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Overtopping av Damkrone

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Hydropower Development
Innlevert: juni 2016
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NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF HYDRAULIC AND ENVIRONMENTAL ENGINEERING

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Abstract:
Avalanches from hillsides and down into water reservoirs has a large damage potential for rock-fill dams. In the spring of 2016 a contract has been drawn between NVE and NTNU on continuation of experiments with avalanches into reservoirs, with focus on rockslides into the reservoir with rock fill dams. The purpose of the research project is to find clearer associations between avalanches, waves and overtopping. The most important parameters is be deemed to be freeboard, slope inclination, geometry in the plane, roughness and design of the dam crest.

Keywords:

1. Dam safety
2. Rock slides
3. Reservoirs
4. Embankment dam

Robert Mortensen

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NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF HYDRAULIC AND ENVIRONMENTAL ENGINEERING

MASTER DEGREE THESIS

Spring 2016

for

Student: Robert Mortensen

LANDSLIDE GENERATED WAVES IN RESERVOIRS- EMBANKMENT DAM OVERTOPPING

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BACKGROUND

Avalanches from hillsides and down into water reservoirs has a large damage potential for rock-fill dams. In the spring of 2016 a contract has been drawn between NVE and NTNU on continuation of experiments with avalanches into reservoirs, with focus on rockslides into the reservoir with rock fill dams. The purpose of the research project is to find clearer associations between avalanches, waves and overtopping. The most important parameters is be deemed to be freeboard, slope inclination, geometry in the plane, roughness and design of the dam crest.

TASK

The assignment will focus on the relationship between the dam construction design and overtopping from landslide-generated waves

TASK DESCRIPTION

Work will contain follow these main points:

1. Review of previously obtained source material literature. Find examples of previous studies on landslide generated wave impacts on embankment dams.

2. Calibration and preparing of physical model (including measuring equipment)

3. Establish test and measurement program. Carried out in collaboration with supervisors on thesis.

4. Implementation, logging and reporting of experiments.

5. Evaluation of results.

6. Report.

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PREFACE

This Master's thesis titled "Landslide generated waves in reservoirs- embankment dam overtopping" is written in collaboration with department of Hydraulic and Environmental Engineering at NTNU. Supervisors are Leif Lia and Kiflom Belete at department of Hydraulic and Environmental Engineering at NTNU.

The experiments are run in a model based on the master "Physical model study on impacts of landslide generated wave action on embankment dams" by Matteo Bolzoni.

Some of the experiments have been run in collaboration with student Ragnhild Hammeren and student María José de las Llanderas Ramirez.

Thesis work started January 2016, and was completed in June 2016.

Robert Mortensen

June 2016

Trondheim, Norway

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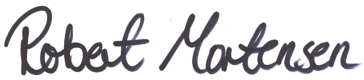
ACKNOWLEDGEMENT

I would like to thank supervisors Leif Lia and Kiflom Belete for all help and support during this project, and Geir Tesaker for his assistance in the laboratory.

My co-students, Ragnhild Hammeren and student María José de las Llanderas Ramirez were valuable company during the experiments.

I would also like to thank my supervisor at department of civil engineering (previously HiST, Institutt for bygg og miljø), Rolf Edvard Petersen for giving me the opportunity to study my Master's.



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SUMMARY

Hovedformålet med denne masteroppgaven er å avklare overtopping på fyllingsdammer ved skred i vannmagasin. Forsøk er modellert hvor man lager skred med varierende størrelse som sklir vinkelrett på et vannmagasin med skalert størrelse ca 420 x 900 meter, målestokk 1:190. Bølger som resulterer fra skredet brer seg gjennom vannet mot en demning i den ene enden, og skyller over med ulik høyde og ulikt volum. Skredet skjer bak en liten vegg, slik at det bare er indirekte, reflekterte bølger som kommer frem til demningen.

Størrelsene på skredene ble holdt forholdsvis små, fra ~40-250 kg, for enkelt å kunne eksperimentere, og som sådan er de bare representative for små og mellomstore overflateskred (0,25-1,5 mill. m^3) som raser ned i relativt store vannmasser. Bredden på skredet er ~halve bredden på vannmagasinet.

En rekke forsøk har blitt utført for å bestemme effekten av å endre følgende parameter:

- Skredstørrelse, både lengde og volum
- Fribord
- Damutforming

Disse parameterne er satt sammen i 40 ulike konstellasjoner og det er kjørt 211 forsøk som er logget. Med ulike parameter er rasets hastighet, bølgehøyde, overtoppingshøyde og overtoppingsvolum registrert, resultatene har blitt sammenlignet og noen verdier skalert opp til fullskala.

Med så mange forsøk som er sammenfallende, kan man konkludere med stor statistisk sannsynlighet at skredets hastighet er det viktigste parameteret for hvor mye overtopping som skjer, og i demningsdesignet er det fribord-parameteret som er viktigst.

Anbefaler at det kjøres nye forsøk med mer variasjon på skredets hastighet og mindre endringer i demningsgeometri, med fortsatt med to ulike fribord. Anbefaler også at skredet blir trukket fram fra den litte veggen som skjermer demningen fra direkte bølger.

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All figures are produced by Robert Mortensen, all pictures are taken by Robert Mortensen, except where otherwise stated

LIST OF TABLES

1. INTRODUCTION

A reservoir intercepting a landslide will produce waves that can have large consequences to the reservoir sidewalls, the dam itself and in case of overtopping could endanger human lives and activities downstream. NVE has been working to address risks associated with landslides and landslide generate wave action on embankment dams. This thesis' will contribute to developing a method to calculate effect of an avalanche generated wave overtopping over an embankment dam.

1.1. NORWAY

Rock falls and rockslides are among the most dangerous natural hazards in Norway, mainly because of their potential to generate tsunamis in fjords and lakes. In Western Norway more than 170 people have lost their lives due to rock avalanches and following tsunamis in the last 100 years (Jørstad 1968). According to an analysis by Norwegian Geotechnical Institute (NGI) and Norwegian Water Resources and Energy Directorate (NVE) about 50 % of all reservoirs in Norway have potential rock slide interception (International Centre for Geohazards 2010).

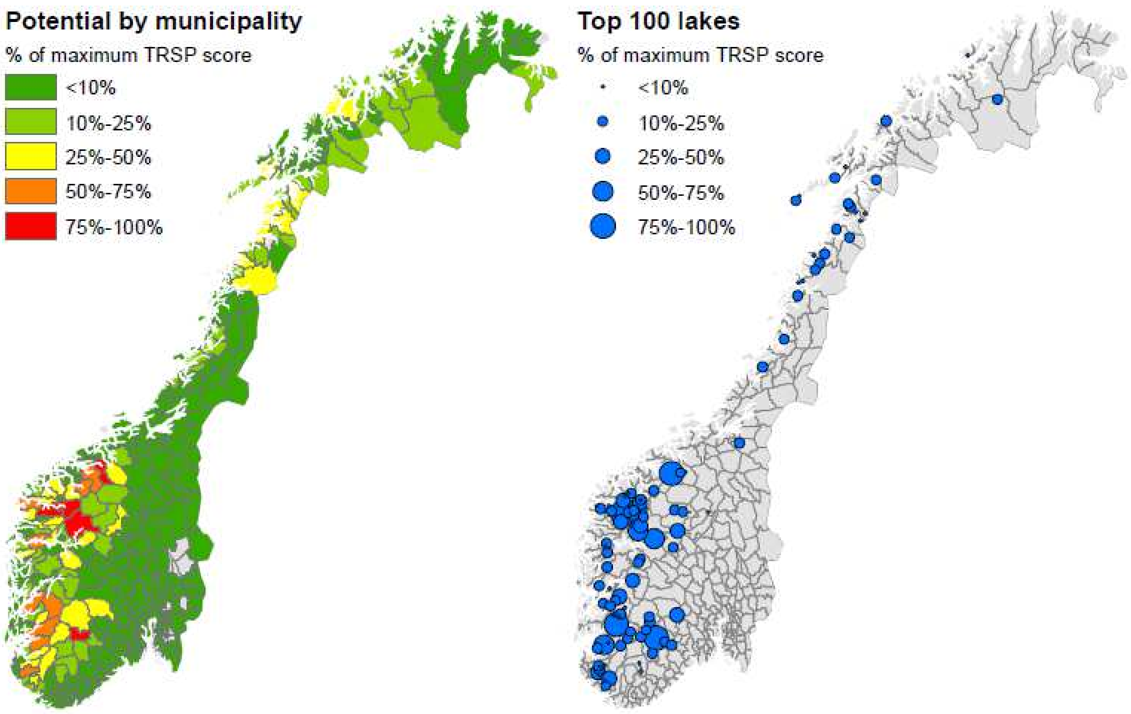


Figure 1 Geographical distribution of rock slide potential within Norwegian municipalities (left) and the 100 lakes with highest rock slide potential (right). TSRP= Topographic Rock Slide Potential) Potential expressed in percent of the maximum value for both maps (Romstad, Harbitz og Domaas 2009)

Figure 1 shows the top 100 lakes in Norway with potential for rock slide. The figure illustrates clearly that the most exposed areas in Norway is in Western Norway and some areas in Northern Norway (Romstad, Harbitz og Domaas 2009)

Of the 100 lakes with the highest risk 46 are hydropower reservoirs with NVE classified dams, Table 1. Important to note that the source has used the old classification, from before the newest changes, (NVE 3-2014), but for the purpose of this report they are directly transferred to the new classes.

Consequence Class	# reservoirs
1	7
2	9
3	15
4	15
Total	46

Table 1 Number of lakes (among the top 100) within different dam consequence classes (Romstad, Harbitz og Domaas 2009)

1.2. HISTORICAL LANDSLIDES

Historical landslides with catastrophic consequences are readily available in literature, and come from all over the world, from the 520 m high Lituya Bay mega-tsunami in Alaska in 1958 triggered by an approximately 30 mill. m^3 avalanche (Miller 1960), to the 200 m high Vajont Dam disaster in 1963, caused by an ~260 mill m^3 landslide killing ~2500 people (Ward og Day 2011), (L. Müller 1964), the 62 m Norwegian Tafjord slide in 1934 killing 34 people, caused by ~1,5-3 mill. m^3 landslide (NGI 2015), the 35 m high tsunami from the 1905 glacier collapse in Disenchantment Bay in Alaska (Lander 2013), the 10-57 m high 1792 Shimabara Bay mega-tsunami, killing 15448 people, caused by an earthquake that made ~500 mill. m^3 of Mount Unzen loosen, triggering a landslide with a following tsunami (Soloviev og Go 1974) and the 1971 disaster in Peru, where a small earthquake triggered a landslide that entered a lake above the small town of Chungar, causing a large amount of the water to topple over and down on the small town killing ~600 people (Davis 2008).

1.3. EARLIER STUDIES

The main earlier model studies are:

Müller looking at wave run-up and overtopping of dams (D. Müller 1995), where Müllers formula for wave run-up was established:

$$R = 1,25(\frac{H\pi}{h})^{5/4}(\frac{H}{L})^{-3/20}(\frac{90°}{\beta})^{1,5} * h \qquad \text{Formula 1}$$

R	Wave run-up height [m]
d	Water depth in front of wave run-up location [m]
β	Inclination of run-up plane [°]
H	Wave height in front of wave run-up location [m]
L	Wavelength in front of wave run-up location [m]

Kamphuis found an estimation of stable wave height (Kamphuis og Bowering 1970):

$$\frac{H}{d} = \frac{H}{d}(stable) + 0,35\ e^{-0,08(\frac{X}{d})} \qquad \text{Formula 2}$$

H	Maximum Wave height
x	Distance from point of impact
d	Depth of water

Marcello Di Risio, Giorgio Bellotti, Andre Panizzo and Paolo De Giralomo ran experiments with an elliptical slide, but with a slope of 1:3. They had some problems with reflecting waves and breaking waves (Di Risio, et al. 2009)

Patrick Lynett and Philip Liu did experiments with a spherical hemisphere sliding down a 1:2 slope, comparing with a numerical model, gaining a ±15 % error margin, which is fairly good. But they also compared a triangular block slide showing poor comparison with up to ±100% error, blaming trouble simulating a triangular slide in their numerical model (Lynett og Liu 2005).

Sælevik, Jensen and Pedersen at UiO did experiments on a fixed width slide avalanche with varying length and height of slide, with focus on the velocity fields. Among their findings were that slide height had less impact than slide velocity (Sælevik, Jensen og Pedersen 2009)

Heller and Spinneken ran experiments with subaerial landslides, running 144 experiments varying the slide Froude number, relative slide slickness and relative slide mass, deriving equations for maximum wave amplitude, wave height, wave period as well as propagation distance. The experiments are similar to the setup used in this thesis, see Figure 2, (Heller og Spinneken, Improved landslide-tsunami prediction: Effects of block model parameters and slide model 2013)

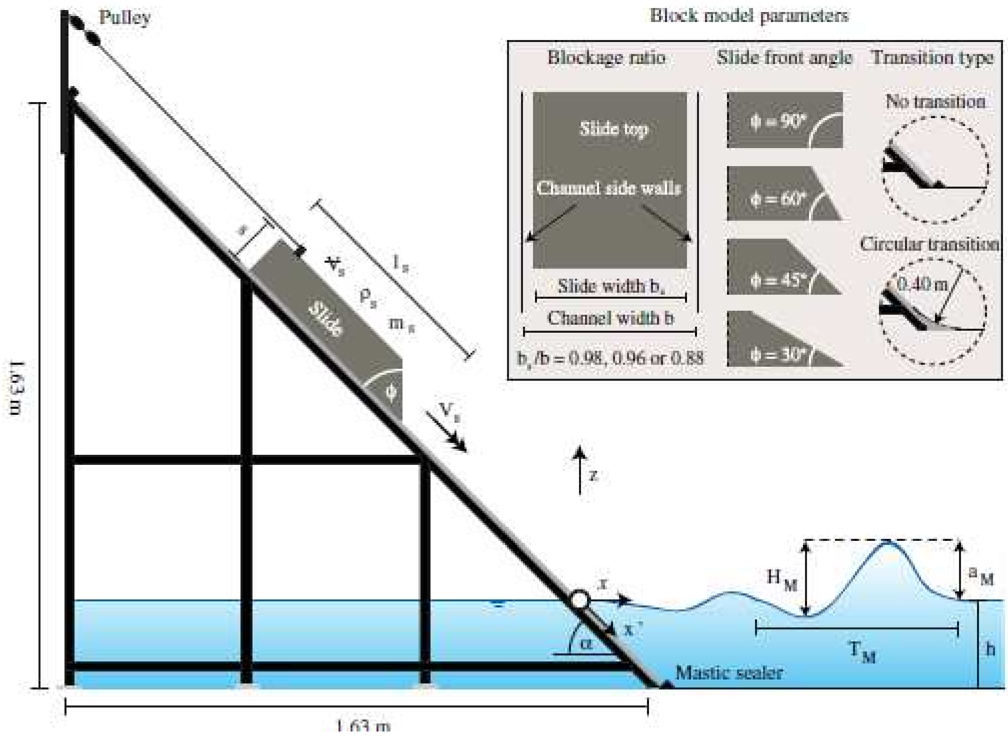


Figure 2 Model setup for Heller and Spinneken, 2013

1.4. MAIN OBJECTIVE

The main objective of this report is to look at overtopping of embankment dams due to waves caused by rockslides, with focus on the two strictest classifications of dams in Norway, class 3 and class 4.

Literature was reviewed to plan the experiments. Then a thorough physical model testing was run with different avalanche sizes, different water levels and different dam layouts.

The experiment was run by sliding a number of blocks down a slide, entering a reservoir at velocity and generating waves. The goal is to have an energy transfer from the sliding mass into the water transferred to water motion and water displacement by the sliding mass, with as little loss as possible. Each experimental setup has been run at least twice, and numbers taken from the results are often the average.

This report will first look at the experimental setup and the model build before looking at the results from the experiments and the following discussion.

2. EXPERIMENTS

The main objective of the thesis is to look at overtopping of embankment dams due to waves caused by landslides, with focus on the two strictest classifications of dams in Norway, class 3 and class 4.

In Norway, dams are divided into 5 classes after how large the consequences are if the dam fails. Class 0 is a dam with insignificant consequences (NVE 3-2014)

Consequence class	Living units	Infrastructure	Environment and property
1	<1	Damage to less trafficked roads or other infrastructure	Damage to environmental values or property
2	1-20	Damage to moderately trafficked roads or other infrastructure with consequences for life and health	Large damage to important environmental values or large damage to property
3	21-150	Damage to heavily trafficked roads or other infrastructure with large consequences for life and health	Large damage to especially important environmental values or especially large damage to property
4	>150		

Table 2 Dam consequence classes, Veileder til damsikkerhetsforskriften (NVE 3-2014)

These different dam classes have different specifications.

Consequence class	Freeboard above Highest Regulated Water Level (HRWL)
Class 3	4,5 meter
Class 4	6 meter

Table 3 Freeboard for different consequence classes, Veileder for fyllingsdammer (NVE 2012)

Experiments were conducted at the waterways lab at the Department of Hydraulic and Environmental Engineering using an existing model from previous master's thesis' (Sunniva Lorås 2014, Joakim Nordberg Sundby 2014, Matteo Bolzoni 2015)

2.1. EXPERIMENTAL SETUP

Based on a number of historical slides, Table 4, an experimental setup was chosen with 4 different avalanche sizes, focusing entirely on subaerial slides.

No	Name	Vol [mill. m3]	Height	Length
1	Verkilsdalen, Rondane	15	675	1600
2	Tjelle, Langfjorden	15	750	2000
3	Melkevoll, Olden	0,25-0,5	480	750
4	Rørsetura, Oterøya	2,5	650	1100
5	Gravem, Sunndal	0,3-0,5	900	1500
6	Sørdalen, Vanylven	2,5-5	675	1500
7	Urdabøuri, Vinje	16-23	470	1350
8	Erdalen, Stryn	8-12	460	1010
9	Hjelle, Stryn	0,5	730	575
10	Bjørkum, Lærdal	0,15-0,3	400	550
11	Furuneset, Tafjorden	0,5-1	900	1500
12	Langhammeren, Tafjorden	2-3	850	1500
13	Grande, Geirangerfjorden	0,5-0,8	1350	1450
14	Hysket, Geirangerfjorden	1,5-3	550	1125
15	Stølaholmen, Fjørland	3-4	420	960
16	Berrføttene, Fjærlandsfjorden	50-100	1000	4000
17	Frykkjelen, Fjærlandsfjorden	2,5-3	950	2200
18	Kubergan N, Tromsø	8	375	700
19	Kubergan S, Tromsø	5	350	640
20	Nakkevatnet, Lyngen	15-25	900	2350
21	Grøtlandsura, Salangen	6-12	500	1200
22	Skjærsura, Valldal	12-15	1000	1750
23	Hellaren, Grovfjorden	100-150	900	4000
24	Gumpedalen, Sørreisa	30-50	720	2200
25	Store Urdi, Jotunheimen	15	400	1400

Table 4 Properties of a number of Norwegian rock slides (NGU 2001)

The blocks used in the experiments to simulate different landslides were of a similar size and form, given in Table 5 Block sizes. The only blocks differing was blocks 7 and 8 which has a sloped end, see Figure 8.

Block #	Block size [cm]	Block volume [cm^3]	Weight [kg]	Density [kg/dm^3]
1	17x45x50	38250	42,3	1,106
2	17x45x50	38250	42,4	1,108
3	17x45x50	38250	42,3	1,106
4	17x45x50	38250	42,4	1,108
5	17x45x50	38250	46,5	1,215
6	17x45x50	38250	46,3	1,210
7	17x45x50	38250	37,7	0,986
8	17x45x50	38250	37,6	0,983

Table 5 Block sizes

Scaled/full size	1 block	2 blocks	4 blocks	6 blocks
[mill. m3]	0,26	0,5	1,0	1,5

Table 6 Scaled blocks into full size avalanches

The experiment was run by sliding a number of blocks down a slide, entering a reservoir at velocity and generating waves. This avalanche mechanism has a 100 cm wide slide, lifted at ~40°. Rectangular blocks are attached to each other with chains on lifted on to a hook, see Figure 12. When the avalanche is triggered, the hook releases the blocks, which slide into the water at a velocity of ~1,8-2,7 m/s, see Table 10 and Table 11.

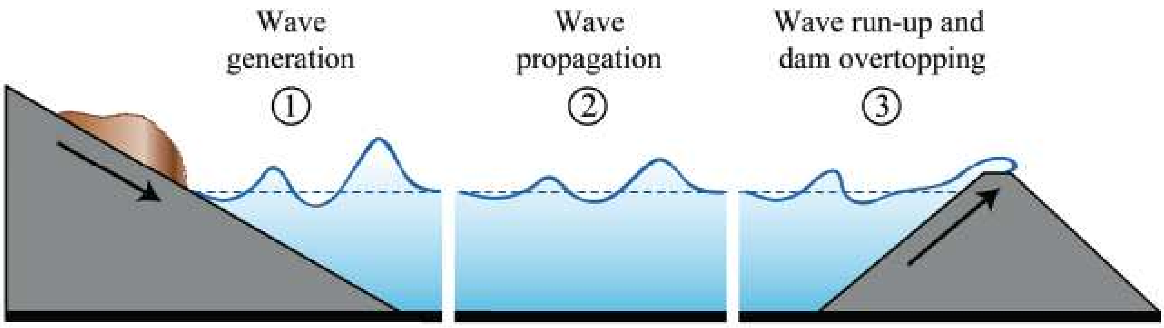


Figure 3 The three phases of an impulse wave above a horizontal reservoir bed: 1- slide impact with wave generation, 2- Wave propagation with wave transformation and 3- impact and run-up with load transfer to dam and possibly overtopping (Heller, Hager og Minor, Landslide generated impulse waves in reservoirs- Basics and computation 2009)

The slide is placed next to a small wall shielding the dam from direct waves from the slide, only indirect, reflected waves reach the dam.

The reservoir has planar sides of water-resistant plywood, about 450 cm long and 170 cm wide at the bottom, 224 cm wide at dam crest level, and about 33 cm deep.

Scale of the model was 1:190, the avalanche entered the water perpendicular to the length of the reservoir, sending waves into the opposite side, which reflected and was directed towards the dam, passing nine sensors gauging wave height. There were wave-breakers at the other end, so that reflecting waves from the other side was ignored See Figure 4 Model sketch planar view, with a section of the dam on top.

The waves flowing over the dam crest was measured by ultrasonic sensor, and collected in tubs and volume was measured.

In this report, Figure 4 is used for orientation, looking from the slide up to dam. This means “left” is the side with sensors 1, 4 and 7, while “right” is the side with sensors 3, 6 and 9.

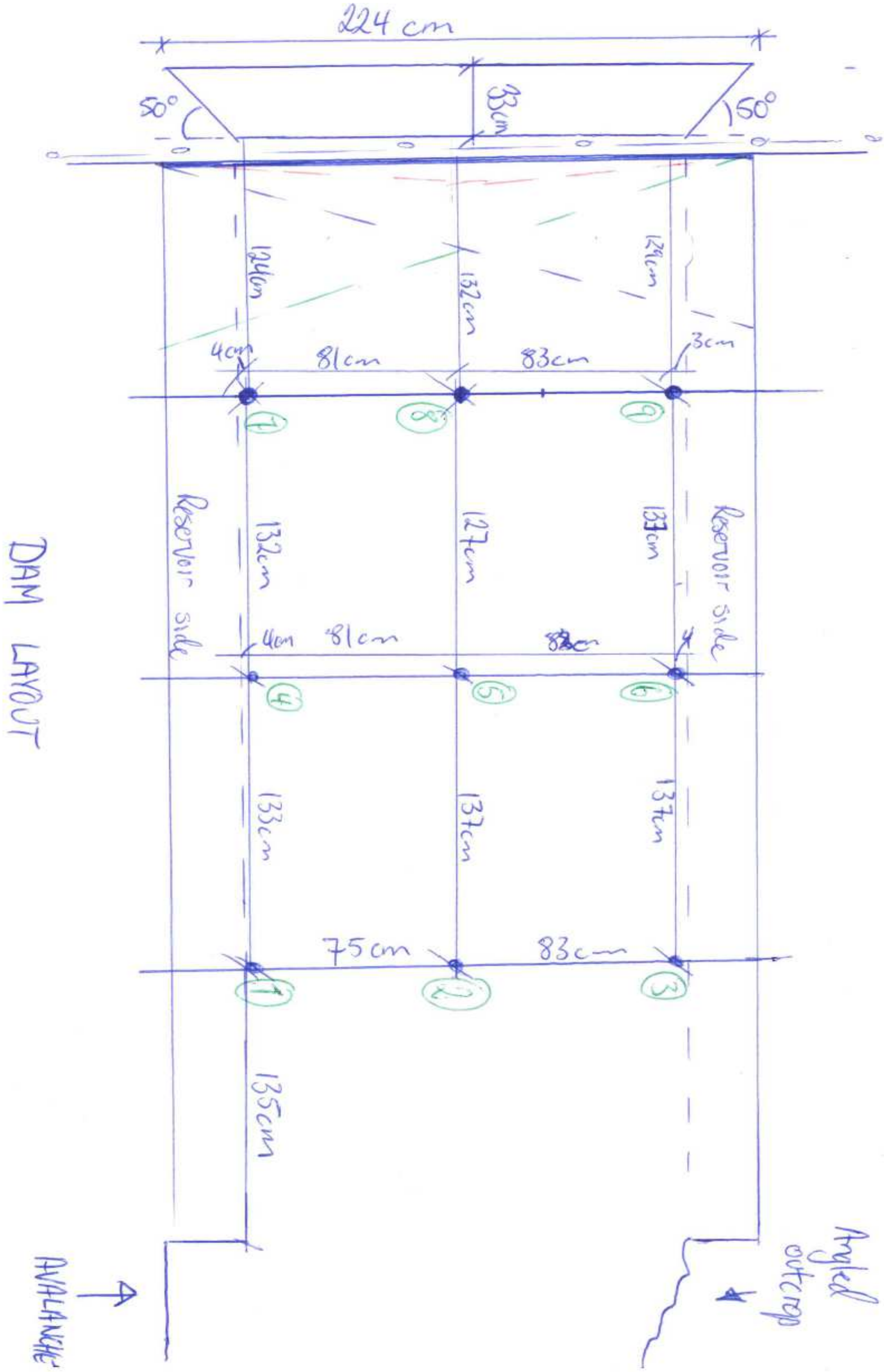


Figure 4 Model sketch planar view, with a section of the dam on top.

