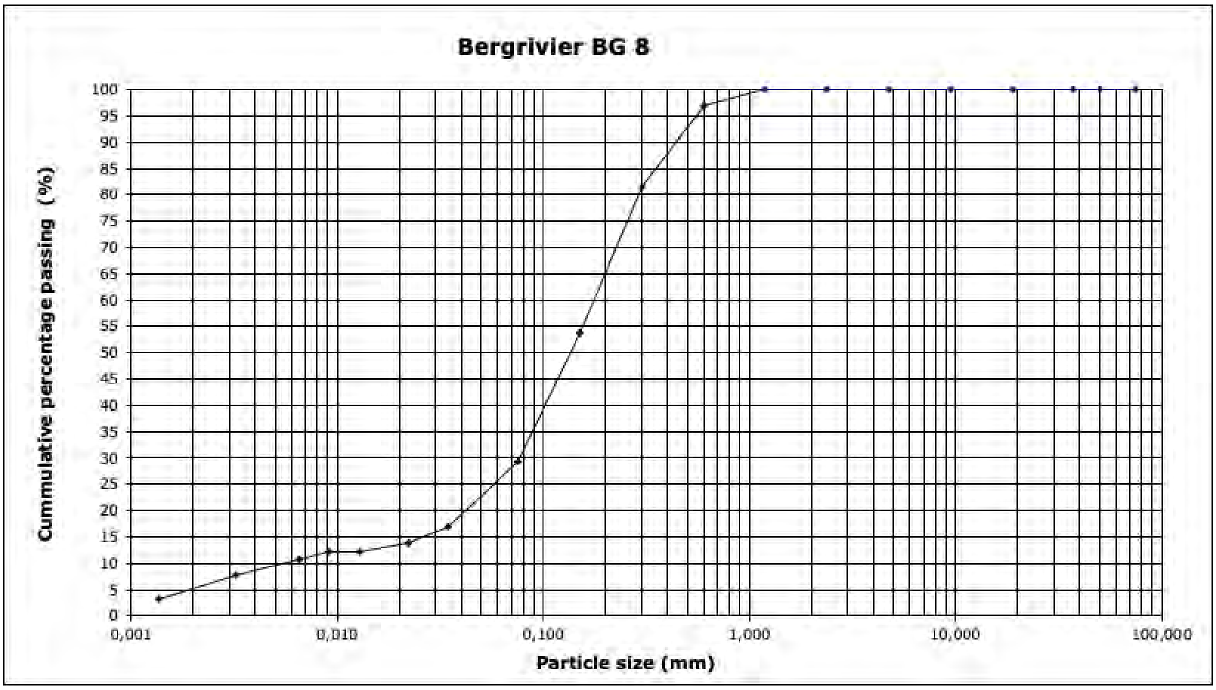
	Airdry	Dry
Total Mass	680	680,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	680,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	16	22	11,00
5	14	22	9,00
15	13	22	8,00
30	13	22	8,00
60	12	22	7,00
250	10	22	5,00
1440	7	22	2,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	2
0.60-0.30	10
0.30-0.150	18
0.150-0.075	16
<0.075	19,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	96,92	0,6
mm	81,54	0,3
mm	53,85	0,15
mm	29,23	0,075
mm	16,92	0,0349
mm	13,85	0,0223
mm	12,31	0,0130
mm	12,31	0,0092
mm	10,77	0,0065
mm	7,69	0,0032
mm	3,08	0,0014



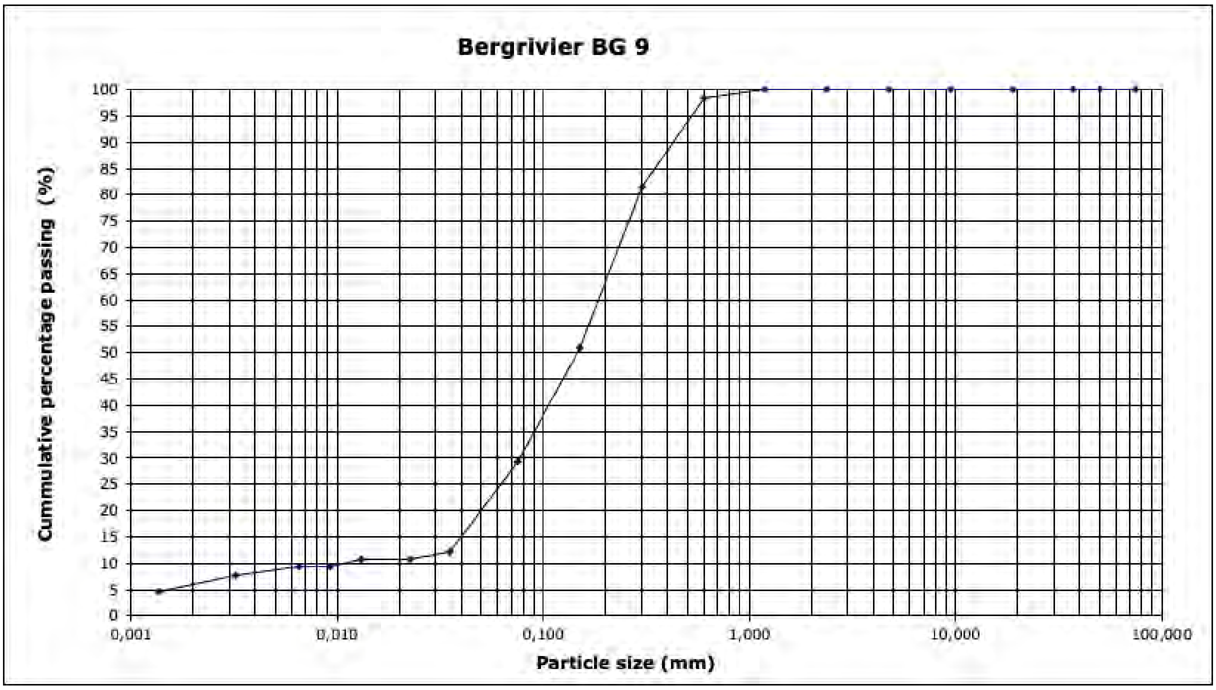
Sample Name	Bergrivier BG 9	
Date	2021/04/16	
Container	9	
Wet Mass	65	
Dry Mass	65	
	Airdry	Dry
Total Mass	666	666,00
Container Mass	65	65,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	11
0.30-0.150	20
0.150-0.075	14
<0.075	19,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	666,00	100,00	0,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	81,54	0,3
mm	50,77	0,15
mm	29,23	0,075
mm	12,31	0,0355
mm	10,77	0,0225
mm	10,77	0,0130
mm	9,23	0,0093
mm	9,23	0,0065
mm	7,69	0,0032
mm	4,62	0,0014

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	13	22	8,00
5	12	22	7,00
15	12	22	7,00
30	11	22	6,00
60	11	22	6,00
250	10	22	5,00
1440	8	22	3,00



Sample Name	Bergrivier BG 10
Date	2021/04/16
Container	10
Wet Mass	65
Dry Mass	65

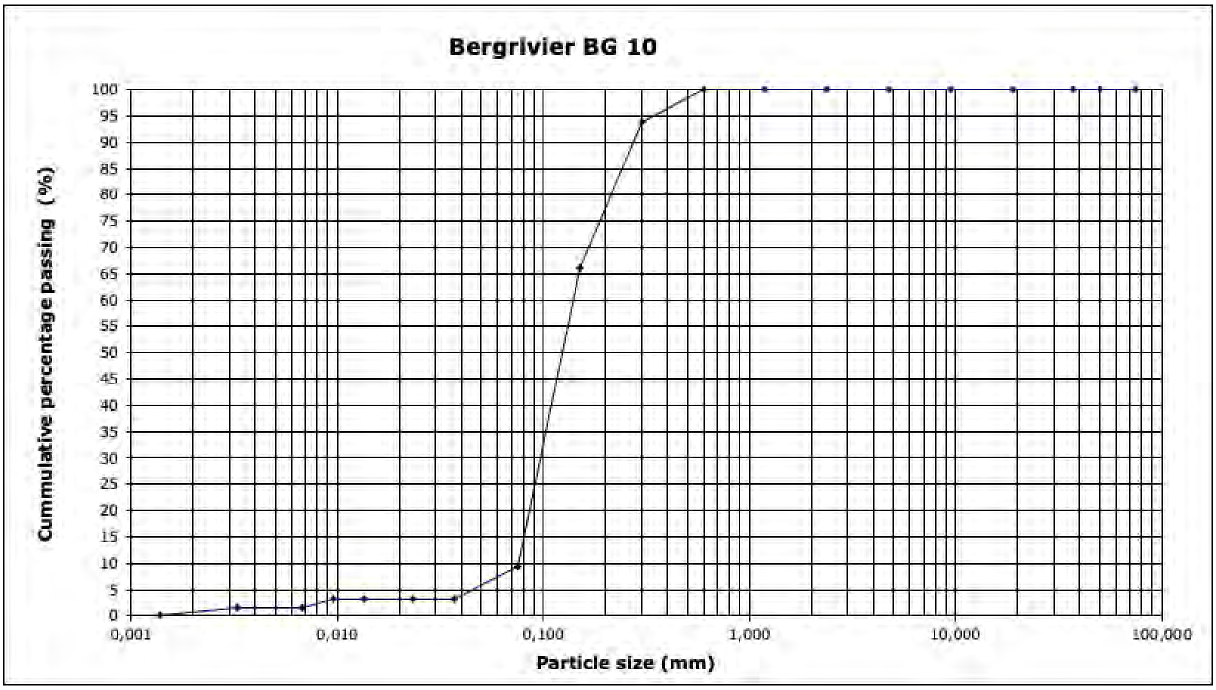
	Airdry	Dry
Total Mass	953	953,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	953,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	7	22	2,00
5	7	22	2,00
15	7	22	2,00
30	7	22	2,00
60	6	22	1,00
250	6	22	1,00
1440	5	22	0,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	0
0.60-0.30	4
0.30-0.150	18
0.150-0.075	37
<0.075	6,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	100,00	0,6
mm	93,85	0,3
mm	66,15	0,15
mm	9,23	0,075
mm	3,08	0,0367
mm	3,08	0,0232
mm	3,08	0,0134
mm	3,08	0,0095
mm	1,54	0,0067
mm	1,54	0,0033
mm	0,00	0,0014



