Integrated Flood Risk Analysis
and Management Methodologies

IMPACT Project Field Tests Data Analysis

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SUMMARY

Part of the FLOODsite Task 4 research programme included a review and more detailed analysis of the IMPACT Project field and laboratory test data relating to breach growth and breach modelling (see www.impact-project.net work package 2). As part of FLOODsite Task 6, HR Wallingford established links with the CEATI facilitated Dam Safety Interest Group project on breach modelling. Through this project, copies of data arising from the IMPACT project, but provided via the original IMPACT Project Norwegian partner, and a number of intermediary organisations, was received by HR Wallingford and noted to significantly differ from the original master data sets held by HR Wallingford (as coordinator of the IMPACT Project, and work package leader for the breach work).

This report presents the conclusions of a long term investigation into the source of the differences in the IMPACT data sets, and concludes recommended values for future use of the IMPACT data. The investigation concluded that:

- There are significant differences between the IMPACT data now being used, as compared to the data used during breach model testing under the IMPACT project. The extent to which this affects research conclusions from the IMPACT project is unclear. Researchers using data originating from the IMPACT project itself should refer to this report and associated data sets to ensure they are using correct data
- It appears that much of the data provided from Norway during the IMPACT project (i.e. the field test data) related to proposed rather than as built test conditions. Significant differences between proposed and as built conditions which were not reported at the time have now been identified. However, whilst these explain a significant number of the data differences, they do not explain all differences, including some of the major differences.
- Some flow data has been recalculated. This includes reservoir releases providing inflow to the test site as well as measured breach flow
- Some revised calculations provided from Norway still appear to be incorrect, hence some questions still remain as to actual data values

These findings are disappointing, both for the IMPACT partners who were assured of data quality at the time of the original research and more recently for a growing number of researchers around the world who have been using data from the original project reports. Whilst the original data was not formally released pending final analyses at the end of the project, it is clear that data has been shared and a number of researchers have published work using the original data. It is recommended that these researchers review their analyses in light of the findings reported here.

This report endeavours to identify errors and offers a 'best estimate' of correct data sets that may subsequently be used in breach model verification and validation.

Copies of the IMPACT project breach data are also now being made publicly available alongside this report.

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1. Introduction

1.1 Background

The Investigation of Extreme Flood Processes & Uncertainty (IMPACT) project was funded by the European Commission (EC), with additional financial support from various partners, and addressed the assessment and reduction of risks from extreme flooding caused by natural events or the failure of dams and flood defence structures. The project started in 2002 and lasted for 3 years. For more information see www.impact-project.net

Research for this project was structured in order to advance scientific knowledge and understanding, and develop predictive modelling tools in four key areas. Firstly, the movement of sediment generated by a failure. Secondly, the mechanisms for the breaching of embankments (dams or flood control dykes) and factors determining breach location. Thirdly, the simulation of catastrophic inundation of valleys and urban areas and fourthly the use of geophysical techniques for the rapid integrity assessment of flood defence embankments.

To advance knowledge in the area of embankment breaching, a series of 5 field and 22 laboratory tests were undertaken at a test site in Norway and at HR Wallingford in the UK, respectively. The Norwegian partner in IMPACT was SWECO (formerly Statkraft Groner). SWECO undertook the field testing in Norway in conjunction with a supporting Norwegian national research programme on dam safety. A range of additional Norwegian partners operated on this project; Norconsult was responsible for the field test construction, implementation and data collection and processing. The data from both the Norwegian field tests and UK laboratory tests wasused to establish a programme of numerical breach model comparison and development within the IMPACT project.

The responsibility for data quality for field, laboratory and numerical model tests resided with the partner responsible for collection of their data, and subsequent provision to the wider research team. As coordinator for this work package, HR Wallingford undertook periodic consistency checks on data provided by all partners during the testing programme. At the time, this identified a number of data quality issues with the field test data which were supposedly addressed. It is clear from the analysis within this report that these issues went much further than originally identified and were not adequately addressed by SWECO at that time – particularly in light of how the data was being used within the IMPACT project team for numerical breach model development, comparison and validation.

After completion of the IMPACT project, HR Wallingford has actively continued with the development of the HR BREACH model. This model which was developed prior to the IMPACT project and is one of the models that was included in the IMPACT numerical modelling programme.

The Dam Safety Interest Group (DSIG) is composed of dam owners from around the world (Canada, US, Australia, Sweden, France, UK and Germany) who jointly sponsor research & development projects designed to help assess and improve the safety of dams (see www.ceatech.ca/DSIG.php). In January 2007 the DSIG invited HR Wallingford to participate in the DSIG breach modelling programme. The programme involves the evaluation of 3 breach models and aims to find the best approach(s) to modelling the breaching of embankments. The DSIG has also identified 7 potential benchmark test cases for the purpose of this program. Three of the test cases are from the IMPACT field tests that were undertaken in Norway. The DSIG acquired this data from SWECO after the completion of the IMPACT project.

HR Wallingford received the benchmark data from the DSIG in order to prepare for the numerical modelling programme. As a quality check, the data received from the DSIG was compared against the data already held by HR Wallingford from the IMPACT project. The initial checks showed differences and discrepancies between the two data sets and hence a more detailed data check was undertaken by

HR Wallingford which revealed that there are significant differences between the DSIG and IMPACT data sets.

In light of the differences found, the DSIG testing programme was delayed pending clarification. Conclusions from the IMPACT project analyses may also be affected by these data differences, however the extent of any impact is not immediately obvious. Discussions were held between HR Wallingford, DSIG, SWECO, and Norconsult by email and personal communication to identify the cause of any differences and hence agree on definitive data sets. The response from the Norwegian partners in this exercise was disappointing.

A wide range of data differences were identified. The investigation concluded that:

- There are significant differences between the IMPACT data now being used, as compared to the data used during breach model testing under the IMPACT project. The extent to which this affects research conclusions from the IMPACT project is unclear. Researchers using data originating from the IMPACT project itself should refer to this report and associated data sets to ensure they are using correct data
- Much of the data provided from Norway during the IMPACT project (i.e. the field test data) related to proposed rather than as built test conditions. Significant differences between proposed and as built conditions which were not reported at the time have now been identified. However, whilst these explain a significant number of the data differences, they do not explain all differences, including some of the major differences.
- Some flow data has been recalculated. This includes reservoir releases providing inflow to the test site as well as measured breach flow
- Some revised calculations provided from Norway still appear to be incorrect

This report aims to present the field test data discrepancies and endeavour to establish logically and objectively a 'correct' data set for each of the field tests that can be used in the DSIG modelling programme. To achieve that, this report depends mainly on two sources of data which are the IMPACT project technical report for Work Package 2 (WP2) 'the breach physical and numerical modelling' and the Norwegian project stability and breaching of embankment dams report on Sub-project 3 (SP3) 'breaching of embankment dams'.

2. Test 1-02 – Homogeneous Cohesive (Clay) Test - Overflow

This test was undertaken in September 2002. The embankment (See Figure 1) was built mainly from clay and silt (D50 < 0.01 mm) with less than 15% sand. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous cohesive embankments failed by overtopping.