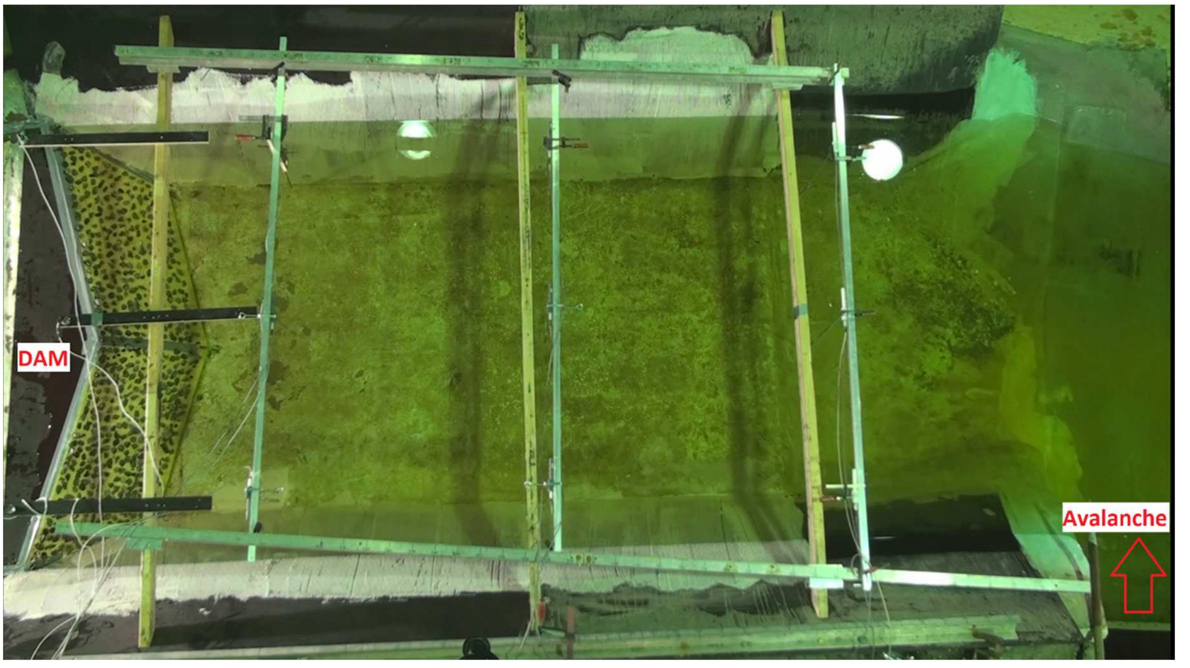


Figure 5 Model overview, here with a chevron dam.

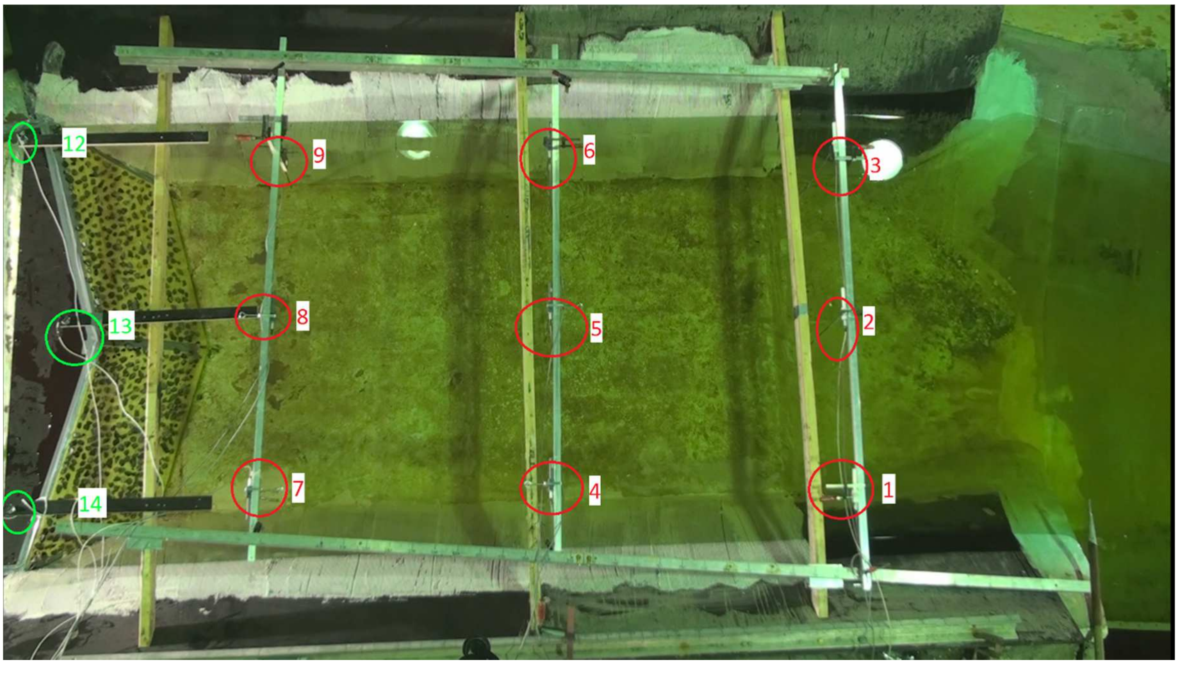


Figure 6 Sensor placement

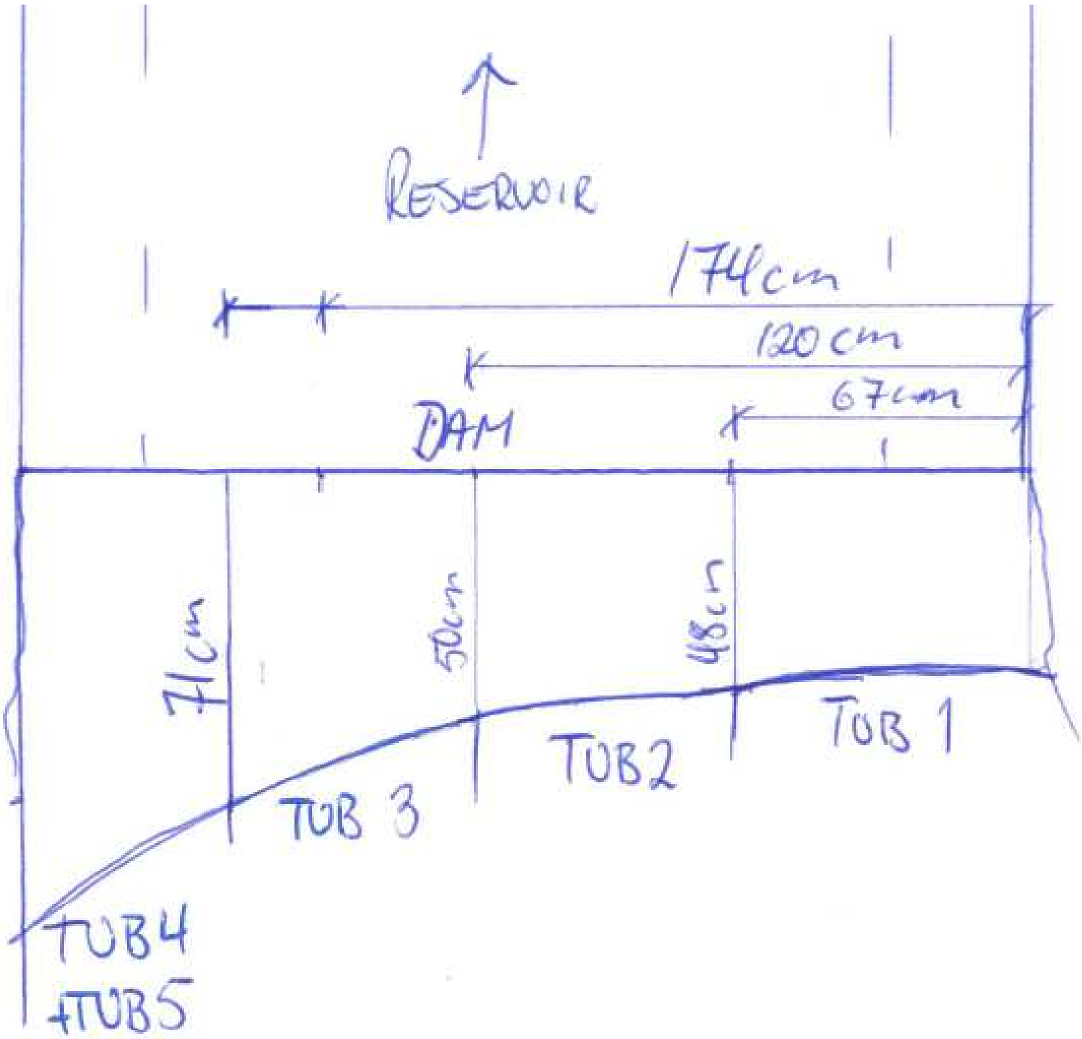


Figure 7 Overtopping measurements

The avalanche has a sloped front, to push the water up and out, to simulate an avalanche that has a smaller front and larger body. Waves generated by rock-avalanches depend on the volume, frontal area shape, permeability and dynamics of the sliding masses, as well as the water depth of the reservoir (Blikra, et al. 2005).

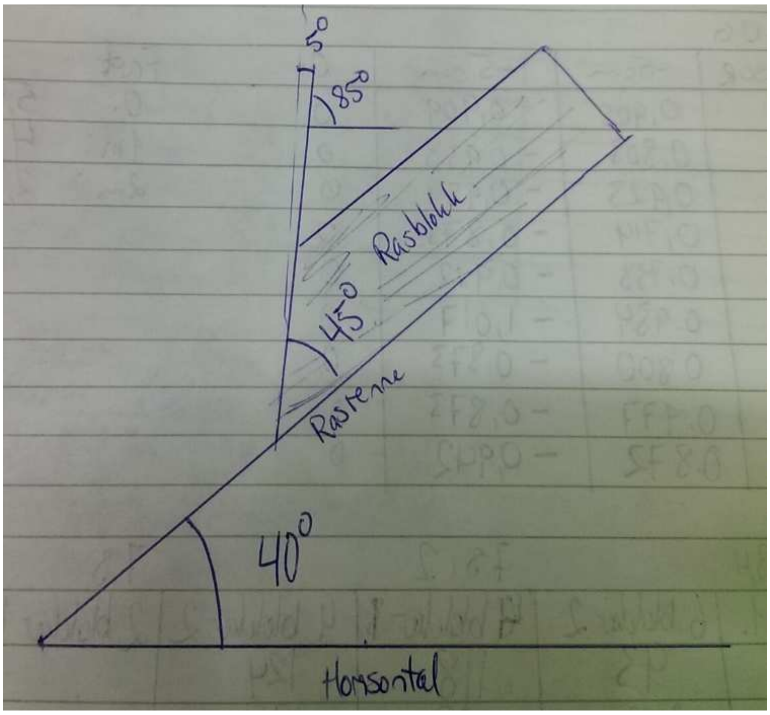


Figure 8 Drawing of block 7 and 8.

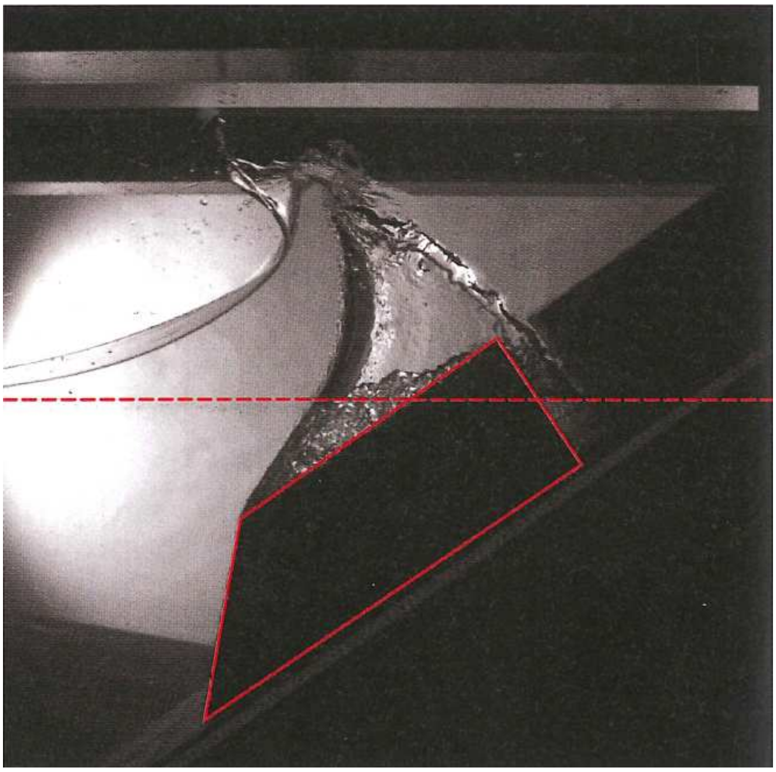


Figure 9 Wave created by an angled front. Dashed line indicates the water surface before avalanche (NGI 2015)

Straight dam 1:1,5	NVE dam class 3	1 block	2 blocks	4 blocks	6 blocks
	NVE dam class 4	1 block	2 blocks	4 blocks	6 blocks
Rotated dam, clockwise, 1:1,5	NVE dam class 3	1 block	2 blocks	4 blocks	6 blocks
	NVE dam class 4	1 block	2 blocks	4 blocks	6 blocks
Rotated, counter clockwise, 1:1,5	NVE dam class 3	1 block	2 blocks	4 blocks	6 blocks
	NVE dam class 4	1 block	2 blocks	4 blocks	6 blocks
Chevron dam, 15°, 1:1,5	NVE dam class 3	1 block	2 blocks	4 blocks	6 blocks
	NVE dam class 4	1 block	2 blocks	4 blocks	6 blocks
Chevron dam, 15°, 1:1,5, rough sides	NVE dam class 3	1 block	2 blocks	4 blocks	6 blocks
	NVE dam class 4	1 block	2 blocks	4 blocks	6 blocks

Table 7 Number of experiments

As stated in Table 7 Number of experiments, there are two different water levels, four different avalanches and five different dam-layouts, resulting in 40 different setups. Each of these setups has been run at least twice, some three or four times.

The data for the wave sensors are not dependent on the dam layout, so that part of the experiment has been run at least 10 times for each water level and avalanche size. Although the wave propagation is outside this thesis' scope there is mention of wave propagation in chapter 4.5.

During each experiment slide velocity, wave height, overtopping height and overtopping volume were measured and documented.

2.2. MODEL SETUP

Figure 10 Photo of reservoir. The avalanche slide is just visible to the near left. Nine wave sensor partially submerged in the water, and the chevron dam in the back.

Figure 11 Model in the waterways lab. Slide to the left, wave breakers not visible at the bottom. 9 wave sensors, control room booth and not visible in the back, overtopping tubs and measuring sensors.

Figure 12 Avalanche slide. Slide width= 100 cm, width of avalanche 2x 45 cm. With 6 blocks there is about 75 cm from bottom of blocks to the water, 4 blocks 135 cm and with 1 or 2 blocks it is 195 cm from bottom of the blocks into the water. With any number of blocks it is 245 cm to the top of the blocks/end of avalanche.

All dams had stones 16-35 mm glued on to simulate roughness. The effect of these stones are debatable, as the depth of the reservoir is ~33 cm, and the freeboard of the dams used are 2,4 cm and 3,2 cm. The wave also travels along the side of the reservoir. One setup applied roughness to the reservoir sides, although there was no significant effect. This is further discussed in chapter 4.7.

Figure 13 Dam model 1:2

Figure 14 Dam model 1:1,5

Figure 15 Dam model, rotated dam 1:1,5. It has stones on both sides so it can be rotated clockwise and counter-clockwise

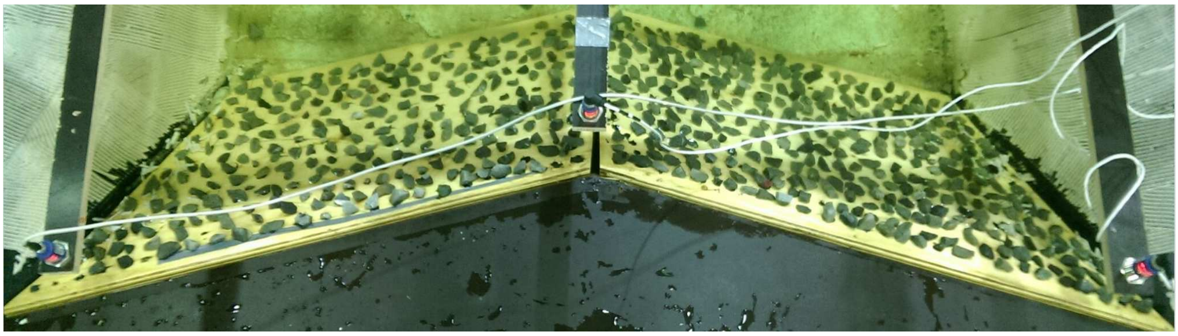


Figure 16 Chevron dam. 15 degrees on each end, 1:1,5. Also visible in this picture are the three ultrasonic overtopping sensors placed above the dam crest.

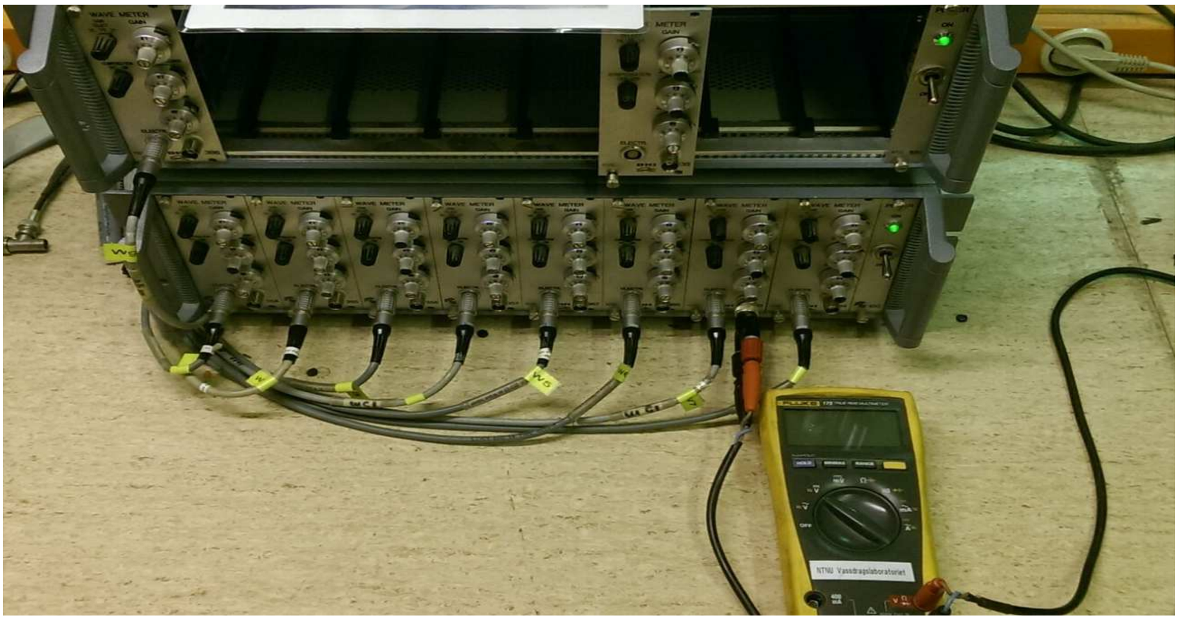


Figure 17 Wave channels, sensors 1-9, for calibration

2.3. MEASUREMENT DEVICES

2.3.1. Wave sensors

The model has nine wave sensors used to record wave height, see Figure 6 Sensor placement and Figure 18 Wave sensor submerged in water. These are of the type DHI Wave-meter 102E. The wave sensor work by electrical conductivity. For calibration the resistance is measured at the desired water level (scaled 4,5 meters and 6 meters), the rods are then elevated 50 mm to simulate wave action and the conductivity is measured again. Then the rods are lowered 50 mm from water level and conductivity is measured and noted again. The resulting numbers are a calibration measurement for volt against 50 mm.

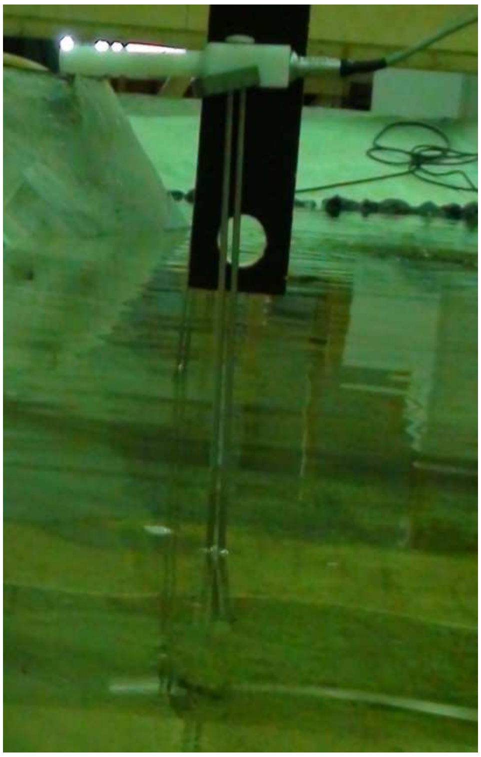


Figure 18 Wave sensor submerged in water

2.3.2. Overtopping height

There are three ultrasonic sensors (Microsonic, art.nr 057059) measuring the overtopping electronically. These are placed at the dam crest, numbered 12-14 in Figure 6 Sensor placement. These are calibrated to 210 mm/10 V.

Figure 19 Dam overtopping. The ultrasonic sensors are visible top left and top middle

2.3.3. Velocity

For measuring the velocity there is a rotational sensor, measuring the position of the avalanche at any given time by measuring the length of chord pulled out. Calibrated every day by measuring the chord in original/zero position, pulling out 1 meter, measuring voltage, pulling out another 1 m and measuring again. This potential and measured distance was then used to calculate speed in m/s.

2.3.4. Overtopping volume

Lastly there is an ultrasonic sensor for measuring the volume of the overtopping tubs. This is done manually and noted.

Figure 20 Overtopping tubs. The tubs has a filling curve with measured mm to liters. Measuring the water height and plotting against the filling curve gives volume of water

Tub 5 is on top, tub 4 to the left, with 3 and 2 following, with tub 1 on the right, see Figure 7.