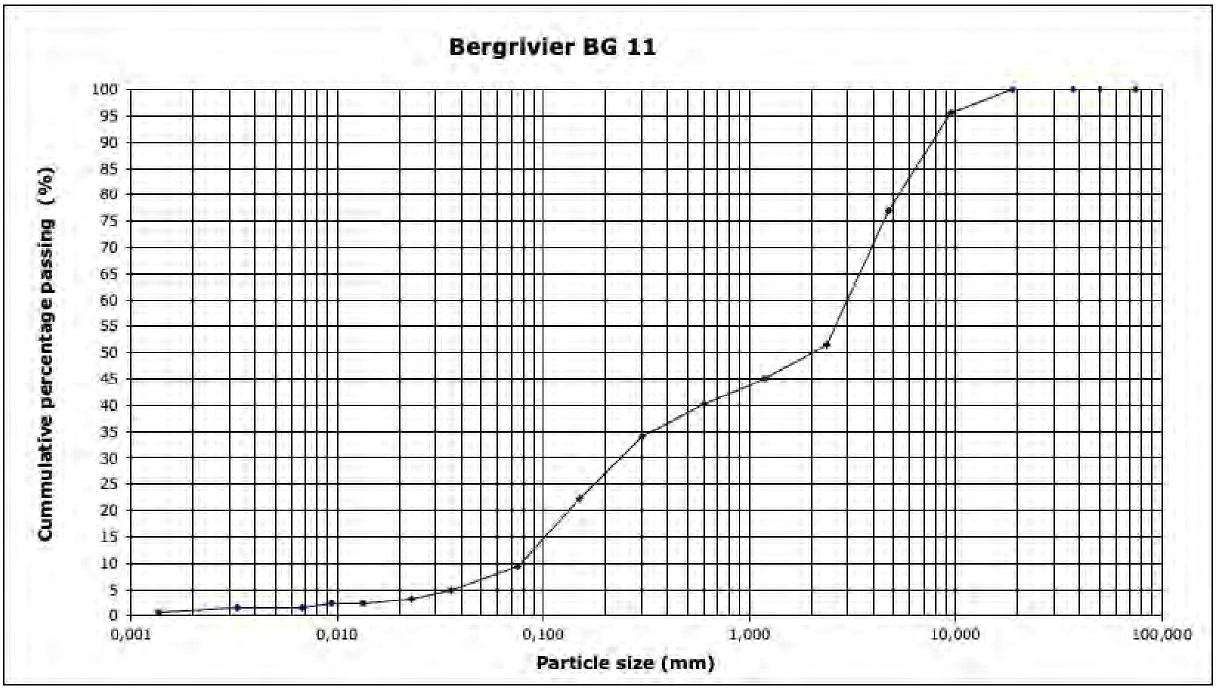
Sample Name	Bergrivier BG 11	
Date	2021/04/16	
Container	11	
Wet Mass	65	
Dry Mass	65	
	Airdry	Dry
Total Mass	459	459,00
Container Mass	65	65,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	8
1.18-0.60	6
0.60-0.30	8
0.30-0.150	15
0.150-0.075	16
<0.075	12,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50	21	4,58	95,42
4,75	85	18,52	76,91
2,36	117	25,49	51,42
<2.36	236,00	51,42	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	11	22	6,00
5	9	22	4,00
15	8	22	3,00
30	8	22	3,00
60	7	22	2,00
250	7	22	2,00
1440	6	22	1,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	95,42	9,5
mm	76,91	4,75
mm	51,42	2,36
mm	45,09	1,18
mm	40,34	0,6
mm	34,01	0,3
mm	22,15	0,15
mm	9,49	0,075
mm	4,75	0,0359
mm	3,16	0,0229
mm	2,37	0,0133
mm	2,37	0,0094
mm	1,58	0,0067
mm	1,58	0,0033
mm	0,79	0,0014



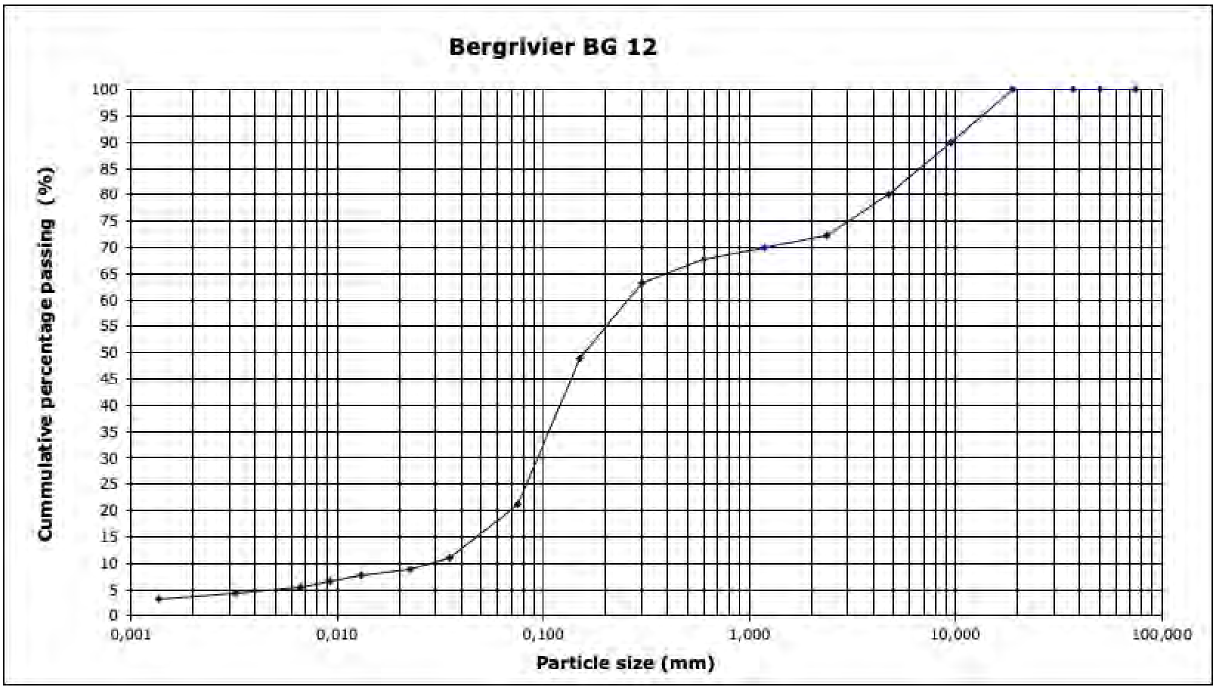
Sample Name	Bergrivier BG 12	
Date	2021/04/16	
Container	12	
Wet Mass	65	
Dry Mass	65	
	Airdry	Dry
Total Mass	277	277,00
Container Mass	65	65,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	2
1.18-0.60	2
0.60-0.30	4
0.30-0.150	13
0.150-0.075	25
<0.075	19,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50	28	10,11	89,89
4,75	27	9,75	80,14
2,36	22	7,94	72,20
<2.36	200,00	72,20	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	15	22	10,00
5	13	22	8,00
15	12	22	7,00
30	11	22	6,00
60	10	22	5,00
250	9	22	4,00
1440	8	22	3,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	89,89	9,5
mm	80,14	4,75
mm	72,20	2,36
mm	69,98	1,18
mm	67,76	0,6
mm	63,32	0,3
mm	48,88	0,15
mm	21,11	0,075
mm	11,11	0,0350
mm	8,89	0,0224
mm	7,78	0,0130
mm	6,66	0,0093
mm	5,55	0,0066
mm	4,44	0,0032
mm	3,33	0,0014