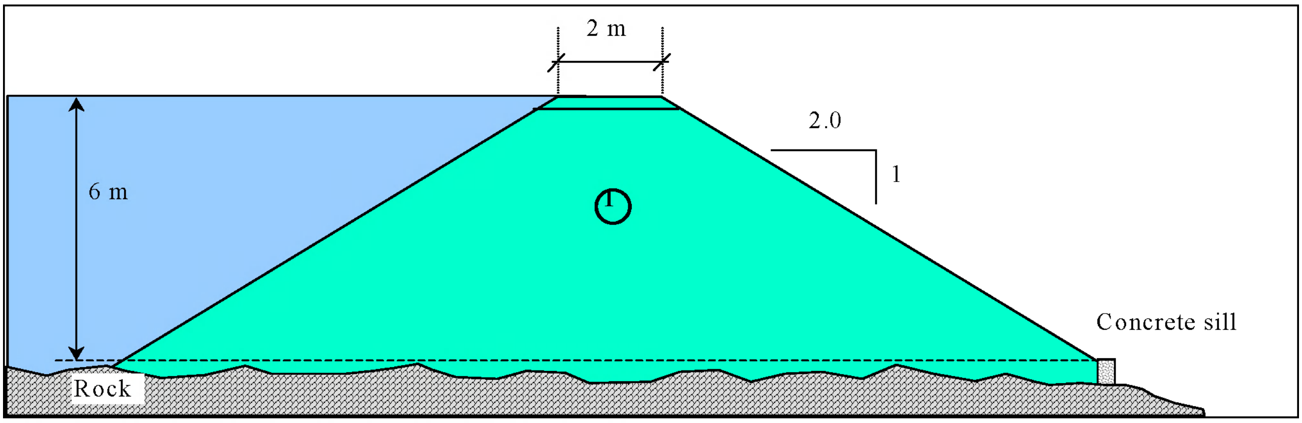

Figure 1: Design data for Test 1-02

2.1 Data checks

2.1.1 Dam geometry:

Table 1 shows the geometry data collected from the SP3 and the IMPACT WP2 reports. As shown in the table, there is a difference between all the items listed. The effect of data differences on breach modelling will depend upon which aspect of breach model performance was being assessed. For example, errors in notch initial size and elevation could significantly affect breach timing. The differences are explained by SWECO and Norconsult as originating from the differences between the design and as built conditions. This shows a disturbing level of variance from design to as built – for example, 100mm difference in crest elevation and a difference in side slopes resulting in a base width some 3.5m greater than planned!

Despite being aware of the purpose of the IMPACT project tests, SWECO and Norconsult did not emphasise any significant differences in design and as built data during the IMPACT project, hence this was not recognised as a potential issue affecting data quality. To the contrary, all reports and publications arising from the work in Norway continued to present the 'design condition data' as the data for research use, including the material provided for the end of project reports.

In the absence of any data to the contrary our recommendation can only be to now use the as built data provided in the SP3 report for the dam geometry of this test case.

Table 1: Test 1-02 dam geometry

Dam Geometry:	SP3	IMPACT WP2	Recommended Values
Dam Height (m)	5.9	6	5.9
Upstream shoulder slope	1:2.4	1:2.0	1:2.4
Downstream shoulder slope	1:2.25	1:2.0	1:2.25
Initial breach depth (m)	0.4-0.5	0.5	0.4-0.5
Initial bottom breach width (m)	5.5	5.4	5.5
Initial top breach width (m)	7.8	8	7.8

2.1.2 Soil properties:

Table 2 shows the soil data collected from the SP3 and IMPACT WP2 reports. Data comparisons show that there are no significant differences between the data sets. There are only small variations which might be due to data being taken from different samples within the same soil. These variations are expected have a minor effect on modelling results. It is recommended to use a combination of the SP3 and WP2 data sets as shown below.

Table 2: Test 1-02 soil properties

Soil Properties:	SP3	IMPACT WP2	Recommended Values
Moisture content	30	30	30
D50 (mm)	0.007	0.009	0.007
Porosity	0.46	0.47	0.46
Angle friction	22.9	22.9	22.9
Cohesion (KN/m^2)	4.9	5	4.9
Dry density (KN/m^3)	14.8*	14.7	14.8

2.1.3 Flow and water level data:

1. Inflow Data:

Figure 2 shows the reservoir inflow data presented in the SP3 and the IMPACT WP2 reports. Data comparisons show a difference of an approximately 5% increase in the peak inflow value and also along the constant inflow that follows the peak. It is unclear why the inflow hydrograph has changed whilst the water levels which were used to obtain the hydrograph have not changed (See below) – no guidance has been given in response to questions on this point. Therefore, in the absence of a response from Norway, it is recommended to use the water levels data, rather than flow data, for this test case as an upstream boundary condition. Where a flow boundary condition is required modellers should undertake two runs using the two different inflow hydrographs and compare the model outflow output with the corresponding outflow hydrographs.

2. Water Level Data:

For this test, data comparisons show that the water level data is identical in both the SP3 and IMPACT WP2 reports. However it should be noted that water level data provided in the DSIG file for this test case is only a sample of the complete data set, as shown in Figure 3 below. The full data set is available via the original IMPACT project data if it has not been provided to the DSIG as part of the SP3 report.

3. Outflow Data:

A visual comparison of the reservoir outflow data presented in the SP3 and IMPACT WP2 reports shows an increase in the peak outflow value and also along the hydrograph from a time approximately equal to 20,000 seconds until the end of the hydrograph. This is probably due to the observed increase in the inflow hydrograph (see above). The full data set used in the SP3 report was not available in suitable digital format therefore Figure 4 shows a comparison between the IMPACT WP2 data set against the data provided from the DSIG modelling data, which is a sub set of the data shown in the SP3 report. The data can be visually compared with Figure 5 which shows the data presented in the SP3 report. Similar to the inflow issue, and in the absence of any clarification from Norway, modellers are asked to follow the same recommendation given for using the inflow data above.