2.4. DAM GEOMETRY

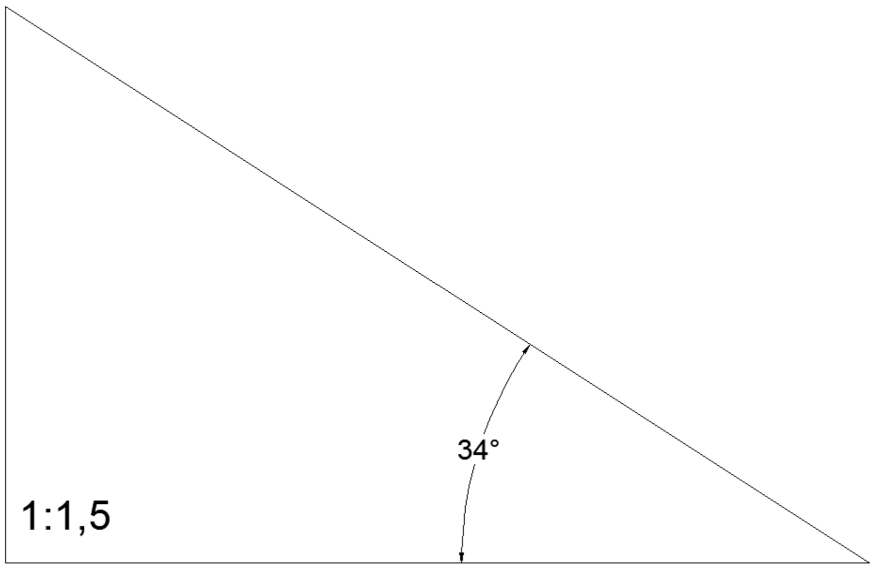


Figure 21 Straight dam inclination, sectional view

Figure 21 show a sectional view of the straight dam. All dams are ~221 cm, spanning the width of the reservoir.

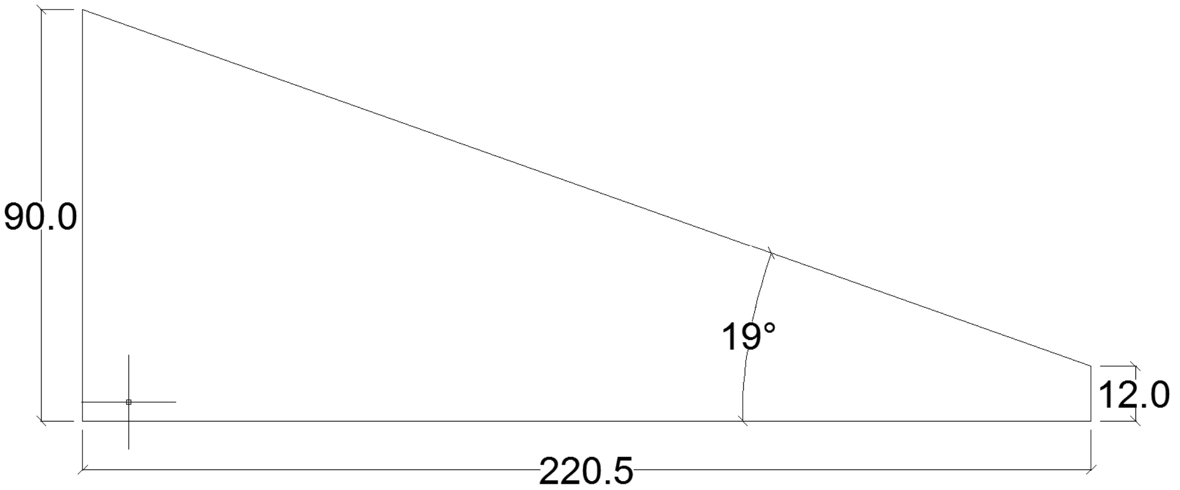


Figure 22 Plan view of clockwise turned dam. The counterclockwise turned dam is the same, only mirrored. Dam inclination is 1:1,5 perpendicular to the dam front.

The clockwise and counter-clockwise turned dam was designed to overcome the reflected wave coming in around sensor 4.

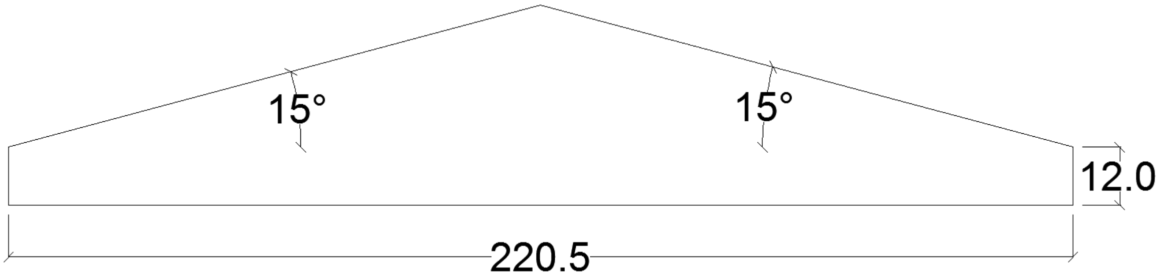


Figure 23 Plan view of chevron dam top/crest. Dam inclination perpendicular to the dam front is 1:1,5

The chevron dam was designed on the background of the layout of 24 existing dams in Norway, chosen from "Klimaendring og damsikkerhet: En pilotstudie av 24 dammer" (NVE 2014). The map-coordinates and satellite photographs of the dams are included on the thumb-drive in the document Damkurvatur.pdf (Mortensen 2016). Most of the dams in the study are straight, but as that alternative was already run, the chevron design was chosen as the second most popular geometric design.

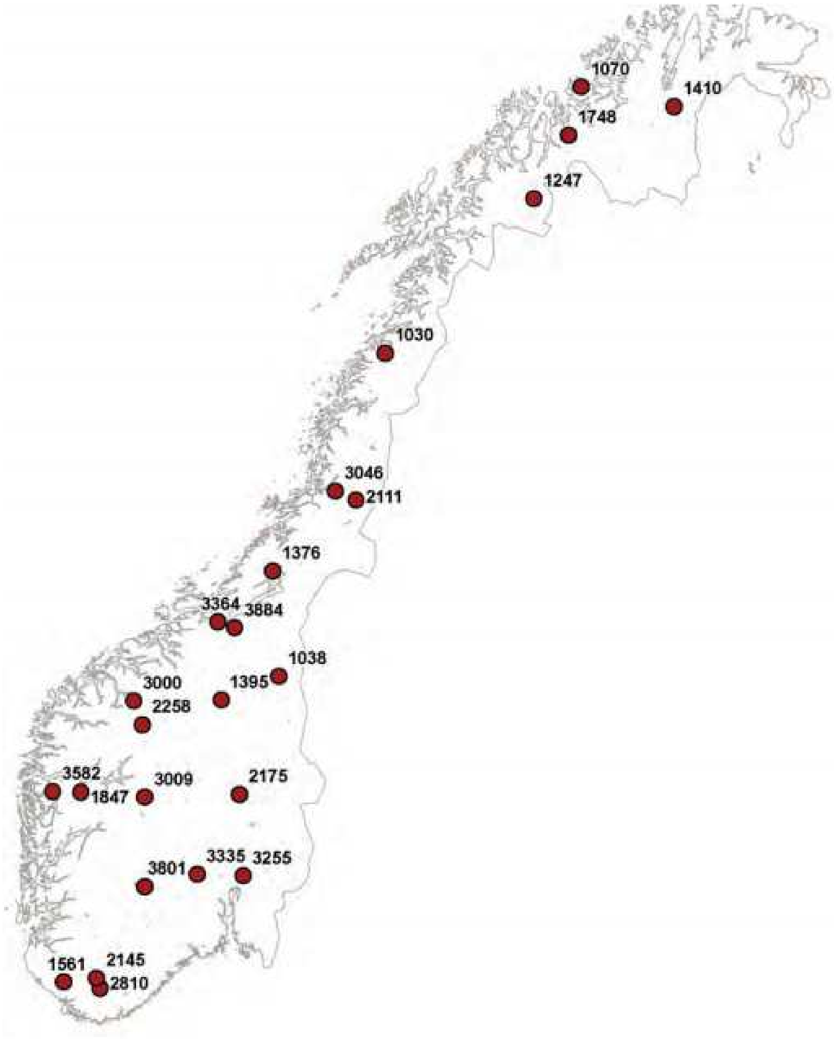


Figure 24 Location of dams used in the pilot study (NVE 2014)

2.5. FROUDE'S MODEL LAW.

When planning a model study, the problem arises regarding the use of scale. Scaling ratios, also called laws of similitude are derived by looking at the relation between different forces, such as inertial, gravitational, viscous and surface tension, (Lysne u.d.). There are several model laws, the most common are Froude's, Reynold's, Euler's, Weber's and Mach's. They are dependent on which forces is prevalent in the model study. In this model study gravity is the prevalent force, and as such it is Froude's model law which is in effect.

All values in this report are unscaled as most of them are used for comparison between each other.

But for the final part, giving volume of overtopped water per meter dam scaling is needed. The following table gives the most common scale ratios for scaled models, as per Froude's model law, (Lysne u.d.).

L=scale factor	**Geometric similarity**	**Conversion factor for common scale ratios**		
		1:25	1:50	1:100
GEOMETRY				
Length	L_r	25	50	10^2
Area	L_r^2	625	2500	10^4
Volume	L_r^3	15.625	125 000	10^6
KINEMATICS				
Time	$L_r^{1/2}$	5	7,07	10
Velocity	$L_r^{1/2}$	5	7,07	10
Acceleration	1	1	1	1
Discharge	$L_r^{5/2}$	3 125	17 675	10^5
DYNAMICS				
Mass	$(L^3\rho)_r$	15 625	125 000	10^6
Force	$(L^3\rho)_r$	15 625	125 000	10^6
Pressure	$(L\rho)_r$	25	50	10^2
Impulse	$(L^{7/2}\rho)_r$	78 125	883 750	10^7
Energy	$(L^4\rho)_r$	390 625	6 250 000	10^8
Effect	$(L^{7/2}\rho)_r$	78 125	883 750	10^7

Table 8 Froude's law. Table giving the most common scale ratios for scaled models

The Froude's number can be scaled with: $F_r = \frac{v_i}{\sqrt{gd}}$, where v_i is the measured velocity of the avalanche along the slide plane on impact and g is gravity and d is water depth (Sælevik, Jensen og Pedersen 2009). Using an average speed of ~2,2 m/s, gives Fr=1,22, giving a supercritical flow.

3. PROCEDURE AND TEST

All data from the experiments was collected by a program, Agilent Measuring Manager. This program is calibrated to sample data from all nine wave sensors, the velocity sensor on top of the slide and the three ultrasonic overtopping sensors.

The sampling rate is 200 Hz, meaning there are 200 data points per second. The data series are not timestamped, but numbered. To change the series from numbering to timestamped, simply take the number and divide by the Hz. Such that for instance number 200 is 1 second.

All sensors register Volts. Before running the experiment, the voltage is calibrated, daily, by first filling the reservoir to the desired level and resetting the voltmeter to 0V. Then the sensors are lowered 5 cm and the currency is measured (say 0,800 V). The sensors are then lifted 10 cm (5 cm above zero-level) and the currency is measured again (say -0,800V). For that day, that sensor is calibrated from *V* to *mm* by using the formula:

$$Waveheight = V\ x\ \frac{50\ mm}{daily\ calibration\ value}$$

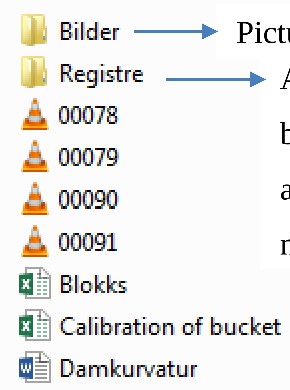
The velocity sensor is calibrated by measuring at 0 cm, 100 cm and 200 cm pullout, giving 1,33 V/m or ~0,75 m/V.

The ultrasonic sensors are calibrated to 210mm/10V or 21 mm/V.

40 experimental setups were conducted, see Table 7 Number of experiments page 12, varying number of blocks, water level and dam design. A total of 211 experiments were run, some in cooperation with students Ragnhild Hammeren and María José de las Llanderas Ramirez.

All dams in this thesis has an inclination of 1:1,5, equaling an inclination angle of ~34°, and all experiments has a scale of 1:190.

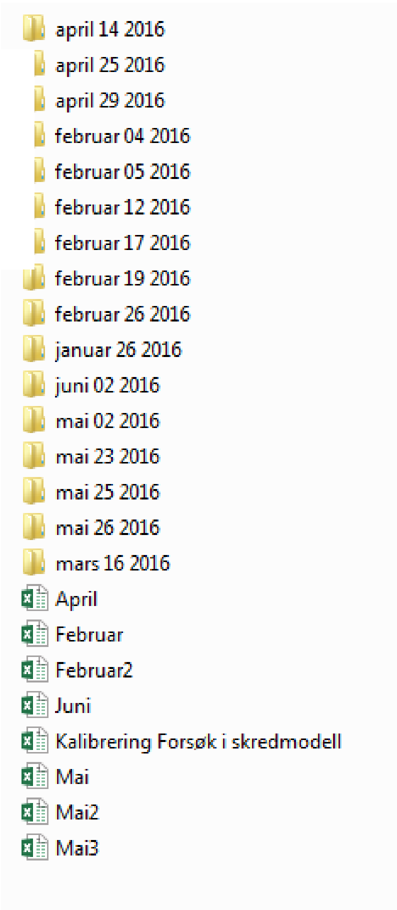
A thumb-drive is enclosed with the copy to supervisor Leif Lia with all the raw data and treated data as well as video from most experiments.



Pictures from the experiments

All readings from the sensors, sorted by date. The files named after months are collected readings for those months, calibrated and transformed

The movies are top down from the crane, and focus on the dam. Rest of the movies are on separate thumbdrive as the files are too large.



4. DATA ANALYSIS AND RESULTS

4.1. TYPICAL WAVE PATTERN

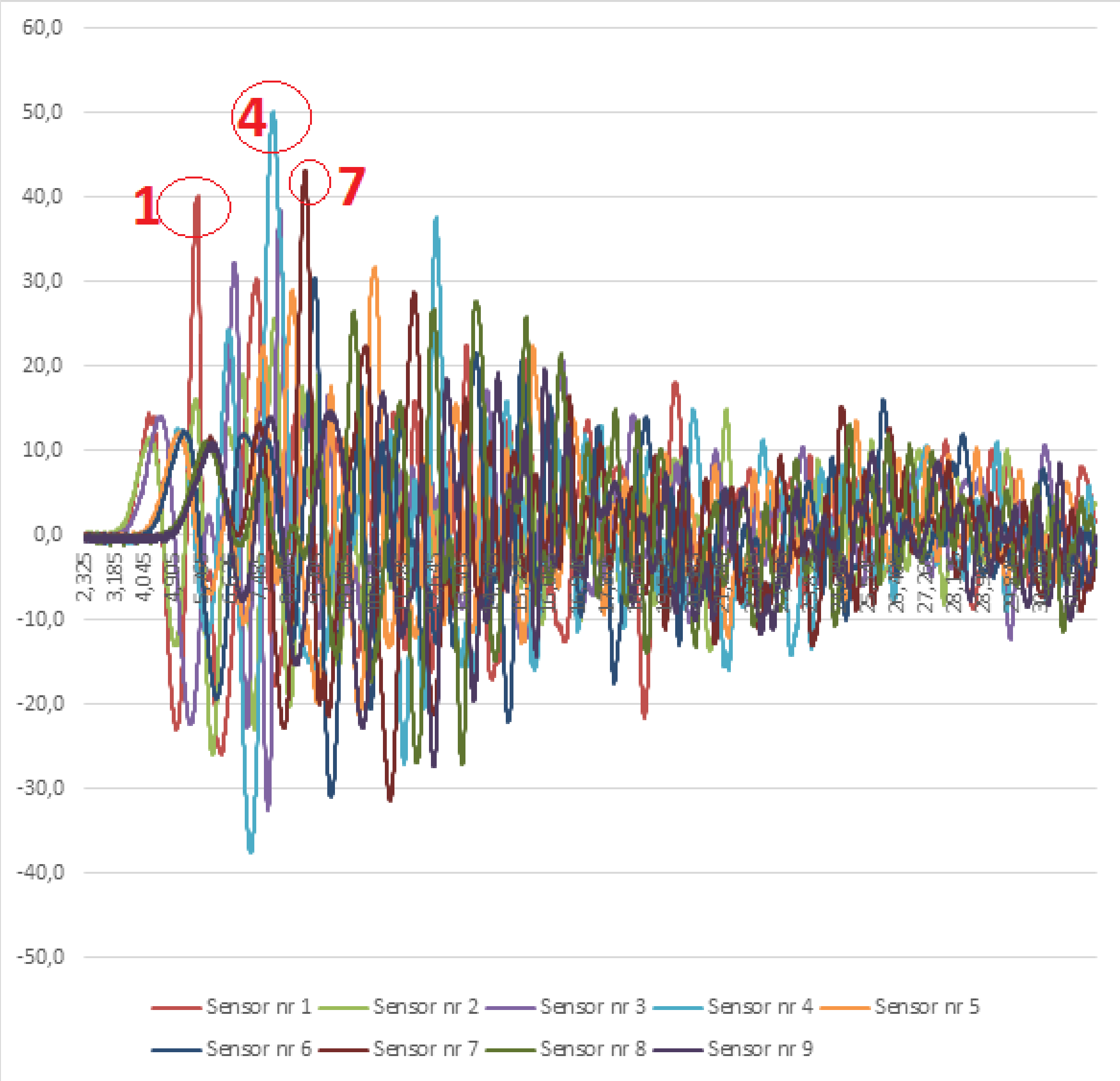


Figure 25 Typical wave pattern (1 block 4,5 meters, chevron dam)

The wave pattern is only dependent on number of blocks and water level. With more blocks and more water the waves are higher, and fewer blocks and lower water level gives smaller waves.

Notice that it is not the first, but the second or third wave that is the largest, while the second wave usually has the largest trough.

But the wave pattern is partly outside the scope of this master's thesis. What is interesting is the three largest waves, which is sensors 1, 4, and 7. All experiments have this pattern, that the waves are largest near the left wall of the reservoir. This is probably due to a combination of the placement of the avalanche slide, a small retaining wall placed near the slide, and the angle of the reflecting reservoir side on the right side of the reservoir.

The significance of this is that whatever layout of dam has been used, the place with the largest overtopping is the left hand corner, sensor 14 on Figure 6 Sensor placement.

4.2. Typical overtopping pattern

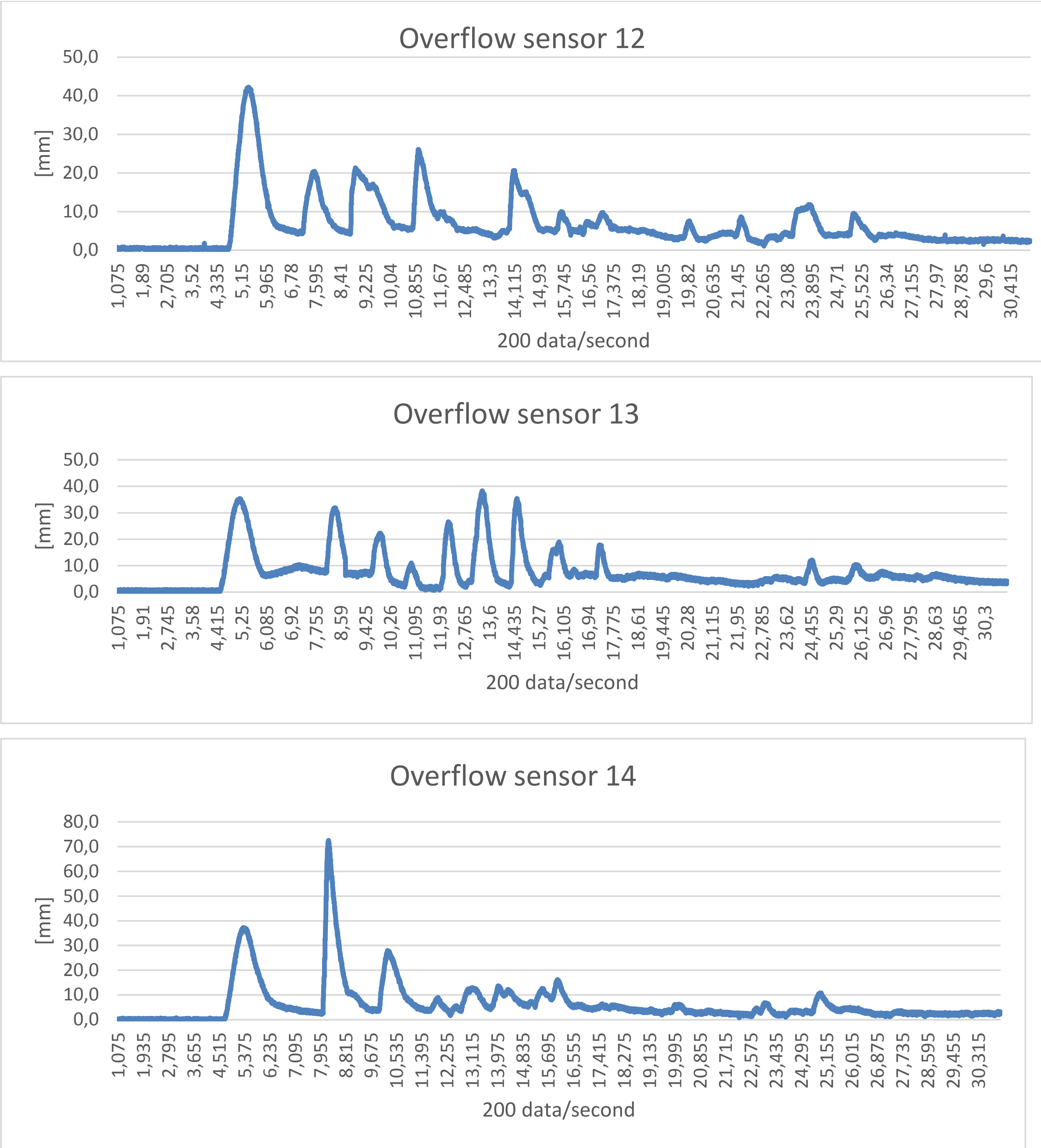


Figure 26 Graph showing overtopping for 4 blocks, 4,5 meters and chevron dam with rough sides.

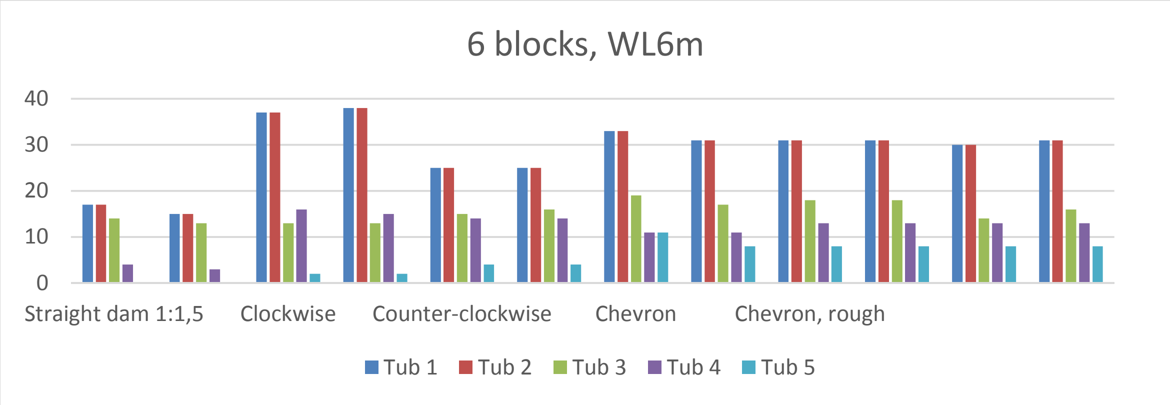
Sensor 14 is the one in the left corner, with a overtopping of ~70 mm. Sensor 12 in the right corner has an overtopping of ~43 mm while the sensor in the middle of the dam, sensor 13, has an overtopping of ~40 mm max.

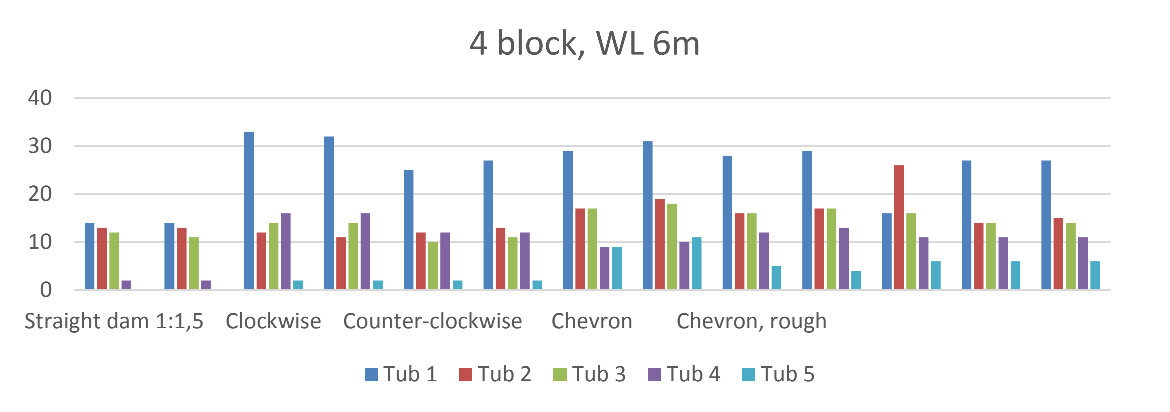
The pattern from the experiments is that the sensors closest to the left wall of the reservoir have the largest waves, and the corresponding overtopping sensor has the highest overtopping, and the corresponding overtopping tub has the largest volume of water, see Figure 7 and Figure 20, pp.11 and 20.