Sample Name	Bergrivier BG 13
Date	2021/04/16
Container	13
Wet Mass	65
Dry Mass	65

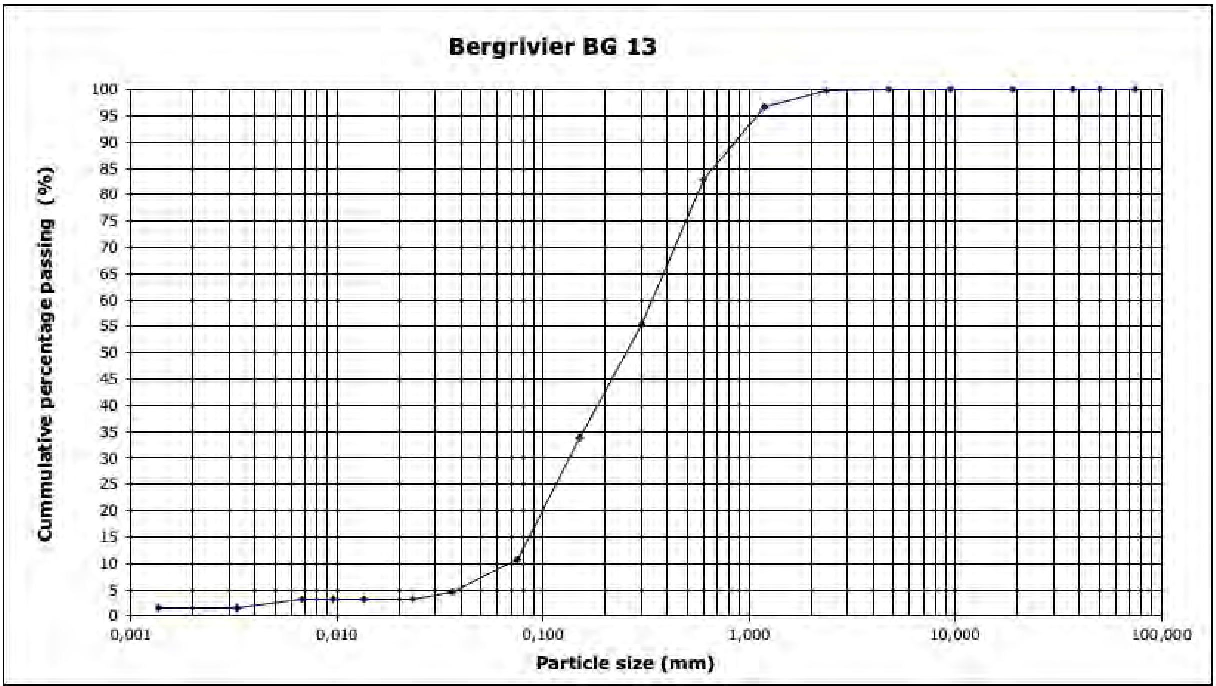
	Airdry	Dry
Total Mass	459	459,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	1	0,22	99,78
<2.36	458,00	99,78	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	8	22	3,00
5	7	22	2,00
15	7	22	2,00
30	7	22	2,00
60	7	22	2,00
250	6	22	1,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	2
1.18-0.60	9
0.60-0.30	18
0.30-0.150	14
0.150-0.075	15
<0.075	7,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	99,78	2,36
mm	96,71	1,18
mm	82,90	0,6
mm	55,26	0,3
mm	33,77	0,15
mm	10,75	0,075
mm	4,61	0,0365
mm	3,07	0,0232
mm	3,07	0,0134
mm	3,07	0,0095
mm	3,07	0,0067
mm	1,54	0,0033
mm	1,54	0,0014



Sample Name	Bergrivier BG 14
Date	2021/04/16
Container	14
Wet Mass	65
Dry Mass	65

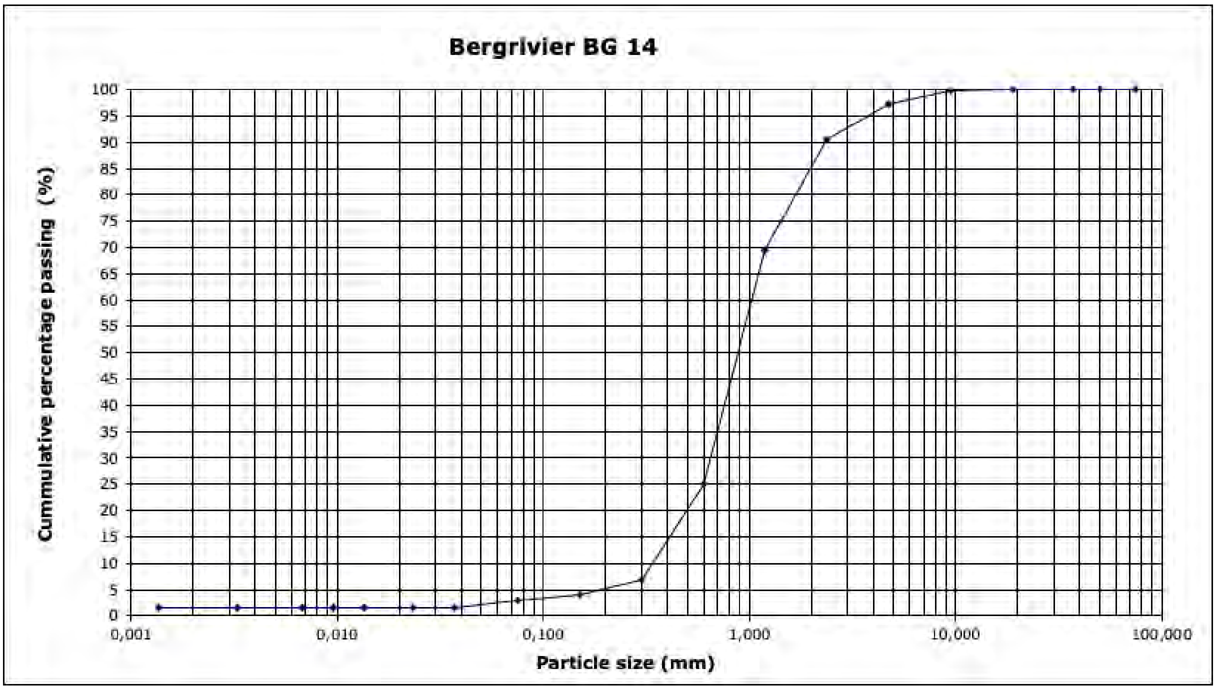
	Airdry	Dry
Total Mass	552	552,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50	2	0,36	99,64
4,75	14	2,54	97,10
2,36	37	6,70	90,40
<2.36	499,00	90,40	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	6	22	1,00
5	6	22	1,00
15	6	22	1,00
30	6	22	1,00
60	6	22	1,00
250	6	22	1,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	15
1.18-0.60	32
0.60-0.30	13
0.30-0.150	2
0.150-0.075	1
<0.075	2,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	99,64	9,5
mm	97,10	4,75
mm	90,40	2,36
mm	69,54	1,18
mm	25,03	0,6
mm	6,95	0,3
mm	4,17	0,15
mm	2,78	0,075
mm	1,39	0,0368
mm	1,39	0,0233
mm	1,39	0,0135
mm	1,39	0,0095
mm	1,39	0,0067
mm	1,39	0,0033
mm	1,39	0,0014



Sample Name	Bergrivier BG 15
Date	2021/04/16
Container	15
Wet Mass	65
Dry Mass	65

