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Wave overtopping at dikes kernel

Test plan

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Title
Wave overtopping at dikes kernel

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Summary
This document describes the test plan for the 'wave overtopping at dikes' kernel. It also contains some recommendations for further improvements on the test procedure.

Samenvatting
Dit document beschrijft het testplan voor rekenkern "golfoverslag bij dijken". Het bevat ook enkele aanbevelingen voor verbeteringen van de testprocedure.

References
KPP Waterveiligheidsinstrumentarium

Version	Date	Author	Initials	Review	Initials	Approval	Initials
0.2	dec. 2012	B. Kuijper		J. Stijnen			
		M.T. Duits					
		R.G. Kamp					
1.0	sep. 2015	J.P. de Waal		P. van Steeg		M.R.A. van Gent	
	oct. 2017	J.P. de Waal		H. van Putten		M.R.A. van Gent	
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Status
final

Contents

1 Introduction

1.1 About this document

This document describes the test plan for the 'wave overtopping at dikes' kernel. It is a part of the software documentation set on this kernel.

Originally this document was written in 2012 by B. Kuijper, M.T. Duits and R.G. Kamp, all from HKV consultants. In fact, that document included the description of both the test plan and the test results. Later the kernel structure was adjusted in order to better fit into the probabilistic program Hydra-Ring and some small adjustments to the functionalities were implemented. Due to a small change in definition of the model parameters all quantitative results slightly changed. Moreover, some of the test cases were adapted. Therefore, the report needed to be updated. This update was combined with a split up into two separate documents, one for the test plan and the other for the test results. These documents were composed by J.P. de Waal from Deltares.

It was outside the scope of the project activities in 2015 to reconsider and - if estimated to be useful - adapt the test procedure and test cases for this kernel. However, while composing the update of these documents on the testing, several shortcomings were noticed. It was then decided to leave the test procedure unchanged, but to include the most important findings on the present test procedure in a separate chapter 'Discussion'.

In 2017 many of the recommendations from this discussion were implemented in the test procedure and test plan document, leading to the present version of the test plan.

1.2 Brief overview of tests

The computational procedure for wave overtopping at dikes can be rather complex, largely depending on the complexity of the dike features (transitions in slope and roughness). The procedure in general includes many transitions ('if' statements) and in many cases iterations and/or interpolations are required. It is therefore hard to cover all computational possibilities in a test procedure. The present procedure aims at covering many of them, including the more likely possibilities.

Present clusters of tests

The present test procedure consists of the following clusters of tests:

•	General tests:	Basic I/O tests including tests on input validation and error message delivery
•	Uniform slope tests:	Tests focussing on the quantitative output for a simple structure: a uniform slope
•	'Omkeervariant' tests:	Tests focussing on the inverse of the basic computation
•	Java/FEWS interface tests:	Basic I/O tests for the data structure to be applied in case of calling the dll from a Java environment (like FEWS)
•	Trend tests:	Test series with varying load and structure parameters, using many small steps
•	Unit tests:	Tests on specific low level kernel functions

The test procedure also includes tests pertaining to encountered issues, but these issue tests are not further discussed in this plan.

Relationship with the V-model for design, implementation and testing

For software that is developed for use as a part of the WBI software the V-model is adopted as the testing methodology. The V-model comprises a test strategy on multiple levels of the software development cycle, as conceptually illustrated in Figure 1.1.

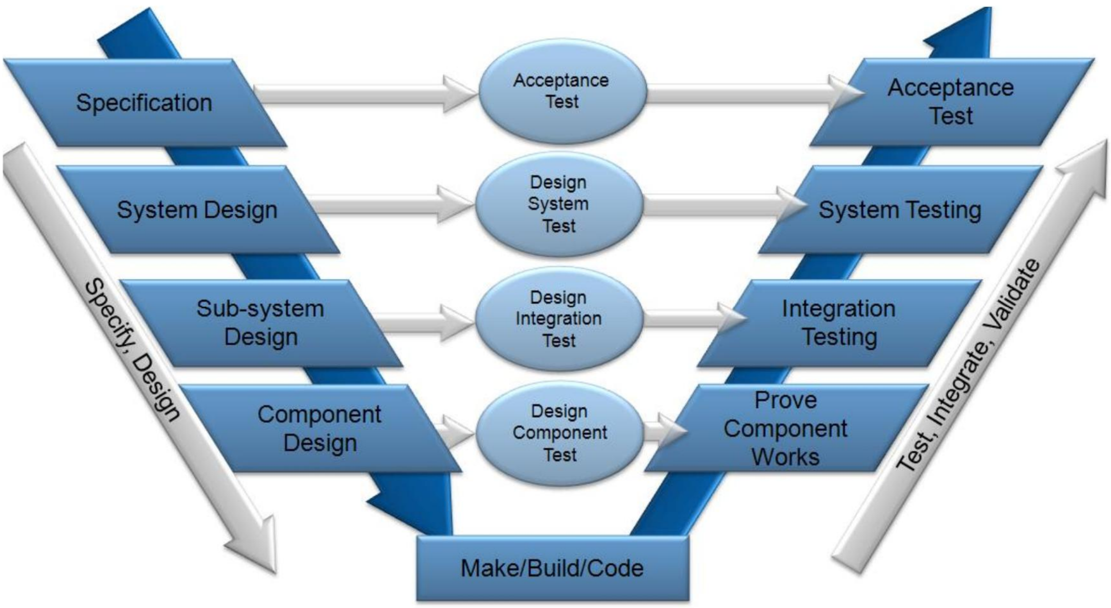

Figure 1.1 V-model for design, implementation and testing.

Testing by the software development team must take place at three different levels: unit tests, integration tests and system tests (the acceptance tests are not carried out by the software development team, but by an independent test team, by the client or by an arbitrary third party).

However, the design and implementation of the wave overtopping at dikes kernel started well before the V-model was actually introduced as the generic methodology. Therefore, the present test procedure for this kernel was not based on the V-model. Nevertheless, the three required levels can be recognized within the present test clusters: system tests are performed on the dll, unit tests are performed on low level functions (subroutines) and integration tests on higher level functions (subroutines).

The three testing levels are not evenly represented though: the present test procedure almost entirely consists of system tests and high level integration tests and contains only two unit tests.

Code coverage

Another part of the common testing methodology for WBI software is achieving a desired code coverage level (percentage). This requires the configuration of a code coverage analysis tool for the present test procedure, which still needs to be carried out.

1.3 Outline of the report

The clusters of tests mentioned in section 1.2 are described in more detail in Chapter 2, 3 and 4, as elaborated in Table 1.1.

Test category	described in
General tests	section 4.1
Uniform slope tests	chapter 2
'Omkeervariant' tests	section 4.2
Java/FEWS interface tests	section 4.3
Trend tests	chapter 3
Unit tests	section 4.4

Table 1.1 Description of the test categories within this document.

Recommendations for future improvements on the test procedure are given in chapter 5.

2 Basic tests for a uniform slope

2.1 Test concept

As pointed out in section 1.2, the complexity of the computational procedure largely depends on the complexity of the dike features input (transitions in slope and roughness). For a simple structure like a uniform slope, the computational procedure is fairly straightforward (no iterations), and results can be compared with manually computed results.

This test procedure focuses on:

- a uniform slope: no berm(s), no other changes in slope, no changes in roughness
- onshore wave direction
- relatively deep water at the toe of the structure

The test procedure contains 18 tests, 9 for a mild slope (breaking waves, see Table 2.1) and 9 for a steep slope (non-breaking waves, see Table 2.2). Within each subset of 9 tests a selected input parameter is varied (highlighted yellow or orange in the tables below).