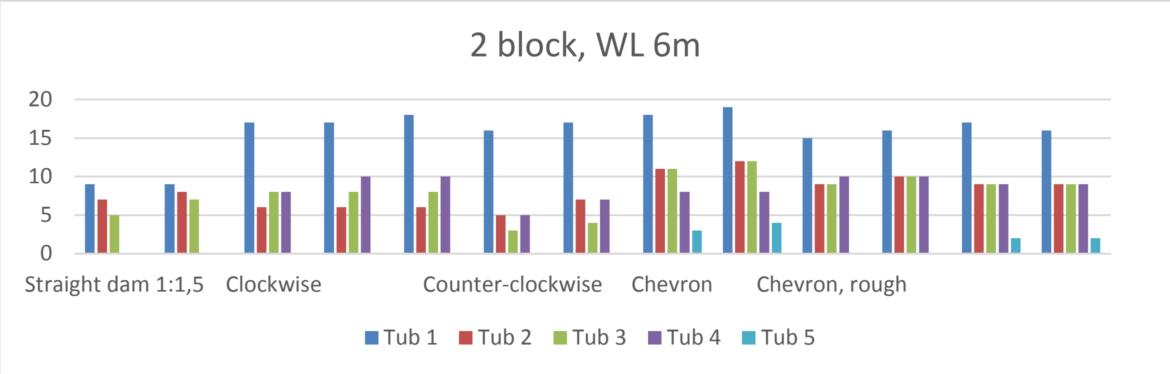
This overtopping pattern is typical for all dams and both water levels and avalanches of all sizes, although the numbers are different the pattern is the same.

4.3. LRWL

LRWL is for the strictest dam class, consequence class 4, 6 meters freeboard.







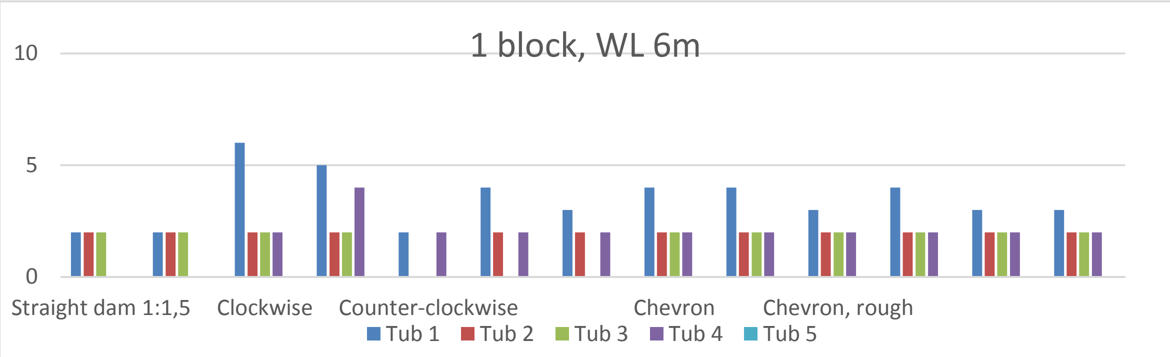


Figure 27 Graphs showing overtopping [liters] for different avalanche sizes and dam designs for LRWL

Observe the small difference between chevron and chevron rough, which is before/after applied roughness, especially in tub 1, which is the leftmost tub. The clockwise turned dam “traps” the water that flows along the reservoir, and is easily the dam design that gives the highest overtopping in tub 1 and 2. But the chevron design traps water in both ends and has the largest overtopped volume.

For the 4 block-avalanche the third chevron rough experiment, there was a faulty connection between tub 1 and 2, allowing water to flow from tub 1 into tub 2, that is why the tub 2 is much higher than for the other results. The total volume is correct, and the overtopping height is correct.

In Figure 28, next page, it is easy to see that the chevron dam is the most susceptible to overtopping, due to “trapping” the water in both ends. The clockwise turned dam also traps a lot of the water, but it does not trap in both ends, such that the total volume of water is less, even though there is more water in tub 1.

For the LWRL, the 1 block rock slide has very little overtopping, almost a quarter of the total volume for 2 blocks, even though the slide is only half as big.

In chapter 4.6 the height of overtopping is further discussed.

Figure 28 Graphs showing total overtopping [liters] for different avalanche sizes and dam designs for LRWL

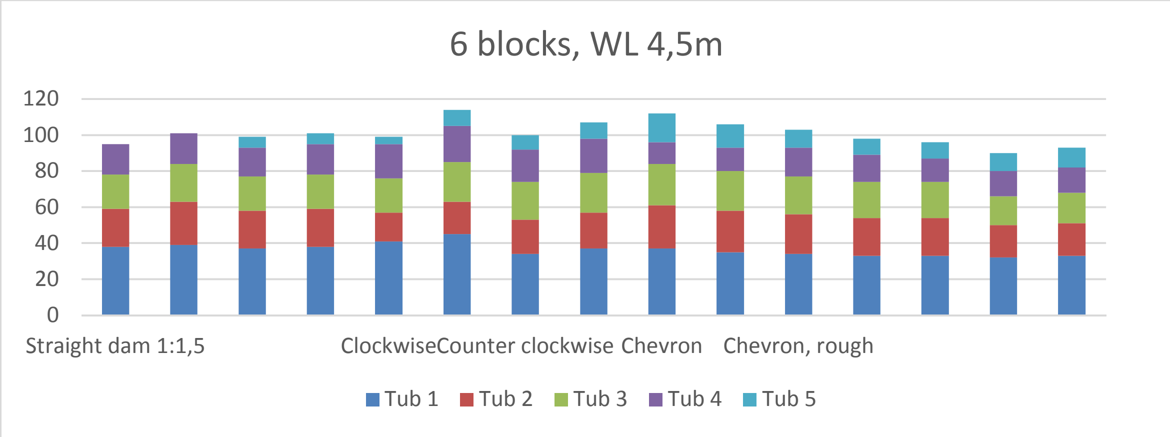
4.4. HRWL

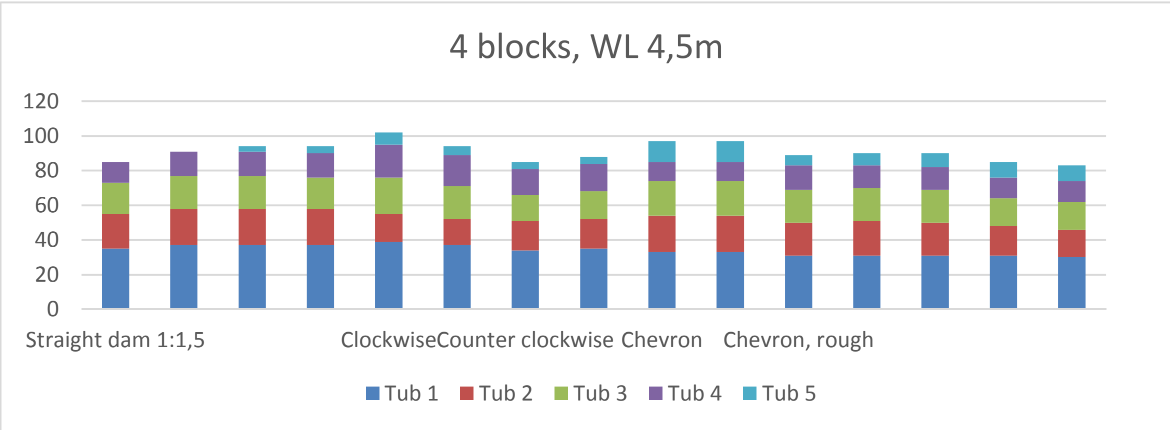
HRWL is for dam consequence class 3, 4,5 meters freeboard.

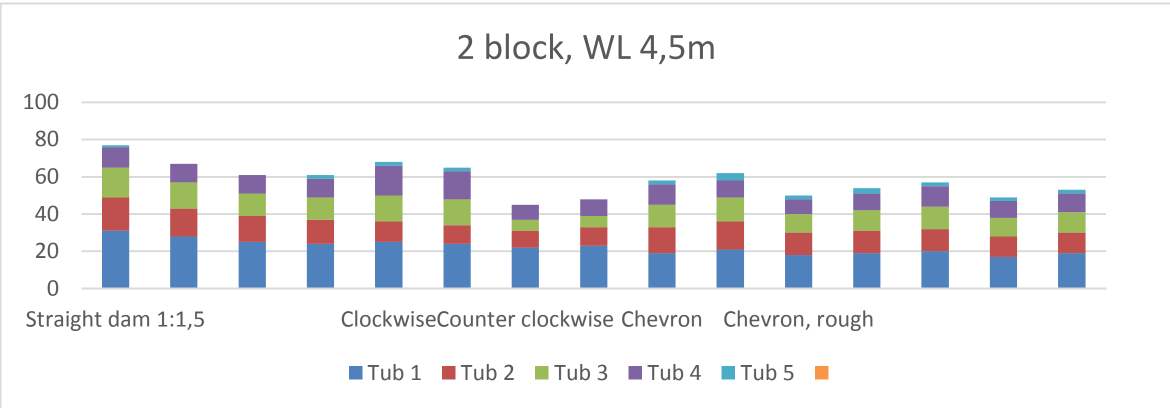
Figure 29 Graphs showing overtopping [liters] for different avalanche sizes and dam designs for HRWL

For HRWL we see the same pattern as from LRWL, that the clockwise turned dam gets the highest overtopping volume in tub 1..

The overtopping is generally higher, and higher than the increased water level alone should account for. This indicates that the freeboard is a very important parameter for dam safety and avoiding overtopping, even more so than the second most important feature being the dams geometry in the plane.







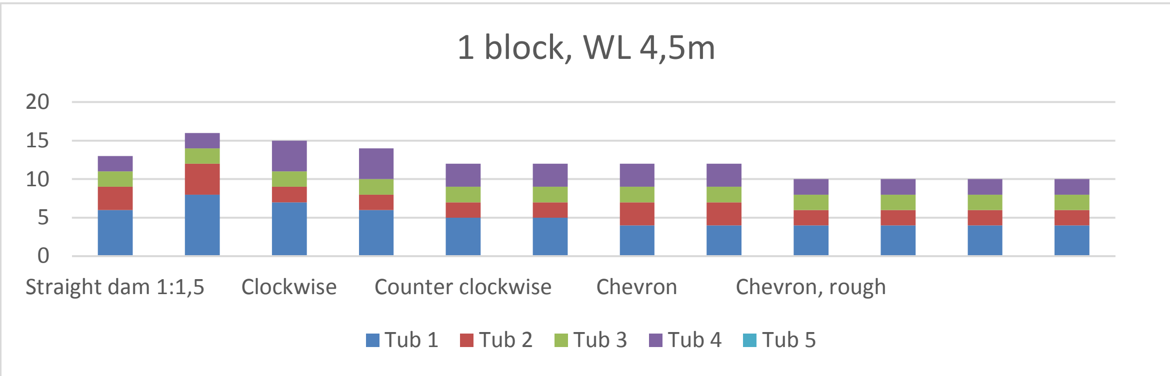
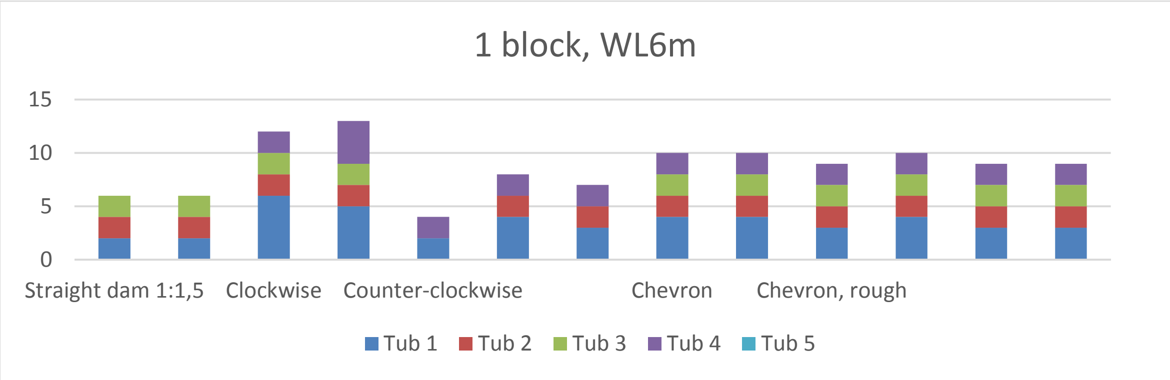


Figure 30 Graphs showing total overtopping [liters] for different avalanche sizes and dam designs for HRWL

We see some of the same patterns here as in LRWL. For HRWL there is generally more water in all experiments, again signifying that freeboard is one of the most prominent parameters. The effect of lowering the freeboard from (scaled) 4,5 meters to 6 meters is larger than the height difference should indicate.

The 1 block rock slide has almost a sixth of the total volume for 2 blocks, even though the slide is only half as big, corresponding to the LRWL-result, Figure 26.



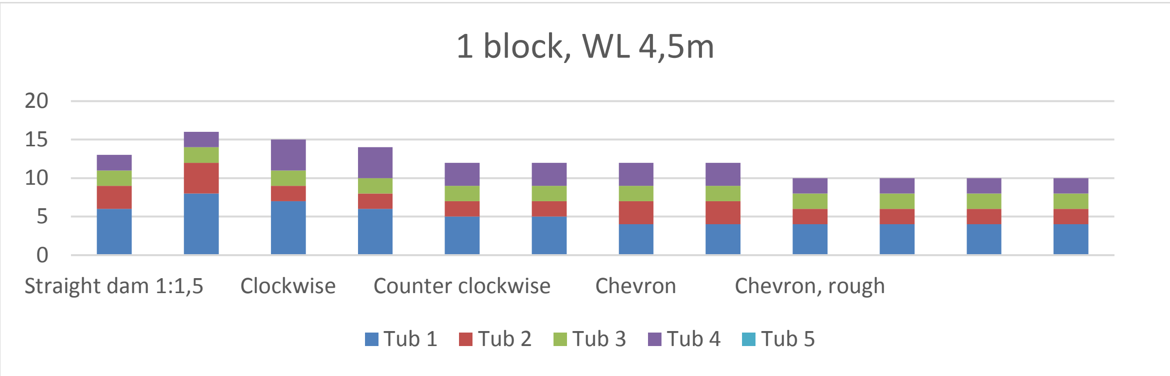


Figure 31 1 block avalanche with the different water levels

If we just compare the two different water levels for one block, Figure 31, one can see that the effect of lowering the water level is largest on the straight dam, almost halving the overtopped volume. The effect is not so great on the other dam designs, almost negligible on the chevron dams.

4.5. WAVE GENERATION AND PROPAGATION

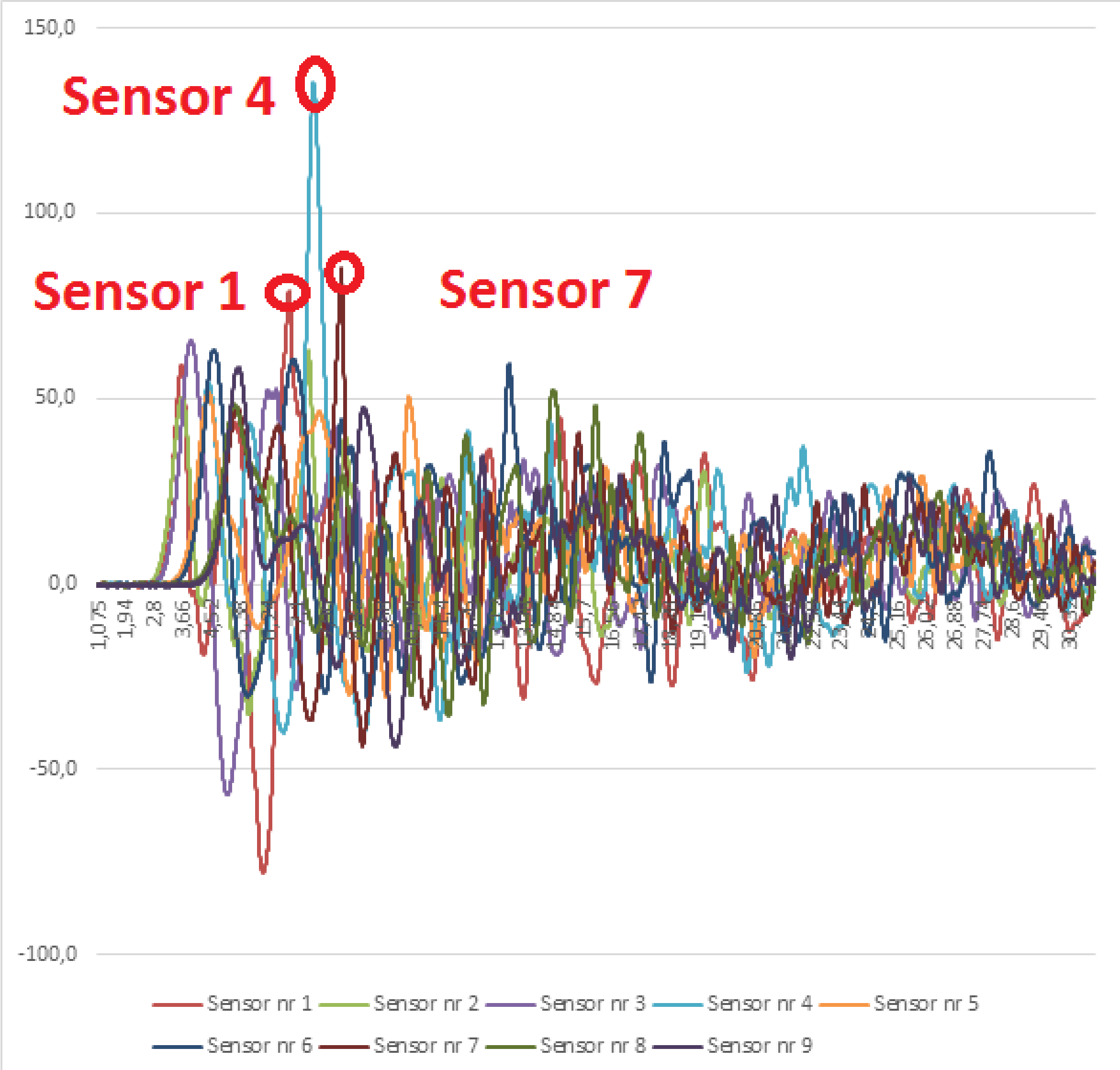


Figure 32 Wave propagation 020616 6bl_4_5m_2_Chevron_rough

As mentioned earlier, one can see the wave propagate through the reservoir. The largest waves are where sensors 1, 4 and 7 are. Wave propagation is outside this thesis' scope. But it is of interest to see that the wave travels along the side of the reservoir.

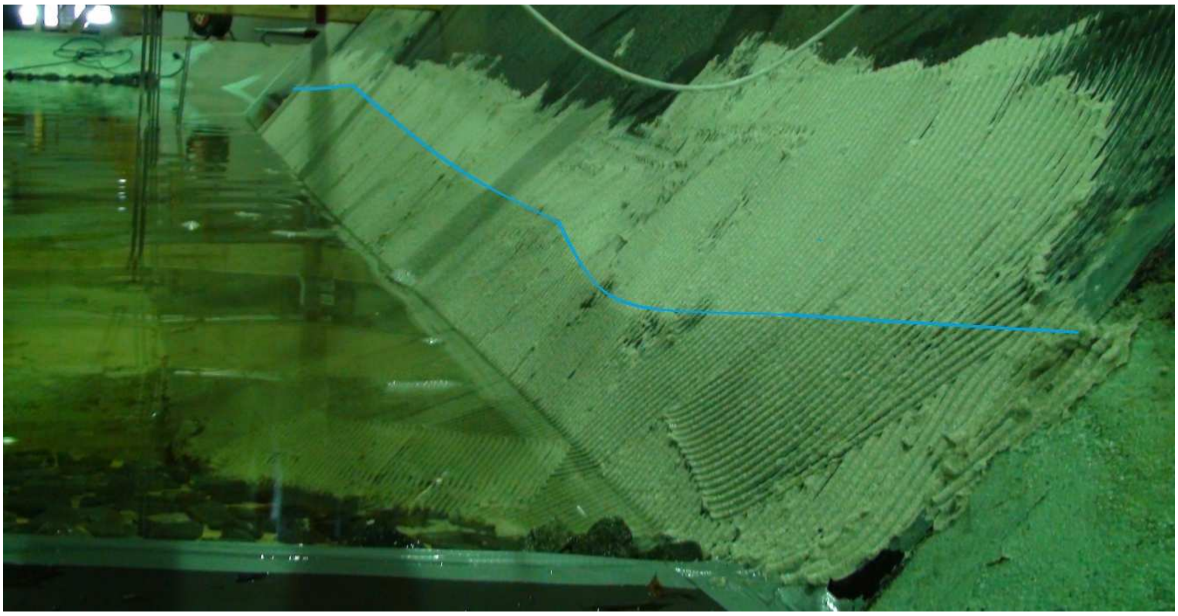


Figure 33 Highlighting of the wave traversing the left side of the reservoir to the dam. Dam is in front of picture, slide in the back.

Figure 33 shows the wave build up from the slide in the back, then the reflected wave coming in and maintaining a higher level, before slightly subsiding, and building up again when encountering the dam slope.

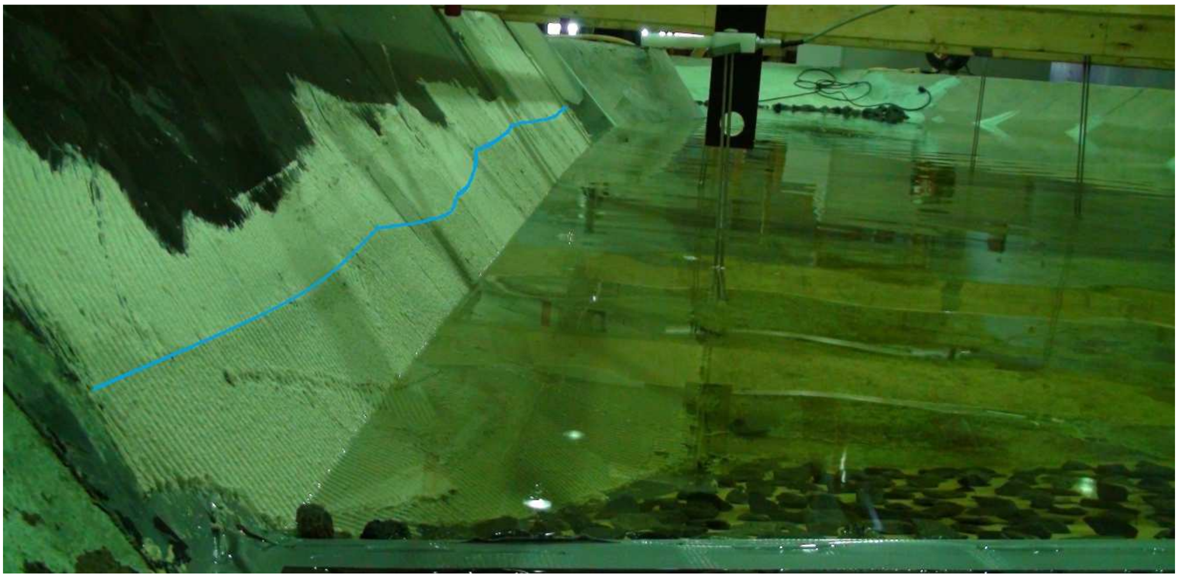
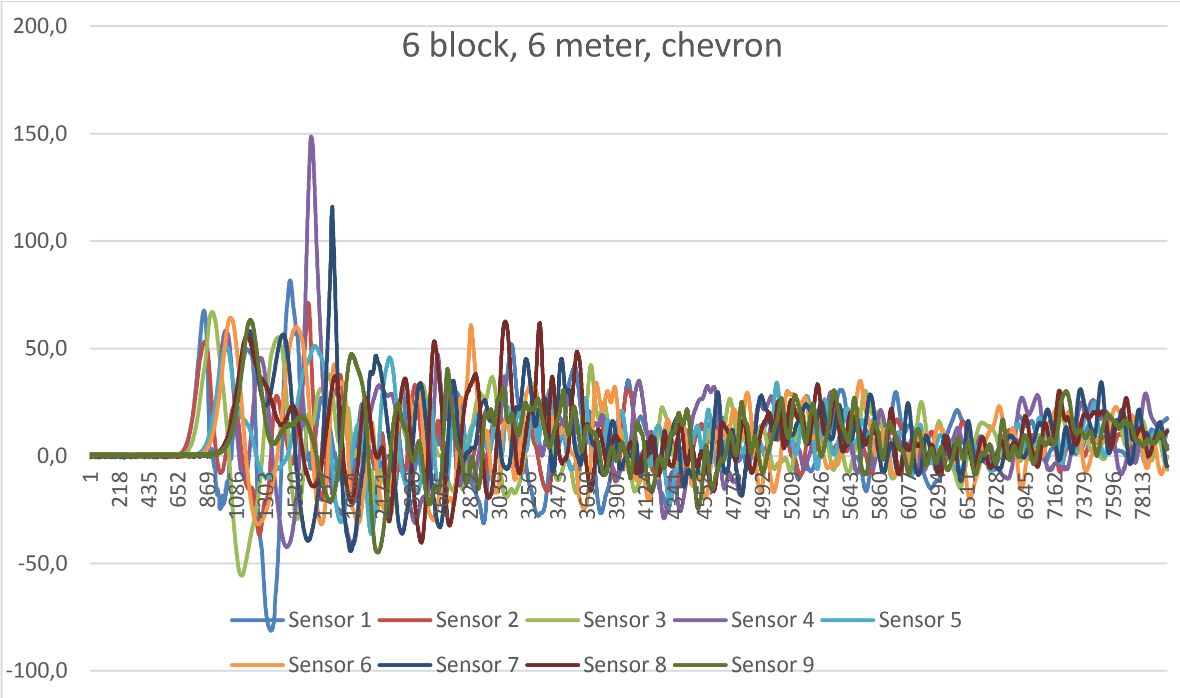


Figure 34 Highlighting of the wave traversing the right side of the reservoir to the dam. Dam is in front of picture, slide is in the back

Figure 34 shows that the height of the wave traversing the right side of the dam is lower and more irregular than the opposite side, conforming well with the results from sensors.