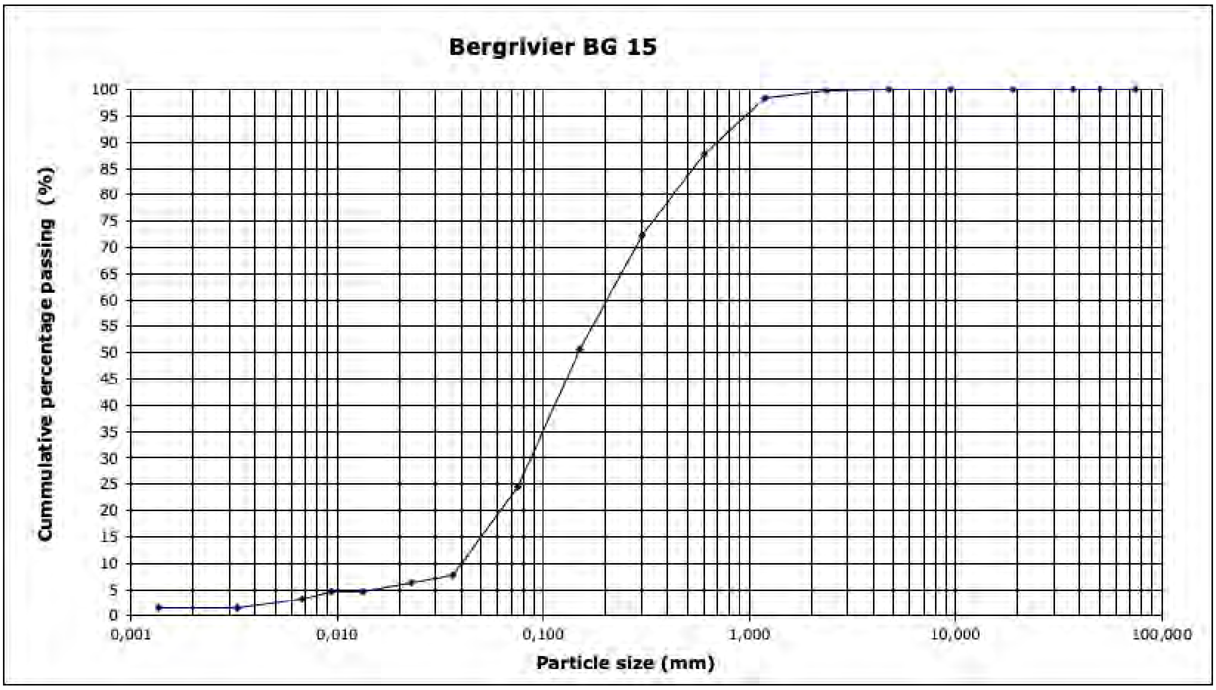
	Airdry	Dry
Total Mass	626	626,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	1	0,16	99,84
<2.36	625,00	99,84	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	10	22	5,00
5	9	22	4,00
15	8	22	3,00
30	8	22	3,00
60	7	22	2,00
250	6	22	1,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	1
1.18-0.60	7
0.60-0.30	10
0.30-0.150	14
0.150-0.075	17
<0.075	16,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	99,84	2,36
mm	98,30	1,18
mm	87,55	0,6
mm	72,19	0,3
mm	50,69	0,15
mm	24,58	0,075
mm	7,68	0,0361
mm	6,14	0,0229
mm	4,61	0,0133
mm	4,61	0,0094
mm	3,07	0,0067
mm	1,54	0,0033
mm	1,54	0,0014



Sample Name	Bergrivier BG 16	
Date	2021/04/16	
Container	16	
Wet Mass	65	
Dry Mass	65	

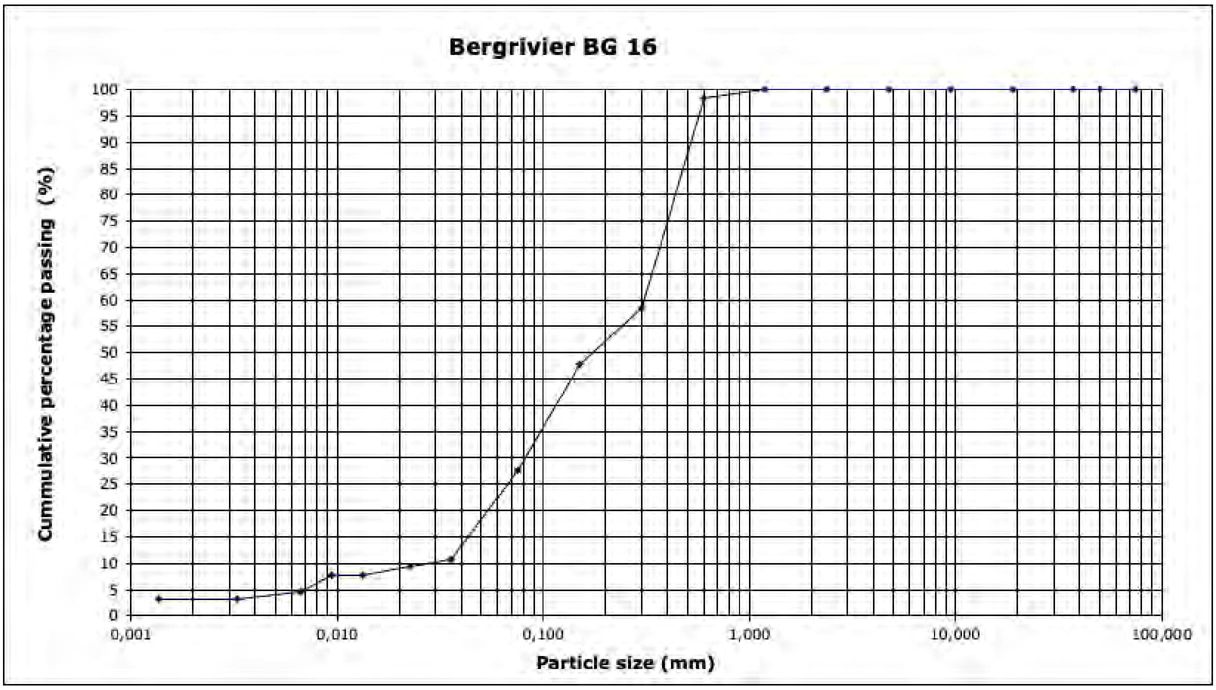
	Airdry	Dry
Total Mass	406	406,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	406,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	12	22	7,00
5	11	22	6,00
15	10	22	5,00
30	10	22	5,00
60	8	22	3,00
250	7	22	2,00
1440	7	22	2,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	26
0.30-0.150	7
0.150-0.075	13
<0.075	18,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	58,46	0,3
mm	47,69	0,15
mm	27,69	0,075
mm	10,77	0,0356
mm	9,23	0,0227
mm	7,69	0,0132
mm	7,69	0,0093
mm	4,62	0,0067
mm	3,08	0,0033
mm	3,08	0,0014



Sample Name	Bergrivier BG 17
Date	2021/04/16
Container	17
Wet Mass	65
Dry Mass	65

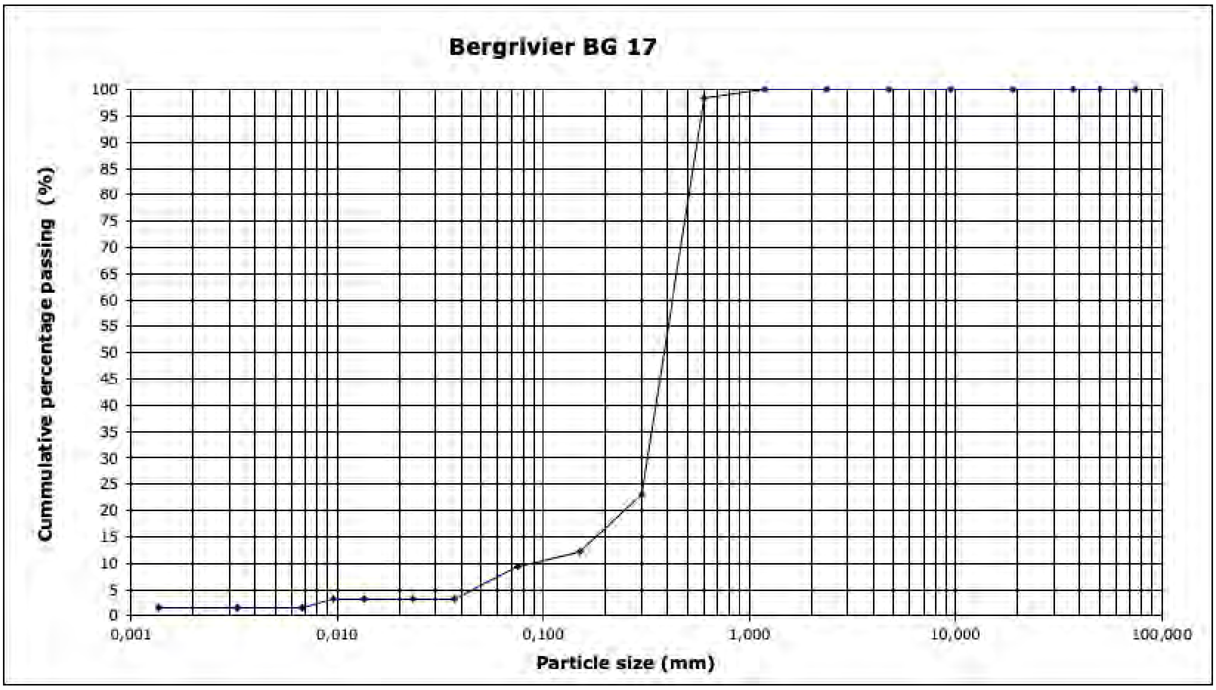
	Airdry	Dry
Total Mass	613	613,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	613,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	7	22	2,00
5	7	22	2,00
15	7	22	2,00
30	7	22	2,00
60	6	22	1,00
250	6	22	1,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	49
0.30-0.150	7
0.150-0.075	2
<0.075	6,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	23,08	0,3
mm	12,31	0,15
mm	9,23	0,075
mm	3,08	0,0367
mm	3,08	0,0232
mm	3,08	0,0134
mm	3,08	0,0095
mm	1,54	0,0067
mm	1,54	0,0033
mm	1,54	0,0014