CASE:		1	2	3	4	5	6	7	8	9
Model parameters:										
m_{z2}	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.00
m_{qc}	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00
f_b	-	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.30
f_n	-	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.30
Structure:										
$\tan\alpha$	-	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
h_{crest}	m	5.00	5.00	5.00	5.00	5.00	4.00	5.00	5.00	5.00
γ_f	-	1.00	1.00	1.00	1.00	1.00	1.00	0.70	1.00	1.00
Hydraulic load:										
h	m	2.00	2.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00
H_{m0}	m	1.00	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00
$T_{m-1,0}$	s	4.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00
β	°	0	0	0	0	45	0	0	0	0
Expected results:										
$z_{2\%}$	m	2.06136	2.06136	1.84374	2.57670	1.85729	2.06136	1.44295	2.26750	2.06136
q_o	$m^3/m/s$	5.83238E-06	3.90356E-05	1.21404E-06	7.13664E-05	7.97870E-07	2.61262E-04	4.39376E-08	5.83238E-06	1.71847E-05
Z	-	5.14433	3.24328	6.71380	2.63993	7.13357	1.34223	10.03274	5.03897	4.06373

Table 2.1 Test cases 1-9 and expected results for a uniform slope 1:4.

CASE:		10	11	12	13	14	15	16	17	18
Model parameters:										
m_{z2}	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.00
m_{qc}	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	1.00
f_b	-	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.30
f_n	-	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.30
Structure:										
$\tan\alpha$	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
h_{crest}	m	5.00	5.00	5.00	5.00	5.00	4.00	5.00	5.00	5.00
γ_f	-	1.00	1.00	1.00	1.00	1.00	1.00	0.70	1.00	1.00
Hydraulic load:										
h	m	2.00	2.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00
H_{m0}	m	1.00	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00
$T_{m-1,0}$	s	4.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00
β	°	0	0	0	0	45	0	0	0	0
Expected results:										
$z_{2\%}$	m	3.05105	3.05105	2.48203	3.15124	2.74900	3.05105	2.22043	3.35616	3.05105
q_o	$m^3/m/s$	2.56622E-04	9.41621E-04	2.61249E-05	2.56622E-04	6.58446E-05	3.45509E-03	1.38699E-05	2.56622E-04	6.31188E-04
Z	-	1.36015	6.01523E-02	3.64487	1.36015	2.72046	-1.23985	4.27801	1.25479	4.60152E-01

Table 2.2 Test cases 10-18 and expected results for a uniform slope 1:2.

In section 2.2 the computational procedure (set of formulas) for these cases is elaborated. Section 2.3 describes the 'manual computation' for case 1.

2.2 Formulas and constants

2.2.1 General

This section uses the equations and notation from the Functional Design. The equations have their own numbering, but the functions that were copied from the Functional Design also show the equation number in the Functional Design, notated like "[FDEqn #.#]".

Constant(s)

$$g = 9.80665 \ \text{m/s}^2 \quad (2.1)$$

$$f_{runup1} = 1.65 \quad \text{[FDEqn 5.6] (2.2)}$$

$$f_{runup2} = 4.00 \quad \text{[FDEqn 5.7] (2.3)}$$

$$f_{runup3} = 1.50 \quad \text{[FDEqn 5.8] (2.4)}$$

$$m_{qo} = 1.0 \quad (2.5)$$

Constants within this test set for uniform slopes

$$\gamma_b = 1.0 \quad (2.6)$$

$$f_{shallow} = 0.92 \quad (2.7)$$

$$q_c = 1 \cdot 10^{-3} \ \text{m}^3\text{/m/s} \quad (2.8)$$

The intersection point for breaking and non-breaking waves:

$$\hat{B} = \gamma_b \xi_{0t} \quad \text{[FDEqn 5.10] (2.9)}$$

$$f_{runup1} \gamma_b \xi_{ot} = f_{runup2} - \frac{f_{runup3}}{\sqrt{\xi_{ot}}} \quad \text{[FDEqn 5.9] (2.10)}$$

$$\hat{B} = \xi_{0t} \quad (2.11)$$

$$1.65 \cdot \xi_{ot} = 4.00 - \frac{1.50}{\sqrt{\xi_{ot}}} \quad (2.12)$$

Solving ξ_{0t} yields:

$$\hat{B} = 1.73384 \quad (2.13)$$

The breaker parameter

$$\xi_o = \frac{\tan \alpha}{\sqrt{s_o}} \quad \text{[FDEqn 5.1] (2.14)}$$

Substituting

$$s_o = \frac{H_{m0}}{L_0} \quad \text{[FDEqn 6.3] (2.15)}$$

and

$$L_0 = \frac{g}{2\pi} T_{m-1,0}^2 \quad \text{[FDEqn 6.2] (2.16)}$$

yields

$$\xi_o = \frac{\tan\alpha}{\sqrt{\dfrac{H_{m0}}{\dfrac{g}{2\pi}T_{m-1,0}^2}}} = \frac{T_{m-1,0}\cdot\tan\alpha}{\sqrt{\dfrac{2\pi}{g}H_{m0}}} \tag{2.17}$$

The influence factor for roughness

Adjust the influence factor for roughness for large breaker parameter values.

if $\gamma_b\xi_o > \hat{B}$

then $\gamma_f := \min\left(1;\max\left(\gamma_f;\gamma_f + (1-\gamma_f)\cdot\dfrac{\gamma_b\xi_o - \hat{B}}{10-\hat{B}}\right)\right)$ [FDEqn 5.20] (2.18)

Substituting constants yields

if $\xi_o > 1.73384$

then $\gamma_f := \min\left(1;\max\left(\gamma_f;\gamma_f + (1-\gamma_f)\cdot\dfrac{\xi_o - 1.73384}{10-1.73384}\right)\right)$ (2.19)

Effect of oblique wave attack

In this test series

$$\beta \le 80 \tag{2.20}$$

Therefore, the following functions apply:

For wave runup

$\gamma_{\beta z} = 1 - 0.0022\cdot\min(\beta;80)$ [FDEqn 5.12] (2.21)

$$\gamma_{\beta z} = 1 - 0.0022\cdot\beta \tag{2.22}$$

For wave overtopping discharge

$\gamma_{\beta o} = 1 - 0.0033\cdot\min(\beta;80)$ [FDEqn 5.13] (2.23)

$$\gamma_{\beta o} = 1 - 0.0033\cdot\beta \tag{2.24}$$

2.2.2 Wave runup

For small breaker parameter calculate the 2% wave run-up for breaking waves, otherwise calculate 2% wave run-up for non-breaking waves:

if $\gamma_b\xi_o < \hat{B}$

then $z_{2\%} = m_{z2}\cdot H_{m0} f_{runup1}\gamma_f\gamma_{\beta z}\gamma_b\xi_o$ [FDEqn 5.2] (2.25)

else $z_{2\%} = m_{z2}\cdot\max\left(H_{m0}\gamma_f\gamma_{\beta z}\cdot\left(f_{runup2} - \dfrac{f_{runup3}}{\sqrt{\xi_o}}\right);0\right)$

$$\begin{array}{ll} \text{if} & \xi_o < 1.73384 \\ \text{then} & z_{2\%} = m_{z2} \cdot H_{m0} \cdot 1.65 \cdot \gamma_f \cdot \gamma_{\beta z} \cdot \xi_o \\ \text{else} & z_{2\%} = m_{z2} \cdot \max\left(H_{m0} \cdot \gamma_f \cdot \gamma_{\beta z} \cdot \left(4.00 - \frac{1.50}{\sqrt{\xi_o}} \right); 0 \right) \end{array} \qquad (2.26)$$