Comparing Figure 35 it is difficult to see the effect of applying roughness to the reservoir sides. The largest wave is the same size, but some of the smaller waves are a bit smaller.



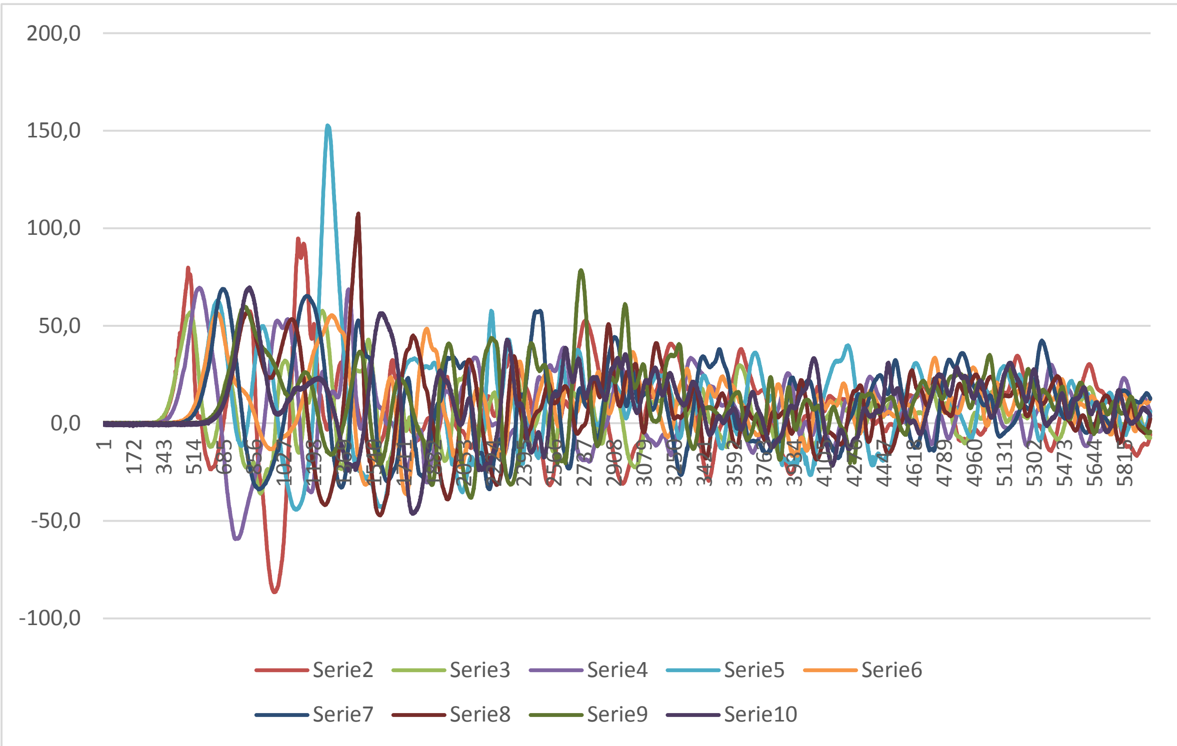
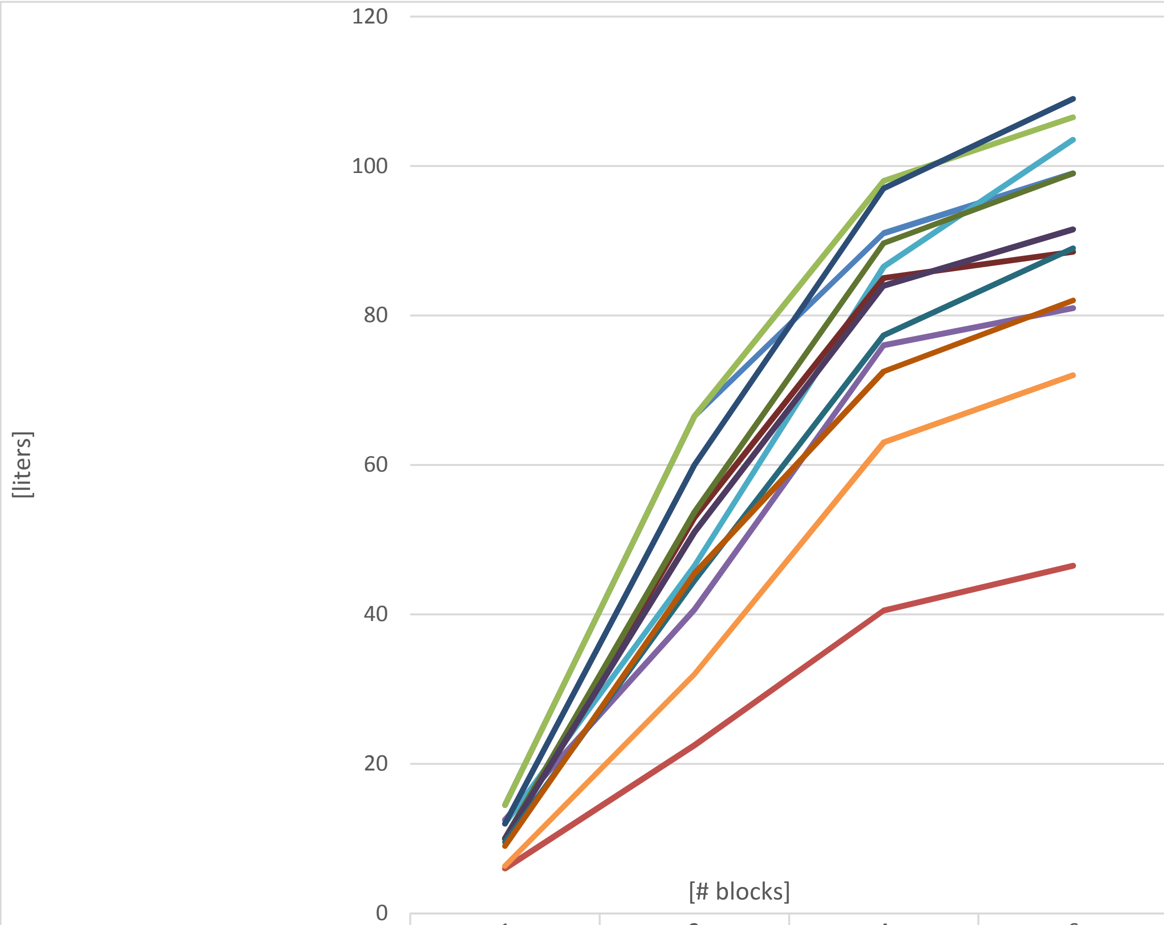


Figure 35 A comparison between chevron (top) and chevron rough (bottom)

Unfortunately, when the chevron dam was installed, the ultrasonic sensors was installed on the wrong side of the beam for ease. This put them outside sensor range. The overtopping readings in [mm] before and after applying roughness on the reservoir walls is for this reason missing. However, the volumetric readings from before/ after applying roughness is provided and this will be an indicator of the effect on overtopping height as well, this is further discussed in chapter 4.6 and 4.7.

4.6. OVERTOPPING

Figure 36 shows the overtopped volume in liters for the different dam designs, water levels and avalanche size.



	1	2	4	6
Total overtop straight dam, WL 4,5 m	15	67	91	99
Total overtop straight dam, WL 6 m	6	23	41	47
Total overtop CW, WL 4,5 m	15	67	98	107
Total overtop CW, WL 6 m	13	41	76	81
Total overtop CCW, WL 4,5 m	12	47	87	104
Total overtop CW, WL 6 m	6	32	63	72
Total overtop Chevron, WL 4,5 m	12	60	97	109
Total overtop Chevron, WL 6 m	10	53	85	89
Total overtop Chevron rough 1, WL 4,5 m	10	54	90	99
Total overtop Chevron rough 2, WL 4,5 m	10	51	84	92
Total overtop Chevron rough 1, WL 6 m	10	45	77	89
Total overtop Chevron rough 2, WL 6 m	9	46	73	82

Figure 36 Overtopping volume in liters for the different dam setups

The largest volume to avalanche size ratio is for 2 blocks. The 4 block avalanche is twice as big and the 6 blocks avalanche is three times larger, but the overtopping volume does not follow this ratio. Both the 4 block-avalanche and the 6 block-avalanche is slower, Table 10 and Table 11.

Heller describes an approach for estimating overtopping volume (Heller, Hager og Minor, Landslide generated impulse waves in reservoirs- Basics and computation 2009), this is part of student Ragnhild Hammerens thesis', comparing the experimental results with a numerical analysis partly based on Heller's approach. Earlier master's thesis' has also looked at the correlation between model studies and Heller's approach (Svendsby 2014) failing to establish the wanted link.

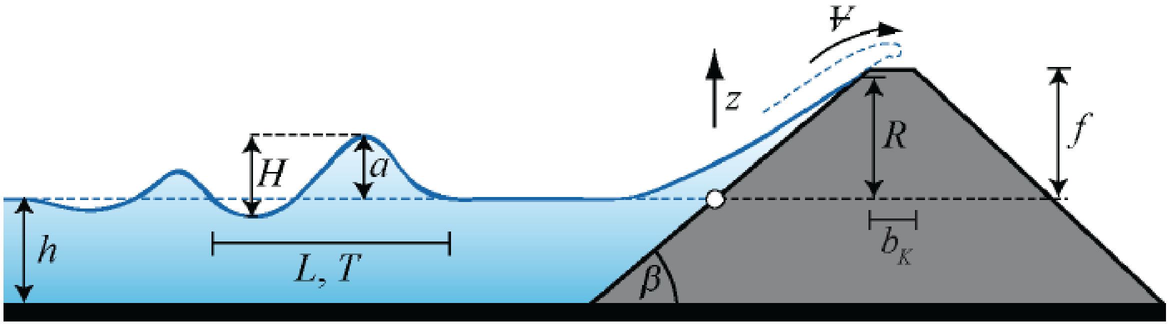
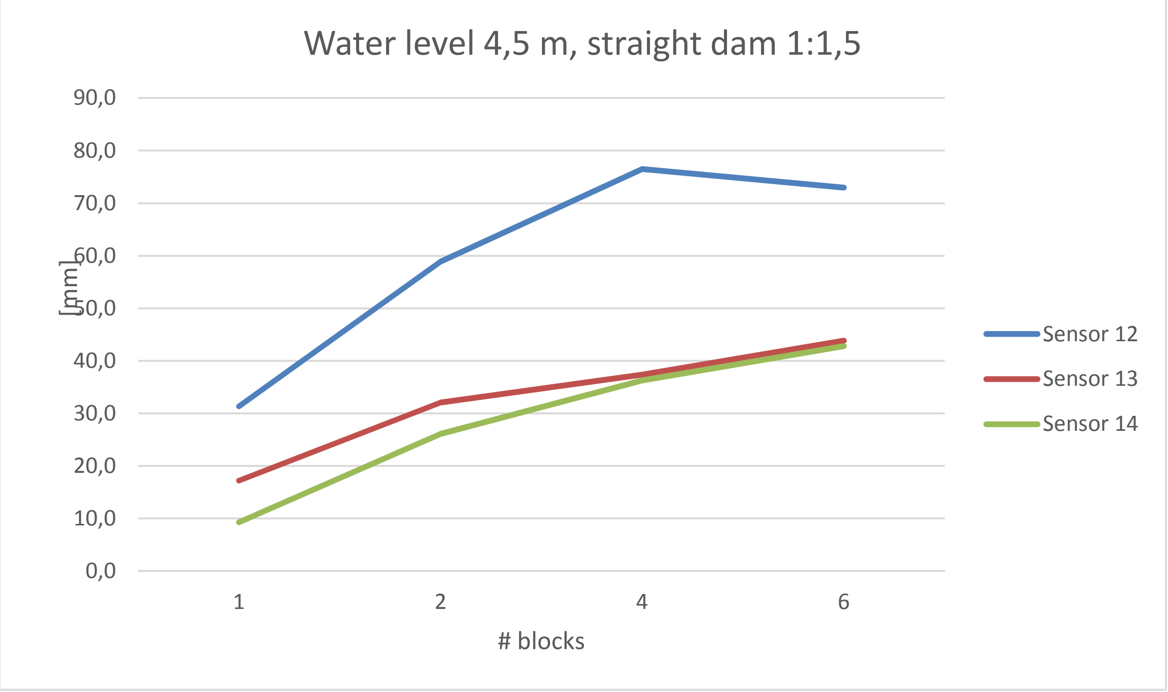


Figure 37 Sketch defining the parameters for the wave run-up and dam overtopping (Heller, Hager og Minor, Landslide generated impulse waves in reservoirs- Basics and computation 2009)

h	Still water depth [m]	β	Run-up angle equal to dam face slope [°]
H	Wave height [m]	V	Run-up volume [m3]
a	Wave amplitude [m]	f	Freeboard [m]
L	Wave length [m]	b_K	Crest width [m]
T	Wave period [second]	R	Run-up height

Following is a closer look at the overtop heights.

One thing to note about Figure 38 and the experiments with straight dam is that sensors 12 and 14 was switched around, so that sensor 12 was the one closest to the left side of the reservoir. In the other tables showed in this thesis they are switched back, but not in this figure.



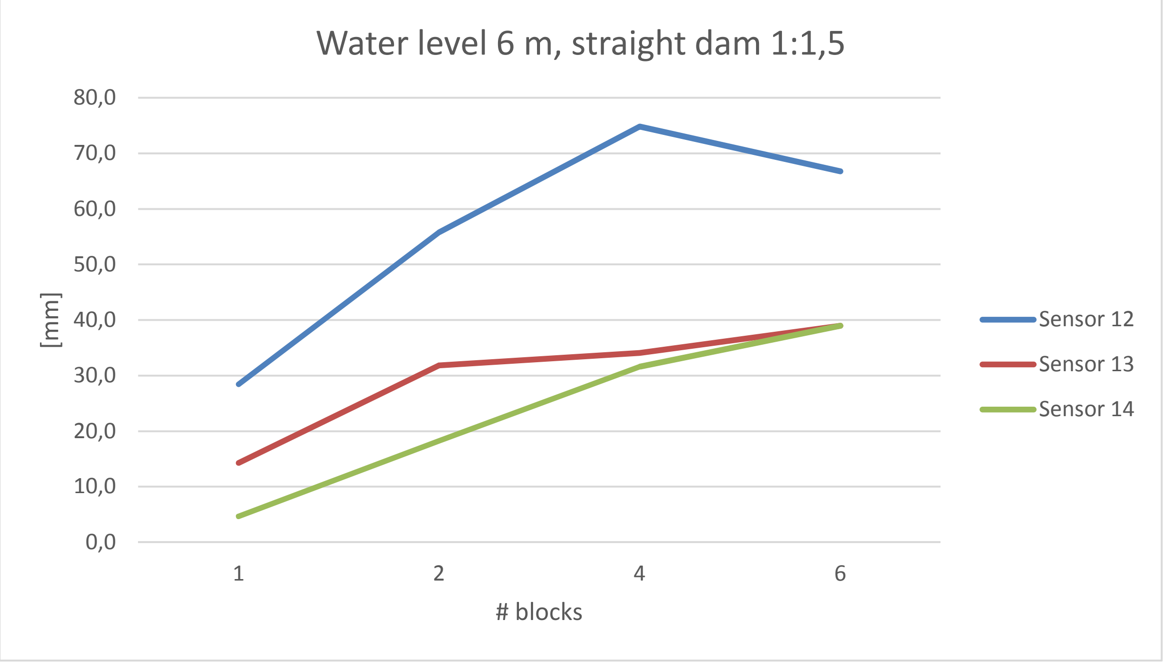
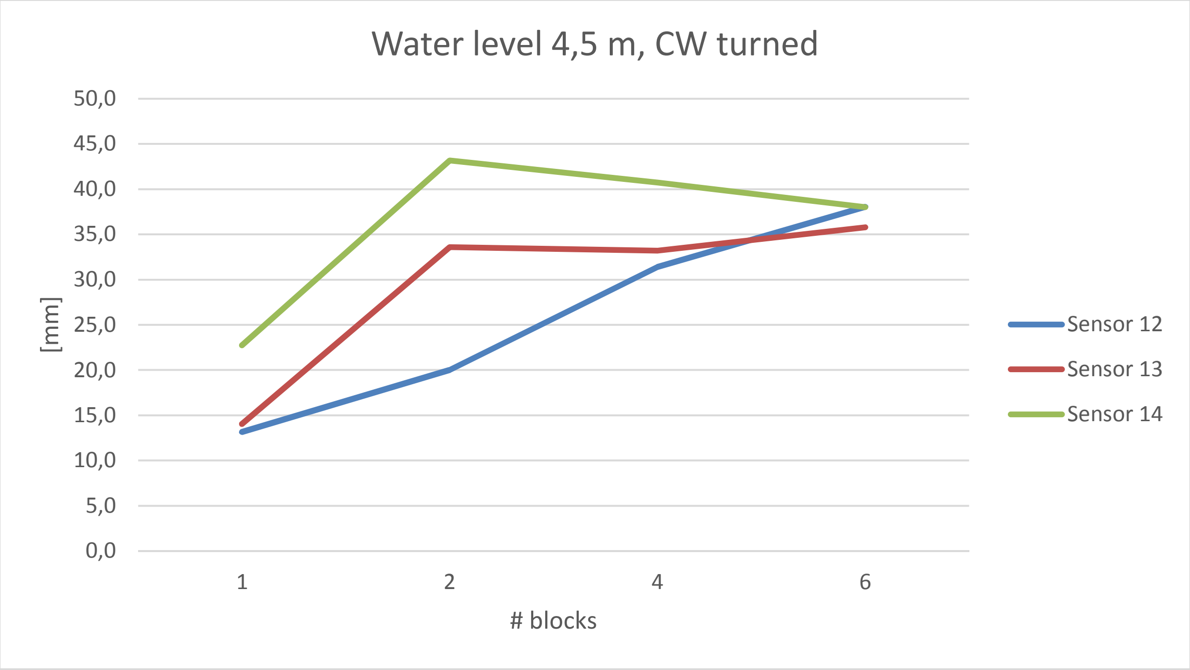


Figure 38 Overtopping with straight dam, WL 4,5 and 6 meters [mm]

Again, it is easily observable from Figure 38 that the 4-block avalanche has higher waves than the 6-block avalanche.

The same pattern is there for the clockwise turned dam for the 6 m water level, the largest waves are after 4 blocks.



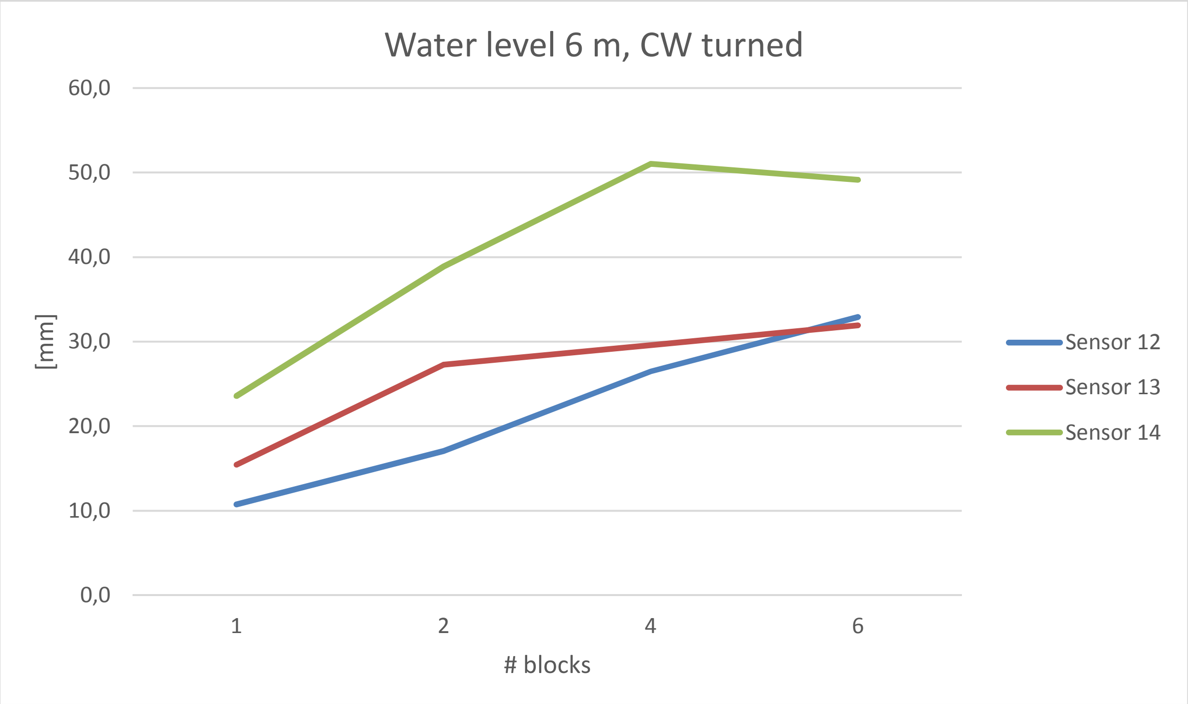
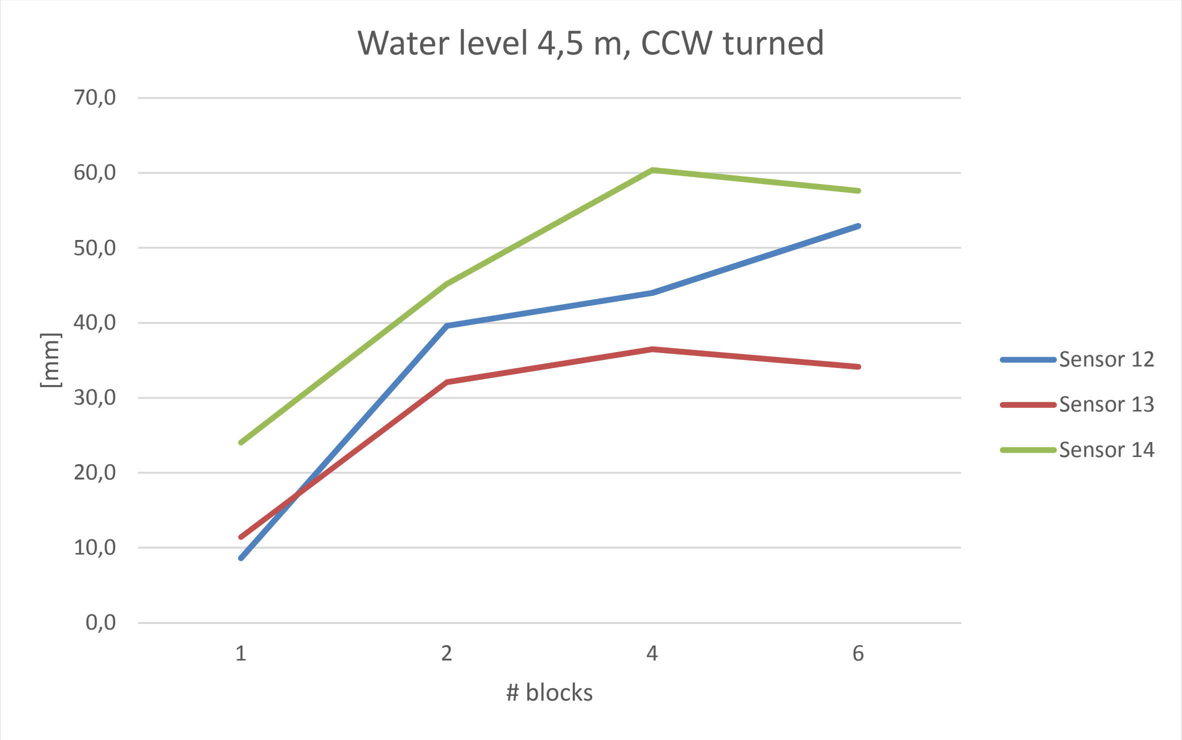


Figure 39 Overtopping with clockwise turned dam, WL 4,5 and 6 meters [mm]

The 4,5 water level, 2 block-avalanche is an anomaly. Table 10 shows that the 2-block avalanche gives lower overtopping than the 4-block avalanche in all other experiments but this one.



