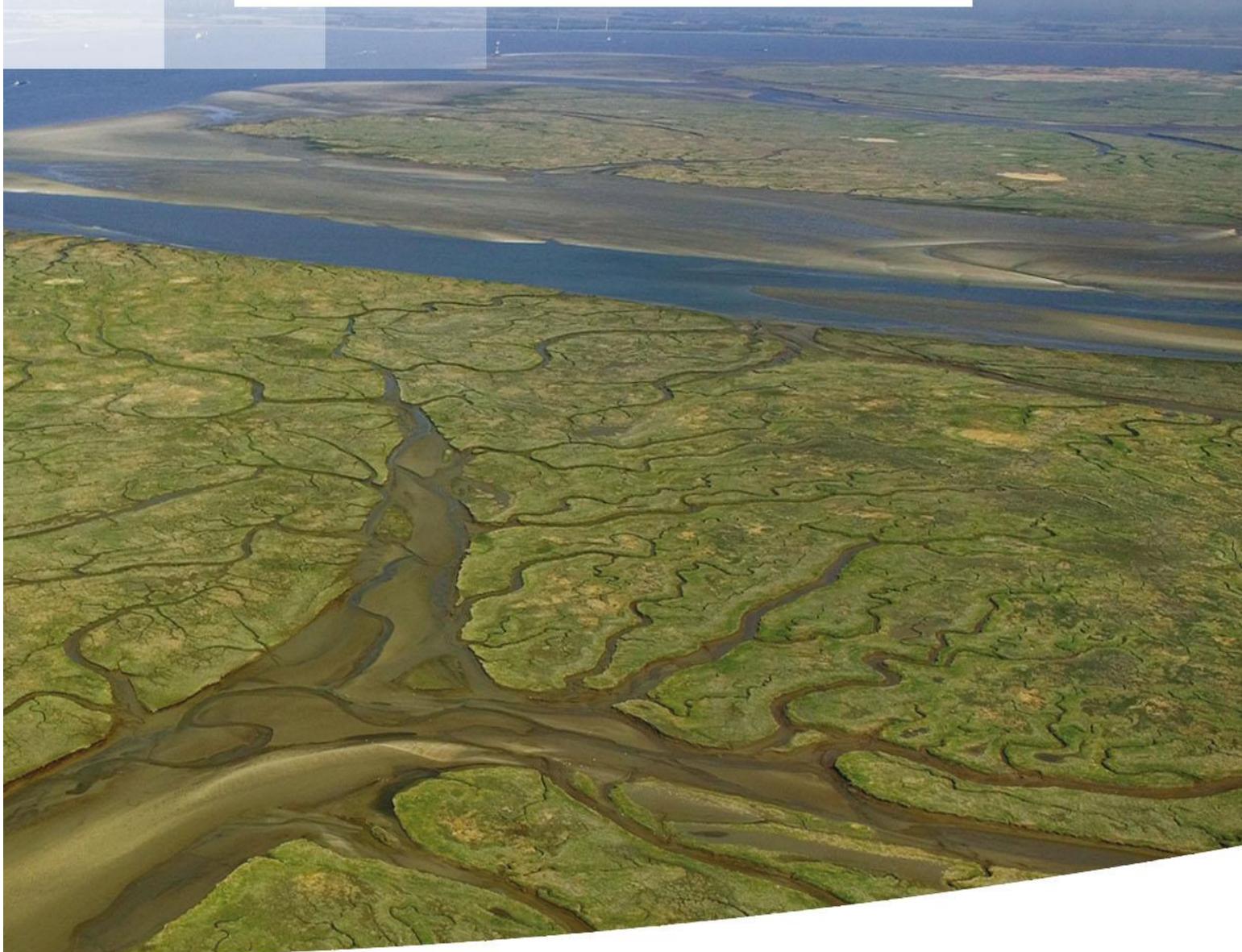




Wave overtopping at dikes kernel Test report



Wave overtopping at dikes kernel Test report

J.P. de Waal

1220043-002

Title

Wave overtopping at dikes kernel
Test report

Client	Project	Reference	Pages
Rijkswaterstaat WVL	1220043-002	1220043-002-HYE-0024	12

Keywords

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

Summary

This document describes the test results for the 'wave overtopping at dikes' kernel.

Samenvatting

Dit document beschrijft de testresultaten voor de rekenkern "golfoverslag bij dijken".

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		Dr. M.R.A. van Gent	

State

final

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State
final

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1 Introduction

1.1 About this document

This document describes the test results for the 'wave overtopping at dikes' 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 (De Waal, 2015) 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 the test plan.

1.2 Outline of the report

Chapter 2 describes the results of the test series. Conclusions and recommendations are given in chapter 3.

2 Test results

2.1 Transition to new reference results

As pointed out in the test plan (De Waal, 2015), 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.

Comparison with old reference results

Initially, the change in definition and setting of the model parameters was the only change in the kernel that is expected to cause a change in the results of the kernel on the test series. First it was verified that other changes in the code, that should not affect the computational results, indeed still produce the (former) reference results. In order to verify this, a switch is implemented in the kernel which enables a choice between the old and the new definition and setting of the model parameters. Setting this switch on 'old' yields - indeed - the old reference results.

After this, two other changes were implemented that could affect the results: the adaptation of the maximum wave height over water depth (above the toe) ratio from 0.5 to 1.0 and some minor changes in the iteration process. The effects of these changes were verified by visual inspection of the trends in computational results.

Trends in new reference results

After setting the above-mentioned switch on 'new', new reference results have been generated. In order to verify the trends in these results, new graphs have been generated. These graphs are included in the Appendix.

Note that the output files contain information on the wave overtopping discharge in 10 digits. For extremely small overtopping discharges the file contains a zero. Such a result is plotted as a red dot, on 10^{-10} ($\text{m}^3/\text{m/s}$).

Note that the scale of the run-up level (the vertical axis of the top graph) is not fixed but automatically adapted to the range in values to be plotted. Therefore, the trends may appear rather pronounced or wobbly at first sight in cases of a small range in values. Figure 6.9 is an example of this: the trend looks very pronounced at first sight, but the results are still regarded to be constant (as expected).

The analysis and explanation of unexpected trends is hampered by the lack of intermediate output from the computations, which was as already mentioned in the test plan as important point of improvement for future test procedures.

The description of the expected trends and the explanation of any occasional disagreement between the expected trends and the observed trend are therefore mainly adopted from the test report on the former test results and given in the next sections.

2.2 Basic test series for each cross section: varying load conditions

The expected results for the basic 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 trends should not show any discontinuities, like jumps or missing data. (Buckling points, i.e. discontinuities in first derivative of the trends in results, may be expected though).

All results from the basic test series fulfil these expectations, with exceptions enumerated in Table 2.1.

Section	Series	Unexpected feature	Location along x-axis
1	5	slight increase (jump) in discharge	0.02
3	1	minor discontinuity in discharge	-0.7
3	2	minor discontinuity in discharge	-0.3
6	2	slight decrease in discharge	1.0 - 1.5
7	1	minor jump in run-up and discharge	0
7	3	minor jump in run-up and discharge	2
7	4	minor jump in run-up and discharge	2.4
7	7	minor drop in run-up and discharge	80 - 81
8	3	minor jump in run-up and discharge	2.25
8	4	minor jump in run-up and discharge	2.7

Table 2.1 Basic test series where trends in computational results do not meet the expectations.

Some unexpected trends were already observed and explained in earlier versions of the test report. These explanations are repeated below.

Cross section 1, test series 5

This (minor) deviation still needs to be explained.

Most likely, the transition in formulas at a breaker parameter value of 7 is important here.

Cross section 3, test series 1 (and 2)

Figure 2.1 shows the dimensionless overtopping discharge for both the breaking and non-breaking waves, for cross section 3, with varying water level (test series 1, former reference results). The resulting overtopping discharge equals the minimum of these two values (multiplied by a factor depending on the wave height). For lower water levels this result is based on the overtopping discharge for non-breaking waves (Q_n), but for higher water levels the result is based on the overtopping discharge for breaking waves (Q_b). The latter does not always increase with increasing water levels, since it depends on the representative slope

angle. For cross section 3 the representative slope angle decreases with increasing water level, because the lower segment has a steeper slope than the upper segment.

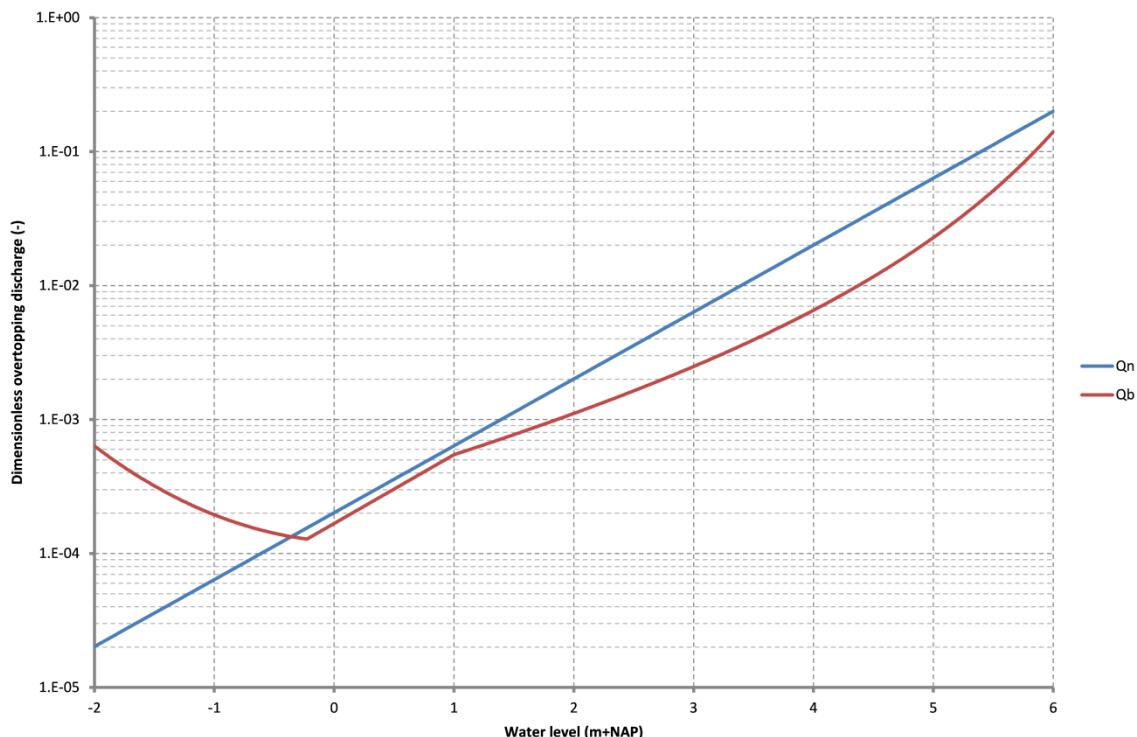


Figure 2.1 Dimensionless overtopping discharge for breaking (Q_b) and non-breaking (Q_n) waves, cross section 3, test series 1, based on old test data

Cross section 6, test series 2

This deviation still needs to be explained.

Cross section 7, test series 1

This deviation still needs to be explained.

Most likely, the transition from no berm to a full berm to be accounted for is important here, see also the next explanation.

Cross section 7 (and 8), test series 3 (and 4)

The test series for cross section 7 and cross section 8 show a remarkable jump in the run-up level and overtopping discharge when the wave height increases (test series 3 and 4). This jump occurs for wave height (H_{m0}) equal to 2 m, and is a direct consequence of a jump in the reduction factor for berms, as shown in Figure 2.2. The calculation of the reduction factor for berms uses the influence width of each berm, which (for each berm separately) is defined as the horizontal distance between cross section point at the berm height minus one wave height and the berm height plus one wave height. For the berms in cross section 7 there is a jump in the influence width of each berm at $H_{m0} = 2$ m, because that is exactly the point at which the width of the other berm is added to the influence width. So, in short: the jump in run-up level occurs at a wave height of 2 m, since that is exactly the vertical distance between the two berms in this cross section.

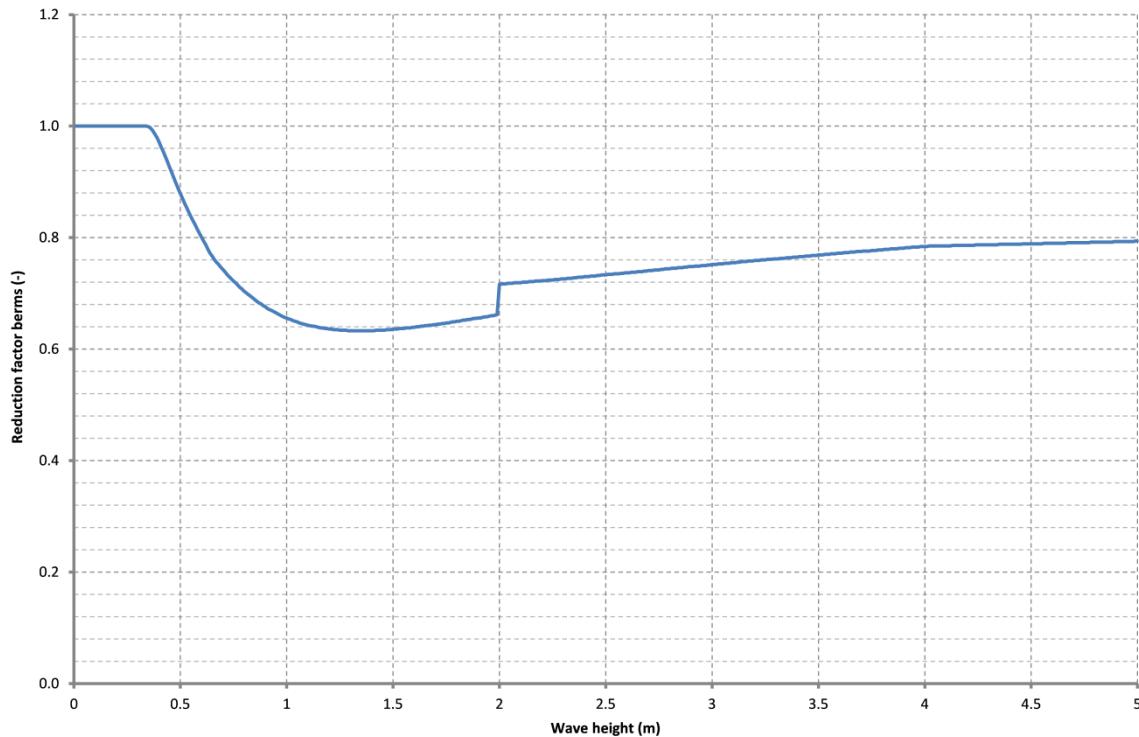


Figure 2.2 Reduction factor berms, cross section 7, test series 3, based on old test data

Cross section 7, test series 7

This deviation still needs to be explained.

Most likely, the (start of) reduction of the wave height due to very oblique wave attack is important here, since it causes a similar change in wave height as the one causing the deviation in series 3.

2.3 Additional test series for each cross section: varying cross section features

The expected results for the cross section specific test series are as follows:

- If the slope angle decreases, the run-up level and the overtopping discharge decrease.
- If the roughness coefficient 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 trends should not show any discontinuities, like jumps or missing data. (Buckling points, i.e. discontinuities in first derivative, may be expected though).

All results from the additional test series fulfil these expectations, with exceptions enumerated in Table 2.2:

Section	Series	Unexpected feature	Location along x-axis
3	15	slight decrease in discharge	0.52 - 0.54
3	19	slight decrease in discharge	0.50 - 0.65
4	17	drop in run-up	0.51 - 0.52
4	17	jump in discharge	0.66 - 0.67
7	10	slight decrease in run-up	0.53 - 0.55
7	11	decrease (drop) in discharge	0.66 - 0.67
7	12	minor jump in run-up	0.67 - 0.68
7	13	jump in discharge	0.79 - 0.80

Table 2.2 Additional test series where trends in computational results do not meet the expectations.

Some unexpected trends were already observed and explained in earlier versions of the test report. These explanations are repeated below.

Cross section 3, test series 15

This (minor) deviation still needs to be explained.

Cross section 3, test series 19

For this test series the overtopping discharge increases when the roughness coefficient decreases (for part of the test series). In this case, the overtopping discharge is completely determined by the overtopping discharge for breaking waves. When all other parameters are fixed, this discharge decreases when the roughness coefficient decreases. In this case however, also the breaker parameter changes and increases with the decreasing roughness coefficient, as can be seen in Figure 2.3. For small roughness coefficients, the increasing breaker parameter has a larger effect than the decreasing value of the roughness coefficient itself, which leads to larger overtopping discharges. The increasing breaker parameter is a side-effect of the decreasing roughness coefficient, since the wave run-up decreases and therefore the representative slope angle is more and more influenced by the steeper lower segment from cross section 3.

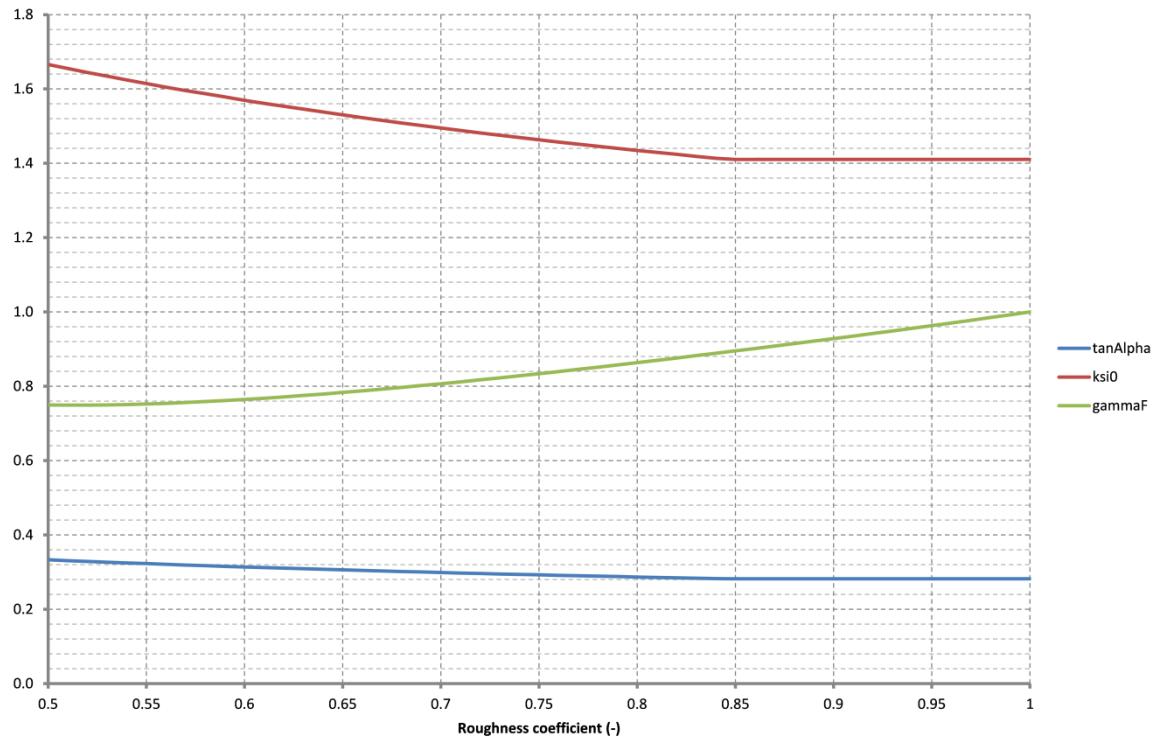


Figure 2.3 Representative slope ($\tan\alpha$), breaker parameter (κ_{i0}) and influence factor roughness (γ_F), cross section 3, test series 19, based on old test data

Cross section 4, test series 17

These deviations still need to be explained.

Cross section 7, test series 10, 11, 12, 13

These deviations still need to be explained.

Most likely the assessment of the representative roughness factor is important here: there is probably a transition in the horizontal length of the profile that is taken into account: with or without the horizontal berm(s).

3 Conclusions and recommendations

This document describes the test results for the wave overtopping kernel. These tests consist of test series in which certain input parameters, for example the wave height or segment slope, are varied to determine the effect of these parameters on the main output, namely: the 2% wave run-up level and the wave overtopping discharge.

Correctness of the computation results is largely examined through visual inspection of the output figures (as presented in the Appendix). In cases where the output didn't meet the expected behaviour, further analysis was adopted from earlier versions of the test report. These results are described in the chapter 2.

Most test results are positive: in most test series the wave run-up and overtopping discharge followed expected behaviour. For some test series where this was not the case, further analysis (adopted from earlier report versions) showed plausible explanations of the results and that they are indeed correct.

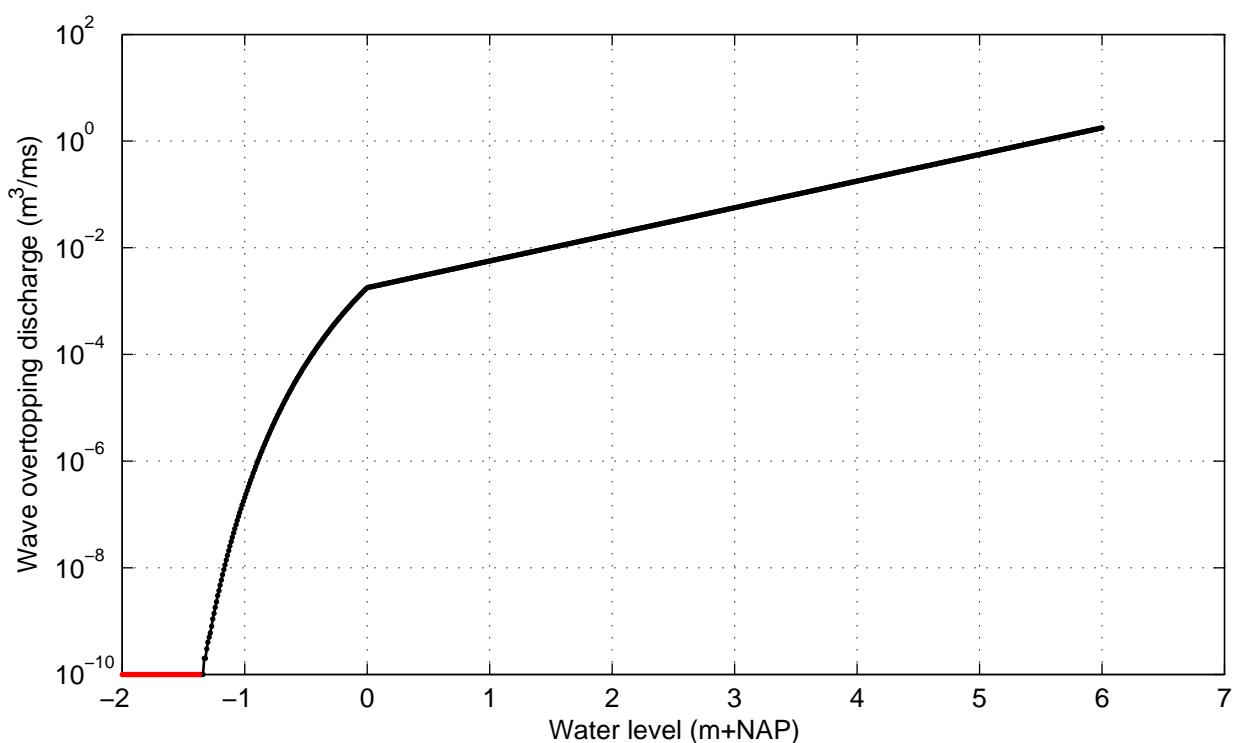
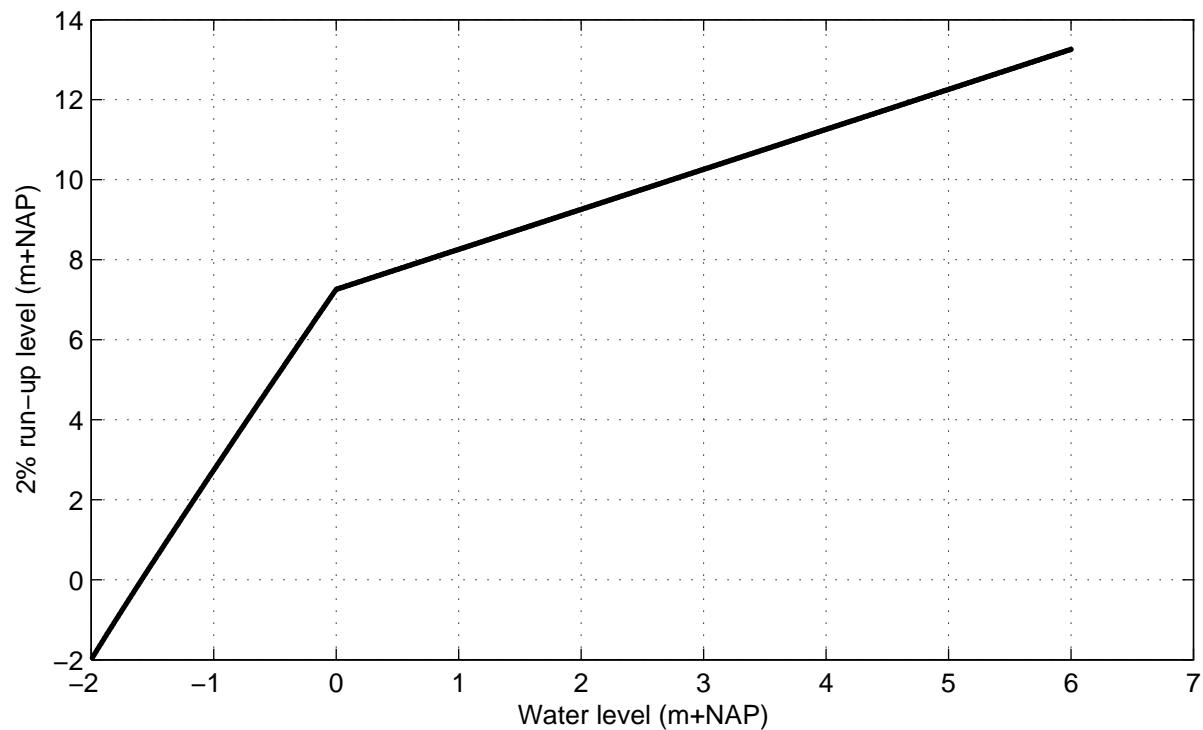
However, there are still some unexpected trends that should be analysed and explained in more detail. These are identified in chapter 2. However, the required analyses are hampered by the lack of intermediate output from the computations. It is recommended to adapt the kernel code on this issue.

Moreover, the test procedure has some serious shortcomings, as pointed out in the test plan (De Waal, 2015). In order to achieve a more solid validation of the kernel, it is strongly recommended to improve the test procedure.

4 References

Waal, J.P. de, 2015. Wave overtopping at dikes kernel. Test plan. Deltires report 1220043-002, September 2015.

Appendix



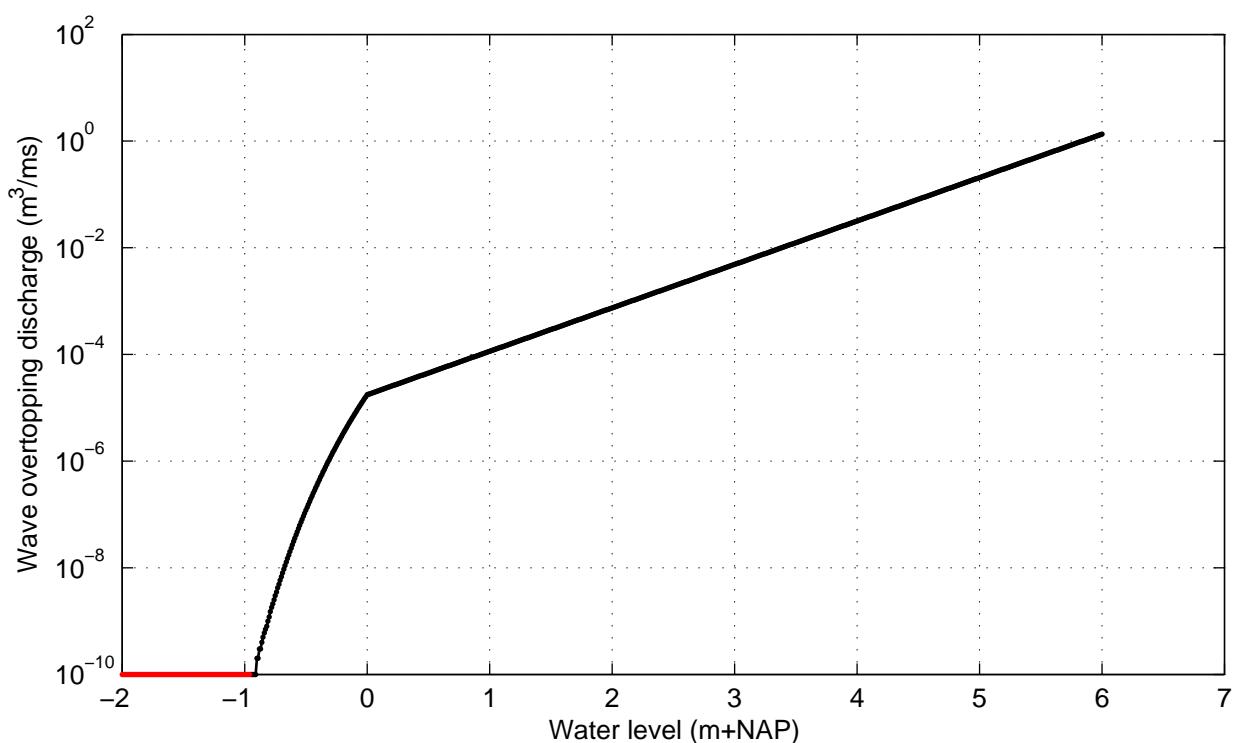
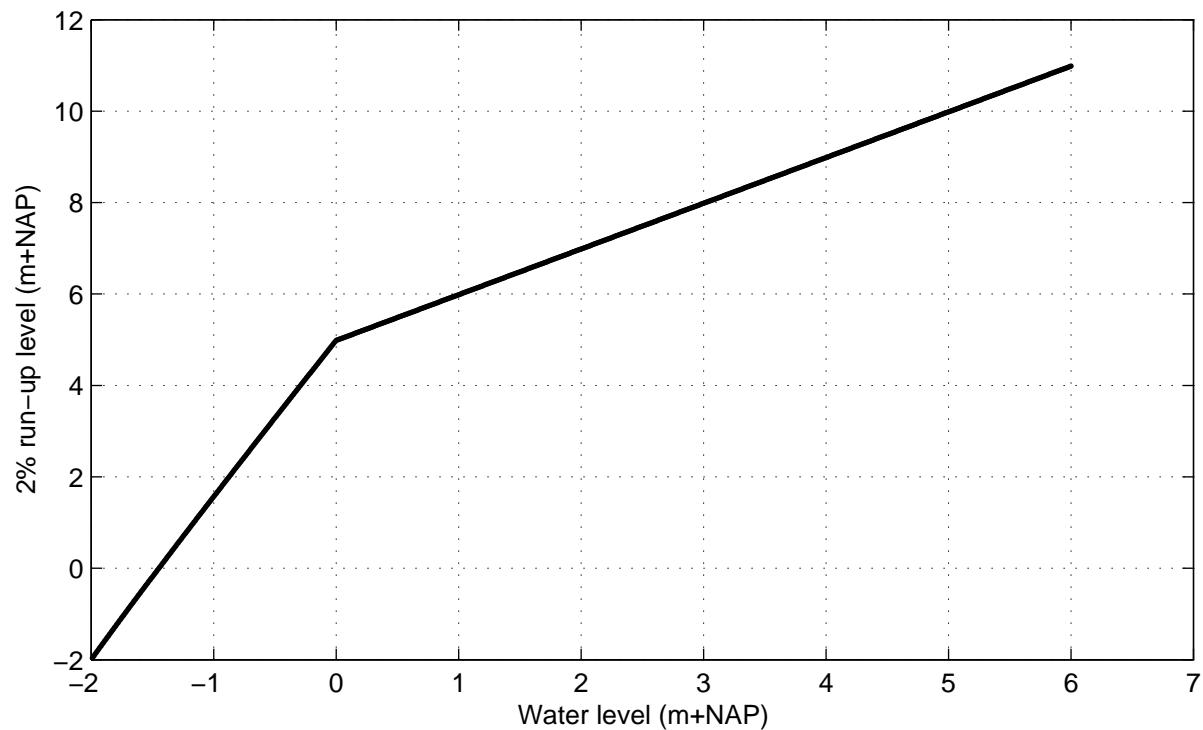
Cross section nr 1; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 1.1



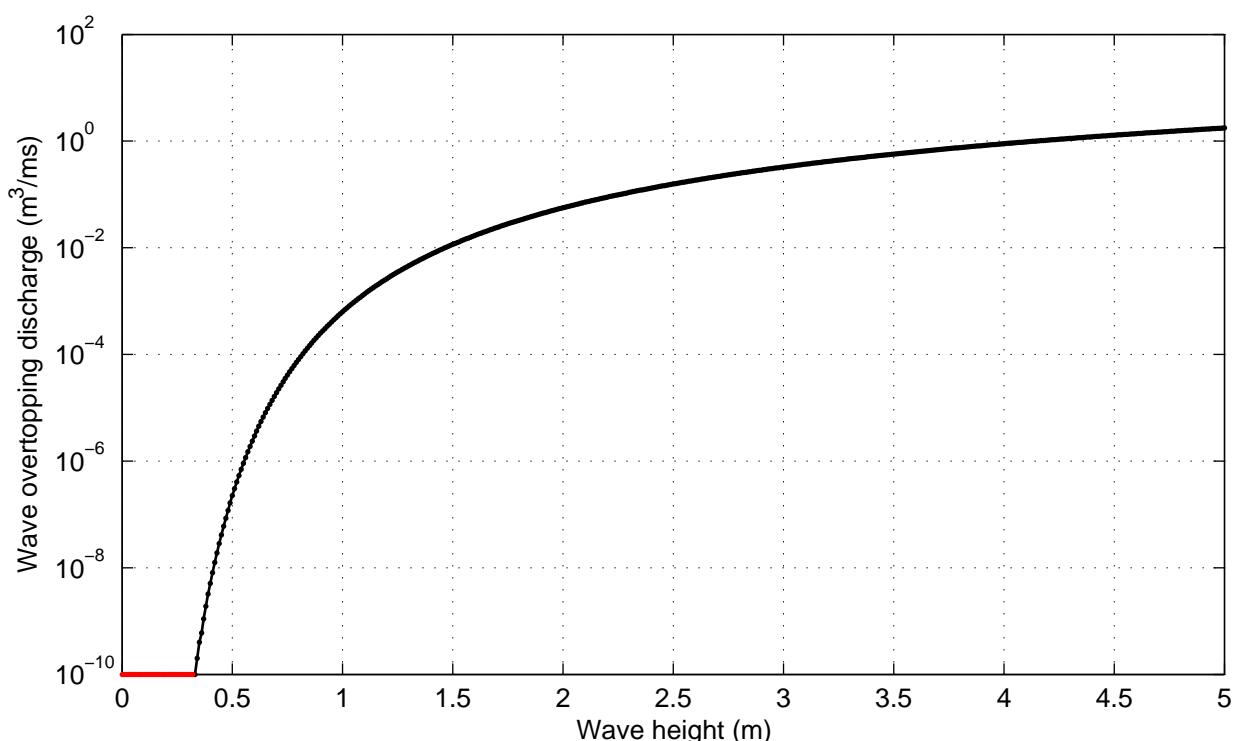
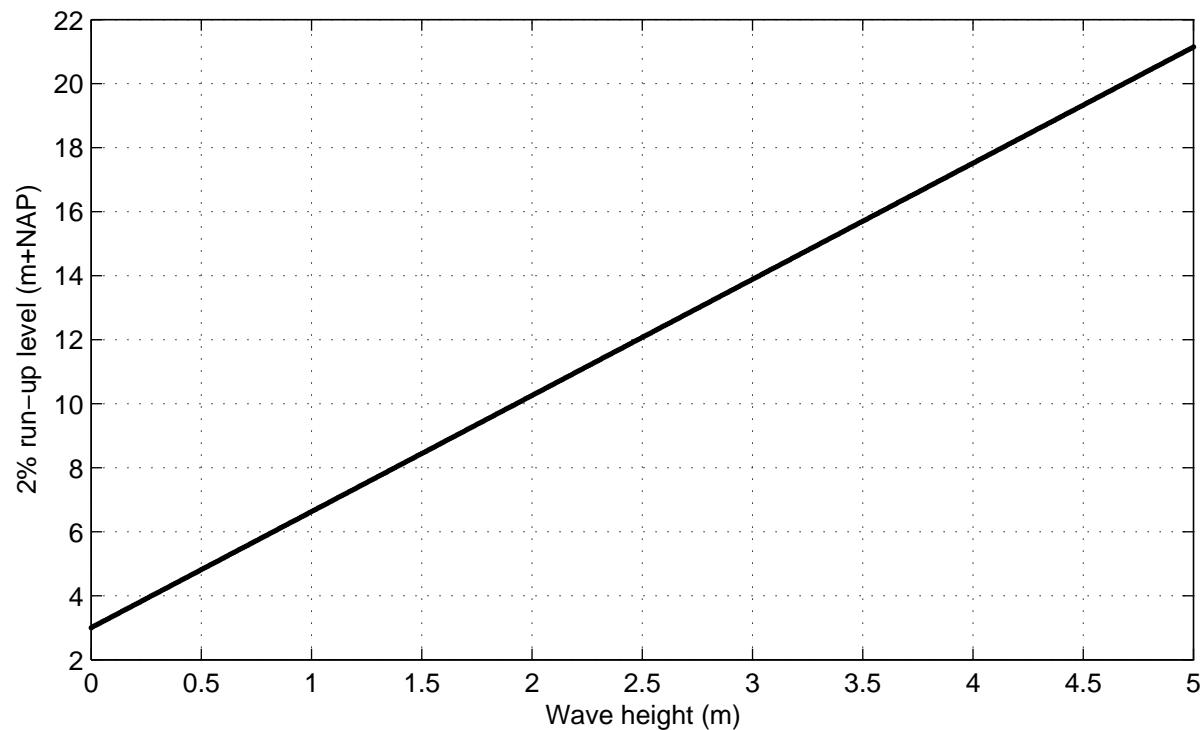
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Varying water level

Wave overtopping kernel tests

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Fig. 1.2



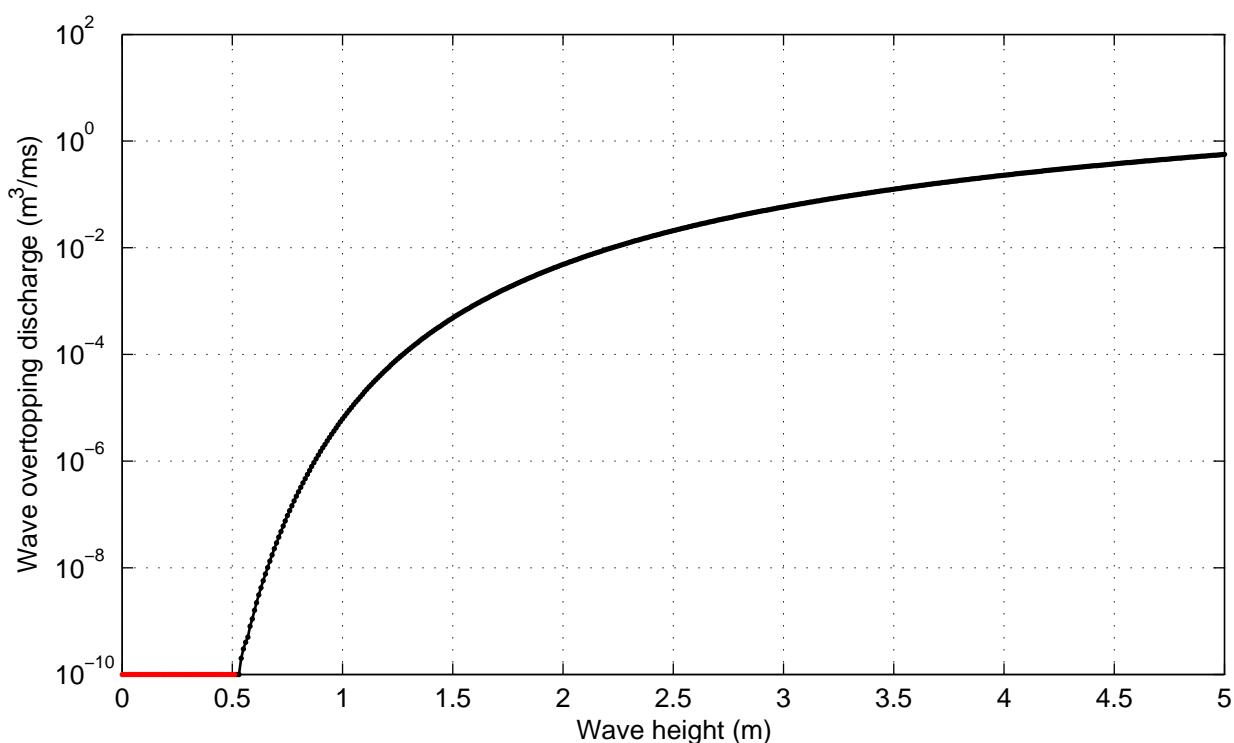
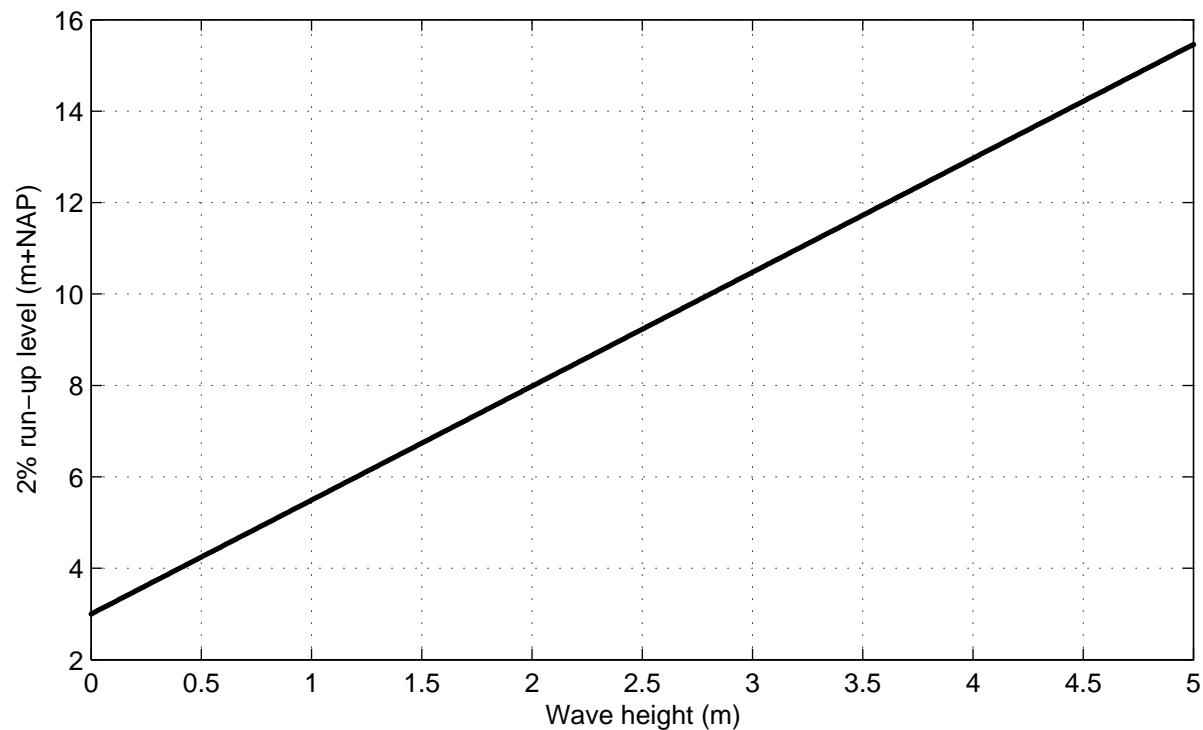
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Varying wave height

Wave overtopping kernel tests

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Fig. 1.3



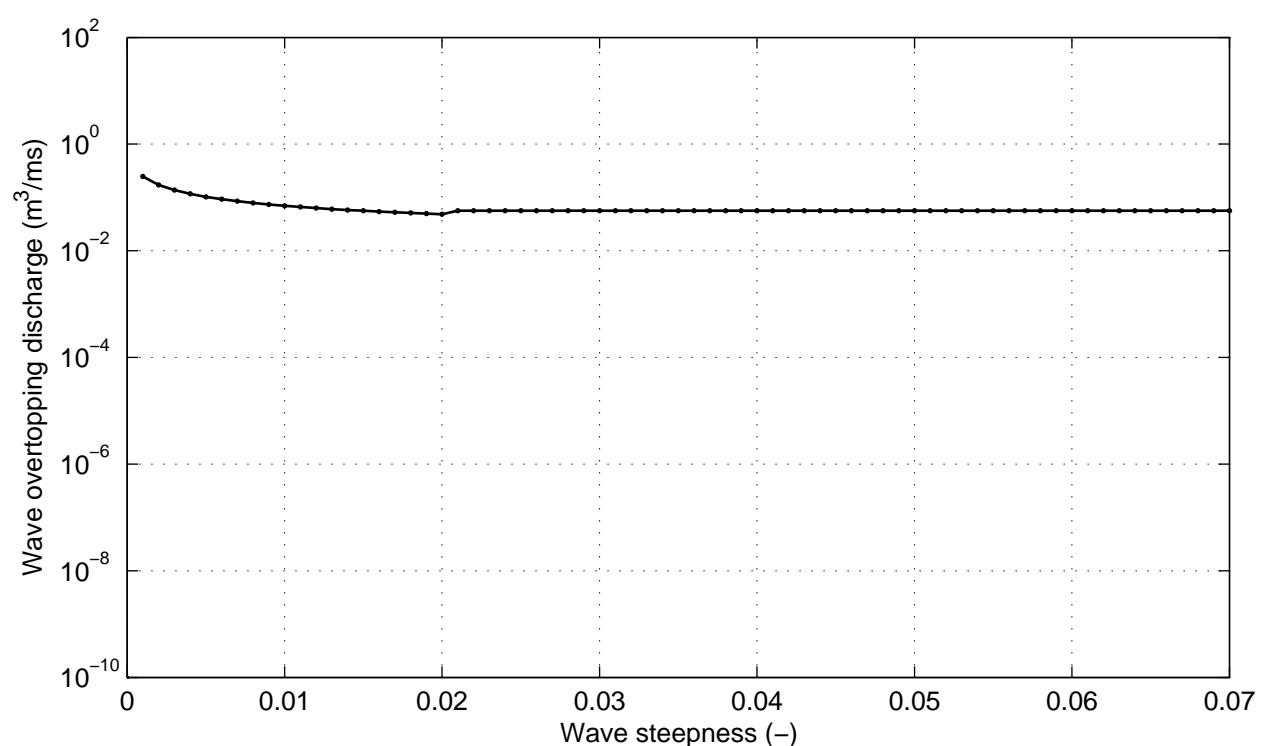
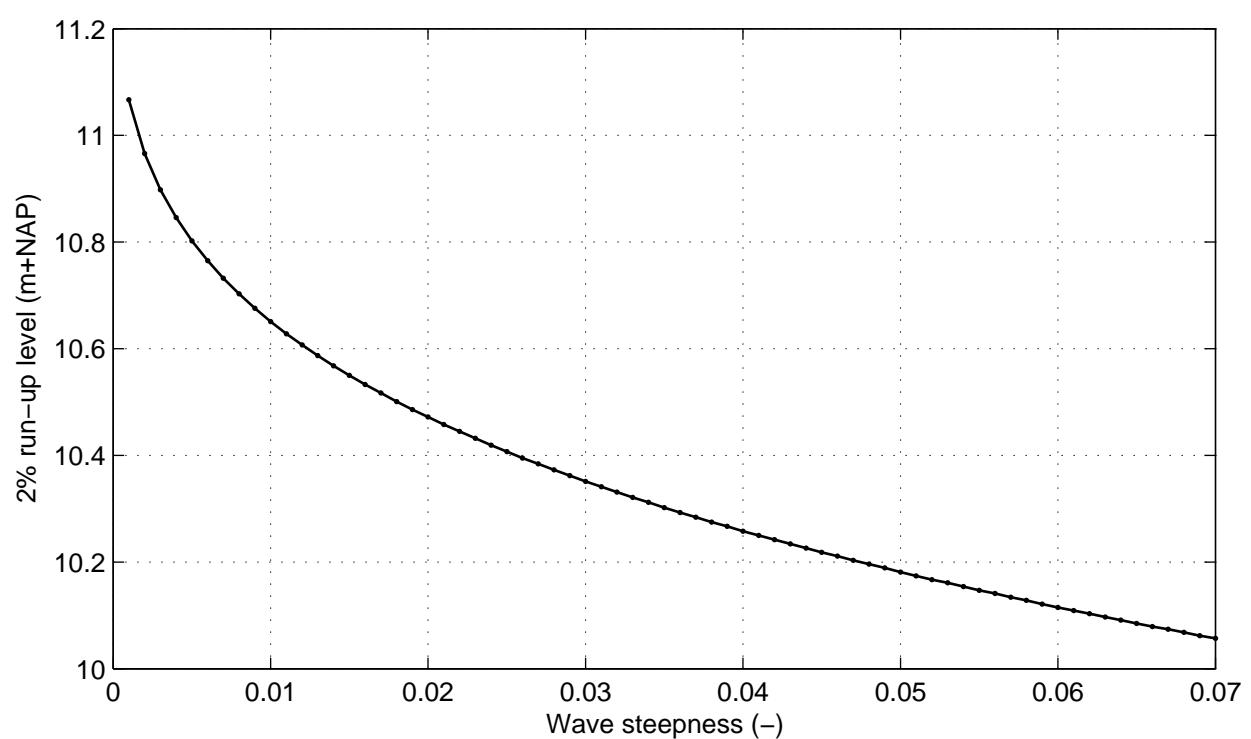
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Varying wave height

Wave overtopping kernel tests

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Fig. 1.4



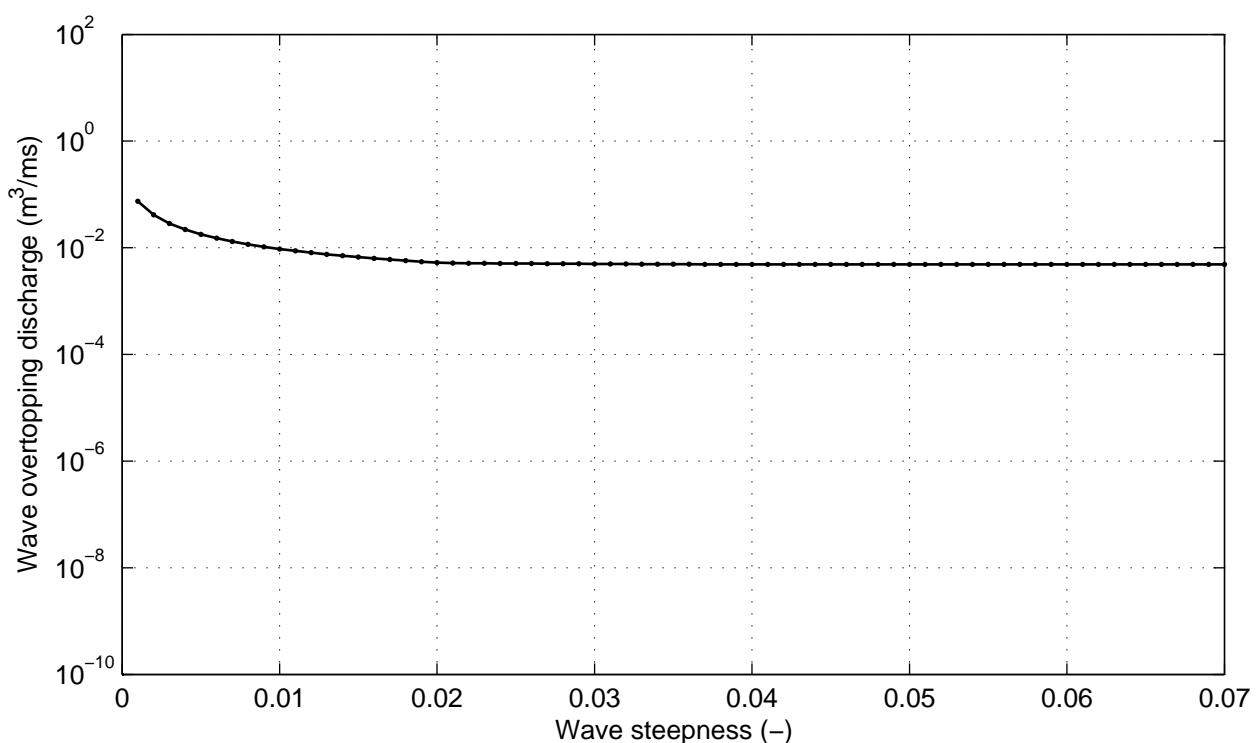
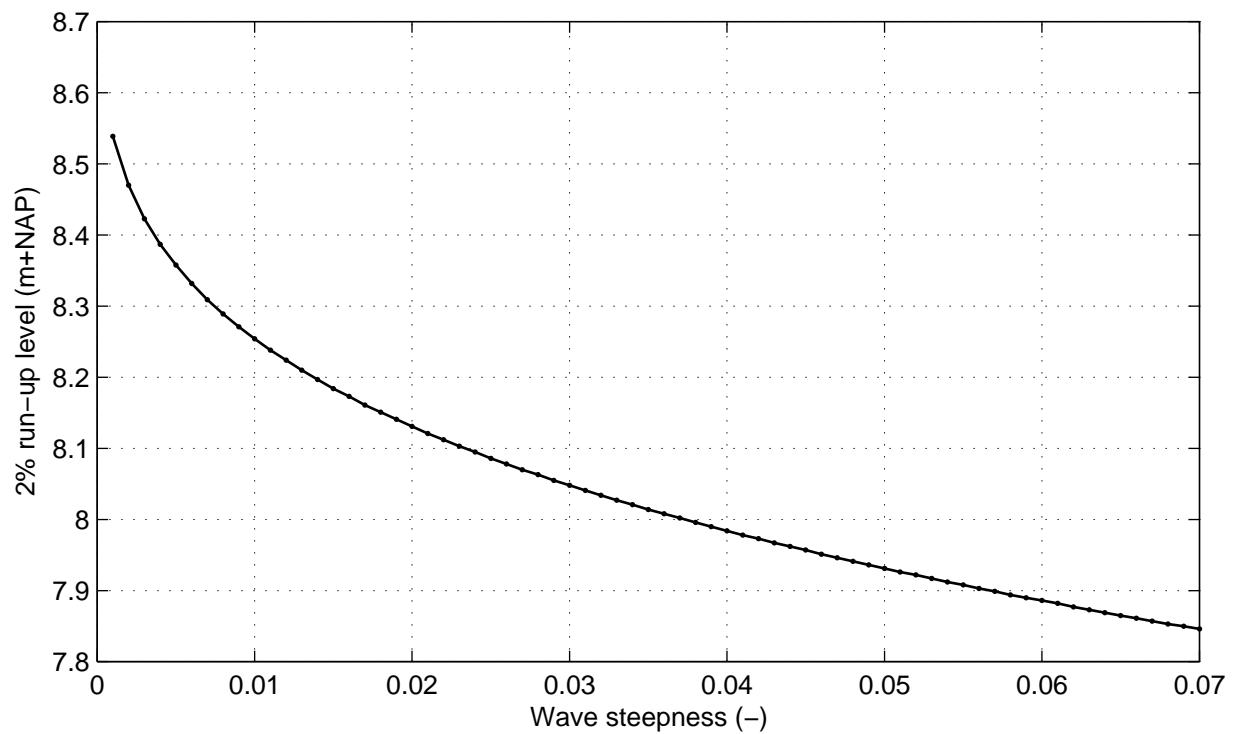
Cross section nr 1; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 1.5



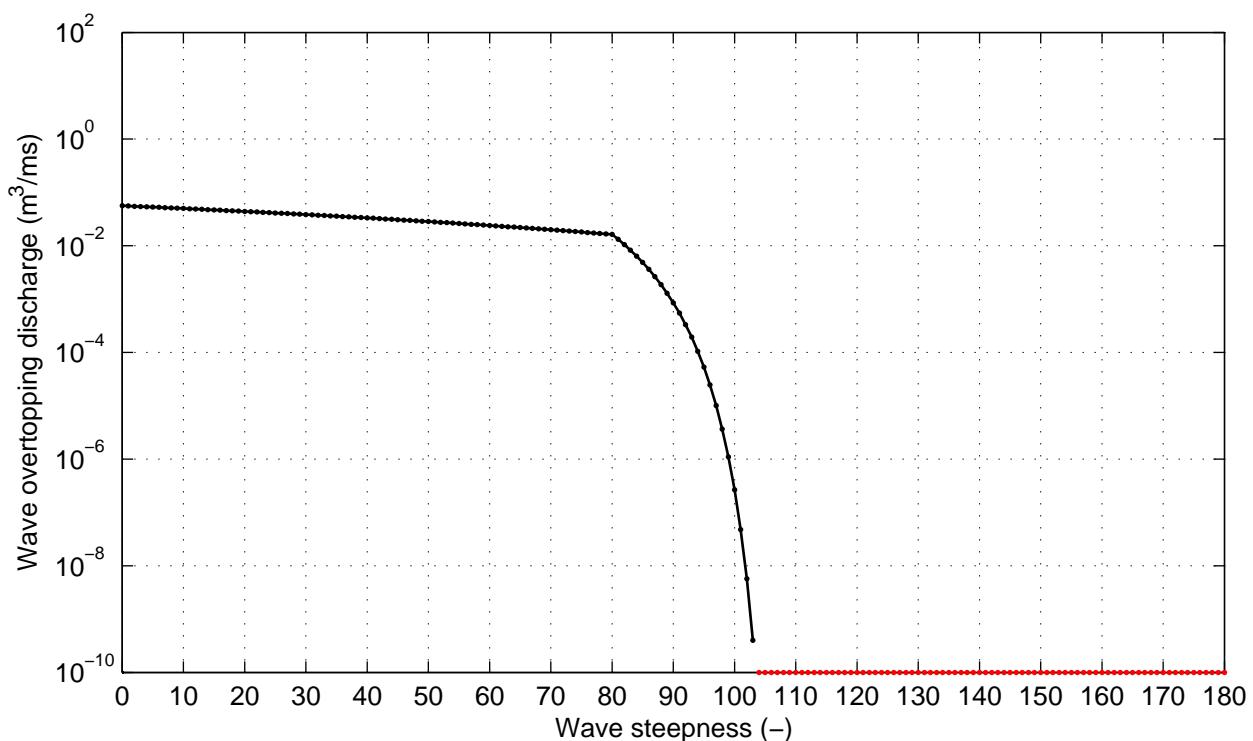
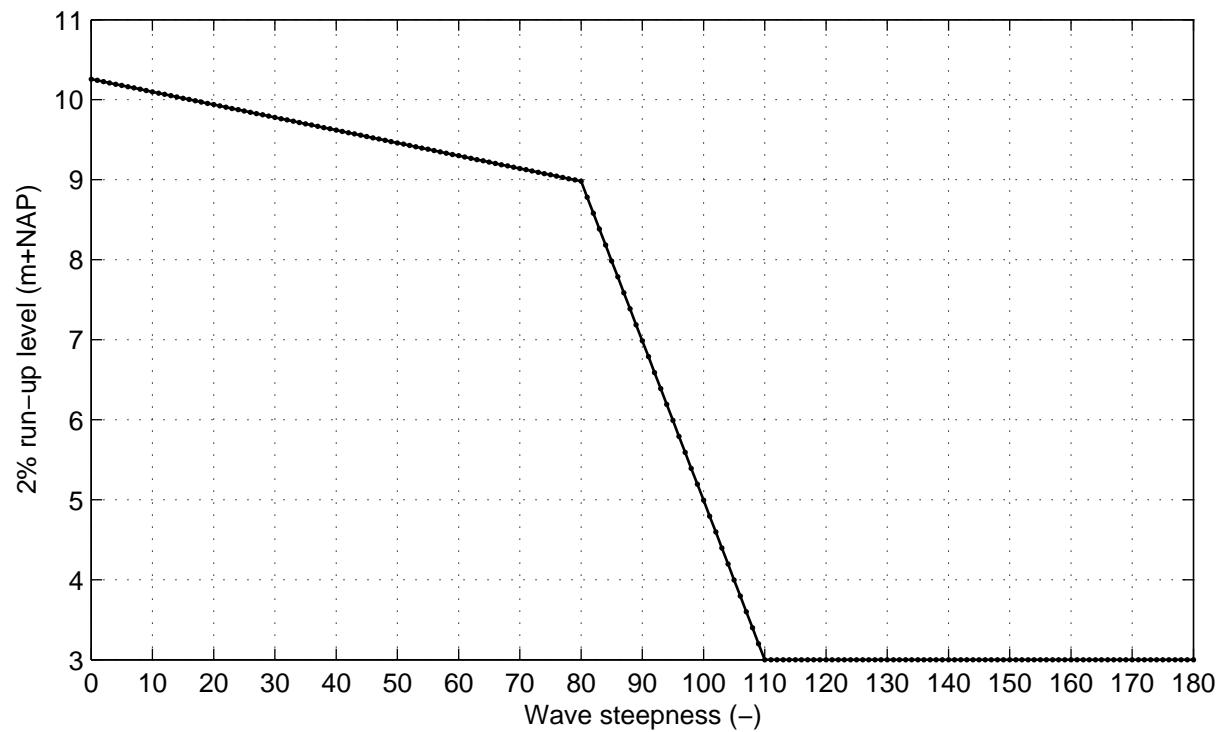
Cross section nr 1; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