Sample Name	Bergrivier BG 18
Date	2021/04/16
Container	18
Wet Mass	65
Dry Mass	65

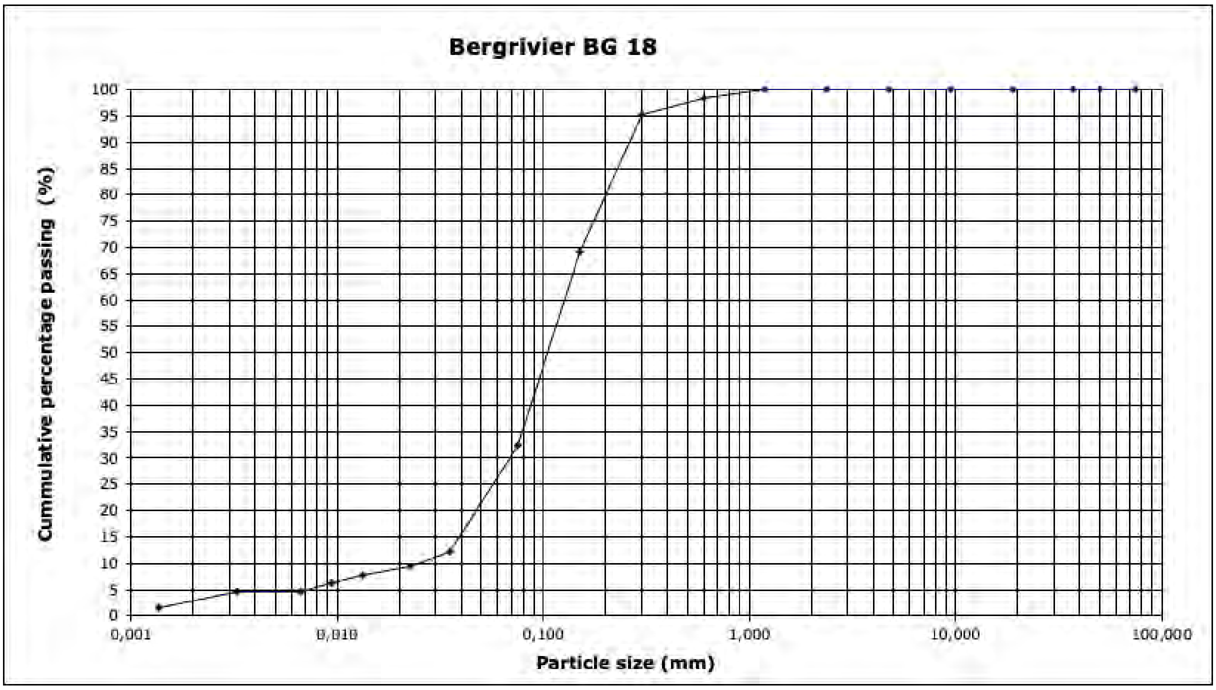
	Airdry	Dry
Total Mass	244	244,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75		0,00	100,00
2,36	0	0,00	100,00
<2.36	244,00	100,00	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	13	22	8,00
5	11	22	6,00
15	10	22	5,00
30	9	22	4,00
60	8	22	3,00
250	8	22	3,00
1440	6	22	1,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	0
1.18-0.60	1
0.60-0.30	2
0.30-0.150	17
0.150-0.075	24
<0.075	21,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	100,00	4,75
mm	100,00	2,36
mm	100,00	1,18
mm	98,46	0,6
mm	95,38	0,3
mm	69,23	0,15
mm	32,31	0,075
mm	12,31	0,0355
mm	9,23	0,0227
mm	7,69	0,0132
mm	6,15	0,0094
mm	4,62	0,0067
mm	4,62	0,0033
mm	1,54	0,0014



Sample Name	Bergrivier BG 25
Date	2021/04/16
Container	25
Wet Mass	65
Dry Mass	65

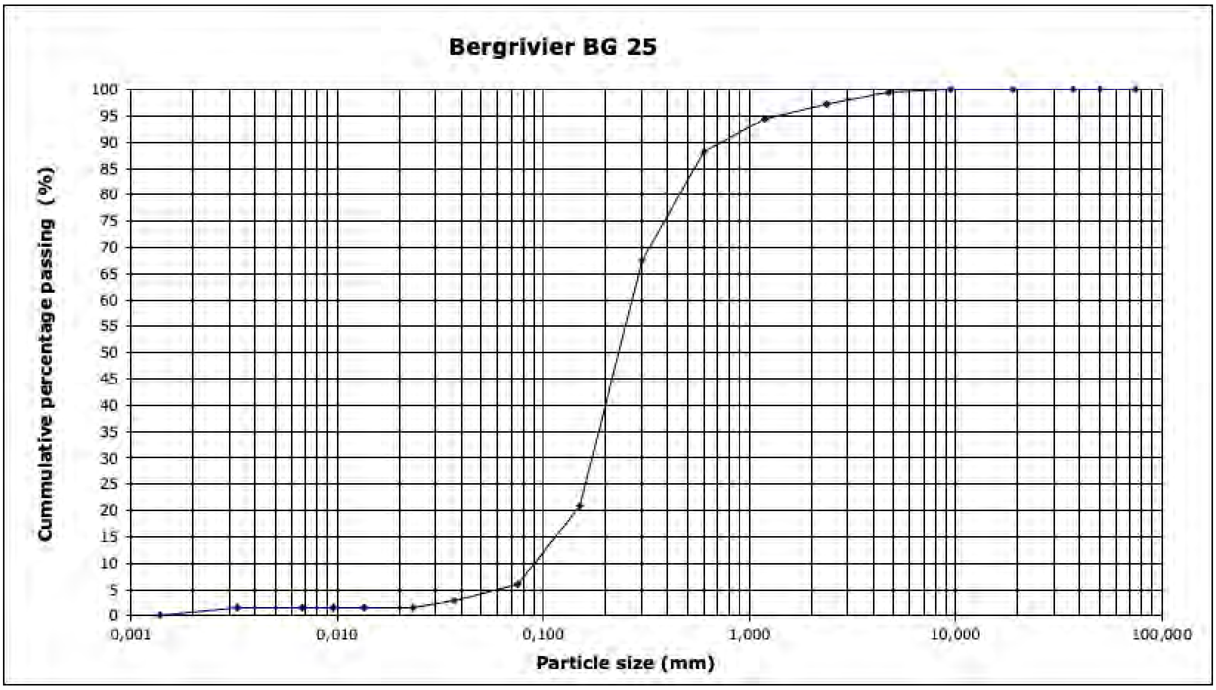
	Airdry	Dry
Total Mass	588	588,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50		0,00	100,00
4,75	3	0,51	99,49
2,36	13	2,21	97,28
<2.36	572,00	97,28	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	7	22	2,00
5	6	22	1,00
15	6	22	1,00
30	6	22	1,00
60	6	22	1,00
250	6	22	1,00
1440	5	22	0,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	2
1.18-0.60	4
0.60-0.30	14
0.30-0.150	31
0.150-0.075	10
<0.075	4,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	100,00	9,5
mm	99,49	4,75
mm	97,28	2,36
mm	94,29	1,18
mm	88,30	0,6
mm	67,35	0,3
mm	20,95	0,15
mm	5,99	0,075
mm	2,99	0,0367
mm	1,50	0,0233
mm	1,50	0,0135
mm	1,50	0,0095
mm	1,50	0,0067
mm	1,50	0,0033
mm	0,00	0,0014



Sample Name	Bergrivier BG 26
Date	2021/04/16
Container	26
Wet Mass	65
Dry Mass	65