2.2.3 Wave overtopping discharge

The dimensionless overtopping discharge for breaking waves:

$$Q_b = \frac{0.067}{\sqrt{\tan\alpha}} \cdot \gamma_b \xi_o \cdot \exp\left(-f_b \frac{y_N - h}{H_{m0}} \cdot \frac{1}{\gamma_{\beta o} \gamma_f \cdot \gamma_b \xi_o} \right) \qquad \text{[FDEqn 5.41] (2.27)}$$

$$Q_b = \frac{0.067}{\sqrt{\tan\alpha}} \cdot \xi_o \cdot \exp\left(-f_b \cdot \frac{h_{crest} - h}{H_{m0}} \cdot \frac{1}{\gamma_{\beta o} \cdot \gamma_f \cdot \xi_o} \right) \qquad (2.28)$$

The dimensionless overtopping discharge for non-breaking waves:

$$Q_n = 0.2 \cdot \exp\left(-f_n \frac{y_N - h}{H_{m0}} \cdot \frac{1}{\gamma_{\beta o} \gamma_f} \right) \qquad \text{[FDEqn 5.42] (2.29)}$$

$$Q_n = 0.2 \cdot \exp\left(-f_n \cdot \frac{h_{crest} - h}{H_{m0}} \cdot \frac{1}{\gamma_{\beta o} \cdot \gamma_f} \right) \qquad (2.30)$$

The overtopping discharge:

$$\begin{array}{ll} \text{if} & \xi_0 \le 5 \\ \text{then} & q_o = \sqrt{g H_{m0}^3} \cdot \min\left(Q_b ; Q_n\right) \end{array} \qquad \text{[FDEqn 5.45] (2.31)}$$

For all present test cases

$$\xi_0 \le 5 \qquad (2.32)$$

Therefore:

$$q_o = \sqrt{g H_{m0}^3} \cdot \min\left(Q_b ; Q_n\right) \qquad (2.33)$$

2.2.4 Limit state function

$$Z = \ln\left(m_{qc} \cdot q_c\right) - \ln\left(m_{qo} \cdot \max\left(q_o ; q_{o,min}\right)\right) \qquad \text{[FDEqn 5.51] (2.34)}$$

In these tests this simplifies to:

$$Z = \ln\left(m_{qc} \cdot q_c\right) - \ln\left(q_o\right) \tag{2.35}$$

2.3 Manual computation example: case 1

2.3.1 Input

Model parameters:

m_{z2}	=	1.0	-	(2.36)
m_{qc}	=	1.0	-	(2.37)
f_b	=	4.75	-	(2.38)
f_n	=	2.60	-	(2.39)

Structure:

$\tan\alpha$	=	0.25	-	(2.40)
h_{crest}	=	5.0	m	(2.41)
γ_f	=	1.0	-	(2.42)

Hydraulic load:

h	=	2.0	m	(2.43)
H_{m0}	=	1.0	m	(2.44)
$T_{m-1,0}$ s	=	4.0	s	(2.45)
β	=	0.0	°	(2.46)

In fact the slope parameter tanα is not an input parameter. The actually applied input leading to tanα = 0.25 is:

x	=	[0.0 40.0]	m	(2.47)
y	=	[-5.0 5.0]	m	(2.48)

And for tanα = 0.50:

x	=	[0.0 20.0]	m	(2.49)
y	=	[-5.0 5.0]	m	(2.50)

In fact also the wave angle β is not an input parameter. The actually applied input leading to β = 0.0 ° is:

ψ	=	0.0	°N	(2.51)
φ	=	0.0	°N	(2.52)

And for β = 45.0 °:

ψ	=	0.0	°N	(2.53)
φ	=	45.0	°N	(2.54)

2.3.2 Computations and output

Profile slope:

$$\tan\alpha = \frac{5.0-(-5.0)}{40.0-0.0} = 0.25 \tag{2.55}$$

Breaker parameter:

$$\xi_o = \frac{4.0 \cdot 0.25}{\sqrt{\frac{2\pi}{g} 1.0}} = 1.249311 \tag{2.56}$$

Wave runup:

$$\gamma_{\beta z} = 1.0 \tag{2.57}$$

$$z_{2\%} = 1.0 \cdot 1.0 \cdot 1.65 \cdot 1.0 \cdot 1.0 \cdot 1.249311 = 2.06136 \text{ m} \tag{2.58}$$

Wave overtopping discharge:

$$\gamma_{\beta o} = 1.0 \tag{2.59}$$

Non dimensional wave overtopping discharge for breaking waves:

$$Q_b = \frac{0.067}{\sqrt{0.25}} \cdot 1.249311 \cdot \exp\left(-4.75 \cdot \frac{5.0 - 2.0}{1.0} \cdot \frac{1}{1.0 \cdot 1.0 \cdot 1.249311}\right) \tag{2.60}$$

$$Q_b = 1.862455 \cdot 10^{-6} \tag{2.61}$$

Non dimensional wave overtopping discharge for non-breaking waves:

$$Q_n = 0.2 \cdot \exp\left(-2.60 \cdot \frac{5.0 - 2.0}{1.0} \cdot \frac{1}{1.0 \cdot 1.0}\right) = 8.19470 \cdot 10^{-5} \tag{2.62}$$

Overtopping discharge:

$$q_o = \sqrt{g \cdot 1.0^3} \cdot \min\left(Q_b ; Q_n\right) = 5.83238 \cdot 10^{-6} \quad \text{m}^3\text{/m/s} \tag{2.63}$$

Limit state function:

$$Z = \ln\left(1.0 \cdot 1.0 \cdot 10^{-3}\right) - \ln\left(1.0 \cdot 5.832384 \cdot 10^{-6}\right) = 5.14433 \tag{2.64}$$

3 Tests on trends in results

3.1 Test concept

Especially for the application of the kernel within a probabilistic environment, the continuity and correctness of the trends in computational results are important.

The tests on trends consist of several test series in which certain input parameters, for example the wave height or segment slope, are varied to determine their effect on the main output, namely: the 2% wave run-up height and the mean wave overtopping discharge.

Tests are carried out for different types of cross sections of flood defences, with increasing complexity, beginning with a cross section with only one segment, then a cross section with two segments, and so on, up to a cross section with five segments, consisting of both slope segments and berms.

For each cross section a number of test series is constructed, characterized by (respectively):
- varying load (i.e. water level and wave parameters);
- varying geometry of the structure;
- varying roughness of the different structure segments.

Expected results

General:
- The trends should not show any discontinuities, like jumps or missing data. (Buckling points, i.e. discontinuities in first derivative, may be expected though).

The expected results for the varying load test series are as follows:
- If the water level increases the run-up level and the overtopping discharge increase.
- If the wave height increases the run-up level and the overtopping discharge increase.
- If the wave steepness increases the run-up level and the overtopping discharge decrease.
- If the wave direction increases the run-up level and the overtopping discharge decrease.

The expected results for the cross section specific test series are as follows:
- If the slope decreases the run-up level and the overtopping discharge decrease.
- If the length of a berm increases the run-up level and the overtopping discharge decrease.

The expected results for the roughness specific test series are as follows:
- If the roughness coefficient decreases the run-up level and the overtopping discharge decrease.

A test result is regarded 'OK' if computed results - written in ASCII output files - are (within a very small margin) equal to computational results from an earlier version of the kernel. These reference results are considered correct, based on the following analysis:
- By visual inspection of output graphs it is verified if trends in the results from test series agree with the expected trends.

- Occasional disagreement between observed and expected trends can be explained on the basis of the specific conditions and the original formulas and/or intermediate computational results.