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Fig. 1.6



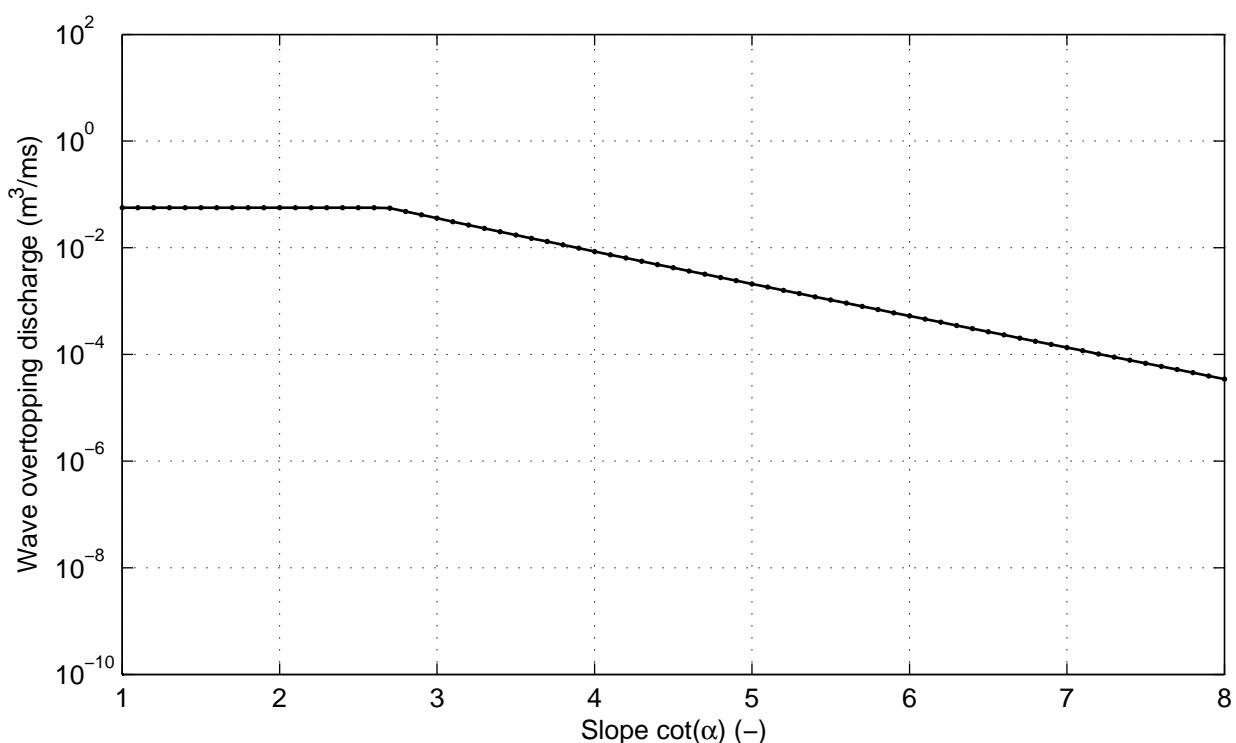
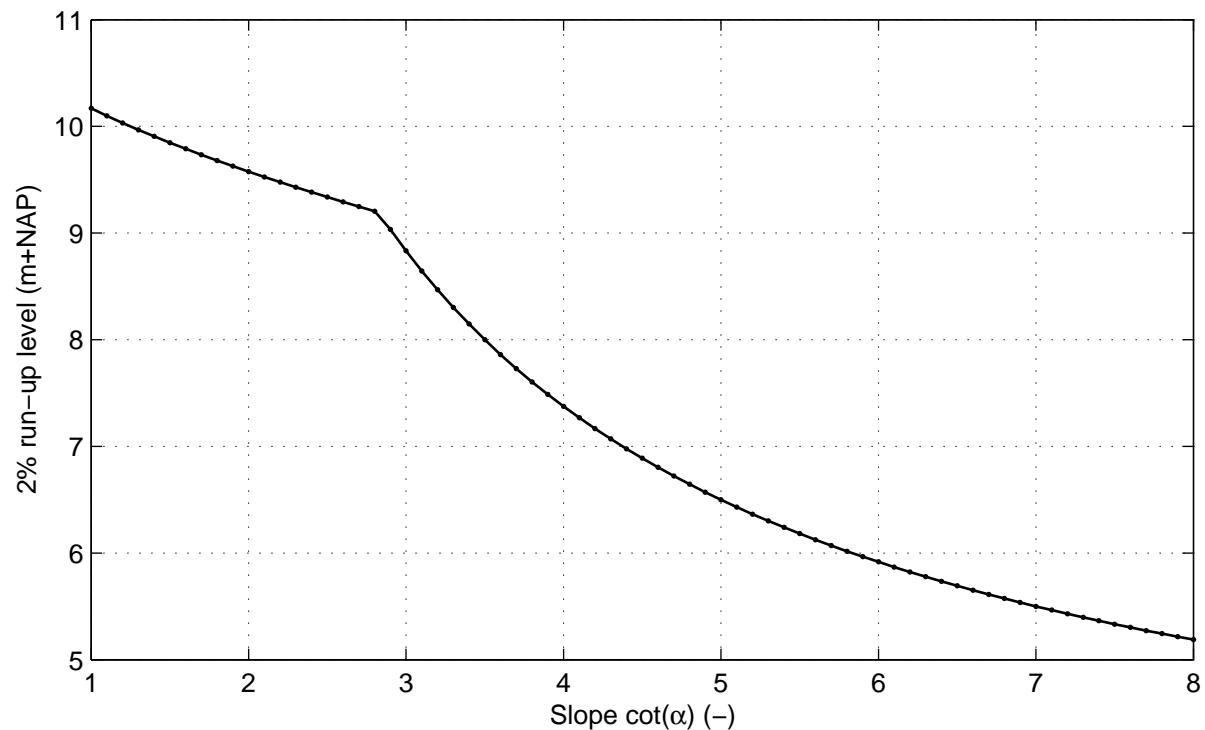
Cross section nr 1; series nr 7;
Varying wave angle

Wave overtopping kernel tests

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Fig. 1.7



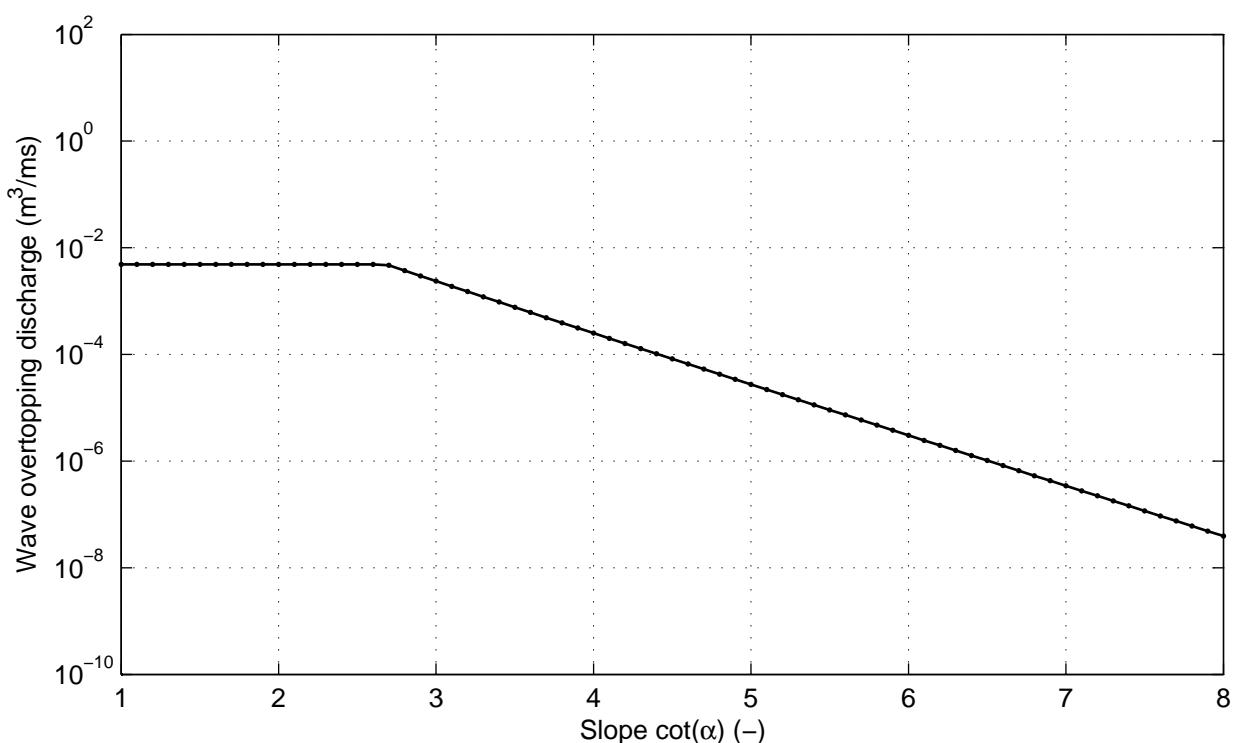
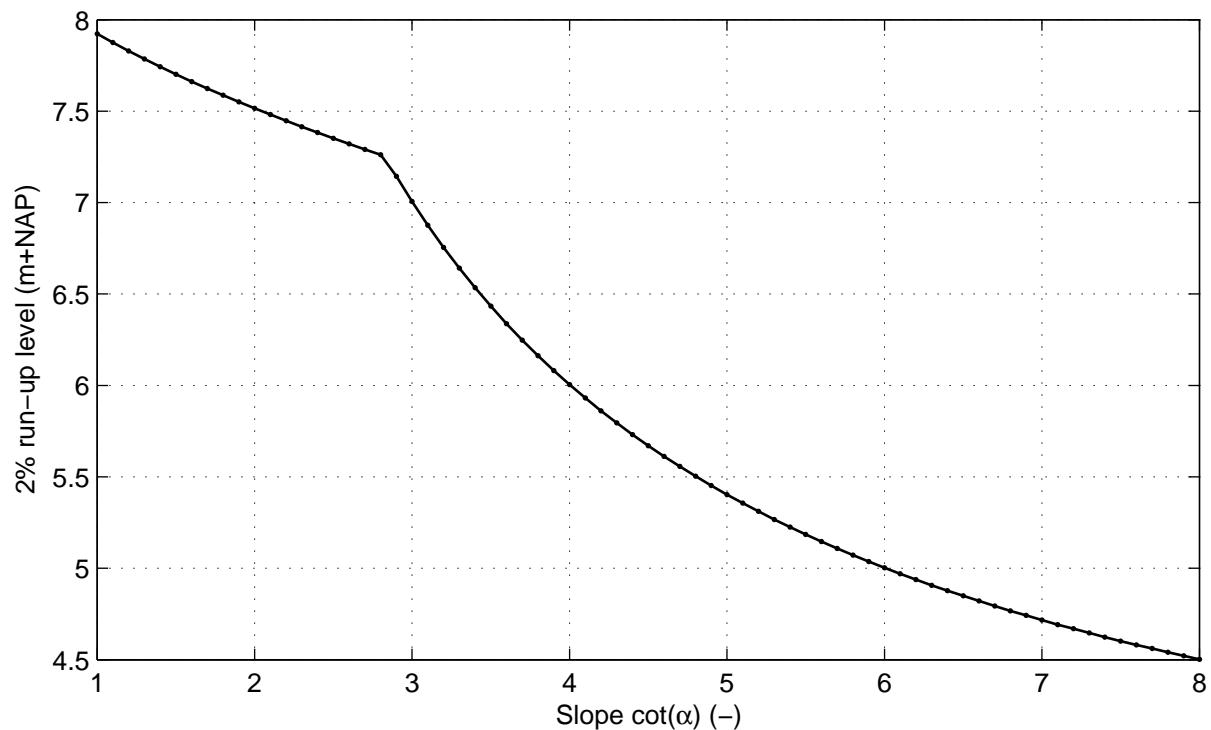
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Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 1.8



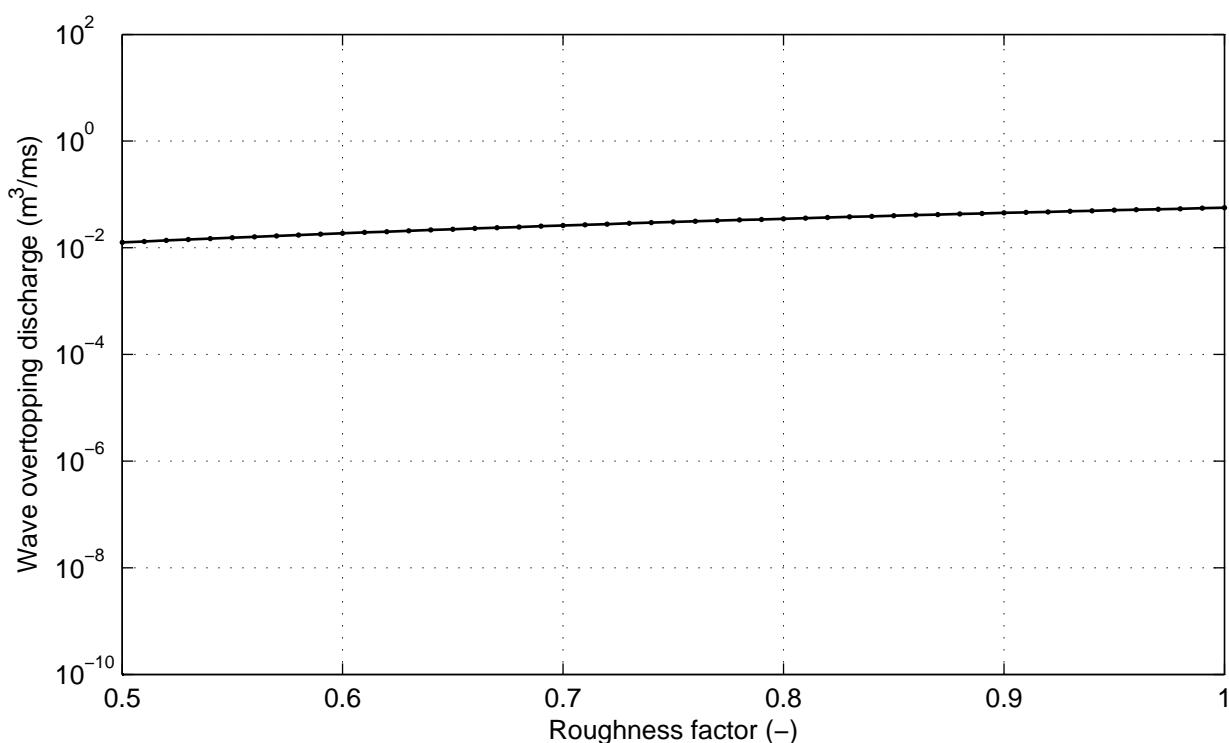
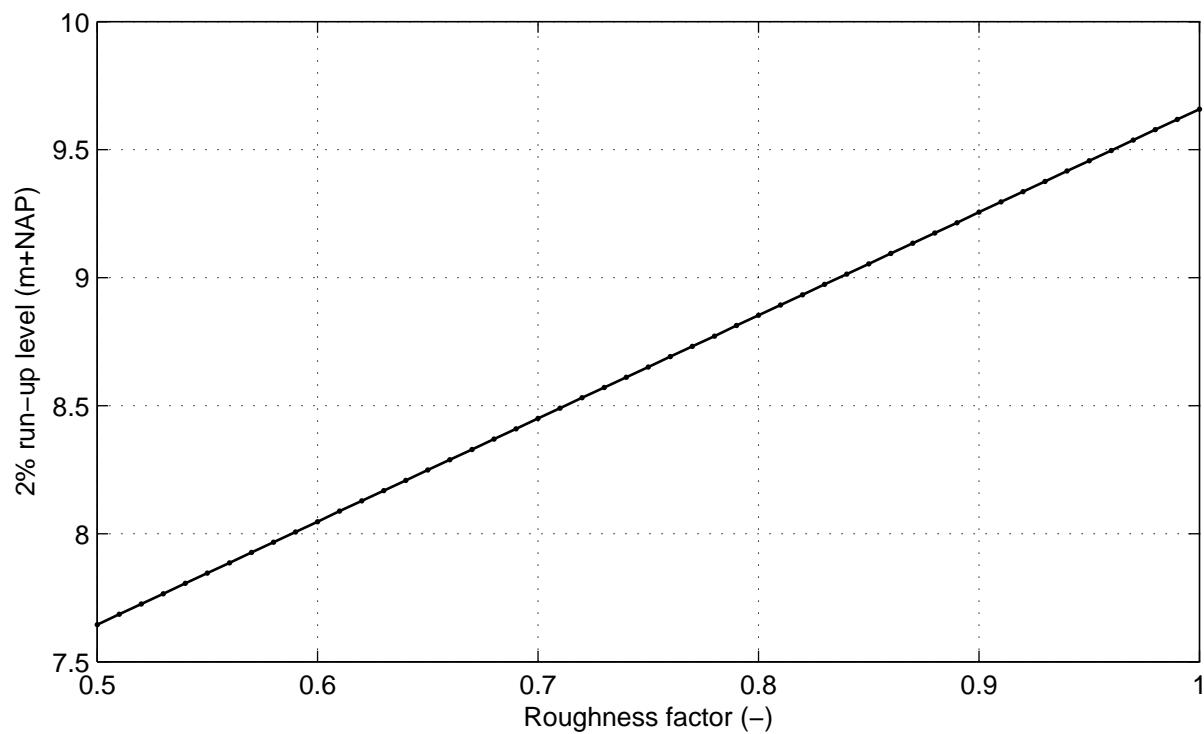
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Varying slope of all ordinary segments

Wave overtopping kernel tests

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Fig. 1.9



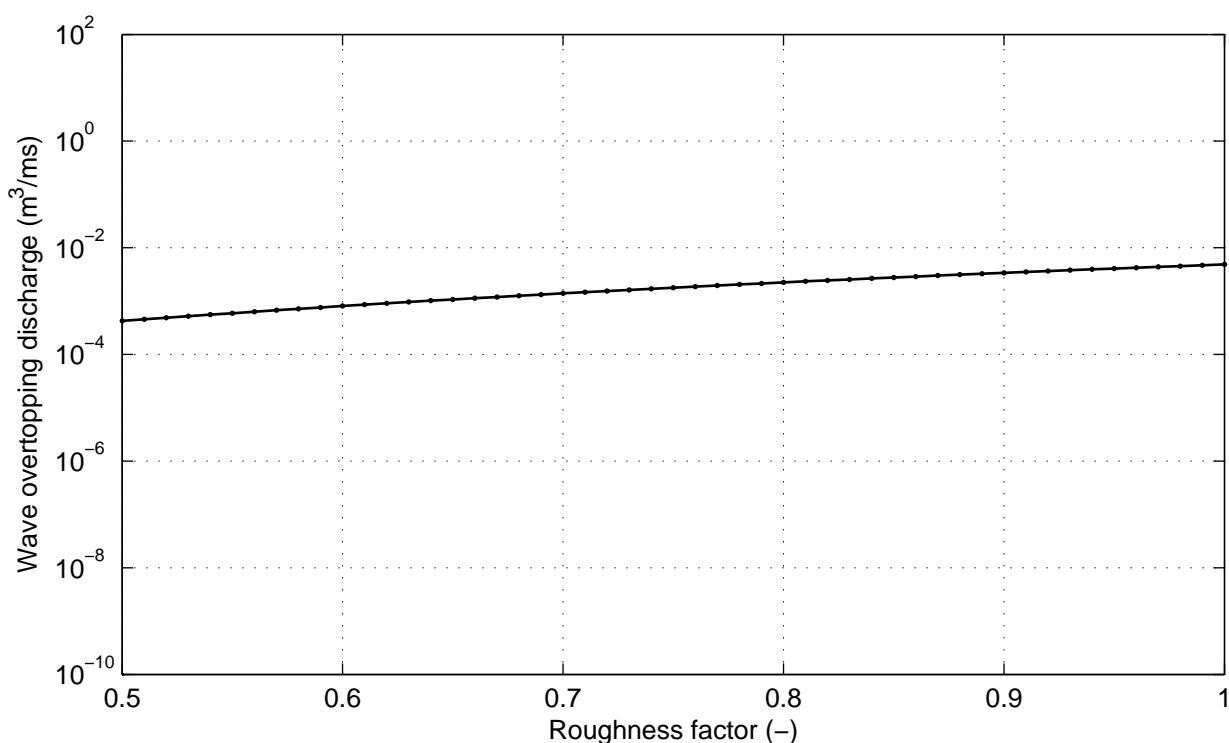
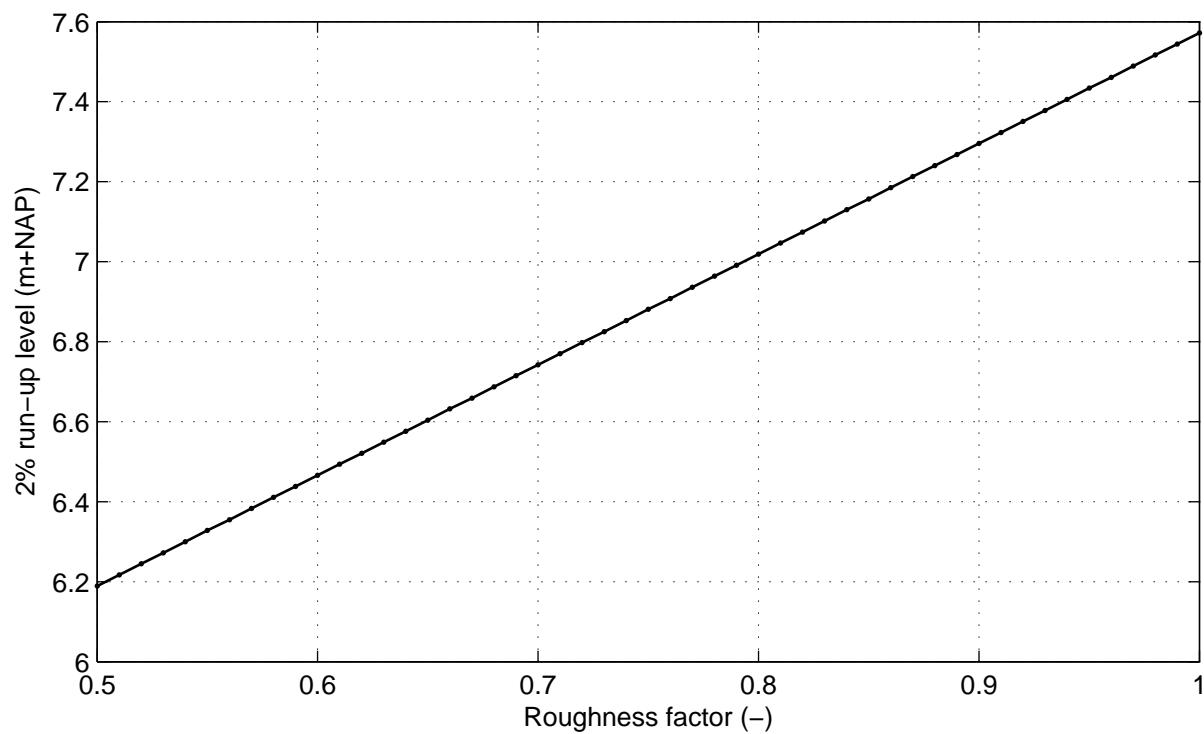
Cross section nr 1; series nr 10; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

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Fig. 1.10



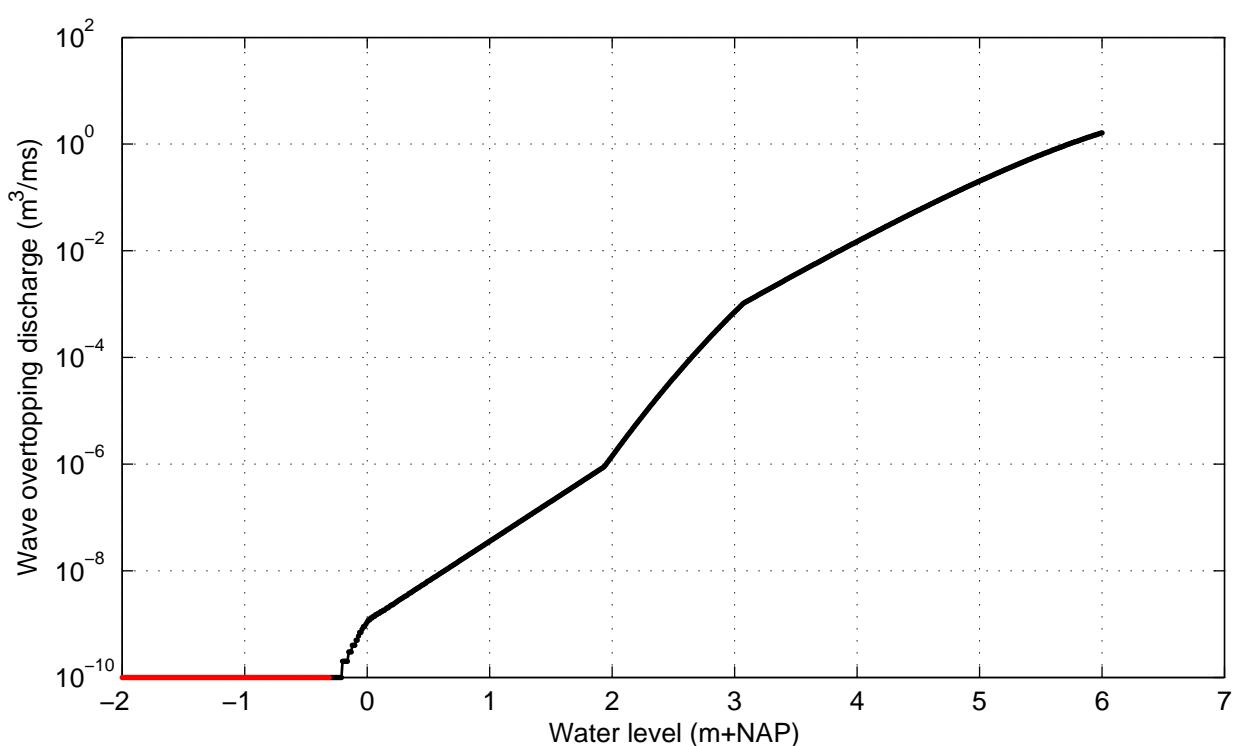
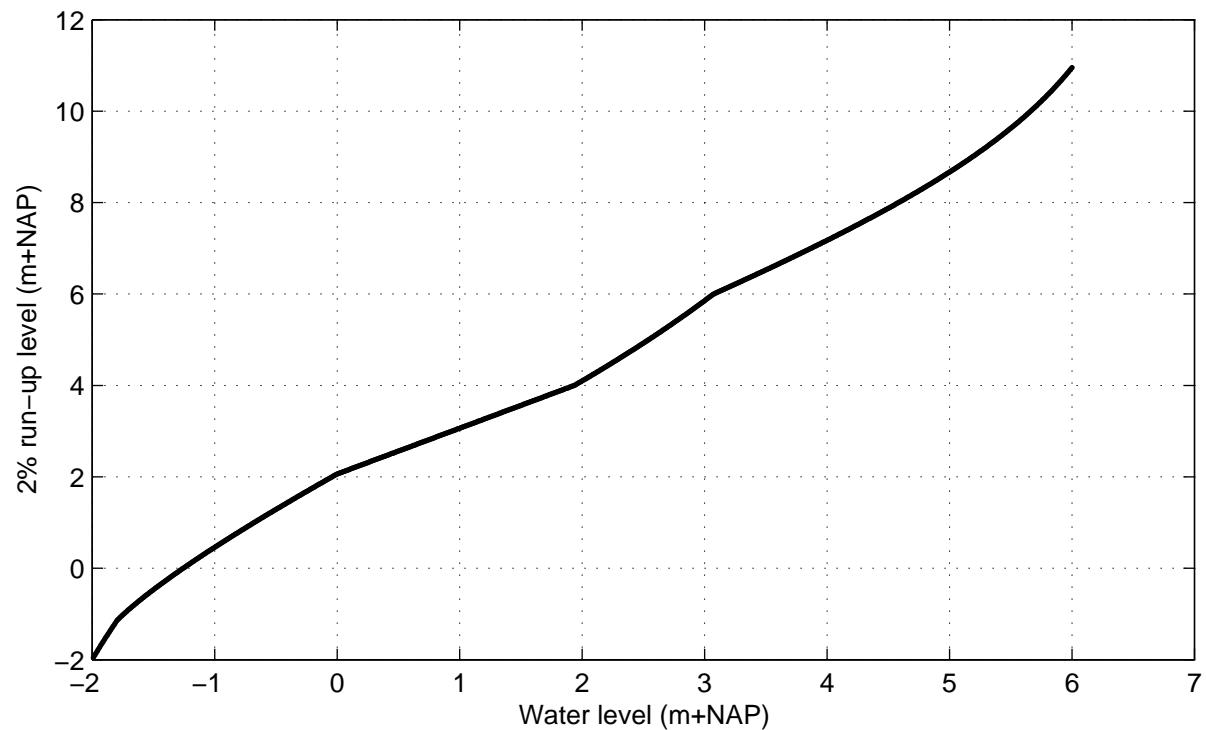
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Varying roughness of all ordinary segments

Wave overtopping kernel tests

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Fig. 1.11



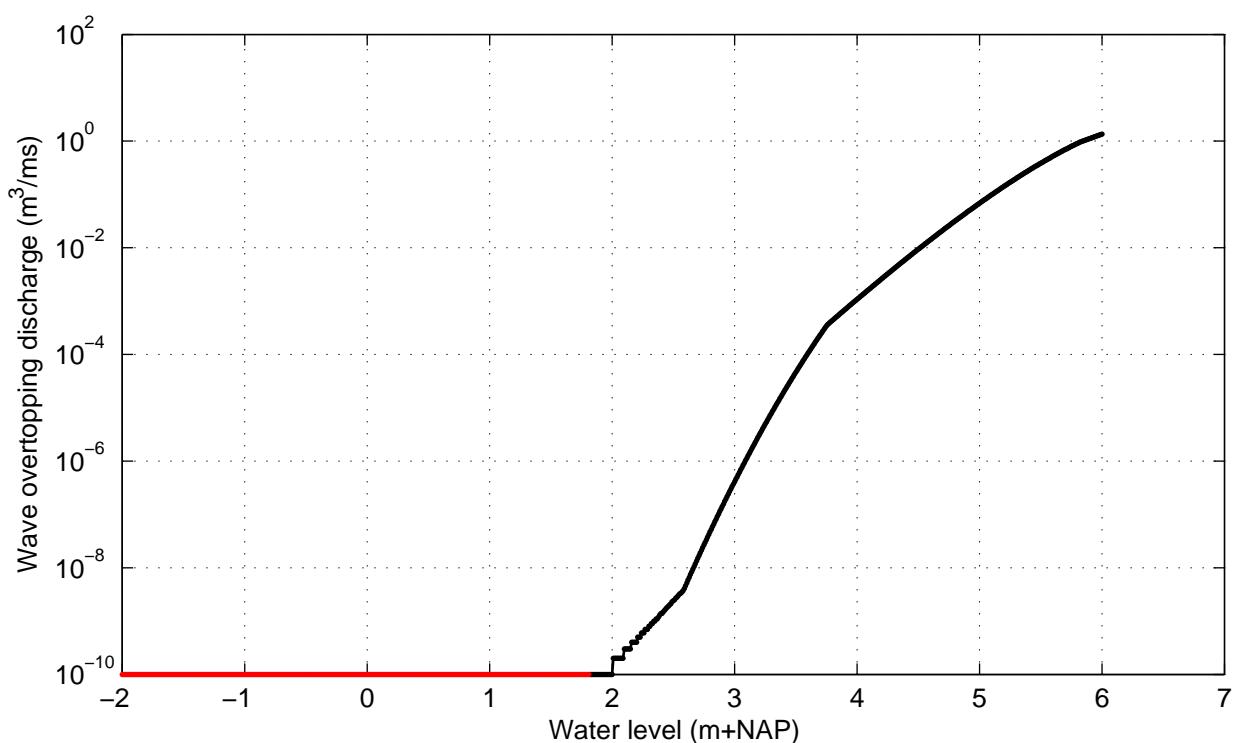
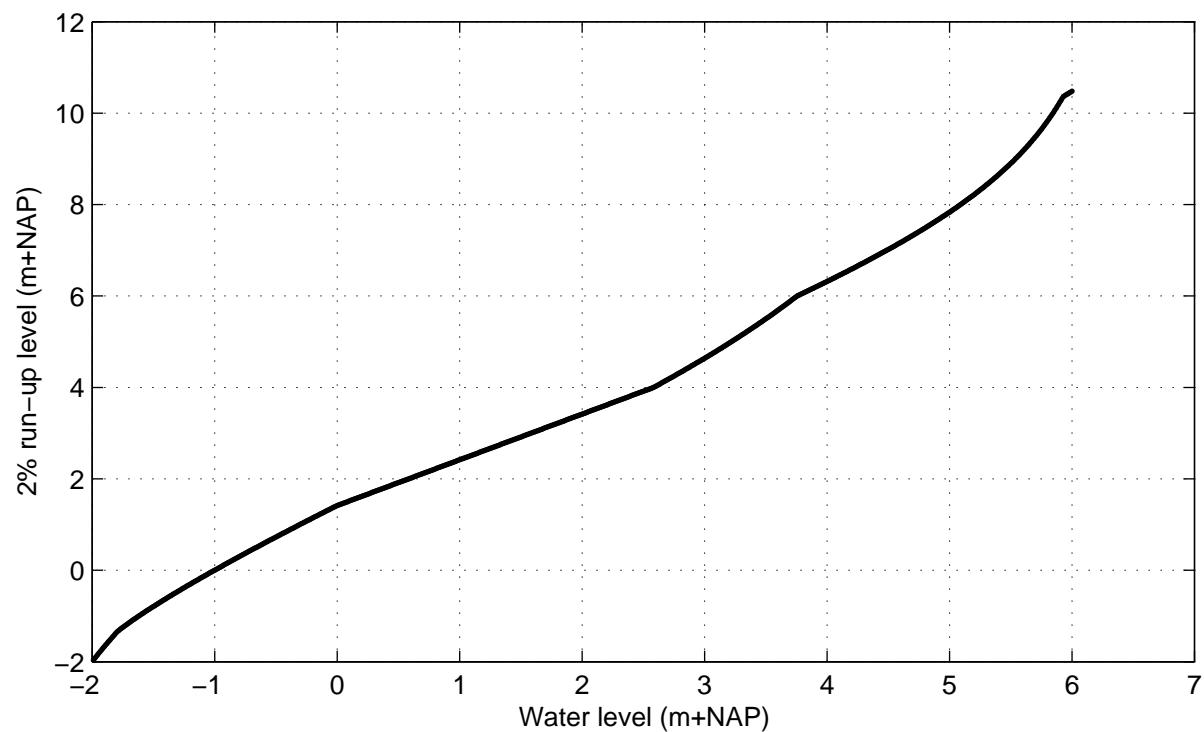
Cross section nr 2; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

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Fig. 2.1



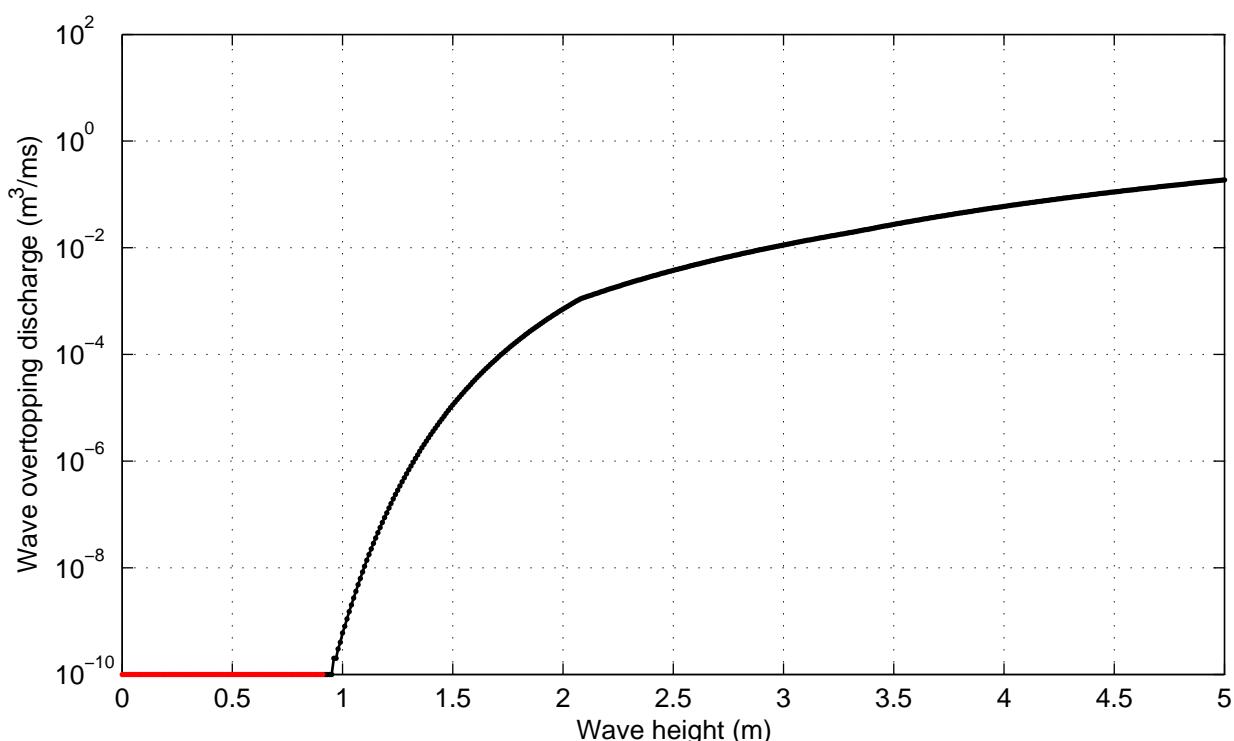
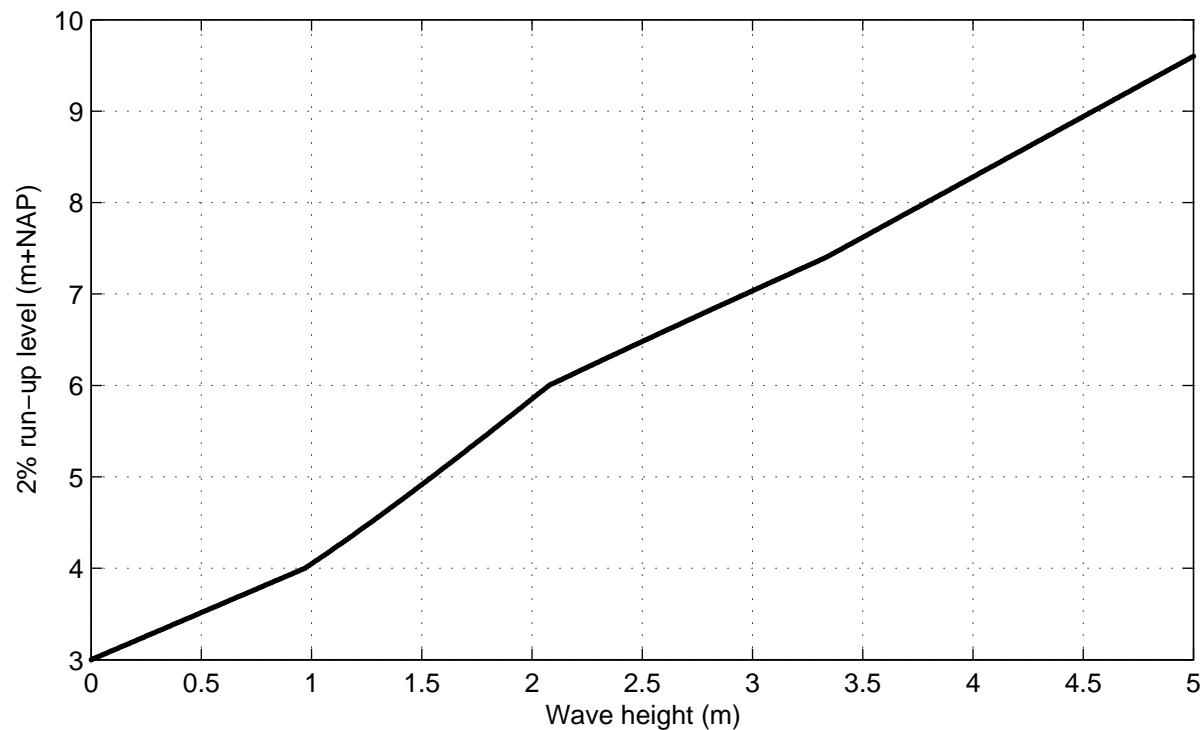
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Varying water level

Wave overtopping kernel tests

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Fig. 2.2



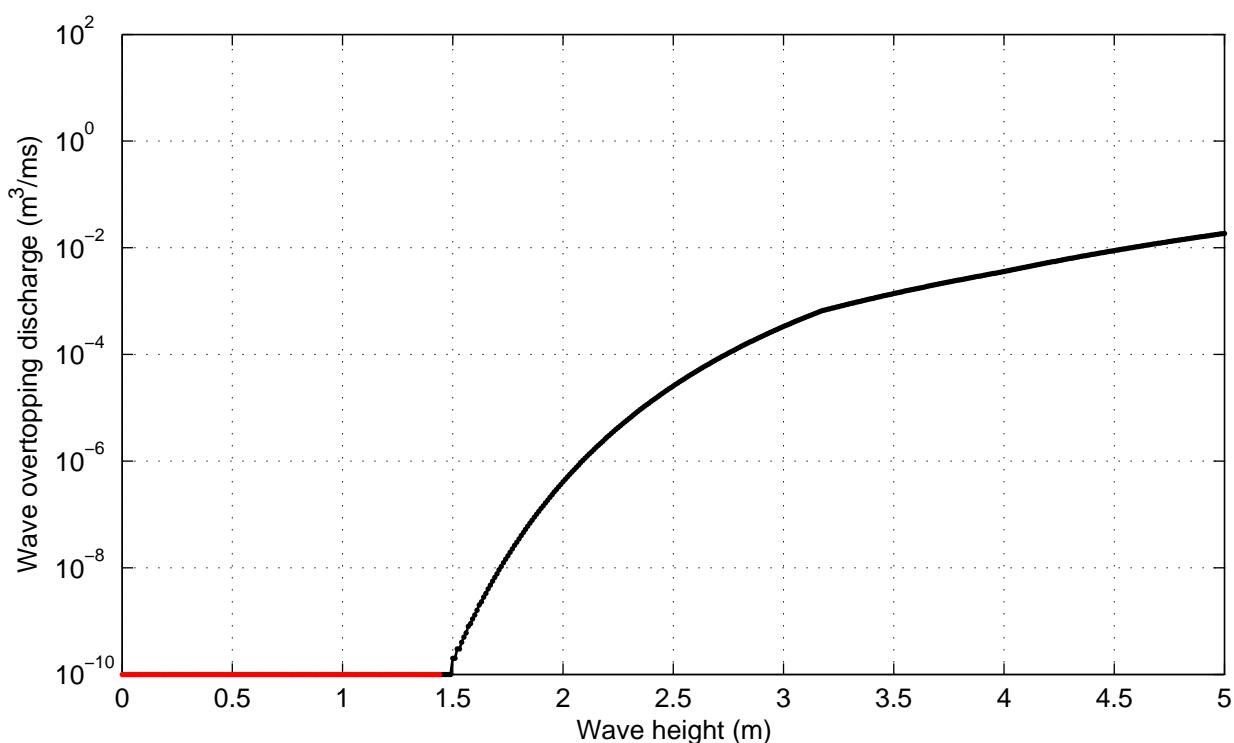
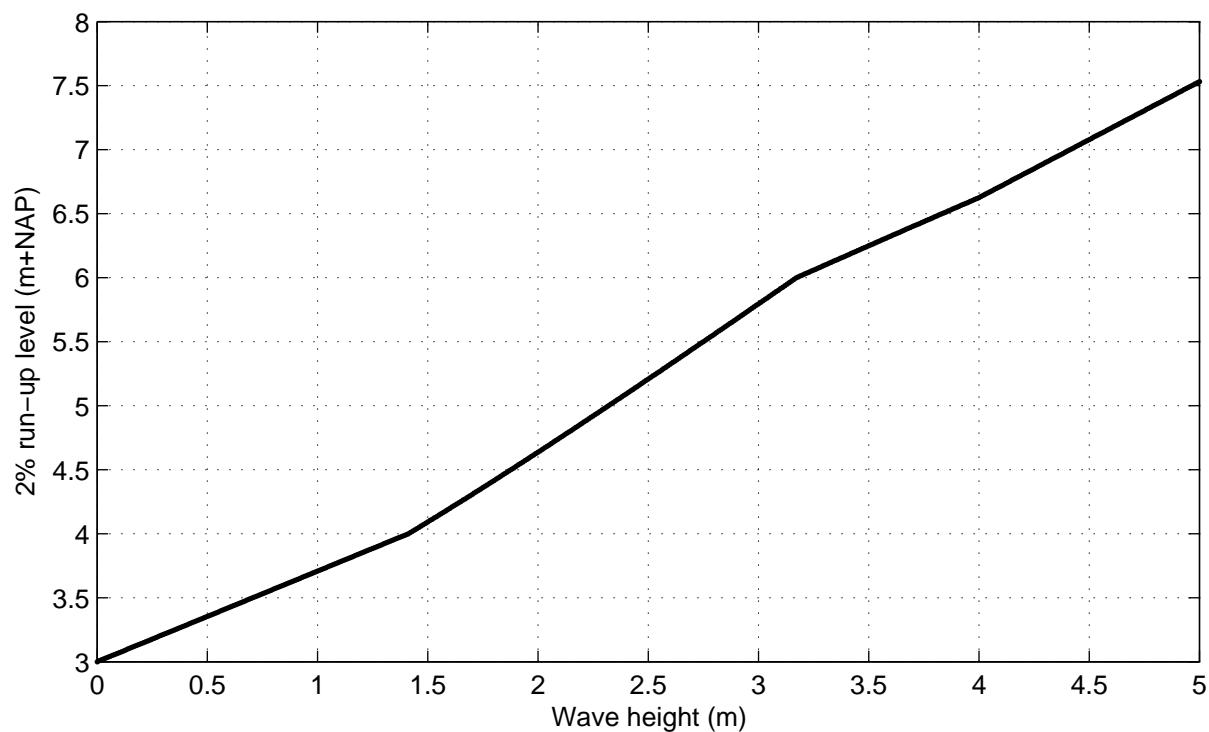
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Varying wave height

Wave overtopping kernel tests

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Fig. 2.3



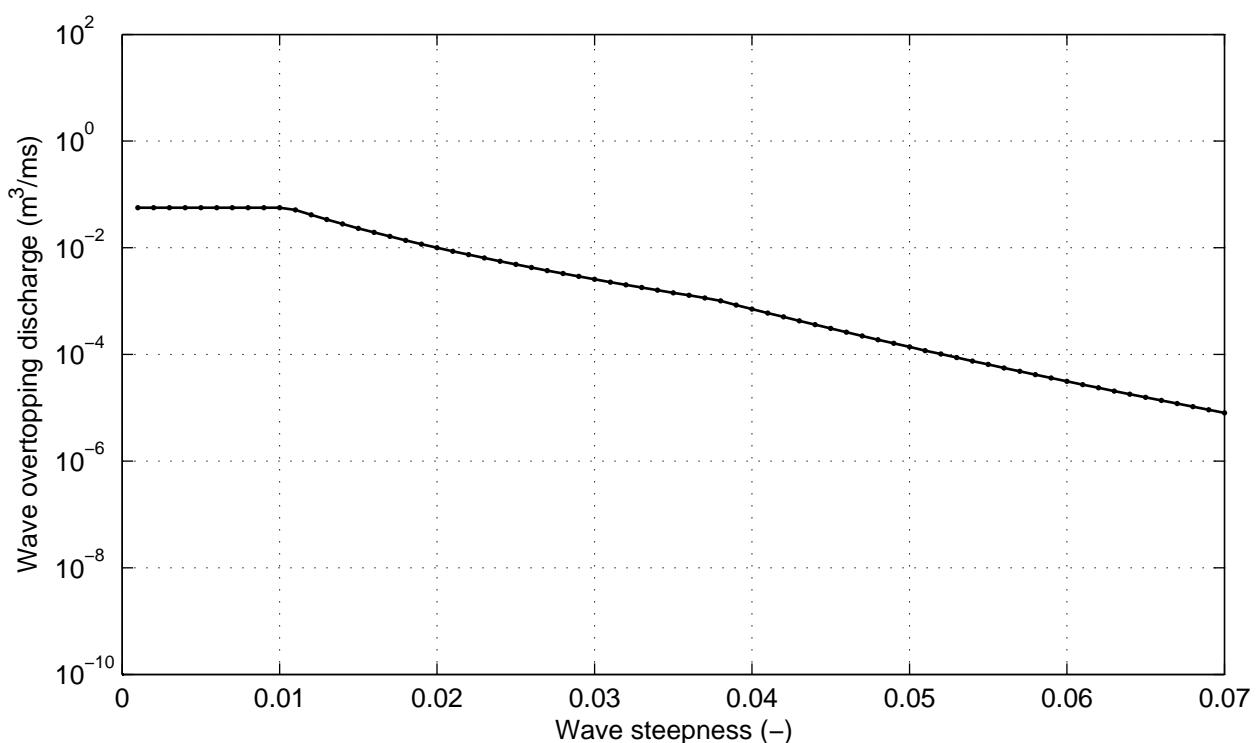
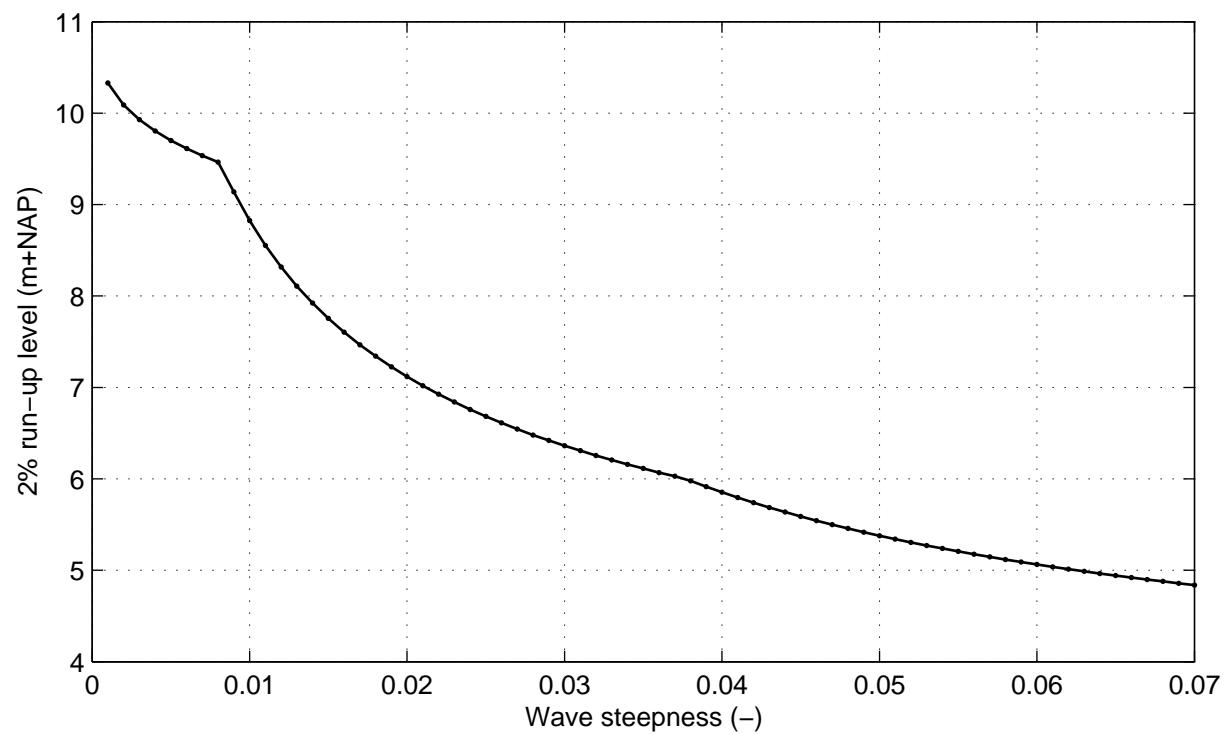
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Varying wave height

Wave overtopping kernel tests

DELTARES

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Fig. 2.4



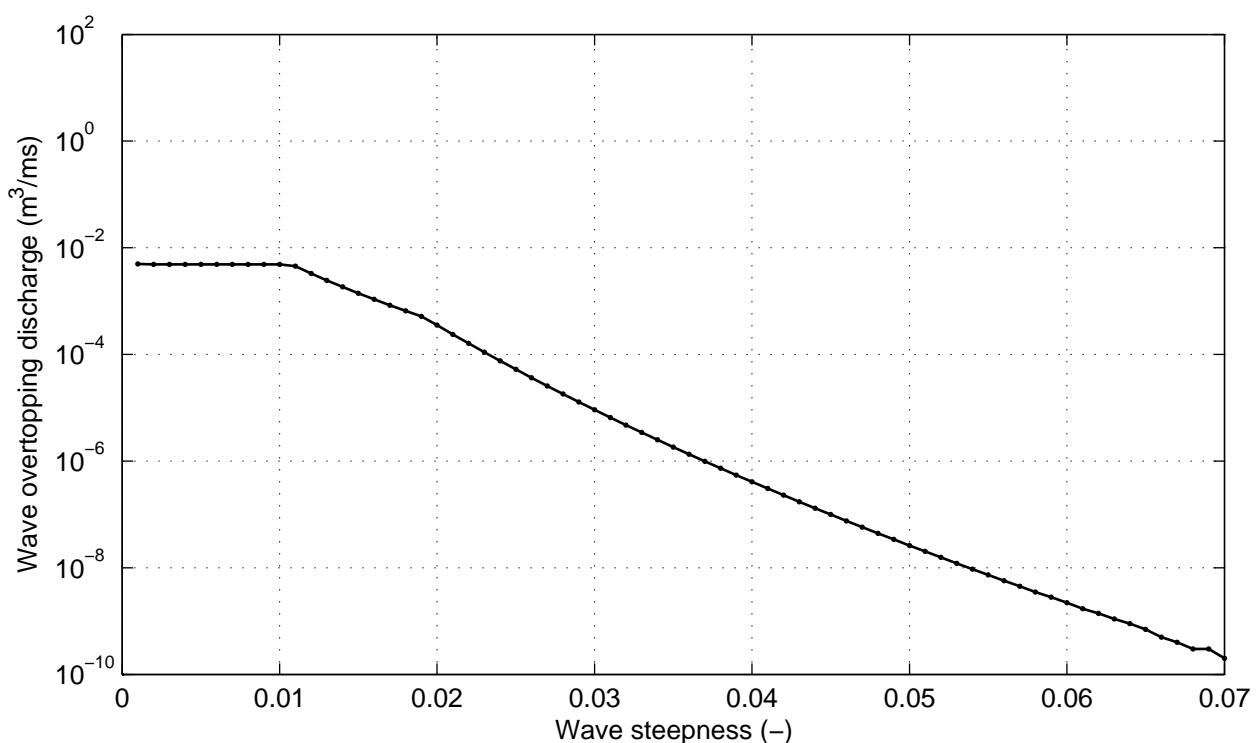
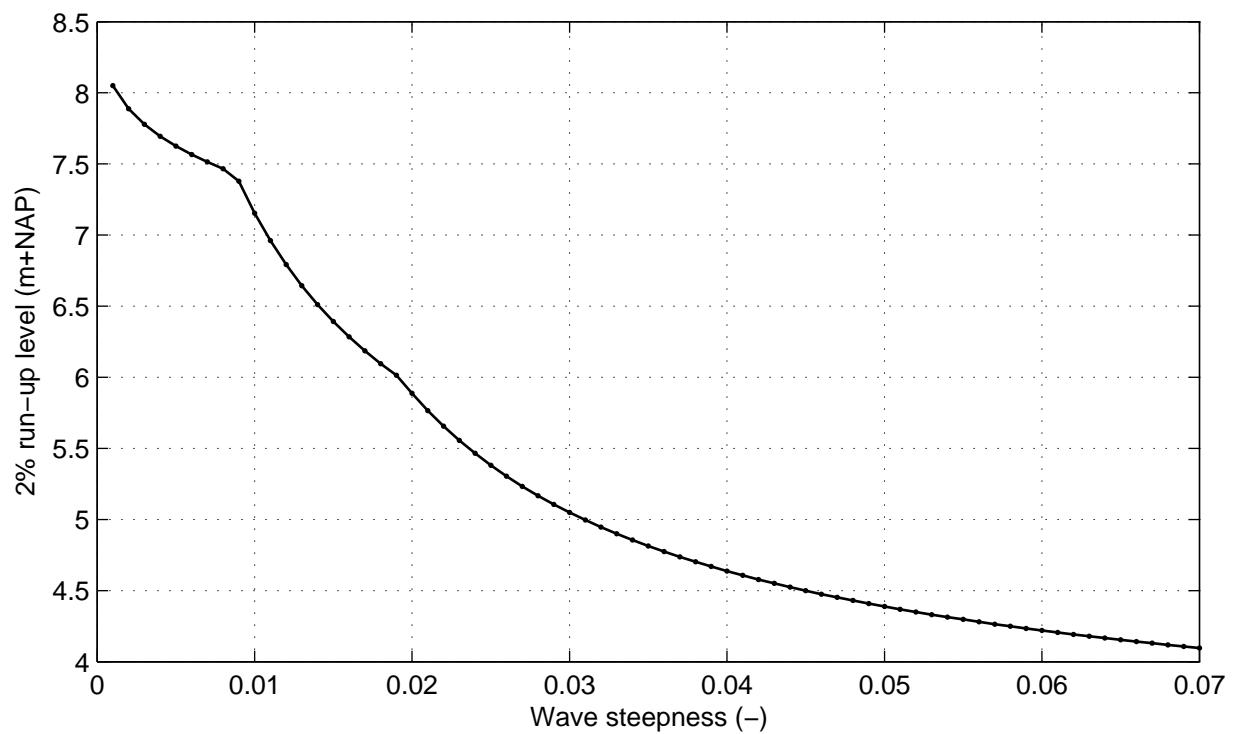
Cross section nr 2; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

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Fig. 2.5



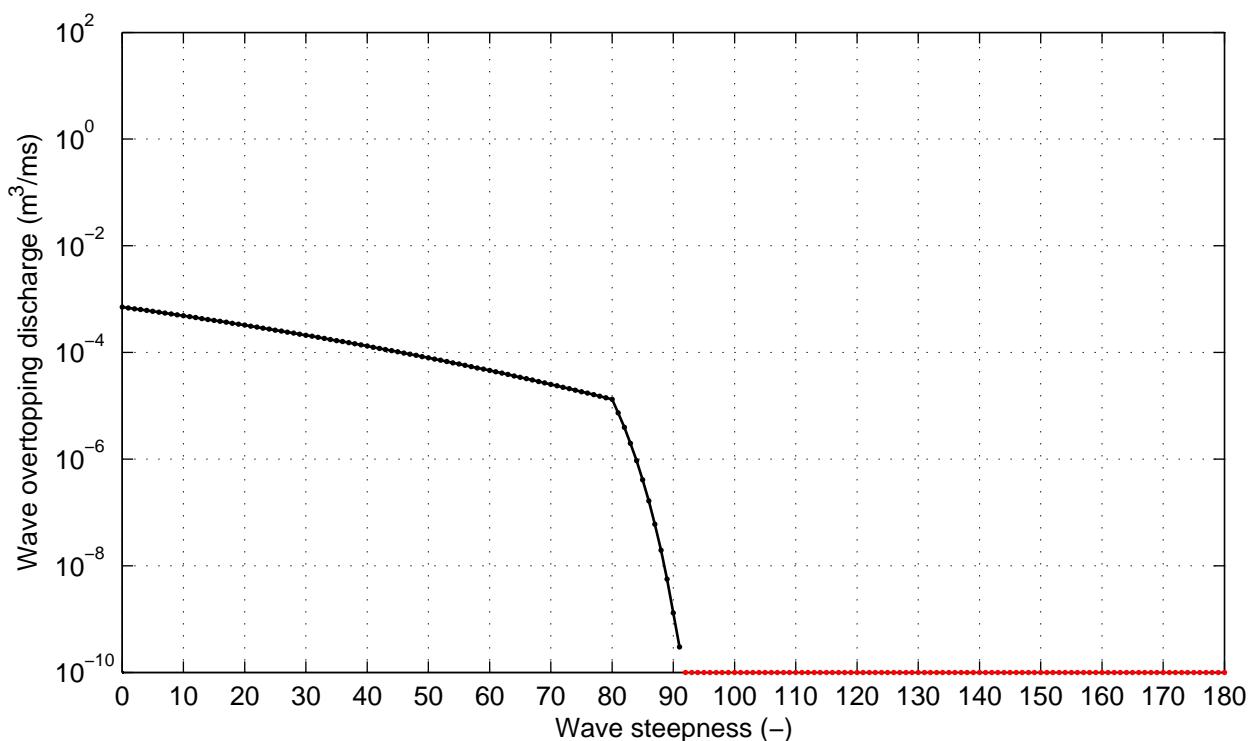
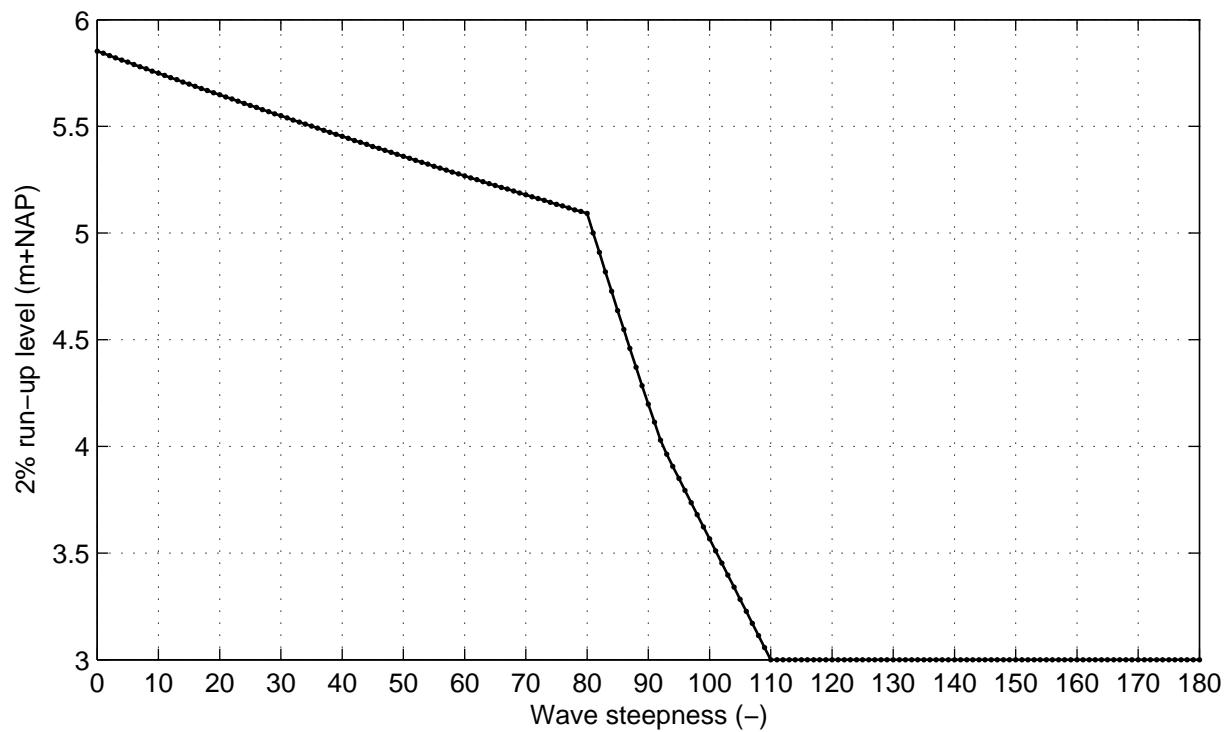
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Varying wave steepness

