Deltares

Enabling Delta Life

Wave overtopping at dikes kernel

Test plan

Deltares

Wave overtopping at dikes kernel

Test plan

J.P. de Waal

1220043-002

Deltares

Title
Wave overtopping at dikes kernel

Client	Project	Reference	Pages
Rijkswaterstaat	1220043-002	1220043-002-HYE-0023	20

Keywords
Wave overtopping, wave run-up, overtopping, run-up, WTI 2017, safety assessment, software, failure mechanism.

Summary
This document describes the test plan for the 'wave overtopping at dikes' kernel. It also contains some recommendation 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 2015 WK07 Waterveiligheidsinstrumentarium - VTV Tools.

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	

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final

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Contents

1 Introduction

1.1 About this document

This document describes the test plan for the 'wave overtopping at dikes' kernel. The functional design of this kernel is given in (De Waal, 2015).

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'.

1.2 Brief description of the test procedure

The tests 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. First, a number of basic test series, in which the water level and wave parameters are varied. Followed by a number of cross section specific tests, in which the slope and roughness of the different segments are varied.

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.

1.3 Outline of the report

Chapter 2 describes the series of hydraulic load conditions for all basic cross sections.

Chapter 3 describes the different cross sections and test series. Figures with the output of the kernel (2% wave run-up and the wave overtopping discharge) for all cross sections and test series are given in the test report.

A discussion and recommendations for future improvements on the test procedure are given in chapter 4.

2 Basic test series of varying load conditions

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

$$s_o = \frac{2\pi H_{m0}}{g \cdot T_{m-1,0}{}^2} \tag{2.1}$$

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 2.1 Overview of basic values for test series

Rewriting formula (2.1) can help to compute the spectral wave period from the wave height and the wave steepness:

$$T_{m-1,0} = \sqrt{\frac{2\pi H_{m0}}{g \cdot s_o}} \tag{2.2}$$

Using the basic values from Table 2.1 the spectral wave period in the basic situation - with use of formula (2.2) - is equal to 5.66 sec.

Starting with the basic values from Table 2.1 seven test series are composed in which each time only one value is varied. The seven test series are presented in Table 2.2. 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 2.2 Basic test series for each cross section

In chapter 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 2.1.

2.2 Output in general

Two output parameters are examined: the wave run-up ($z_{2\%}$) and the overtopping discharge. 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. Notice that the wave run-up in the figures is the level of the 2% wave run-up, that is: the local water level plus the wave run-up in meters. The latter is the actual output of the overtopping module.