In fact, however, there are still some tests in which the reference results do not fully agree with the expectations, as will be described in the Test Report. These disagreements (still) require additional analysis. It is quite well possible that disagreements result from the design of the computational procedure. In that case, the Functional Design should be adapted. This uncertainty on the source of remaining disagreements is a weak point of this test cluster.

3.2 Basic test series of varying load conditions

3.2.1 Series of varying load conditions for each cross section

The overtopping module has four input parameters describing the load conditions: water level, significant spectral wave height, wave period (spectral wave period) and the wave direction. In practice the wave height and the wave period are correlated. For instance: a large wave height in combination with a short wave period is not very likely. This combination gives steep waves. The steepness of a wave can be computed by

$$s_o = \frac{2\pi H_{m0}}{g \cdot T_{m-1,0}{}^2} \qquad (2.65)$$

with

s_o	the wave steepness (-)
H_{m0}	the wave height (m)
$T_{m-1,0}$	the spectral wave period (s)
g	the gravity constant (m/s^2).

In practice, the value of the wave steepness is limited. To prevent computations with non-necessary combinations of wave heights and wave periods test series will have input that consists of water levels, wave heights, wave steepnesses and wave angles. The basic values are presented in Table 2 1. For the wave direction two values are chosen. One value is not enough because of the additional reductions for wave directions larger than 80 degrees. These also have to be tested.

Input value	Basic value
Water level (m+NAP)	3.0
Wave height (m)	2.0
Wave steepness (-)	0.04
Wave angle (°)	0.0 85.0

Table 3.1 Overview of basic values for test series

Rewriting formula (2.65) can help to compute the spectral wave period from the wave height and the wave steepness:

$$T_{m-1,0} = \sqrt{\frac{2\pi H_{m0}}{g \cdot s_o}} \qquad (2.66)$$

Using the basic values from Table 3.1 the spectral wave period in the basic situation - with use of formula (2.66) - is equal to 5.66 sec.

Starting with the basic values from Table 3.1 seven test series are composed in which each time only one value is varied. The seven test series are presented in Table 3.2. These are the basic test series for each cross section.

Test series	Water level (m+NAP)	Wave height (m)	Wave steepness (-)	Wave angle (º)
1	-2 [0.01] 6	2	0.04	0
2	-2 [0.01] 6	2	0.04	85
3	3	0 [0.01] 5	0.04	0
4	3	0 [0.01] 5	0.04	85
5	3	2	0.001 [0.001] 0.07	0
6	3	2	0.001 [0.001] 0.07	85
7	3	2	0.04	0 [1] 180

Table 3.2 Basic test series for each cross section

In section 3.3 additional tests are presented for each cross section, in which the slope and roughness of the different segments is varied. These cross section specific test series are combined with the water level, wave height and wave steepness from Table 3.1.

3.2.2 Output in general

Five output parameters are examined:

- the wave run-up, $z_{2\%}$(m+NAP)
- the overtopping discharge, q_o (m^3/m/s)
- the required crest level for critical overtopping discharge 10^{-4} (m^3/m/s), HBN4 (m+NAP)
- the required crest level for critical overtopping discharge 10^{-3} (m^3/m/s), HBN3 (m+NAP)
- the required crest level for critical overtopping discharge 10^{-2} (m^3/m/s), HBN2 (m+NAP)

The output is presented by figures with the varied parameter on the x-axis. An example is presented below for the slope of the cross section.