Wave overtopping kernel tests

DELTARES

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Fig. 2.6



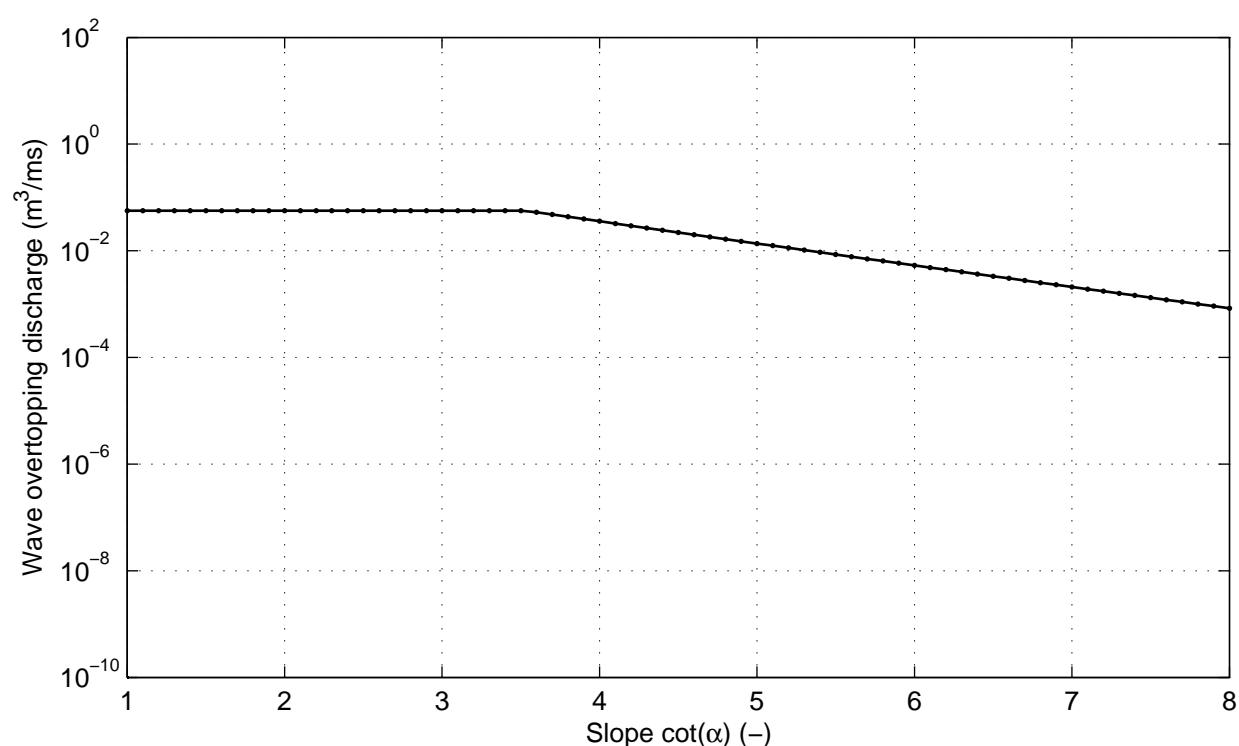
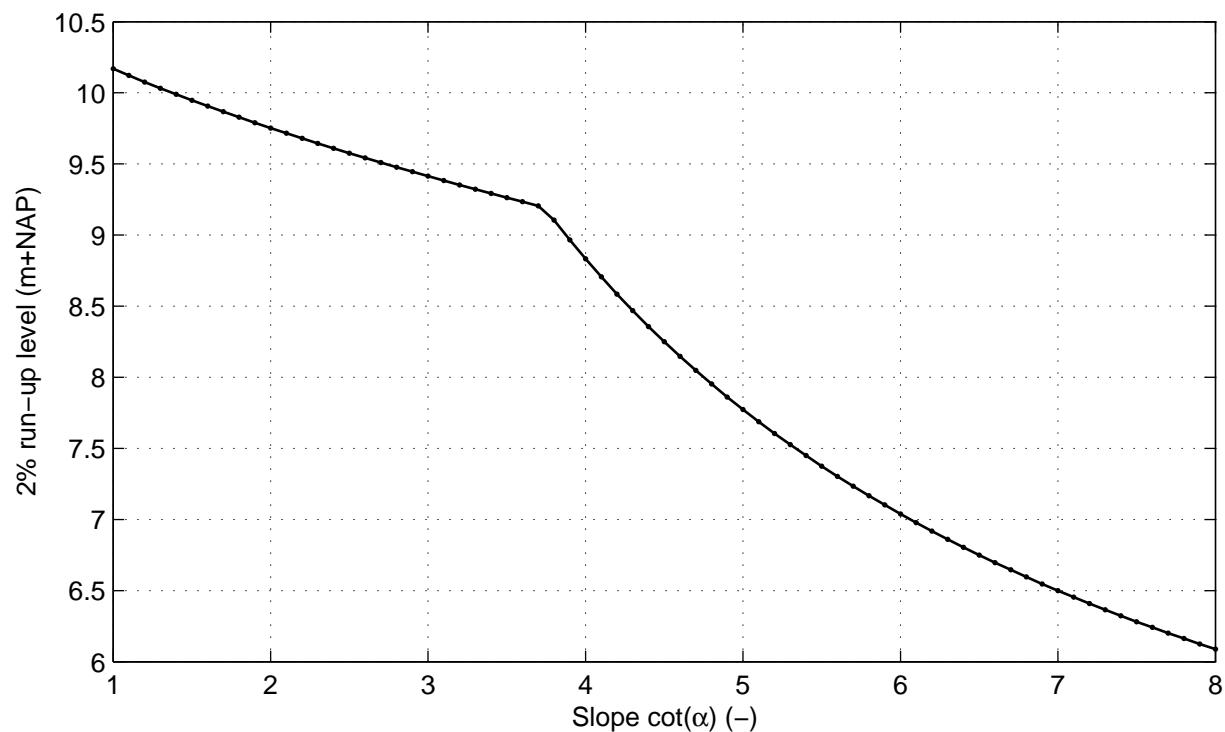
Cross section nr 2; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.7



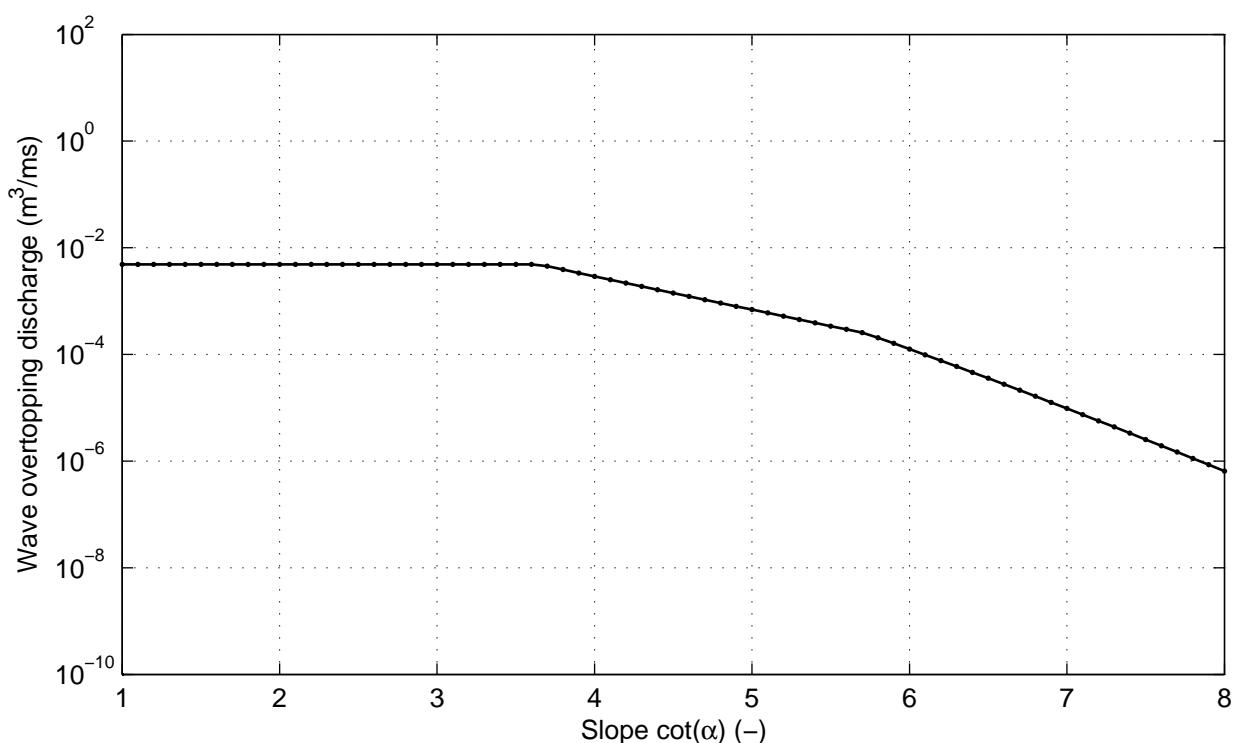
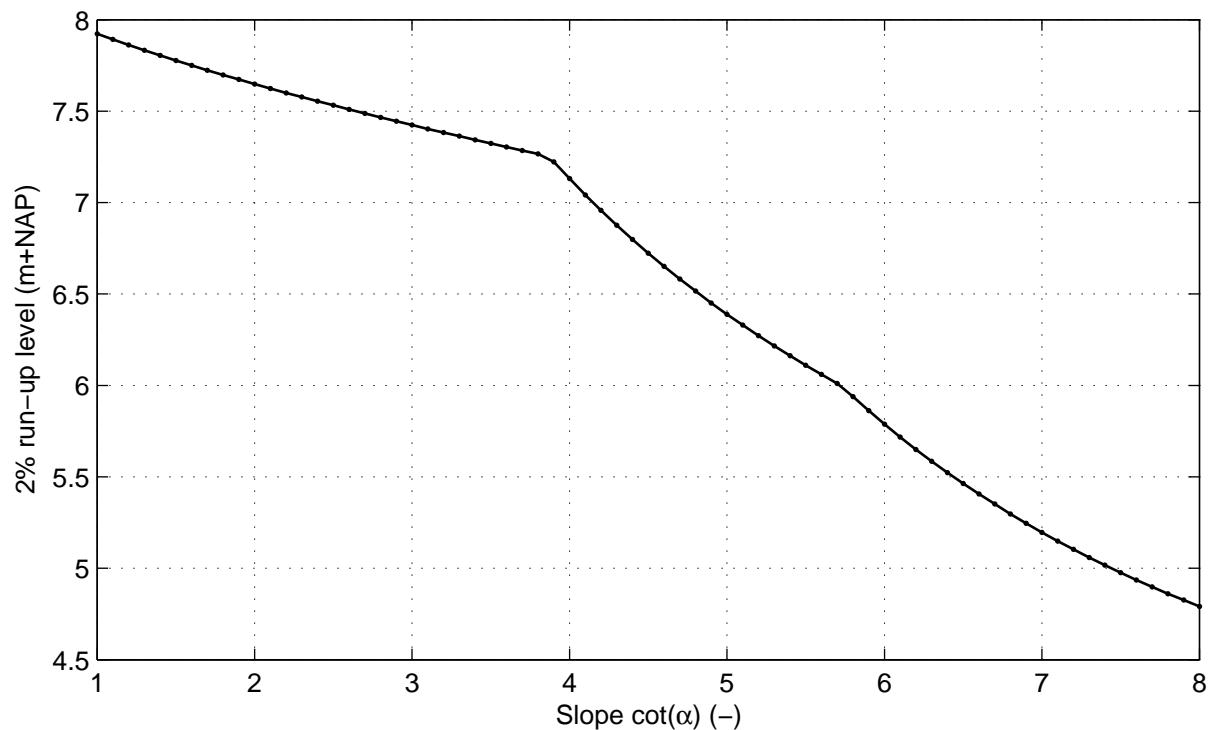
Cross section nr 2; series nr 8; Wave angle: 0 °
Varying slope lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.8



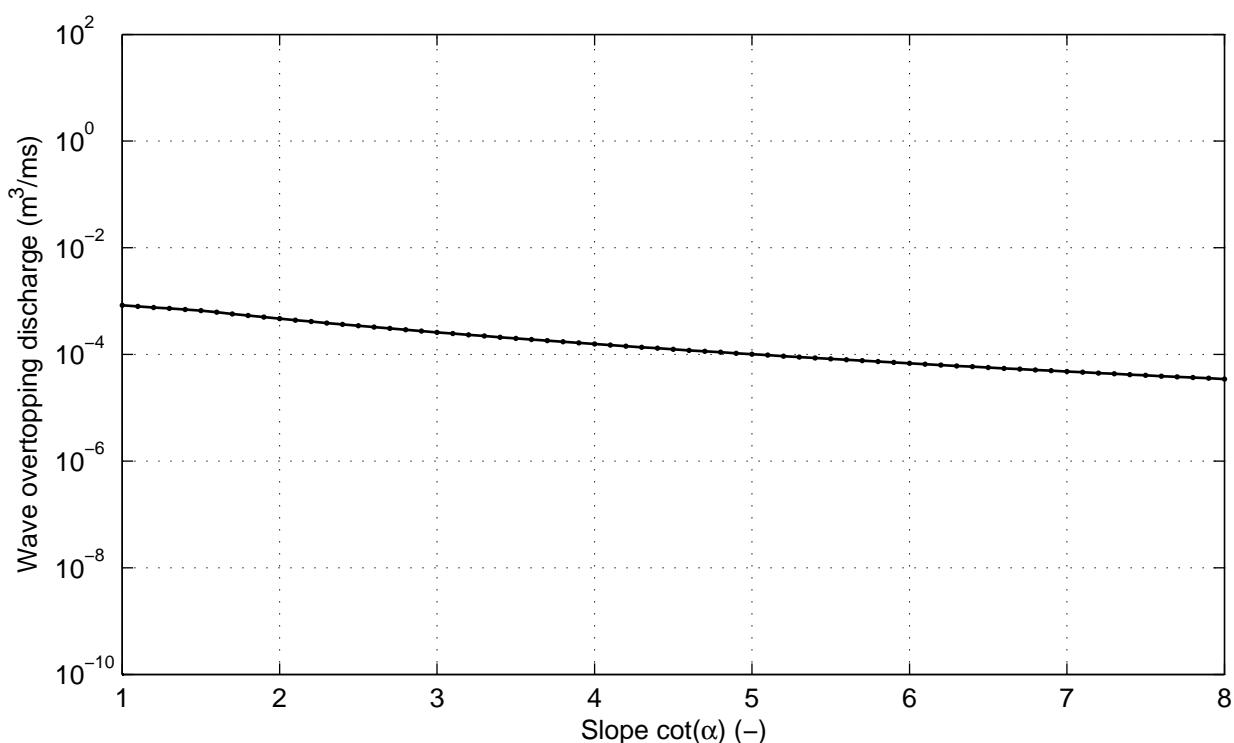
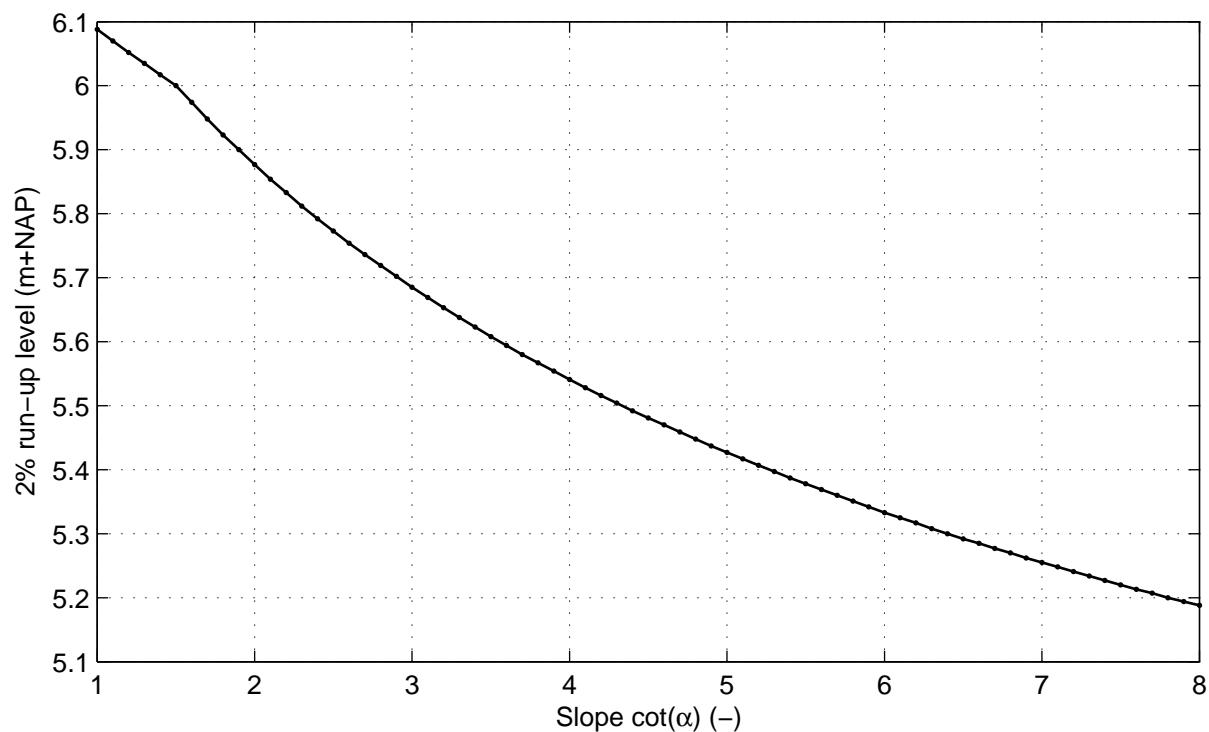
Cross section nr 2; series nr 9; Wave angle: 85 °
Varying slope lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.9



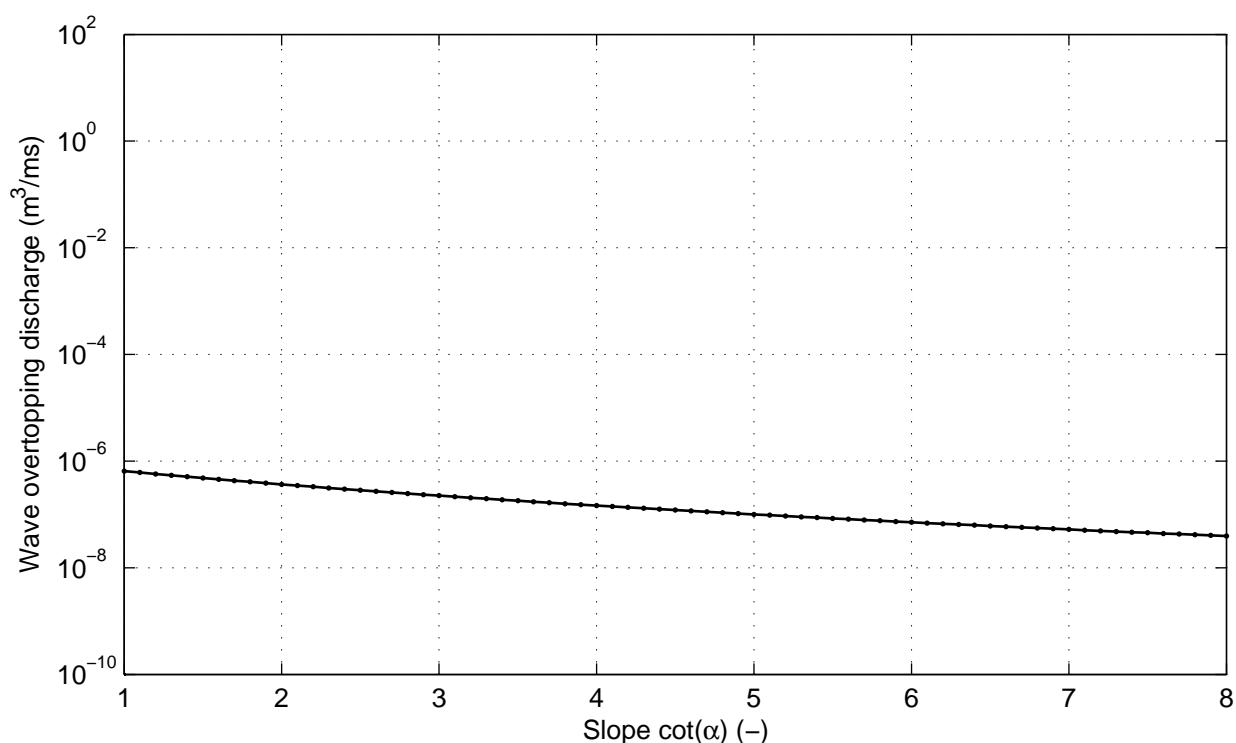
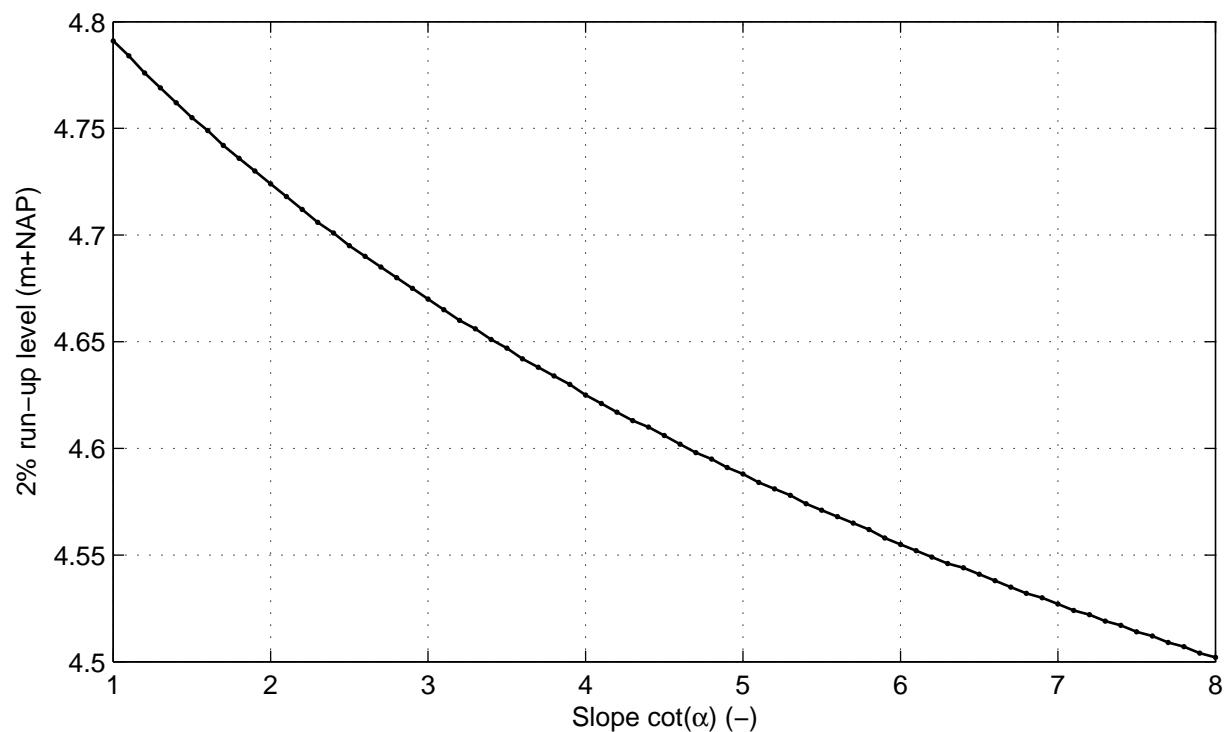
Cross section nr 2; series nr 10; Wave angle: 0 °
Varying slope upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.10



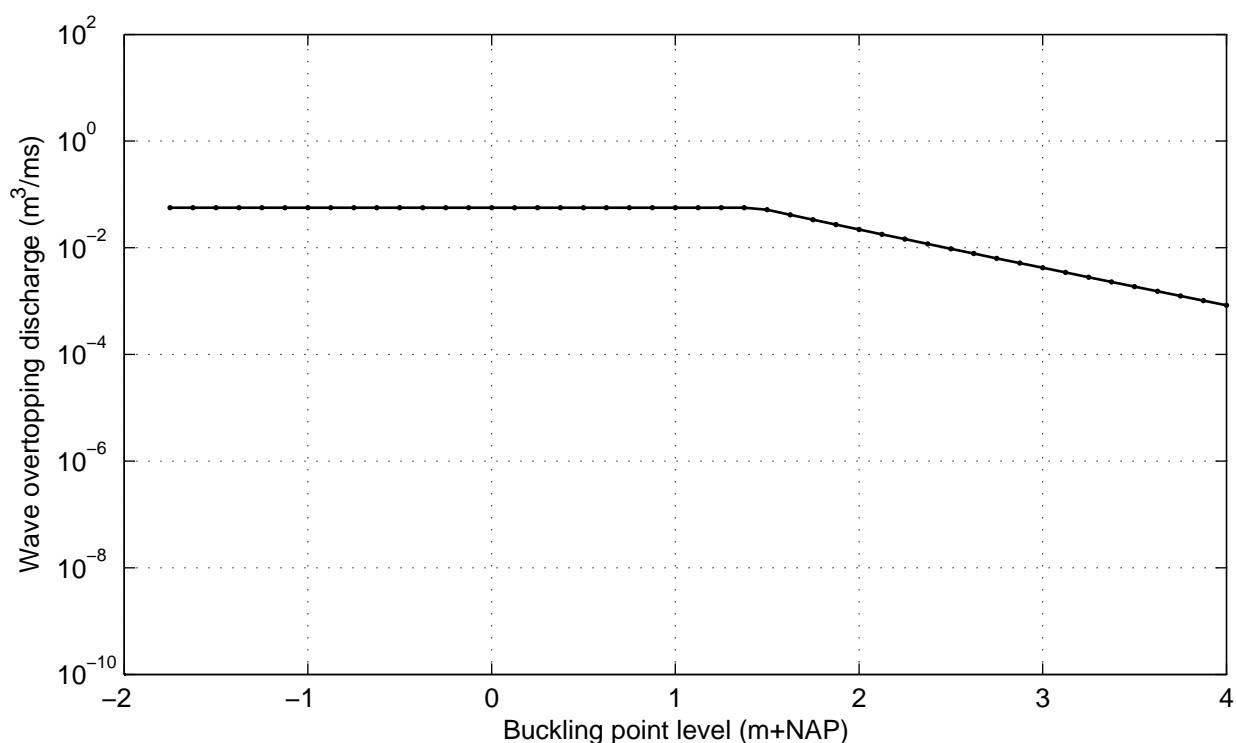
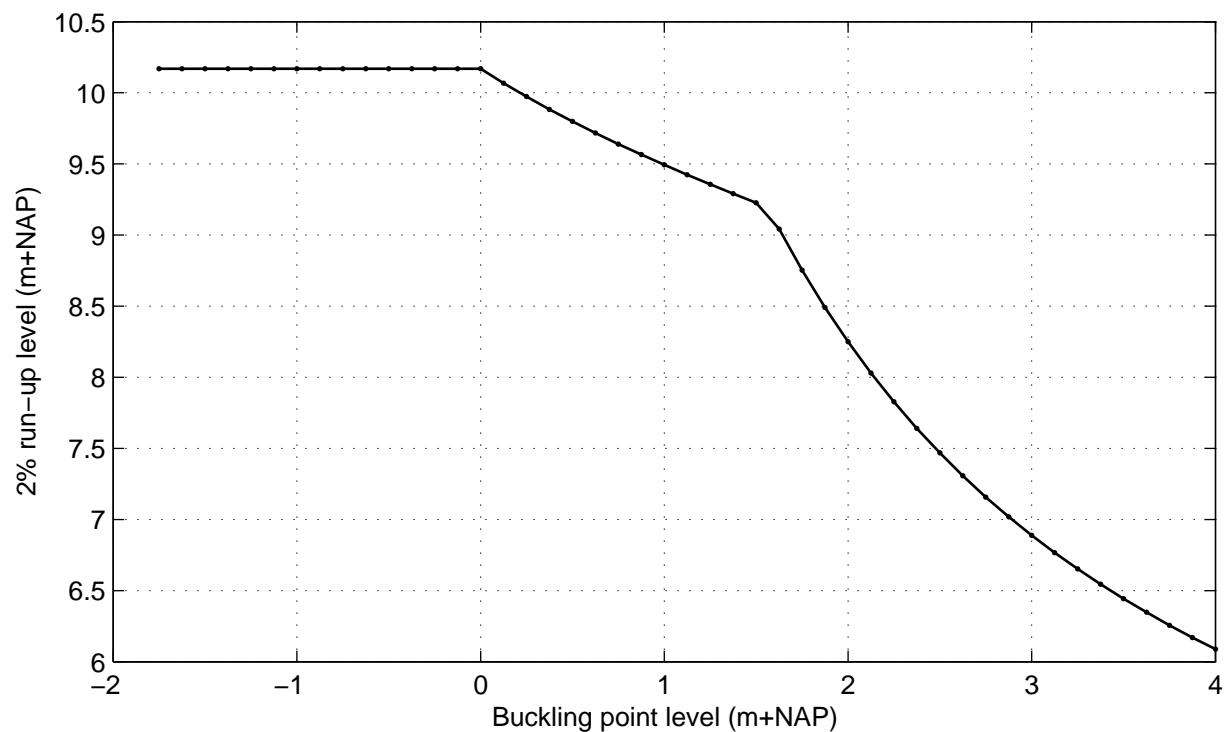
Cross section nr 2; series nr 11; Wave angle: 85 °
Varying slope upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.11



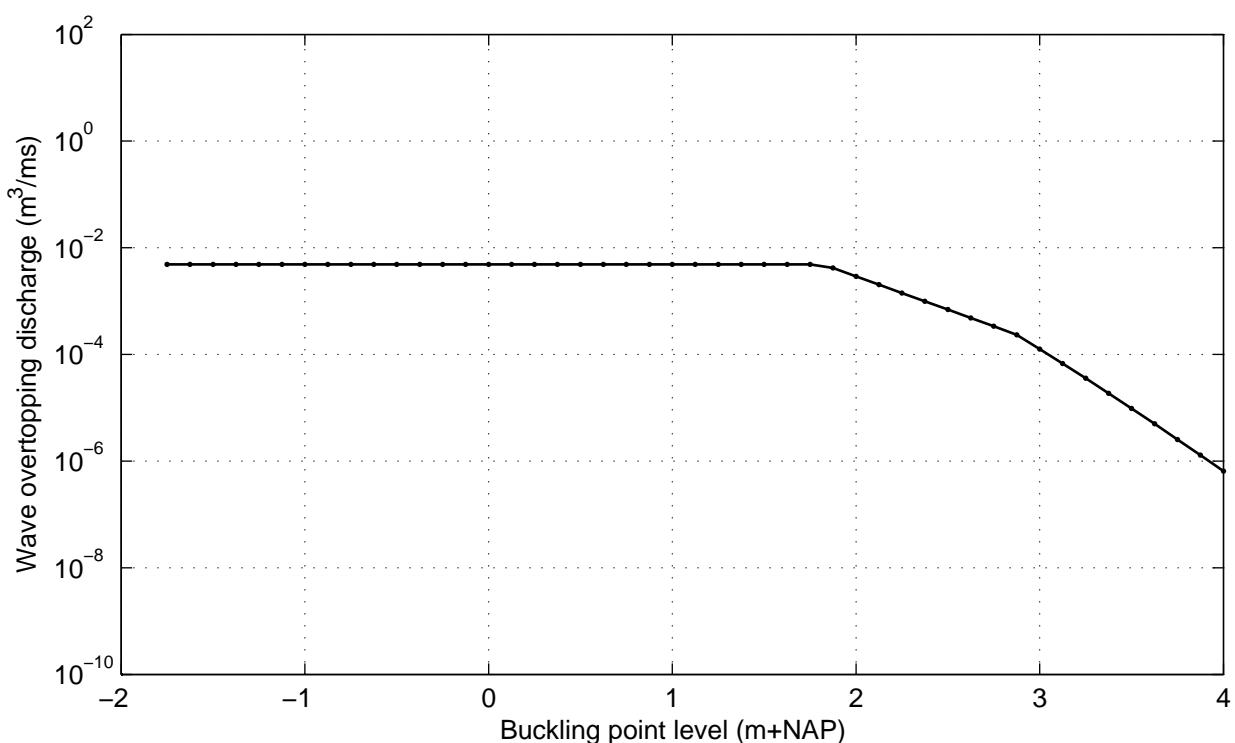
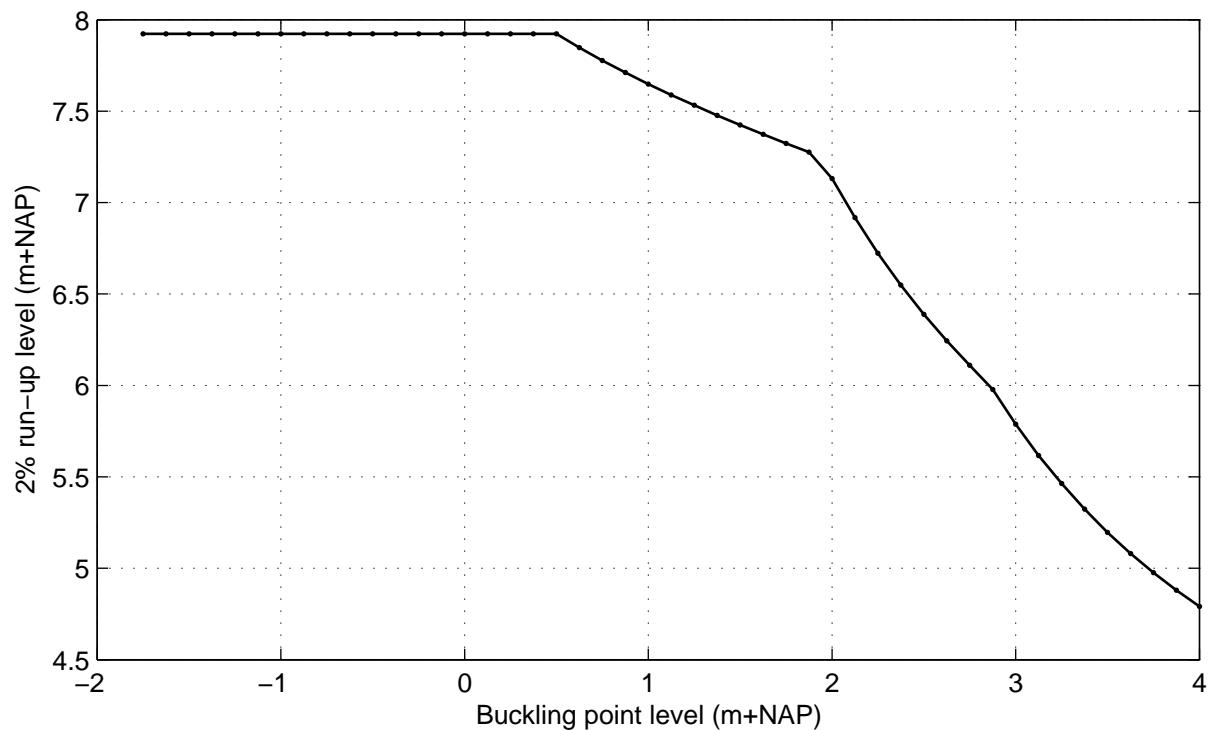
Cross section nr 2; series nr 12; Wave angle: 0 °
Varying level buckling point

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.12



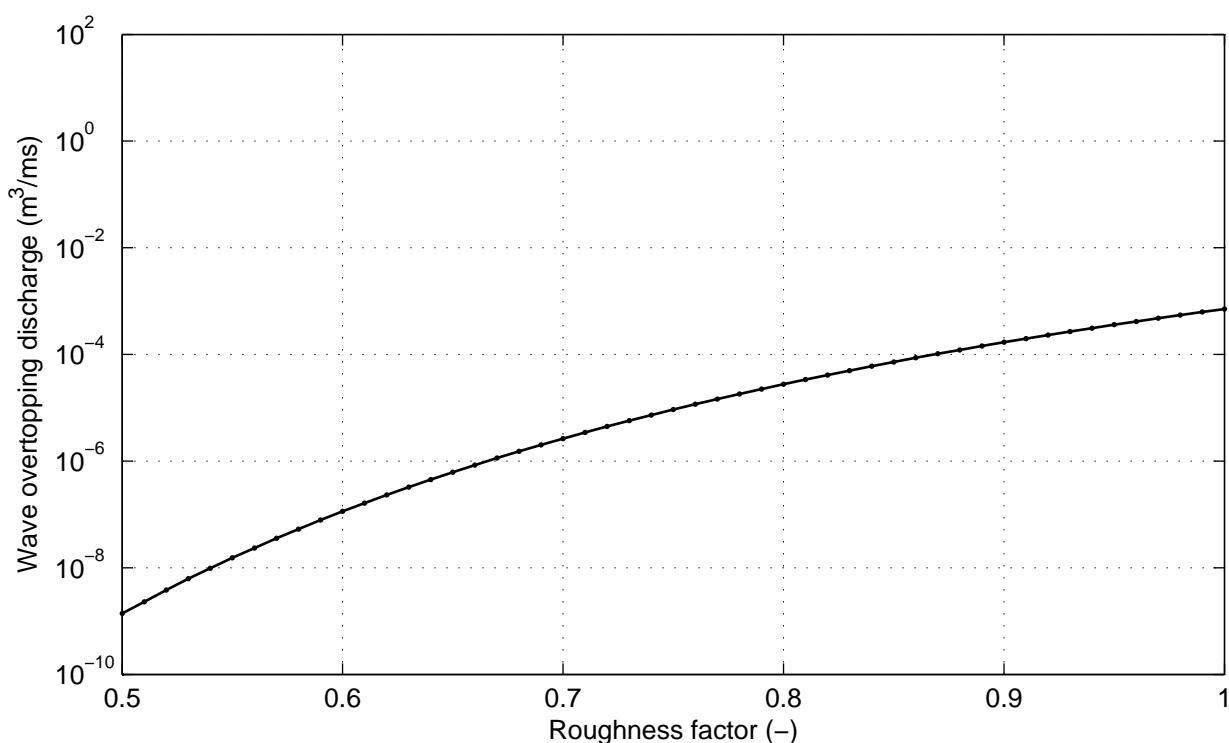
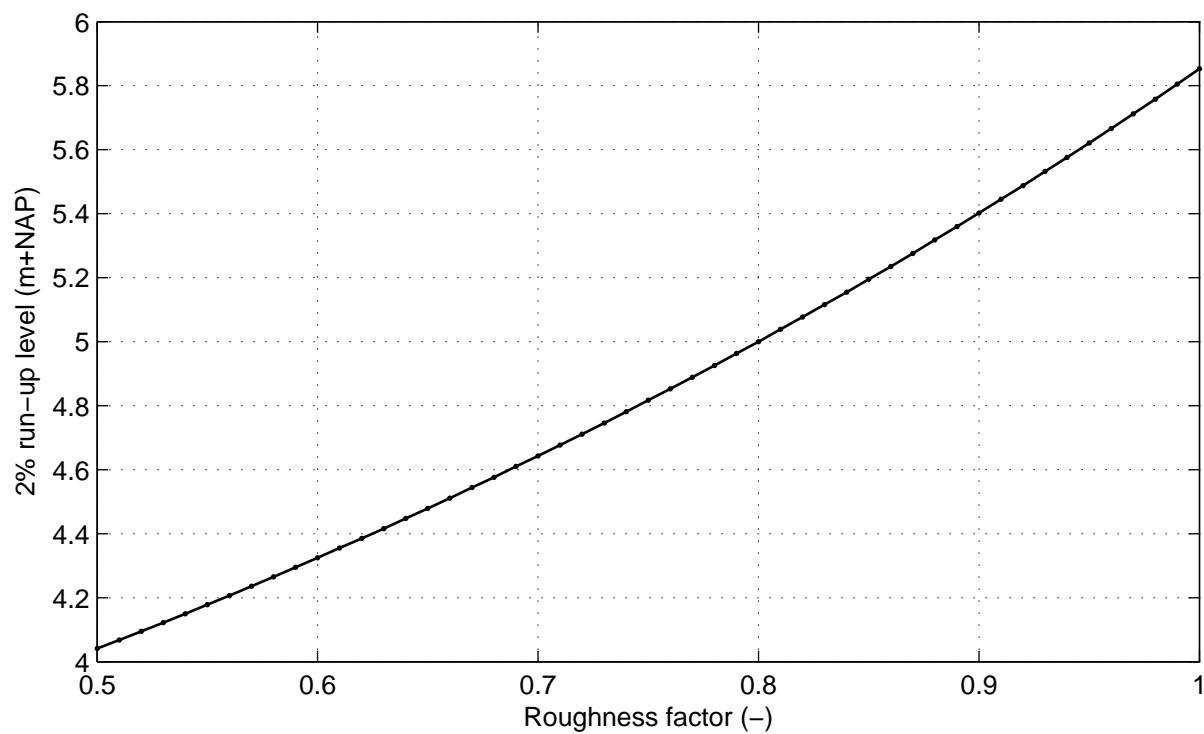
Cross section nr 2; series nr 13; Wave angle: 85 °
Varying level buckling point

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.13



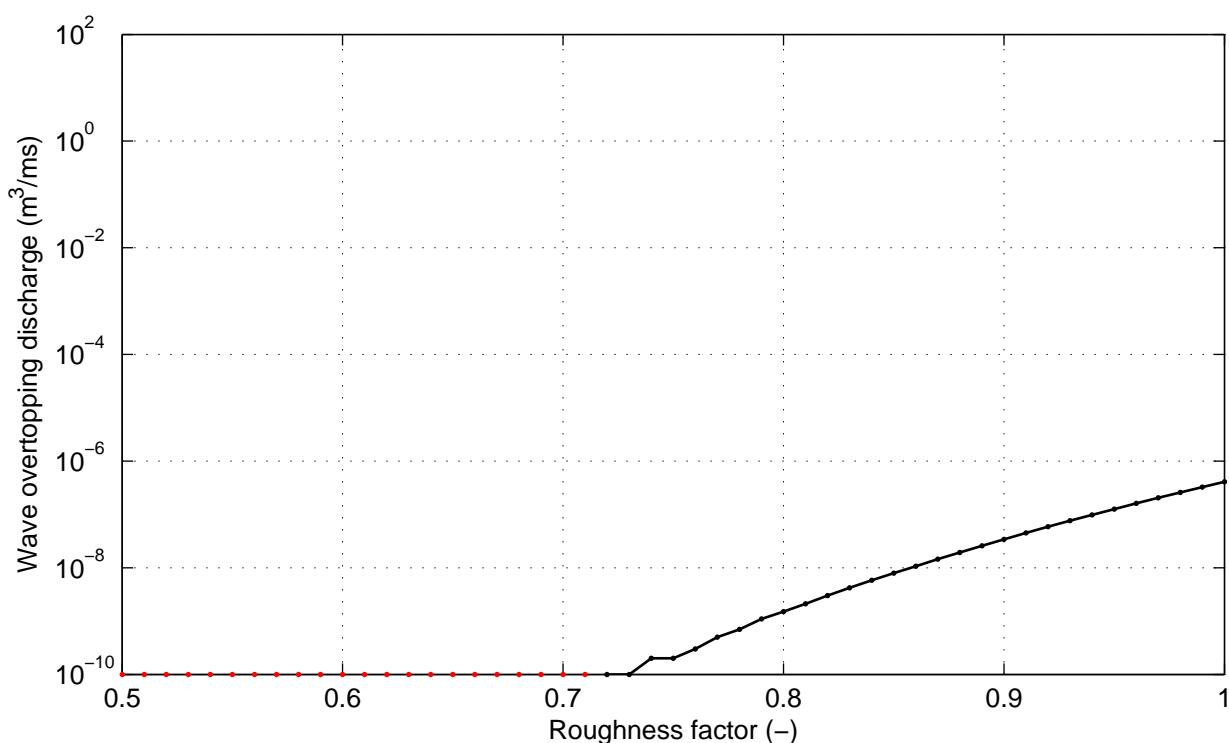
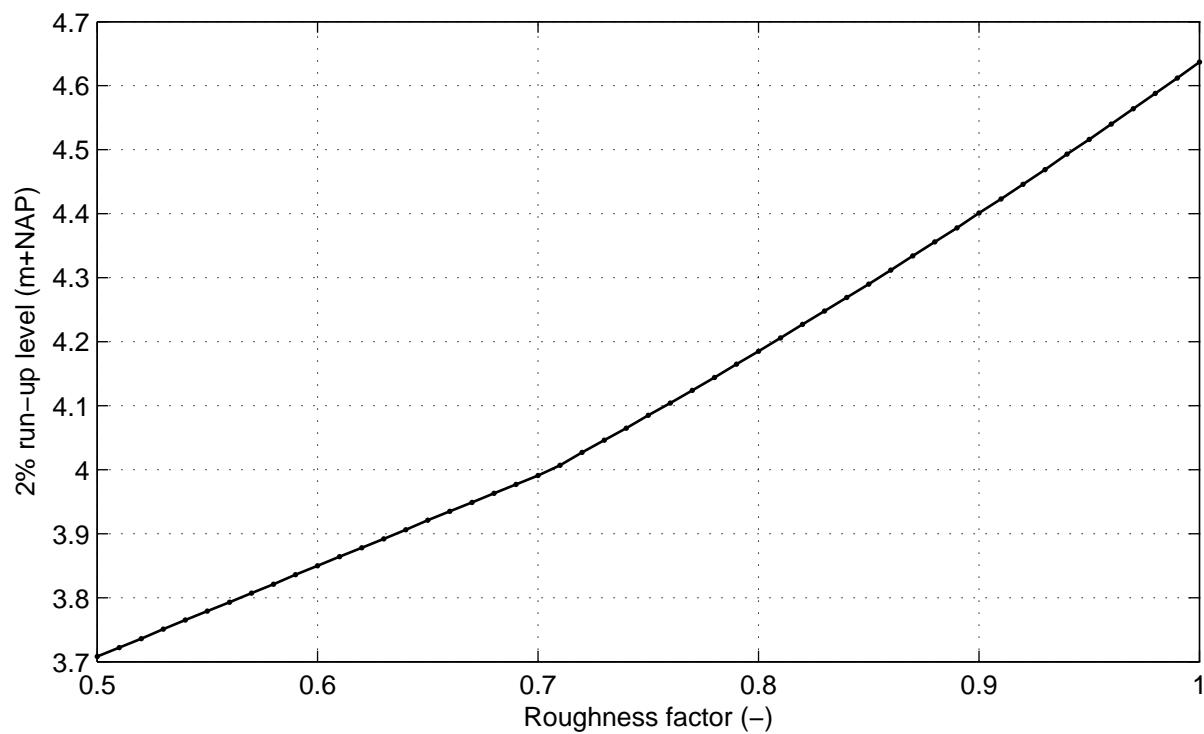
Cross section nr 2; series nr 14; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.14



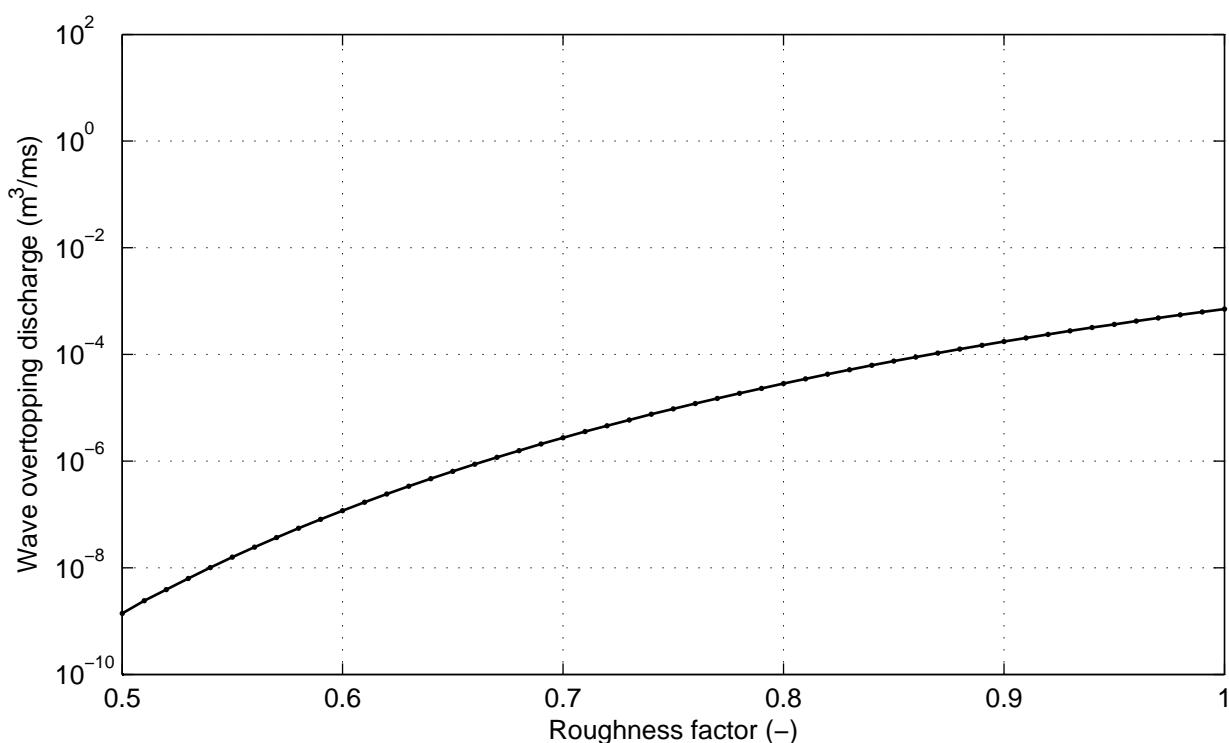
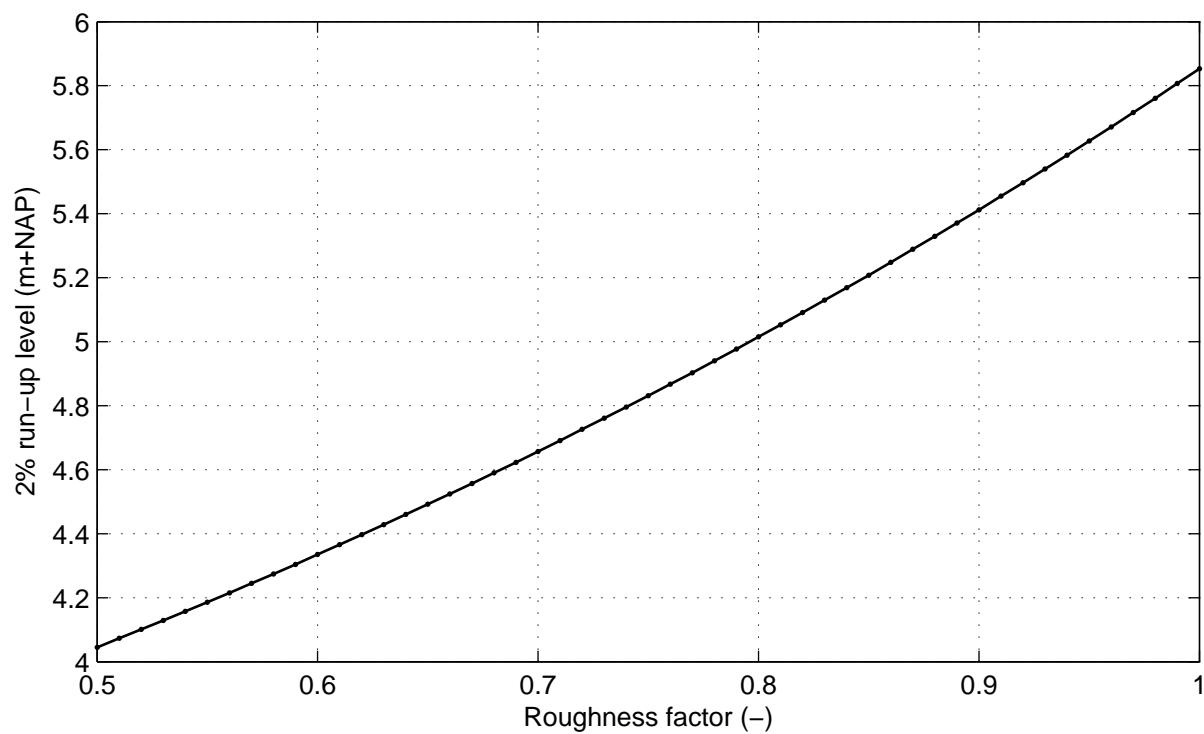
Cross section nr 2; series nr 15; Wave angle: 85 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.15



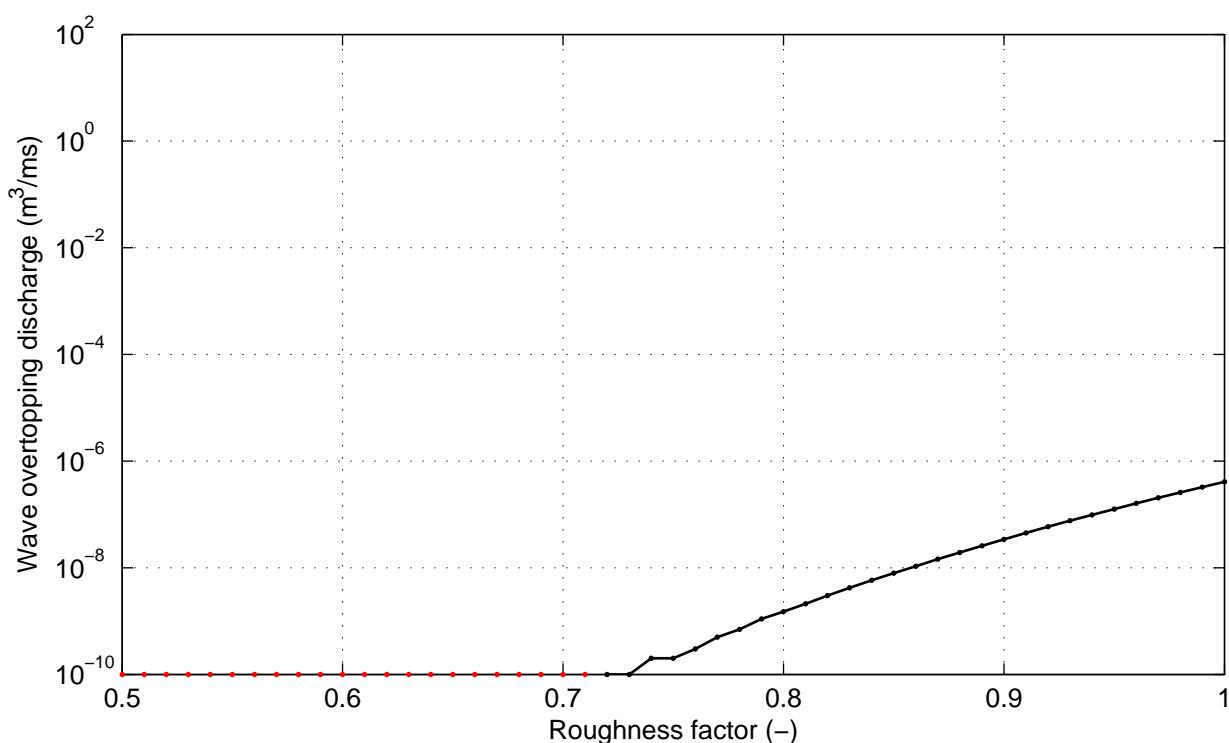
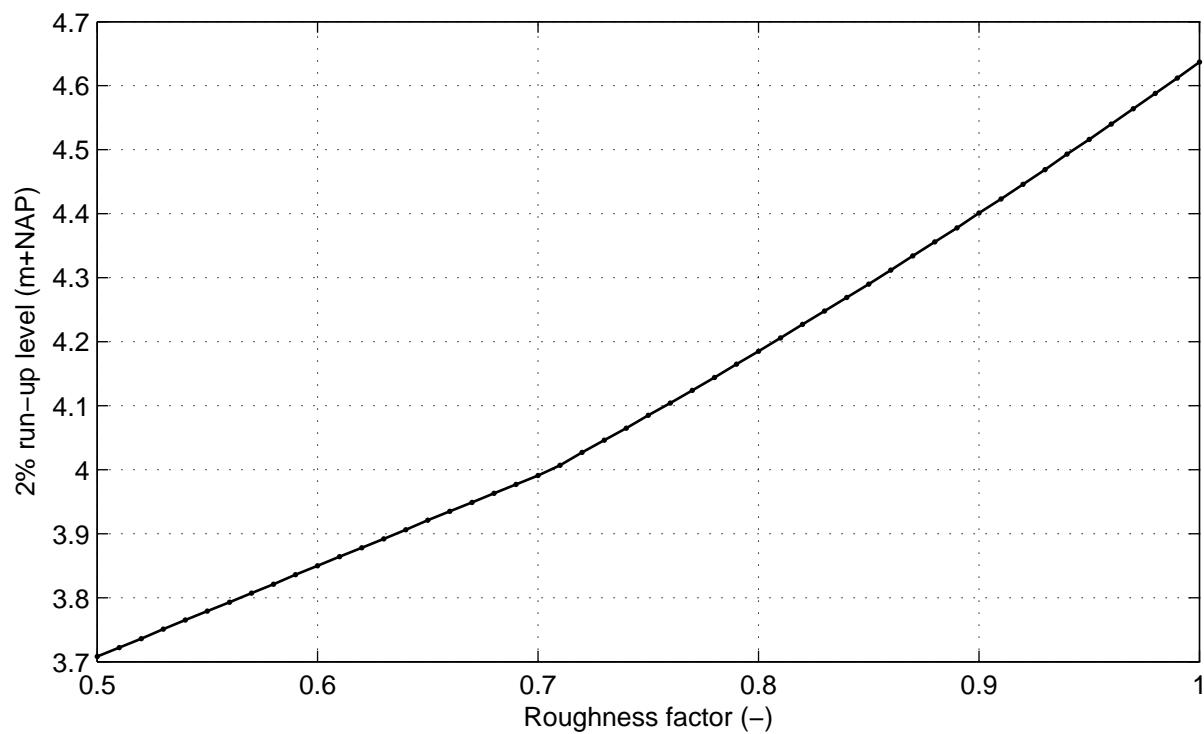
Cross section nr 2; series nr 16; Wave angle: 0 °
Varying roughness lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.16