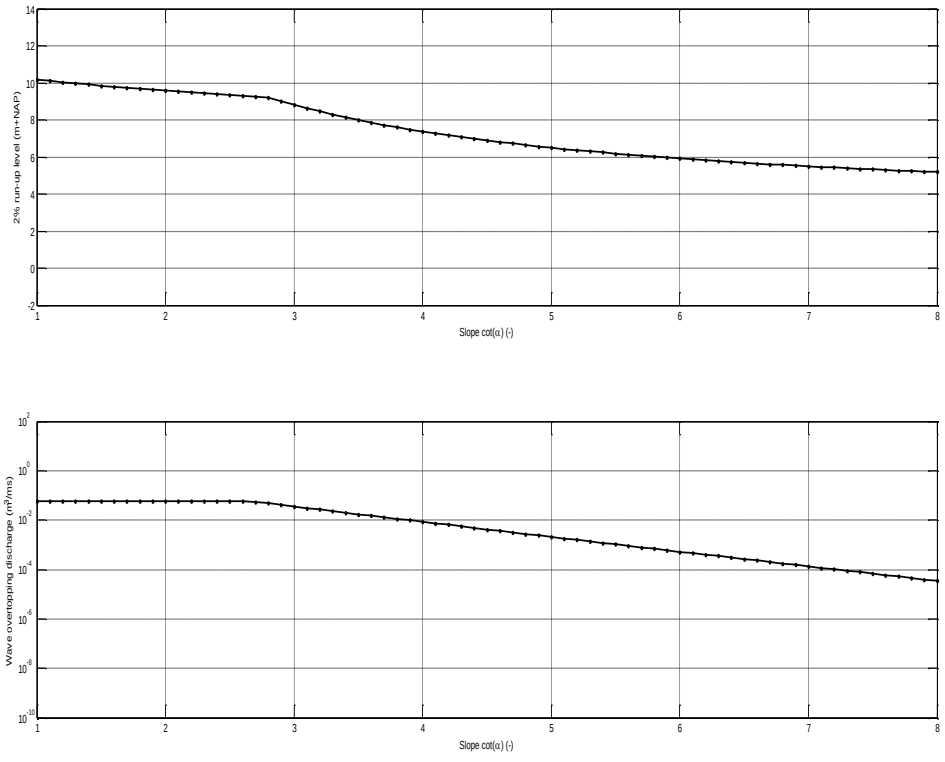

Figure 2.1 Example for the output of the test series

3 Basic cross sections and series of varying characteristics

3.1 Cross section nr 1

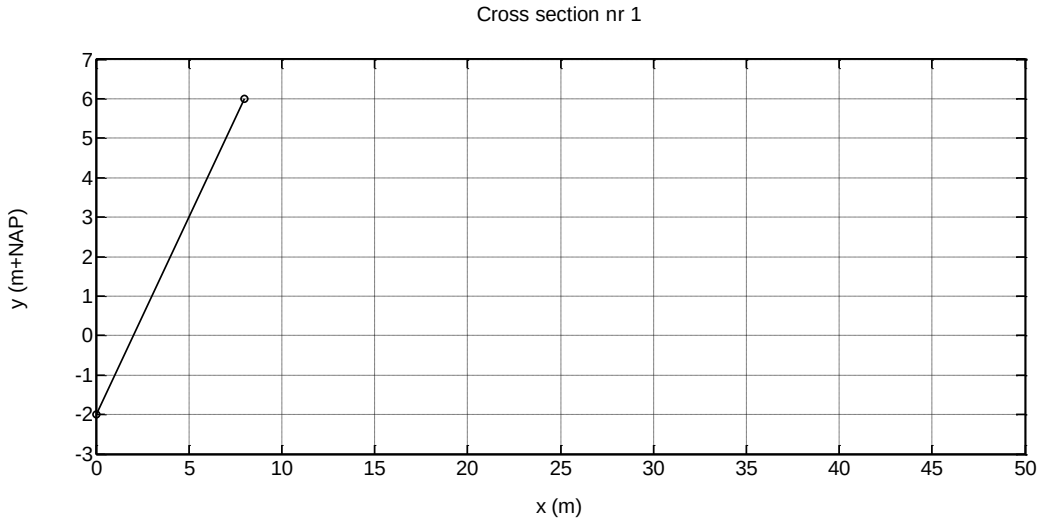

Figure 3.1 Cross section nr 1, basic geometry

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

Table 3.1 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 3.2 Cross section nr 1, additional test series on variation in geometry