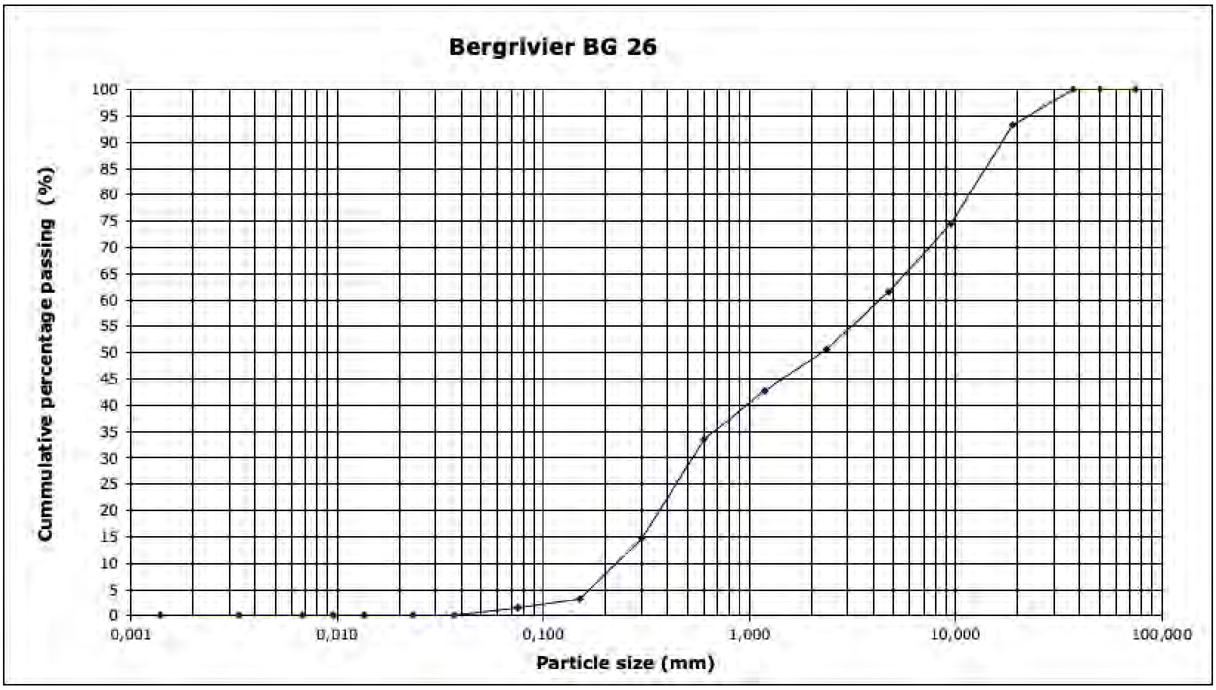
	Airdry	Dry
Total Mass	701	701,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00	47	6,70	93,30
9,50	132	18,83	74,47
4,75	91	12,98	61,48
2,36	76	10,84	50,64
<2.36	355,00	50,64	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	5	22	0,00
5	5	22	0,00
15	5	22	0,00
30	5	22	0,00
60	5	22	0,00
250	5	22	0,00
1440	5	22	0,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	10
1.18-0.60	12
0.60-0.30	24
0.30-0.150	15
0.150-0.075	2
<0.075	2,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	93,30	19
mm	74,47	9,5
mm	61,48	4,75
mm	50,64	2,36
mm	42,85	1,18
mm	33,50	0,6
mm	14,80	0,3
mm	3,12	0,15
mm	1,56	0,075
mm	0,00	0,0371
mm	0,00	0,0235
mm	0,00	0,0135
mm	0,00	0,0096
mm	0,00	0,0068
mm	0,00	0,0033
mm	0,00	0,0014



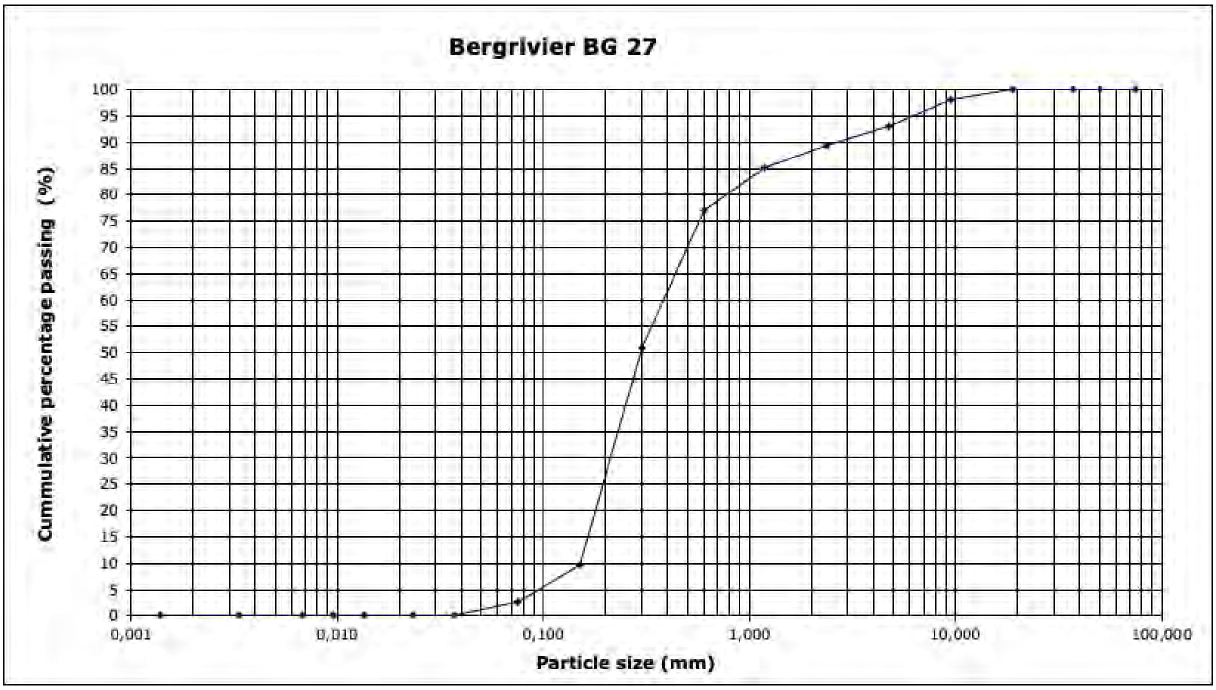
Sample Name	Bergrivier BG 27	
Date	2021/04/16	
Container	27	
Wet Mass	65	
Dry Mass	65	
	Airdry	Dry
Total Mass	533	533,00
Container Mass	65	65,00

Sieve Analysis			
Sieve Size (mm)	Mass leftover (g)	% on sieve	% greater
75,00		0,00	100,00
50,00		0,00	100,00
37,50		0,00	100,00
19,00		0,00	100,00
9,50	11	2,06	97,94
4,75	26	4,88	93,06
2,36	20	3,75	89,31
<2.36	476,00	89,31	0,00

Hydrometer readings			
Time (min)	True reading	Temp C	Corrected
2	5	22	0,00
5	5	22	0,00
15	5	22	0,00
30	5	22	0,00
60	5	22	0,00
250	5	22	0,00
1440	5	22	0,00

Sieve test	
Sieve size (mm)	Mass (g)
2.36-1.18	3
1.18-0.60	6
0.60-0.30	19
0.30-0.150	30
0.150-0.075	5
<0.075	2,00

Unit	% Concentration	Diameter (mm)
mm	100,00	75
mm	100,00	50
mm	100,00	37,5
mm	100,00	19
mm	97,94	9,5
mm	93,06	4,75
mm	89,31	2,36
mm	85,18	1,18
mm	76,94	0,6
mm	50,84	0,3
mm	9,62	0,15
mm	2,75	0,075
mm	0,00	0,0371
mm	0,00	0,0235
mm	0,00	0,0135
mm	0,00	0,0096
mm	0,00	0,0068
mm	0,00	0,0033
mm	0,00	0,0014



Appendix F: Floodlines for the 50-year and 100-year floods with future climate change impact as well as proposed expropriation lines upstream of the proposed abstraction works and weir

The following floodlines, water level and other lines were indicated on the floodline drawing which is also available in CAD:

- Q50cc floodline: current scenario without weir and abstraction works, and no saddle berm
- Q50cc floodline: future scenario with weir and abstraction works, but no saddle berm
- Q50cc floodline: future scenario with weir and abstraction works and with saddle berm
- Q100cc floodline: current scenario without weir and abstraction works, and no saddle berm
- Q100cc floodline: future scenario with weir and abstraction works, but no saddle berm
- Q100cc floodline: future scenario with weir and abstraction works and with saddle berm
- MOL of proposed weir and abstraction works at 51.6 masl (EWR spilling with 0.3 m head on the fishway-canoe chute)
- Compensation lines based on the TCTA guidelines given above.
- Cadastral boundaries