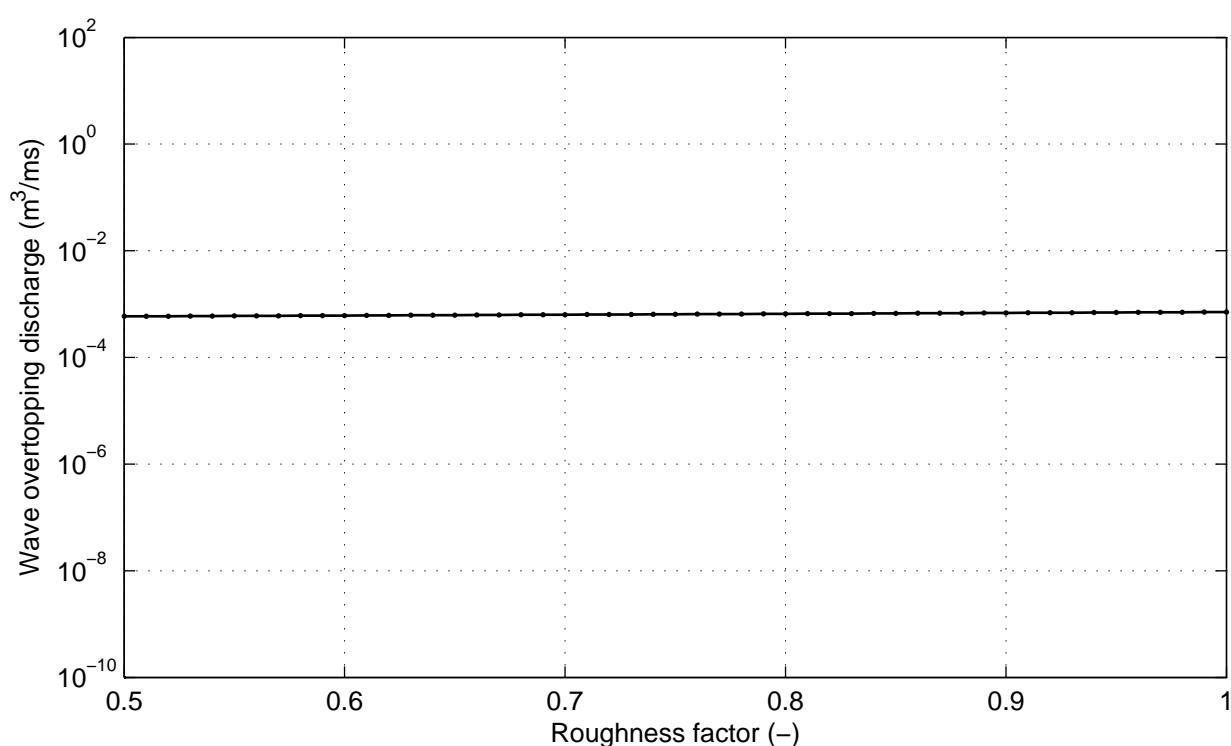
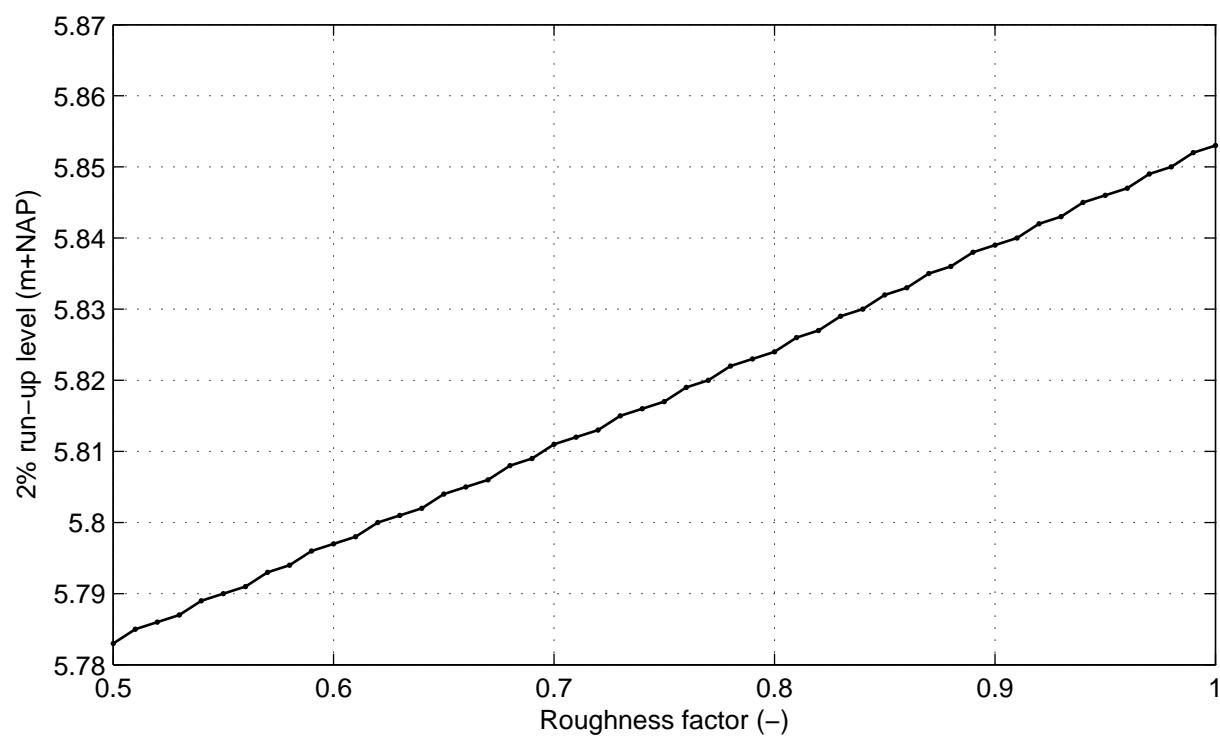
Cross section nr 2; series nr 17; Wave angle: 85 °
Varying roughness lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.17



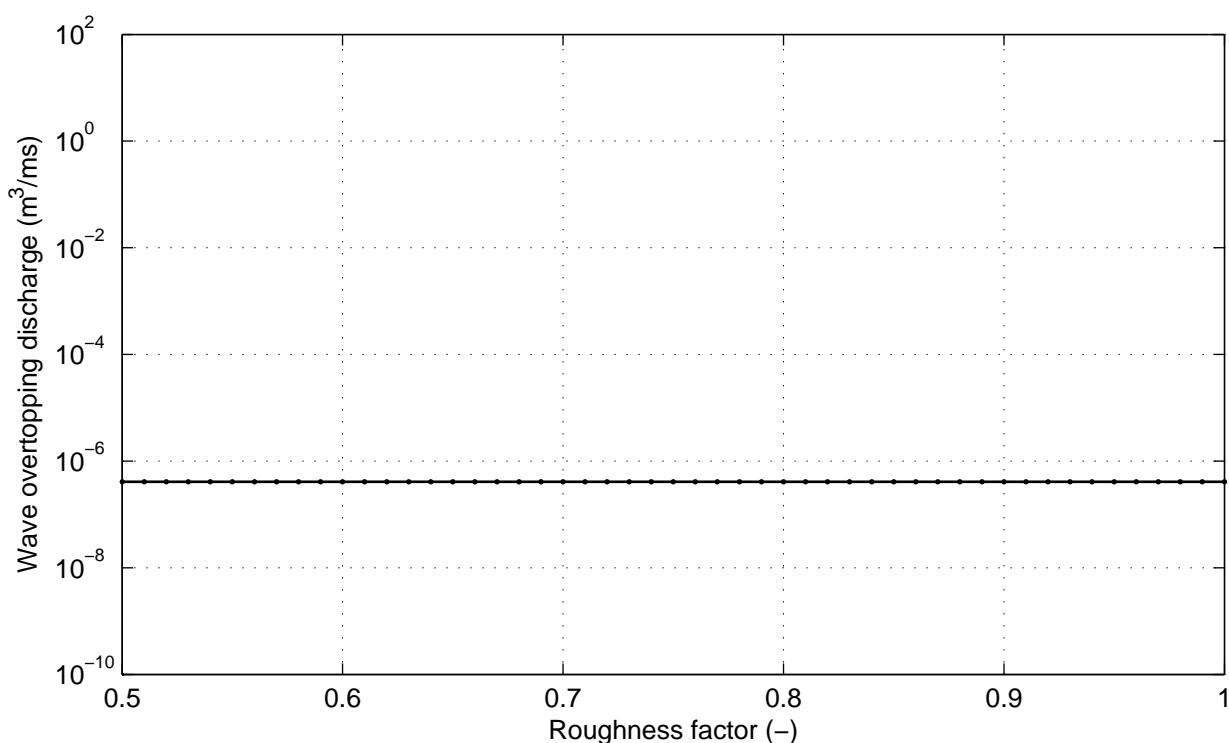
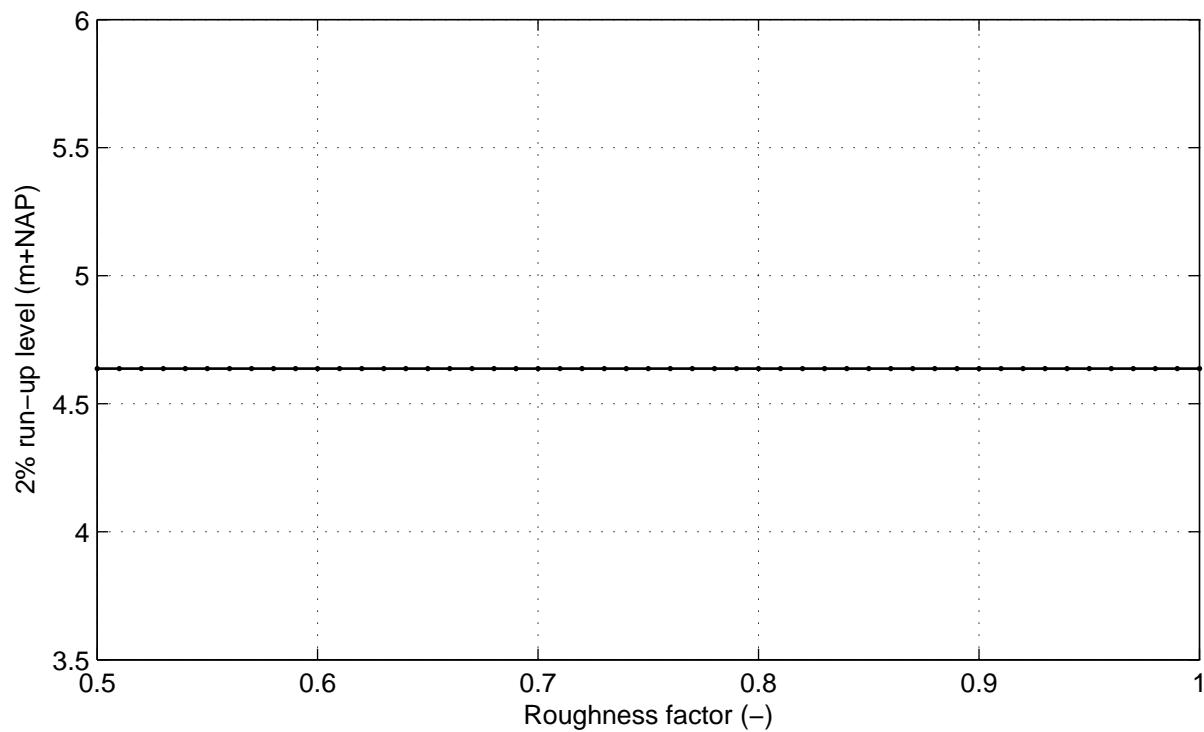
Cross section nr 2; series nr 18; Wave angle: 0 °
Varying roughness upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.18



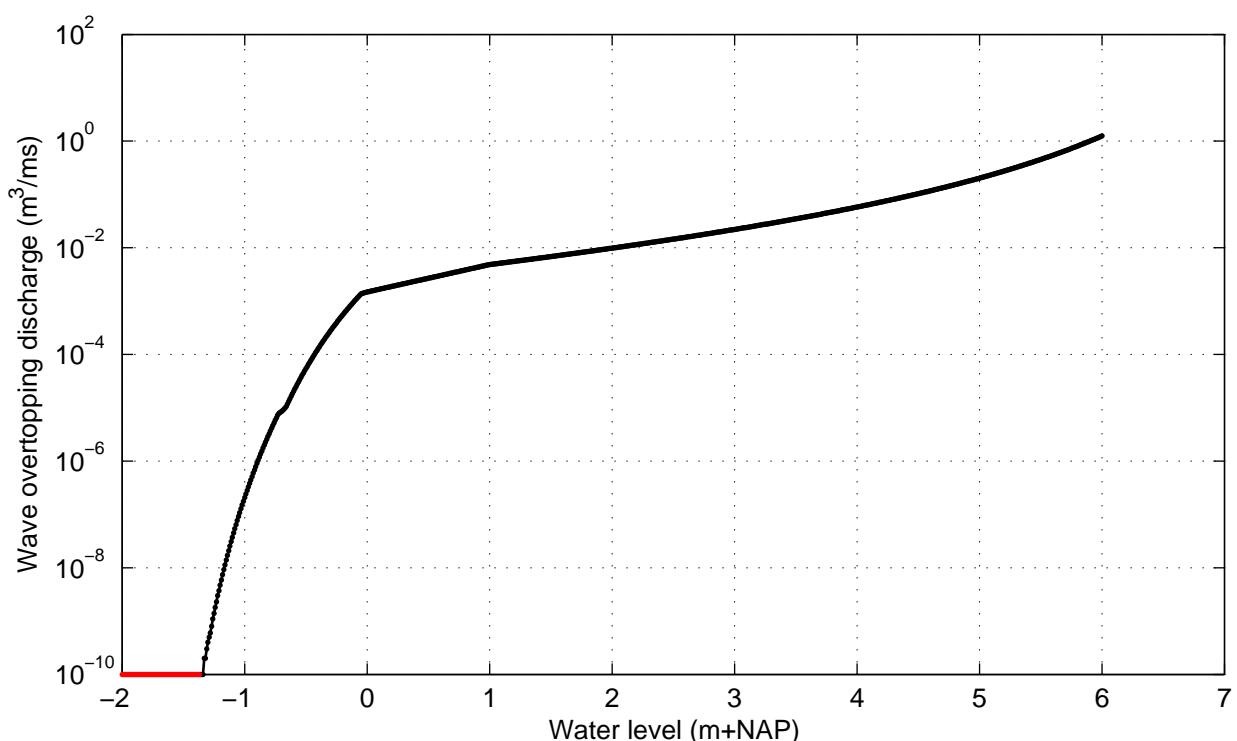
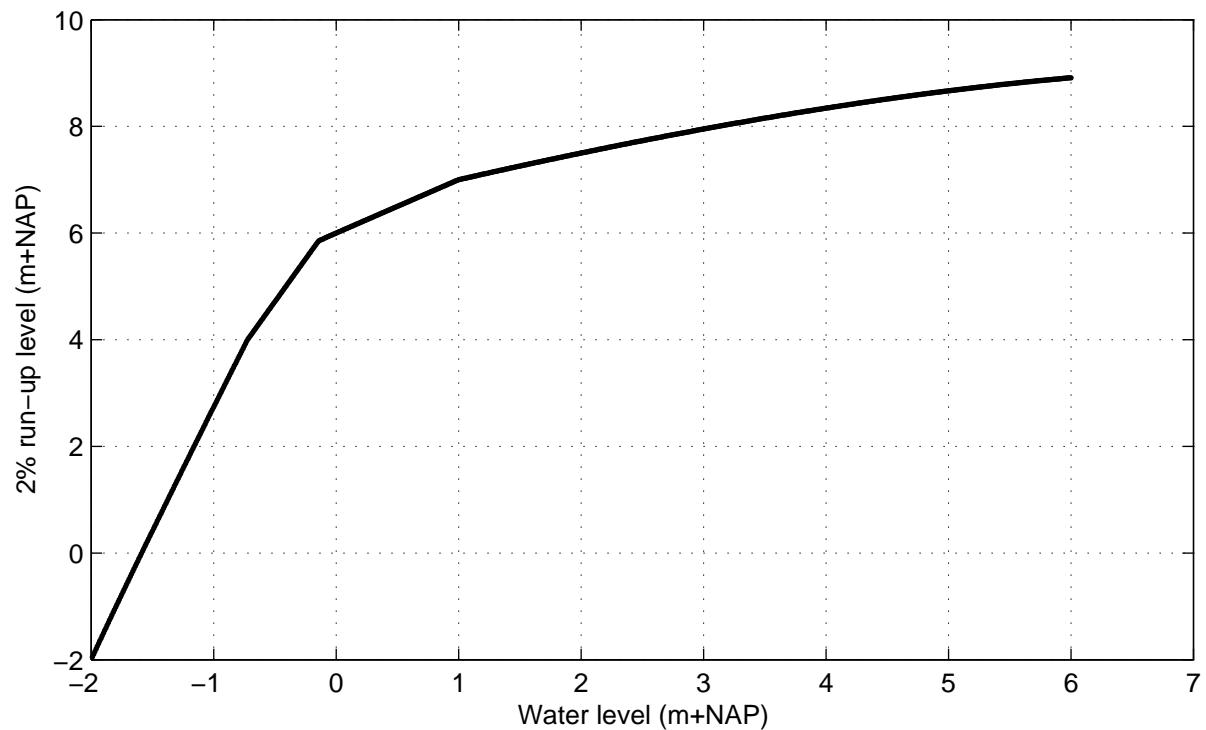
Cross section nr 2; series nr 19; Wave angle: 85 °
Varying roughness upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 2.19



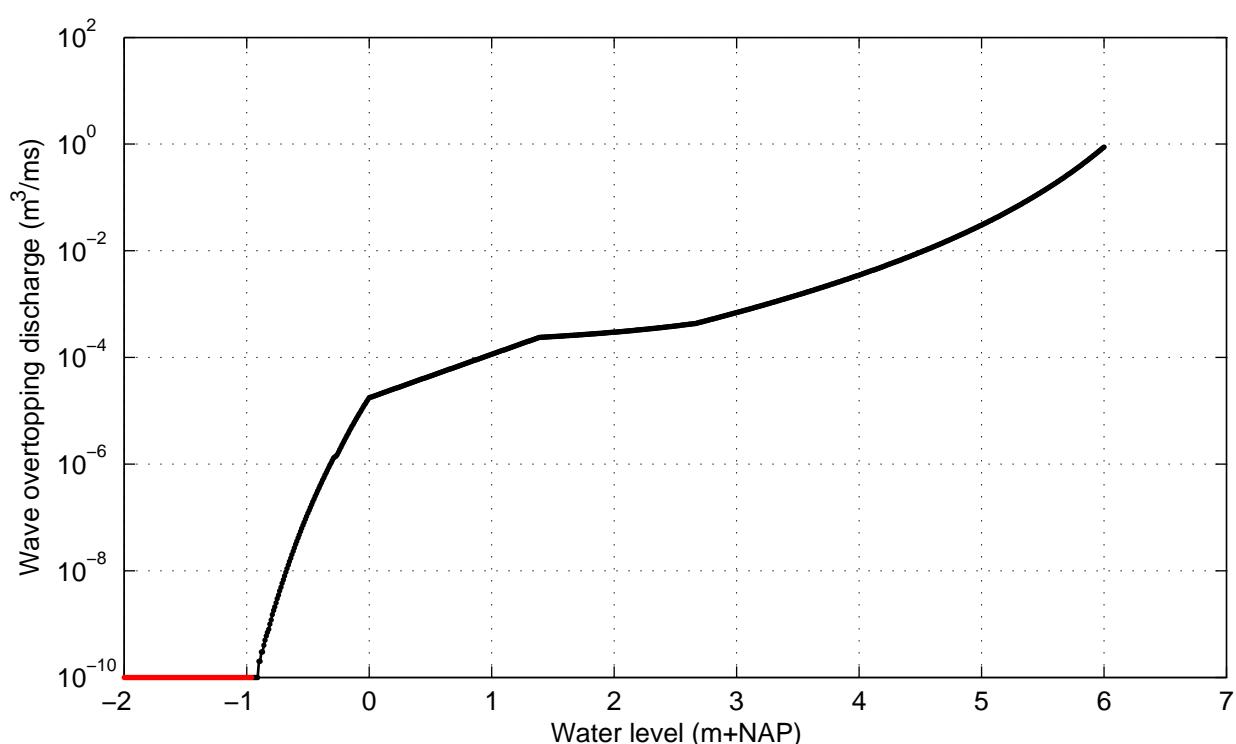
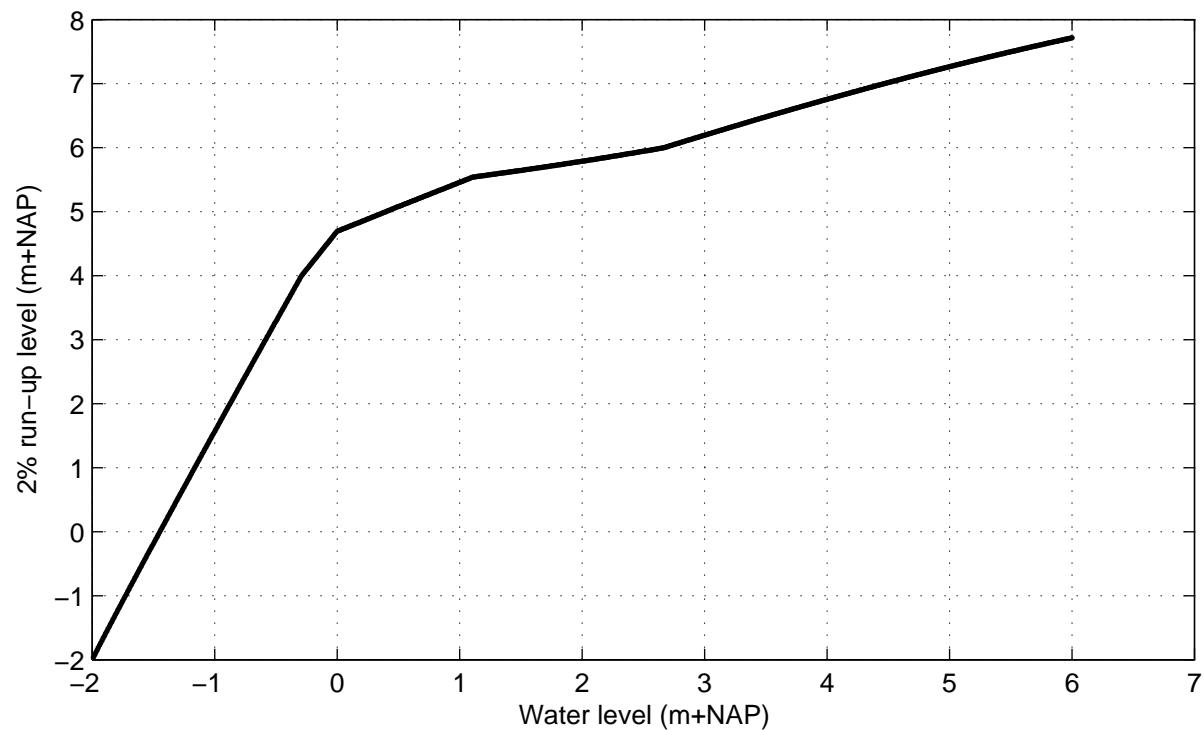
Cross section nr 3; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.1



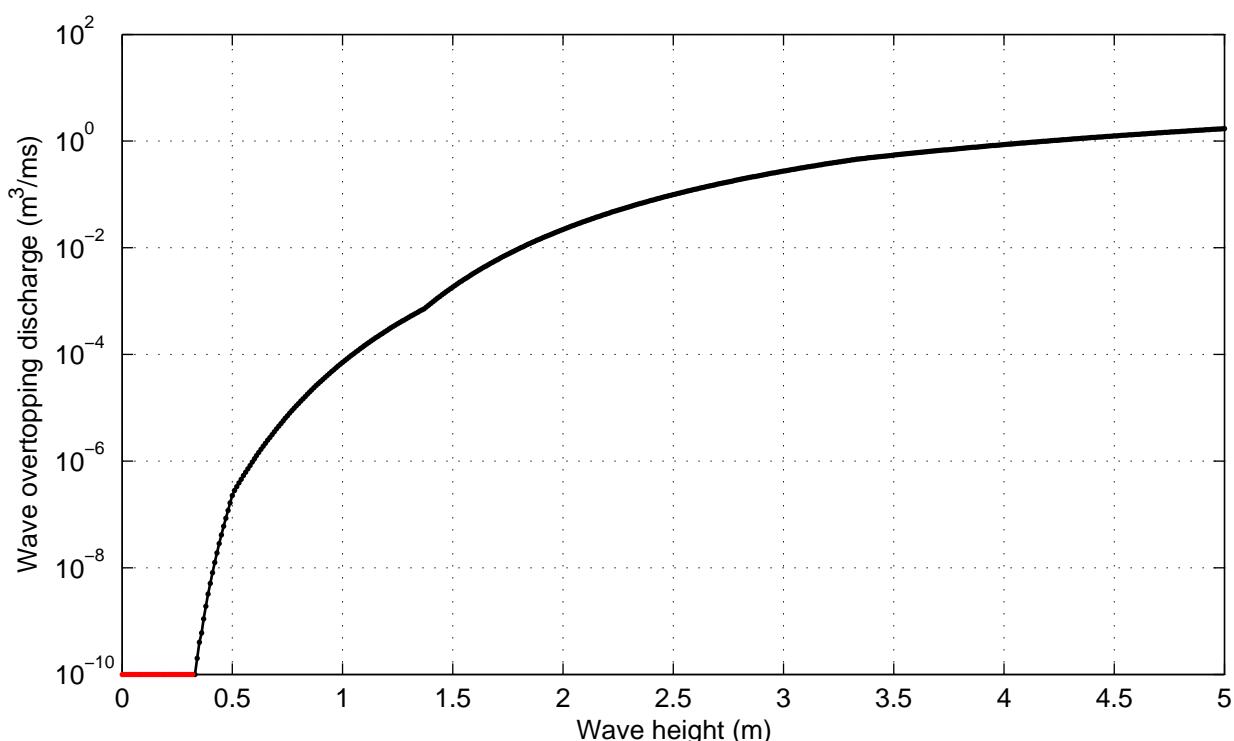
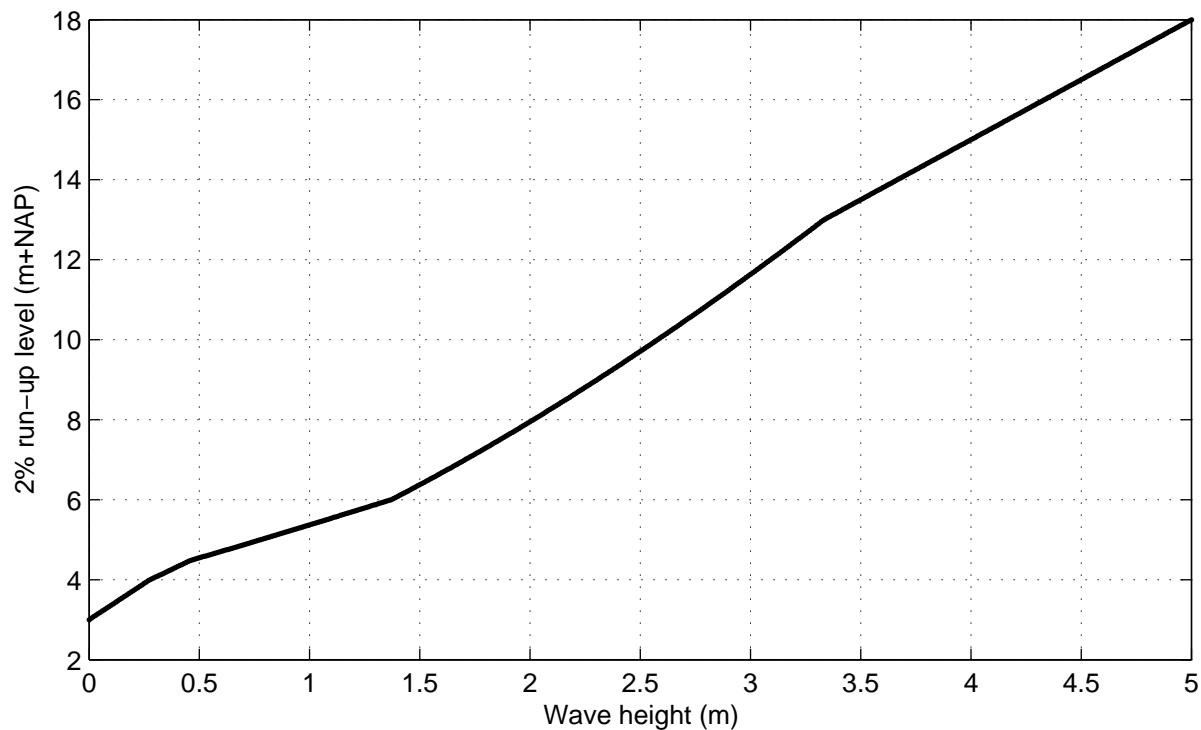
Cross section nr 3; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.2



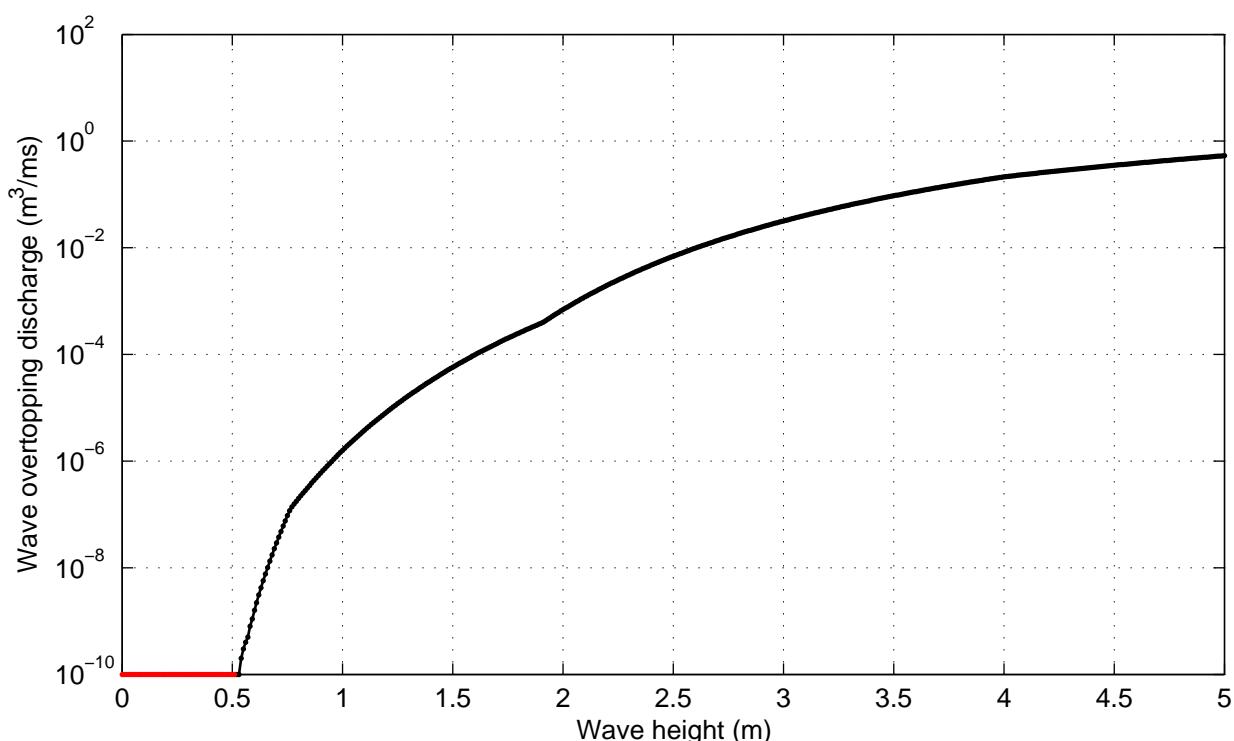
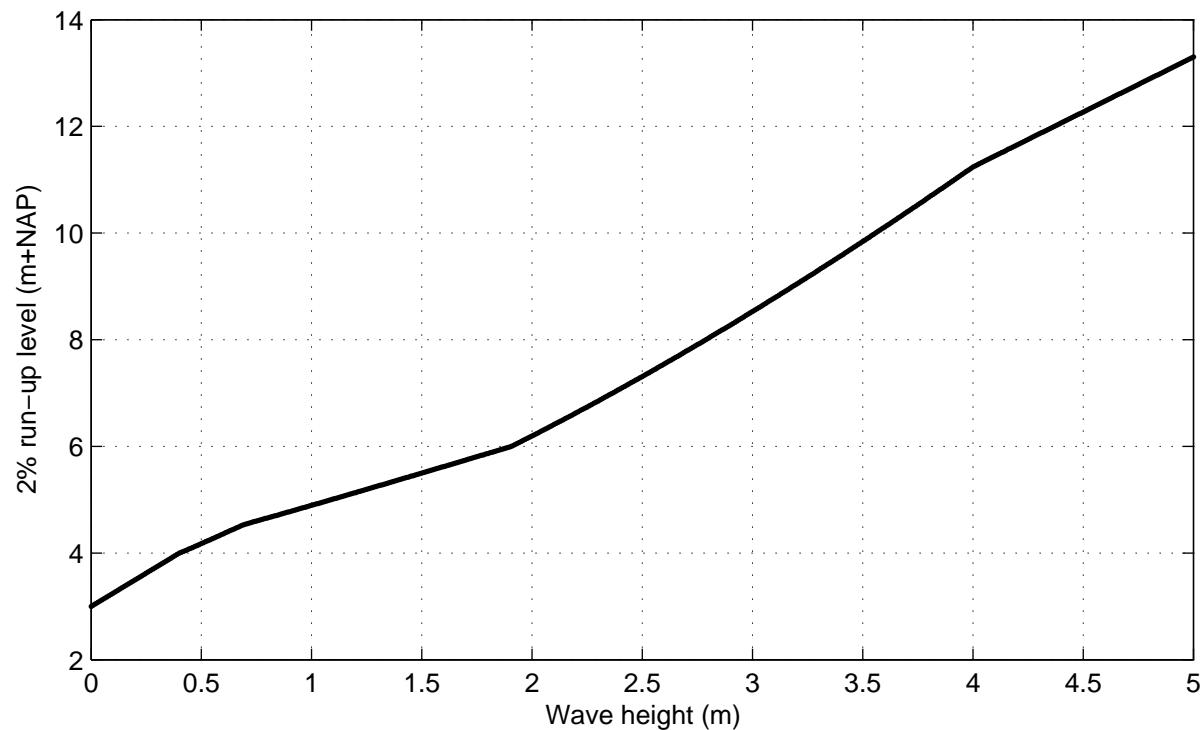
Cross section nr 3; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.3



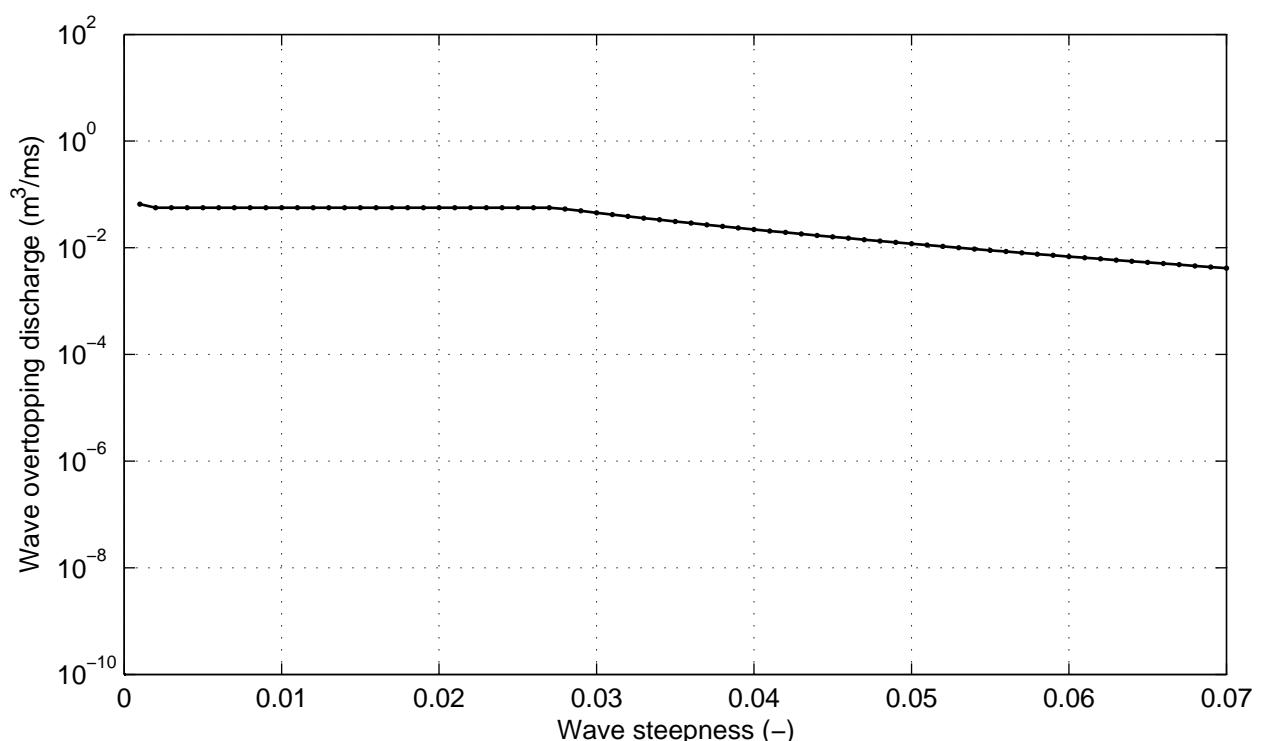
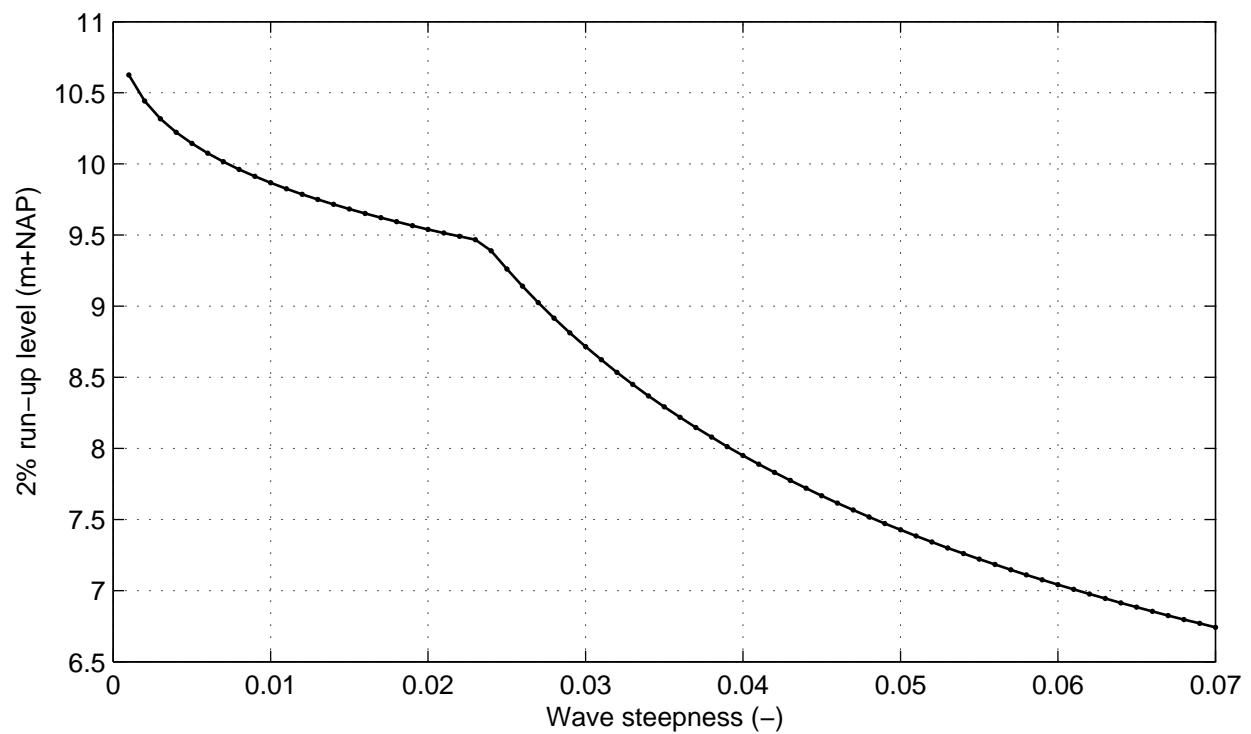
Cross section nr 3; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.4



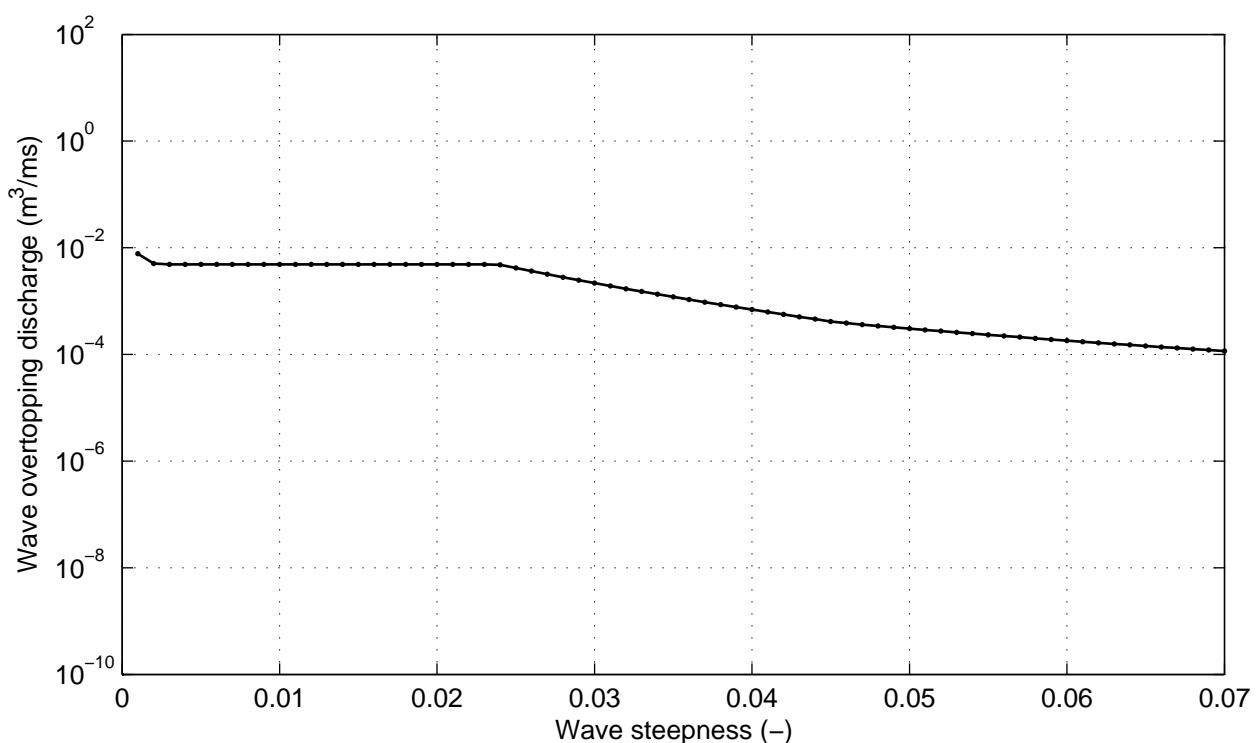
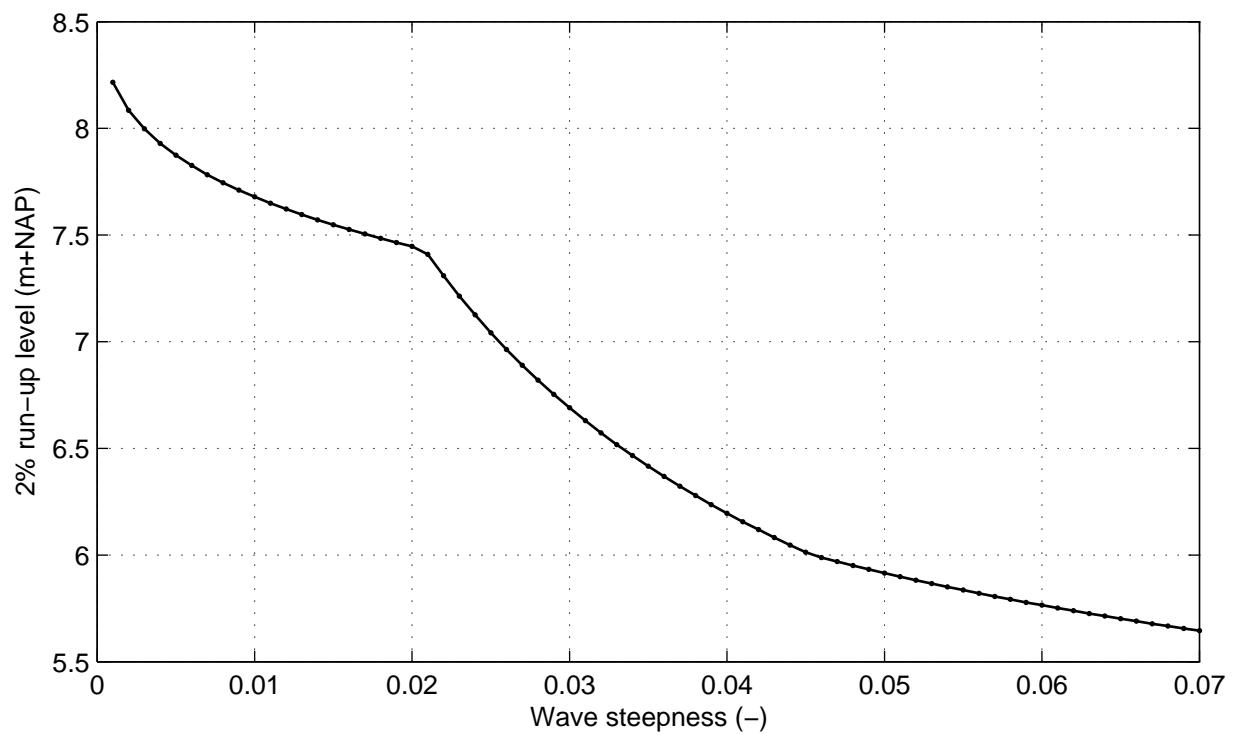
Cross section nr 3; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.5



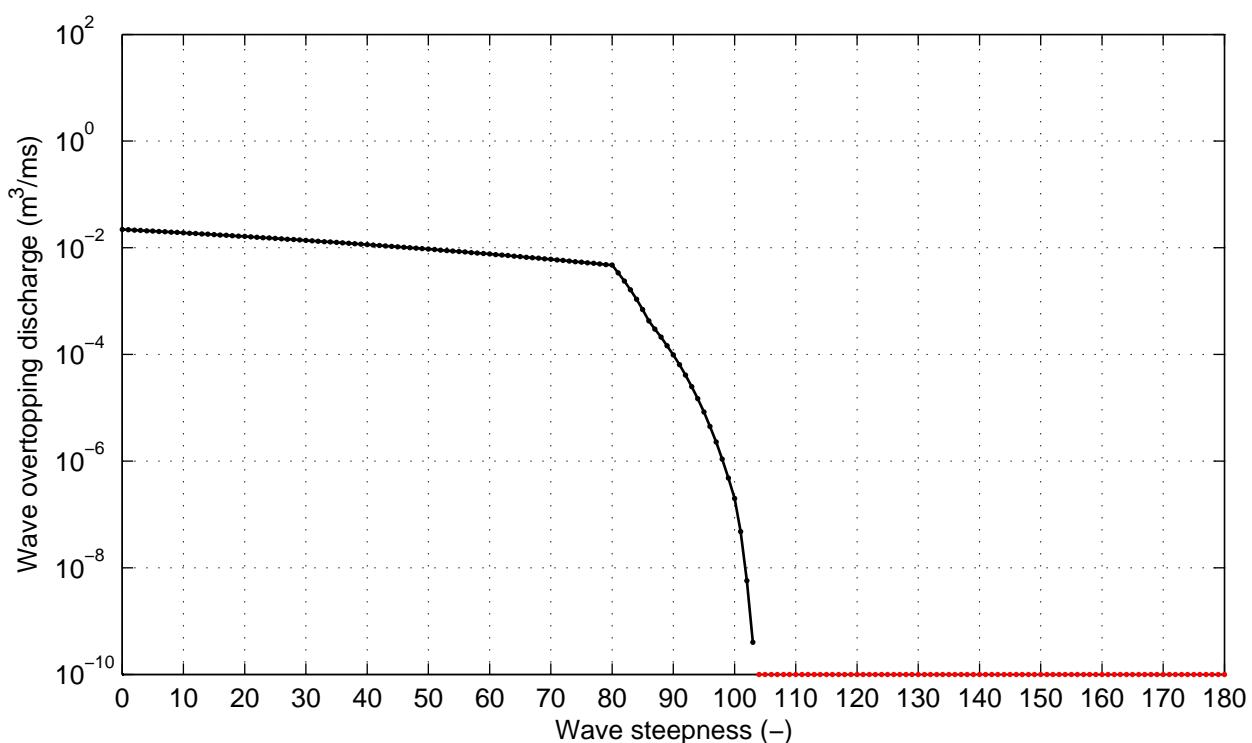
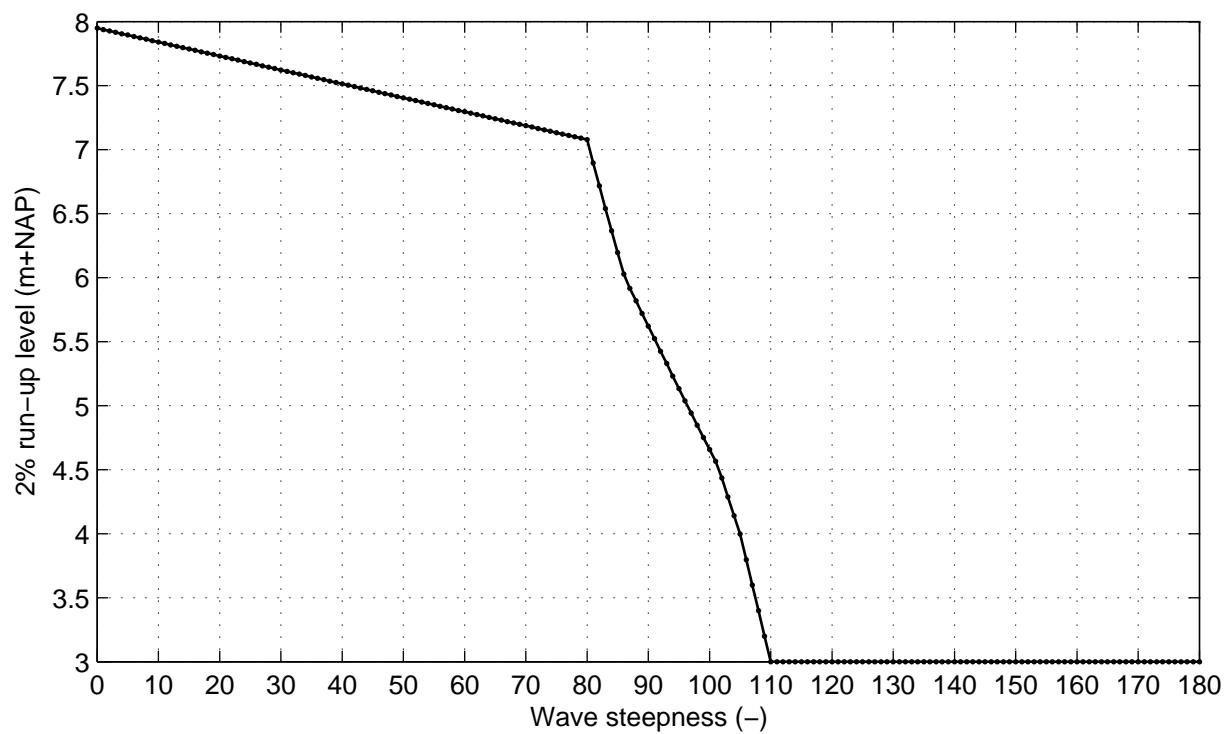
Cross section nr 3; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.6



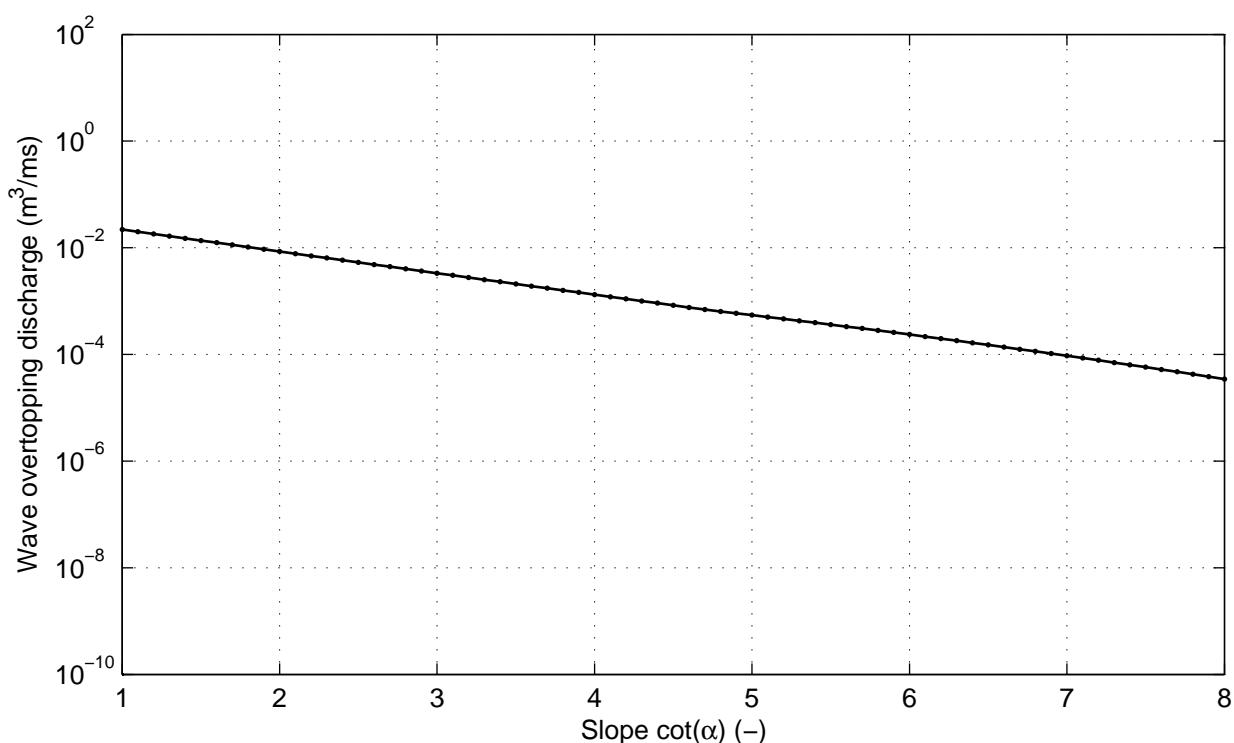
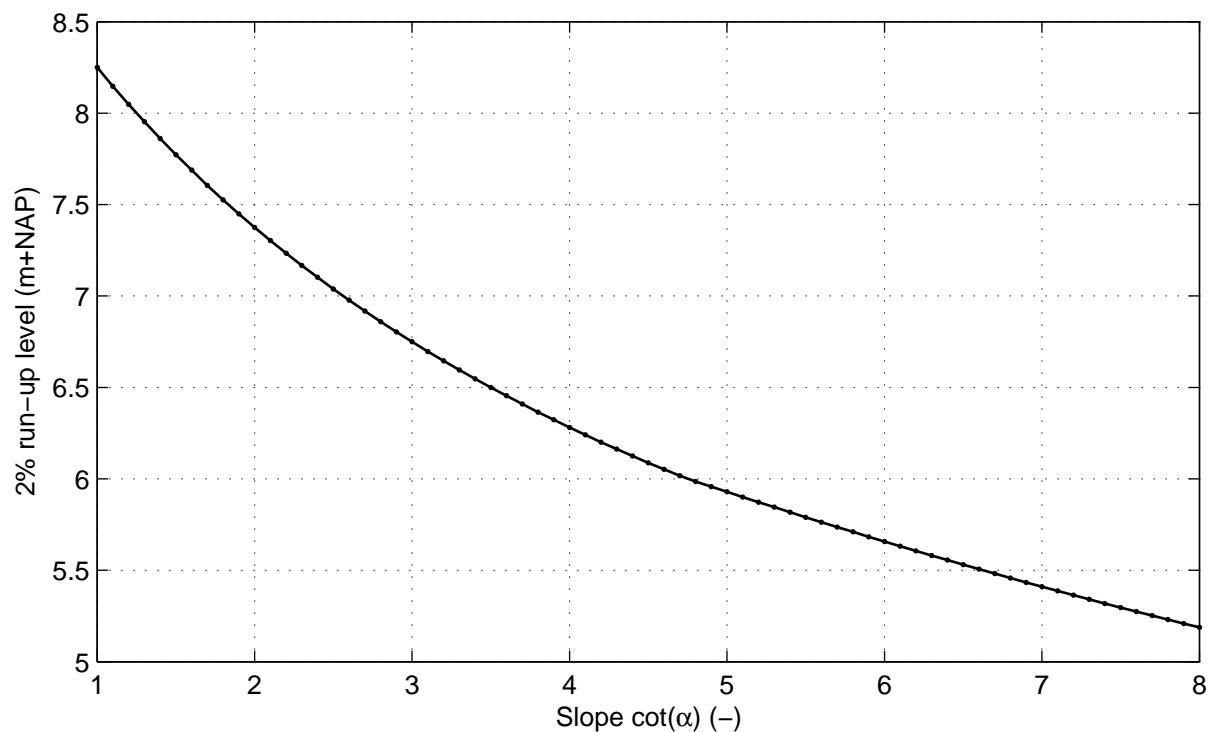
Cross section nr 3; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.7



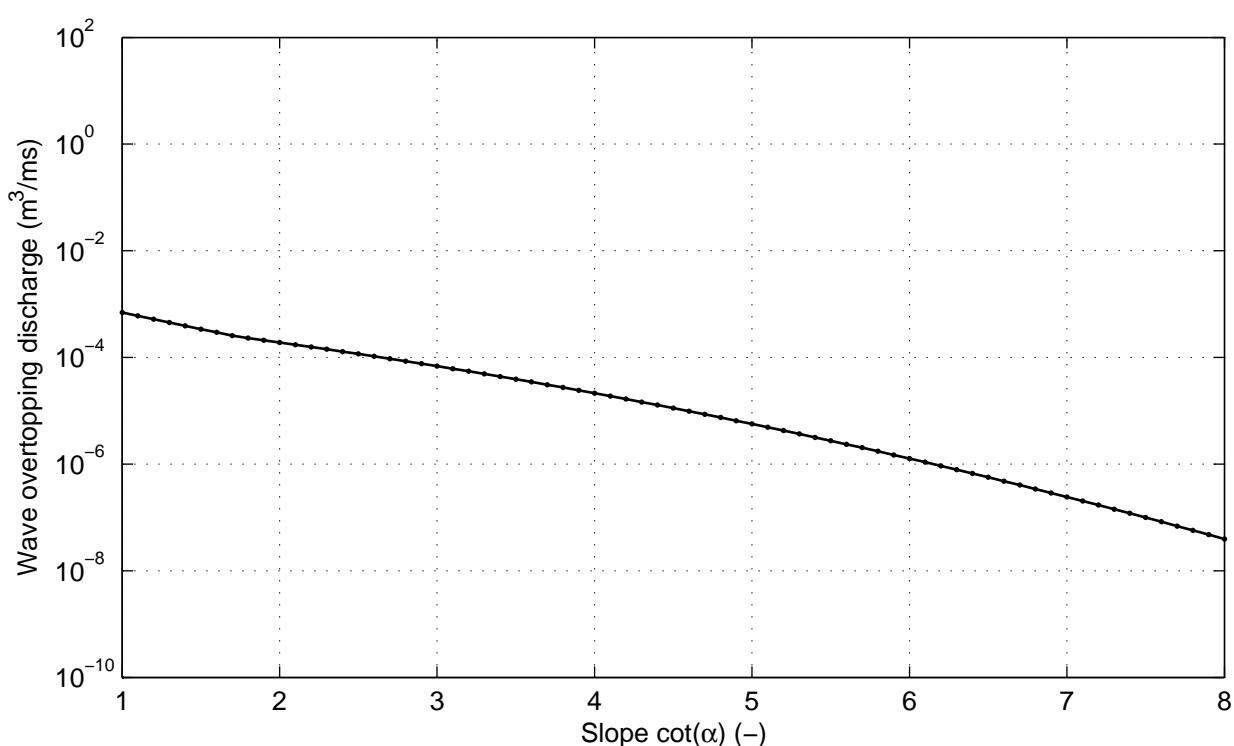
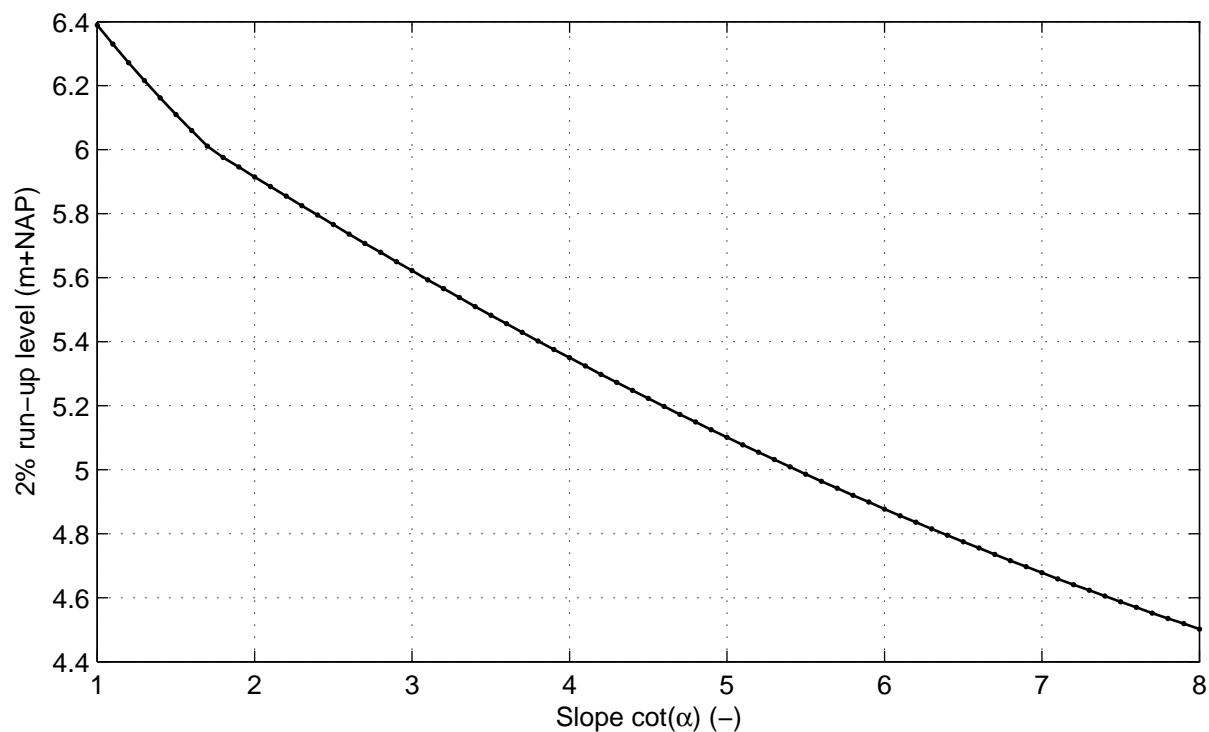
Cross section nr 3; series nr 8; Wave angle: 0 °
Varying slope lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.8