* Calculated based upon grain density and porosity values

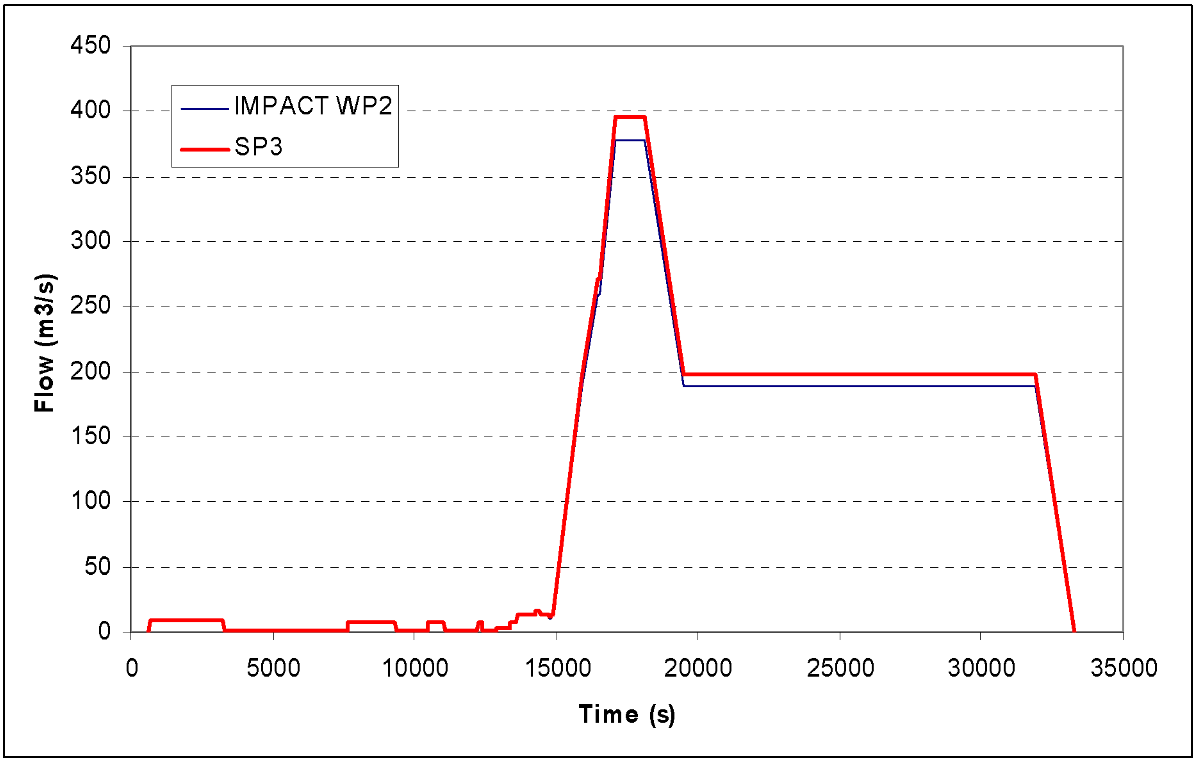

Figure 2: Inflow to the reservoir

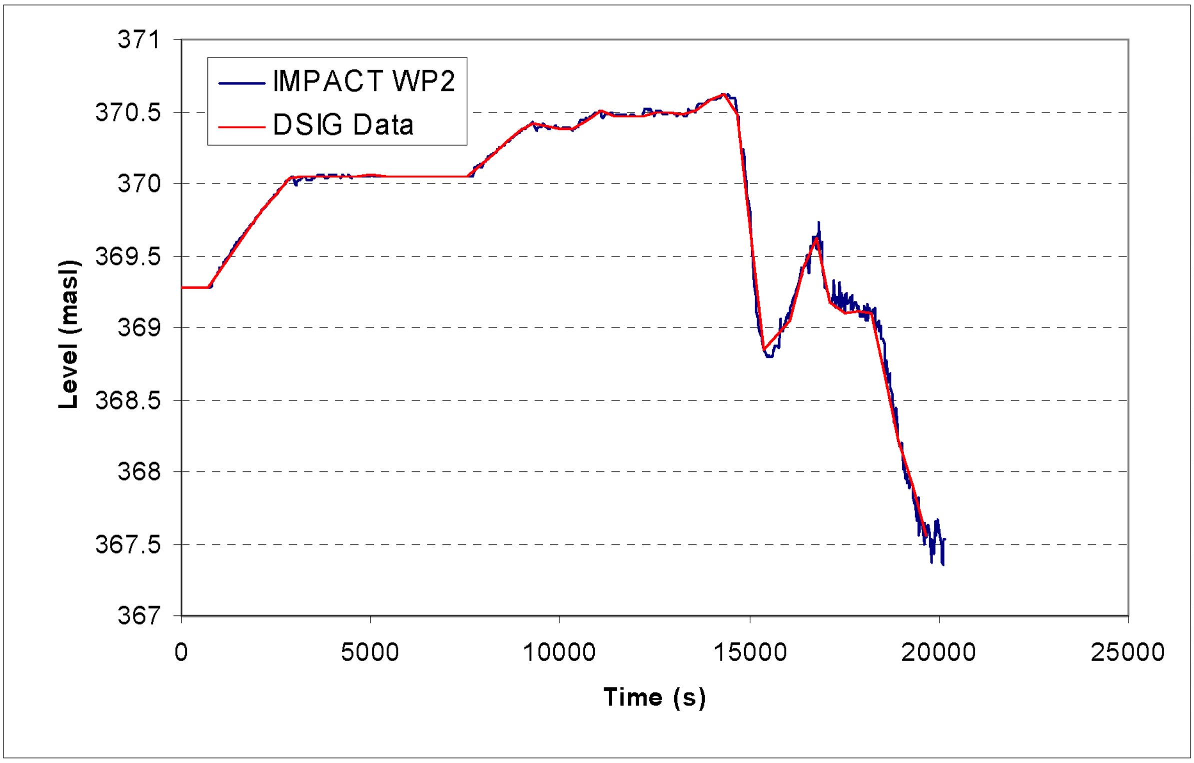

Figure 3: Test 1-02 water level.