3.2 Cross section nr 2

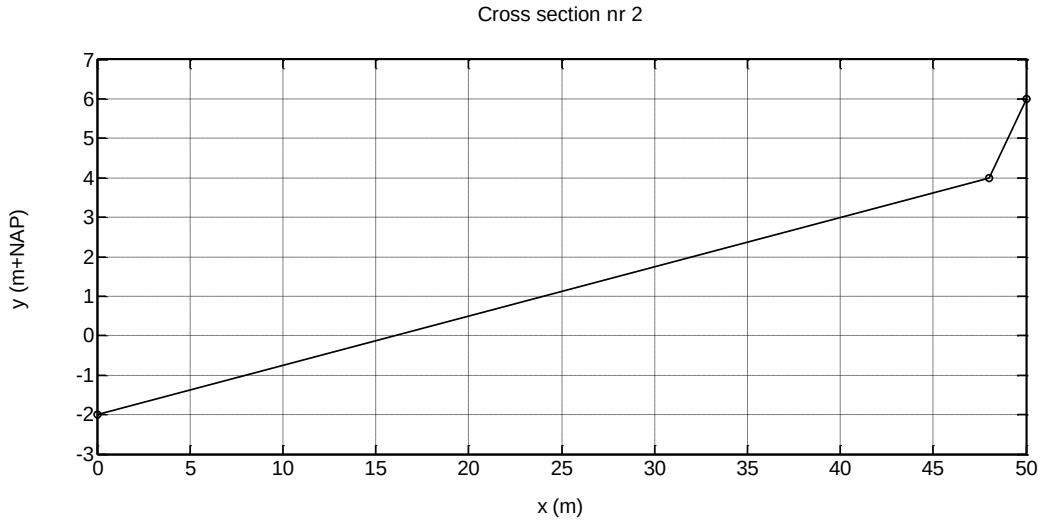

Figure 3.2 Cross section nr 2, basic geometry.

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

Table 3.3 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 3.4 Cross section nr 2, additional test series on variation in geometry.

3.3 Cross section nr 3

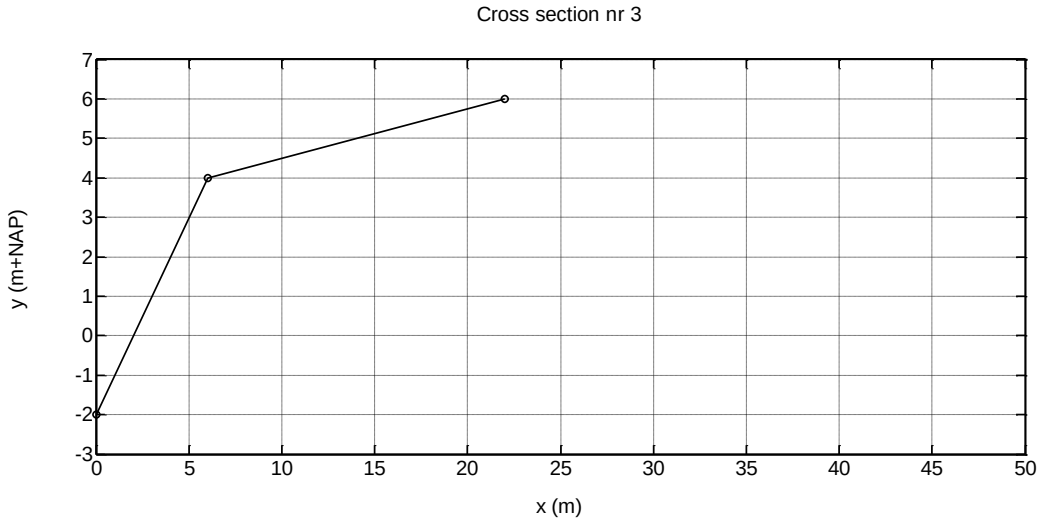

Figure 3.3 Cross section nr 3, basic geometry.

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

Table 3.5 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 3.6 Cross section nr 3, additional test series on variation in geometry.