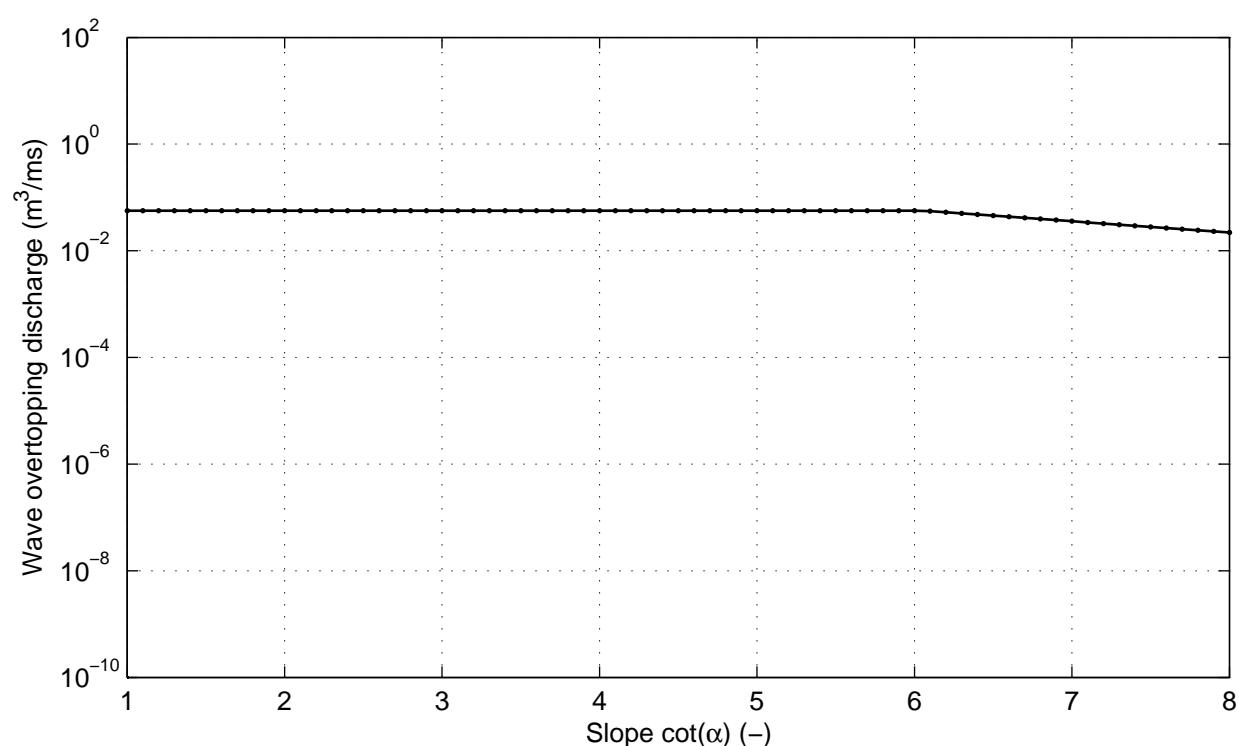
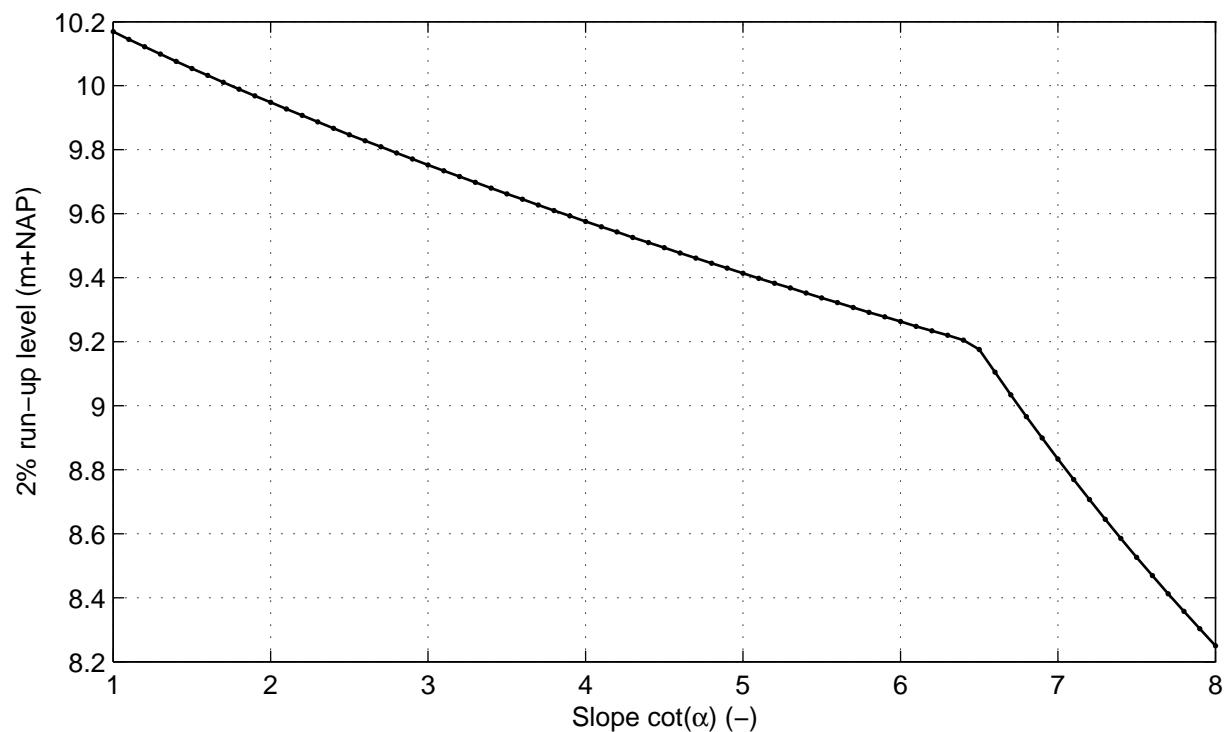
Cross section nr 3; series nr 9; Wave angle: 85 °
Varying slope lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.9



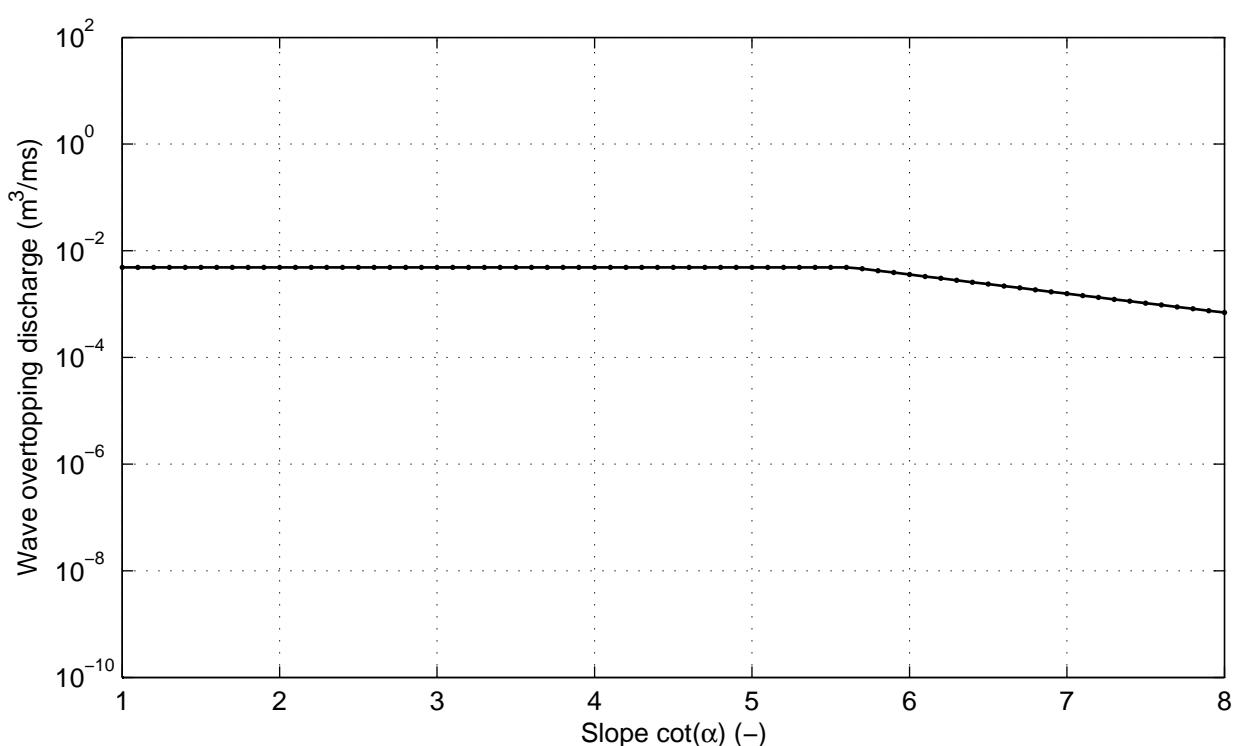
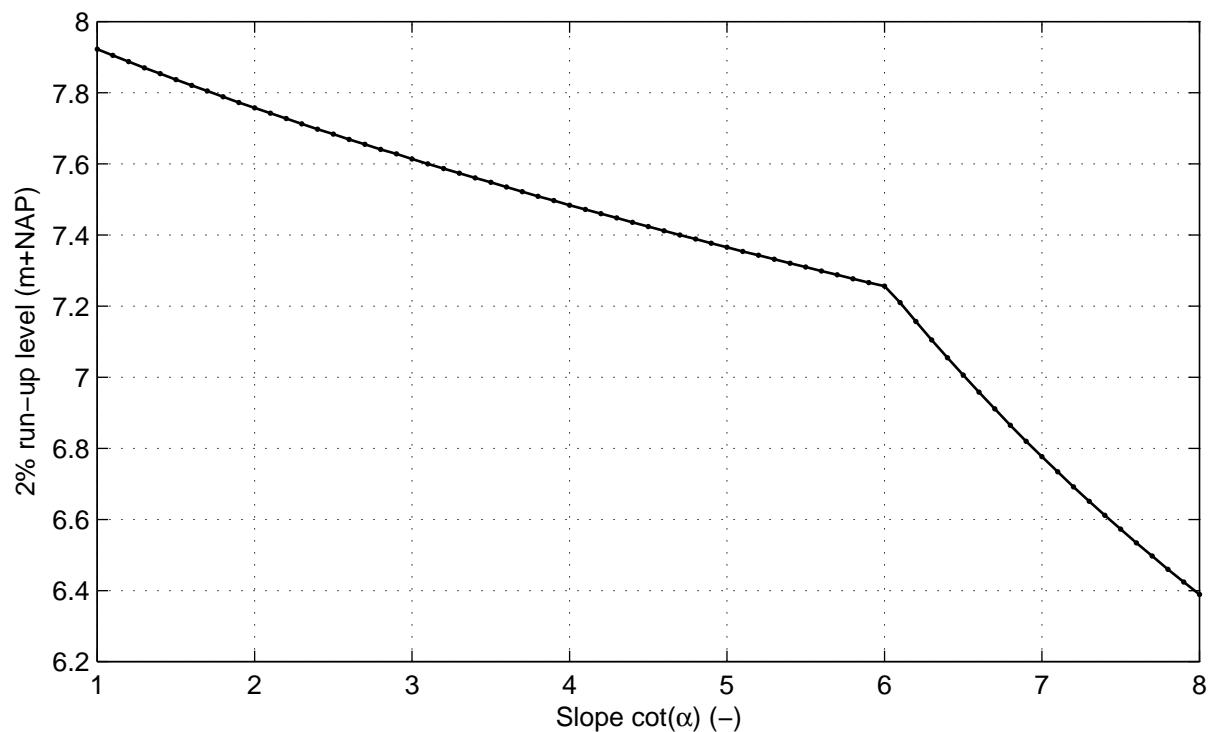
Cross section nr 3; series nr 10; Wave angle: 0 °
Varying slope upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.10



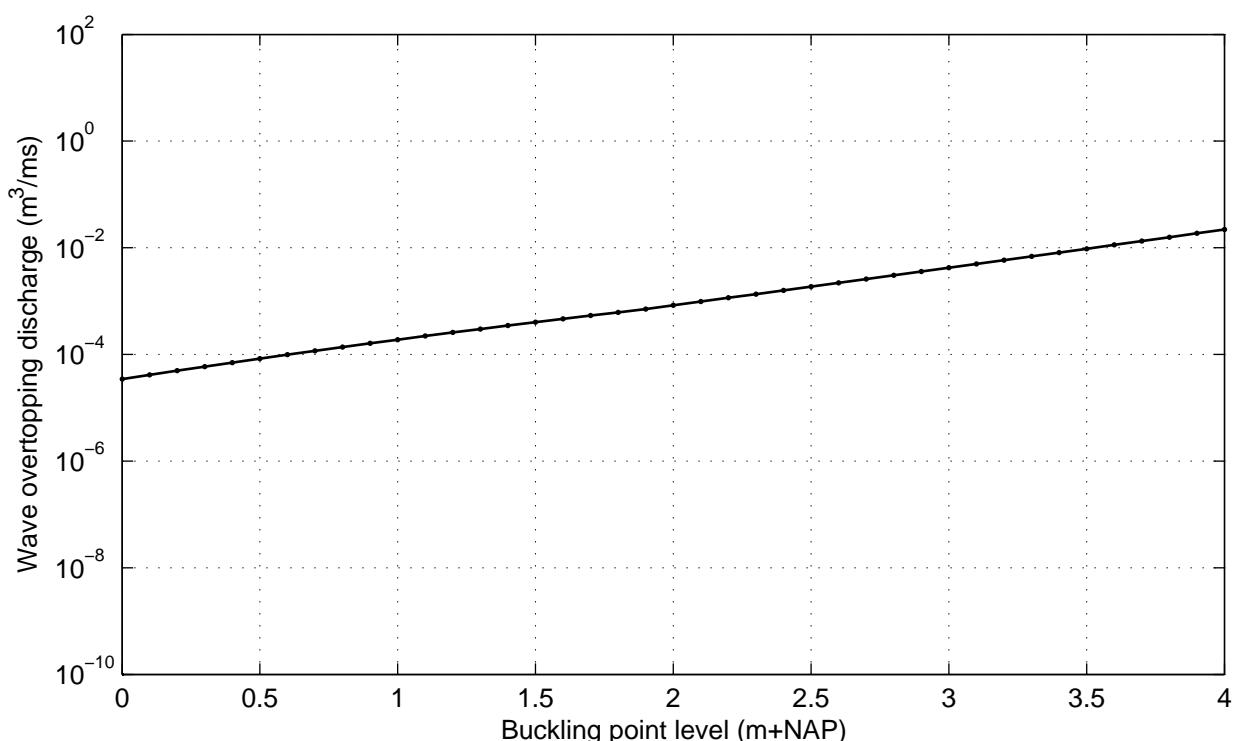
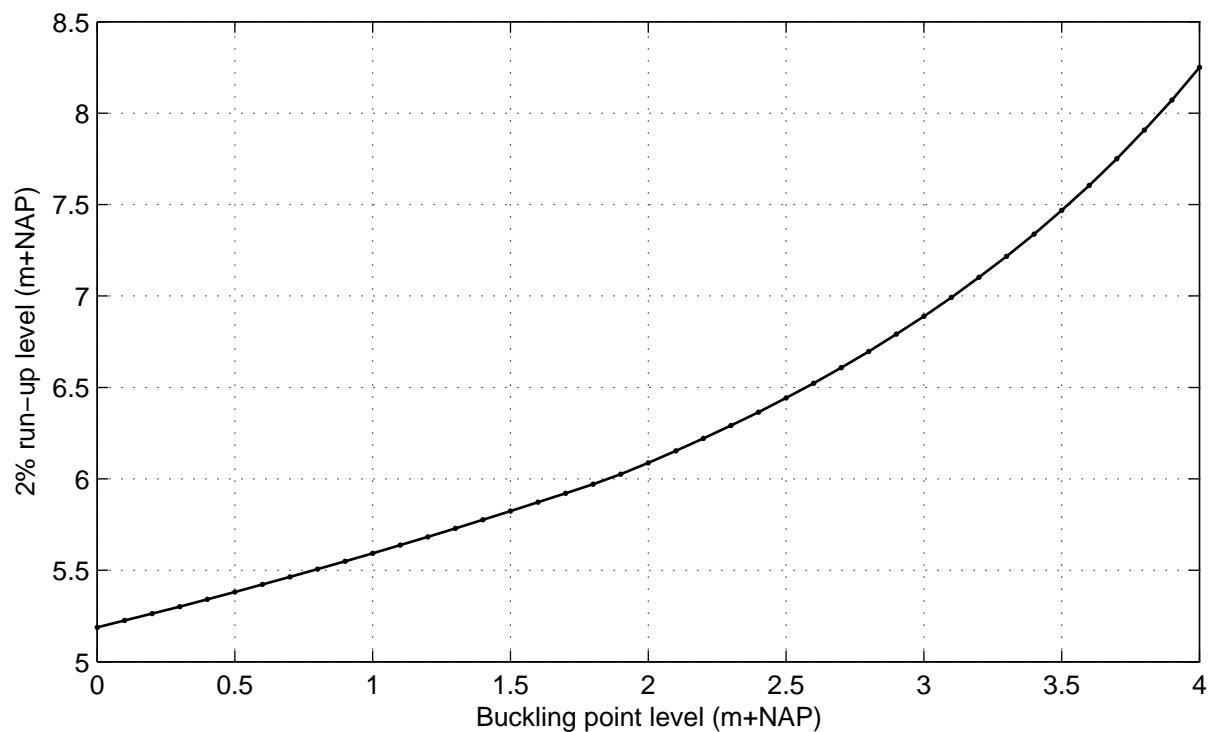
Cross section nr 3; series nr 11; Wave angle: 85 °
Varying slope upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.11



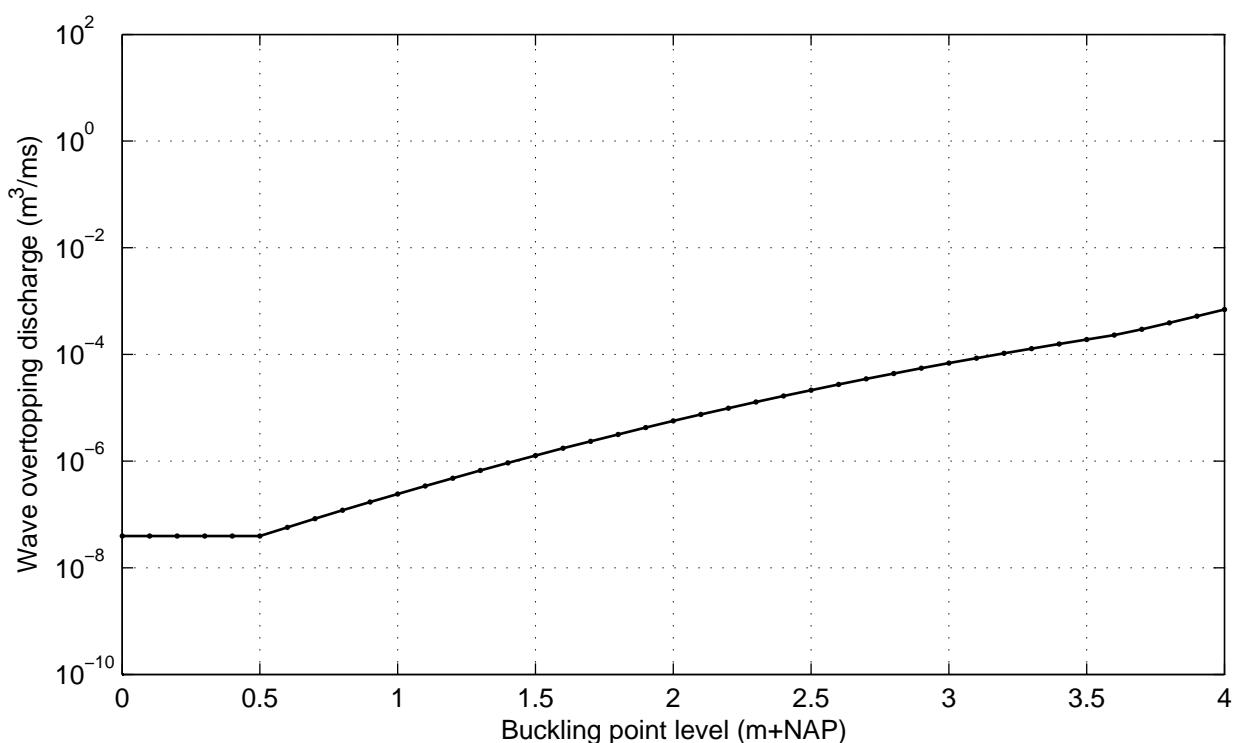
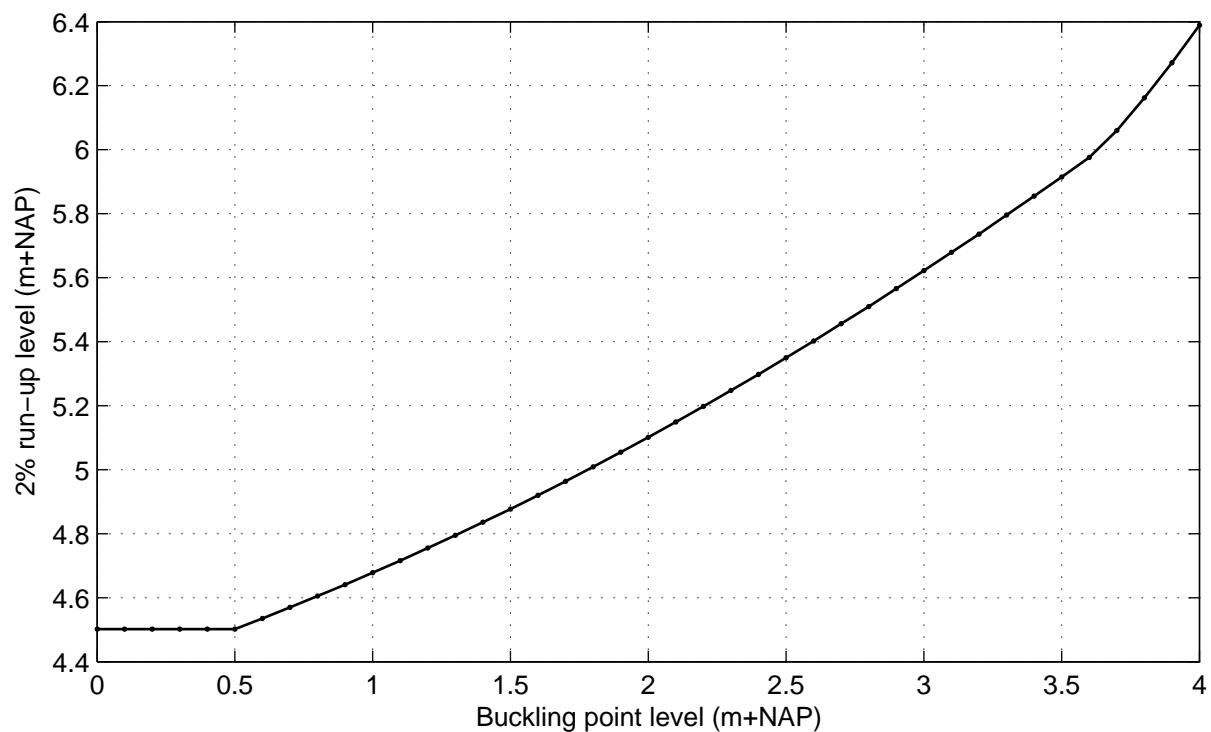
Cross section nr 3; series nr 12; Wave angle: 0 °
Varying level buckling point

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.12



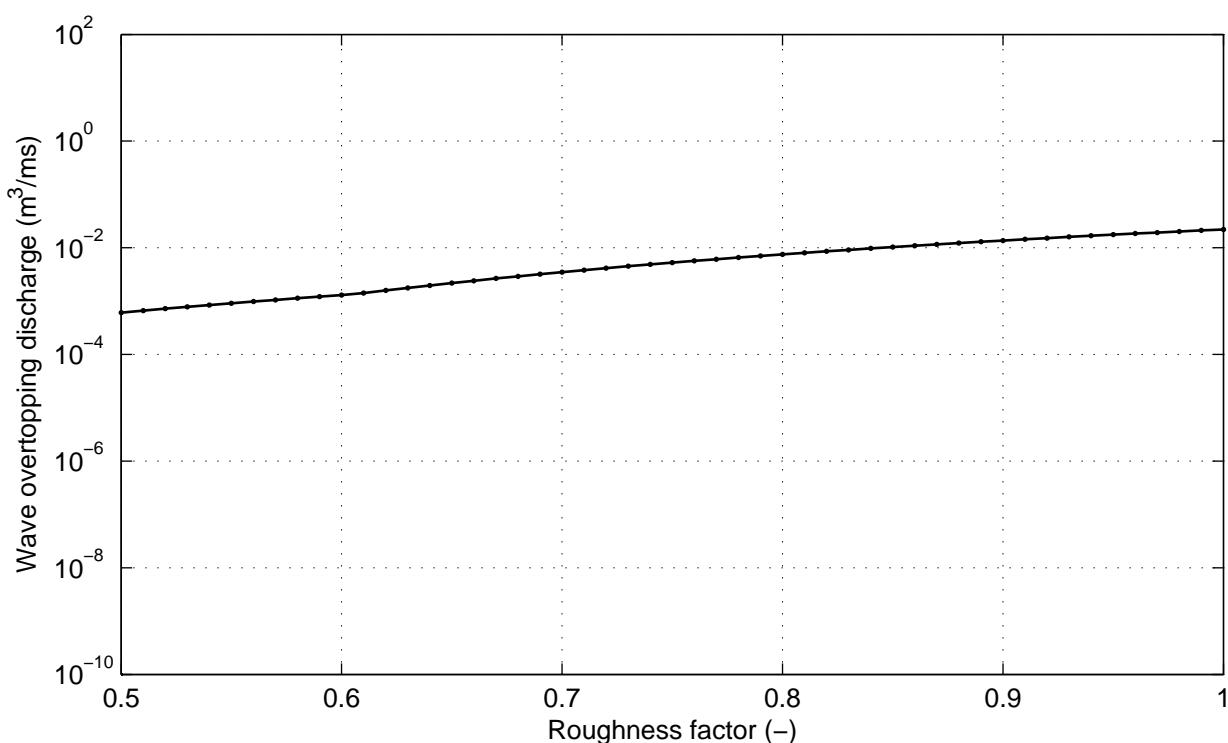
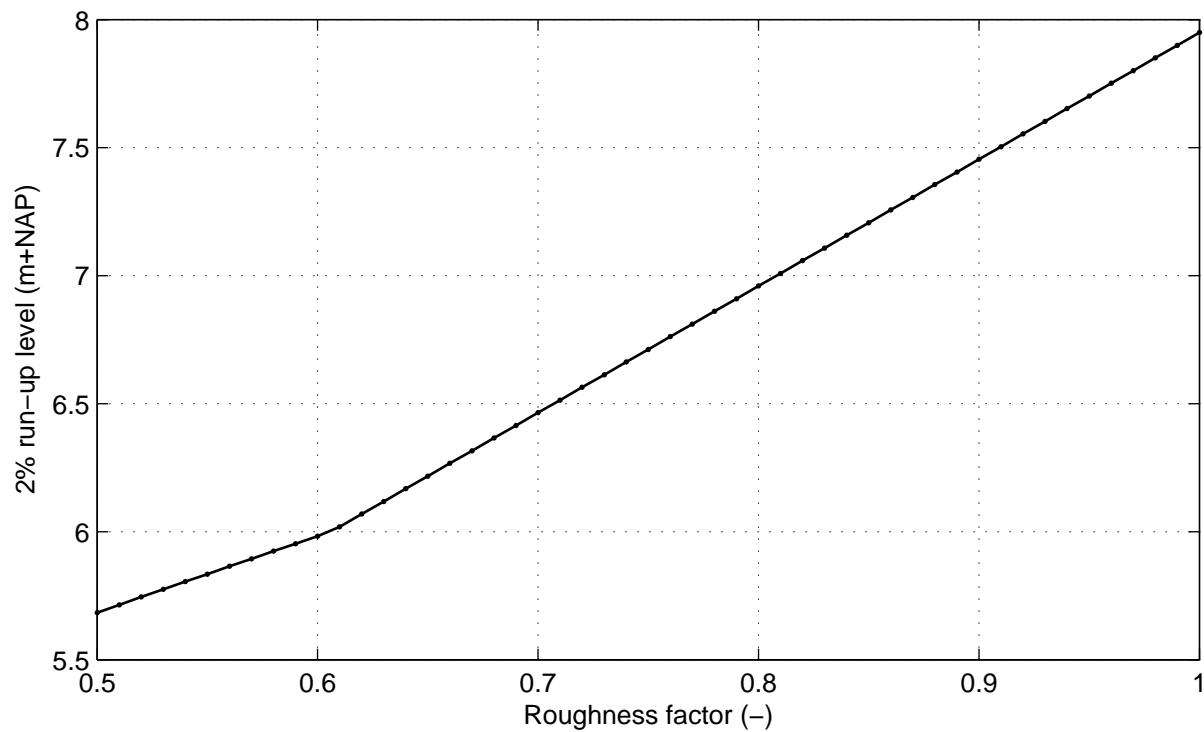
Cross section nr 3; series nr 13; Wave angle: 85 °
Varying level buckling point

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.13



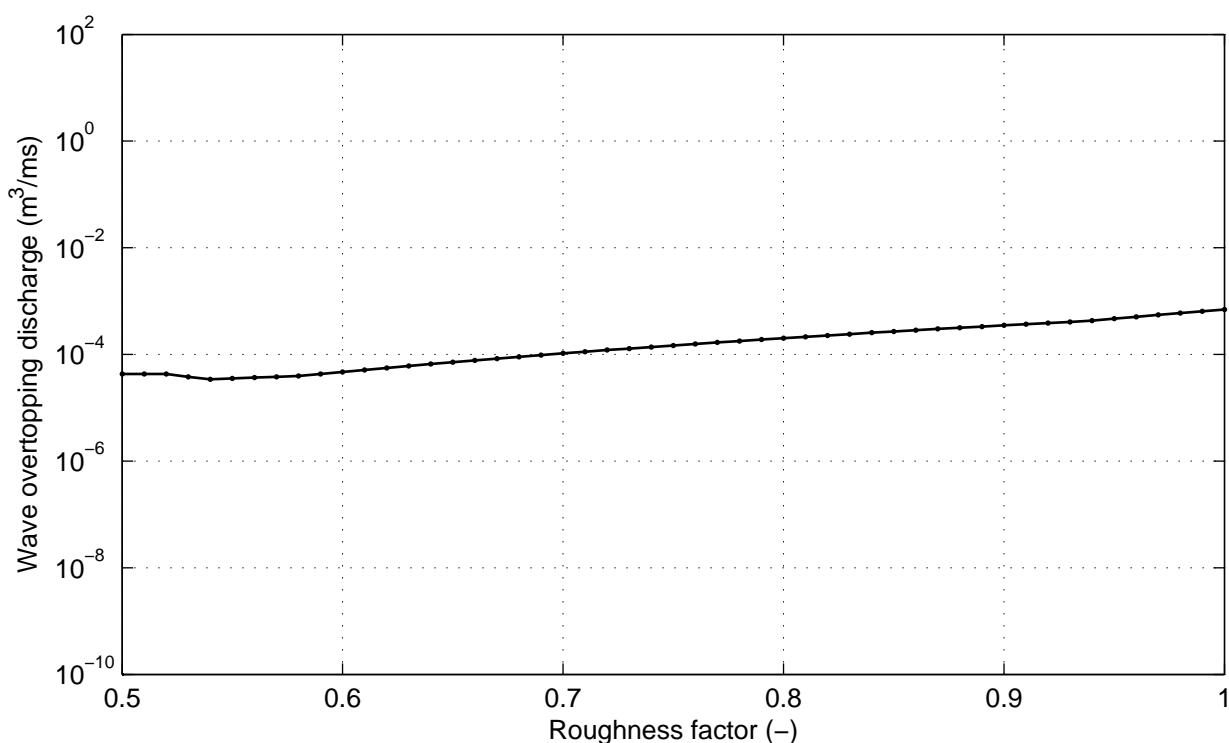
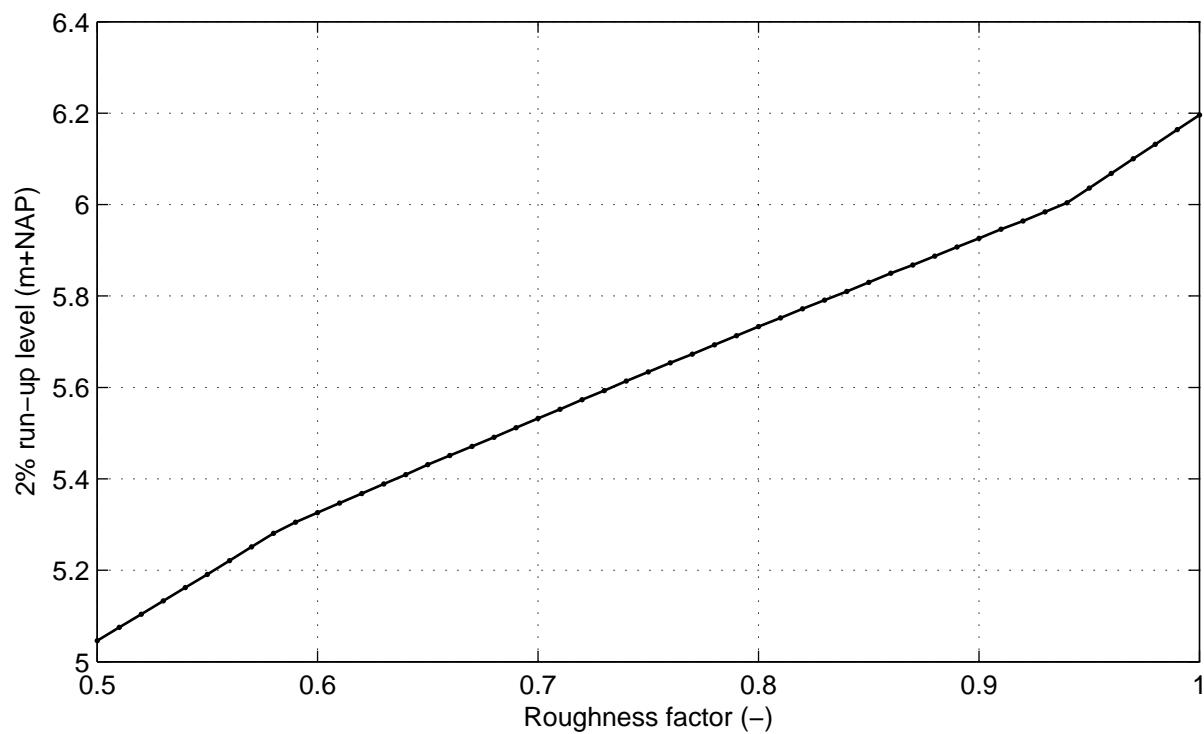
Cross section nr 3; series nr 14; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.14



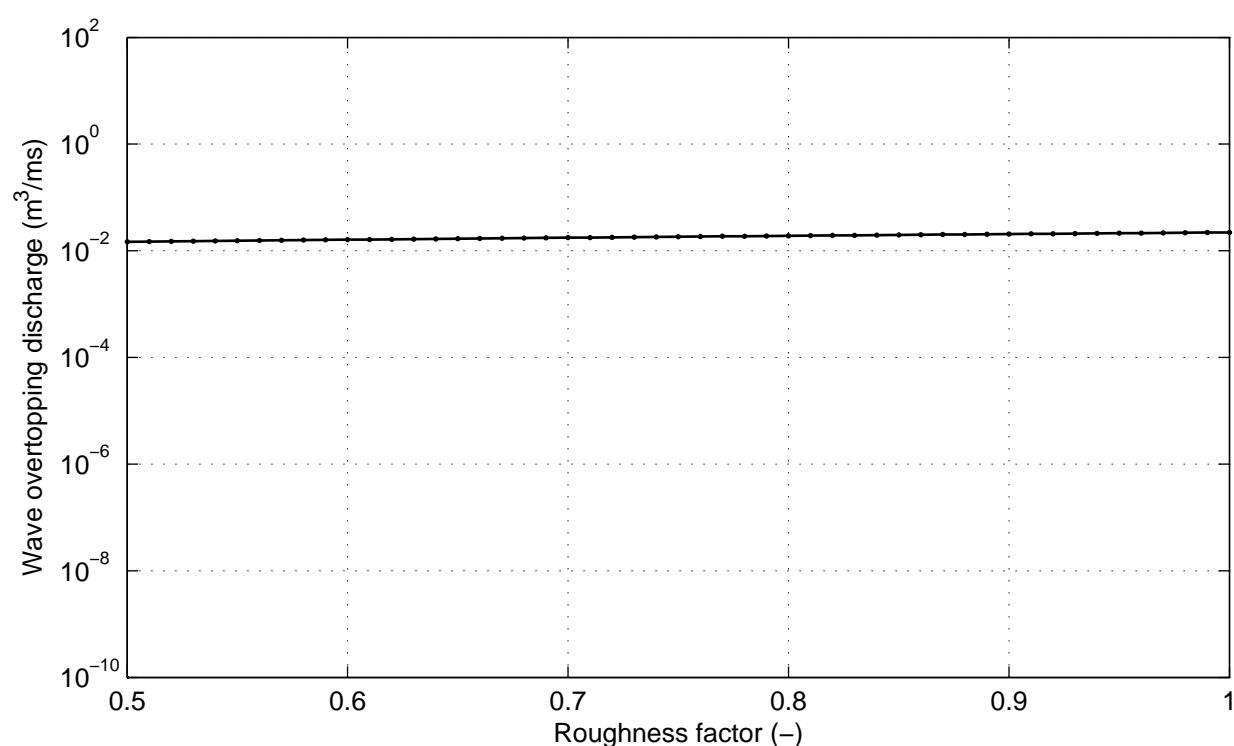
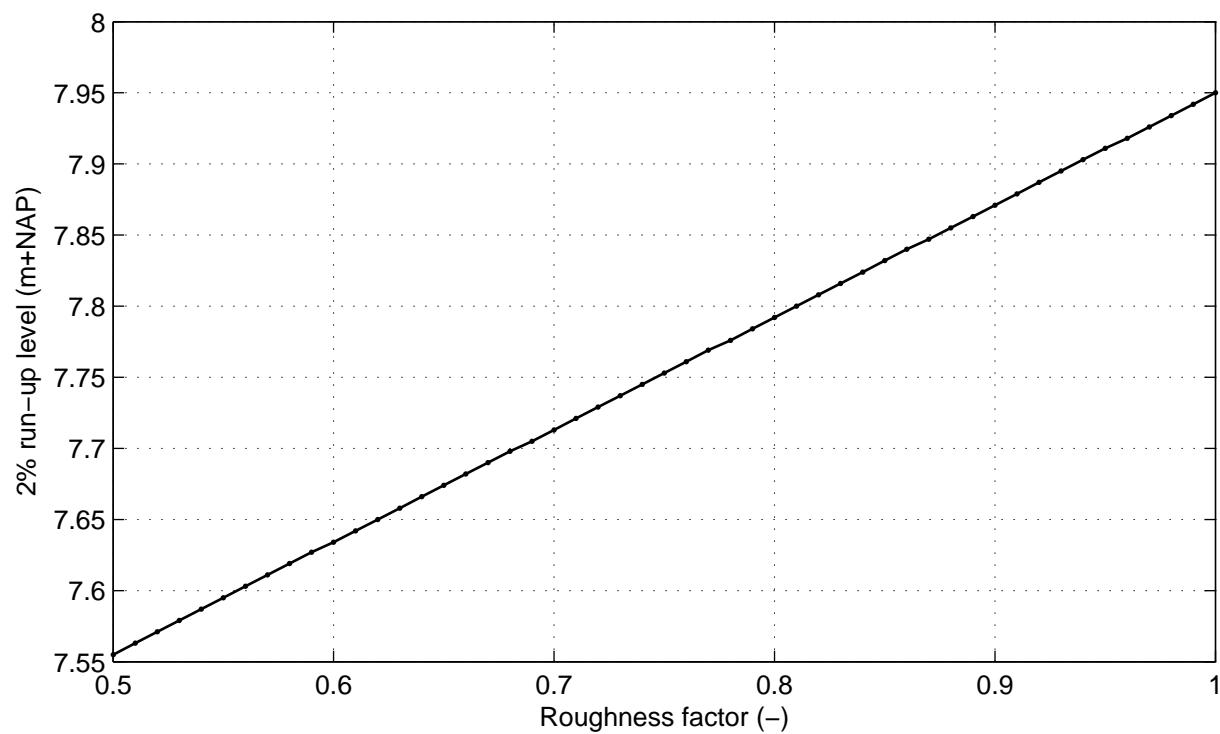
Cross section nr 3; series nr 15; Wave angle: 85 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.15



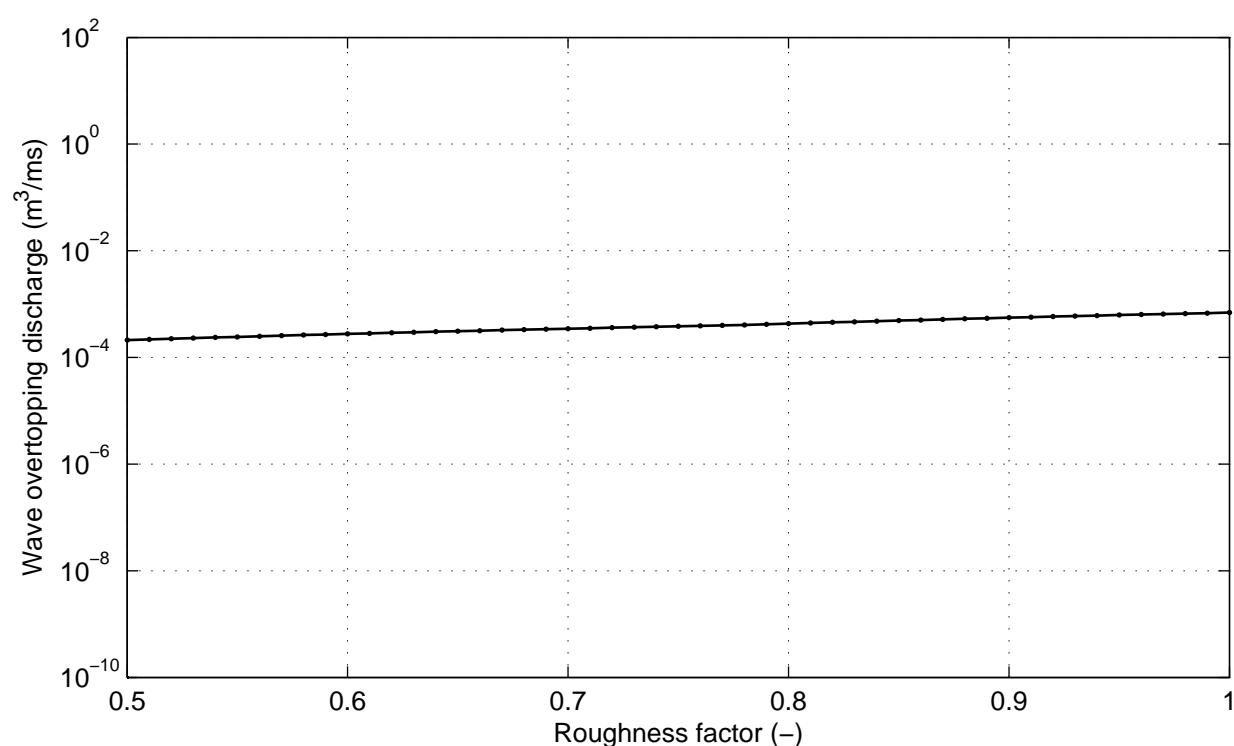
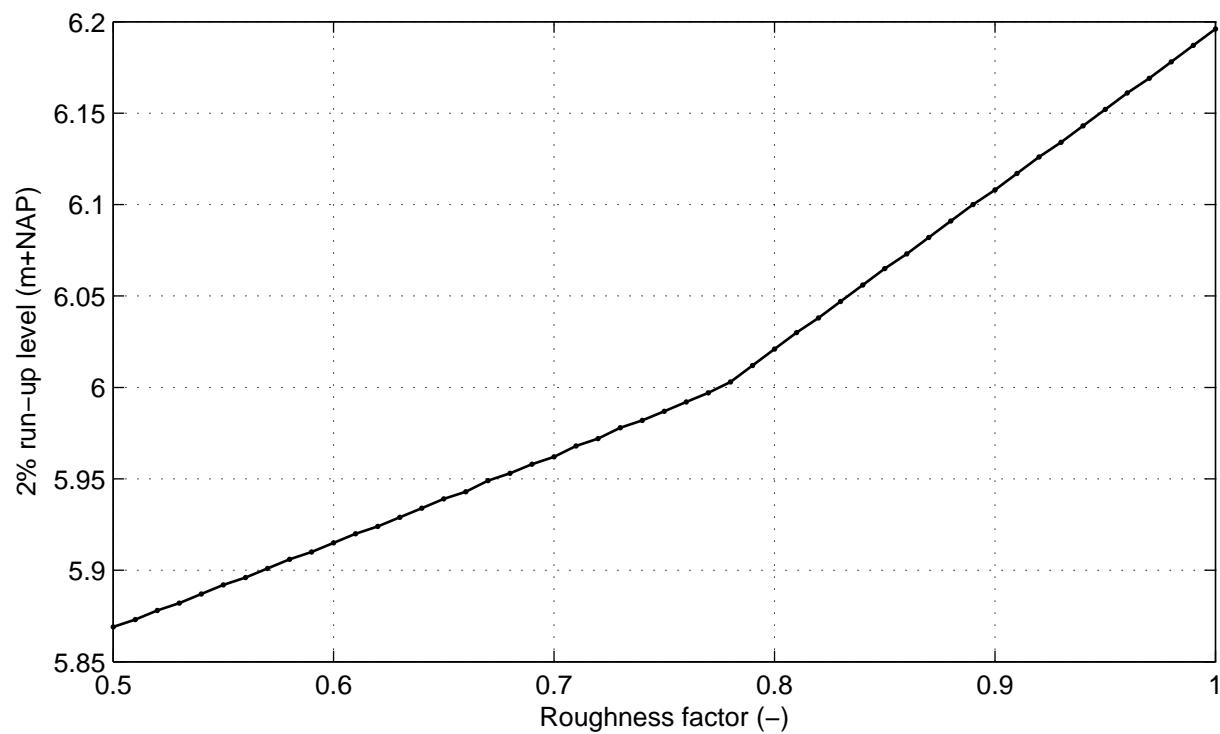
Cross section nr 3; series nr 16; Wave angle: 0 °
Varying roughness lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.16



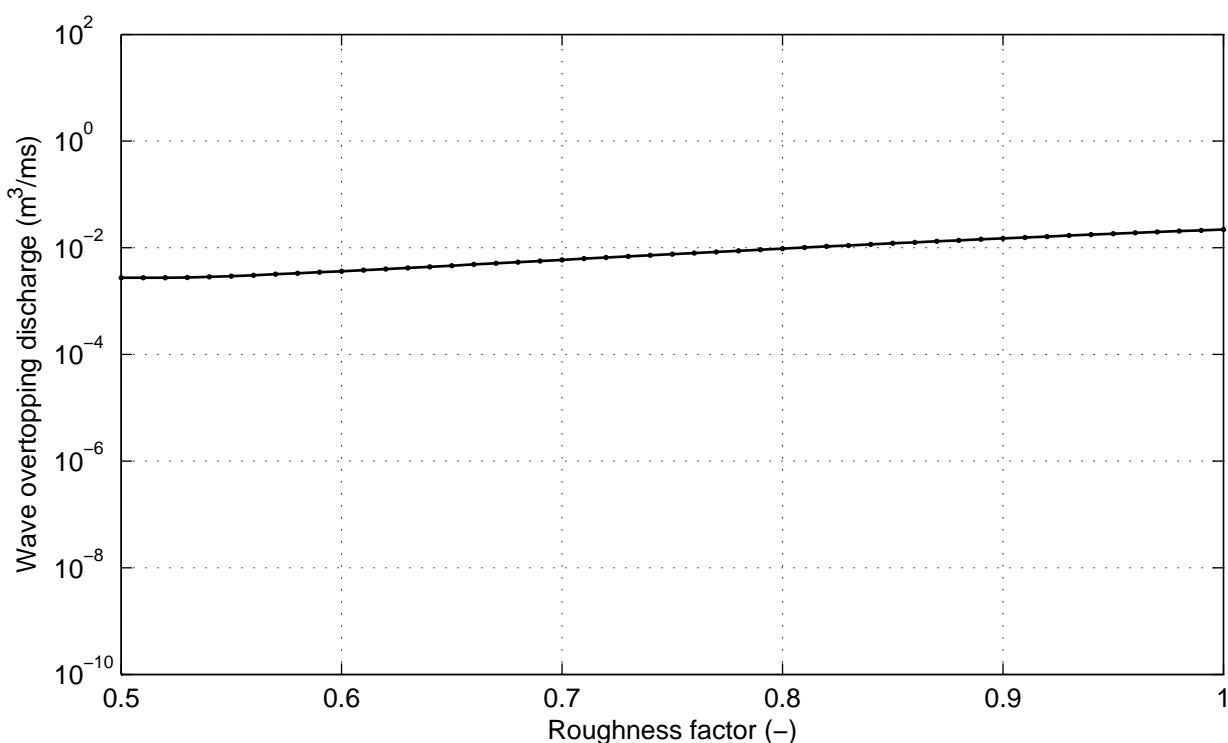
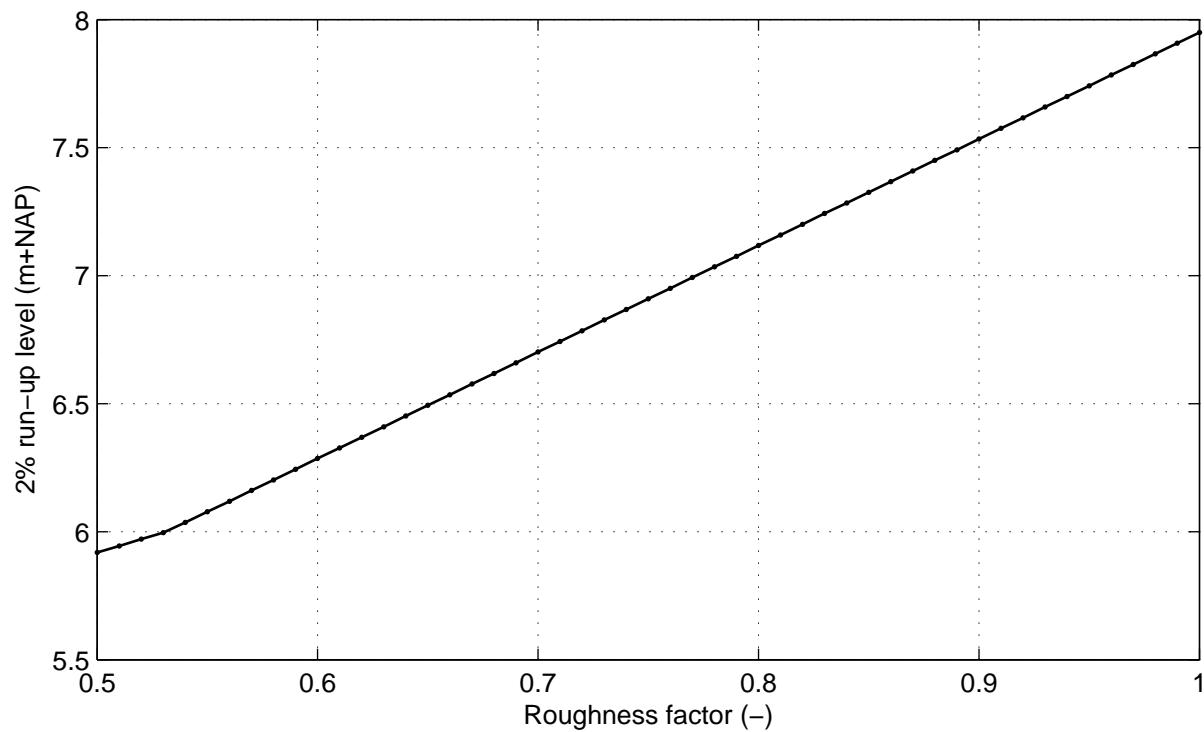
Cross section nr 3; series nr 17; Wave angle: 85 °
Varying roughness lower segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.17



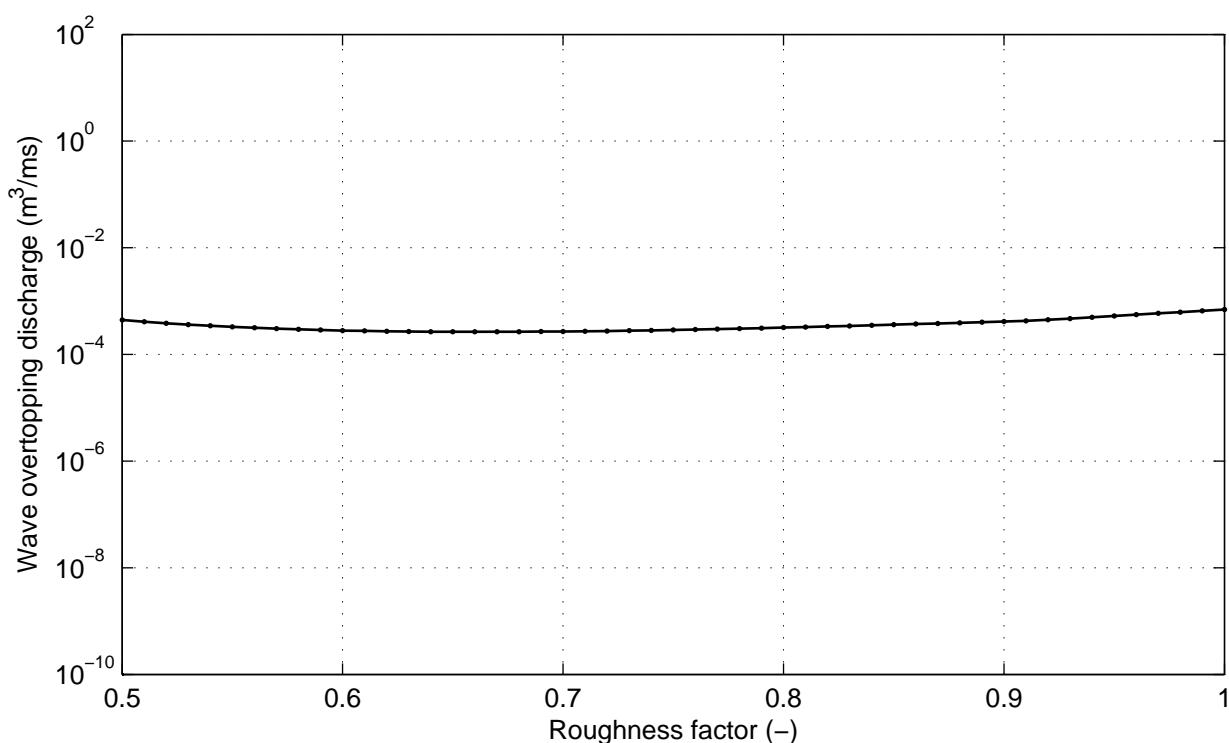
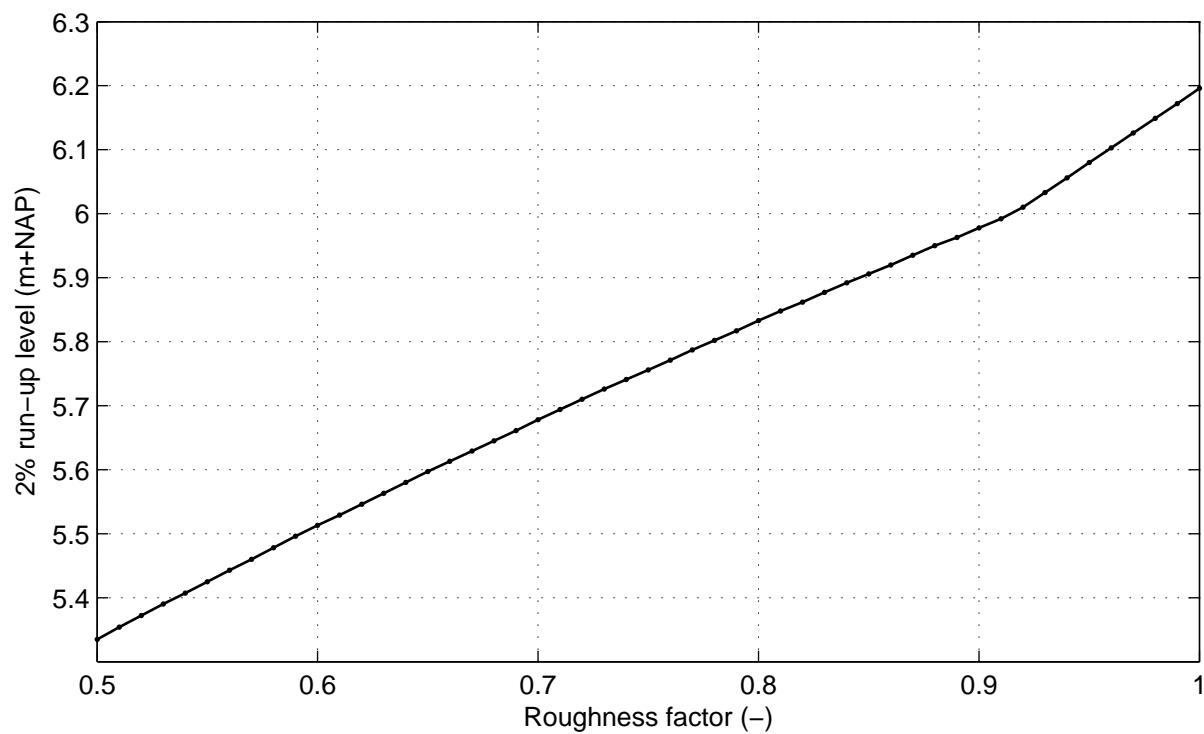
Cross section nr 3; series nr 18; Wave angle: 0 °
Varying roughness upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.18