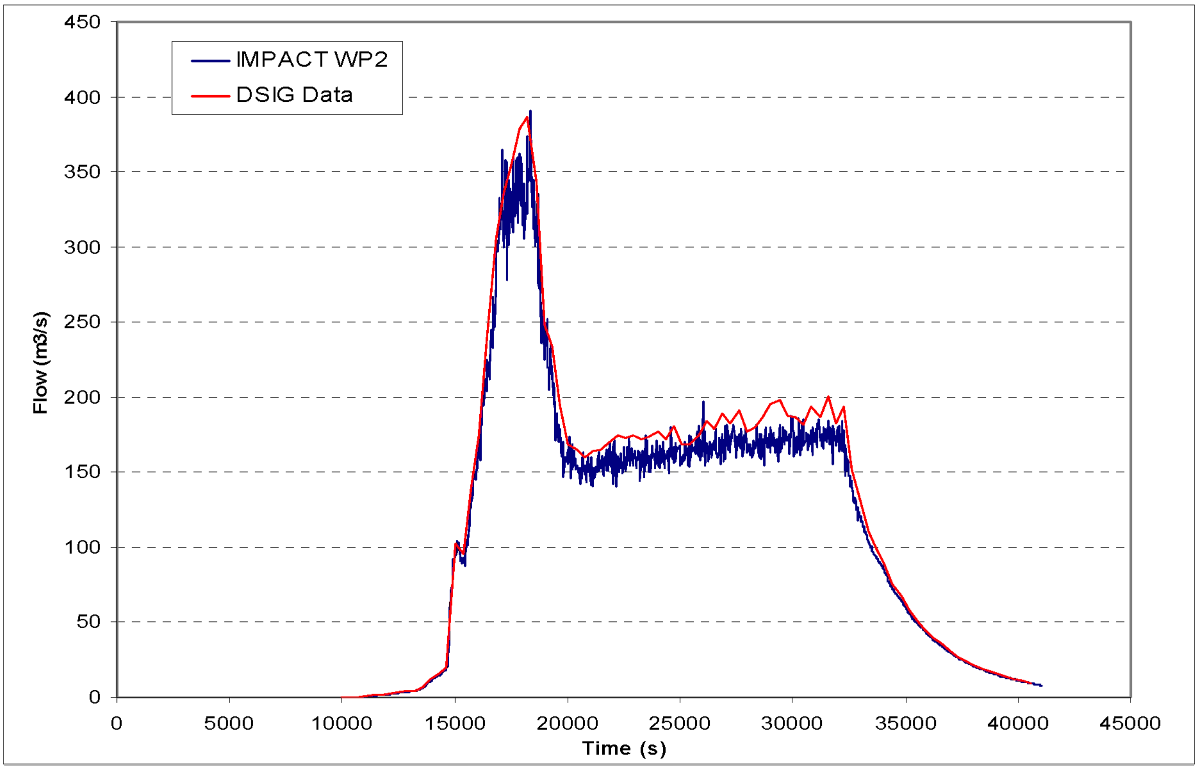

Figure 4: Test 1-02 outflow hydrograph

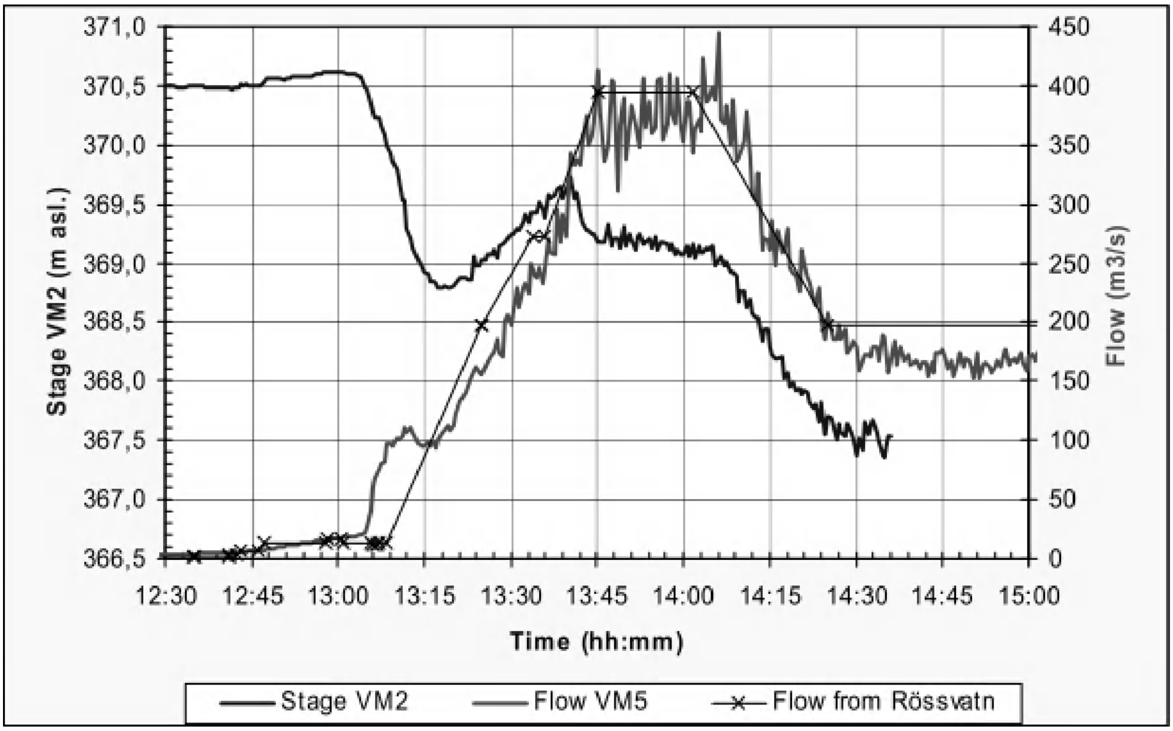

Figure 5: Test 1-02 outflow hydrograph from the SP3 report (called flow VM5 in the legend)

2.2 Additional comments

The specification for this test was to use dozer compaction of the clay in 0.15m layers. However, due to the high water content in the clay deposit (w = 28-33%) and spells of rainy weather, the construction of this dam became difficult. At a height 1.5-2 m (and maybe even as high as 3 m) above foundation the compaction layer thickness was increased to 0.4 m to improve construction speed and the compaction pressure of about 50 kN/m2 was reduced by replacing the 30-ton backhoe by a 17-ton backhoe with wider belts.

The effect of this for breach modelling is that the embankment is likely to comprise of broadly two layers of clay, compacted to different conditions and hence with different erodibility. The magnitude of this effect on breach growth is not immediately clear.

3. Test 2C-02 – Homogeneous Non Cohesive (Gravel) Test - Overflow

This test was undertaken in October 2002. The embankment (See Figure 6) was built mainly from non-cohesive materials (D50 ≈ 5 mm) with less than 5 % fines. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous non-cohesive embankments failed by overtopping and also to assess / inspect the effect of seepage on the breach formation processes.

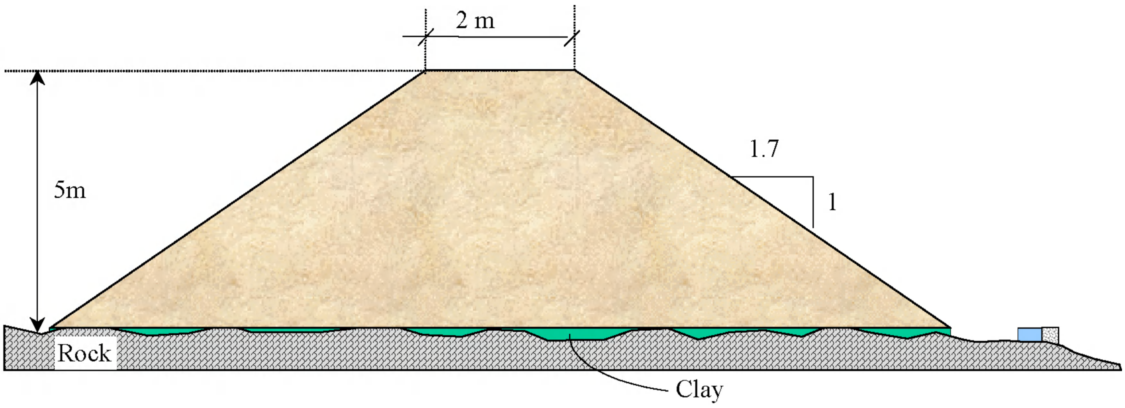

Figure 6: Design data for Test 2C-02

3.1 Data checks

3.1.1 Dam geometry:

Table 3 shows a comparison of the geometry data collected from SP3 and IMPACT WP2 reports. As shown in the table, there is a difference between most of the items listed. In this case, differences could have a medium to significant difference on breach model analysis. As with Test1-02, the suggestion is that these differences arise from differences in design and as built conditions.

As with Test1-02, if these differences do arise from as built compared to design, then the differences suggest relatively poor construction tolerance / control. Additionally, these values directly contradict clear statements received from SWECO during the IMPACT project regarding construction geometry. However, in the absence of a more detailed response from Norway, our recommendation is to use the as built data provided in the SP3 report for the dam geometry of this test case.