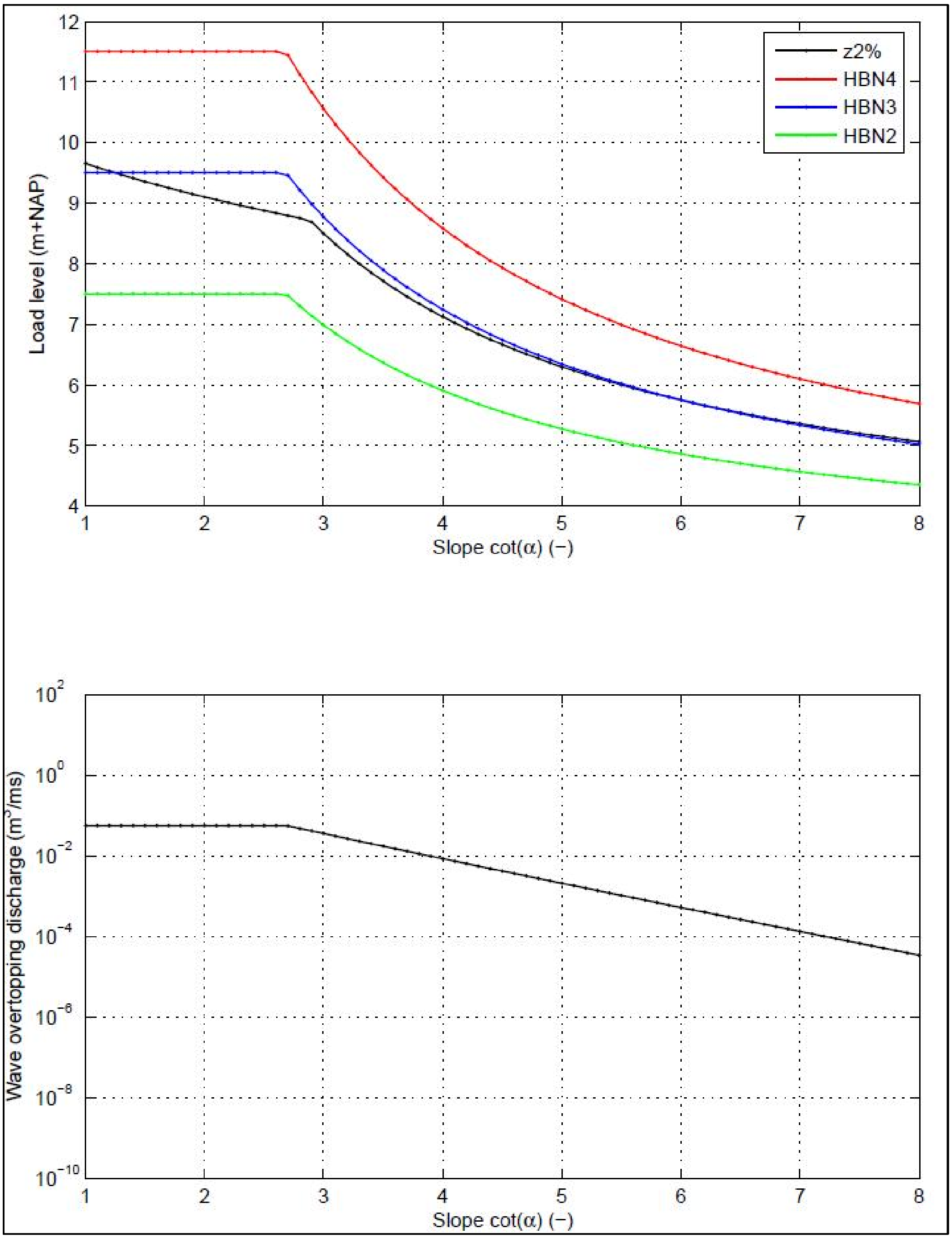

Figure 3.1 Example for the output of the test series

3.3 Basic cross sections and series of varying characteristics

3.3.1 Cross section nr 1

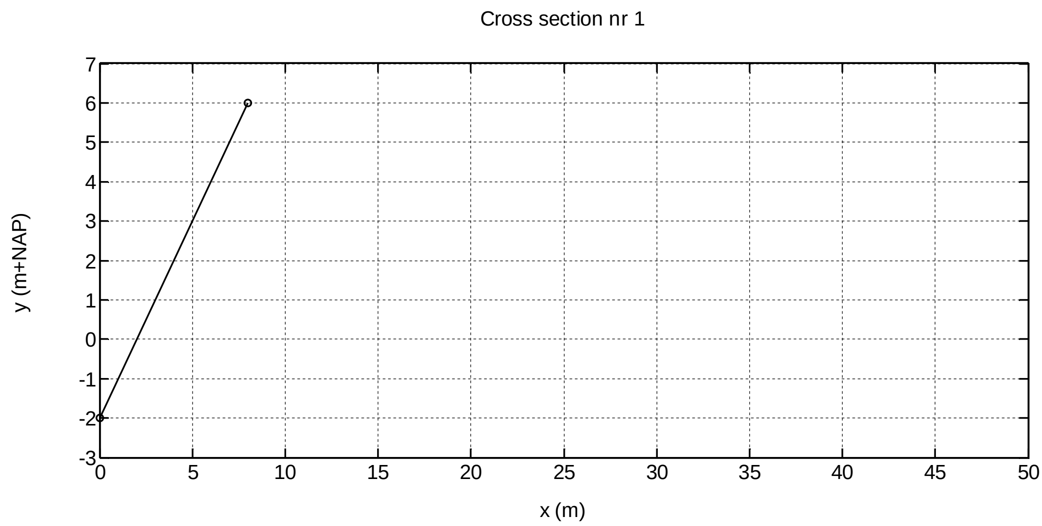

Figure 3.2 Cross section nr 1, basic geometry

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
1	0	-2	1	1.0	1.0
2	8	6			

Table 3.3 Cross section nr 1, basic geometry

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8	slope (-)	1 [0.1] 8	0
9	slope (-)	1 [0.1] 8	85
10	roughness (-)	0.5 [0.01] 1.0	0
11	roughness (-)	0.5 [0.01] 1.0	85

Table 3.4 Cross section nr 1, additional test series on variation in geometry

3.3.2 Cross section nr 2

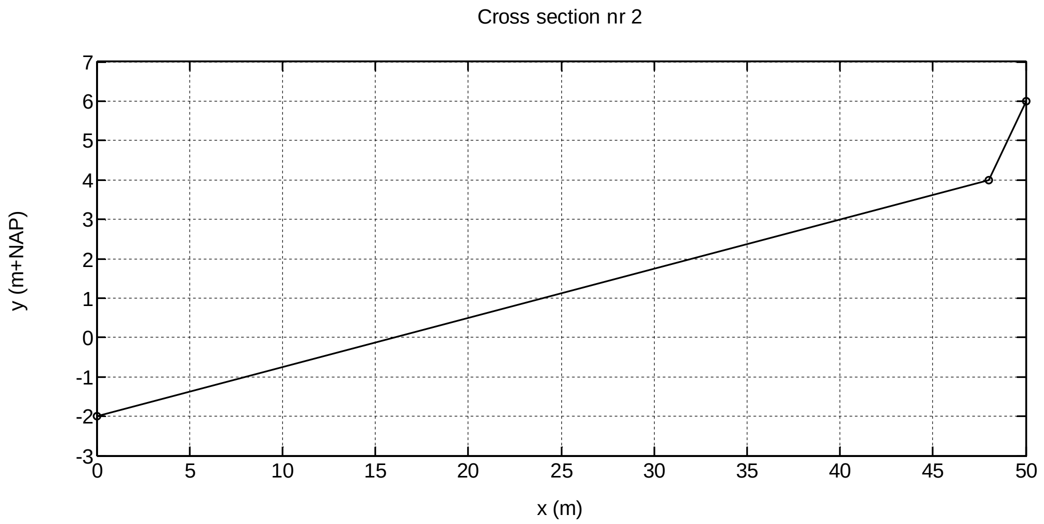

Figure 3.3 Cross section nr 2, basic geometry.

point nr	x	y	segment nr	slope	roughness
-	(m)	(m+NAP)	-	-	-
1	0	-2	1	8.0	1.0
2	48	4	2	1.0	1.0
3	50	6			

Table 3.5 Cross section nr 2, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8	slope lower segment (-)	1 [0.1] 8	0
9	slope lower segment (-)	1 [0.1] 8	85
10	slope upper segment (-)	1 [0.1] 8	0
11	slope upper segment (-)	1 [0.1] 8	85
12	buckling point (m+NAP)	-1.75 [0.125] 4.00	0
13	buckling point (m+NAP)	-1.75 [0.125] 4.00	85
14	roughness both segments (-)	0.5 [0.01] 1.0	0
15	roughness both segments (-)	0.5 [0.01] 1.0	85
16	roughness lower segment (-)	0.5 [0.01] 1.0	0
17	roughness lower segment (-)	0.5 [0.01] 1.0	85
18	roughness upper segment (-)	0.5 [0.01] 1.0	0
19	roughness upper segment (-)	0.5 [0.01] 1.0	85

Table 3.6 Cross section nr 2, additional test series on variation in geometry.

3.3.3 Cross section nr 3

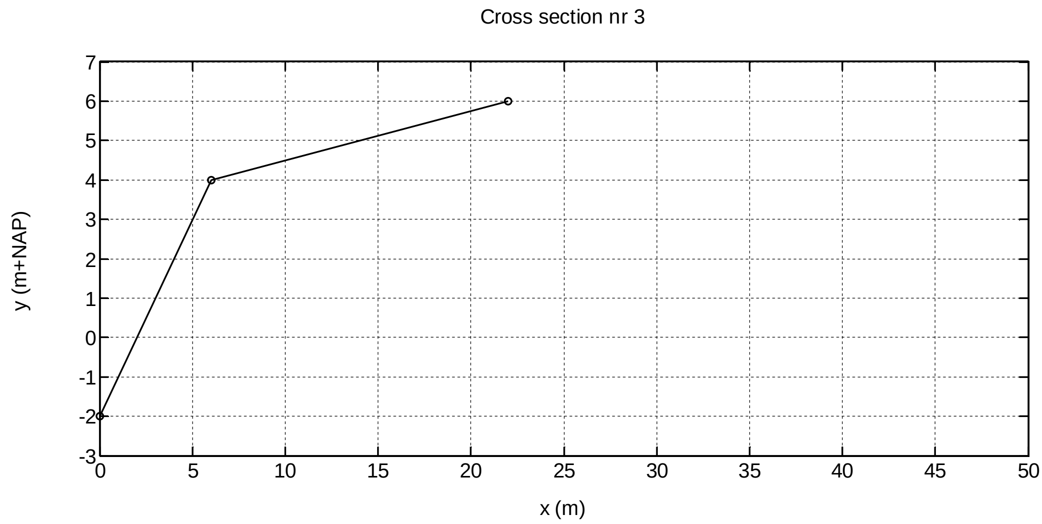

Figure 3.4 Cross section nr 3, basic geometry.

point nr	x	y	segment nr	slope	roughness
-	(m)	(m+NAP)	-	-	-
1	0	-2	1	1.0	1.0
2	6	4	2	8.0	1.0
3	22	6			

Table 3.7 Cross section nr 3, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8	slope lower segment (-)	1 [0.1] 8	0
9	slope lower segment (-)	1 [0.1] 8	85
10	slope upper segment (-)	1 [0.1] 8	0
11	slope upper segment (-)	1 [0.1] 8	85
12	buckling point (m+NAP)	0 [0.1] 4	0
13	buckling point (m+NAP)	0 [0.1] 4	85
14	roughness both segments (-)	0.5 [0.01] 1.0	0
15	roughness both segments (-)	0.5 [0.01] 1.0	85
16	roughness lower segment (-)	0.5 [0.01] 1.0	0
17	roughness lower segment (-)	0.5 [0.01] 1.0	85
18	roughness upper segment (-)	0.5 [0.01] 1.0	0
19	roughness upper segment (-)	0.5 [0.01] 1.0	85

Table 3.8 Cross section nr 3, additional test series on variation in geometry.