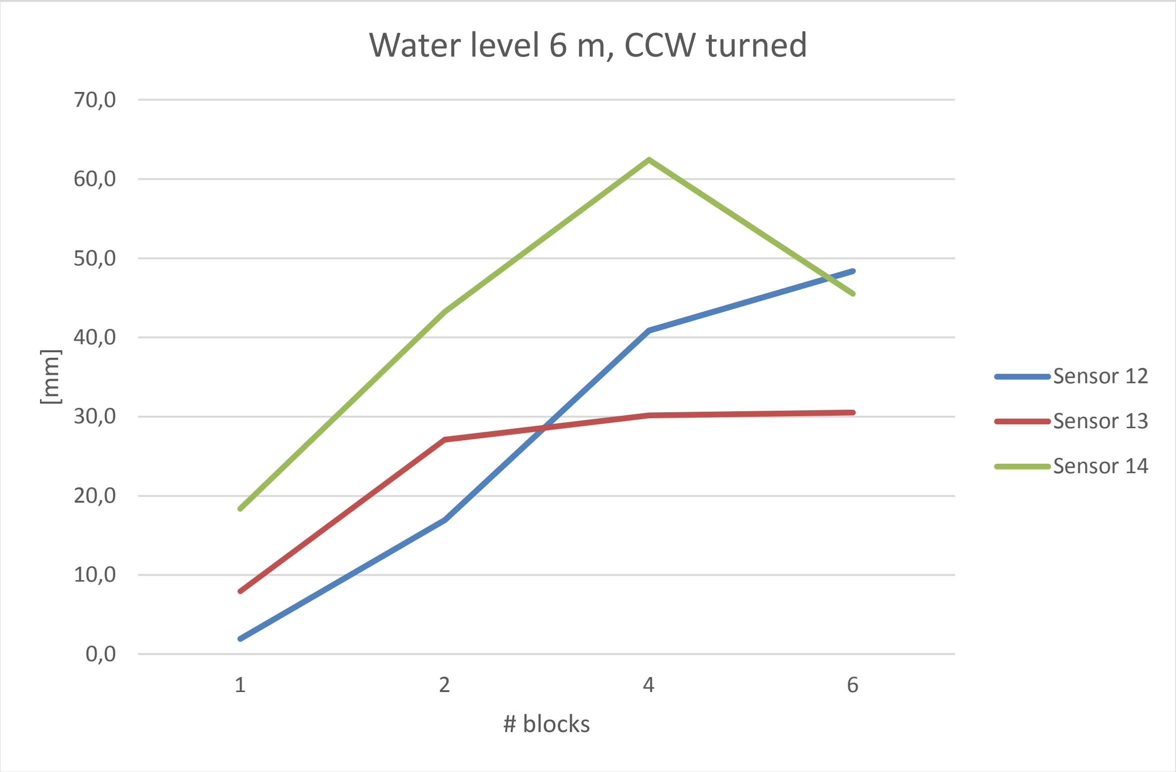
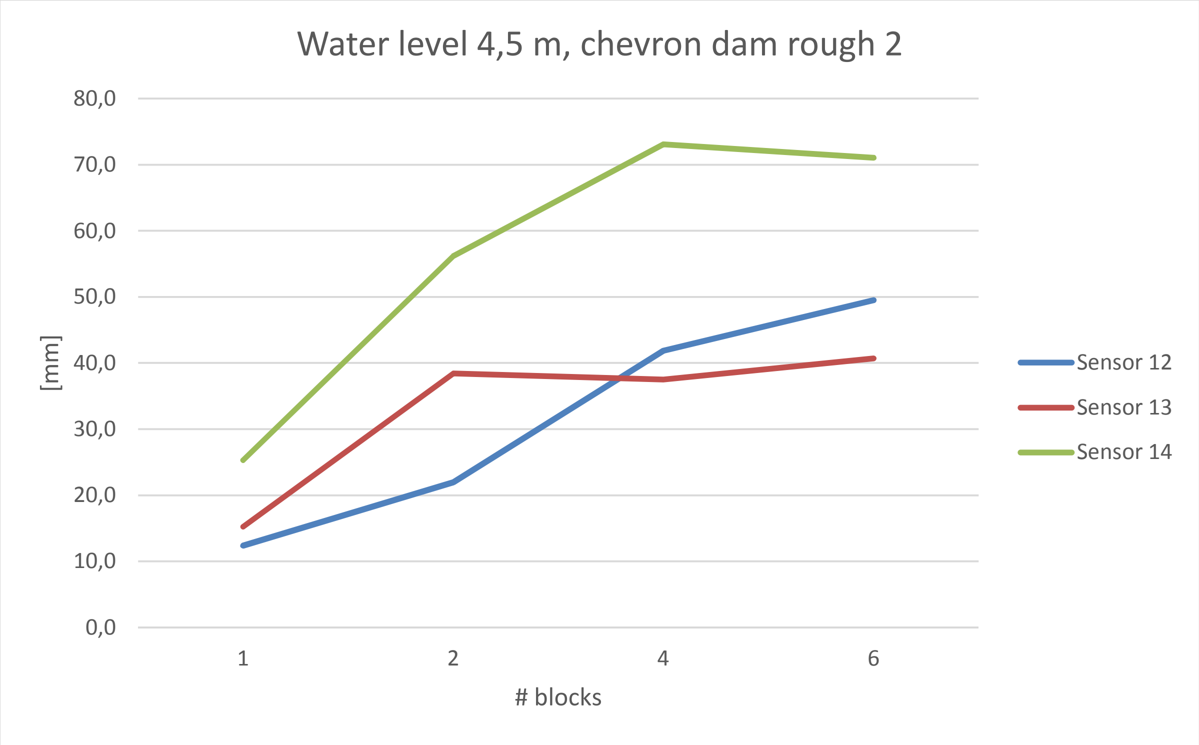


Figure 40 Overtopping with counter-clockwise turned dam, WL 4,5 and 6 meters [mm]

The same pattern is visible in the overtopping height for the counterclockwise turned dam, that the 4-block avalanche gives the highest overtopping height.

The chevron overtopping height data is missing, see chapter 4.7



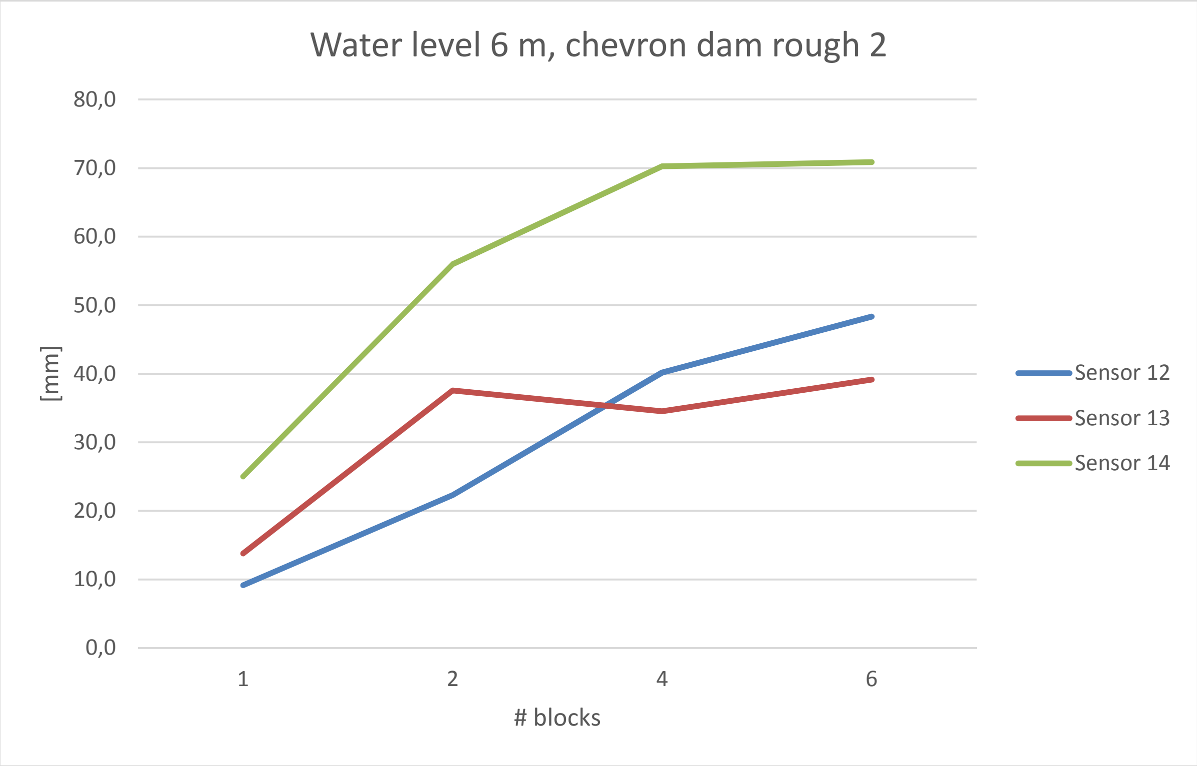
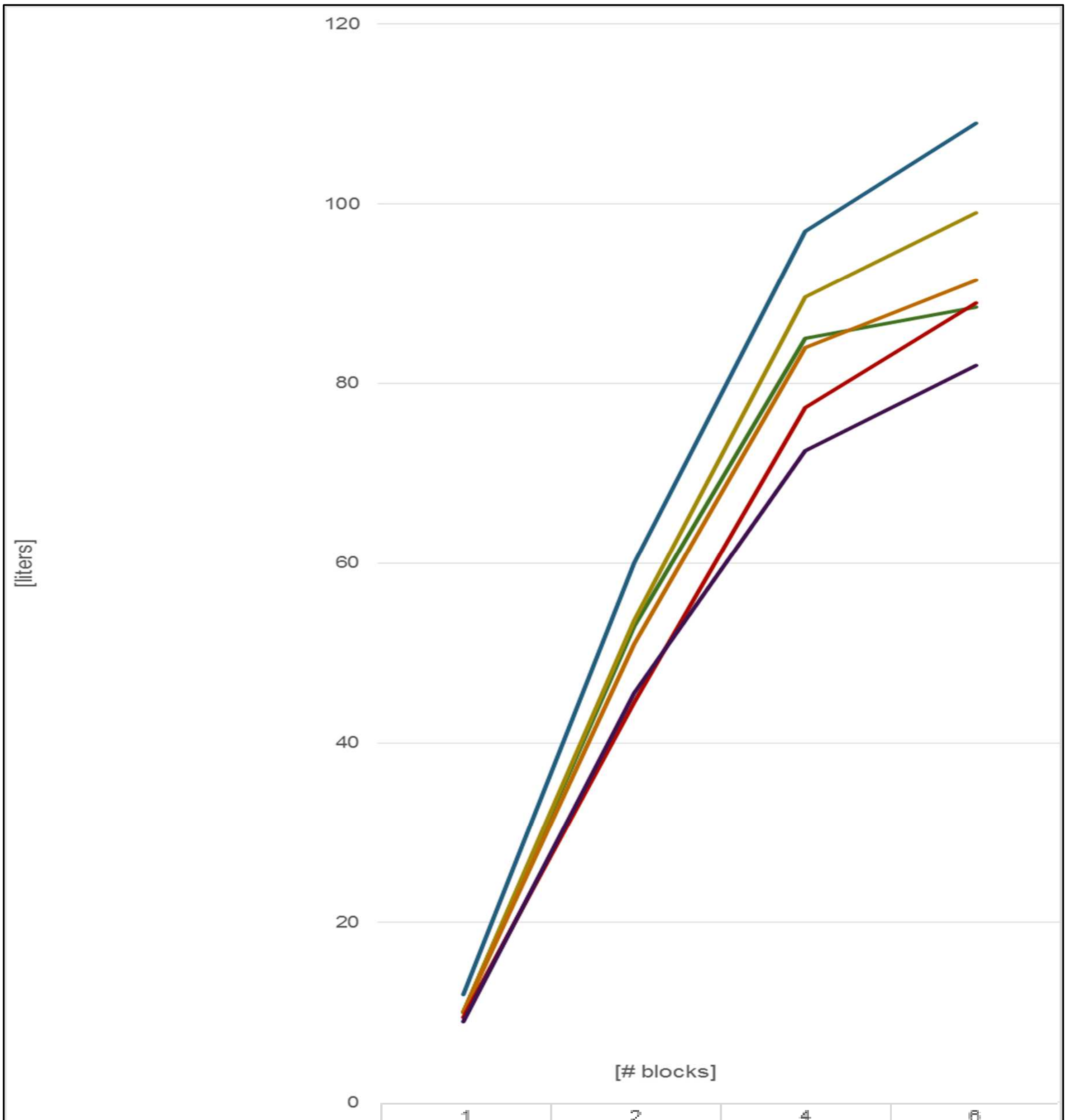


Figure 41 Overtopping with chevron dam, WL 4,5 and 6 meters [mm]

And again for the rough chevron dam this pattern is visible, the 4-block avalanche gives the highest overtopping height.

4.7. APPLICATION OF ROUGHNESS

Roughness was applied to the reservoir sides to imitate real world scenarios with rough valley sides, instead of sleek model sides.



	1	2	4	6
Total overtop Chevron, WL 4,5 m	12	60	97	109
Total overtop Chevron, WL 6 m	10	53	85	89
Total overtop Chevron rough 1, WL 4,5 m	10	54	90	99
Total overtop Chevron rough 2, WL 4,5 m	10	51	84	92
Total overtop Chevron rough 1, WL 6 m	10	45	77	89
Total overtop Chevron rough 2, WL 6 m	9	46	73	82

Figure 42 Overtopping in liters for the different chevron dam w/o roughness

The largest overtopping is Chevron, WL=4,5 m and Chevron, rough, WL=4,5 m. The chevron WL 6 and chevron, rough WL 6 is almost identical. The difference is not larger than for the other dams with varying water level. This shows that the roughness applied has minor impact on the overtopping volume, even though the largest wave traversed the whole length of the reservoir side.

Unfortunately, when the chevron dam was installed, the ultrasonic sensors was installed on the wrong side of the beam for ease. Unwittingly, this put them outside sensor range. The overtopping readings in [mm] before and after applying roughness on the reservoir walls is for this reason missing. However, the volumetric readings from before/ after applying roughness is provided and this will be an indicator of the effect on overtopping height as well

4.8. AVALANCHE CHARACTERISTICS FOR EACH SETUP

1 block avalanche			
PROPERTIES	**UNIT**	**MODEL**	**FULL SCALE**
Volume	m^3	0,038250	262 350
Width	m	0,45	85,5
Height	m	0,17	32,3
Density	g/cm^3	0,986	
Freeboard	m	0,0237	**4,5**
	m	0,0316	**6,0**
Block #	7 or 8		

2 block avalanche			
PROPERTIES	**UNIT**	**MODEL**	**FULL SCALE**
Volume	m^3	0,07650	521 300
Width	m	0,90	171
Height	m	0,17	32,3
Density	g/cm^3	0,985	
Freeboard	m	0,0237	**4,5**
	m	0,0316	**6,0**
Block #	7+8		

4 block avalanche			
PROPERTIES	**UNIT**	**MODEL**	**FULL SCALE**
Volume	m^3	0,1530	1 049 400
Width	m	0,90	171
Height	m	0,17	32,3
Density	g/cm^3	1,045	
Freeboard	m	0,0237	**4,5**
	m	0,0316	**6,0**
Block #	1+2+7+8		

6 block avalanche			
PROPERTIES	**UNIT**	**MODEL**	**FULL SCALE**
Volume	m^3	0,2295	1 574 150
Width	m	0,90	171
Height	m	0,17	32,3
Density	g/cm^3	1,066	
Freeboard	m	0,0237	**4,5**
	m	0,0316	**6,0**
Block #	1+2+3+4+7+8		

Table 9 Slide characteristics for each setup

Table 10 Overview of experiment results. Sorted by dam type, water level and number of blocks used. Green-shaded cells indicate largest value for that sensor, part I

RESULTS				[mm]	[mm]	[mm]	Scaled [m]	Scaled [m]	Scaled [m]	Total overtop [liter]	Scaled overtop Q [m3]	Velocity of avalanche [m/s]	Average speed [m/s]	Scaled velocity [m/s]
Date	Dam type	Water level [m]	# blocks	Sensor 12	Sensor 13	Sensor 14	Sensor 12	Sensor 13	Sensor 14					
17. & 19. februar	Straight 1:1,5	4,5	1	9,3	17,2	31,3	1,8	3,3	6,0	15	7 215	2,7	2,5	34,7
			2	26,1	32,1	58,9	5,0	6,1	11,2	67	33 091	2,5	2,5	34,4
			4	36,3	37,4	76,5	6,9	7,1	14,5	91	45 282	2,2	2,0	28,2
			6	42,8	43,8	72,9	8,1	8,3	13,9	99	49 263	1,7	1,7	24,1
		6	1	4,6	14,3	28,4	0,9	2,7	5,4	6	2 986	2,7		
			2	18,3	31,8	55,8	3,5	6,0	10,6	23	11 196	2,5		
			4	31,6	34,1	74,9	6,0	6,5	14,2	41	20 153	2,0		
			6	39,0	39,0	66,8	7,4	7,4	12,7	47	23 139	1,8	2,2	
14. & 25. april	Clockwise turned	4,5	1	13,1	14,0	22,7	2,5	2,7	4,3	15	7 215	2,1		
			2	20,0	33,6	43,2	3,8	6,4	8,2	67	33 091	2,4		
			4	31,4	33,2	40,7	6,0	6,3	7,7	98	48 765	2,1		
			6	38,1	35,8	38,0	7,2	6,8	7,2	107	52 995	1,6		
		6	1	10,8	15,5	23,6	2,0	2,9	4,5	13	6 220	2,6		
			2	17,1	27,3	38,9	3,2	5,2	7,4	41	20 236	2,5		
			4	26,5	29,6	51,0	5,0	5,6	9,7	76	37 818	2,1		
			6	32,9	31,9	49,1	6,3	6,1	9,3	81	40 306	1,8		
29. april & 2. mai	Counter-clockwise turned	4,5	1	8,6	11,4	24,0	1,6	2,2	4,6	12	5 971	2,5		
			2	39,6	32,1	45,2	7,5	6,1	8,6	47	23 139	2,5		
			4	44,0	36,5	60,4	8,4	6,9	11,5	87	43 043	2,1		
			6	52,9	34,1	57,6	10,1	6,5	11,0	104	51 502	1,7		
		6	1	1,9	7,9	18,4	0,4	1,5	3,5	6	3 151	2,5		
			2	16,9	27,1	43,2	3,2	5,1	8,2	32	15 923	2,5		
			4	40,8	30,2	62,4	7,8	5,7	11,9	63	31 349	1,8		
			6	48,4	30,5	45,5	9,2	5,8	8,6	72	35 827	1,8		

Table 11 Overview of experiment results. Sorted by dam type, water level and number of blocks used. Green-shaded cells indicate largest value for that sensor, part II

Date	Dam type	Water level [m]	# blocks	[mm] Sensor 12	[mm] Sensor 13	[mm] Sensor 14	Scaled [m] Sensor 12	Scaled [m] Sensor 13	Scaled [m] Sensor 14	Total overtop [liter]	Scaled overtop Q [m3]
23.mai	Chevron	4,5	1	2,0	0,8	0,7	0,4	0,2	0,1	12	5 971
			2	5,8	0,5	0,5	1,1	0,1	0,1	60	29 856
			4	22,7	0,9	0,8	4,3	0,2	0,1	97	48 268
			6	30,5	0,9	1,7	5,8	0,2	0,3	109	54 239
		6	1	1,7	0,6	0,9	0,3	0,1	0,2	10	4 976
			2	4,6	0,9	0,5	0,9	0,2	0,1	53	26 373
			4	21,1	1,0	1,1	4,0	0,2	0,2	85	42 296
			6	29,0	0,9	0,8	5,5	0,2	0,2	89	44 038
26.mai	Chevron, rough	4,5	1	2,8	0,6	0,8	0,5	0,1	0,2	10	4 976
			2	2,3	1,1	1,3	0,4	0,2	0,2	54	26 705
			4	22,6	1,1	1,3	4,3	0,2	0,2	90	44 619
			6	30,0	1,2	1,3	5,7	0,2	0,3	99	49 263
		6	1	2,0	0,9	0,6	0,4	0,2	0,1	10	4 727
			2	1,6	1,0	0,3	0,3	0,2	0,1	45	22 143
			4	21,1	1,2	1,3	4,0	0,2	0,2	77	38 481
			6	29,3	1,1	1,3	5,6	0,2	0,3	89	44 287
02.jun	Chevron, Rough	4,5	1	12,4	15,2	25,3	2,3	2,9	4,8	10	4 976
			2	22,0	38,4	56,2	4,2	7,3	10,7	51	25 378
			4	41,9	37,5	73,1	8,0	7,1	13,9	84	41 799
			6	49,5	40,7	71,1	9,4	7,7	13,5	92	45 531
		6	1	9,1	13,8	25,0	1,7	2,6	4,8	9	4 478
			2	22,3	37,6	56,0	4,2	7,1	10,6	46	22 641
			4	40,2	34,5	70,3	7,6	6,6	13,4	73	36 076
			6	48,3	39,2	70,9	9,2	7,4	13,5	82	40 804

Given the large number of experiments there are some results that are statistically significant:

- The wave travels along the left side of the reservoir, independent of dam design, and the wave reflected from the opposing reservoir side comes in around sensor 4. This should be further examined.
- The 2 block-avalanche has the largest overtopping volume to avalanche size ratio.
- The 4 block-avalanche has the highest waves.
- The 6 block-avalanche has the largest overtopping volume.
- The previous three conclusions leads to the conclusion that avalanche speed is more important than avalanche size in estimating overtopping risk
- The straight dam has the highest overtopping height.
- The chevron dam has the highest overtopping volume, due to having a gutter trench-effect on both sides of the dam.
- The freeboard is the single most dam design parameter to increase dam safety.

These are solid results with a large number of experiments backing them up.

Some results are discarded due to being very atypical. The results from the first day of experimenting is ignored as most data from this data is a bit “strange” with very different readings and different patterns than all other days. This is explained as learner’s mistakes.