Table 3: Test 2C-02 dam geometry

Dam Geometry:	SP3	IMPACT WP2	Recommended Values
Dam Height (m)	5	5	5
Upstream shoulder slope	1:1.9	1:1.7	1:1.9
Downstream shoulder slope	1:1.6	1:1.7	1:1.6
Initial breach depth (m)	0.12	0.1	0.12
Initial breach width (m)	2	2	2

3.1.2 Soil properties:

Table 4 shows the soil data collected from SP3 and IMPACT WP2 reports. Data comparisons show that there is no significant difference between the data sets except for the values of the angle of friction and dry density which can have a significant effect on modelling results.

Table 4: Test 2C-02 soil properties

Soil Properties:	SP3	IMPACT WP2	Recommended Values
Moisture content	7	7	7
D50 (mm)	4.75	4.65	4.75
Porosity	0.22	0.22	0.22
Angle friction	-	42	42
Cohesion (KN/m^2)	0	0.9	0.9
Dry density (KN/m^3)	21.2*	21.2	21.2

Specific data of the angle of friction and dry density for this test was sent to HR Wallingford by SWECO during the IMPACT project. For all the other soil properties, there are only small variations which might arise from data being taken from different soil samples. These variations are expected have a minor effect on modelling results. It is recommended to use a combination of the SP3 and WP2 data sets as shown in Table 4 above.

3.1.3 Flow and water level data:

1. Inflow Data:

Data comparisons show that the inflow data is identical in both the SP3 and IMPACT WP2 reports.

2. Water level Data:

Data comparisons show that water levels data is identical in both the SP3 and IMPACT WP2 reports.

3. Outflow Data:

Data comparisons show a significant difference between the data reported in the SP3 and IMPACT WP2 reports (See Figure 7). SP3 shows data calculated using HECRAS. This suggests a recalculation of breach flow in some form. It is stated in the SP3 report that errors were found in the volume balance calculation for this test case which is probably due to ice build up at the location of the flow measurement downstream of the dam. However, email records show that corrections to data were made during the IMPACT project and that modified data was correct at that time. .

Recent volume calculations undertaken by HR Wallingford show that neither of the hydrographs shown in Figure 7 satisfy the volume balance equation. Based upon the hydrographs shown in Figure 7, the volume of water under the SP3 and WP2 hydrographs is 23,478 and 81,227 m^3 respectively starting from time T=0 to T=2690 seconds. The inflow volume for this period of time is approximately 1,100 m^3. The reservoir water level at T=0 was 369.808 (m.a.s.l.) which translates to a volume equals 31,920 m^3. Based upon the information presented in the SP3 report, the reservoir was empty at the end of the test. Using the above figures for both data sets does not satisfy the following volume balance equation:

Inflow Volume + Initial Reservoir Volume – Outflow Volume – Final Reservoir Volume = 0

For the SP3 Report:

$1100 + 31920 – 23478 – 0 = 9542\ m^3$

* Calculated based upon grain density and porosity values

For the WP2 data

$1100 + 31920 – 81227 - 0 = -48207 m^3$

This shows that there is still a problem with the two hydrographs provided by SWECO and Norconsult and that the correct hydrograph probably lies between the two curves, but likely closer to the SP3 curve. No further comment on this has been received from Norway.

It is therefore recommended that modellers use the two hydrographs for purpose of comparison, knowing that their outflow results should lie between the two given outflow hydrographs (Figure 7) and probably closer to the one calculated by HECRAS.

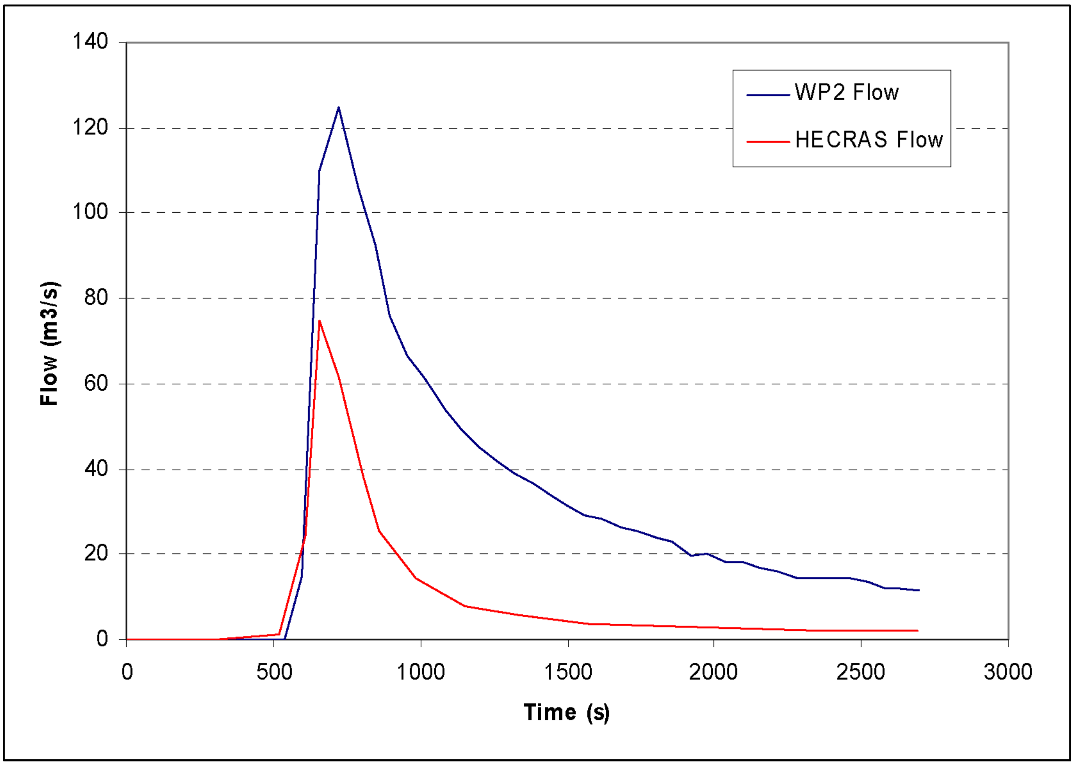

Figure 7: Test 2C-02 outflow hydrograph.

3.2 Additional comments

This gravel embankment was constructed using vibratory roller compaction in 0.5m layers.

Inspection of the video footage for this test highlights the fact that the test was late in the year (16th October 2002) and that temperatures had dropped sufficiently to cause ice to form on the upstream reservoir and that (at least) the surface of the gravel material had become frozen. To defrost the crest material, the initiation notch was blocked and water allowed to rise and sit within the notch. When the surface was considered sufficiently defrosted, the plank and sand bags used to block the notch were removed and the test began.

The freezing conditions and defrosting of the crest has two significant implications for breach modelling:

1 The test actually starts with a water level higher than the base of the initiation notch. This needs to be considered if the timing of model predictions of breach growth are to be assessed,

since modelling this breach and ignoring this effect will invariably result in models predicting breach earlier than was observed.

2 The subsequent growth of the breach through the embankment may have be affected by frozen material. The breach growth demonstrates strict headcut growth with rigidly vertical sides and migrating erosion face that remains vertical until it cuts back through the upstream face of the embankment. This behaviour is not normally expected of a non cohesive gravel material and may reflect significant ice formation within the embankment.