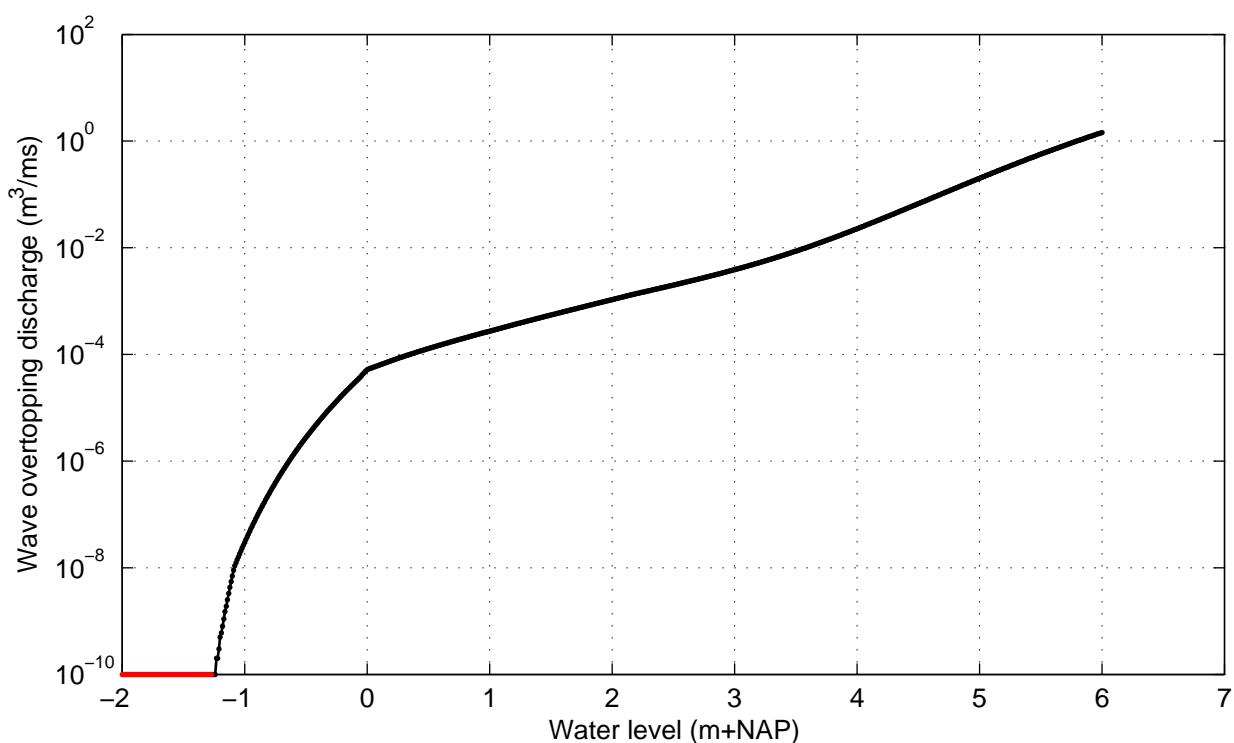
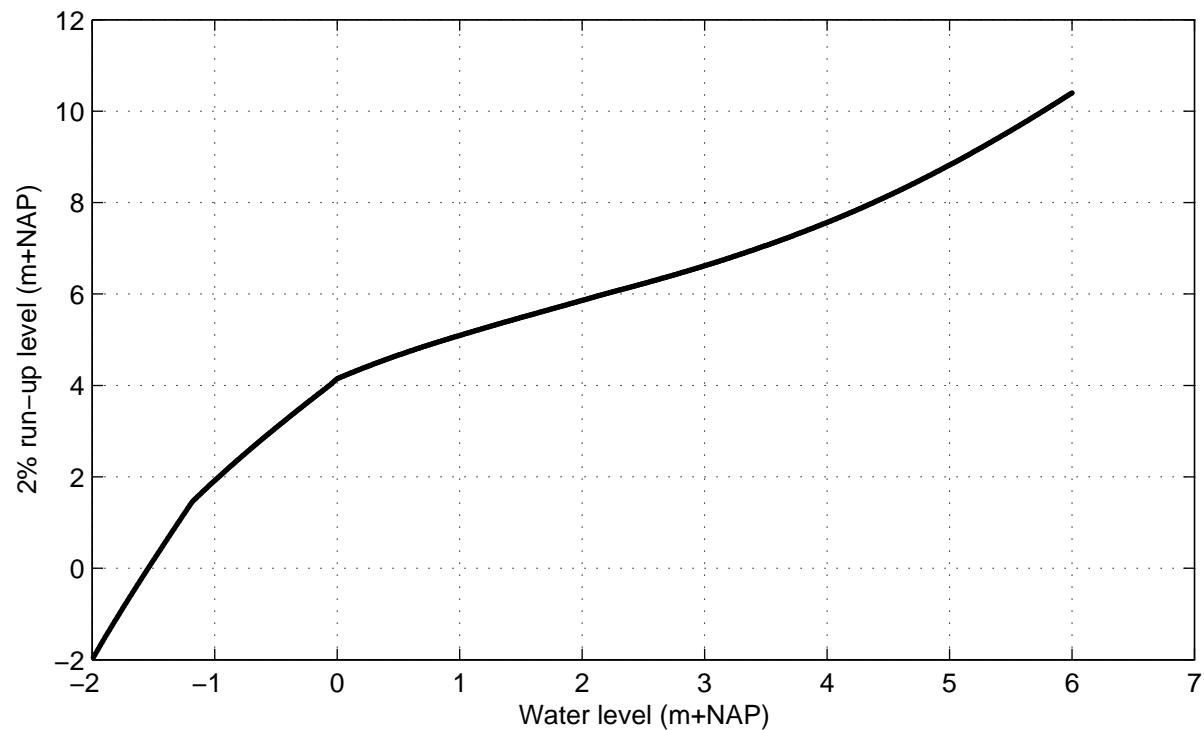
Cross section nr 3; series nr 19; Wave angle: 85 °
Varying roughness upper segment

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 3.19



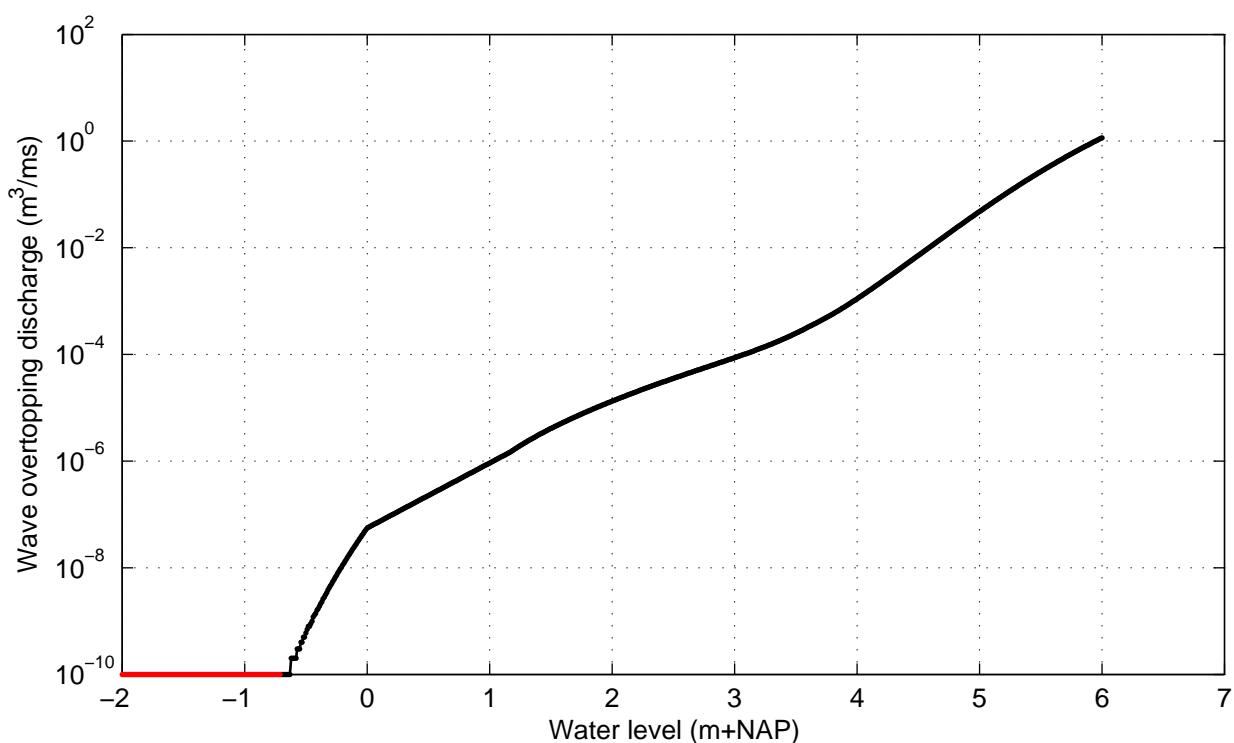
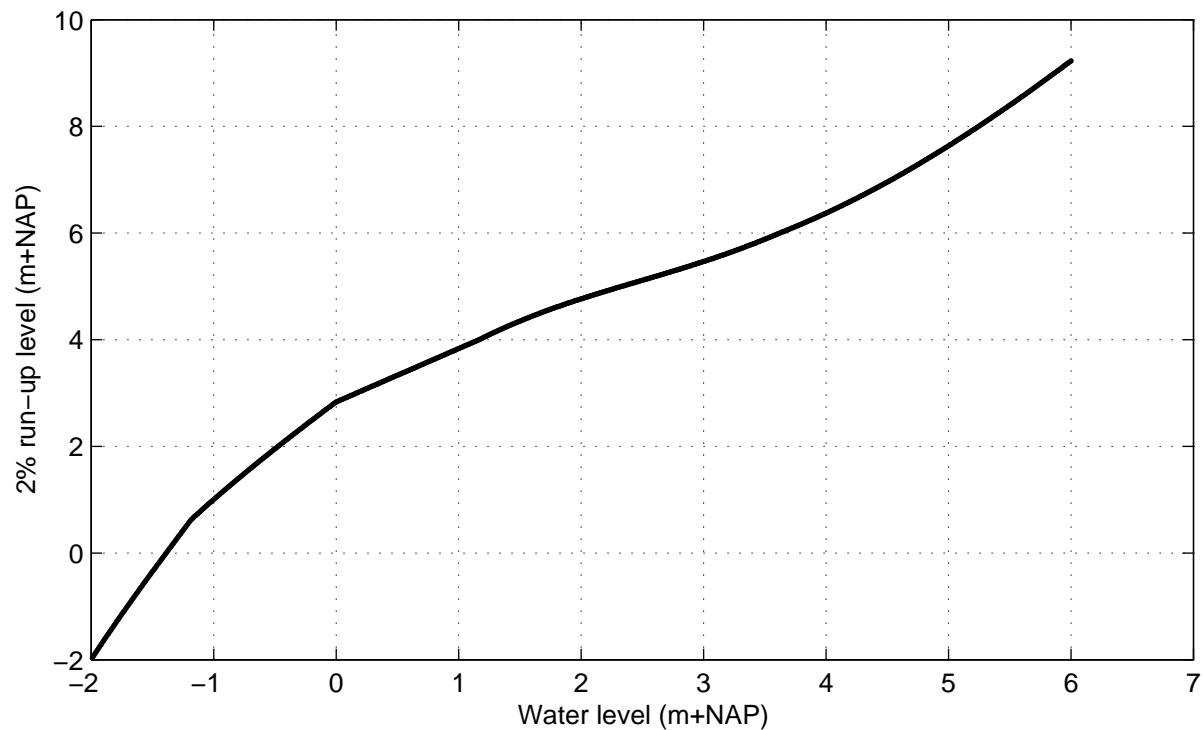
Cross section nr 4; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.1



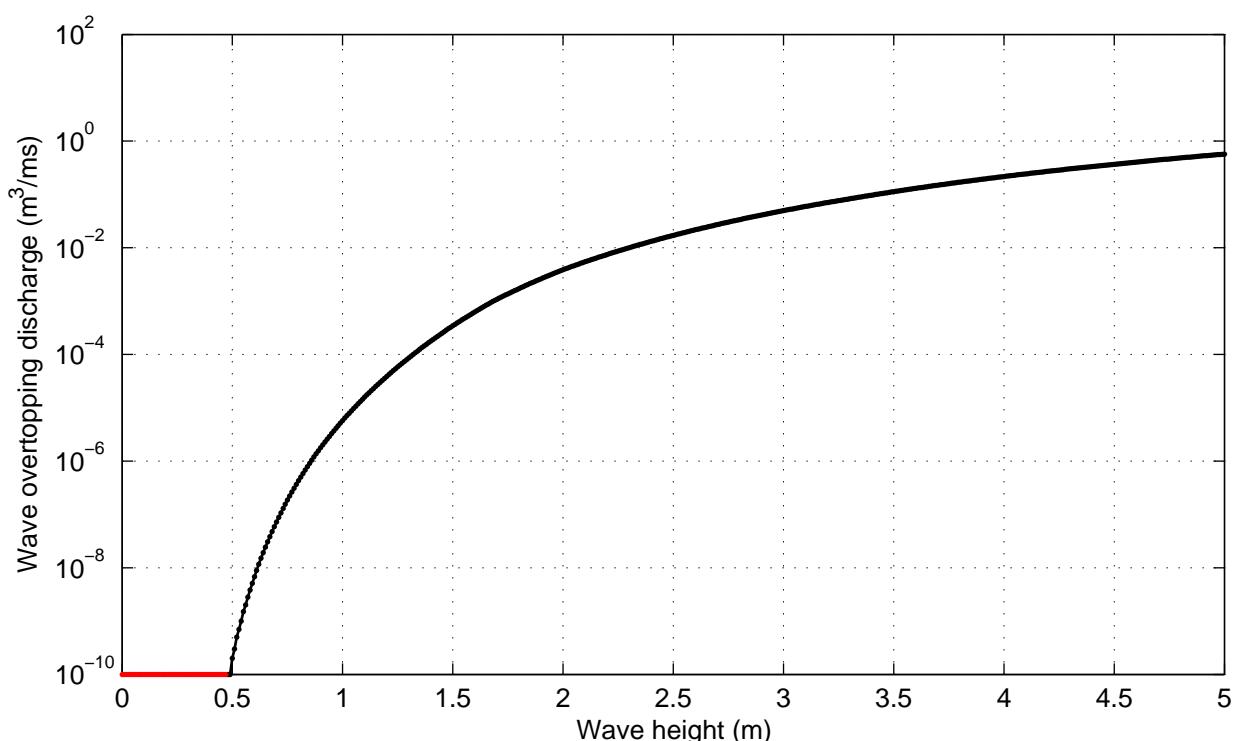
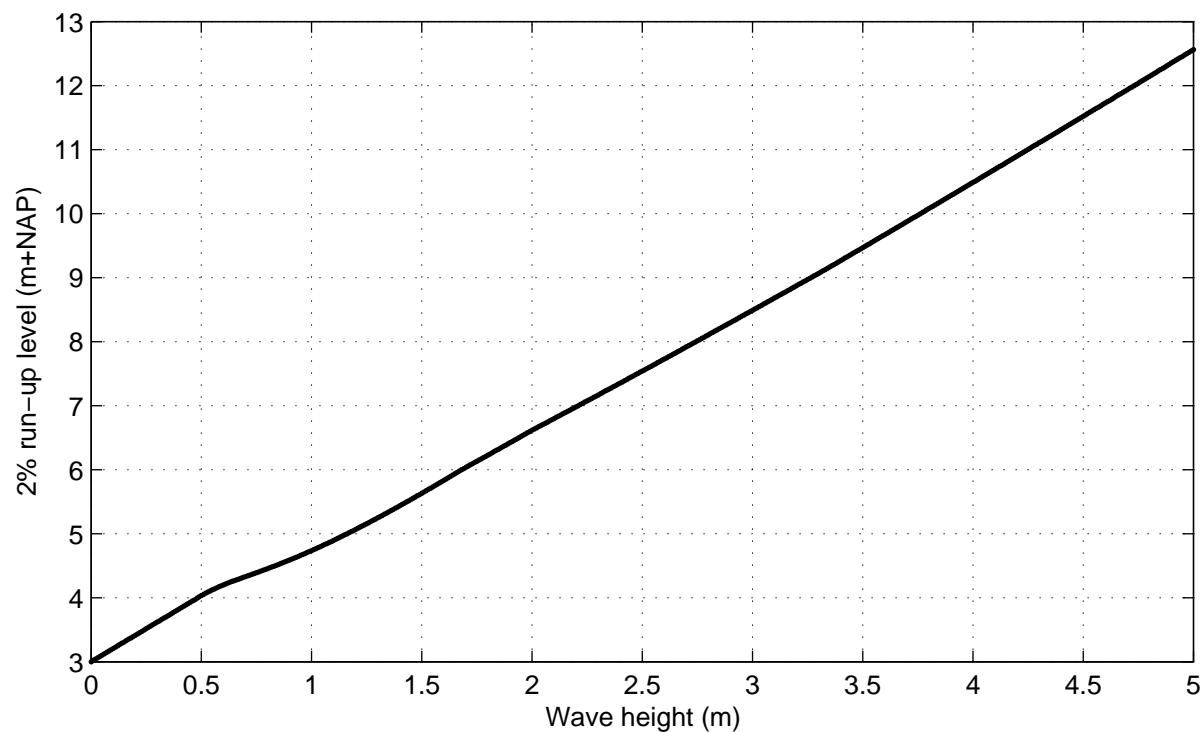
Cross section nr 4; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.2



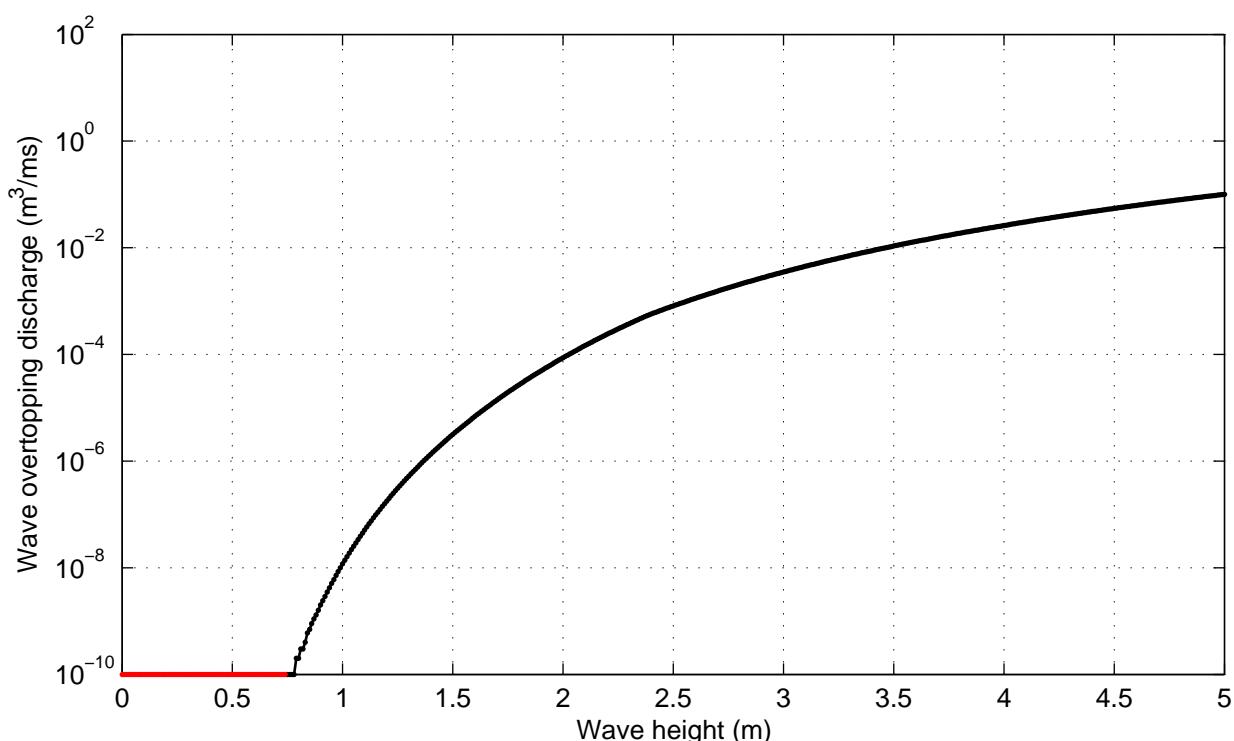
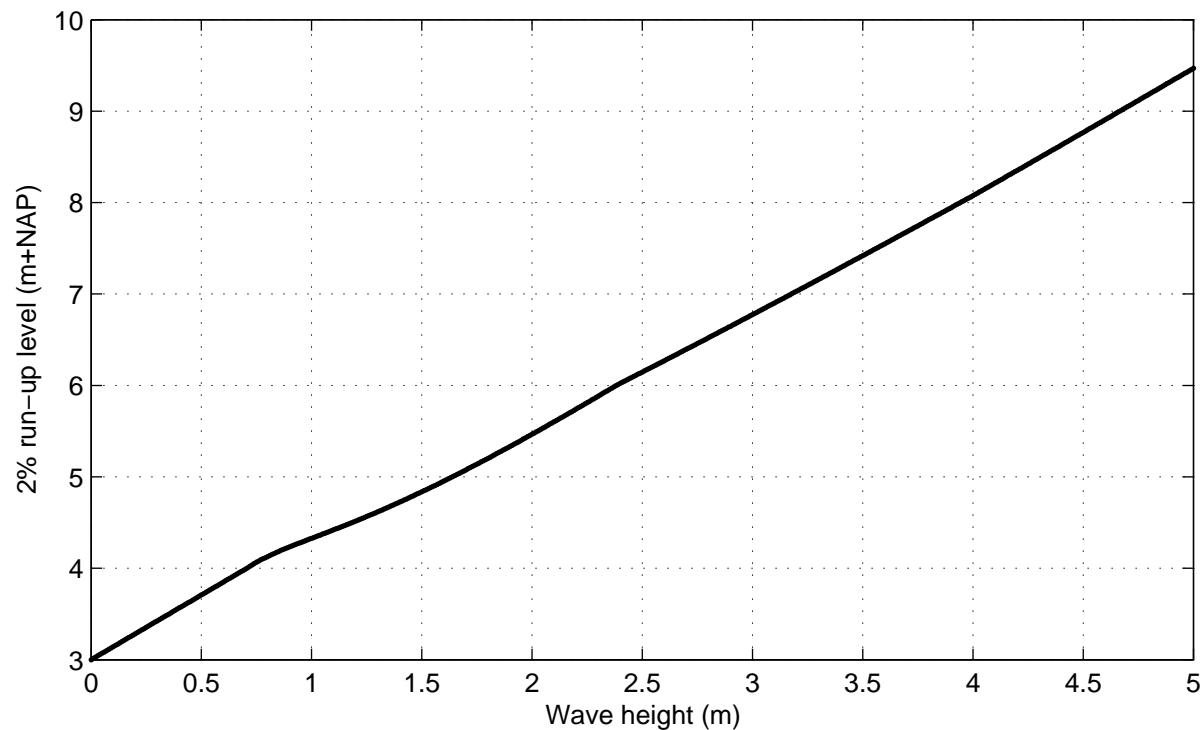
Cross section nr 4; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.3



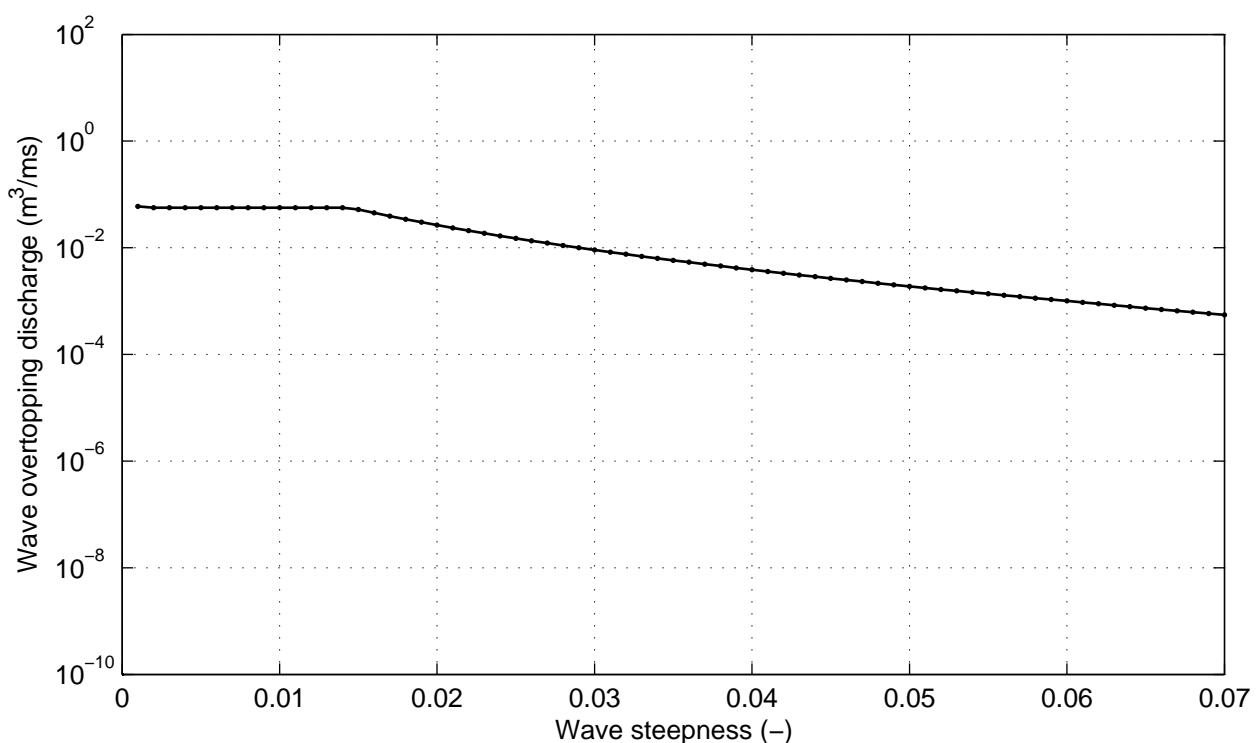
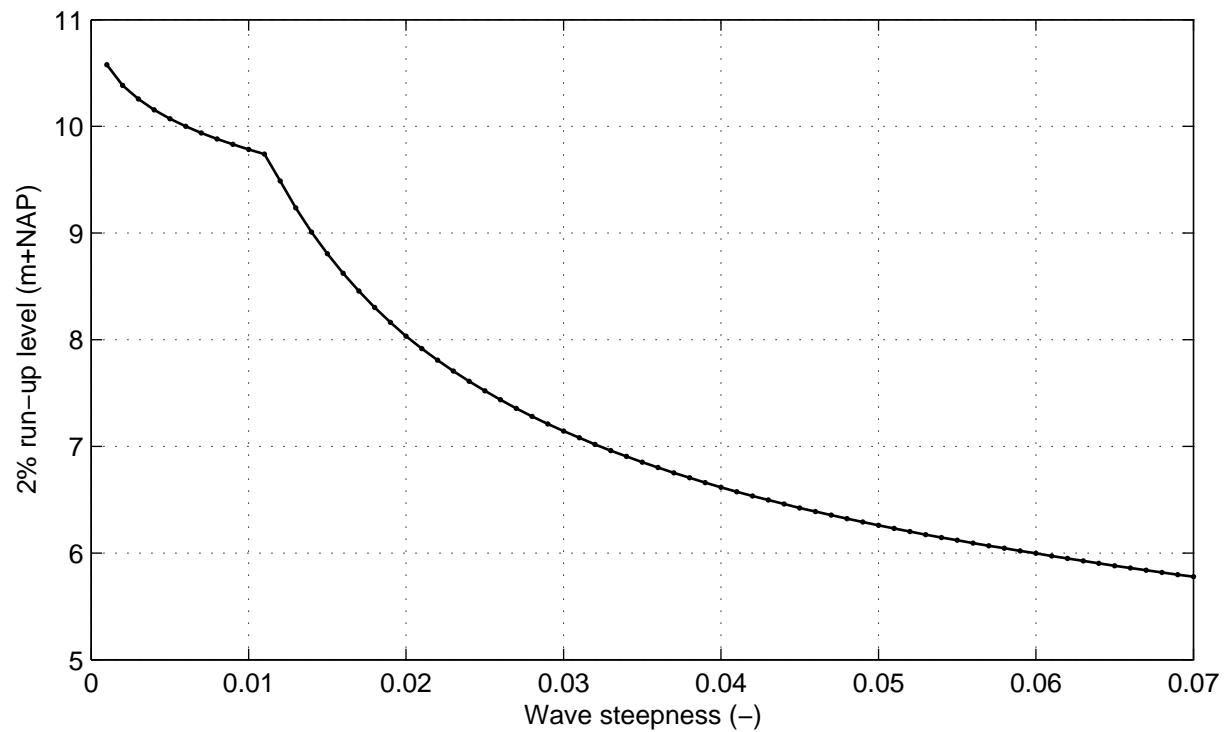
Cross section nr 4; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.4



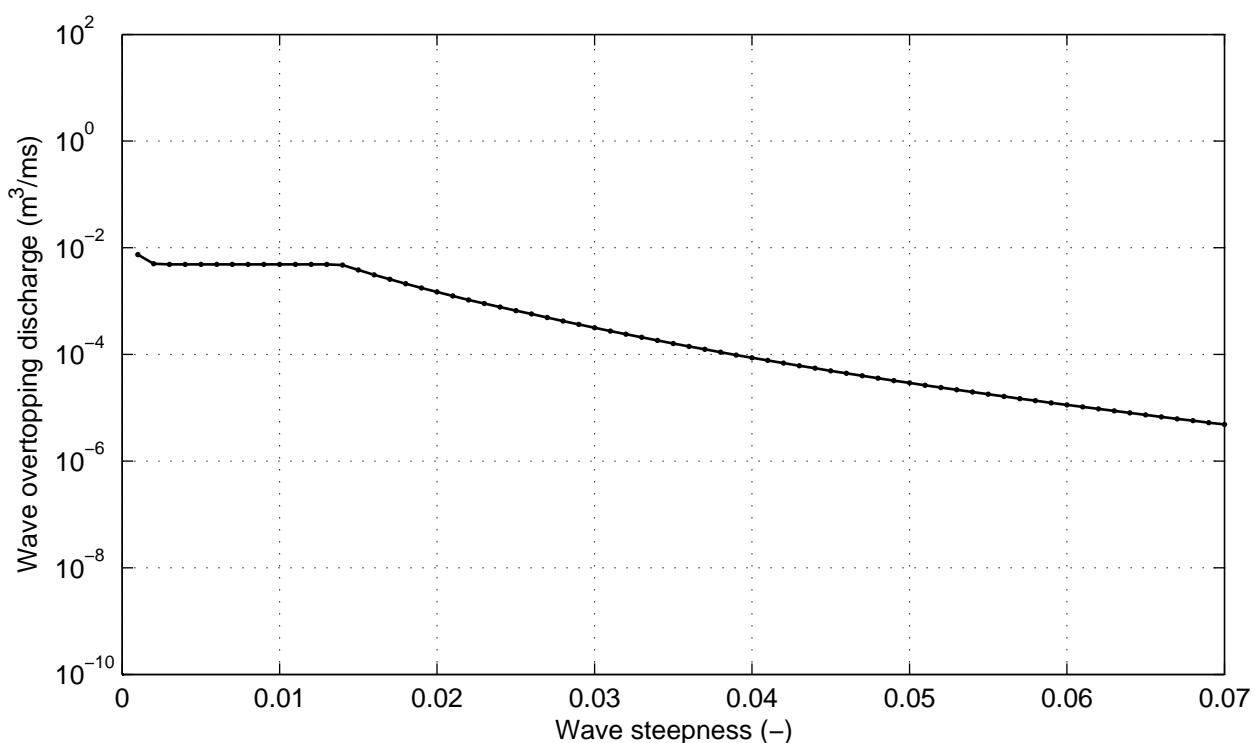
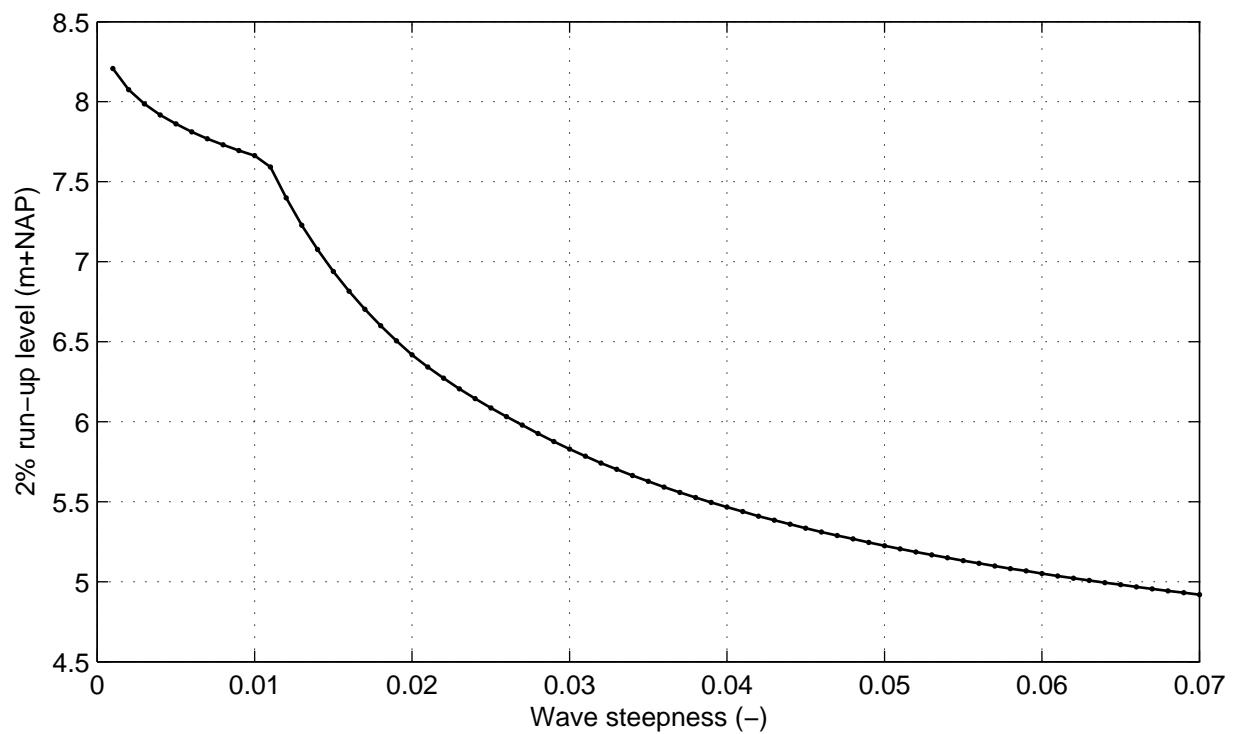
Cross section nr 4; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.5



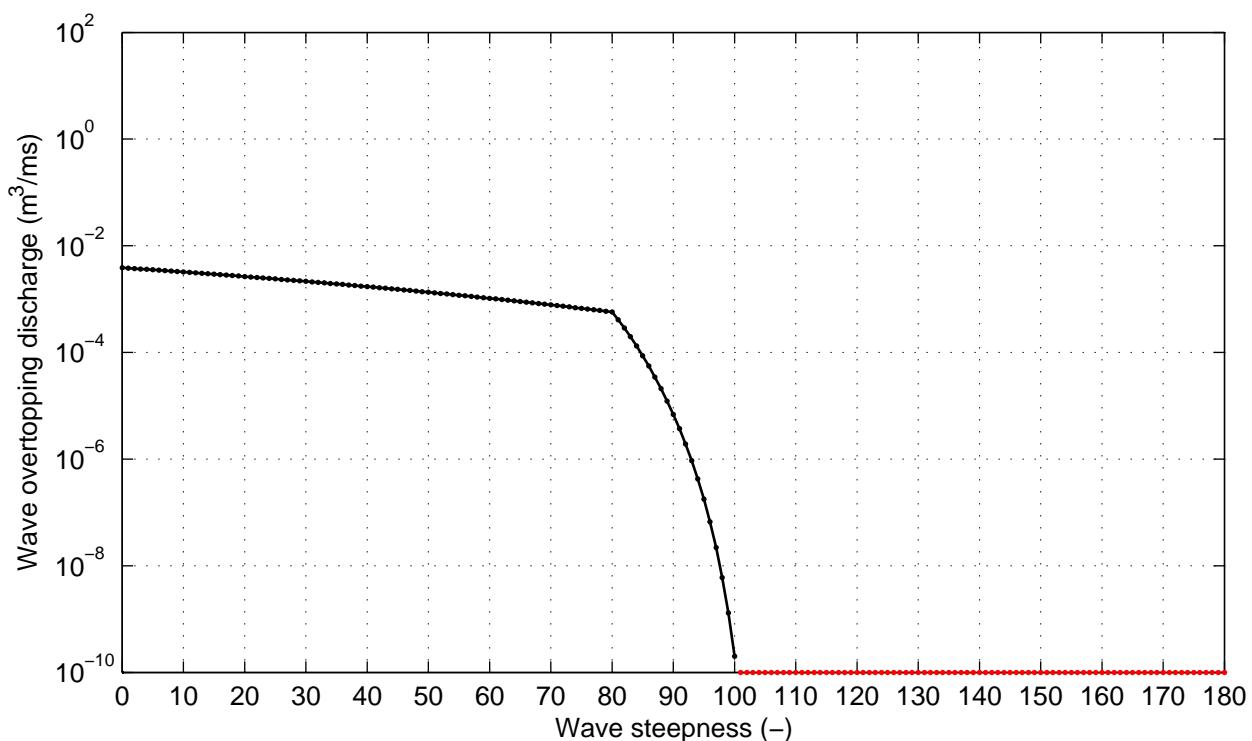
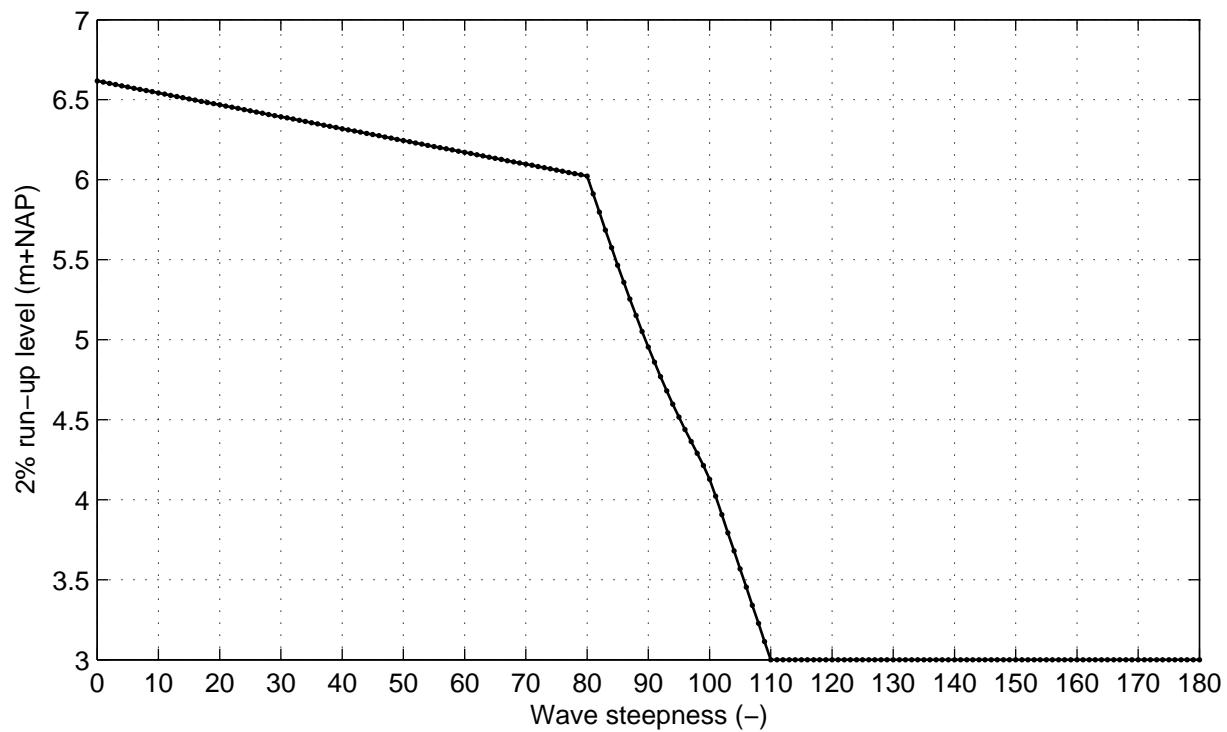
Cross section nr 4; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.6



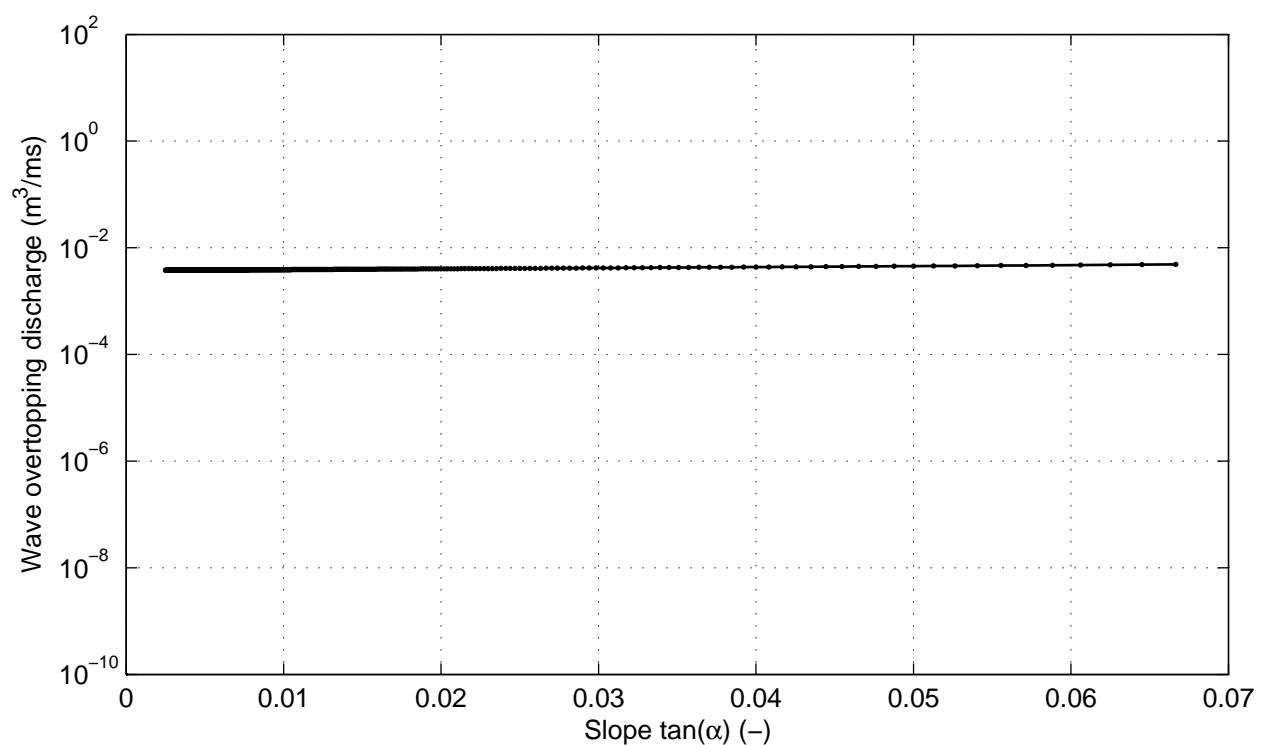
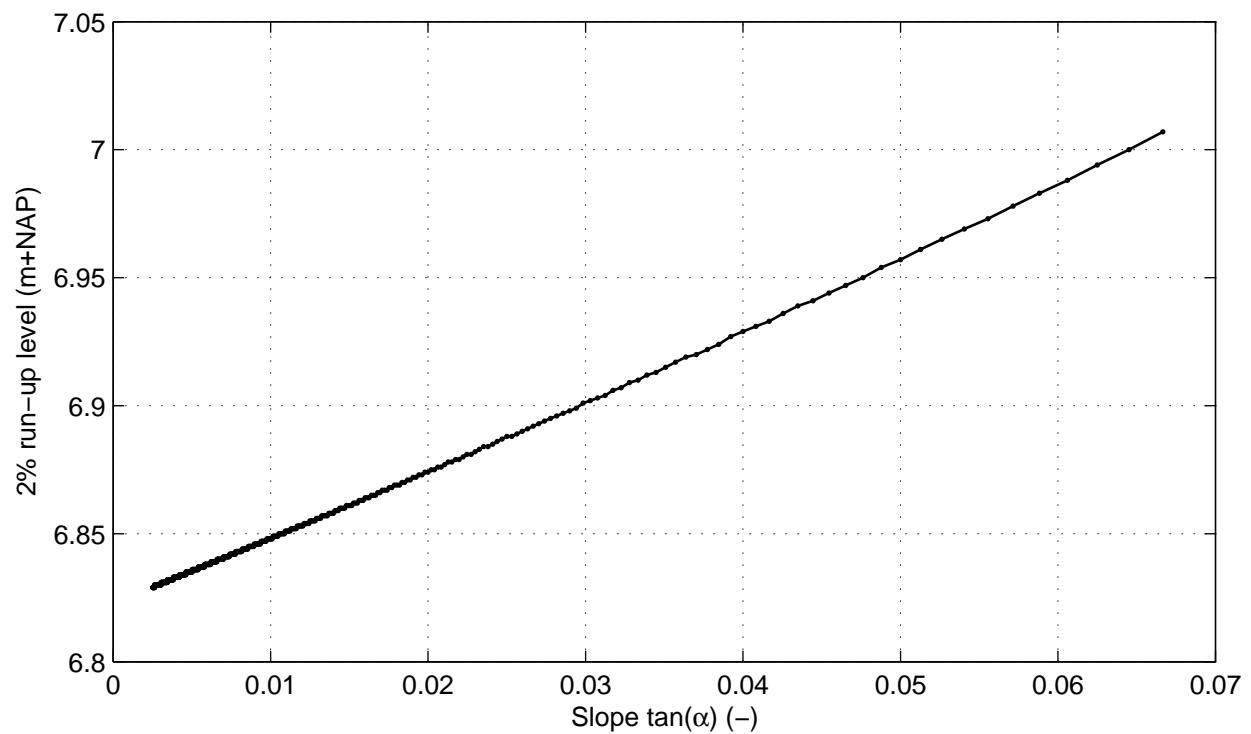
Cross section nr 4; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.7



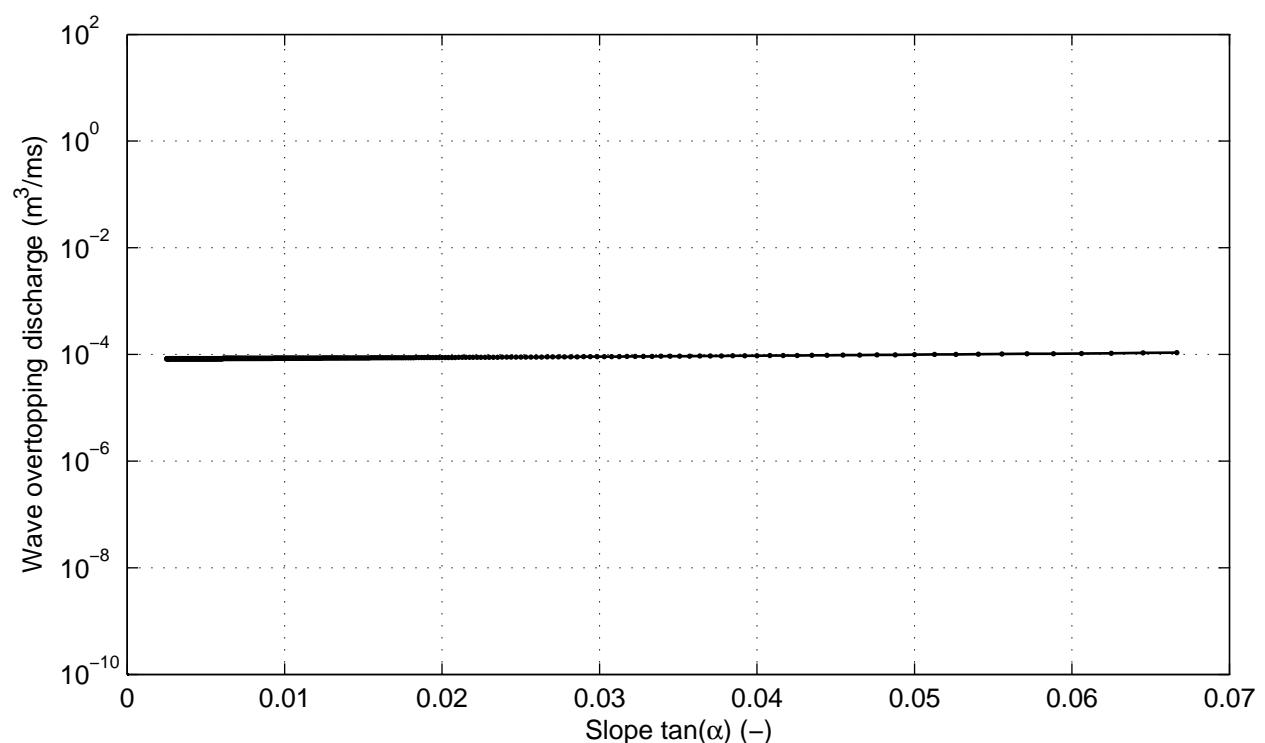
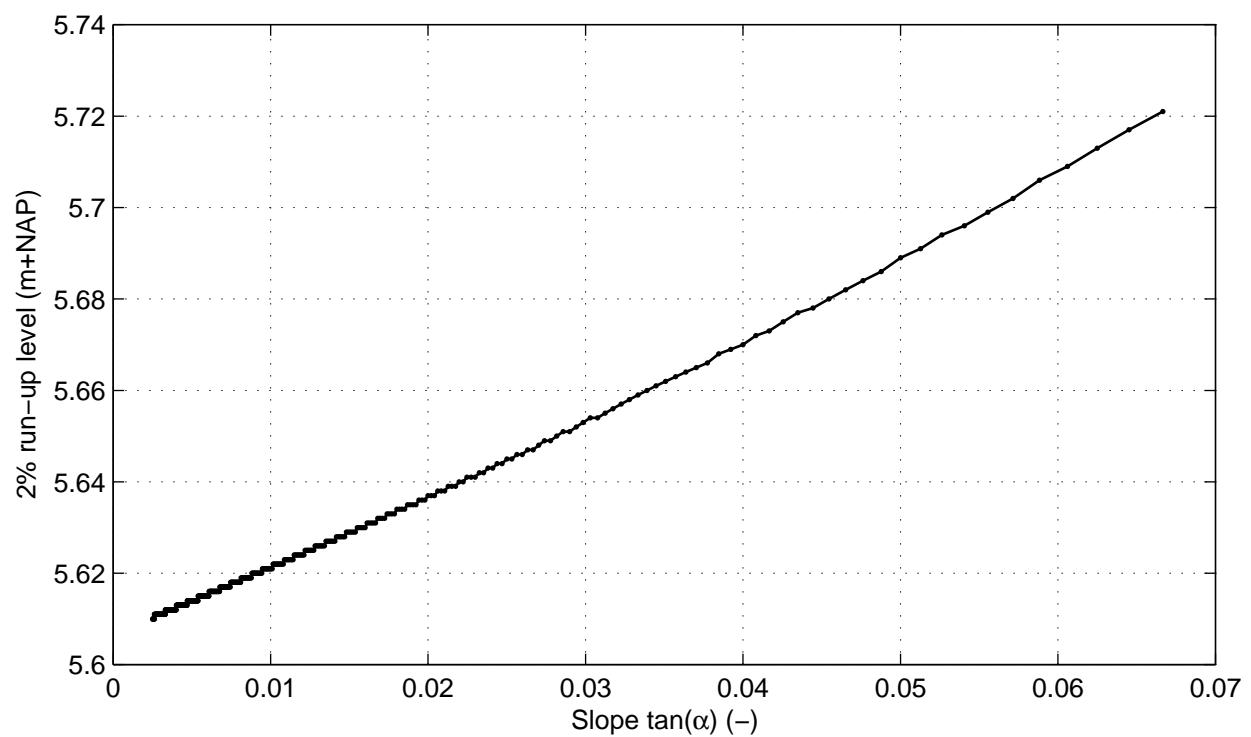
Cross section nr 4; series nr 8; Wave angle: 0 °
Varying slope of all berm segments as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.8



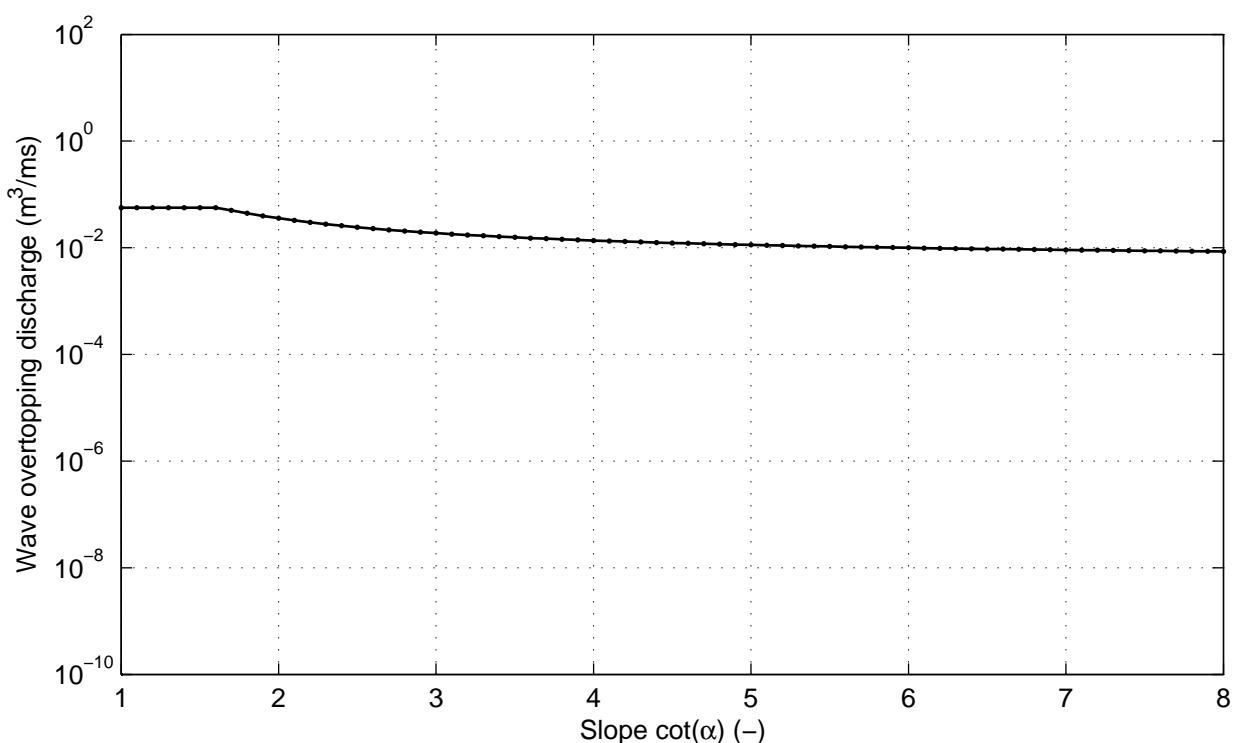
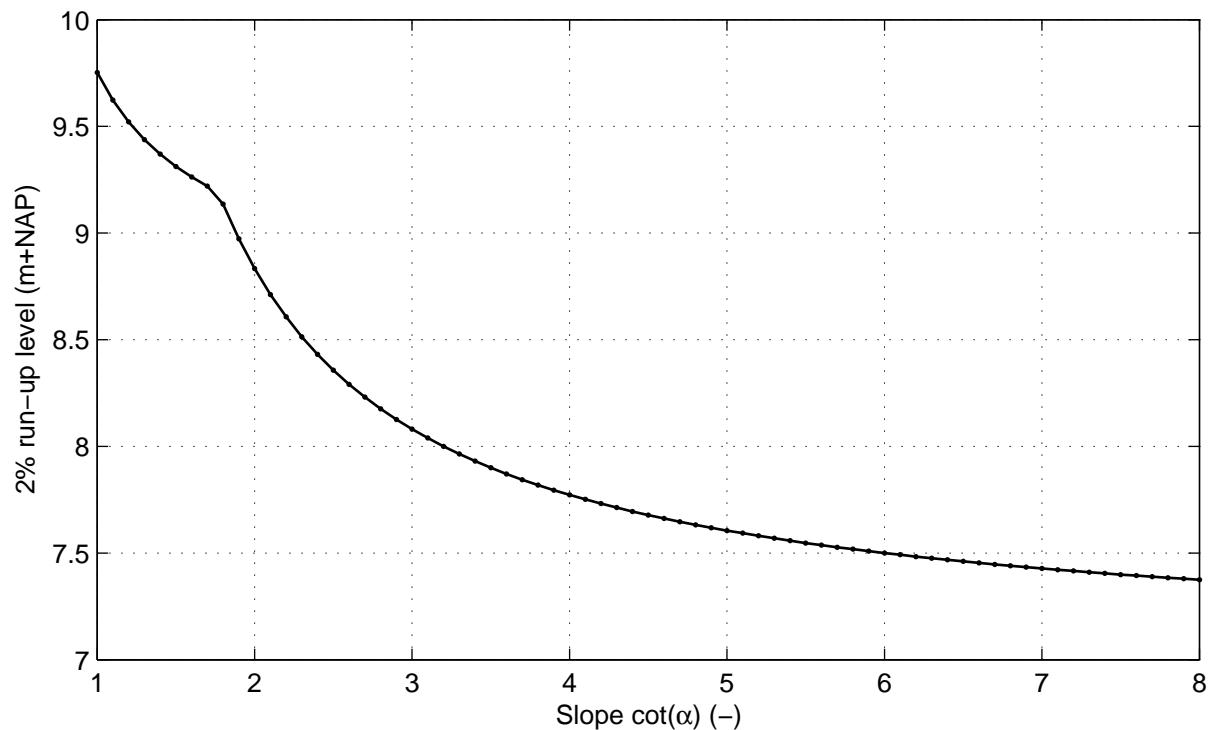
Cross section nr 4; series nr 9; Wave angle: 85 °
Varying slope of all berm segments as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.9



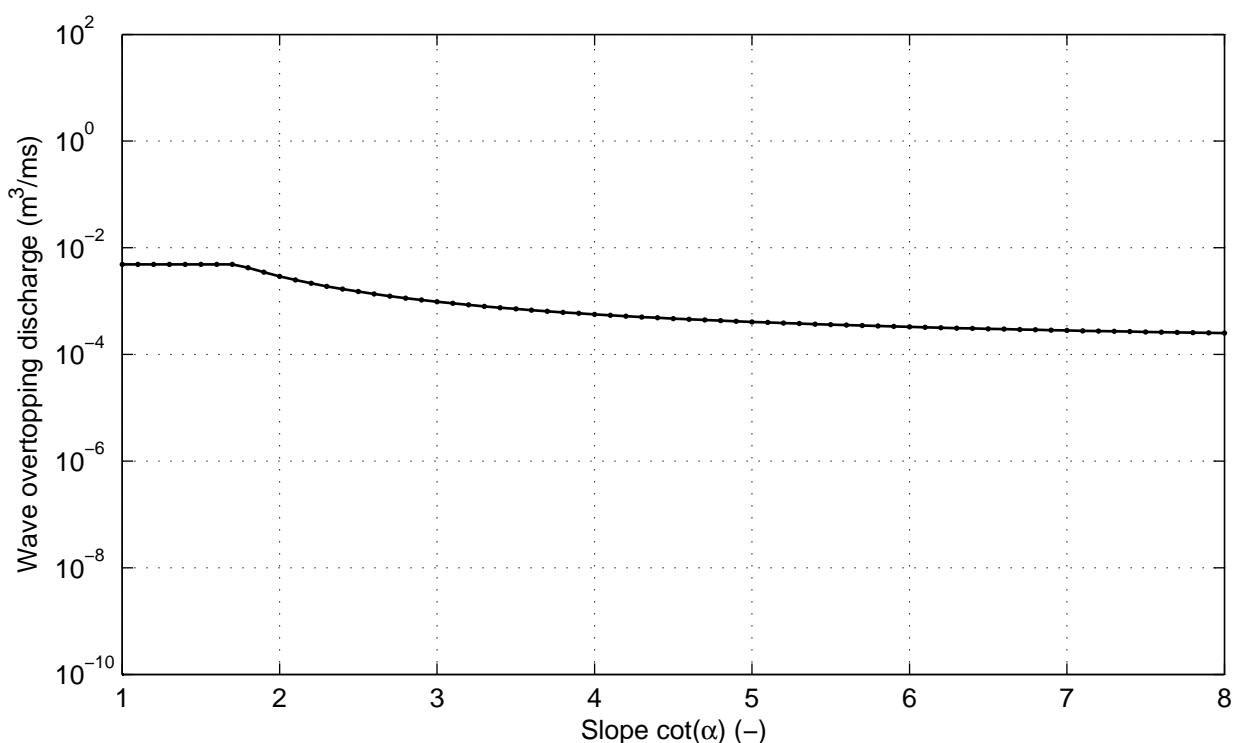
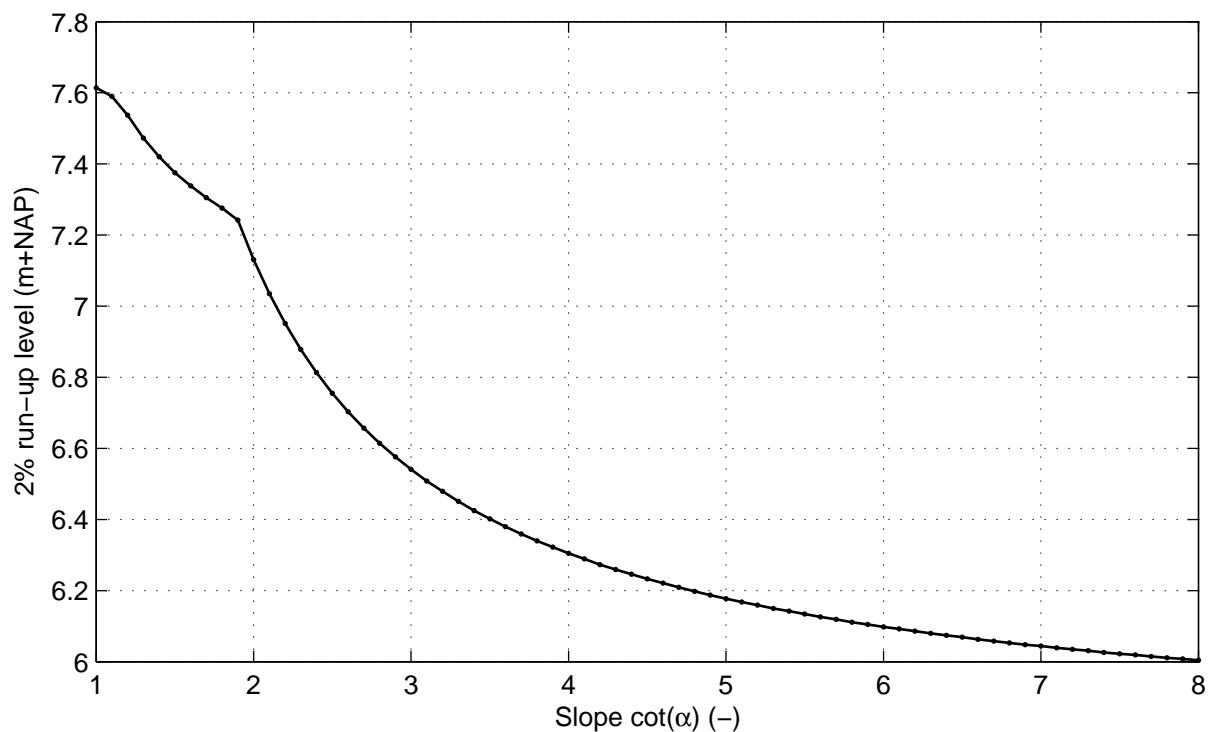
Cross section nr 4; series nr 8; Wave angle: 0 °
Varying slope of all berm segments as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.10