3.3.4 Cross section nr 4

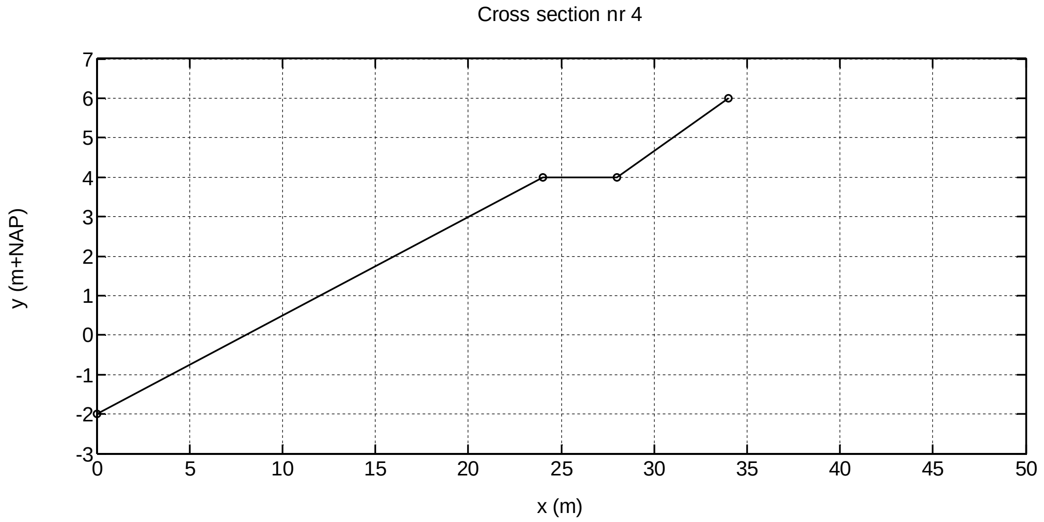

Figure 3.5 Cross section nr 4, basic geometry.

point nr	x	y	segment nr	slope	roughness
-	(m)	(m+NAP)	-	-	-
1	0	-2	1	4.0	1.0
2	24	4	2	0.0	1.0
3	28	4	3	3.0	1.0
4	34	6			

Table 3.9 Cross section nr 4, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8berm	slope berm segment (-)	15 [0.5] 400	0
9berm	slope berm segment (-)	15 [0.5] 400	85
8	slope berm segment (-)	1 [0.1] 8	0
9	slope berm segment (-)	1 [0.1] 8	85
10	slope other segments (-)	1 [0.1] 8	0
11	slope other segments (-)	1 [0.1] 8	85
12	length berm segment (m)	2 [1] 20	0
13	length berm segment (m)	2 [1] 20	85
14	roughness berm segment (-)	0.5 [0.01] 1.0	0
15	roughness berm segment (-)	0.5 [0.01] 1.0	85
16	roughness ordinary segments (-)	0.5 [0.01] 1.0	0
17	roughness ordinary segments (-)	0.5 [0.01] 1.0	85

Table 3.10 Cross section nr 4, additional test series on variation in geometry.

3.3.5 Cross section nr 5

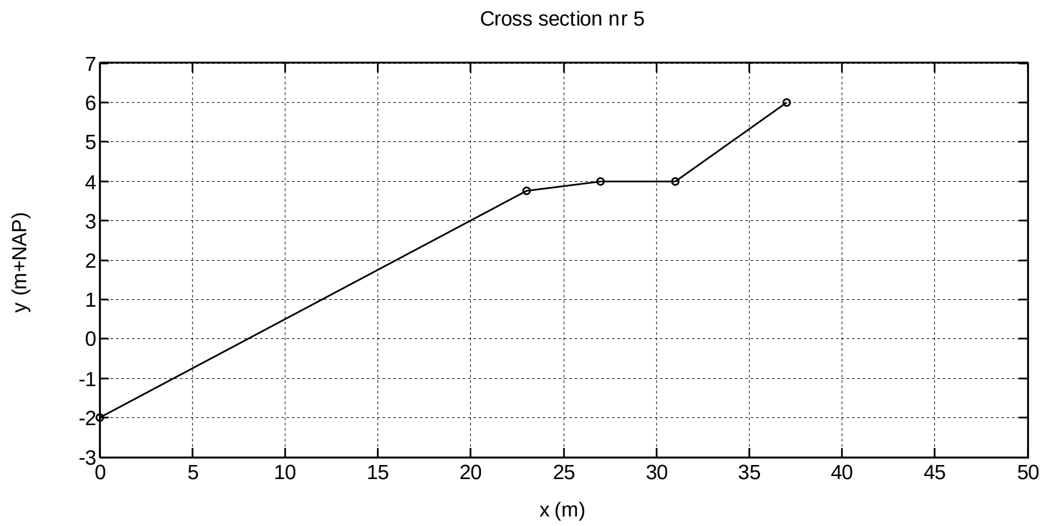

Figure 3.6 Cross section nr 5, basic geometry.

point nr	x	y	segment nr	slope	roughness
-	(m)	(m+NAP)	-	-	-
1	0	-2	1	4.0	1.0
2	23	3.75	2	16.0	1.0
3	27	4	3	0.0	1.0
4	31	4	4	3.0	1.0
5	37	6			

Table 3.11 Cross section nr 5, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8berm	slope segment 2 (-)	15 [0.5] 400	0
9berm	slope segment 2 (-)	15 [0.5] 400	85
8	slope segment 2 (-)	1 [0.1] 8	0
9	slope segment 2 (-)	1 [0.1] 8	85
10	slope segment 1 and 4 (-)	1 [0.1] 8	0
11	slope segment 1 and 4 (-)	1 [0.1] 8	85
12	roughness segment 2 (-)	0.5 [0.01] 1.0	0
13	roughness segment 2 (-)	0.5 [0.01] 1.0	85
14	roughness segment 3 (-)	0.5 [0.01] 1.0	0
15	roughness segment 3 (-)	0.5 [0.01] 1.0	85
16	roughness segment 1 and 3 (-)	0.5 [0.01] 1.0	0
17	roughness segment 1 and 3 (-)	0.5 [0.01] 1.0	85
18	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	0
19	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	85

Table 3.12 Cross section nr 5, additional test series on variation in geometry.

3.3.6 Cross section nr 6

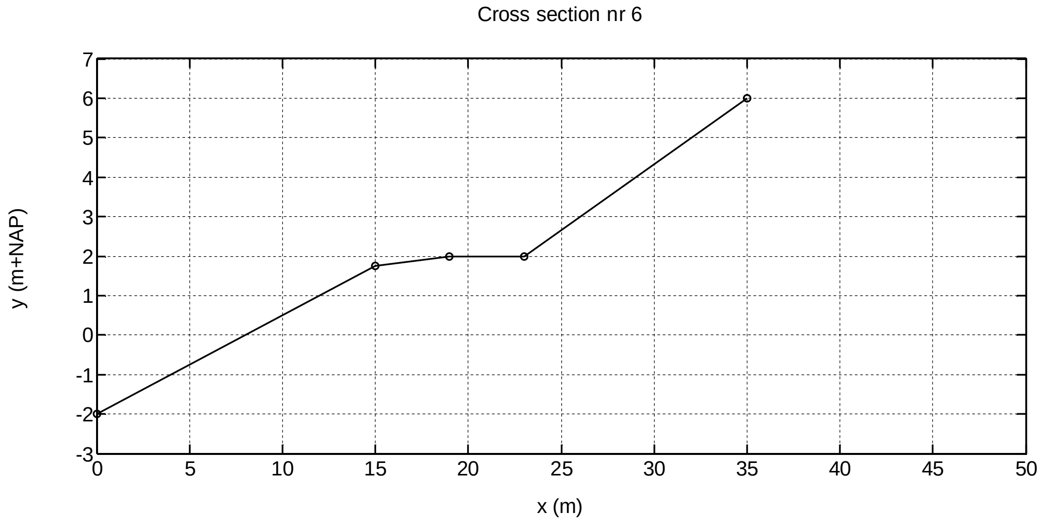

Figure 3.7 Cross section nr 6, basic geometry.