4.9. OVERTOPPED VOLUME PER METER DAM, SCALED

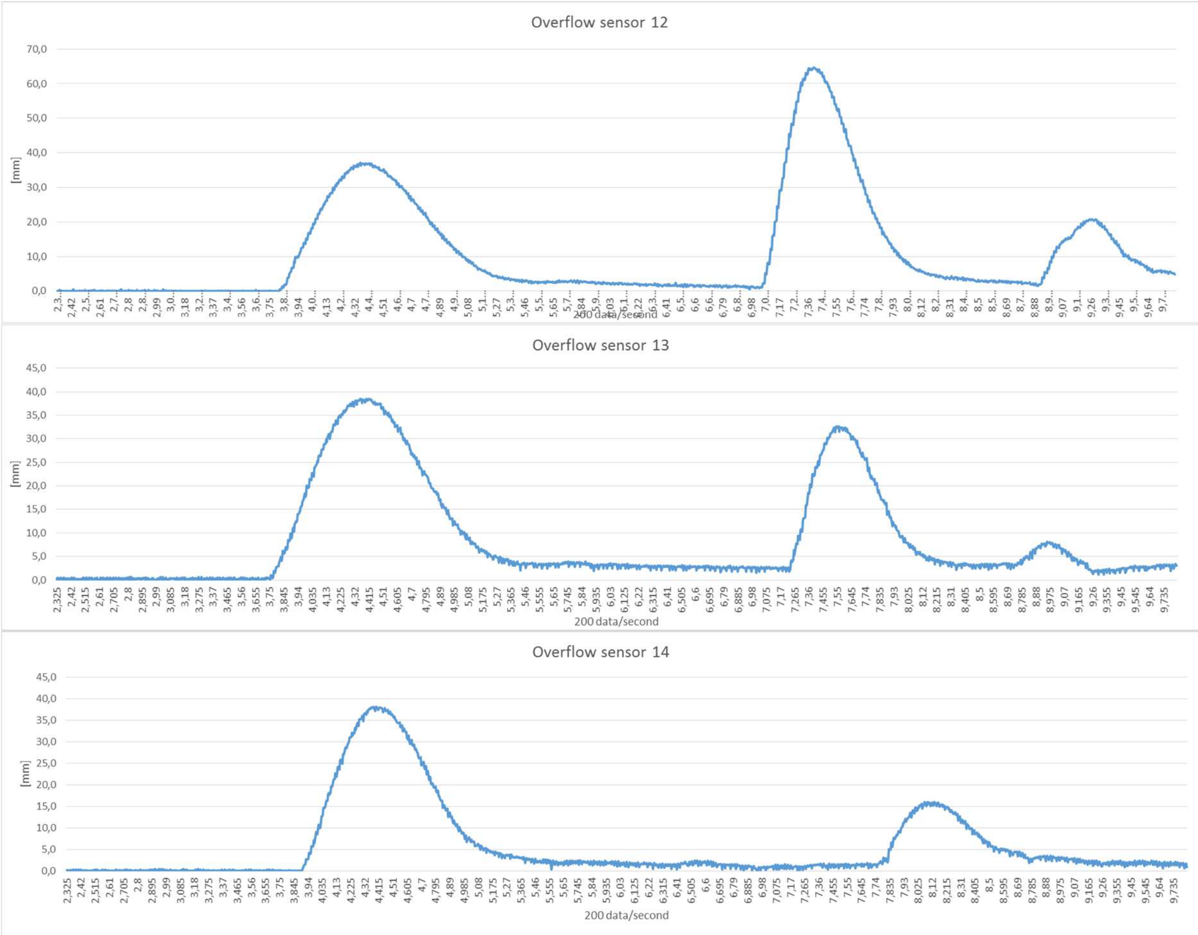


Figure 43 Overtopping [mm] for a 6 block-avalanche, straight dam, Water level 6 m 190216. Sensor 12 and 14 are switched, meaning that sensor 12 is to the left, while sensor 14 is to the right.

From Figure 43, the length of time for the largest overtopping (sensor 12) to spill over the dam crest is ~1 second. Sensor 13's overtopping takes ~1,5 seconds. Using the formula ($t=L_r^{1/2}$) from Table 8, the scaled time is ~~14 seconds and ~21 seconds, averaging ~17 seconds.

The scaled length of the dam is 221 cm x 190 = 420 meters.

Using these values for calculating the Q/m/s scaled, gives the results in Table 12. The overflow per meter dam ranges between 0,4- 7,5 m^3/m/s.

Using only 1 second instead of the average to get the largest flow over in the shortest time gives the results in Table 13, with values ranging between 0,5- 9,4 m^3/m/s.

The results show that the speed of the avalanche is of the utmost importance.

RESULTS				Scaled [m]	Scaled [m]	Scaled [m]	Scaled overtop Q [m3]	Q per meter dam per second,
Date	Dam type	Water level [m]	# blocks	Sensor 12	Sensor 13	Sensor 14		
17. & 19. februar	Straight 1:1,5	4,5	1	6,0	3,3	1,8	7 215	1,0
			2	11,2	6,1	5,0	33 091	4,6
			4	14,5	7,1	6,9	45 282	6,3
			6	13,9	8,3	8,1	49 263	6,8
		6	1	5,4	2,7	0,9	2 986	0,4
			2	10,6	6,0	3,5	11 196	1,5
			4	14,2	6,5	6,0	20 153	2,8
			6	12,7	7,4	7,4	23 139	3,2
14. & 25. april	Clockwise turned	4,5	1	2,5	2,7	4,3	7 215	1,0
			2	3,8	6,4	8,2	33 091	4,6
			4	6,0	6,3	7,7	48 765	6,7
			6	7,2	6,8	7,2	52 995	7,3
		6	1	2,0	2,9	4,5	6 220	0,9
			2	3,2	5,2	7,4	20 236	2,8
			4	5,0	5,6	9,7	37 818	5,2
			6	6,3	6,1	9,3	40 306	5,6
29. april & 2. mai	Counter-clockwise turned	4,5	1	1,6	2,2	4,6	5 971	0,8
			2	7,5	6,1	8,6	23 139	3,2
			4	8,4	6,9	11,5	43 043	6,0
			6	10,1	6,5	11,0	51 502	7,1
		6	1	0,4	1,5	3,5	3 151	0,4
			2	3,2	5,1	8,2	15 923	2,2
			4	7,8	5,7	11,9	31 349	4,3
			6	9,2	5,8	8,6	35 827	5,0
23.mai	Chevron	4,5	1	0,4	0,2	0,1	5 971	0,8
			2	1,1	0,1	0,1	29 856	4,1
			4	4,3	0,2	0,1	48 268	6,7
			6	5,8	0,2	0,3	54 239	7,5
		6	1	0,3	0,1	0,2	4 976	0,7
			2	0,9	0,2	0,1	26 373	3,6
			4	4,0	0,2	0,2	42 296	5,8
			6	5,5	0,2	0,2	44 038	6,1
26.mai	Chevron, rough	4,5	1	0,5	0,1	0,2	4 976	0,7
			2	0,4	0,2	0,2	26 705	3,7
			4	4,3	0,2	0,2	44 619	6,2
			6	5,7	0,2	0,3	49 263	6,8
		6	1	0,4	0,2	0,1	4 727	0,7
			2	0,3	0,2	0,1	22 143	3,1
			4	4,0	0,2	0,2	38 481	5,3
			6	5,6	0,2	0,3	44 287	6,1
02.jun	Chevron, Rough	4,5	1	2,3	2,9	4,8	4 976	0,7
			2	4,2	7,3	10,7	25 378	3,5
			4	8,0	7,1	13,9	41 799	5,8
			6	9,4	7,7	13,5	45 531	6,3
		6	1	1,7	2,6	4,8	4 478	0,6
			2	4,2	7,1	10,6	22 641	3,1
			4	7,6	6,6	13,4	36 076	5,0
			6	9,2	7,4	13,5	40 804	5,6

Table 12 Scaled overtopping [mm], [liter] and [Q/m dam/s] using the average overtopping speed of 17 seconds

RESULTS				Scaled [m]	Scaled [m]	Scaled [m]	Scaled overtop Q [m3]	Q per meter dam per second,
Date	Dam type	Water level [m]	# blocks	Sensor 12	Sensor 13	Sensor 14		
17. & 19. februar	Straight 1:1,5	4,5	1	6,0	3,3	1,8	7 215	1,2
			2	11,2	6,1	5,0	33 091	5,7
			4	14,5	7,1	6,9	45 282	7,8
			6	13,9	8,3	8,1	49 263	8,5
		6	1	5,4	2,7	0,9	2 986	0,5
			2	10,6	6,0	3,5	11 196	1,9
			4	14,2	6,5	6,0	20 153	3,5
			6	12,7	7,4	7,4	23 139	4,0
14. & 25. april	Clockwise turned	4,5	1	2,5	2,7	4,3	7 215	1,2
			2	3,8	6,4	8,2	33 091	5,7
			4	6,0	6,3	7,7	48 765	8,4
			6	7,2	6,8	7,2	52 995	9,2
		6	1	2,0	2,9	4,5	6 220	1,1
			2	3,2	5,2	7,4	20 236	3,5
			4	5,0	5,6	9,7	37 818	6,5
			6	6,3	6,1	9,3	40 306	7,0
29. april & 2. mai	Counter-clockwise turned	4,5	1	1,6	2,2	4,6	5 971	1,0
			2	7,5	6,1	8,6	23 139	4,0
			4	8,4	6,9	11,5	43 043	7,4
			6	10,1	6,5	11,0	51 502	8,9
		6	1	0,4	1,5	3,5	3 151	0,5
			2	3,2	5,1	8,2	15 923	2,8
			4	7,8	5,7	11,9	31 349	5,4
			6	9,2	5,8	8,6	35 827	6,2
23.mai	Chevron	4,5	1	0,4	0,2	0,1	5 971	1,0
			2	1,1	0,1	0,1	29 856	5,2
			4	4,3	0,2	0,1	48 268	8,3
			6	5,8	0,2	0,3	54 239	9,4
		6	1	0,3	0,1	0,2	4 976	0,9
			2	0,9	0,2	0,1	26 373	4,6
			4	4,0	0,2	0,2	42 296	7,3
			6	5,5	0,2	0,2	44 038	7,6
26.mai	Chevron, rough	4,5	1	0,5	0,1	0,2	4 976	0,9
			2	0,4	0,2	0,2	26 705	4,6
			4	4,3	0,2	0,2	44 619	7,7
			6	5,7	0,2	0,3	49 263	8,5
		6	1	0,4	0,2	0,1	4 727	0,8
			2	0,3	0,2	0,1	22 143	3,8
			4	4,0	0,2	0,2	38 481	6,7
			6	5,6	0,2	0,3	44 287	7,7
02.jun	Chevron, Rough	4,5	1	2,3	2,9	4,8	4 976	0,9
			2	4,2	7,3	10,7	25 378	4,4
			4	8,0	7,1	13,9	41 799	7,2
			6	9,4	7,7	13,5	45 531	7,9
		6	1	1,7	2,6	4,8	4 478	0,8
			2	4,2	7,1	10,6	22 641	3,9
			4	7,6	6,6	13,4	36 076	6,2
			6	9,2	7,4	13,5	40 804	7,1

Table 13 Scaled overtopping [mm], [liter] and [Q/m dam/s] using the shortest overtopping speed of 14 seconds

5. CONCLUSION AND RECOMMENDATIONS

Experiments was modelled to slide an avalanche of varying size perpendicular into a reservoir. The slide entered the water behind a small wall, shielding the dam, so that only indirect, reflecting waves reached the dam. The impulse waves resulting from the avalanche criss-crossed the reservoir onto an embankment dam at one end. The sizes of the avalanches were kept relatively small, for ease of experimenting, and as such is only applicable to small and medium sized subaerial slides (0,25-1,5 mill. m^3) sliding into relatively large reservoirs bodies of water scaled size of reservoir used in experiments is 418 x ~900 meters).

A series of tests was performed to determine the effect of changing the these parameters:

- Avalanche size
- Freeboard
- Dam design

While logging the slide velocity, wave height, overtopping height and overtopping volume, results have been compared and some values have been transformed to full scale values.

Wave propagation graphs show that it is not the first wave, but the second or third wave that gives the largest overtopping, while the second wave gives the largest trough, supporting results from (Di Risio, et al. 2009).

The direction of the slide motion influences the wave distribution in the reservoir, and in this model the reflecting waves from the opposing side is transmitted inwards to around sensor 4, and then following the reservoir wall to sensor 14, giving a large overtopping there, independent of dam geometry, partly as stated by (Di Risio, et al. 2009).

The speed of the avalanche is the most important factor in the overtopping results, with freeboard coming in as the second most important factor, supporting (Sælevik, Jensen og Pedersen 2009)

For further experiments the speed of the avalanche should be regulated, both slower and faster, to find the correlation between avalanche velocity and overtopping.

In Norway dam consequence classes only look at the consequence of a dam break, not the probability of a dam break. This thesis shows the importance of taking the probability of an avalanche occuring into consideration when deciding on the consequence class for a dam that might be susceptible for avalanche incident.

The freeboard is one of the most efficient dam design parameters to lessen or avoid a catastrophe.

Historical catastrophes like the Lituya Bay mega-tsunami, which was caused by a glacier failing, show that it is not only rock slides one should fear, but avalanches of all kinds.

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7. APPENDICES

General about content, work and presentation

The text for the master thesis is meant as a framework for the work of the candidate. Adjustments might be done as the work progresses. Tentative changes must be done in cooperation and agreement with the professor in charge at the Department.

In the evaluation thoroughness in the work will be emphasized, as will be documentation of independence in assessments and conclusions. Furthermore the presentation (report) should be well organized and edited; providing clear, precise and orderly descriptions without being unnecessary voluminous.

The report shall include:

- Standard report front page (from DAIM, http://daim.idi.ntnu.no/)
- Title page with abstract and keywords.(template on: http://www.ntnu.no/bat/skjemabank)
- Preface
- Summary and acknowledgement. The summary shall include the objectives of the work, explain how the work has been conducted, present the main results achieved and give the main conclusions of the work.
- The main text.
- Text of the Thesis (these pages) signed by professor in charge as Attachment 1.

The thesis can as an alternative be made as a scientific article for international publication, when this is agreed upon by the Professor in charge. Such a report will include the same points as given above, but where the main text includes both the scientific article and a process report.

Advice and guidelines for writing of the report is given in “Writing Reports” by Øivind Arntsen, and in the departments “Råd og retningslinjer for rapportskriving ved prosjekt og masteroppgave” (In Norwegian) located at http://www.ntnu.no/bat/studier/oppgaver.

Submission procedure

Procedures relating to the submission of the thesis are described in DAIM (http://daim.idi.ntnu.no/). Printing of the thesis is ordered through DAIM directly to Skipnes Printing delivering the printed paper to the department office 2-4 days later. The department will pay for 3 copies, of which the institute retains two copies. Additional copies must be paid for by the candidate / external partner.

The master thesis will not be registered as delivered until the student has delivered the submission form (from DAIM) where both the Ark-Bibl in SBI and Public Services (Building Safety) of SB II has signed the form. The submission form including the appropriate signatures must be signed by the department office before the form is delivered Faculty Office.

Documentation collected during the work, with support from the Department, shall be handed in to the Department together with the report.

According to the current laws and regulations at NTNU, the report is the property of NTNU. The report and associated results can only be used following approval from NTNU (and external cooperation partner if applicable). The Department has the right to make use of the results from the work as if conducted by a Department employee, as long as other arrangements are not agreed upon beforehand.

Tentative agreement on external supervision, work outside NTNU, economic support etc.
Separate description is to be developed, if and when applicable. See http://www.ntnu.no/bat/skjemabank for agreement forms.

Health, environment and safety (HSE) http://www.ntnu.edu/hse
NTNU emphasizes the safety for the individual employee and student. The individual safety shall be in the forefront and no one shall take unnecessary chances in carrying out the work. In particular, if the student is to participate in field work, visits, field courses, excursions etc. during the Master Thesis work, he/she shall make himself/herself familiar with "Fieldwork HSE Guidelines". The document is found on the NTNU HMS-pages at http://www.ntnu.no/hms/retningslinjer/HMSR07E.pdf

The students do not have a full insurance coverage as a student at NTNU. If you as a student want the same insurance coverage as the employees at the university, you must take out individual travel and personal injury insurance.

Startup and submission deadlines
Startup and submission deadlines are according t o information found in DAIM.

Professor in charge: Leif Lia

Other supervisors: Kiflom Belete

Department of Civil and Transport Engineering, NTNU
Date: 15.01.2016

____

Professor in charge (signature)

7.1. Calibration and overtopping forms

Forsøksdato: 26. januar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler			
	1	-0.814	0.734	-0.021	0 m=	6,17	V	
	2	-0.823	0.763	-0.021	1,35m=	4,37	V	
	3	-0.856	0.809	-0.021				
	4	-0.794	0.669	-0.015		1,33	volt/m	
	5	-0.797	0.661	-0.016				
	6	-0.702	0.966	-0.159				
	7	-0.799	0.713	-0.013				
	8	-0.811	0.73	-0.015				
	9	-0.825	0.785	-0.01				

Vannstand for forsøk: Damlinje (1:1,5)

Kar:	6 blokk 1		4 blokk 1				1 blokk 1
1	193		210				251
2	257		266				284
3	262		272				295
4	255		270				290
5	292		300				

Vannmengde for forsøk: Damlinje (1:1,5)

Kar:	6 blokk 1		4 blokk 1				1 blokk 1
1	21		18				9
2	8		6				3
3	7		5				2
4	9		5				2
5	2		0				0

Figure 44 Calibration and overtopping form, January 26th.

Forsøksdato: 4. februar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler		
	1	0,790	-0,853	0,000	0 m=	7,44	V
	2	0,817	-0,890	-0,032	1m=	8,75	V
	3	0,878	-0,927	-0,016	2m=		
	4	0,699	-0,835	-0,028		1,31	volt/m
	5	0,697	0,844	-0,026			
	6	0,813	-0,926	-0,001			
	7	0,728	-0,845	-0,025			
	8	0,728	-0,842	-0,030			
	9	0,805	-0,866	-0,016			

Vannstand for forsøk: Damlinje (1:1,5) [mm]

Kar:	4 blokk 1	4 blokk 2	4 blokk 3	4 blokk 4	4 blokk 5	2 blokk 1	2 blokk 2	2 blokk 3
1	256	250	251	253	250	246	251	248
2	286	278	284	286	284	283	285	284
3	295	292	295	294	292	291	294	290
4	293	289	290	292	290	291	291	289
5								

Vannmengde for forsøk: Damlinje (1:1,5) [liter]

Kar:	4 blokk 1	4 blokk 2	4 blokk 3	4 blokk 4	4 blokk 5	2 blokk 1	2 blokk 2	2 blokk 3
1	8	10	9	9	10	10	9	10
2	2	4	3	2	3	3	3	3
3	2	2	2	2	2	2	2	2
4	2	2	2	2	2	2	2	2
5	0	0	0	0	0	0	0	0

Figure 45 Calibration and overtopping form, February 4th

Forsøksdato: 5. februar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler		
	1	0.877	-0.924	0,000	0 m=	7,44	
	2	0.9	-0.949	-0.005	1m=	8,75	
	3	0.969	-0.981	0.007	2m=		
	4	0.757	-0.916	-0.006		1,31	volt/m
	5	0.76	-0.911	0.007			
	6	0.924	-1.038	0.001			
	7	0.784	-0.922	-0.007			
	8	0.807	-0.933	-0.002			
	9	0.883	-0.95	-0.003			

Vannstand for forsøk: Damlinje (1:1,5) [mm]

Kar:	4 blokk 1	4 blokk 2	4 blokk 3	4 blokk 4	4 blokk 5	4 blokk 6
1	256	250	251	253	250,00	245
2	286	278	284	286	284,00	281
3	295	292	295	294	292,00	288
4	293	289	290	292	293,00	286
5						

Kar:	6 blokk 1	6 blokk 2	6 blokk 3	6 blokk 4	6 blokk 5	6 blokk 6
1	240	234	228	237	237,00	239
2	278	273	271	274	275,00	276
3	286	284	280	284	283,00	284
4	284	276	275	281	280,00	280
5						

Vannmengde for forsøk: Damlinje (1:1,5) [liter]

Kar:	4 blokk 1	4 blokk 2	4 blokk 3	4 blokk 4	4 blokk 5	4 blokk 6
1	8	10	9	9	10	11
2	2	4	3	2	3	3
3	2	2	2	2	2	2
4	2	2	2	2	2	2
5	0	0	0	0	0	0

Kar:	6 blokk 1	6 blokk 2	6 blokk 3	6 blokk 4	6 blokk 5	6 blokk 6
1	12	13	14	12	12	12
2	4	5	5	5	4	4
3	2	3	4	3	3	3
4	3	4	4	3	4	4
5	0	0	0	0	0	0

Figure 46 Calibration and overtopping form, February 5th

Forsøksdato: 12. februar 2016

Kalibrering av måler 1-9	-5 cm	+5 cm	0	Fartsmåler
1	0,783	-0,871	-0,026	0 m=
2	0,818	-0,896	-0,034	1m=
3	0,880	-0,945	-0,035	2m=
4	0,713	-0,833	-0,005	
5	0,719	-0,842	-0,011	
6	0,877	-0,977	-0,038	
7	0,771	-0,850	0,013	
8	0,777	-0,831	-0,012	
9	0,835	-0,889	-0,020	

Vannstand for forsøk: 6 m (1:1,5) [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	156	149	149	148	196	176	271	262
2	228	167	223	224	247	236	288	287
3	239	227	233	228	257	249	293	290
4	232	226	236	231	262	254	291	290
5	283	281	290	292		297		

Vannstand for forsøk: 4,5 m (1:1,5) [mm]

Kar:				2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2	1 blokk 3
1				138	152	230	240	226
2				199	215	277	277	254
3				210	222	286	286	265
4				236	240	287	290	272
5				289	294			

Vannmengde for forsøk: 6 m (1:1,5) [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	27	29	29	29	19	23	5	6
2	13	25	13	13	9	11	2	2
3	10	13	12	13	7	9	0	1
4	12	13	11	12	6	8	1	1
5	2	3	1	0	0	0	0	0

Vannmengde for forsøk: 4,5 m (1:1,5) [liter]

Kar:				2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2	1 blokk 3
1				31	28	12	10	13
2				18	15	4	4	8
3				16	14	2	2	6
4				11	10	2	1	4
5				1	0	0	0	0

Figure 47 Calibration and overtopping form, February 12th

Forsøksdato: 17. februar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler		
	1	0,718	-0,802	-0,030	0 m=	5,35	V
	2	0,768	-0,831	-0,019	1m=	4,02	V
	3	0,845	-0,886	-0,023	2m=		
	4	0,675	-0,783	-0,012		1,33	Volt/m
	5	0,683	-0,787	-0,003			
	6	0,840	-0,903	0,004			
	7	0,735	-0,814	-0,032			
	8	0,730	-0,795	-0,034			
	9	0,782	-0,858	-0,034			

Vannstand for forsøk: 4,5 m (1:1,5) [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2		
1	122	116	132	124		
2	193	183	198	196		
3	202	194	210	205		
4	216	214	236	230		
5	268	264	282	299		

Vannmengde for forsøk: 4,5 m (1:1,5) [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2
1	38	39	35	37		
2	21	24	20	21		
3	19	21	18	19		
4	17	17	12	14		
5						

Figure 48 Calibration and overtopping form, February 17th

Forsøksdato: 19. februar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler				
	1	0,839	-0,900	-0,011	0 m=	5,53	V		
	2	0,855	-0,933	-0,011	1m=	4,19	V		
	3	0,938	-0,977	-0,003	2m=				
	4	0,760	-0,888	-0,013		1,34	Volt/m		
	5	0,756	-0,894	-0,010					
	6	0,937	-1,040	-0,020					
	7	0,856	-0,889	0,008					
	8	0,827	-0,879	-0,005					
	9	0,894	-0,940	-0,008					

Vannstand for forsøk: 4,5 m (1:1,5)

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	128	123	125	128	178	183	266	259
2	197	196	194	194	229	232	284	277
3	206	202	205	207	239	240	291	287
4	219	216	226	226	250	248	294	291
5	269	265	281	280	298	296		

Vannstand for forsøk: 6 m (1:1,5)

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	147	160	161	160	211	210	276	270
2	215	225	227	230	252	254	288	289
3	227	232	235	235	263	260	296	295
4	227	232	240	242	273	264	293	293
5	279	284	292	292				

Vannmengde for forsøk: 4,5 m (1:1,5) [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	37	38	37	37	25	24	6	8
2	21	21	21	21	14	13	3	4
3	19	19	19	18	12	12	2	2
4	16	17	14	14	10	10	2	2
5	6	6	3	4	0	2	0	0

Vannmengde for forsøk: 6 m (1:1,5) [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	17	15	14	14	9	9	2	2
2	14	13	13	13	7	8	2	2
3	14	13	12	11	5	7	2	2
4	4	3	2	2	0	0	0	0
5	0	0	0	0	0	0	0	0

Figure 49 Calibration and overtopping form, February 19th

Forsøksdato: 26. februar 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler				
	1	0.769	-0.902	-0.009	0 m=	5,60	V		
	2	0.813	-0.916	-0.03	1m=	4,27	V		
	3	0.855	-0.999	-0.04	2m=				
	4	0.78	-0.863	0.006		1,33	Volt/m		
	5	0.774	-0.864	-0.004					
	6	0.896	-1.025	-0.035					
	7	0.843	-0.886	-0.014					
	8	0.831	-0.884	-0.008					
	9	0.886	-0.9	0.006					

Vannstand for forsøk: Vannlinje (1:2) 9 cm [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2			1 blokk 1	1 blokk 2
1	207	204	207	211			289	291
2	259	257	264	264			299	299
3	265	264	270	271			300	300
4	259	256	267	266			300	300
5	294	295	294	297			300	299