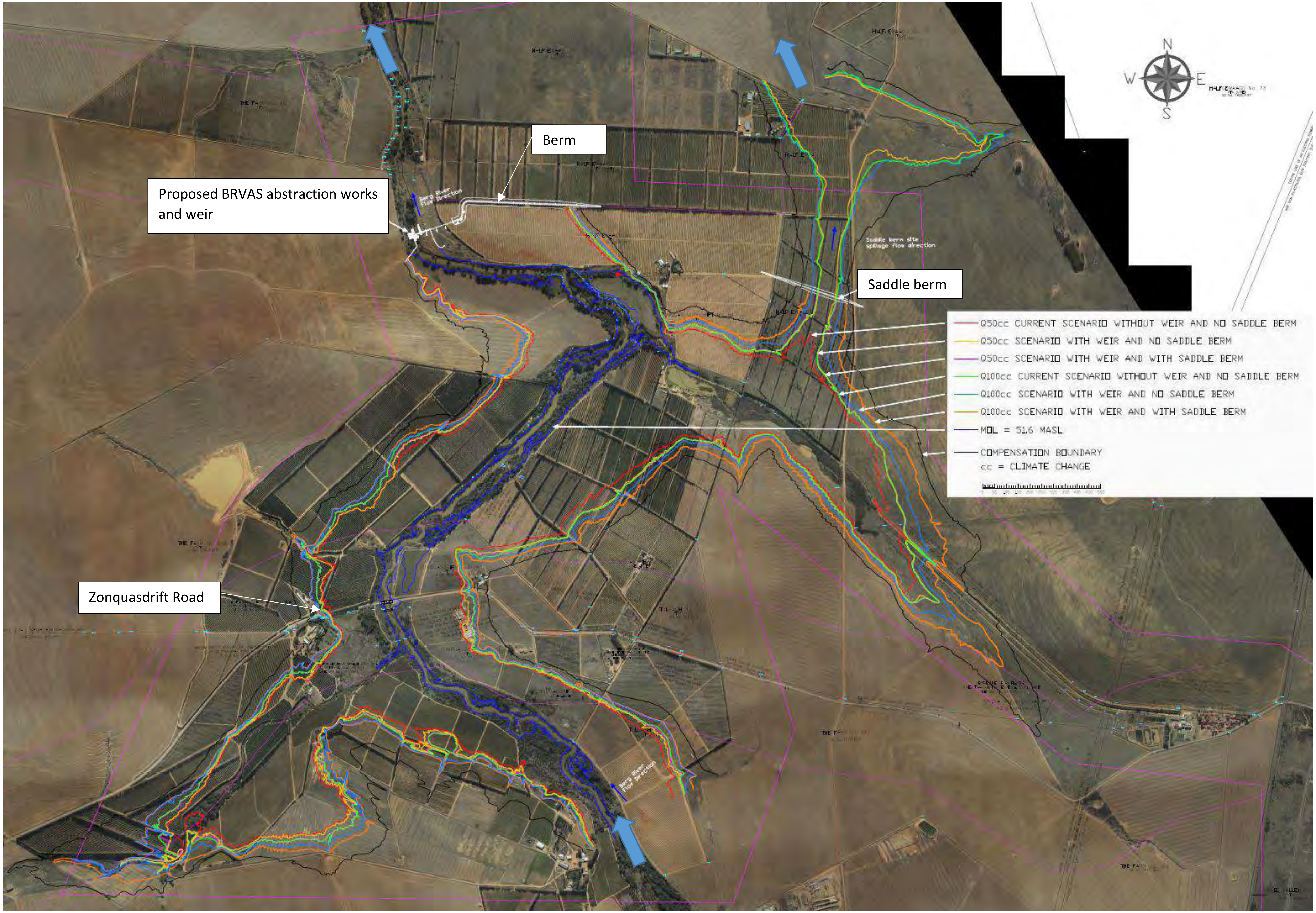


Figure F-1: Physical model observed floodlines and proposed expropriation line upstream of the proposed BRVAS weir and abstraction works extended upstream by 2D hydrodynamic model (Refer to CAD dwg supplied with this report for more details)

Appendix G: Measured water levels and flow velocities, as well as scanned movable bed equilibrium scoured bed levels of the proposed temporary works diversion canal

Table G1: Measured flow velocities and water levels for the modified option C temporary works layout

			Q2				Q5				Q10			
Point	Chainage (m)	Bed Level (masl)	Water level (masl)		Velocity (m/s)		Water level (masl)		Velocity (m/s)		Water level (masl)		Velocity (m/s)	
			LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
1	30.16	47.30	-	51.46	-	2.63	-	52.90	-	2.66	-	54.0	-	2.7
2	73.76	47.30	-	51.43	-	2.61	-	52.92	-	2.59	-	53.9	-	2.64
3	122.65	47.30	51.40	51.40	2.76	2.52	52.93	52.96	2.59	2.69	54.1	53.9	2.59	2.61
4	156.90	47.26	51.39	51.39	2.61	2.52	52.92	52.82	2.79	2.77	53.8	53.7	2.59	2.76
5	198.61	47.22	51.33	51.43	2.76	2.61	52.77	52.90	2.83	2.84	53.7	53.8	2.67	2.72
6	238.18	47.18	51.44	51.33	2.79	2.52	52.86	52.77	2.76	2.74	53.8	53.8	2.64	2.56
7	277.99	47.14	51.31	51.42	2.58	2.57	52.84	52.98	2.72	2.69	53.8	53.8	2.74	2.56
8	316.90	47.10	51.38	51.36	2.83	2.62	52.77	52.78	2.8	2.54	53.6	53.9	2.66	2.73
9	355.48	47.06	51.31	51.32	2.82	2.82	52.58	52.55	2.69	2.68	53.6	53.7	2.65	2.64
10	395.75	47.02	51.26	51.32	2.61	2.55	52.62	52.84	2.74	2.66	53.6	53.6	2.66	2.81
11	434.49	46.98	51.24	51.28	2.54	2.53	52.74	52.87	2.25	2.64	53.5	53.6	2.66	2.78

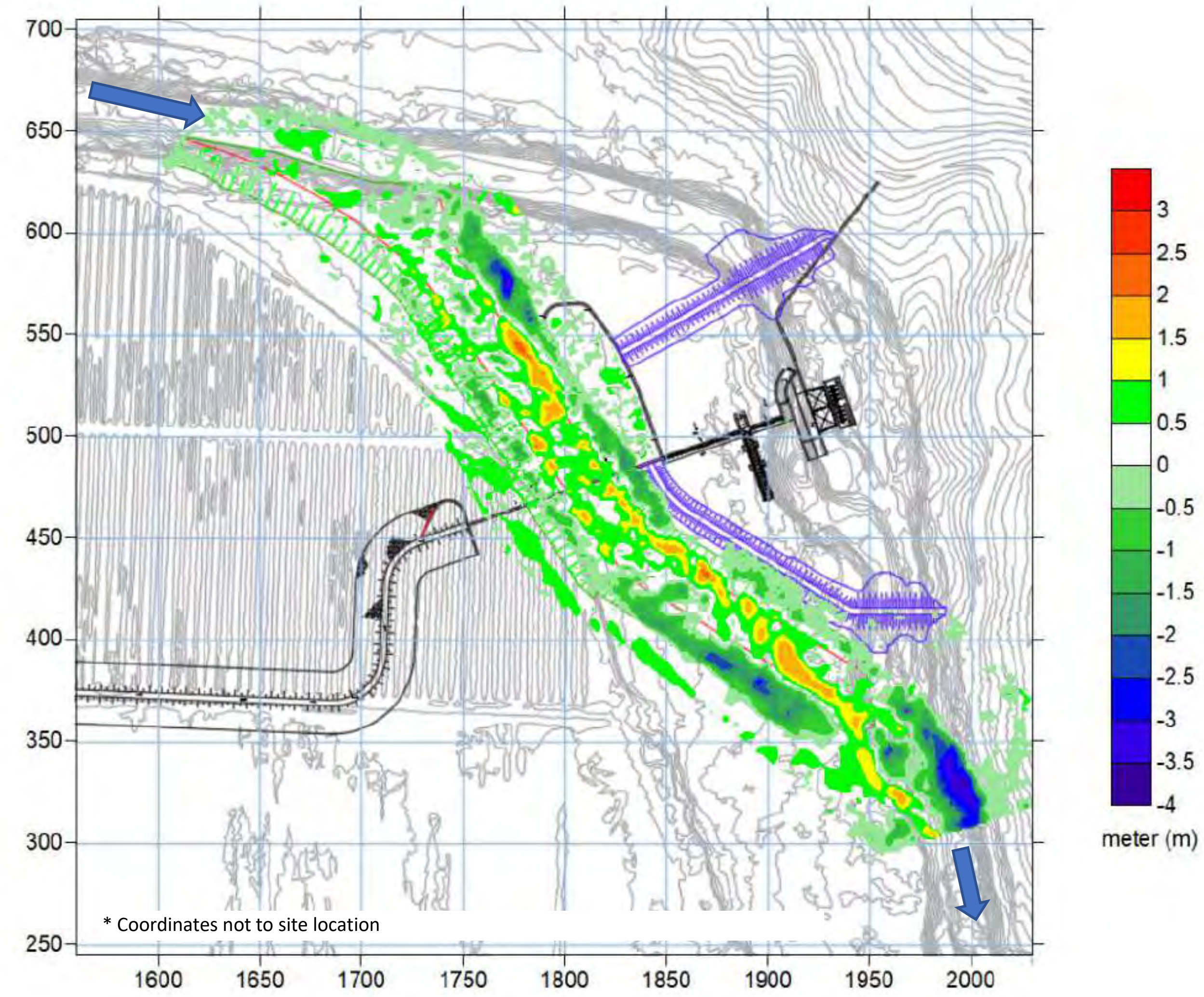


Figure G1: Measured bed level change after the 2-year flood (negative values = scour; positive values = deposition)