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
1	0	-2	1	4.0	1.0
2	15	1.75	2	16.0	1.0
3	19	2	3	0	1.0
4	23	2	4	3.0	1.0
5	35	6			

Table 3.13 Cross section nr 6, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8berm	slope segment 3 (-)	15 [0.5] 400	0
9berm	slope segment 3 (-)	15 [0.5] 400	85
8	slope segment 3 (-)	1 [0.1] 8	0
9	slope segment 3 (-)	1 [0.1] 8	85
10	slope segment 1 and 4 (-)	1 [0.1] 8	0
11	slope segment 1 and 4 (-)	1 [0.1] 8	85
12	roughness segment 2 (-)	0.5 [0.01] 1.0	0
13	roughness segment 2 (-)	0.5 [0.01] 1.0	85
14	roughness segment 3 (-)	0.5 [0.01] 1.0	0
15	roughness segment 3 (-)	0.5 [0.01] 1.0	85
16	roughness segment 1 and 3 (-)	0.5 [0.01] 1.0	0
17	roughness segment 1 and 3 (-)	0.5 [0.01] 1.0	85
18	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	0
19	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	85

Table 3.14 Cross section nr 6, additional test series on variation in geometry.

3.3.7 Cross section nr 7

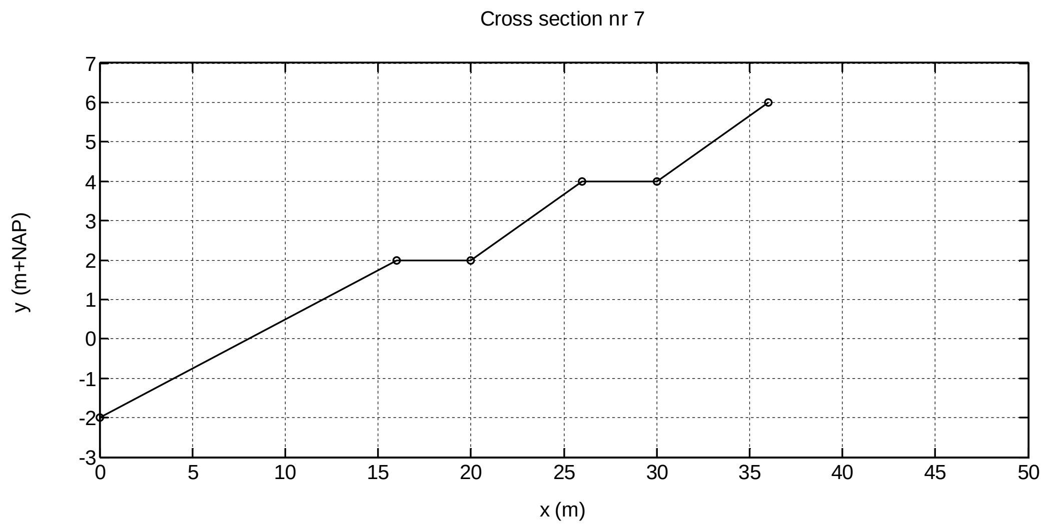

Figure 3.8 Cross section nr 7, basic geometry.

point nr	x	y	segment nr	slope	roughness
-	(m)	(m+NAP)	-	-	-
1	0	-2	1	4.0	1.0
2	16	2	2	0.0	1.0
3	20	2	3	3.0	1.0
4	26	4	4	0.0	1.0
5	30	4	5	3.0	1.0
6	36	6			

Table 3.15 Cross section nr 7, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8	slope segment 1, 3 and 5	1 [0.1] 8	0
9	slope segment 1, 3 and 5	1 [0.1] 8	85
10	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	0
11	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	85
12	roughness segment 1, 3 and 5 (-)	0.5 [0.01] 1.0	0
13	roughness segment 1, 3 and 5 (-)	0.5 [0.01] 1.0	85

Table 3.16 Cross section nr 7, additional test series on variation in geometry.

3.3.8 Cross section nr 8

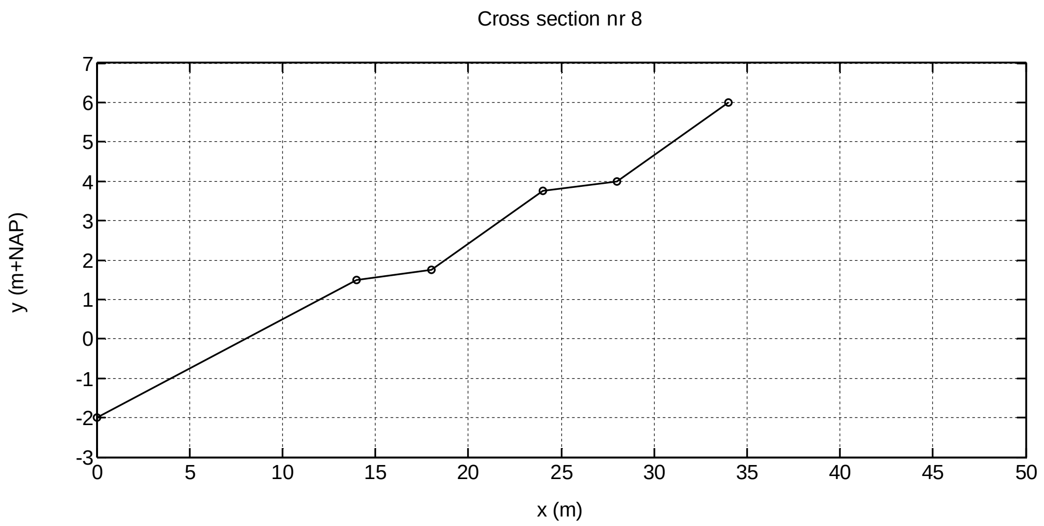

Figure 3.9 Cross section nr 8, basic geometry.

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
1	0	-2	1	4.0	1.0
2	14	1.5	2	16.0	1.0
3	18	1.75	3	3.0	1.0
4	24	3.75	4	16.0	1.0
5	28	4	5	3.0	1.0
6	34	6			

Table 3.17 Cross section nr 8, basic geometry.

series nr	Parameter to vary in the test series	Variation	Wave angle (º)
8	slope segment 1, 3 and 5	1 [0.1] 8	0
9	slope segment 1, 3 and 5	1 [0.1] 8	85
10	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	0
11	roughness segment 2 and 4 (-)	0.5 [0.01] 1.0	85
12	roughness segment 1, 3 and 5 (-)	0.5 [0.01] 1.0	0
13	roughness segment 1, 3 and 5 (-)	0.5 [0.01] 1.0	85

Table 3.18 Cross section nr 8, additional test series on variation in geometry.