4. Test 1-03 – Composite Structure (Gravel with Moraine Core) - Overflow

This test was undertaken in August 2003. The upstream and downstream shoulders were built from rock fill with a central moraine core. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in composite embankments failed by overtopping.

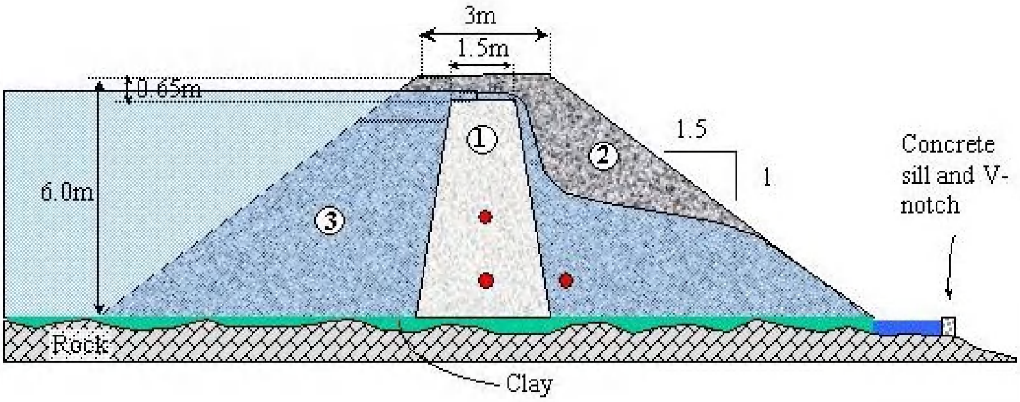

Figure 8: Design data for Test 1-03

4.1 Data checks

4.1.1 Dam geometry:

Table 5 shows the geometry data collected from the SP3 and the IMPACT WP2 reports. As shown in the, table there is a difference between all the items listed. Some differences would have a small effect on breach modelling, whilst others could have a medium to significant difference. . As with the previous tests it has been suggested by SWECO that these differences originated from the difference between the design and as built data. .

Again, as with previous test data, there are inconsistencies between email correspondence from the IMPACT project and the current suggestion as to the cause of differences. In particular, correspondence relating to the size of the initiation notch is quite clear and contradictory.

Our recommendation is to use the as built data provided in the SP3 report for the dam geometry of this test case except for the notch dimensions where as built data sent to HR Wallingford should be used.

Table 5: Test 1-03 dam geometry

Dam Geometry:	SP3	IMPACT WP2	Recommended Values
Dam Height (m)	5.9	6	5.9
Upstream shoulder slope	1:1.55	1:1.5	1:1.55
Downstream shoulder slope	1:1.45	1:1.5	1:1.55
Core slopes	4:1	5:1	4:1
Initial breach depth (m)	0.24	0.2	0.24
Initial bottom breach width (m)	6.5	8	6.1
Initial top breach width (m)	6.5	8	7.8

4.1.2 Soil properties:

Table 6 shows the soil data collected from SP3 and IMPACT WP2 reports. Data comparisons show that there are some differences between the data sets for both the moraine and the rock fill materials. The following explanation was received from Norway:

1. The same grading data was reported in the SP3 and the IMPACT WP2 reports for both the moraine and rock fill.

2. The angle of friction was never measured for rock fill.

3. For other differences, several samples were taken with different moisture content, sieve curves and dry density.

Data checks show that:

1. Point No.1 above is correct. The same curves are used in the SP3 and the IMPACT WP2 reports. However, by using that curve (See Figure 9) it can be concluded that the D_{50} is between 6 and 7 mm and a value equals 7 mm was used. (It is hard to see how using this curve provides a D_{50} equal to 5.5 mm).

2. Point No. 2 contradicts information emailed to HR Wallingford during the IMPACT project in which laboratory data is given for the moraine and rockfill material for all the tests undertaken in 2003.

3. Point No 3 may be true but was not previously advised.

Table 6: Test 1-03 soil properties

Moraine	SP3	IMPACT WP2	Recommended Values
D_{50} (mm)	5.5	7	7
Moisture content	0.06	0.06	0.06
Angle of friction	45.6	42	45.6
Cohesion (KN/m^2)	-	20	20
Porosity	0.244	0.21	0.244
Dry density (KN/m^3)	20.6*	20.5	20.6
Rockfill			
D_{50} (mm)	85	85	85
Moisture content	0.02	-	0.02
Angle of friction	-	42	42
Porosity	0.235	0.163	0.235

* Calculated based upon grain density and porosity values

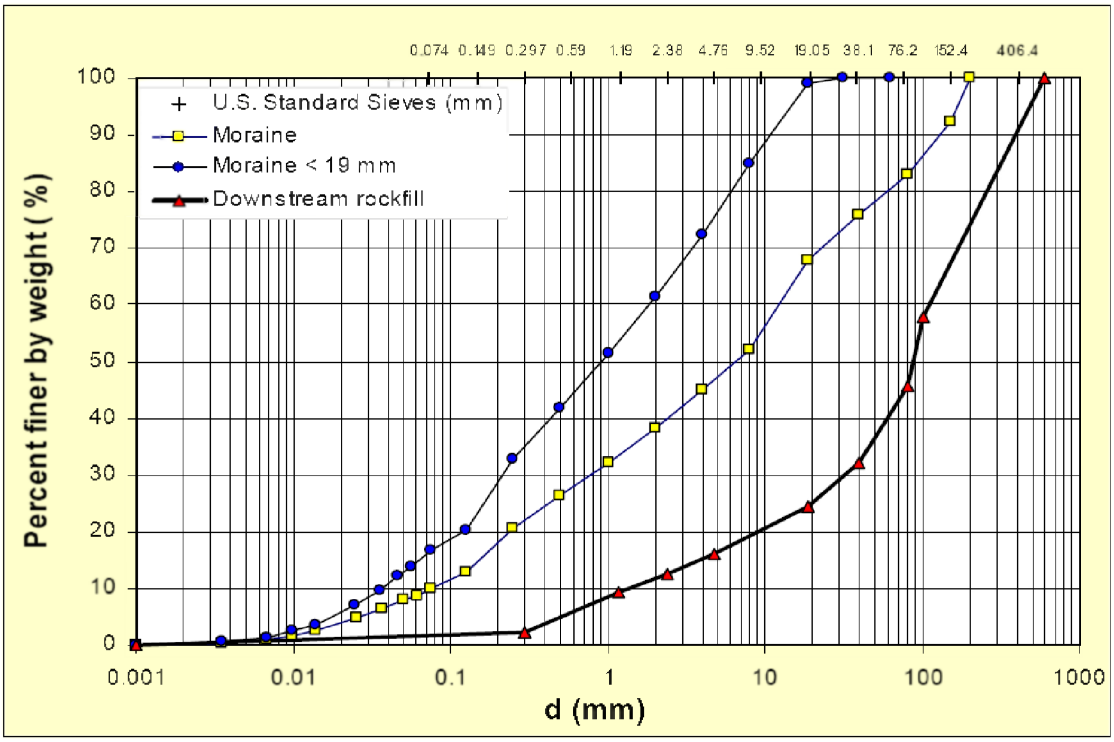

Figure 9: Grading curves for moraine and rock fill used in test 1-03

Table 7: Data provided (by SWECO) during IMPACT for tests undertaken in 2003.