3.4 Cross section nr 4

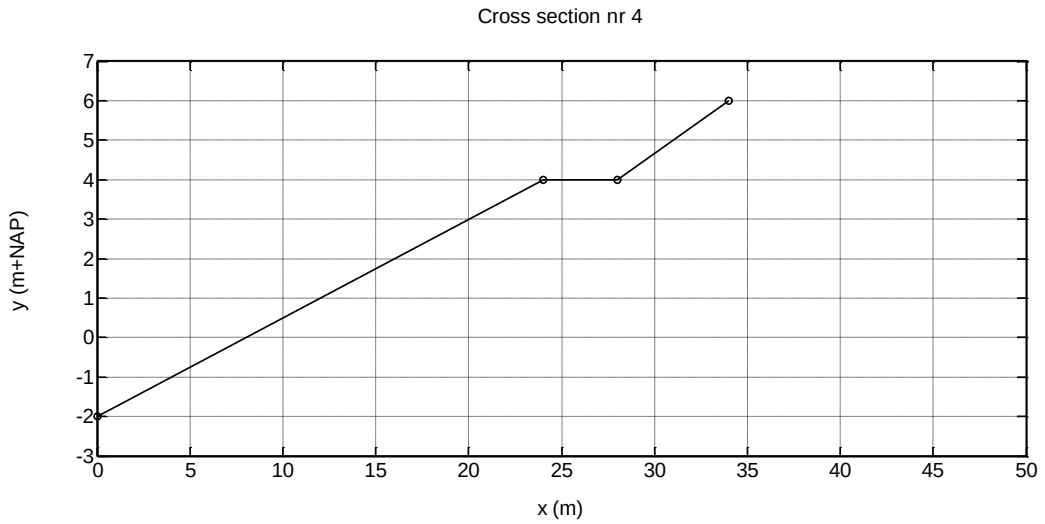

Figure 3.4 Cross section nr 4, basic geometry.

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
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 3.7 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 3.8 Cross section nr 4, additional test series on variation in geometry.

3.5 Cross section nr 5

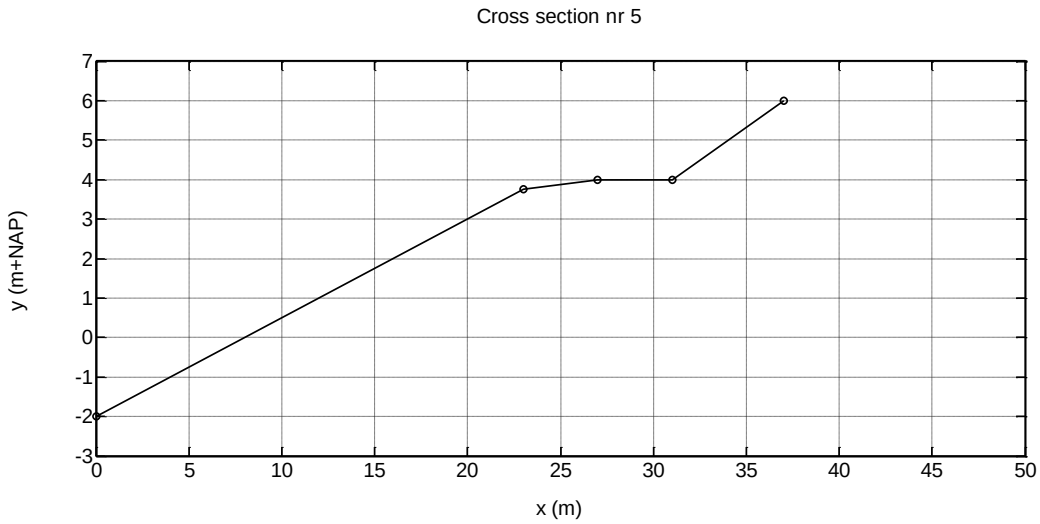

Figure 3.5 Cross section nr 5, basic geometry.

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
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 3.9 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 3.10 Cross section nr 5, additional test series on variation in geometry.