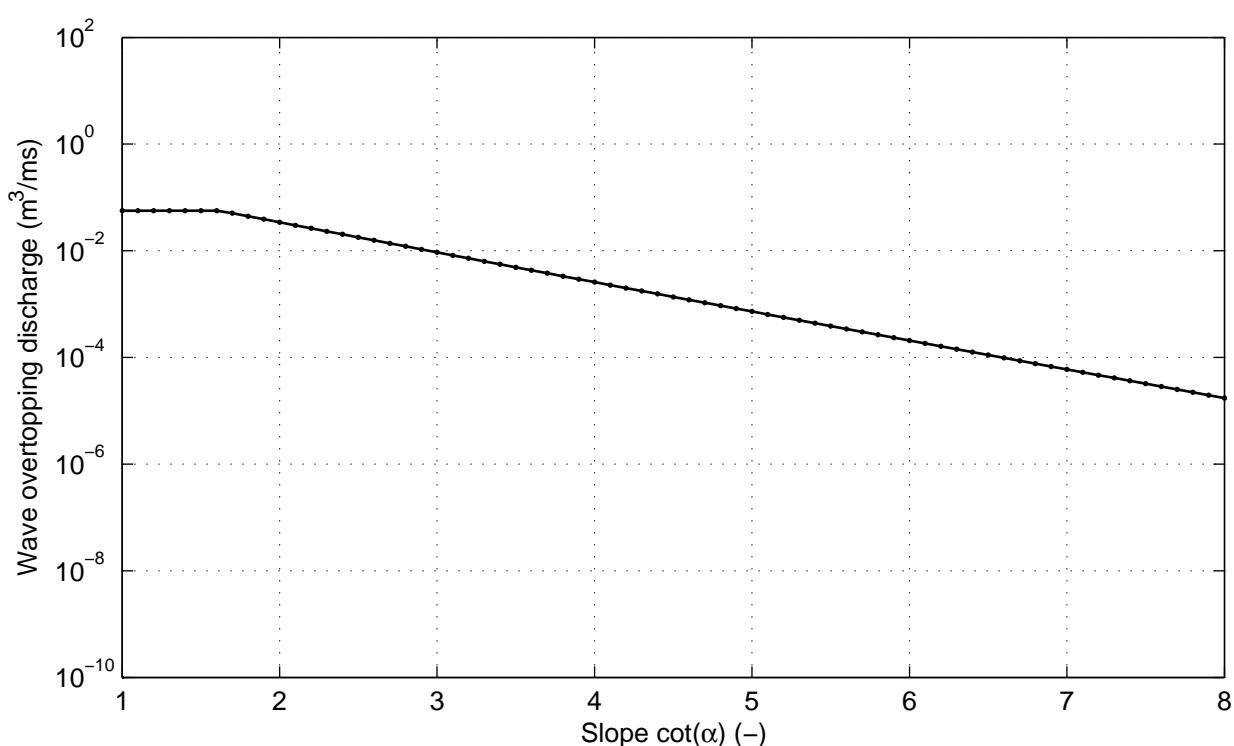
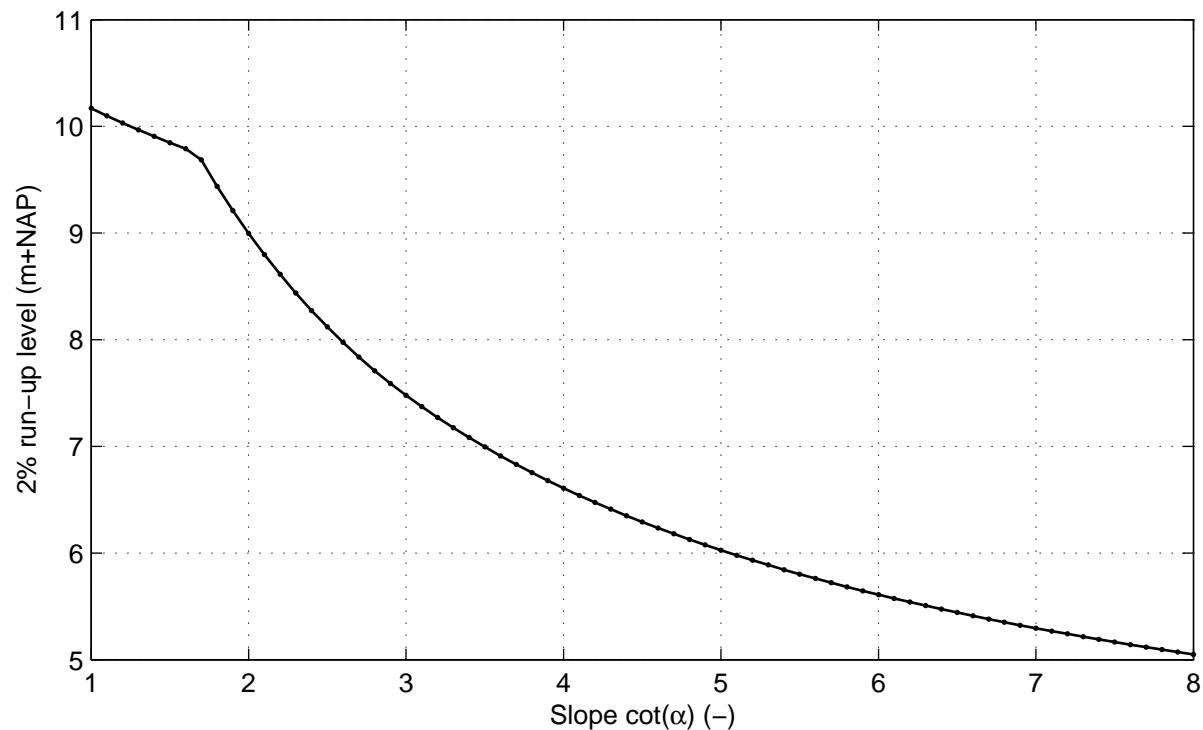
Cross section nr 4; series nr 9; Wave angle: 85 °
Varying slope of all berm segments as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.11



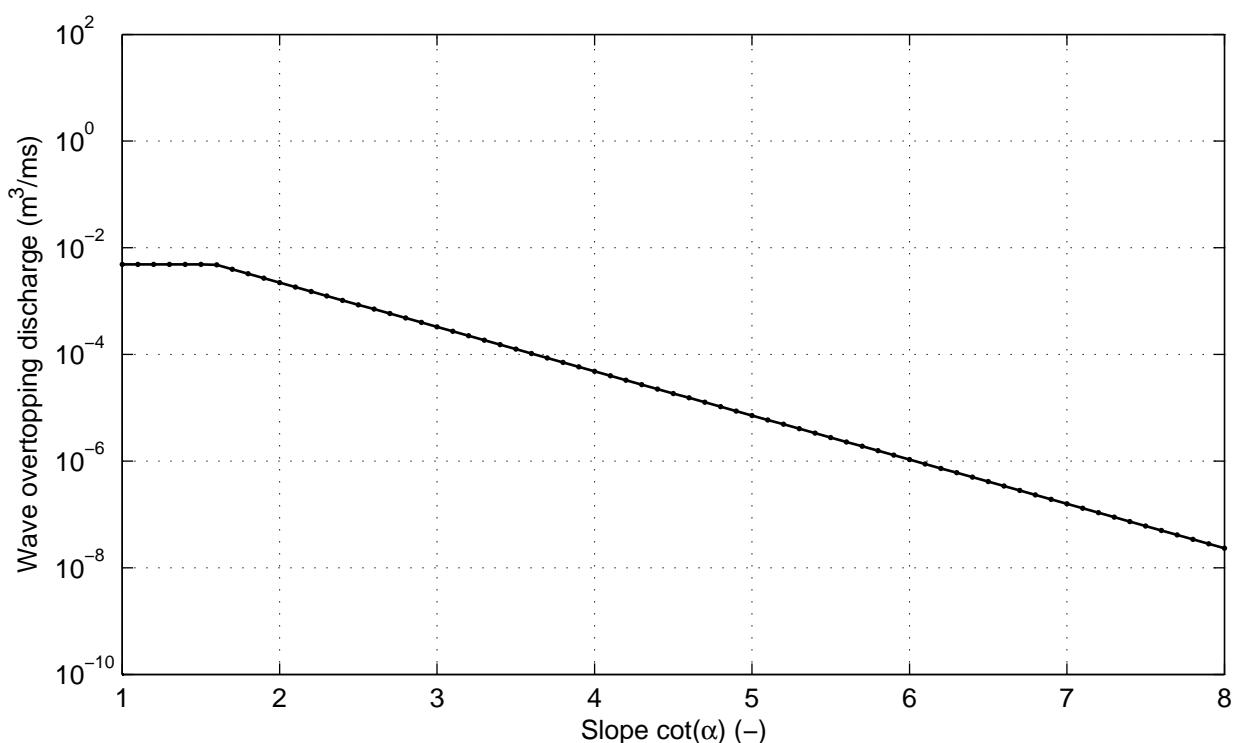
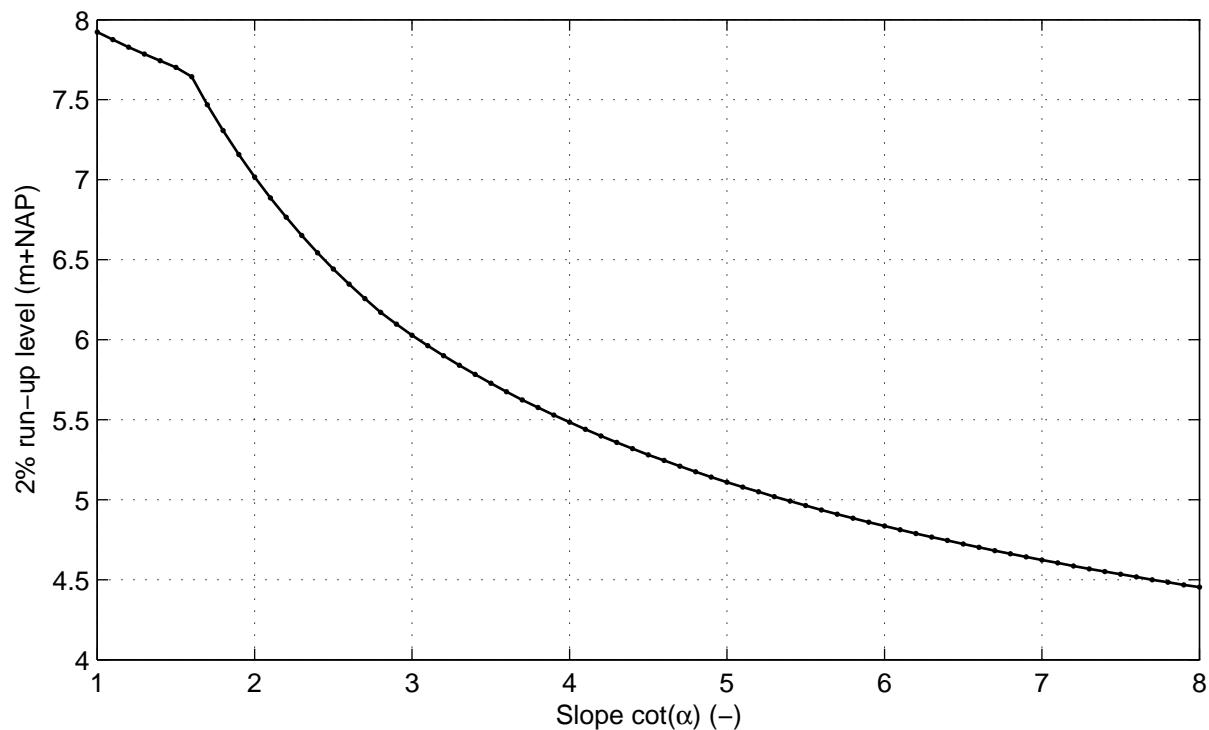
Cross section nr 4; series nr 10; Wave angle: 0 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.12



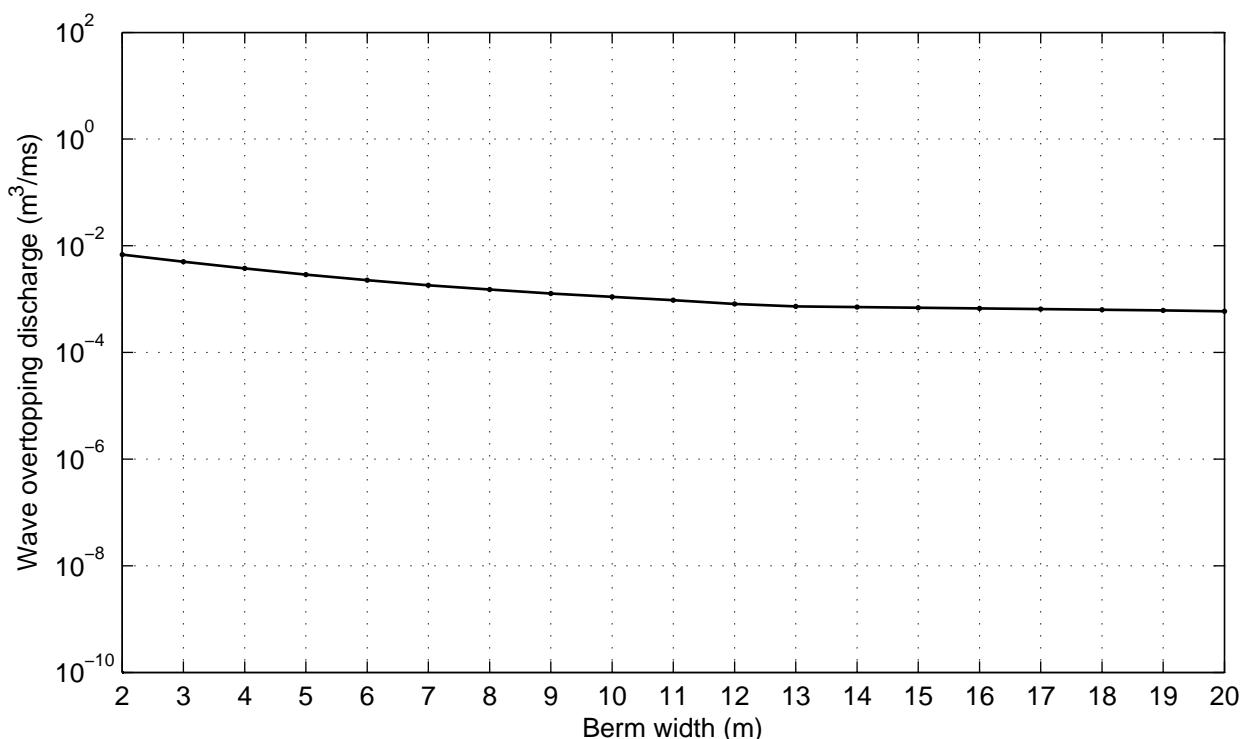
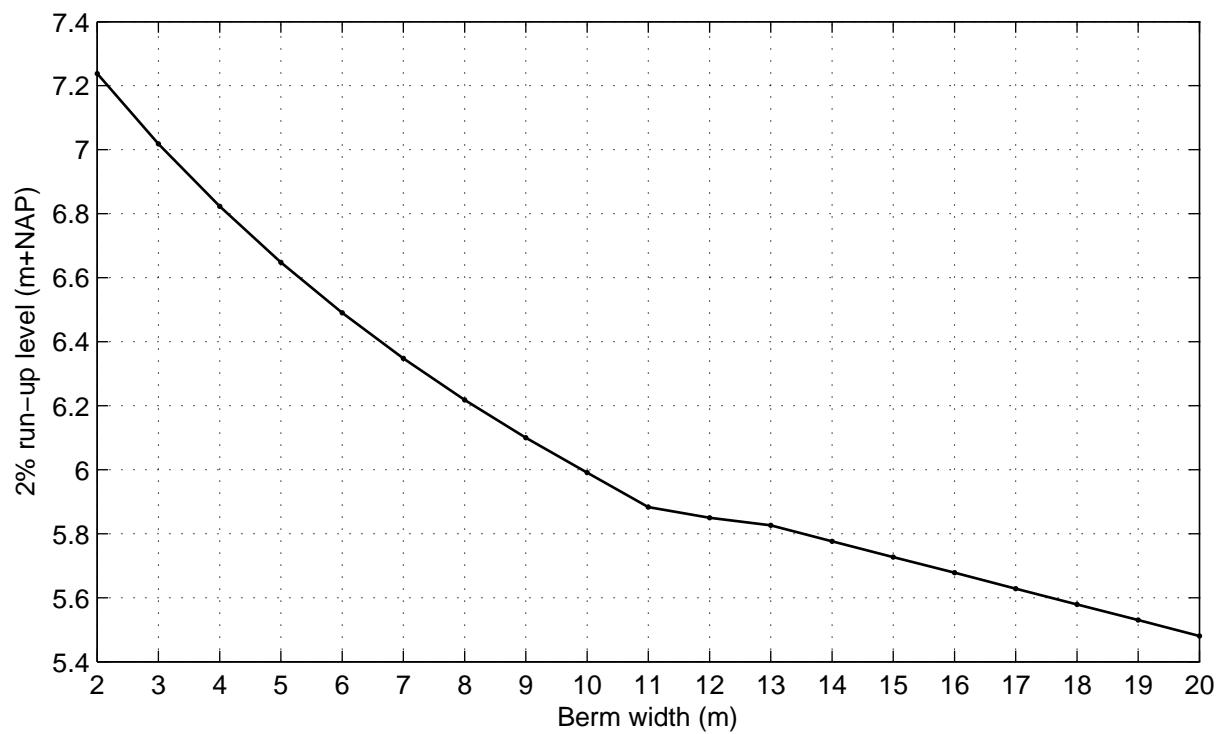
Cross section nr 4; series nr 11; Wave angle: 85 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.13



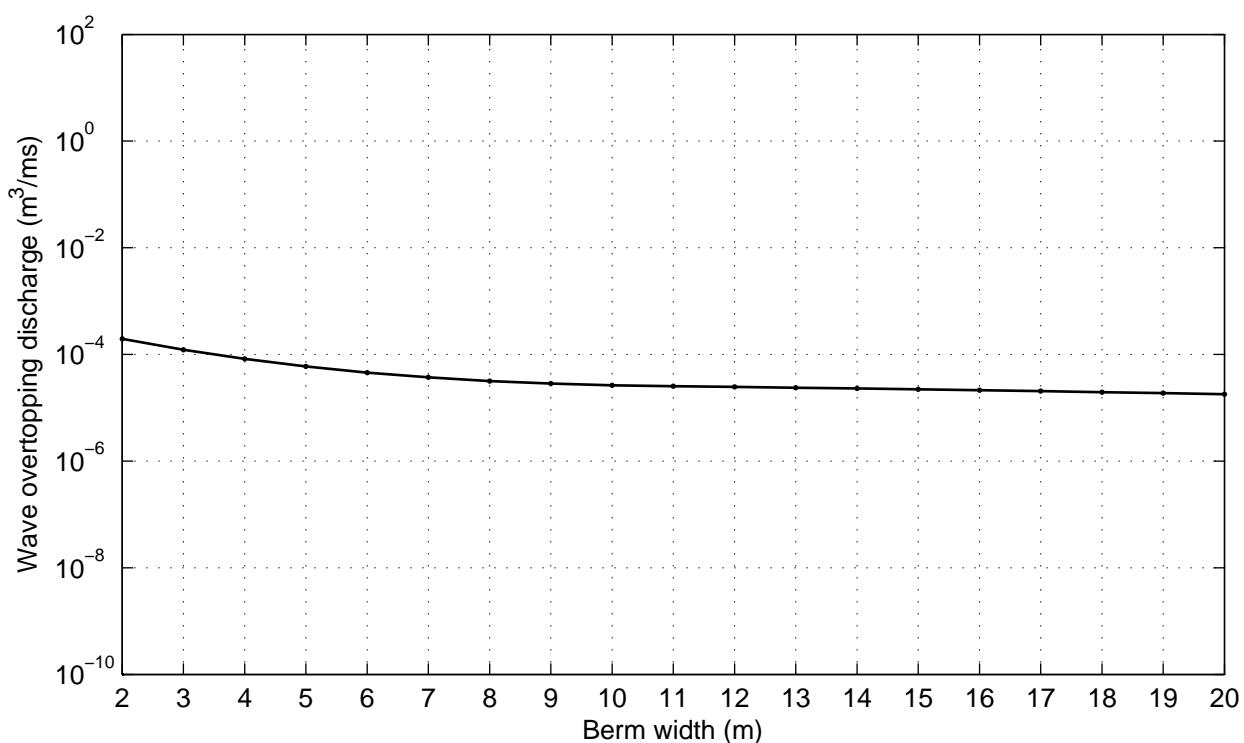
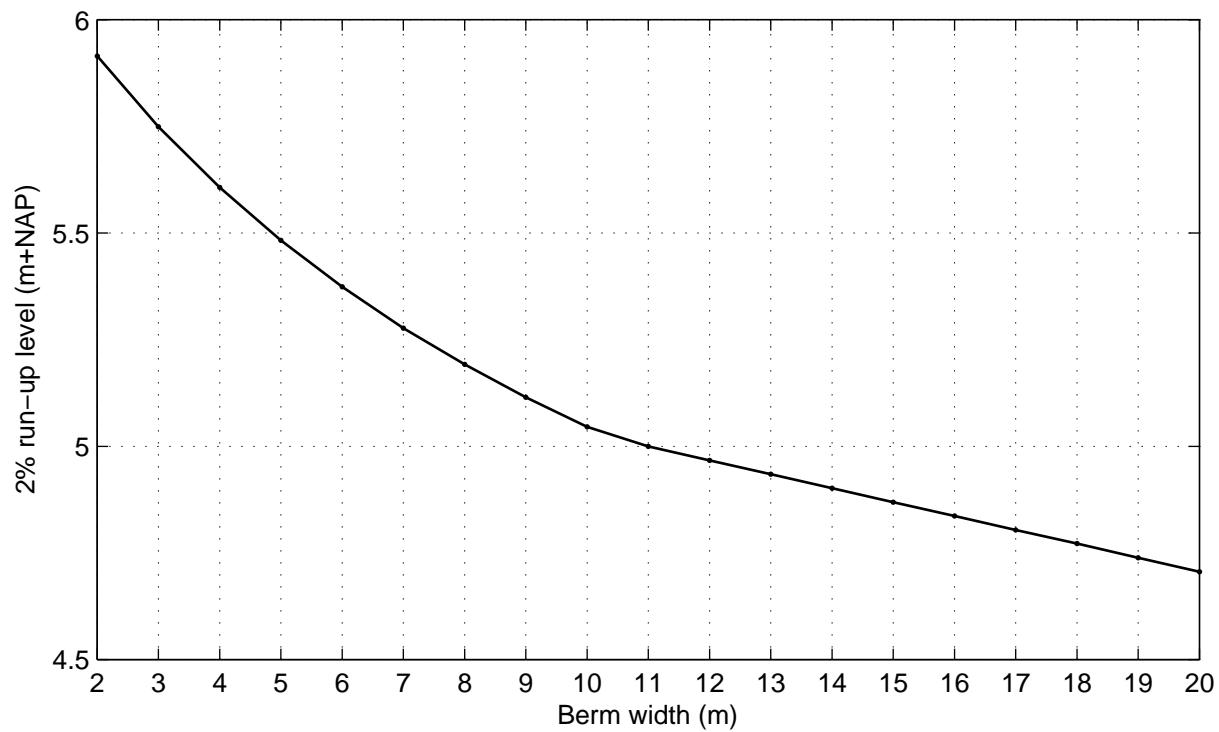
Cross section nr 4; series nr 12; Wave angle: 0 °
Varying berm width

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.14



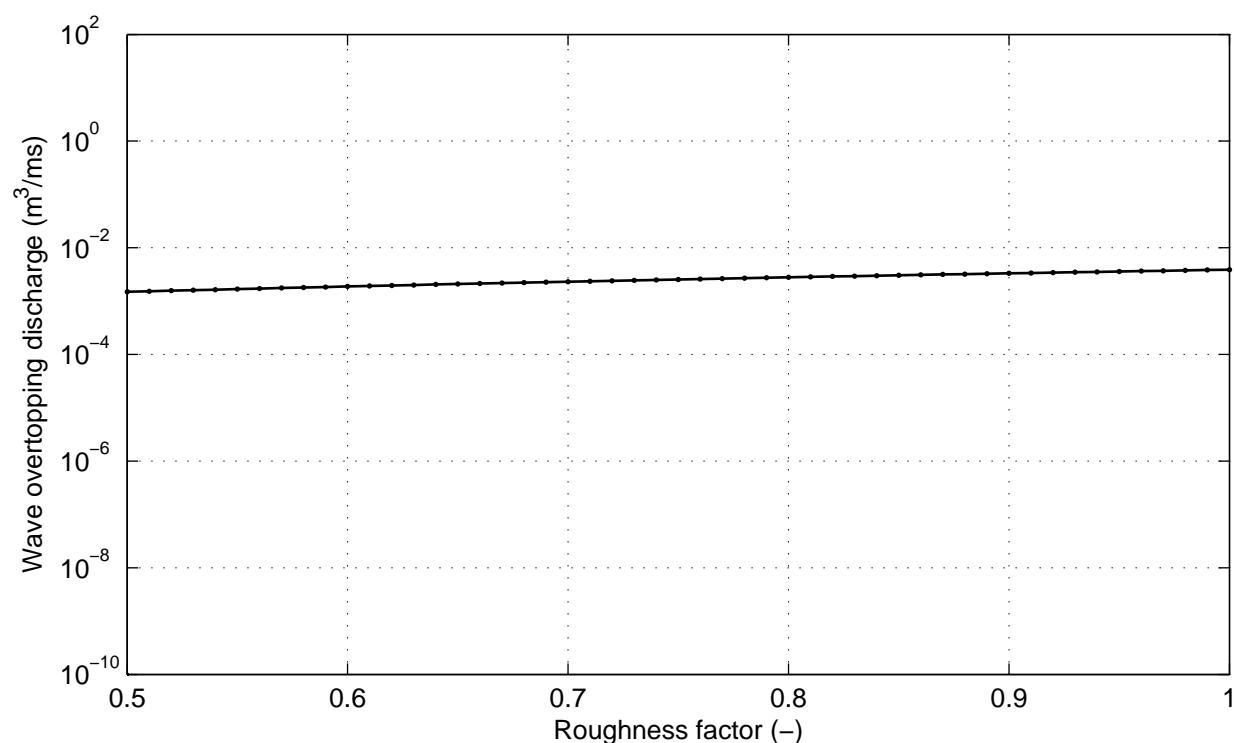
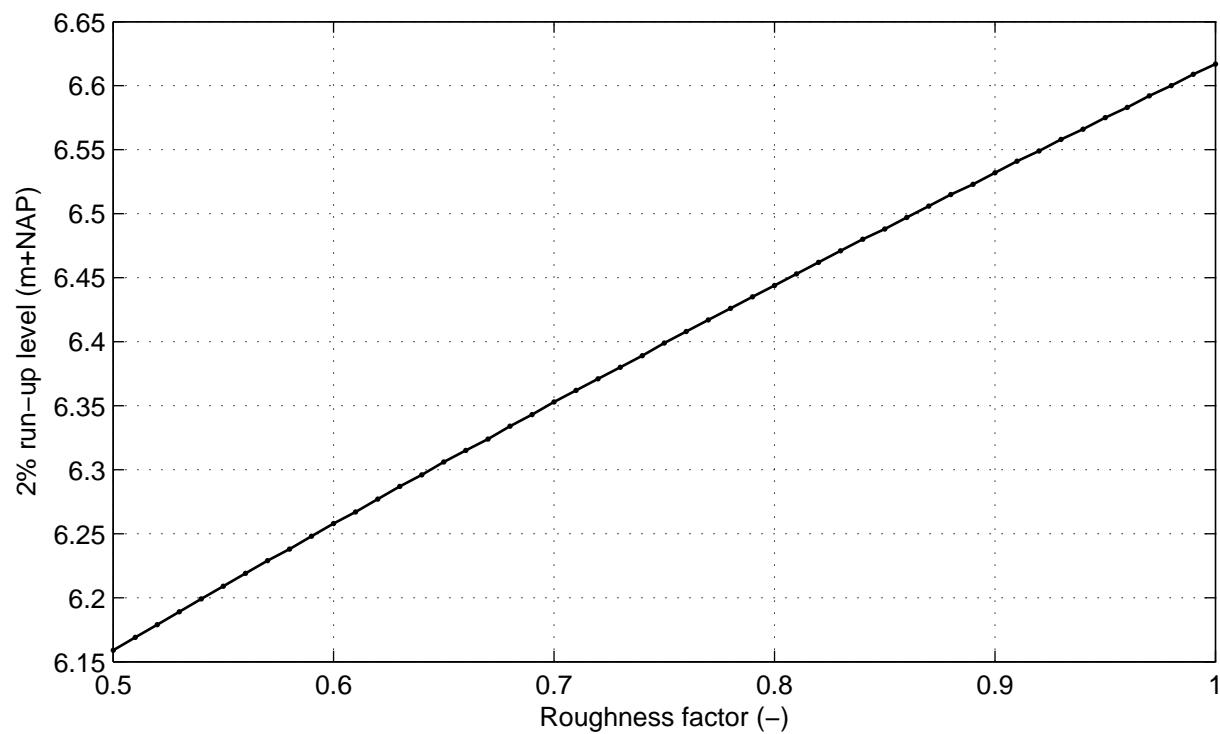
Cross section nr 4; series nr 13; Wave angle: 85 °
Varying berm width

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.15



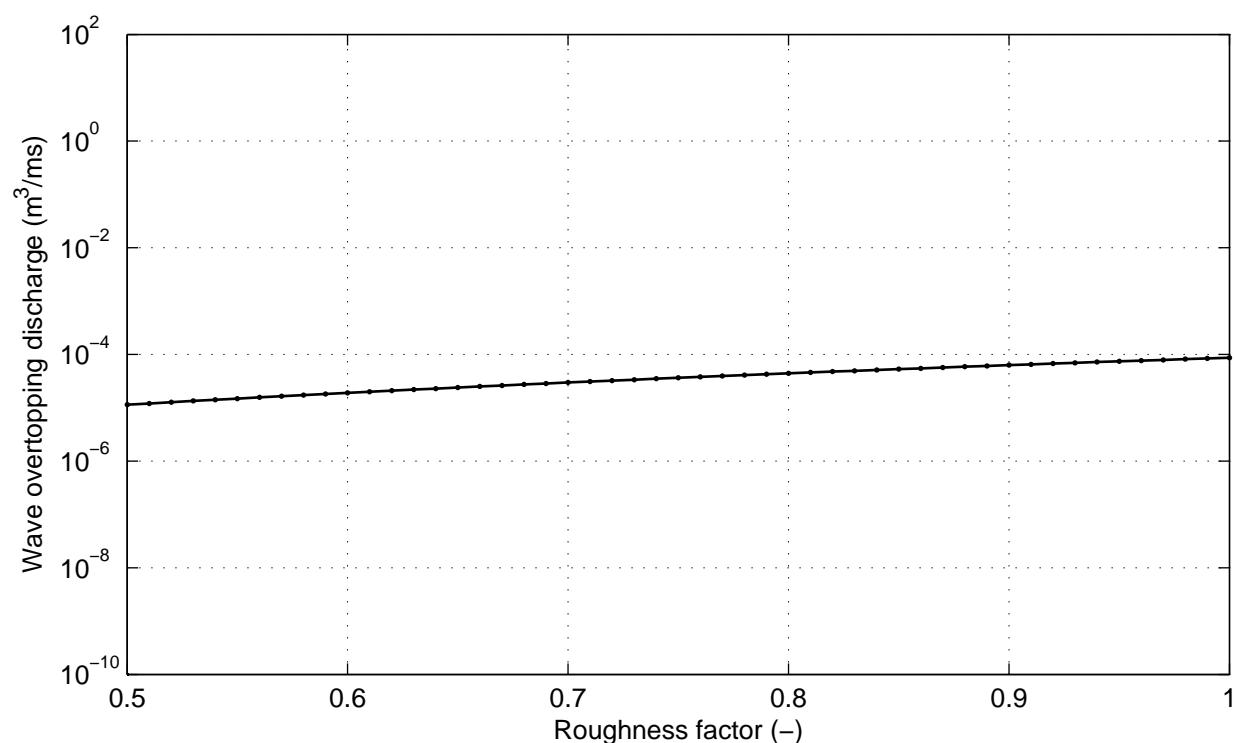
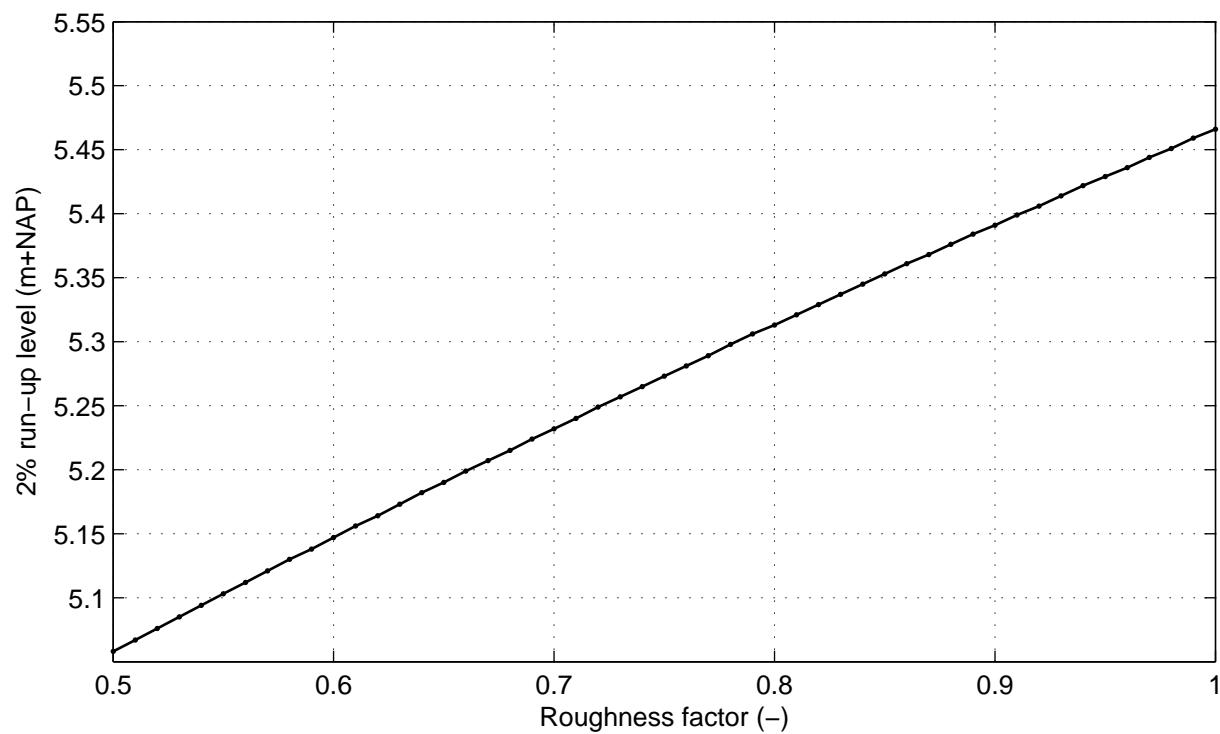
Cross section nr 4; series nr 14; Wave angle: 0 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.16



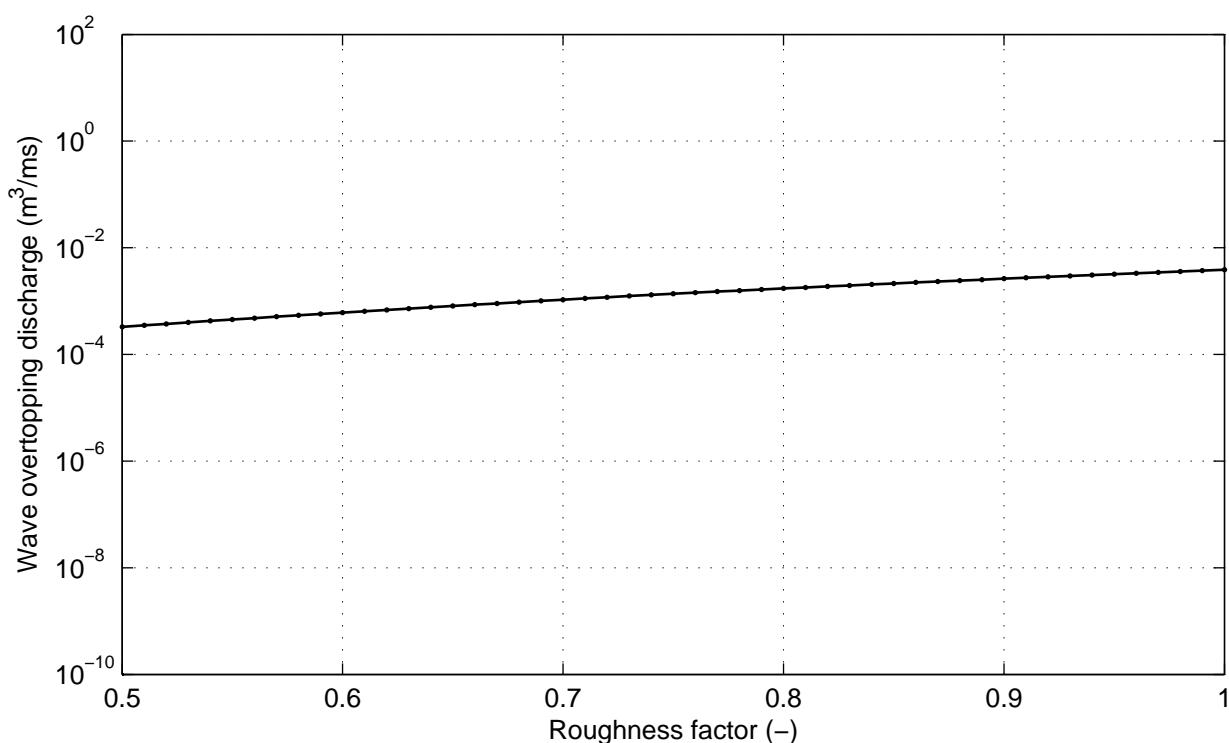
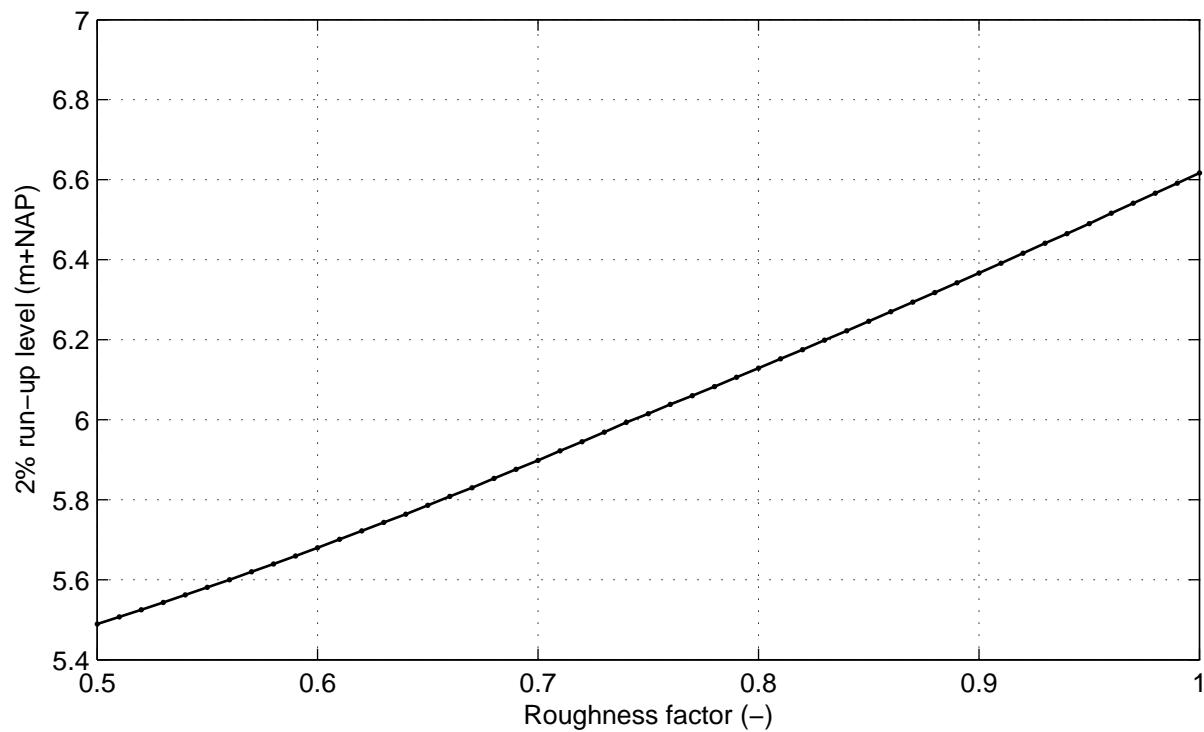
Cross section nr 4; series nr 15; Wave angle: 85 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.17



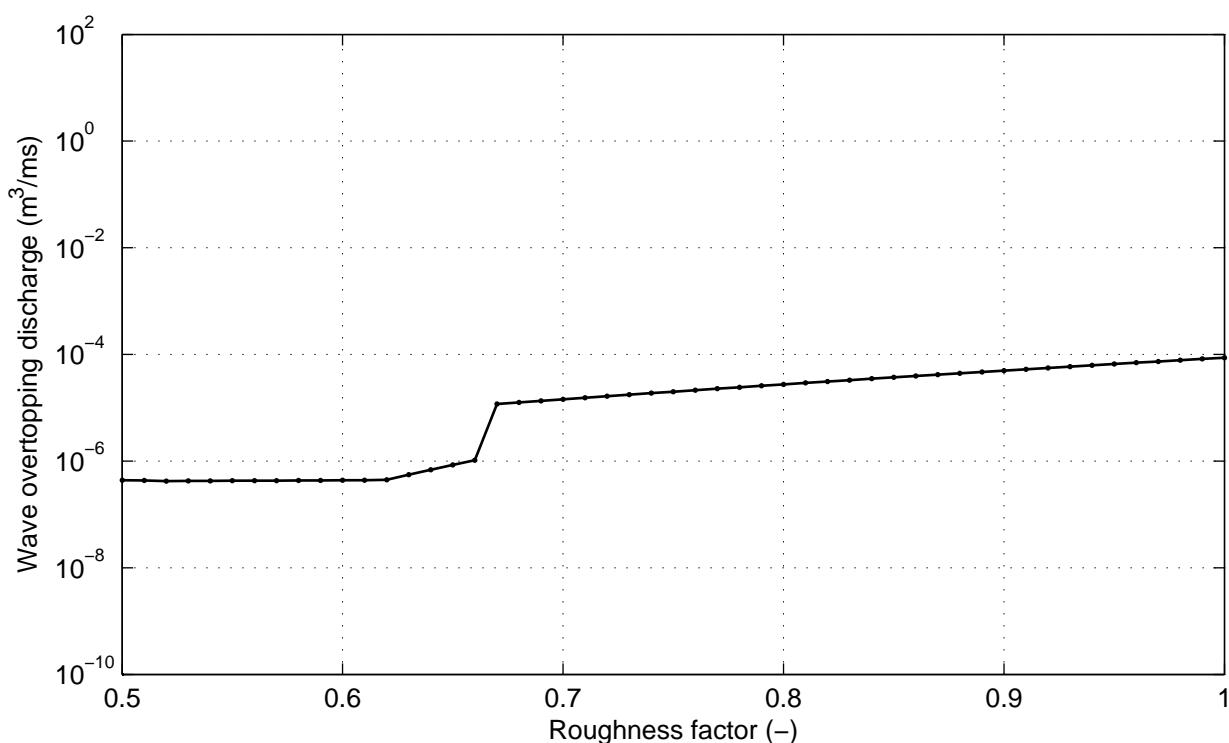
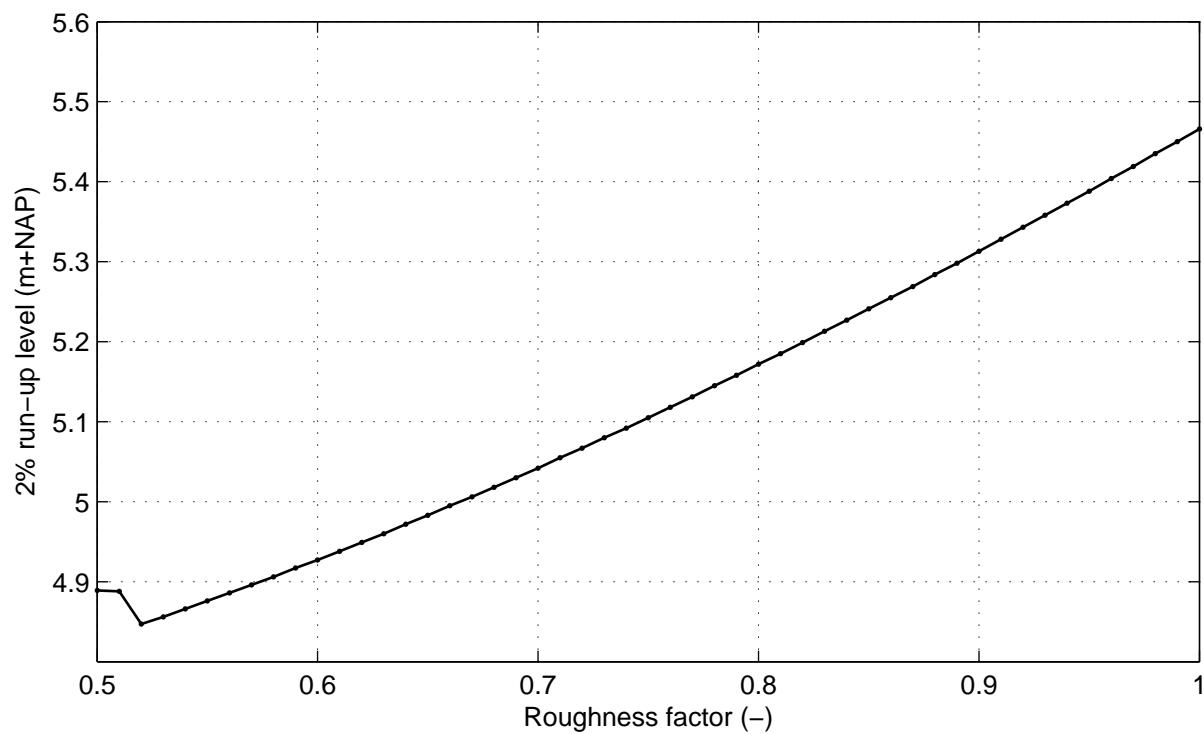
Cross section nr 4; series nr 16; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.18



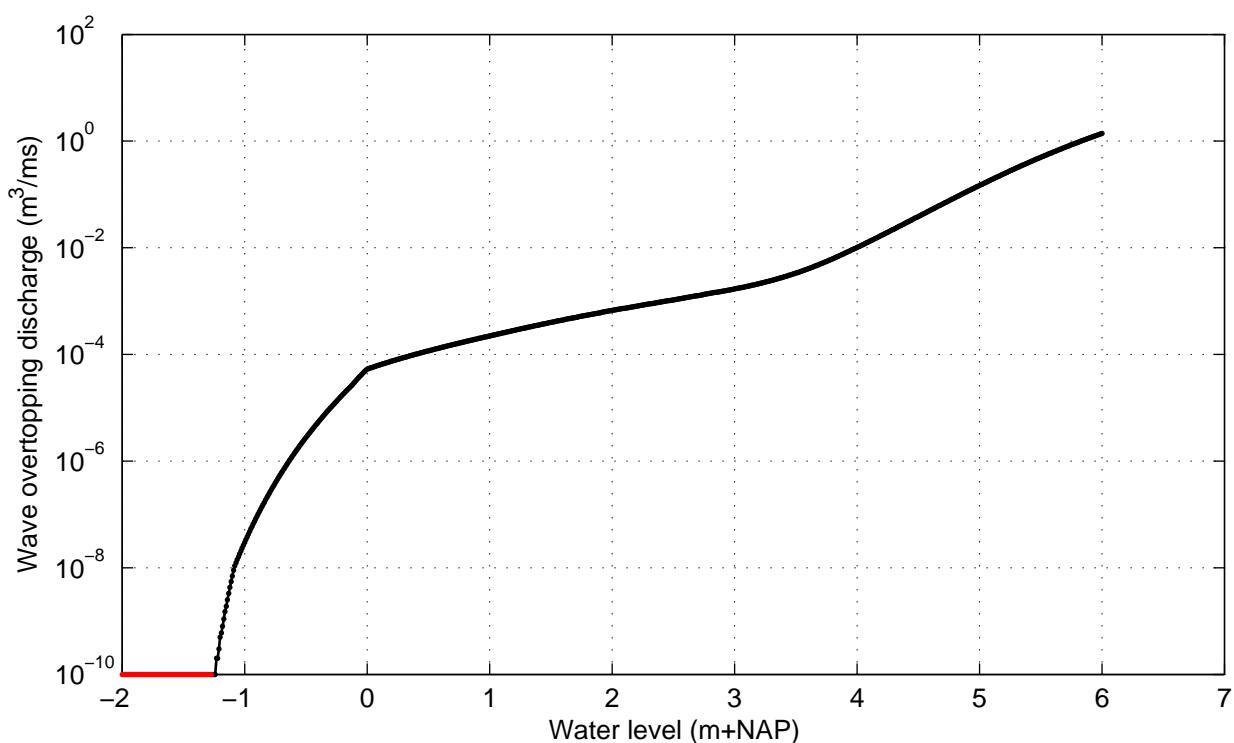
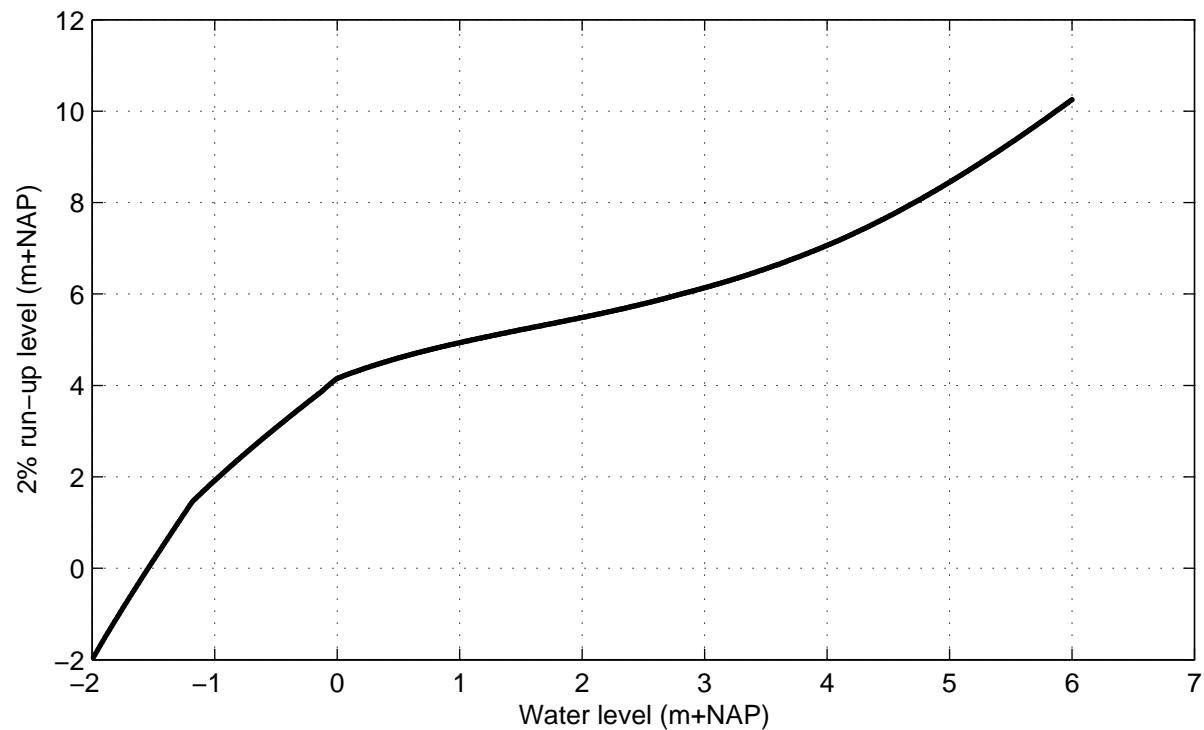
Cross section nr 4; series nr 17; Wave angle: 85 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 4.19



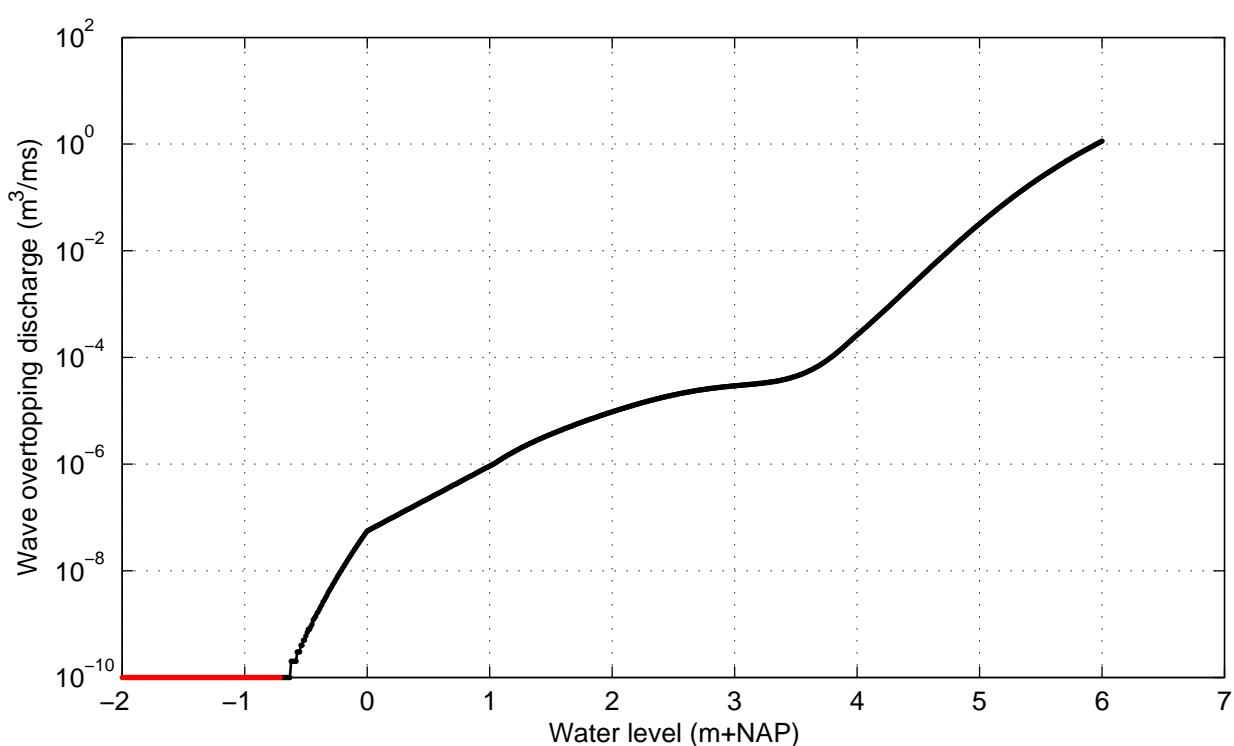
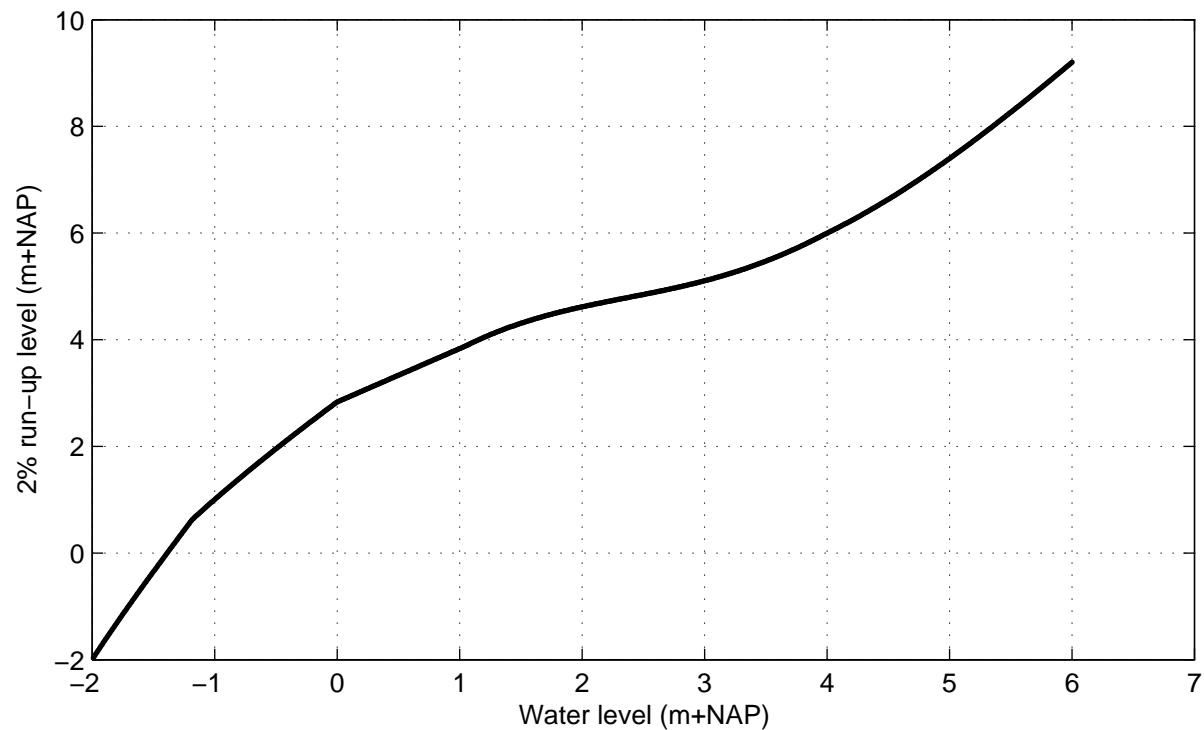
Cross section nr 5; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.1



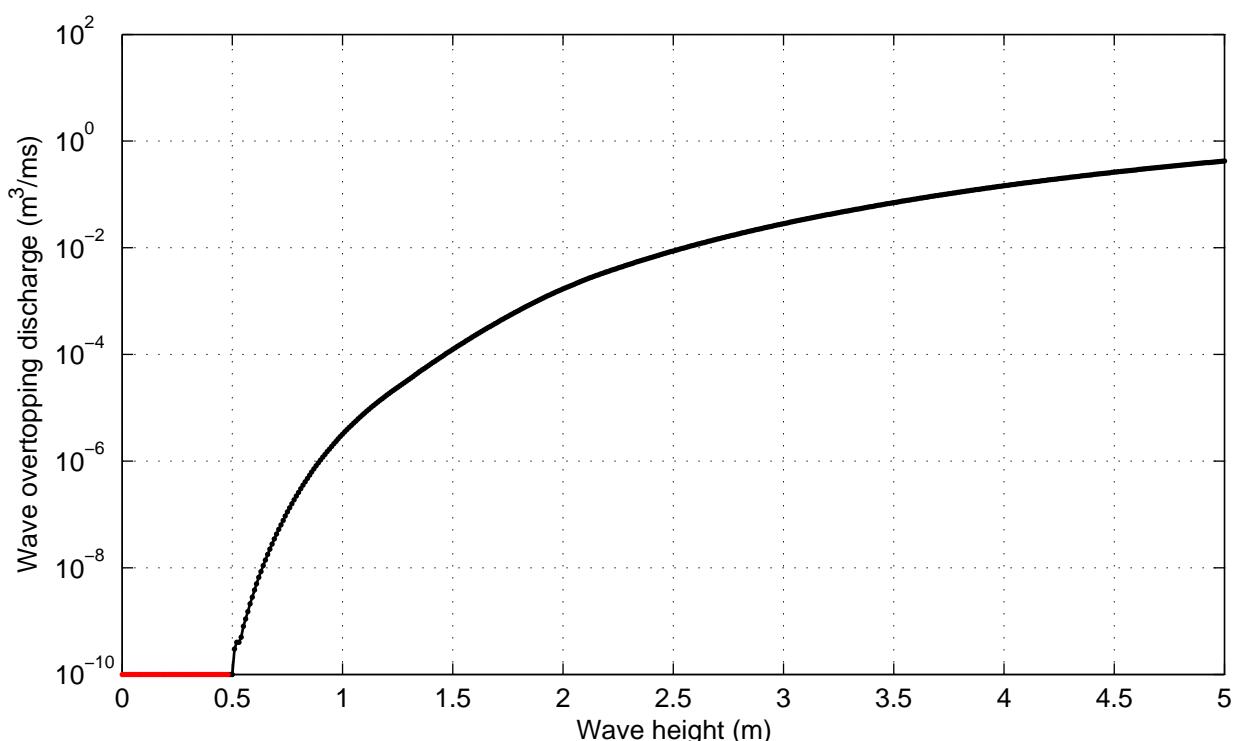
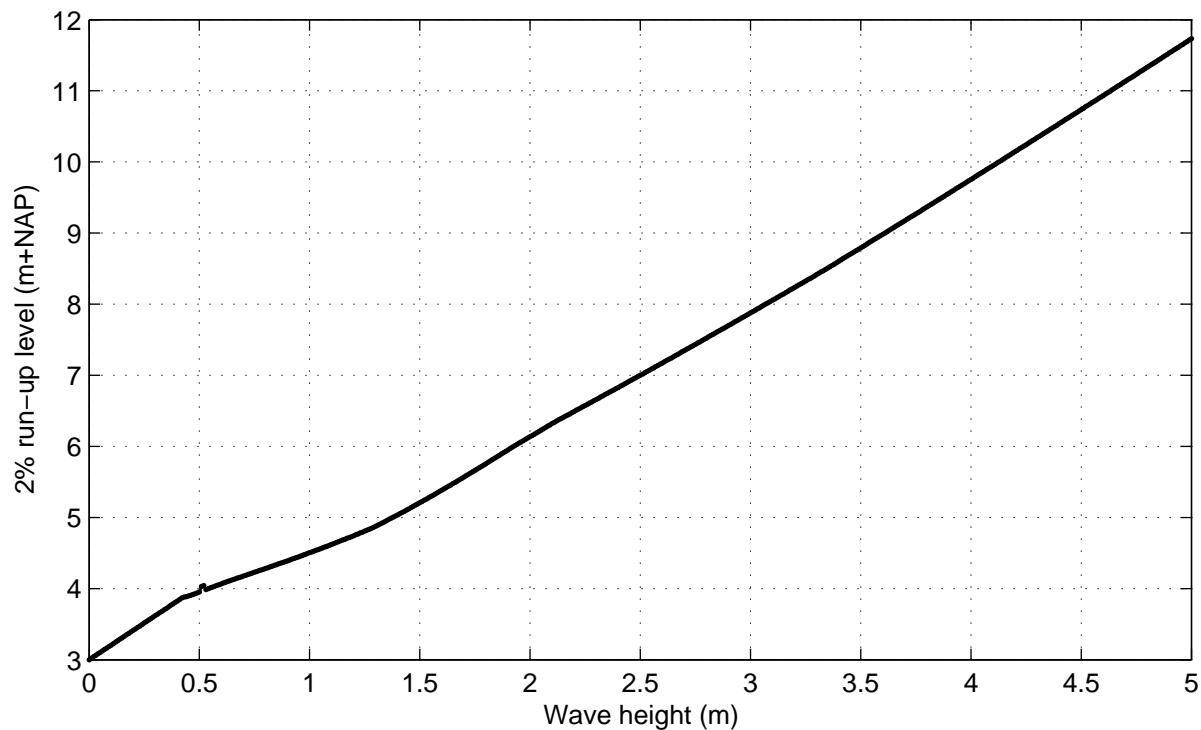
Cross section nr 5; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.2