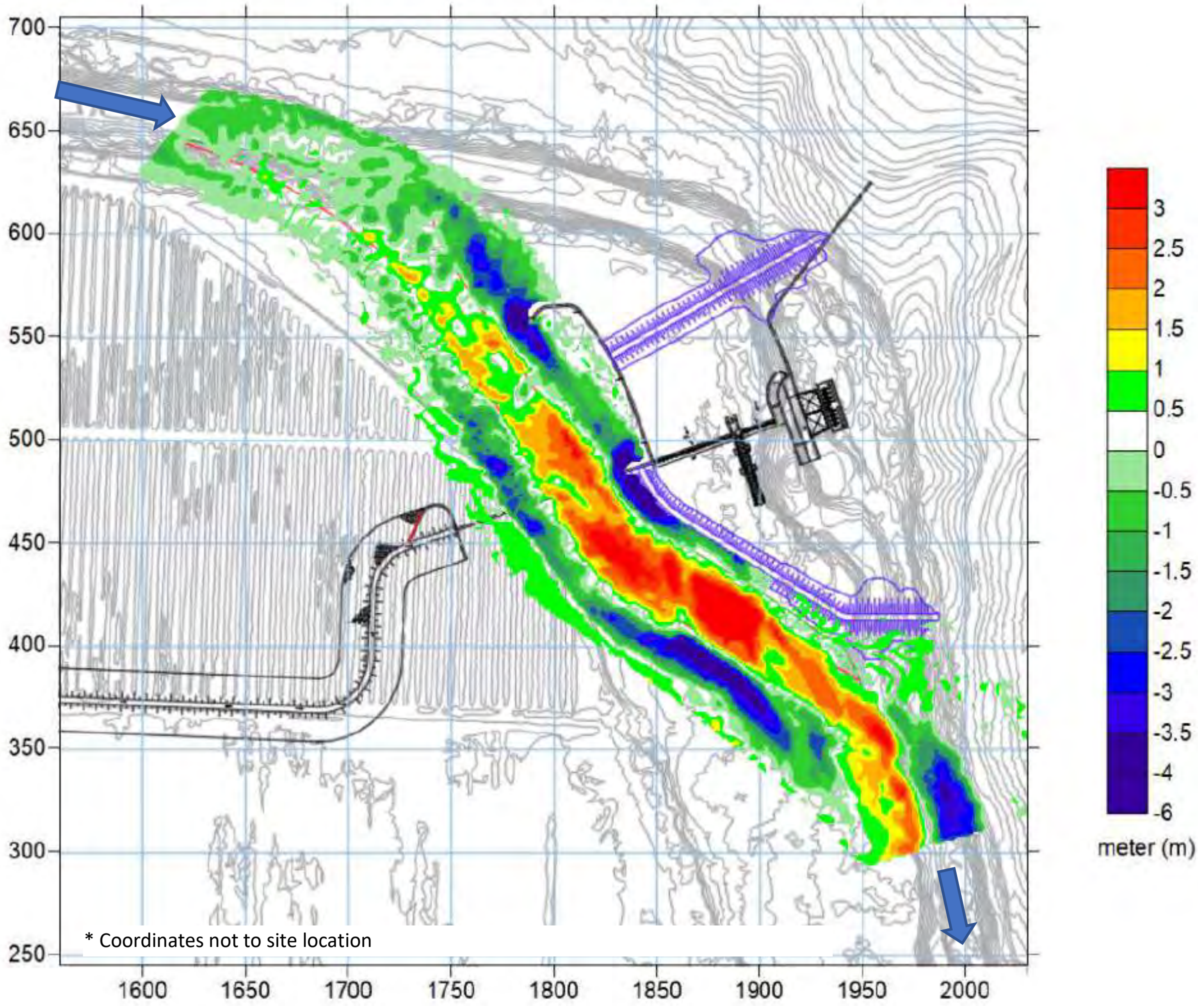


Figure G2: Measured bed level change after the 5-year flood

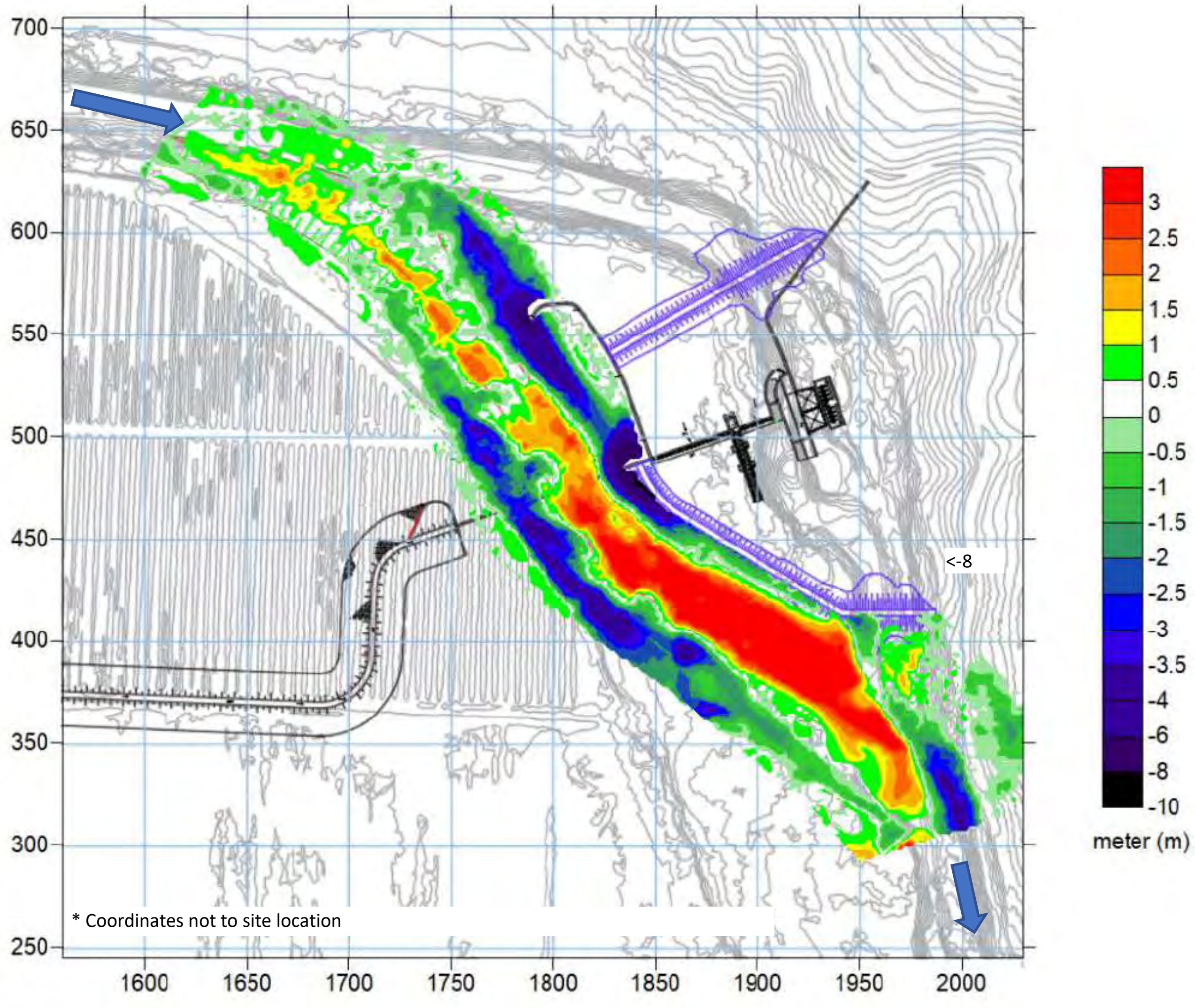


Figure G3: Measured bed level change after the 10-year flood