3.6 Cross section nr 6

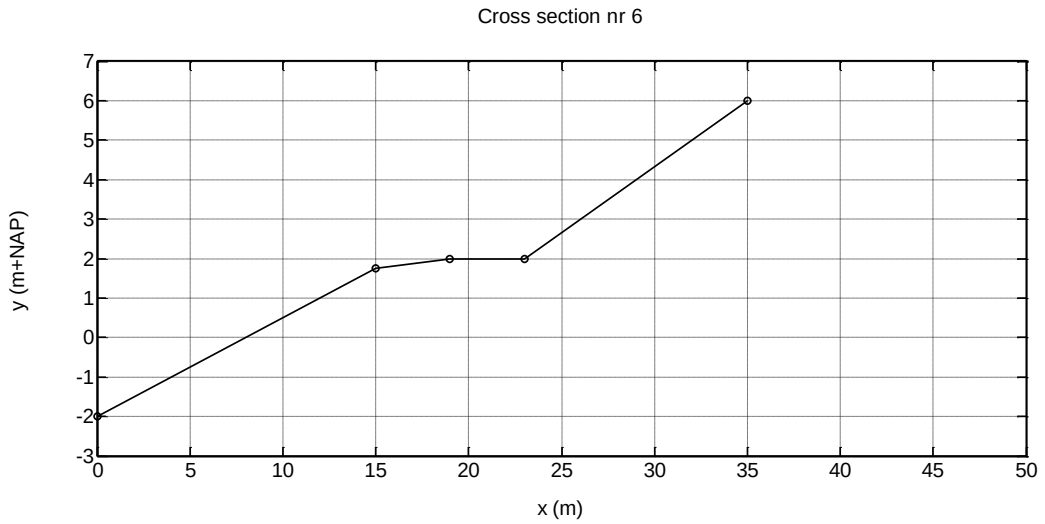

Figure 3.6 Cross section nr 6, basic geometry.

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
7	35	6			

Table 3.11 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 3.12 Cross section nr 6, additional test series on variation in geometry.

3.7 Cross section nr 7

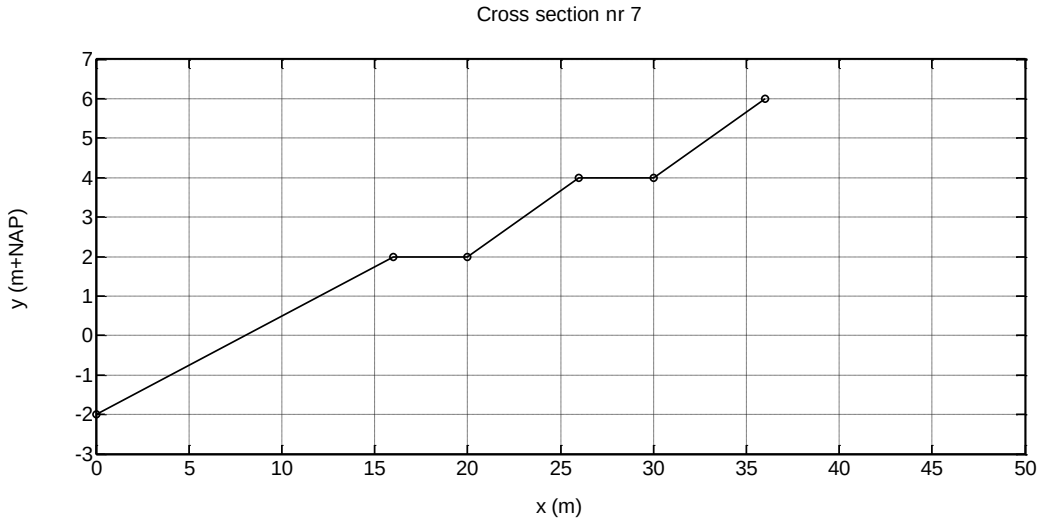

Figure 3.7 Cross section nr 7, basic geometry.

point nr -	x (m)	y (m+NAP)	segment nr -	slope -	roughness -
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 3.13 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 3.14 Cross section nr 7, additional test series on variation in geometry.