Vannmengde for forsøk: Vannlinje (1:2) 9 cm [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2			1 blokk 1	1 blokk 2
1	18	19	18	18			2	2
2	8	8	7	7			0	0
3	6	7	5	5			0	0
4	8	8	6	6			0	0
5	2	2	2	1			0	0

Figure 50 Calibration and overtopping form, February 26th

Forsøksdato: 16. mars 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler
	1	-0.789	0.74	-0.012	0 m=
	2	-0.8	0.747	-0.012	1m=
	3	-0.84	0.813	-0.008	2m=
	4	-0.783	0.683	-0.01	
	5	-0.783	0.706	-0.015	
	6	-0.867	0.862	-0.005	
	7	-0.783	0.752	-0.004	
	8	-0.792	0.733	-0.01	
	9	-0.829	0.76	-0.036	

Vannstand for forsøk: Vannlinje (1:1,5) 9 cm

Kar:			2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2	1 blokk 3
1			252	251	248	291	295	294
2			292	290	284			
3				297	292			
4			294	292	285			
5								

Vannmengde for forsøk: Vannlinje (1:2) 9 cm [liter]

Kar:			2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2	1 blokk 3
1			9	9	10	2	2	2
2			2	2	3	0	0	0
3			0	1	2	0	0	0
4			2	2	3	0	0	0
5								

Figure 51 Calibration and overtopping form, March 16th

Forsøksdato: 14. April 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler		
	1	0,905	-0,909	0	0 m=	5,42	V
	2	0,803	-0,938	0	1m=	4,09	V
	3	0,923	-0,989	0	2m=	2,763	V
	4	0,714	-0,873	0			
	5	0,738	-0,912	0		1,33	V/m
	6	0,934	-1,017	0			
	7	0,8	-0,873	0			
	8	0,777	-0,873	0			
	9	0,872	-0,942	0			

Vannstand for forsøk: 4,5 m (klasse 3) SKRÅ DAM med klokka [mm]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2
	1	108	93	118	124		
	2	218	208	220	224		
	3	206	192	196	203		
	4	203	201	206	209		
	5	275	251	262	270		

Vannmengde for forsøk: 4,5 m (klasse 3) SKRÅ DAM med klokka [liter]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2		
	1	41	45	39	37		
	2	16	18	16	15		
	3	19	22	21	19		
	4	19	20	19	18		
	5	4	9	7	5		

Figure 52 Calibration and overtopping form, April 14th

Forsøksdato: 25. April 2016

Kalibrering av måler 1-9	-5 cm	+5 cm	0	Fartsmåler		
1	0,741	-0,848	0,000	0 m=	5,34	V
2	0,652	-0,776	0,000	1m=	4,02	V
3	0,825	-0,883	0,000	2m=	2,676	V
4	0,639	-0,806	0,000			
5	0,657	-0,816	0,000		1,33	V/m
6	0,821	-0,925	0,000			
7	0,716	-0,783	0,000			
8	0,705	-0,775	0,000			
9	0,785	-0,841	0,000			

Vannstand for forsøk: 4,5 m (klasse 3) SKRÅ DAM med klokka [mm]

Kar:					2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2	
1					179	183	263	268	
2					244	246	286	287	
3					229	230	288	290	
4					220	224	277	280	
5					293	292			

Vannstand for forsøk: 6,0 m (klasse 4). SKRÅ DAM med klokka [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2
1	124	122	143	145	214	213	211	266	270
2	232	235	238	242	268	266	266	290	292
3	232	235	227	230	260	258	256	291	293
4	220	223	217	220	257	248	246	286	280
5	287	287	288	293					
						uten fartmåling			

Vannmengde for forsøk: 4,5 m (klasse 3) SKRÅ DAM med klokka [liter]

Kar:					2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	0	0	0	0	25	24	7	6
2	0	0	0	0	11	10	2	2
3	0	0	0	0	14	14	2	2
4	0	0	0	0	16	15	4	4
5	0	0	0	0	2	2	0	0

Vannmengde for forsøk: 6,0 m (klasse 4) SKRÅ DAM med klokka [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2
1	37	38	33	32	17	17	18	6	5
2	13	13	12	11	6	6	6	2	2
3	13	13	14	14	8	8	8	2	2
4	16	15	16	16	8	10	10	2	4
5	2	2	2	2	0	0	0	0	0

Figure 53 Calibration and overtopping form, April 25th

Forsøksdato: 29. April 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler					
	1	0,824	-0,826	0,000	0 m=	4,72	V			
	2	0,746	-0,762	0,000	1m=	3,41	V			
	3	0,868	-0,871	0,000	2m=	2,07	V			
	4	0,670	-0,789	0,000						
	5	0,692	-0,811	0,000		1,33	V/m			
	6	0,855	-0,908	0,000						
	7	0,660	-0,787	0,000						
	8	0,700	-0,767	0,000						
	9	0,798	-0,829	0,000						

Vannstand for forsøk: 6,0 m (klasse 4). SKRÅ DAM mot klokka [mm]

	Kar:					2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2	1 blokk 3
	1					220	212	292	279	283
	2					270	264		295	293
	3					282	280			
	4					273	264	292	289	291
	5									

Vannmengde for forsøk: 6,0 m (klasse 4) skrå dam mot klokka [liter]

	Kar:					2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2	1 blokk 3
	1					16	17	2	4	3
	2					5	7	0	2	2
	3					3	4	0	0	0
	4					5	7	2	2	2
	5					0	0	0	0	0

Figure 54 Calibration and overtopping form, April 29th

Forsøksdato: 2. mai 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	-5 cm	+5 cm		Fartsmåler		
	1	0,879	-0,925	0,000	0,882	-0,958		0 m=	4,73	V
	2	0,800	-0,849	0,000	0,818	-0,860		1m=	3,4	V
	3	0,934	-0,959	0,000	0,955	-0,987		2m=	2,075	V
	4	0,722	-0,012	0,000	0,717	-0,895				
	5	0,735	-0,885	0,000	0,736	-0,916			1,33	V/m
	6	0,830	-1,054	0,000	0,923	-1,002				
	7	0,707	-0,868	0,000	0,717	-0,882				
	8	0,731	-0,857	0,000	0,747	-0,866				
	9	0,840	-0,920	0,000	0,874	-0,922				
		6,0 m			4,5 m					

Vannstand for forsøk: 4,5 m (klasse 3). Mot klokka [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	136	128	136	134	190	185	272	272
2	206	199	216	212	253	249	287	288
3	197	192	224	219	269	265	291	291
4	209	206	224	221	258	253	284	281
5	258	253	277	276				

Vannstand for forsøk: 6,0 m (klasse 4). Mot klokka [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2
1	176	178	177	168
2	232	230	240	235
3	224	221	247	244
4	227	230	239	237
5	276	276	287	289

Vannmengde for forsøk: 4,5 m (klasse 3). Mot klokka [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	34	37	34	35	22	23	5	5
2	19	20	17	17	9	10	2	2
3	21	22	15	16	6	6	2	2
4	18	19	15	16	8	9	3	3
5	8	9	4	4	0	0	0	0

Vannmengde for forsøk: 6,0 m (klasse 4). Mot klokka [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2
1	25	25	25	27
2	13	14	12	13
3	15	16	10	11
4	14	14	12	12
5	4	4	2	2

Figure 55 Calibration and overtopping form, May 2nd

Forsøksdato: 23. og 25. mai 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler				
	1	0,869	-0,9	0	0 m=	4,6	V		
	2	0,772	-0,84	0	1m=	3,27	V		
	3	0,88	-0,916	0	2m=	1,95	V		
	4	0,694	-0,863	0					
	5	0,718	-0,874	0		1,33	V/m		
	6	0,892	-0,956	0					
	7	0,663	-0,867	0					
	8	0,637	-0,843	0					
	9	0,789	-0,892	0					

Vannstand for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	124	132	142	140	138	202	193	280	276
2	181	187	194	196	194	230	225	284	282
3	185	190	198	198	199	237	233	287	286
4	238	231	244	245	245	241	251	285	283
5	220	233	237	236	240	294	279		
								Avløp 3 og 4 gikk i samme kar	

Vannstand for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	144	152	159	149	160	208	202	275	276
2	202	212	215	205	217	244	237	286	288
3	203	214	215	208	217	245	239	289	291
4	245	242	252	249	254	257	257	288	288
5	242	259	253	245	258	284	278		

Vannmengde for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	37	35	33	33	34	19	21	4	4
2	24	23	21	21	21	14	15	3	3
3	23	22	20	20	20	12	13	2	2
4	12	13	11	11	11	11	9	3	3
5	16	13	12	12	12	2	4	0	0

Vannmengde for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	33	31	29	31	29	18	19	4	4
2	19	17	17	19	16	11	12	2	2
3	19	17	17	18	16	11	12	2	2
4	11	11	9	10	9	8	8	2	2
5	11	8	9	11	8	3	4	0	0

Figure 56 Calibration and overtopping form, May 23. and 25.

Forsøksdato: 26. mai 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler		
	1	0,815	-0,835	0	0 m=	4,11	V
	2	0,724	-0,873	0	1m=	2,796	V
	3	0,888	-0,892	0	2m=	1,454	V
	4	0,671	-0,845	0			
	5	0,691	-0,868	0		1,33	V/m
	6	0,848	-0,955	0			
	7	0,722	-0,852	0			
	8	0,615	-0,81	0			
	9	0,76	-0,899	0			

Vannstand for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [mm]

Kar:	6 blokk 1	6 blokk 2	6 blokk 3	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2
1	138	144	142	151	150	150	211	205	200	278	276
2	191	196	196	205	201	203	240	239	236	288	286
3	196	200	200	206	206	206	246	241	237	290	290
4	221	225	232	227	232	235	256	253	243	287	289
5	248	254	251	266	264	256	289	282	288		
					Glemte agilent			Glemte agilent			

Vannstand for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [mm]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	151	152	164	158	217	222	220	281	279
2	206	206	220	215	171	252	250	289	289
3	211	208	219	216	220	254	250	292	290
4	232	232	238	231	245	249	249	290	290
5	260	260	274	279	269				
					Feilkoblet 1 og 2 delvis i samme kar				

Vannmengde for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [liter]

Kar:	6 blokk 1	6 blokk 2	6 blokk 3	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	2 blokk 3	1 blokk 1	1 blokk 2
1	34	33	33	31	31	31	18	19	20	4	4
2	22	21	21	19	20	19	12	12	12	2	2
3	21	20	20	19	19	19	10	11	12	2	2
4	16	15	13	14	13	13	8	9	11	2	2
5	10	9	9	6	7	8	2	3	2	0	0

Vannmengde for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [liter]

Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	4 blokk 3	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
1	31	31	28	29	16	15	16	3	4
2	19	19	16	17	26	9	10	2	2
3	18	18	16	17	16	9	10	2	2
4	13	13	12	13	11	10	10	2	2
5	8	8	5	4	6	0	0	0	0

Figure 57 Calibration and overtopping form, May 26th

Forsøksdato: 2. juni 2016

Kalibrering av måler 1-9		-5 cm	+5 cm	0	Fartsmåler				
	1	0,863	-0,835	0	0 m=	4,11	V		
	2	0,772	-0,803	0	1m=	2,796	V		
	3	0,882	-0,885	0	2m=	1,454	V		
	4	0,687	-0,814	0					
	5	0,682	-0,868	0		1,33	V/m		
	6	0,866	-0,926	0					
	7	0,729	-0,817	0					
	8	0,684	-0,815	0					
	9	0,816	-0,88	0					

Vannstand for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [mm]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
	1	146	142	151	156	213	206	279	279
	2	211	208	213	217	244	241	290	288
	3	218	214	217	219	249	244	291	291
	4	230	226	237	238	251	249	292	287
	5	250	245	255	255	291	287		

Vannstand for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [mm]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
	1	156	152	166	168	214	220	282	282
	2	222	218	227	225	252	254	293	295
	3	228	220	229	228	254	254	294	294
	4	233	232	243	242	253	254	294	294
	5	260	258	267	268	294	291		

Vannmengde for forsøk: 4,5 m (klasse 3). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [liter]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
	1	32	33	31	30	17	19	4	4
	2	18	18	17	16	11	11	2	2
	3	16	17	16	16	10	11	2	2
	4	14	14	12	12	9	10	2	2
	5	10	11	9	9	2	2	0	0

Vannmengde for forsøk: 6,0 m (klasse 4). Chevron-dam, 15 grader på hver side. Ruhet påført på reservoirsider [liter]

	Kar:	6 blokk 1	6 blokk 2	4 blokk 1	4 blokk 2	2 blokk 1	2 blokk 2	1 blokk 1	1 blokk 2
	1	30	31	27	27	17	16	3	3
	2	15	16	14	15	9	9	2	2
	3	14	16	14	14	9	9	2	2
	4	13	13	11	11	9	9	2	2
	5	8	8	6	6	2	2	0	0

Figure 58 Calibration and overtopping form, June 2nd

7.2. WAVE GENERATION

The wave generation and propagation curves are too many to paste in here, as 211 experiments were ran with the Agilent Measuring Manager. The files are placed on the thumb drive, both original comma separated value-files, and transformed into excel-sheets.

Figure 59 Wave generation files

2block78_2_WLline_inc15.xls Korrigert
2block78_WLline_inc15_040216

6block_WLline_inc15201625_141750171	12.02.2016 11:25	Microsoft Excel 97-2003 Worksheet	2 824 kB
6blokker_WLline_inc15_201625_1456531	12.02.2016 13:55	Microsoft Excel 97-2003 Worksheet	1 641 kB
6blokker_WLline_inc15_201625_132828...	12.02.2016 13:46	Microsoft Excel 97-2003 Worksheet	1 304 kB
6blokker_WLline_inc15_201625_134326...	12.02.2016 13:48	Microsoft Excel 97-2003 Worksheet	1 191 kB
6blokker_WLline_inc15_201625_143542...	12.02.2016 13:45	Microsoft Excel 97-2003 Worksheet	1 360 kB

1blokk8_1_WL4-5m_inc1_5_Robert	31.05.2016 22:34	Microsoft Excel 97-2003 Worksheet	5 577 kB
120216 1blokk8_1_WL4-5m_inc1_5	17.02.2016 13:27	Microsoft Excel 97-2003 Worksheet	1 473 kB
120216 1blokk8_2_WL4-5m_inc1_5	17.02.2016 13:28	Microsoft Excel 97-2003 Worksheet	1 529 kB
120216 1blokk8_3_WL4-5m_inc1_5	17.02.2016 13:29	Microsoft Excel 97-2003 Worksheet	1 304 kB
120216 2blokk78_1_WL4-5m_inc1_5	17.02.2016 13:31	Microsoft Excel 97-2003 Worksheet	1 361 kB
120216 2blokk78_2_WL4-5m_inc1_5	17.02.2016 13:34	Microsoft Excel 97-2003 Worksheet	2 149 kB

120216 1blokk8_1_WL6m_inc1_5	12.02.2016 13:43	Microsoft Excel 97-2003 Worksheet	1 360 kB
120216 1blokk8_2_WL6m_inc1_5	12.02.2016 13:49	Microsoft Excel 97-2003 Worksheet	966 kB
120216 2blokk78_1_WL6m_inc1_5	12.02.2016 13:25	Microsoft Excel 97-2003 Worksheet	1 191 kB
120216 2blokk78_2_WL6m_inc1_5	12.02.2016 13:36	Microsoft Excel 97-2003 Worksheet	1 529 kB
120216 4blokk1278_1_WL6m_inc15	12.02.2016 12:51	Microsoft Excel 97-2003 Worksheet	1 191 kB
120216 4blokk1278_2_WL6m_inc15	12.02.2016 13:04	Microsoft Excel 97-2003 Worksheet	1 979 kB
120216_6block123478_1_WL6m_inc1.5	12.02.2016 12:04	Microsoft Excel 97-2003 Worksheet	1 247 kB
120216_6blokk123478_2_WL6m_inc1_2...	12.02.2016 12:52	Microsoft Excel 97-2003 Worksheet	1 528 kB

170216 4blokk1278_1_WL4-5m_inc1_5	01.06.2016 11:09	Microsoft Excel 97-2003 Worksheet	6 258 kB
170216 4blokk1278_2_WL4-5m_inc1_5	01.06.2016 11:11	Microsoft Excel 97-2003 Worksheet	2 148 kB
170216 6blokk123478_1_WL4-5m_inc1_5	17.02.2016 13:19	Microsoft Excel 97-2003 Worksheet	2 430 kB
170216 6blokk123478_2_WL4-5m_inc1_5	01.06.2016 11:13	Microsoft Excel 97-2003 Worksheet	2 430 kB

190216 1blokk8_1_WL6m_inc1_5	19.02.2016 11:56	Microsoft Excel 97-2003 Worksheet	2 318 kB
190216 1blokk8_2_WL6m_inc1_5	19.02.2016 12:21	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 2blokk78_1_WL6m_inc1_5	19.02.2016 12:30	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 2blokk78_2_WL6m_inc1_5	19.02.2016 13:06	Microsoft Excel 97-2003 Worksheet	3 443 kB
190216 4blokk1278_1_WL6m_inc1_5	19.02.2016 13:07	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 4blokk1278_2_WL6m_inc1_5	19.02.2016 13:23	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 6blokk123478_1_WL6m_1_5	19.02.2016 13:42	Microsoft Excel 97-2003 Worksheet	2 824 kB
190216 6blokk123478_2_WL6m_1_5	19.02.2016 13:51	Microsoft Excel 97-2003 Worksheet	2 824 kB

190216 1blokk8_1_WL4_5m_15	19.02.2016 11:14	Microsoft Excel 97-2003 Worksheet	2 205 kB
190216 1blokk8_2_WL4_5m_15	19.02.2016 11:21	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 2blokk78_1_WL4_5m_15	19.02.2016 10:57	Microsoft Excel 97-2003 Worksheet	2 486 kB
190216 2blokk78_2_WL4_5m_15	19.02.2016 11:08	Microsoft Excel 97-2003 Worksheet	2 711 kB
190216 4blokk1278_1_WL4_5m_15	19.02.2016 10:38	Microsoft Excel 97-2003 Worksheet	2 261 kB
190216 4blokk1278_2_WL4_5m_15	19.02.2016 10:41	Microsoft Excel 97-2003 Worksheet	2 317 kB
190216 6blokk123478_1_WL4_5m_15	19.02.2016 10:06	Microsoft Excel 97-2003 Worksheet	11 269 kB
190216 6blokk123478_2_WL4_5m_15	19.02.2016 10:28	Microsoft Excel 97-2003 Worksheet	2 317 kB

1blokk7_1_WLline_inc2_2016226_10191...	28.02.2016 23:00	Microsoft Excel Worksheet	594 kB
1blokk7_2_WLline_inc2_2016226_10263...	28.02.2016 23:00	Microsoft Excel Worksheet	702 kB
4blokk1278_1_WLline_inc2_2016226_94...	28.02.2016 23:00	Microsoft Excel Worksheet	451 kB
4blokk1278_2_WLline_inc2_2016226_95...	28.02.2016 23:00	Microsoft Excel Worksheet	484 kB
6blokk123478_1_WLline_inc2_2016226_...	28.02.2016 23:00	Microsoft Excel Worksheet	451 kB
6blokk123478_2_WLline_inc2_2016226_...	28.02.2016 23:00	Microsoft Excel Worksheet	529 kB

4block7812_1_4_5m_skraVmotHinc1_5	14.04.2016 15:41	Microsoft Excel Worksheet	1 095 kB
4block7812_2_4_5m_skraVmotHinc1_5	14.04.2016 15:39	Microsoft Excel Worksheet	1 224 kB
6block781234_1_4_5m_skraVmotHinc1...	14.04.2016 15:37	Microsoft Excel Worksheet	1 002 kB
6block781234_2_4_5m_skraVmotHinc1...	14.04.2016 15:36	Microsoft Excel Worksheet	1 199 kB
140416 4block7812_1_4_5m_skraVmot...	14.04.2016 15:41	Microsoft Excel Worksheet	1 095 kB
140416 4block7812_2_4_5m_skraVmot...	14.04.2016 15:39	Microsoft Excel Worksheet	1 224 kB
140416 6block781234_1_4_5m_skraVm...	14.04.2016 15:37	Microsoft Excel Worksheet	1 002 kB
140416 6block781234_2_4_5m_skraVm...	14.04.2016 15:36	Microsoft Excel Worksheet	1 199 kB

1block7_1_4_5m_skraVmotHinc1_5	29.04.2016 11:06	Microsoft Excel Worksheet	985 kB
1block7_1_6m_skraVmotHinc1_5	29.04.2016 11:03	Microsoft Excel Worksheet	1 204 kB
1block7_2_4_5m_skraVmotHinc1_5	29.04.2016 10:59	Microsoft Excel Worksheet	950 kB
1block7_2_6m_skraVmotHinc1_5	29.04.2016 10:57	Microsoft Excel Worksheet	1 183 kB
2block78_1_4_5m_skraVmotHinc1_5	29.04.2016 10:02	Microsoft Excel Worksheet	1 179 kB
2block78_1_6m_skraVmotHinc1_5	29.04.2016 10:54	Microsoft Excel Worksheet	1 212 kB
2block78_2_4_5m_skraVmotHinc1_5	29.04.2016 10:45	Microsoft Excel Worksheet	1 036 kB
2block78_3_6m_skraVmotHinc1_5	29.04.2016 10:40	Microsoft Excel Worksheet	1 606 kB
2block78_23_6m_skraVmotHinc1_5	29.04.2016 11:46	Microsoft Excel Worksheet	1 212 kB
4block1278_1_6m_skraVmotHinc1_5	29.04.2016 10:26	Microsoft Excel Worksheet	1 313 kB
4block1278_2_6m_skraVmotHinc1_5	29.04.2016 10:13	Microsoft Excel Worksheet	1 423 kB
6block123478_1_6m_skraVmotHinc1_5	29.04.2016 10:09	Microsoft Excel Worksheet	1 343 kB
6block123478_2_6m_skraVmotHinc1_5	29.04.2016 10:06	Microsoft Excel Worksheet	1 280 kB
250416 1block_6m_1_skraVmotH_15	29.04.2016 11:03	Microsoft Excel Worksheet	1 204 kB
250416 1block_6m_2_skraVmotH_15	29.04.2016 10:57	Microsoft Excel Worksheet	1 183 kB
250416 1block_45m_1_skraVmotH	29.04.2016 11:06	Microsoft Excel Worksheet	985 kB
250416 1block_45m_2_skraVmotH	29.04.2016 10:59	Microsoft Excel Worksheet	950 kB
250416 2block_6m_1_skraVmotH	29.04.2016 10:40	Microsoft Excel Worksheet	1 606 kB
250416 2block_6m_2_skraVmotH	29.04.2016 10:54	Microsoft Excel Worksheet	1 212 kB
250416 2block_6m_3_skraVmotH	29.04.2016 11:46	Microsoft Excel Worksheet	1 212 kB
250416 2block_45m_1_skraVmotH	29.04.2016 10:02	Microsoft Excel Worksheet	1 179 kB
250416 2block_45m_2_skraVmotH	29.04.2016 10:45	Microsoft Excel Worksheet	1 036 kB
250416 4block_6m_1_skraVmotH	29.04.2016 10:26	Microsoft Excel Worksheet	1 313 kB
250416 4block_6m_2_skraVmotH	29.04.2016 10:13	Microsoft Excel Worksheet	1 423 kB
250416 6block_6m_1_skraVmotH	29.04.2016 10:09	Microsoft Excel Worksheet	1 343 kB
250416 6block_6m_2_skraVmotH	29.04.2016 10:06	Microsoft Excel Worksheet	1 280 kB

1block7_1_6m_skraHmotVinc1_5	02.05.2016 14:10	Microsoft Excel Worksheet	1 179 kB
1block7_2_6m_skraHmotVinc1_5	02.05.2016 14:22	Microsoft Excel Worksheet	1 180 kB
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290416 1block_6m_2_skraHmotV	02.05.2016 14:22	Microsoft Excel Worksheet	1 180 kB
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290416 2block_6m_2_skraHmotV	02.05.2016 14:13	Microsoft Excel Worksheet	1 298 kB

1block7_1_4_5m_skraHmotVinc1_5	02.05.2016 15:24	Microsoft Excel Worksheet	1 189 kB
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1block7_3_6m_DobbelSkra_inc1_5	25.05.2016 11:27	Microsoft Excel Worksheet	1 192 kB
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230516 4block_6m_3_Chevron_ukar	25.05.2016 11:10	Microsoft Excel Worksheet	1 159 kB
230516 4block_45m_1_Chevron	25.05.2016 11:17	Microsoft Excel Worksheet	1 137 kB
230516 4block_45m_2_Chevron	25.05.2016 11:14	Microsoft Excel Worksheet	1 223 kB
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230516 6block_45m_2_Chevron	25.05.2016 10:58	Microsoft Excel Worksheet	1 138 kB

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