4 Other tests

4.1 General tests

The general test cluster consists of basic I/O tests including tests on input validation and error message delivery. It contains the following tests:

- General; Test functions versionNumber, calculateQoF, calcZValue in the dll
  - test call versionNumber
  - test actual computations in calculateQo for waterlevel < dikeheight
  - test actual computations in calculateQo for waterlevel > dikeheight (overflow)
  - test actual computations in calculateQo for waterlevel < dikeheight, without waves
- General; Test a dikeheight at one of the profile points
- General; Test influence roughness
- General; Test validation of incorrect profile and negative model factor
  - test validation of input (geometry not correct)
  - test validation of input (modelfactor m_z2 < 0)
  - test validation of input (modelfactor foreshore < 0.3)
- General; Test validation of invalid roughness
- General; Test validation of incorrect profile and negative model factor in one call
- General; Test message of incorrect profile (z-value)
- General; Test h+z2 > dikeheight
- General; Test error handling in case of NaN in load
- General; Test whether the profile is adapted correctly
- General; ISSUE; Test A for calculateGammaF related to issue 44
- General; ISSUE; Test B for calculateGammaF related to issue 44
- General; ISSUE; Test for issue 45

4.2 Omkeervariant tests

The 'omkeervariant' test cluster focuses on the inverse of the basic computation. It contains the following tests:

- OmkeerVariant; inverse of overtoppingDllTest test
- OmkeerVariant; high discharge
- OmkeerVariant; expected dikeheight in profile
- OmkeerVariant; with berm
- OmkeerVariant; with berm and dikeheight just above berm
- OmkeerVariant; with berm and expected dikeheight just above berm
- OmkeerVariant; with 1:15 berm and expected dikeheight halfway berm
- OmkeerVariant; with a very small discharge
- OmkeerVariant; with water level below toe
- OmkeerVariant; with expected dikeheight halfway last slope segment
- OmkeerVariant; ISSUE; test A related to issue 34
- OmkeerVariant; ISSUE; test B related to issue 34
- OmkeerVariant; ISSUE; test C related to issue 34
- OmkeerVariant; ISSUE; test A related to issue 35
- OmkeerVariant; ISSUE; test B related to issue 35

- OmkeerVariant; ISSUE; test C related to issue 35
- OmkeerVariant; ISSUE; test A related to issue 36: wl at toe; 1:4; long dike
- OmkeerVariant; ISSUE; test B related to issue 36: wl at toe; 1:4; short dike
- OmkeerVariant; ISSUE; test A related to issue 42: berm at waterlevel
- OmkeerVariant; ISSUE; test B related to issue 42: resulting dikeheight at end of berm
- OmkeerVariant; ISSUE; test A related to issue 51
- OmkeerVariant; load tests
- OmkeerVariant; ISSUE; test A related to issue 52

4.3 Java/FEWS interface tests

The 'Java/FEWS interface' test cluster consists of basic I/O tests for the data structure to be applied in case of calling the dll from a Java environment (like FEWS). It contains the following tests:

- Java/FEWS interface; Test validation (A)
  - test validation of input (geometry not correct)
  - test validation of input (modelfactor m_z2 < 0)
  - test validation of input (modelfactor foreshore < 0.3)
- Java/FEWS interface; Test validation (B)
- Java/FEWS interface; Test CalculateQoJ
  - test actual computations in calculateQo for waterlevel < dikeheight
  - test actual computations in calculateQo for waterlevel > dikeheight (overflow)
  - test actual computations in calculateQo for waterlevel < dikeheight, without waves
- Java/FEWS interface; Test omkeerVariantJ

4.4 Unit tests

The unit test cluster consists of tests on specific low level kernel functions. At present it contains the following tests:

- Unit tests; Test CalculateGammaF (tiny waves)
- Unit tests; Test CalculateGammaF (normal waves)

5 Recommendations

The test series described in the earlier chapters is quite extensive and is very useful for testing the wave overtopping kernel. However, there are also still some opportunities for further improvement. These are pointed out below.

It is recommended to extend the test environment with a tool to determine the code coverage.

The present test procedure almost entirely consists of system tests and high level integration tests. It is recommended to add more unit tests and lower level integration tests, especially for parts of the code that may appear not to be covered by the test procedure yet.

It is recommended to redesign the i/o definition and code of the trend tests, since the present procedure shows the following drawbacks:

- The input of the test series is partly defined in ascii files and partly hard-coded in the test program, whereas there is some interdependency.
- The current numbering of series and corresponding naming of output files show variation over the cross sections, see Appendix A.
- The parameters and layout of the current output files show variation over the varied parameters.
- The code of the test program is quite extensive.

It is recommended to further analyse the remaining disagreements between reference trend results and expected trend results, in order to assess whether the disagreement is caused by a flaw in the design or an error in the implementation.

6 References

Waal, J.P. de, 2017. Wave overtopping at dikes kernel. Functional design. Deltares report, October 2017.

A Overview of Trend test series

cross section								Angle		Variation
1	2	3	4	5	6	7	8			
1	1	1	1	1	1	1	1	0		water level
2	2	2	2	2	2	2	2	85		water level
3	3	3	3	3	3	3	3	0		wave height
4	4	4	4	4	4	4	4	85	Load	wave height
5	5	5	5	5	5	5	5	0		wave steepness
6	6	6	6	6	6	6	6	85		wave steepness
7	7	7	7	7	7	7	7			wave angle
			8berm					0		slope of all berm segments as a berm
			9berm					85		slope of all berm segments as a berm
				8berm				0		slope first (lower) berm segment as a berm
				9berm				85		slope first (lower) berm segment as a berm
					8berm			0		slope second (higher) berm segment as a berm
					9berm			85		slope second (higher) berm segment as a berm
			8					0		slope of all berm segments as a slope
			9					85		slope of all berm segments as a slope
				8				0		slope first (lower) berm segment as a slope
				9				85		slope first (lower) berm segment as a slope
					8			0	Geometry	slope second (higher) berm segment as a slope
					9			85		slope second (higher) berm segment as a slope
8			10	10	10	8	8	0		slope of all ordinary segments
9			11	11	11	9	9	85		slope of all ordinary segments
	8	8						0		slope lower segment
	9	9						85		slope lower segment
	10	10						0		slope upper segment
	11	11						85		slope upper segment
	12	12						0		level buckling point
	13	13						85		level buckling point
			12					0		berm width
			13					85		berm width
			14			10	10	0		roughness of all berm segments
			15			11	11	85		roughness of all berm segments
10	14	14	16			12	12	0		roughness of all ordinary segments
11	15	15	17			13	13	85		roughness of all ordinary segments
	16	16						0		roughness lower segment
	17	17						85		roughness lower segment
	18	18						0		roughness upper segment
	19	19						85	Roughness	roughness upper segment
				12	12			0		roughness of segment 2
				13	13			85		roughness of segment 2
				14	14			0		roughness of segment 3
				15	15			85		roughness of segment 3
				16	16			0		roughness of segments 1 and 3
				17	17			85		roughness of segments 1 and 3
				18	18			0		roughness of segments 2 and 4
				19	19			85		roughness of segments 2 and 4

This table gives an overview of the test series on trends.

The final column presents the feature that is varied in the test series. Most of these features appear twice in the table, since in most cases the series is computed for two values of the wave angle (column 9), yielding a different test series.

The first 8 columns refer to the cross section numbers. The blue figures in the first 8 columns refer to the test series numbers per cross section.

The varied feature in test series numbers 1 to 7 is identical for each column (i.e. cross section) as pointed out in section 3.2.1. The varied feature in test series numbers 8 and up is described in the eight subsections of section 3.3. These latter test series numbers are not consistently related to a specific varied feature, which hampers the analysis.

The names of the output files of the test procedure are composed as follows:

"output_section" <CrossSectionNumber> "_test" <TestSeriesNumber> ".txt"

Examples of output filenames are:

output_section2_test01.txt
output_section4_test09berm.txt
output_section8_test12.txt