Moraine		units	1-2003	2-2003	3-2003
	Dry density	ton/m3	2.09	2.09	2.09
	Moisture content	%	5.99	6	6
	Friction angel	tg Fi	0.9	0.9	0.9
	Cohesion		20	20	20
	Permeability				
	From test	m/s	$7,7*10^{-6}$	$7,7*10^{-6}$	$7,7*10^{-6}$
	From sieve curve	m/s	$2,5 - 4,85*10^{-6}$	$2,5 - 4,85*10^{-6}$	$2,5 - 4,85*10^{-6}$
Rock fill					
Downstream	Density bulk	ton/m3	2.173	2.173	
	Density dry	ton/m3	2.12	2.12	
	Density grain	ton/m3	2.53	2.53	
	Porosity	n	0.163	0.163	
	Cohesion		0	0	
	Friction angel	tg Fi	0.9	0.9	
Upstream	Porosity	n	0.4	0.4	
	Density dry	ton/m3	1.67	1.67	
	Density grain	ton/m3	2.776	2.776	
	Cohesion		0	0	
	Friction angel	tg Fi	0.9	0.9	

It can be noted from the above table that the angle of friction and porosity for rockfill and the cohesion for moraine were provided. It should be also noted that moraine porosity was calculated by HR Wallingford using the moraine dry density data provided above and assuming a grain density of 2.65. This might explain the difference in the moraine porosity.

4.1.3 Flow and water level data:

1. Inflow Data:
   Data comparisons show that the inflow data is identical in both the SP3 and IMPACT WP2 reports.

2. Water Level Data:
   Data comparisons show that water levels data is identical in both the SP3 and IMPACT WP2 reports.

3. Outflow Data:
   Data comparisons show that the outflow data is identical in both the SP3 and IMPACT WP2 reports.

4.2 Additional comments

Undertaken in August 2003, this embankment comprised a moraine core that was vibratory roller compacted in 0.5m layers, with well graded rock fill from tunnel spoil 0-500mm, vibratory roller compacted in 1m layer thicknesses and uniform rock fill 300-400mm, also vibratory roller compacted in 1m layer thicknesses.

Viewing video footage of the breach formation raises some further concerns regarding the geometry of the layer construction. Depth of rock fill on the moraine core should be in the order of 700mm however eroded faces suggest this may have been significantly less, in some areas the rockfill acting more as a surface layer covering than a substantial zone within the embankment body.

5. Test 2-03 – Composite Structure (Gravel with Moraine Core) - Piping

This test was undertaken in September 2003. The upstream and downstream shoulders were built from rock fill with a central moraine core (Figure 10). The purpose of this test was to better understand breach formation processes and to identify the different failure mechanisms that occur in composite embankments failing through piping. Two triggering options were used in this test case. Option #1 was a pipe that was perforated along certain lengths and built with a valve at the downstream end to control initial flow. The pipe was filled and surrounded by sand, providing an easy erosion route through the dam. Option #2 was similar to Option #1, but with the surrounding sand fill extended from the bottom of the dam to the top. Option #1 did not appear to work during initial testing so failure was initiated using Option #2 instead.

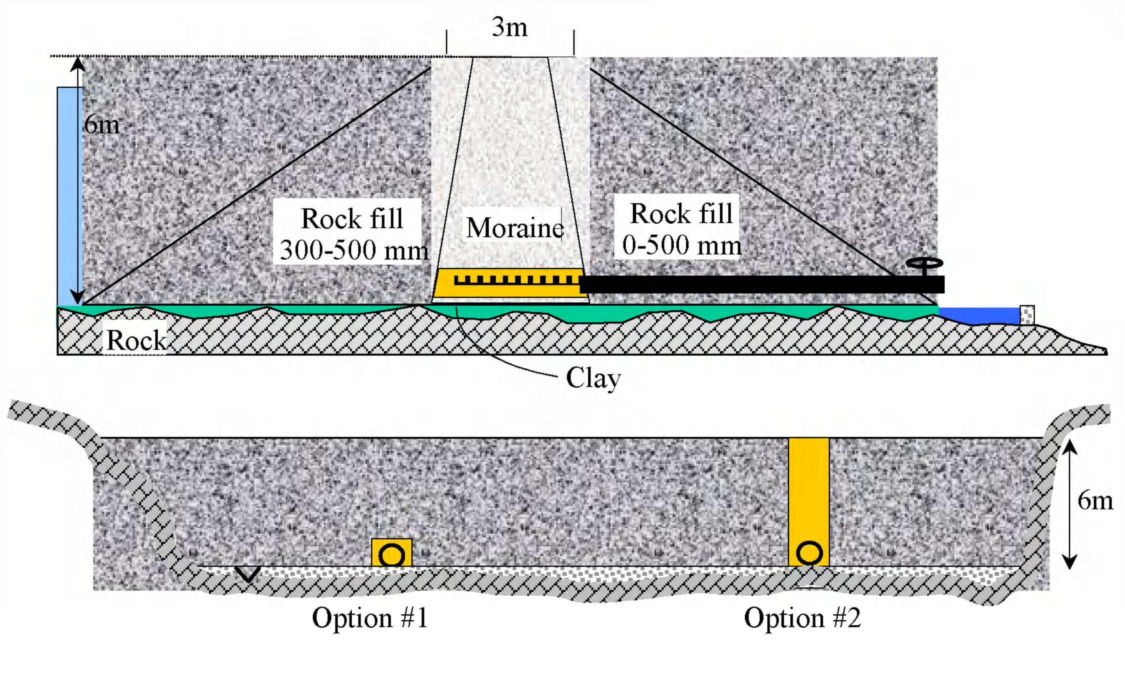

Figure 10: Design data for Test 2-03

5.1 Data checks

5.1.1 Dam geometry:

Table 5 shows the geometry data collected from the SP3 and the IMPACT WP2 reports. As shown in the table there is no significant differences between all of the items listed.

Table 8: Test 2-03 dam geometry

Dam Geometry:	SP3	IMPACT WP2	Recommended Values
Dam Height (m)	6	6	6
Upstream shoulder slope	1:1.56	1:1.5	1:56
Downstream shoulder slope	1:1.48	1:1.5	1.48
Core slopes	4:1	4:1	4:1
Initial pipe diameter (m)	---	0.215	0.215
Initial piping level (mOAD)	---	365.1	365.1

Our recommendation is to use the data provided in Table 5 for the dam geometry of this test case.

5.1.2 Soil properties:

Discussion in Section 0 for Test 1-03 also applies to this test case. Recommended values for use in the modelling for this test are as given in Table 6 .

5.1.3 Flow and water level data:

1. Inflow Data:

Data comparisons show that the inflow data is identical in both the SP3 and IMPACT WP2 reports.

2. Water Level Data:

Data comparisons show that water levels data is identical in both the SP3 and IMPACT WP2 reports but data in the SP3 report extends beyond that of the WP2 report.