3.8 Cross section nr 8

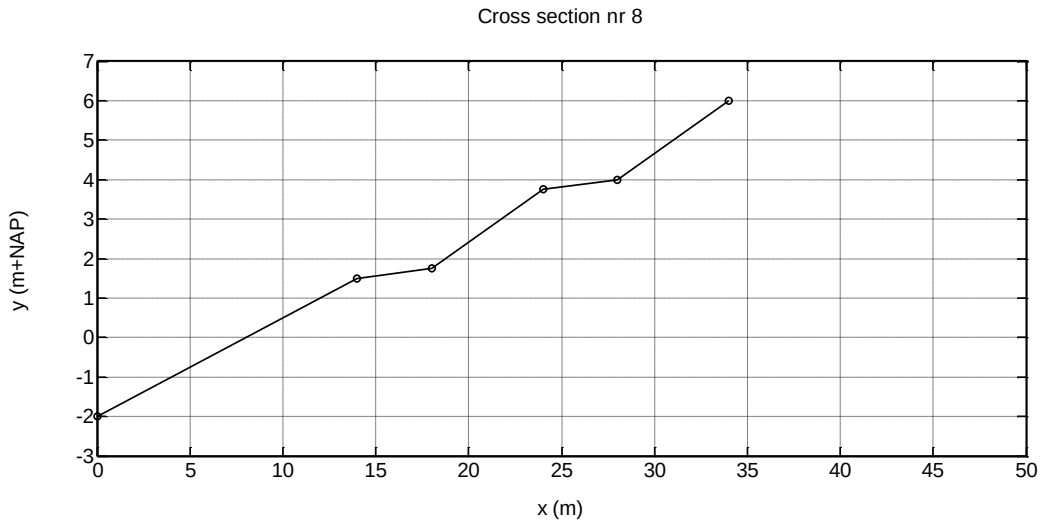

Figure 3.8 Cross section nr 8, basic geometry.

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 3.15 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 3.16 Cross section nr 8, additional test series on variation in geometry.

4 Discussion

4.1 Introduction

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 some shortcomings of this test set, some of which are considered serious enough to mention in this report.

4.2 Shortcomings in strategy

1 Not all output variables are evaluated, see Table 4.1.
2 Not all input variables are varied, see Table 4.2.
3 There are only integration tests, no unit tests (on specific parts of the computation).
4 There are no specific tests on input validation and error handling.
5 The definition of 'correct results' (see section 1.2) is rather weak.

Output		**Type**	**Explicitly validated?**
run-up			
	run-up height	basic	yes (table)
	run-up level	derived	yes (graph)
	non-dimensional run-up height	derived	no
discharge			
	wave overtopping discharge	basic	yes
	non-dimensional wave overtopping discharge	derived	no
z-function			
	z-value	basic	no

Table 4.1 Overview of output parameters and their role in the present test series

Input			Explicitly tested?
Cross section			
	orientation		only combined with wave direction as 'wave angle'
	profile		
		slopes	yes
		roughnesses	yes
	forced crest level		no
	critical wave overtopping discharge		no
Hydraulic conditions			
	water level		yes
	wave height		yes
	wave period		yes, via wave steepness
	wave direction		only combined with cross section orientation as 'wave angle'
Model parameters[1]			
	run-up		
		m_{z2}	no: only mean value
	discharge		
		(m_{z2})	(no: only mean value)
		f_n	no: only mean value
		f_b	no: only mean value
		$f_{shallow}$	no: only mean value
	z-function		
		m_{qo}	no
		m_{qc}	no

Table 4.2 Overview of input parameters and their role in the present test series

4.3 Recommendations

Naturally, it is recommended to improve on the shortcomings mentioned in the former section.

In addition, it is recommended to redesign the i/o definition and code of the test procedure, 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.

[1] *These parameters - like al other input and output parameters of the kernel - are described in (De Waal 2015).*

5 References

Waal, J.P. de, 2015. Wave overtopping at dikes kernel. Functional design. Deltares report 1220043-002, september 2015.

A Overview of 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	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	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 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.

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 Chapter 2. The varied feature in test series numbers 8 and up is described in the eight sections of Chapter 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