3. Outflow Data:

Data comparisons show that the outflow data is identical in both the SP3 and IMPACT WP2 reports.

5.2 Additional comments

Undertaken in September 2003, this embankment comprised a moraine core that was vibratory roller compacted in 0.5m layers, with well graded rock fill from tunnel spoil 0-500mm, vibratory roller compacted in 1m layer thicknesses and uniform rock fill 300-400mm, also vibratory roller compacted in 1m layer thicknesses (i.e. same construction method and materials as Test 1-03).

It was unfortunate that the first of the large scale piping tests were undertaken on a composite structure, since the outer layers of rock fill material made it very difficult to determine what action, if any, was occurring through the core material. The following test (Test3-03) was through a single homogeneous embankment. Initiation using Option#1 was allowed to run for many hours, but was perceived to have failed, in that no significant change in flow or erosion was observed. Consequently, failure was initiated using Option#2, which did successfully lead to failure of the embankment. Upon investigation (excavation), it was found that the Option#1 triggering mechanism had in fact worked and that failure would have ensued if the test had been allowed to run for longer. Flow through the pipe in Option#1 had led to erosion, but material within the embankment body had progressively collapsed into the eroding flow and the seepage path had migrated up through the embankment. When the test was stopped, the erosion had migrated close to the crest, and would eventually have resulted in collapse of material near the crest and then overflowing breach generation.

6. Test 3-03 – Homogeneous (Moraine) - Piping

This test was undertaken in October 2003. It was built from moraine (See Figure 11). The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous embankments failed by piping.

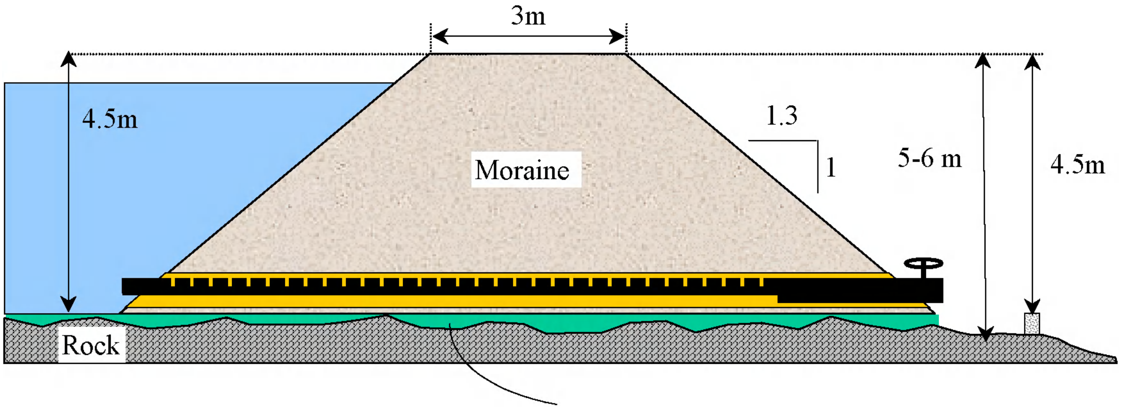

Figure 11: Design data for Test 3-03

6.1 Data checks

6.1.1 Dam geometry:

Table 9 shows the geometry data collected from the SP3 and the IMPACT WP2 reports. As shown in the table there is a difference between all the items listed. Similar to other test cases, some differences would have a minor effect on modelling and others could have a medium to significant difference..

Again, as with previous test data, there are inconsistencies between email correspondence from the IMPACT project and the current suggestion as to the cause of differences. However, will no detailed evidence to justify original data against current suggestions, and despite some of those differences being significant in terms of physical construction, our recommendation can only be to use the as built data provided in the SP3 report for the dam geometry of this test case.

Table 9: Test 3-03 dam geometry

Dam Geometry:	SP3	IMPACT WP2	Recommended Values
Dam Height (m)	4.3	4.5	4.3
Upstream shoulder slope	1:1.40	1:1.3	1:1.40
Downstream shoulder slope	1:1.40	1:1.3	1:1.40
Crest width (m)	2.8	3.0	2.8

6.1.2 Soil properties:

Discussion for Test1-03 regarding the moraine material also applies to this test case. Recommended values for use in the modelling are in Table 6 .

6.1.3 Flow and water level data:

1. Inflow Data:

The SP3 data was not available in suitable digital format to allow direct comparisons with the IMPACT WP2 data. However, visual data comparisons did not reveal any obvious differences either in value or timing between the data sets of both reports.

2. Water Level Data:

The SP3 data was not available in suitable digital format to allow direct comparisons with the IMPACT WP2 data. However, visual data comparisons did not reveal any obvious differences either in value or timing between the data sets of both reports.

3. Outflow Data:

The SP3 data was not available in suitable digital format to allow direct comparisons with the IMPACT WP2 data. However, visual data comparisons did not reveal any obvious differences either in value or timing between the data sets of both reports.

6.2 Additional comments

Construction of this embankment from moraine material was undertaken using vibratory plate compaction in 0.5m layer thicknesses.

7. Conclusions

A thorough review of the quality and validity of the IMPACT Project breach field data has been undertaken following the identification of inconsistencies between data provided recently to the Dam Safety Interest Group (DSIG) breach modelling project (originating from Norway), as compared to original project data sets held by HR Wallingford.

The differences between data sets are significant, and particularly relevant to researchers using the data for the development and validation of predictive breach models. The extent of impact of these differences upon breach research work carried out during the IMPACT project has not been assessed here; the aim of this review was to indentify errors and establish a best estimate of 'correct' data set for each of the field tests that can be used in the DSIG and subsequent breach modelling programmes.

A range of differences in data were noted. Discussions were held between HR Wallingford, DSIG, SWECO, and Norconsult by email and personal communication to try and identify the cause of these differences and hence agree on definitive data sets. The response from the Norwegian partners in this exercise was disappointing; in some areas it has not been possible to demonstrate the scientific basis for using revised values.

The investigation concluded that:

- There are significant differences between the IMPACT data now being used, as compared to the data used during breach model testing under the IMPACT project. The extent to which this affects research conclusions from the IMPACT project is unclear. Researchers using data originating from the IMPACT project itself should refer to this report and associated data sets to ensure they are using correct data
- It appears that much of the data provided from Norway during the IMPACT project (i.e. the field test data) related to proposed rather than as built test conditions. Significant differences between proposed and as built conditions which were not reported at the time have now been identified. However, whilst these explain a significant number of the data differences, they do not explain all differences, including some of the major differences.
- Some flow data has been recalculated. This includes reservoir releases providing inflow to the test site as well as measured breach flow
- Some revised calculations provided from Norway still appear to be incorrect, hence some questions still remain as to actual data values

These findings are disappointing, both for the IMPACT partners who were assured of data quality at the time of the original research and more recently for a growing number of researchers around the world who have been using data from the original project reports. Whilst the original data was not formally released pending final analyses at the end of the project, it is clear that data has been shared and a number of researchers have published work using the original data. It is recommended that these researchers review their analyses in light of the findings reported here.

8. References

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