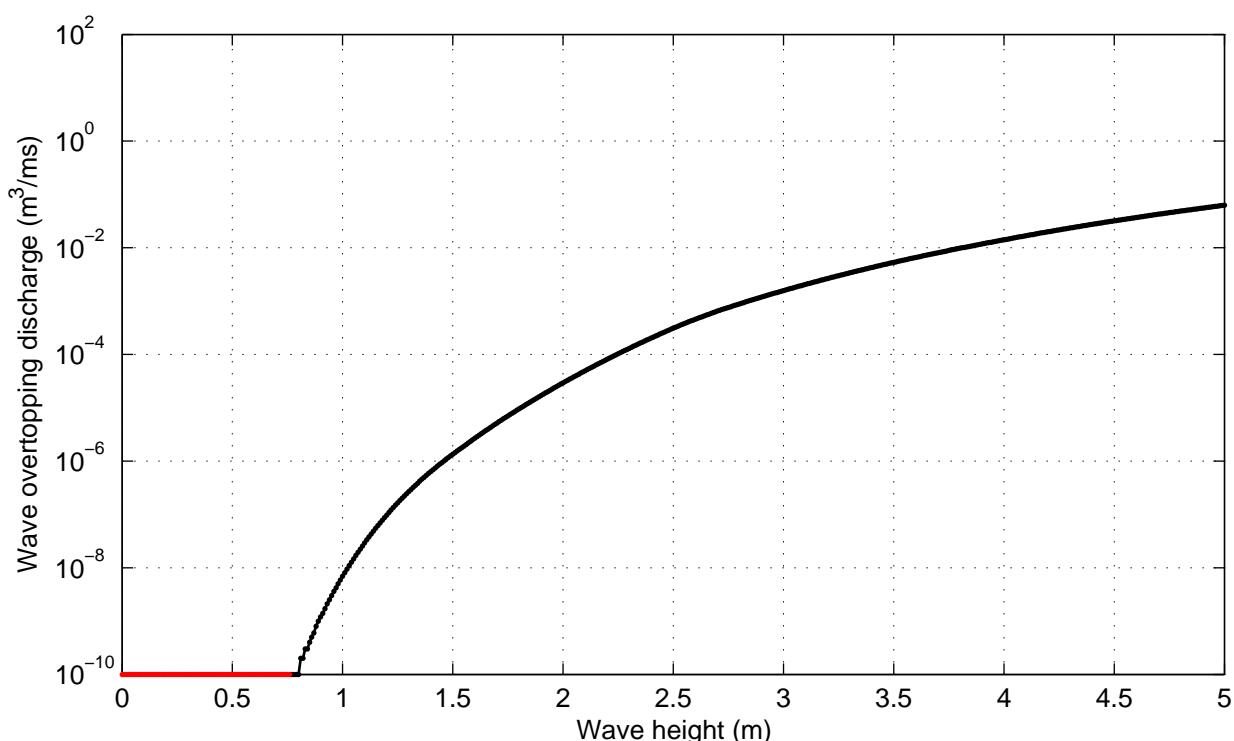
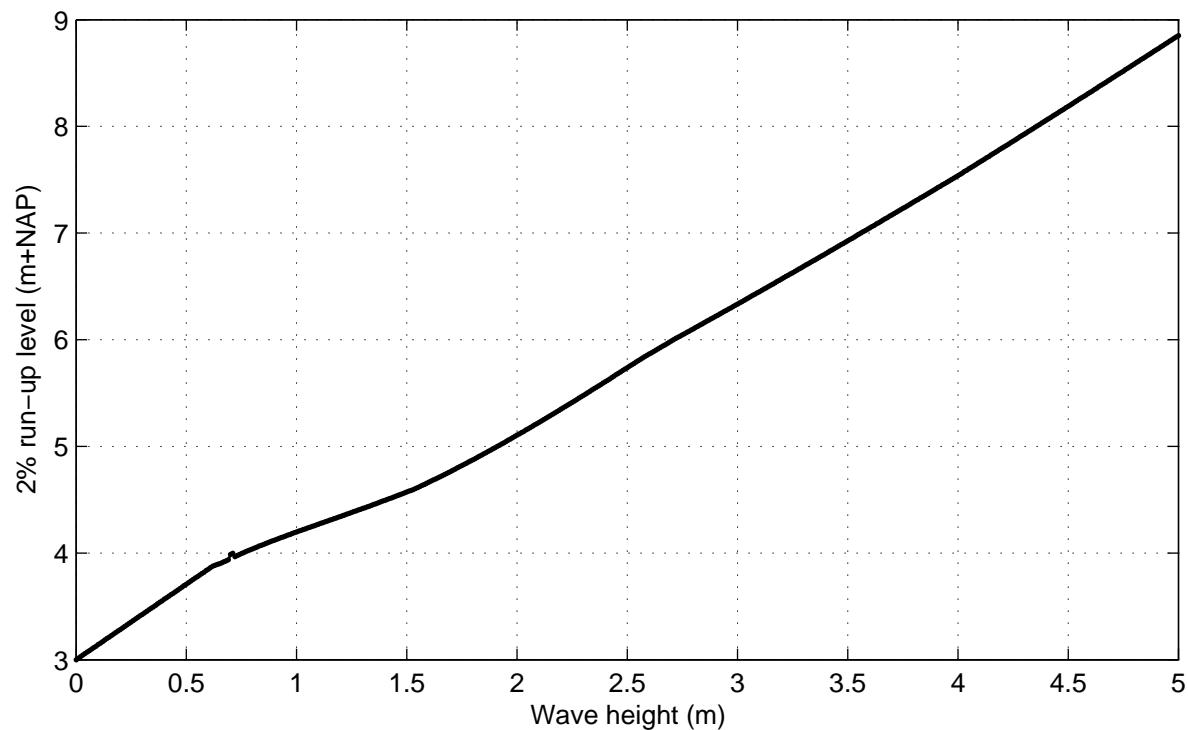
Cross section nr 5; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.3



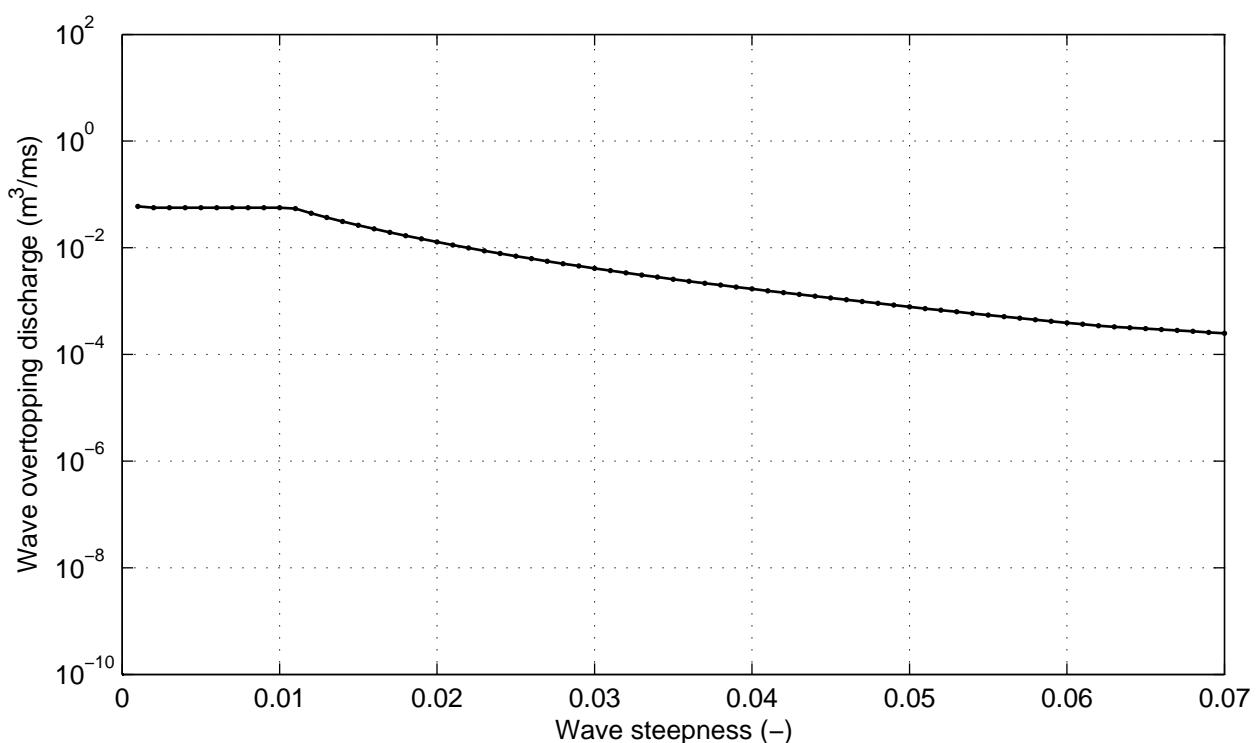
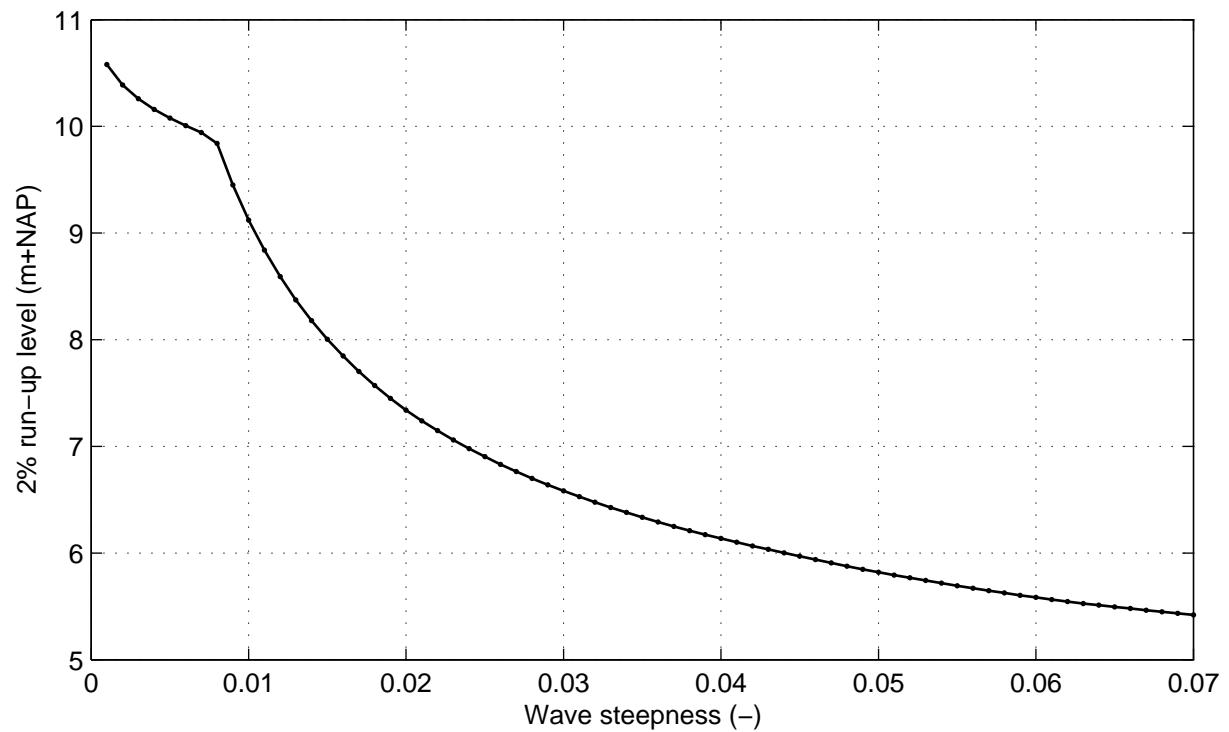
Cross section nr 5; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.4



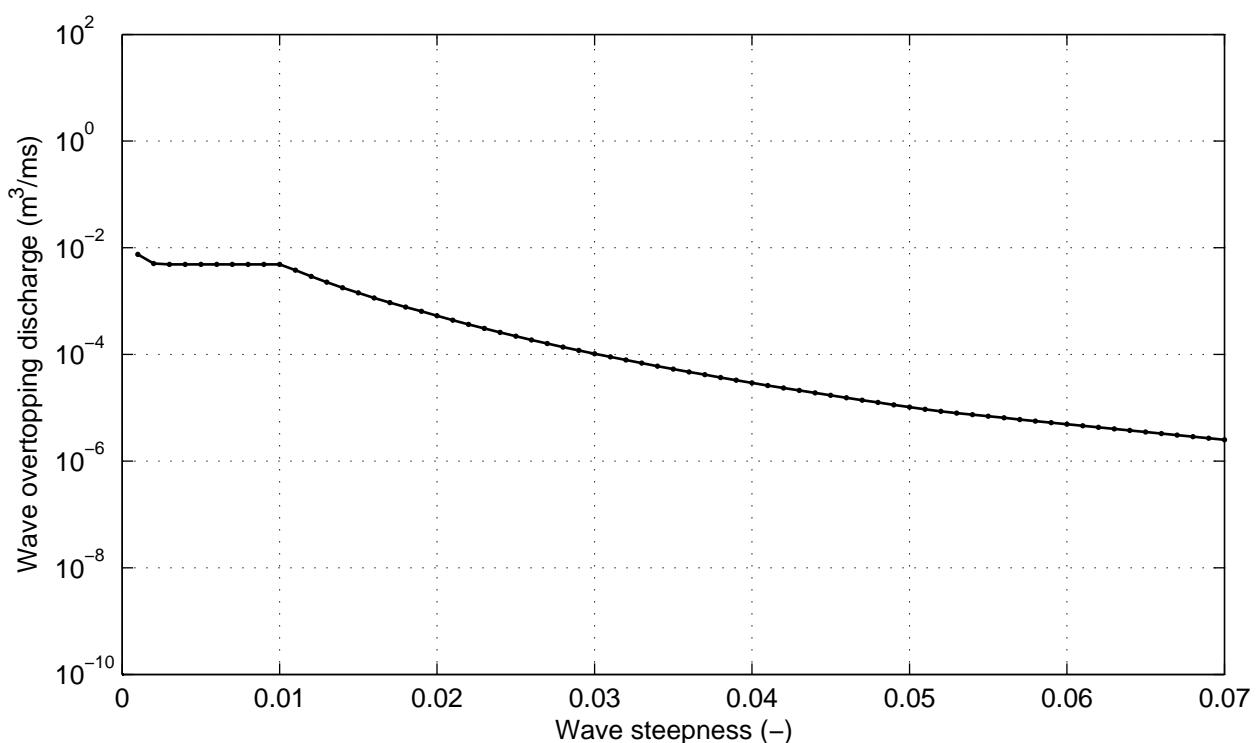
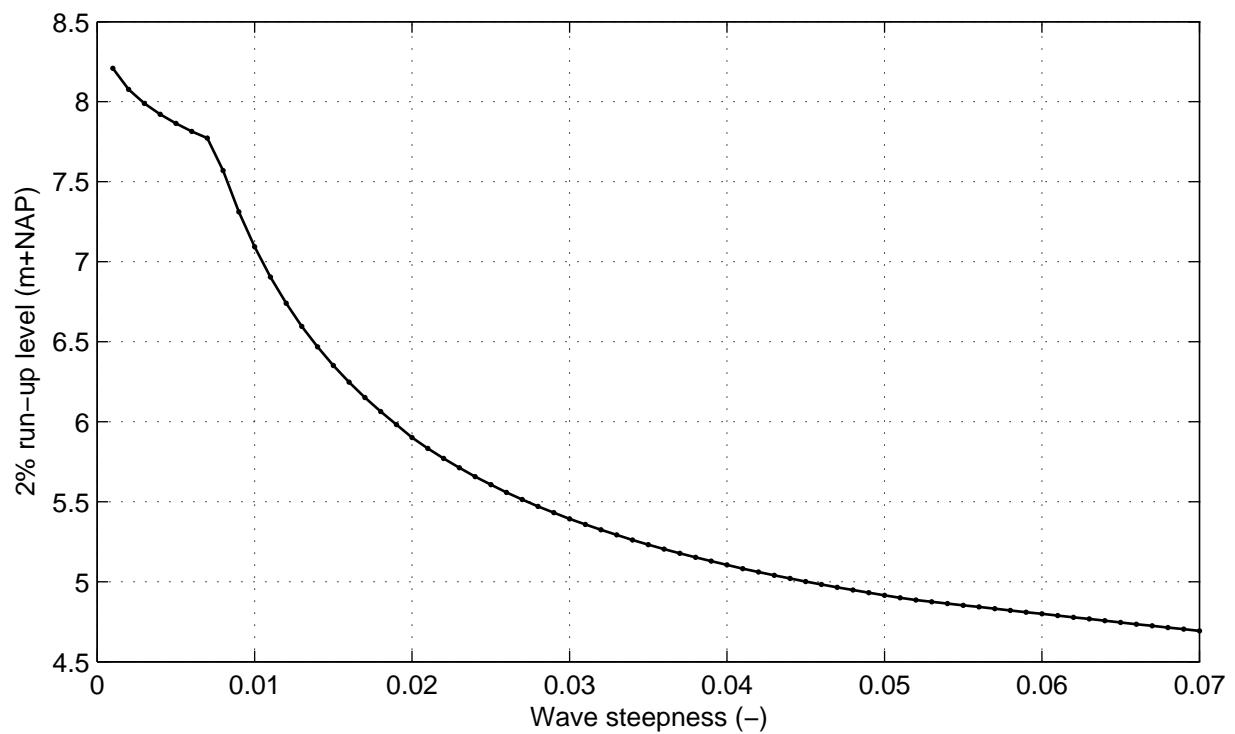
Cross section nr 5; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.5



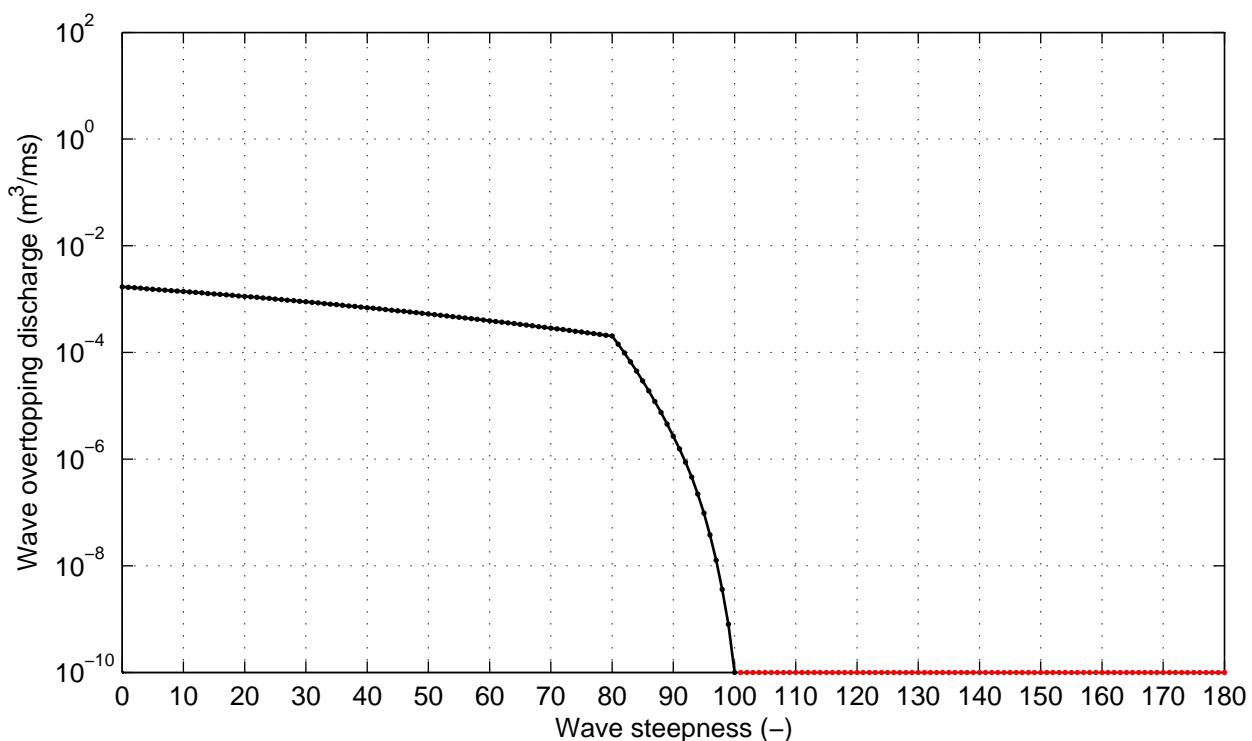
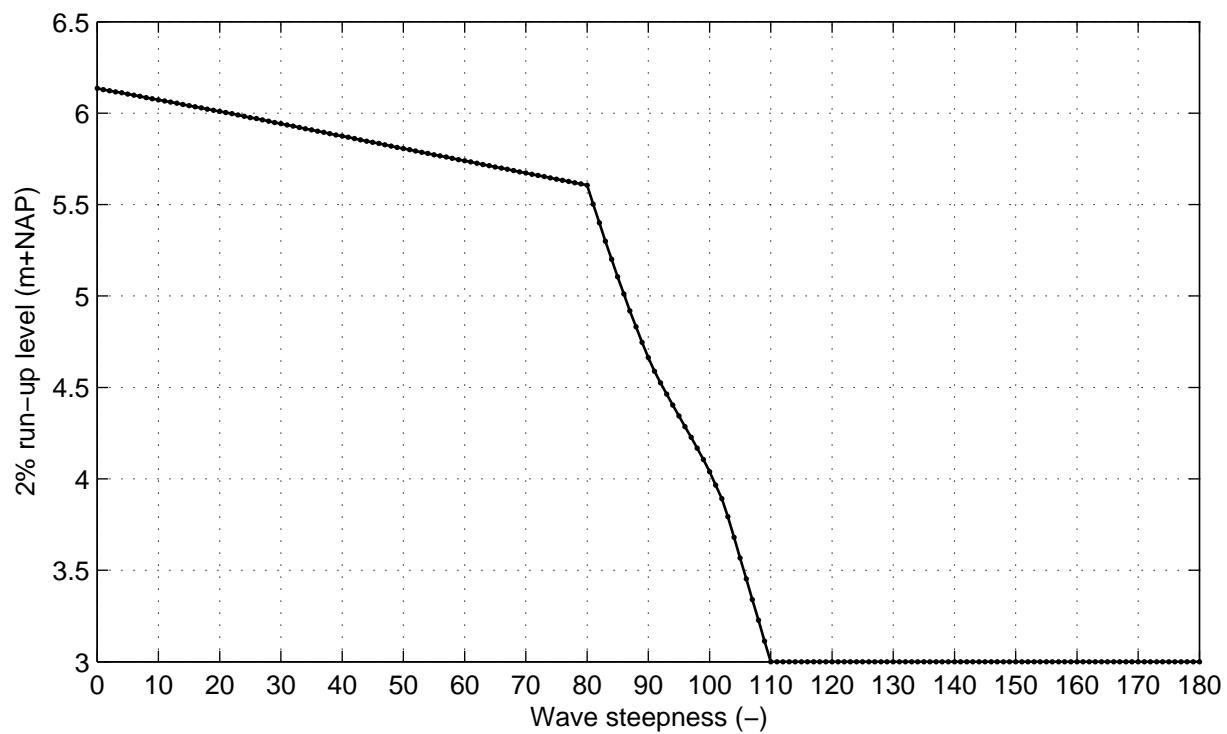
Cross section nr 5; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.6



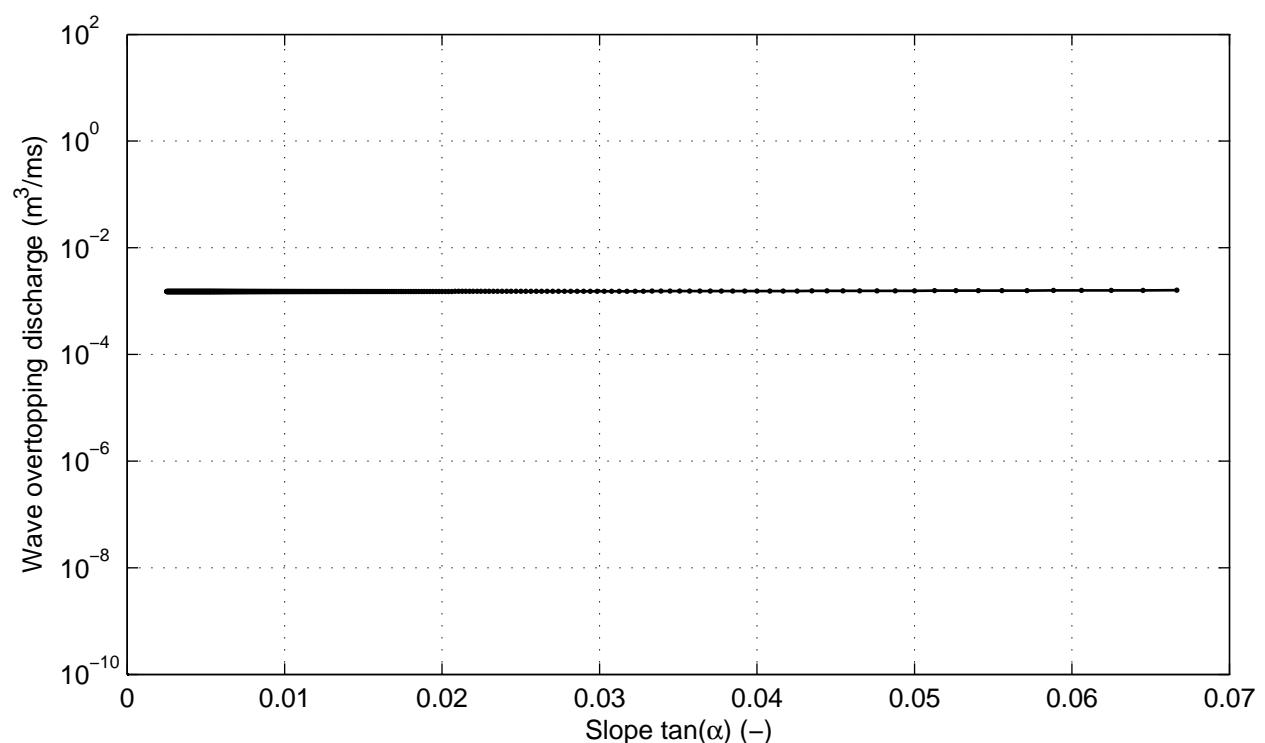
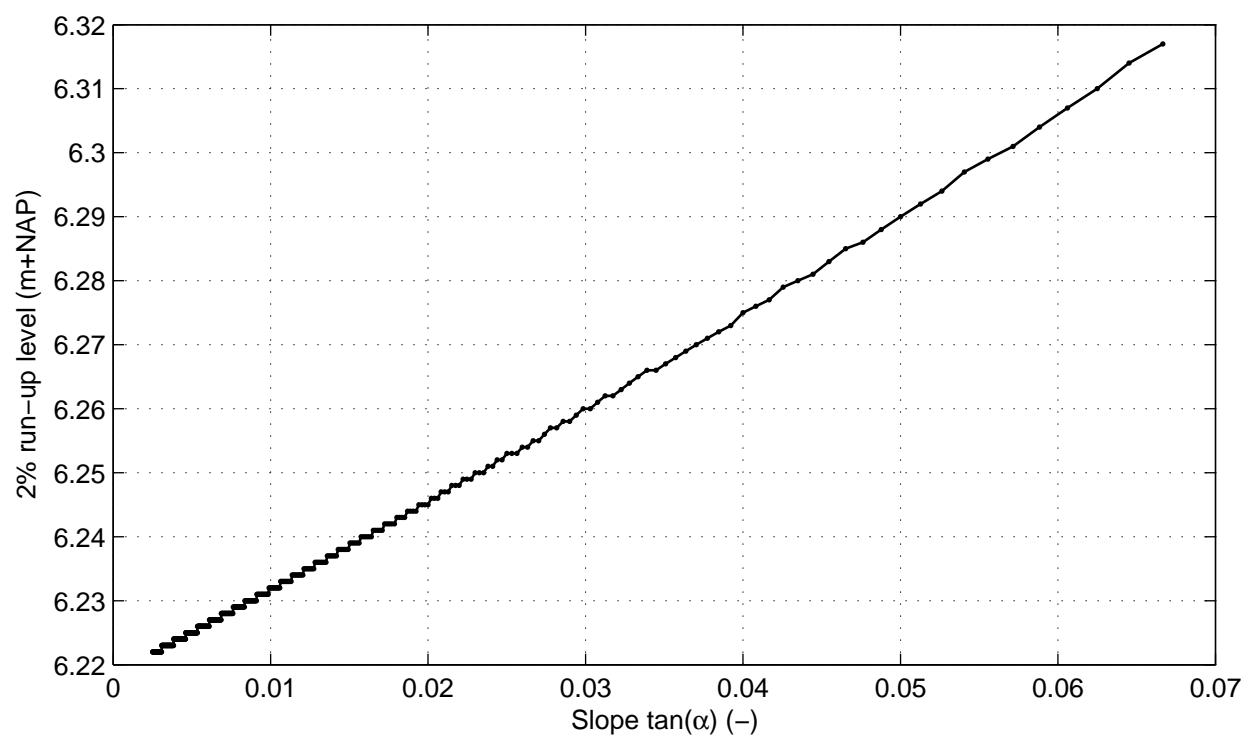
Cross section nr 5; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.7



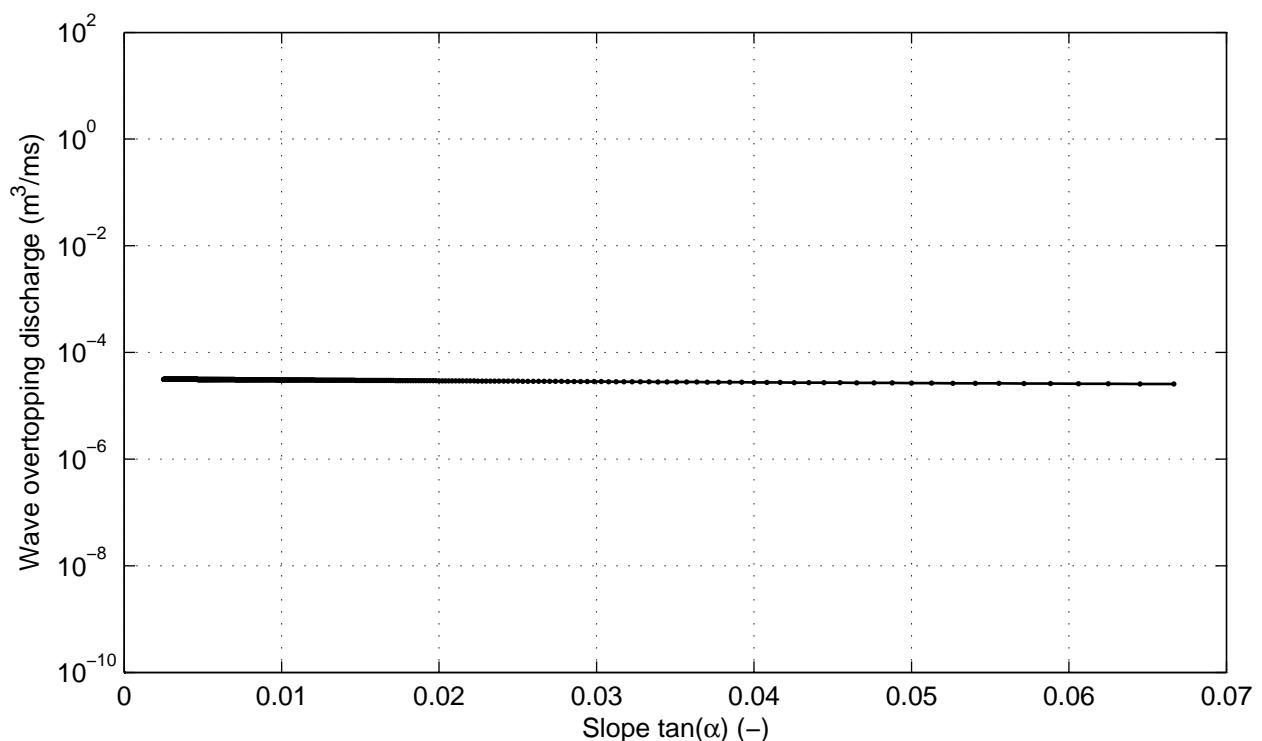
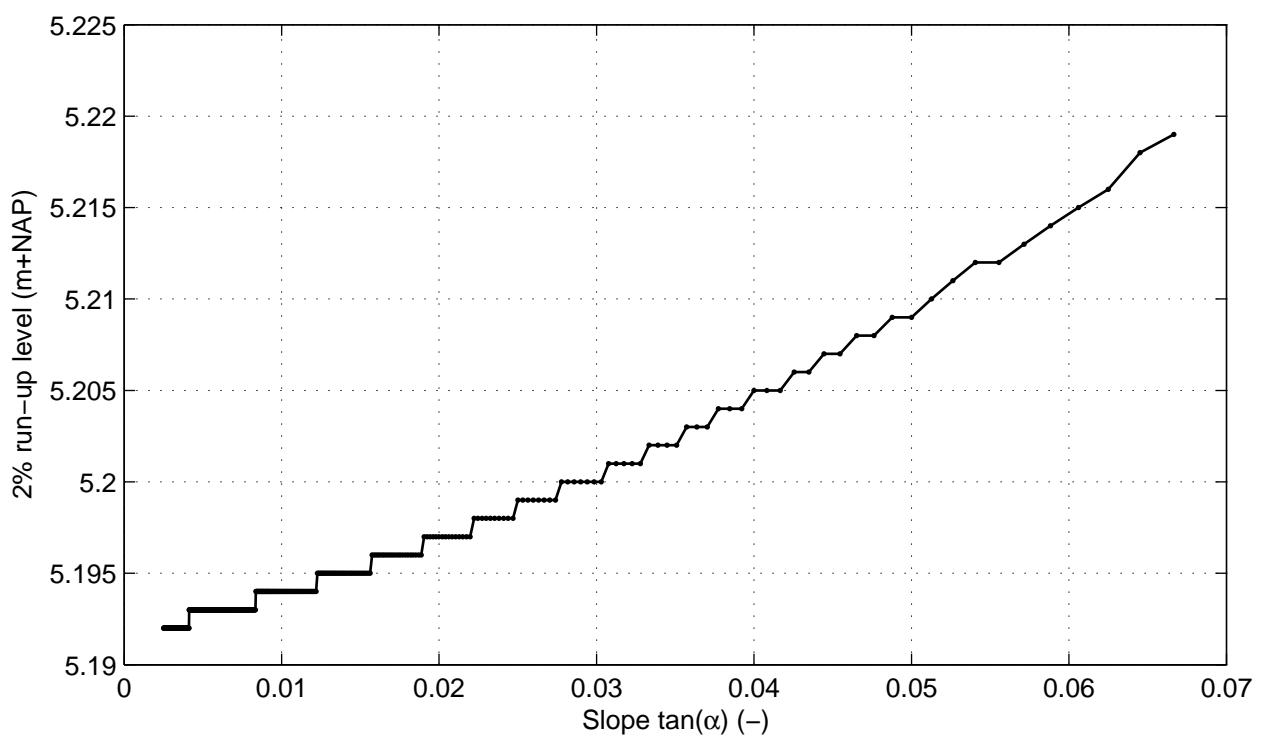
Cross section nr 5; series nr 8; Wave angle: 0 °
Varying slope first (lower) berm segment as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.8



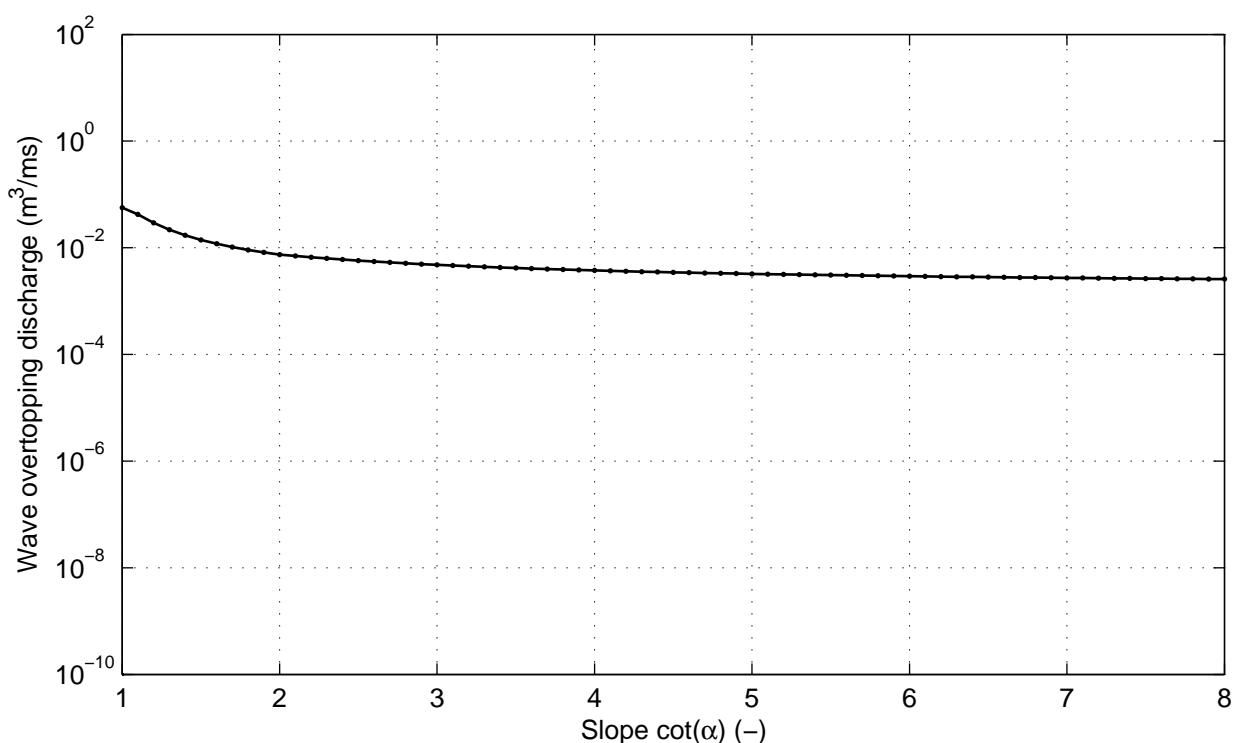
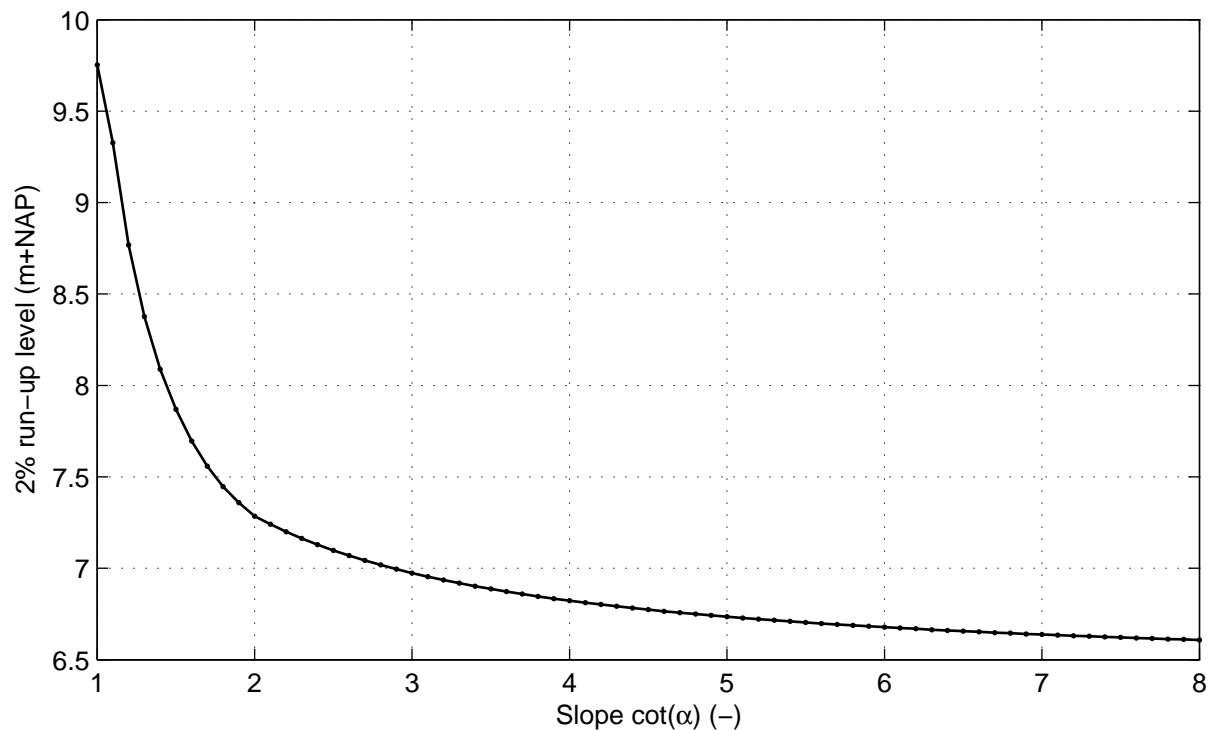
Cross section nr 5; series nr 9; Wave angle: 85 °
Varying slope first (lower) berm segment as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.9



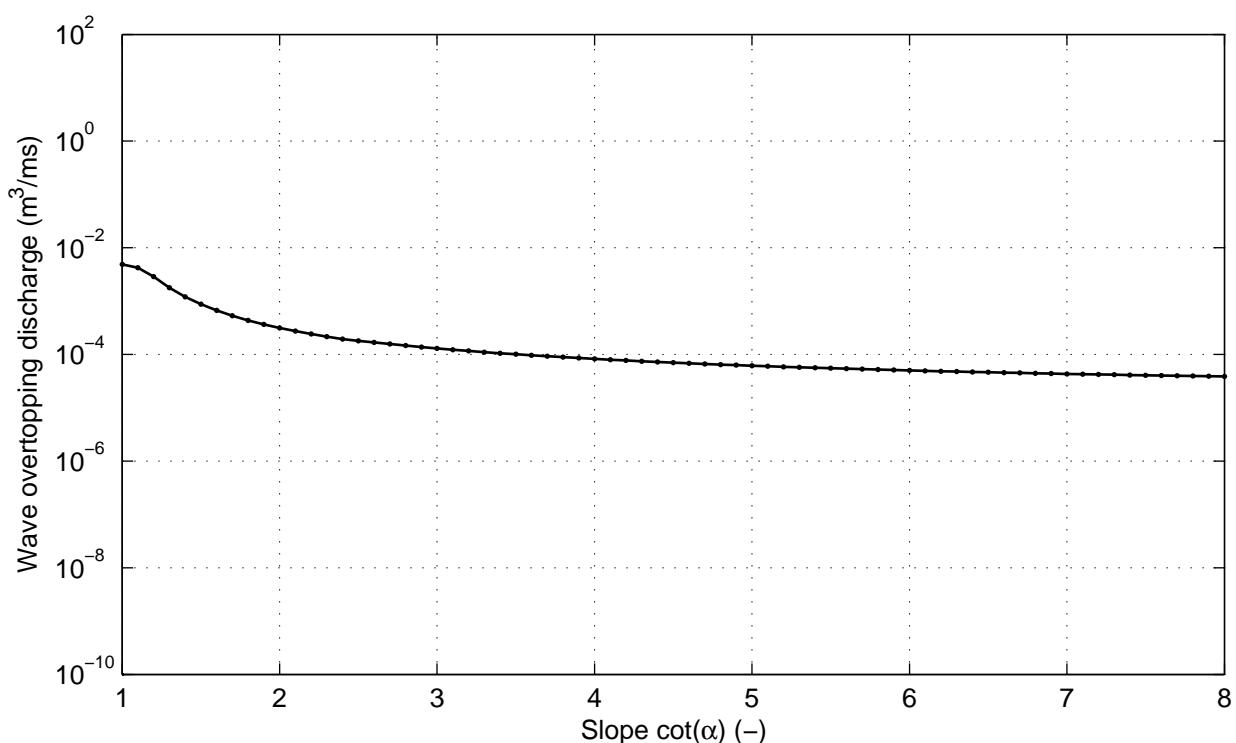
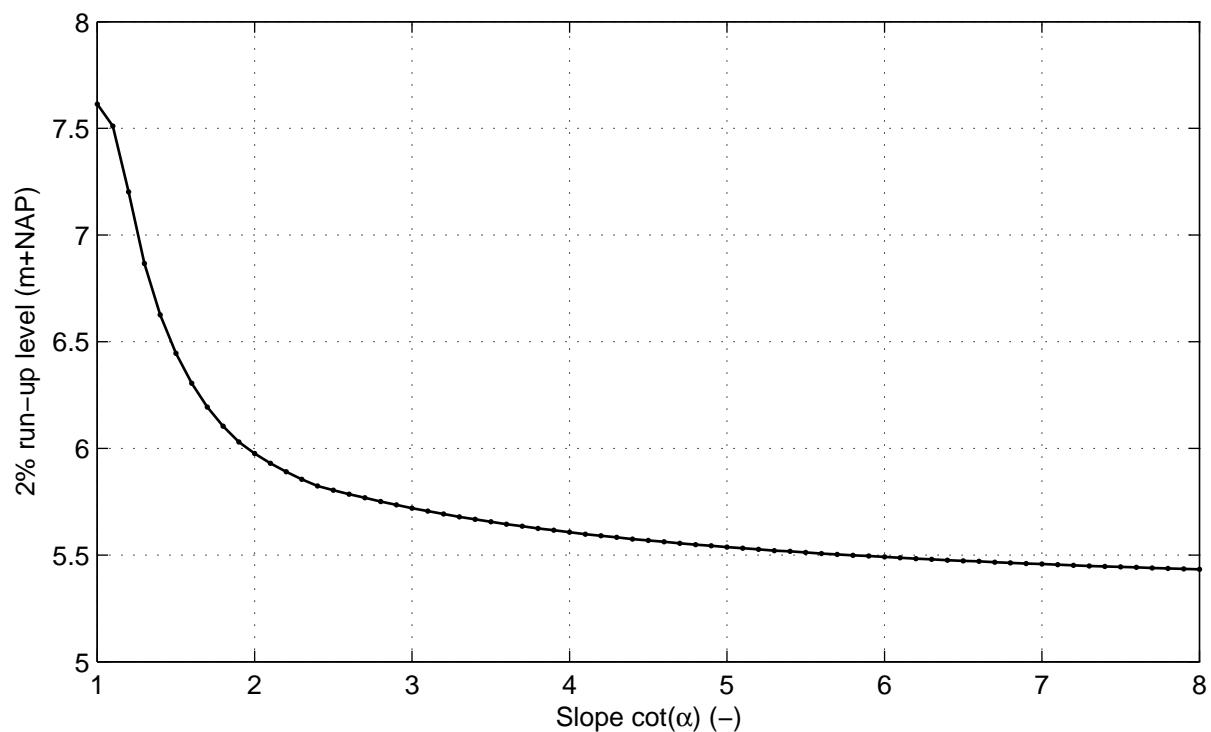
Cross section nr 5; series nr 8; Wave angle: 0 °
Varying slope first (lower) berm segment as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.10



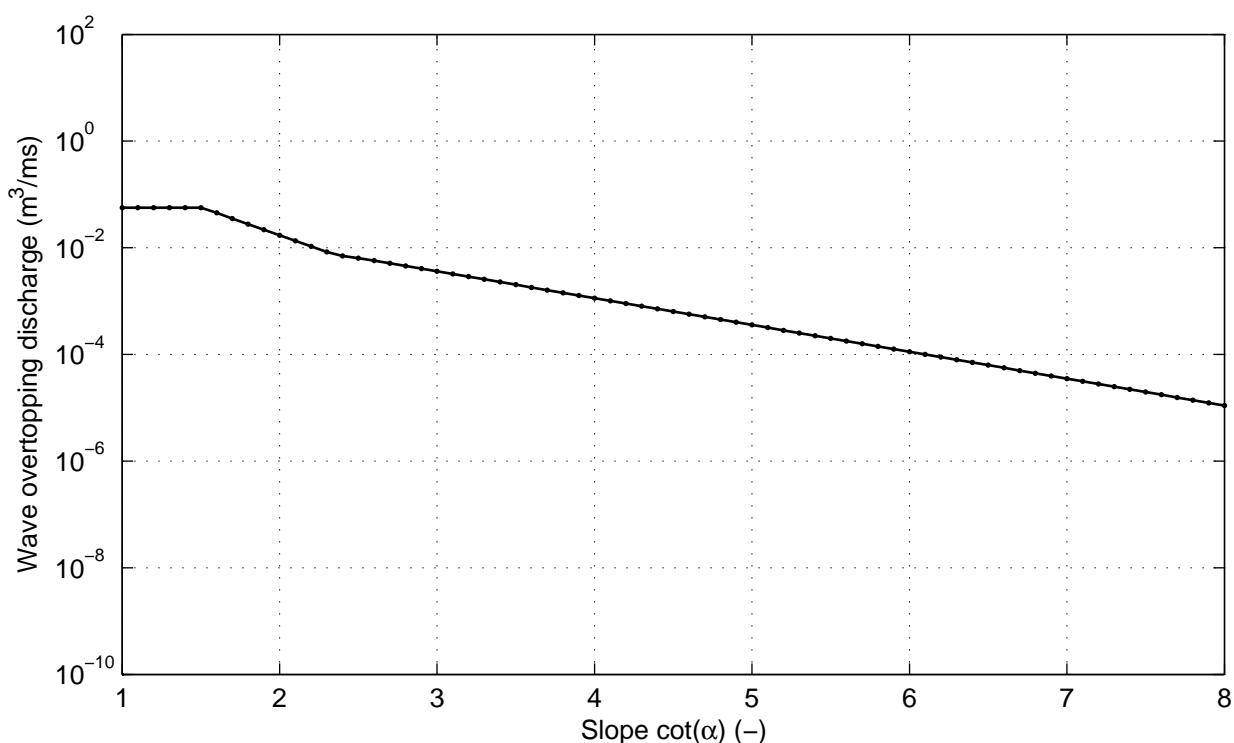
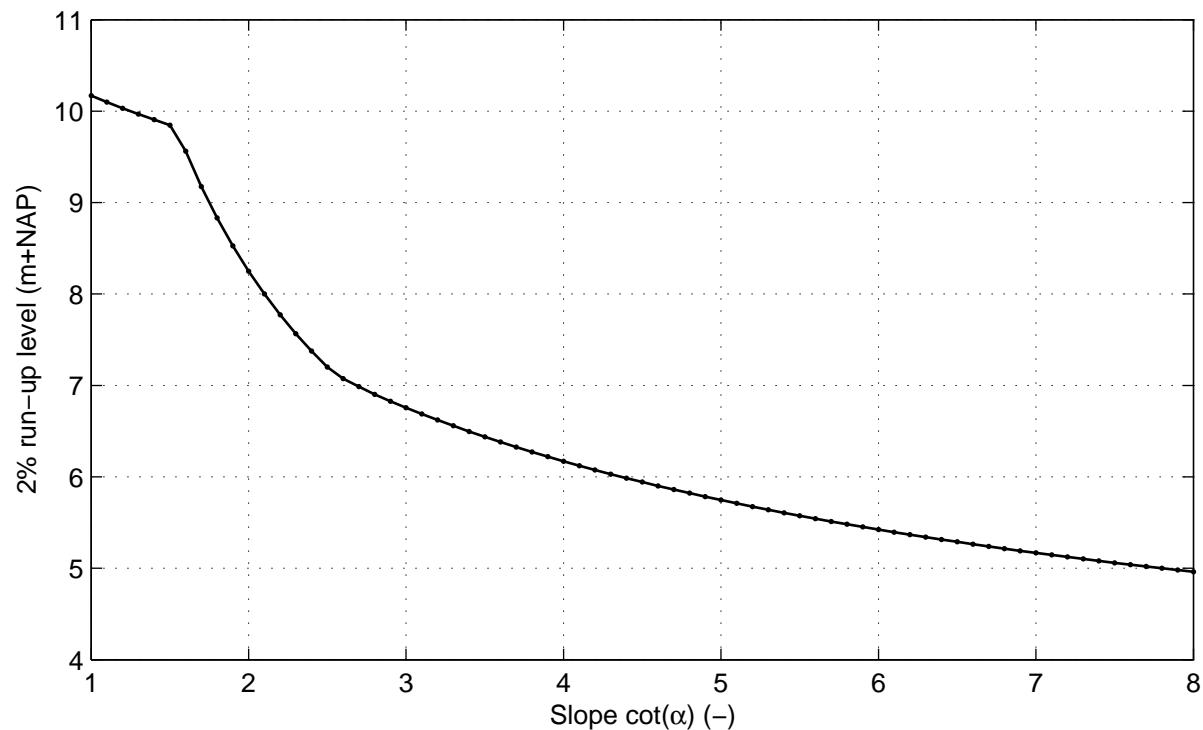
Cross section nr 5; series nr 9; Wave angle: 85 °
Varying slope first (lower) berm segment as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.11



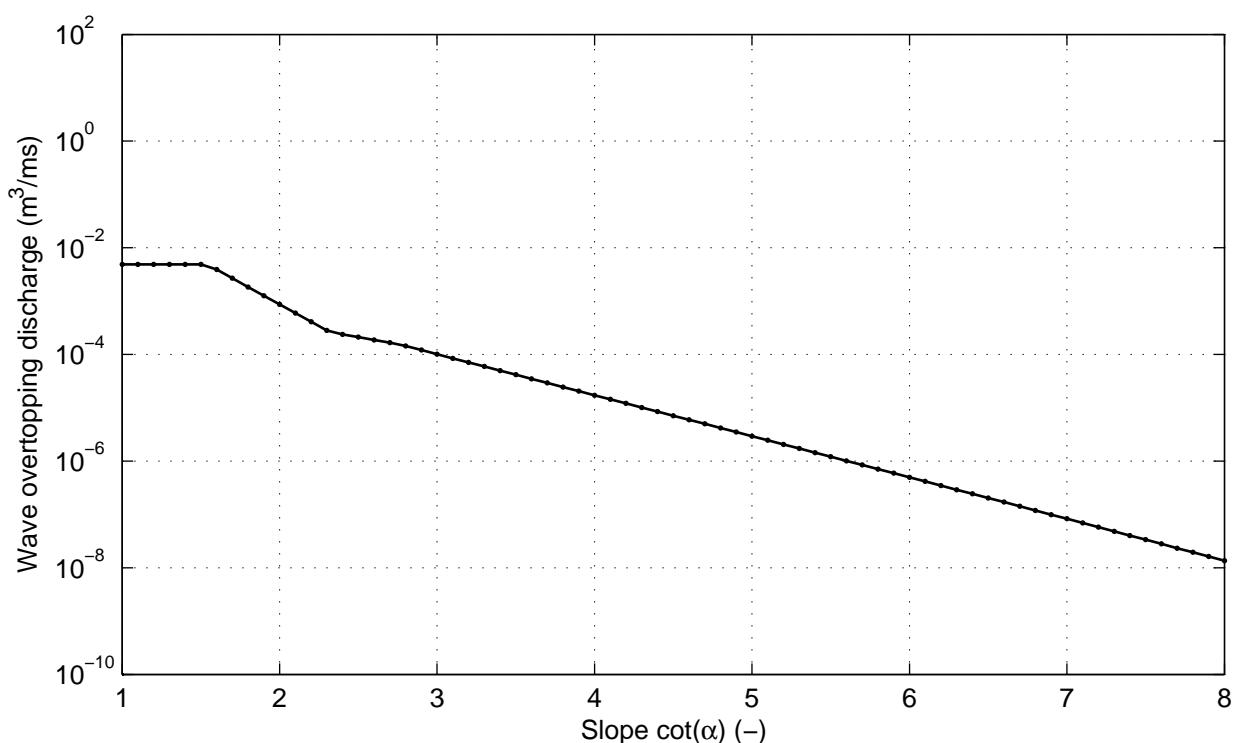
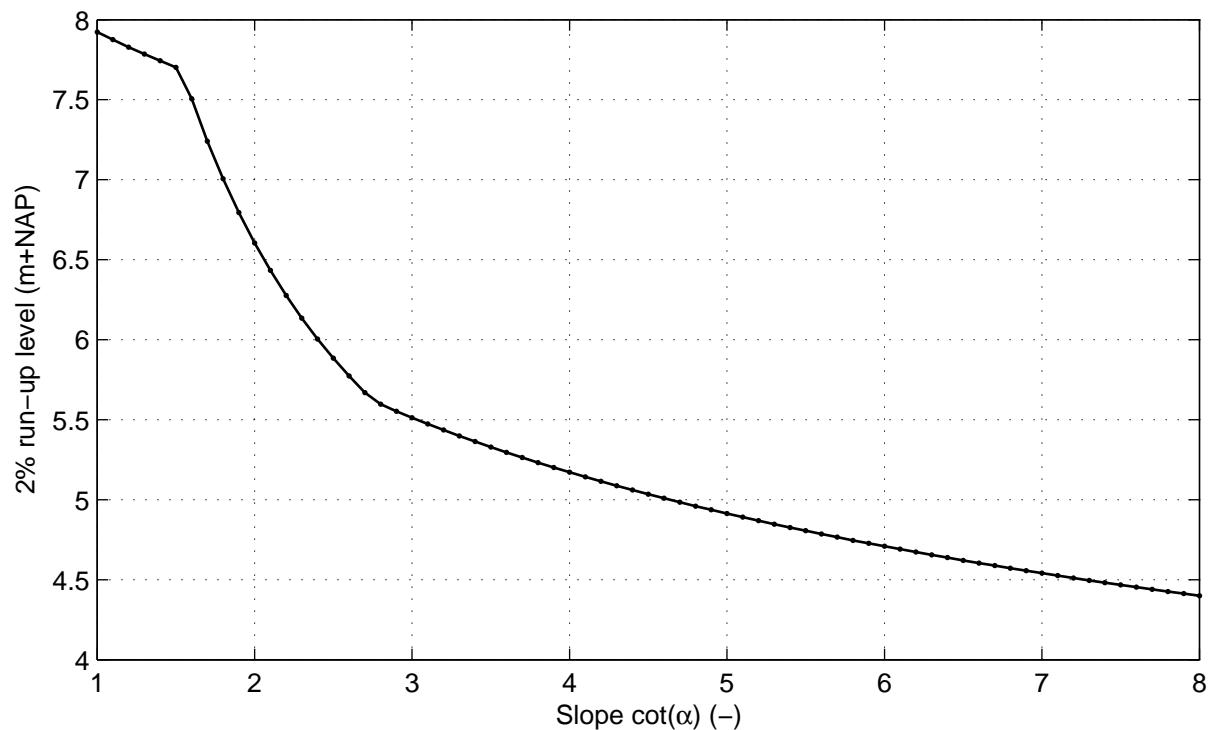
Cross section nr 5; series nr 10; Wave angle: 0 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.12



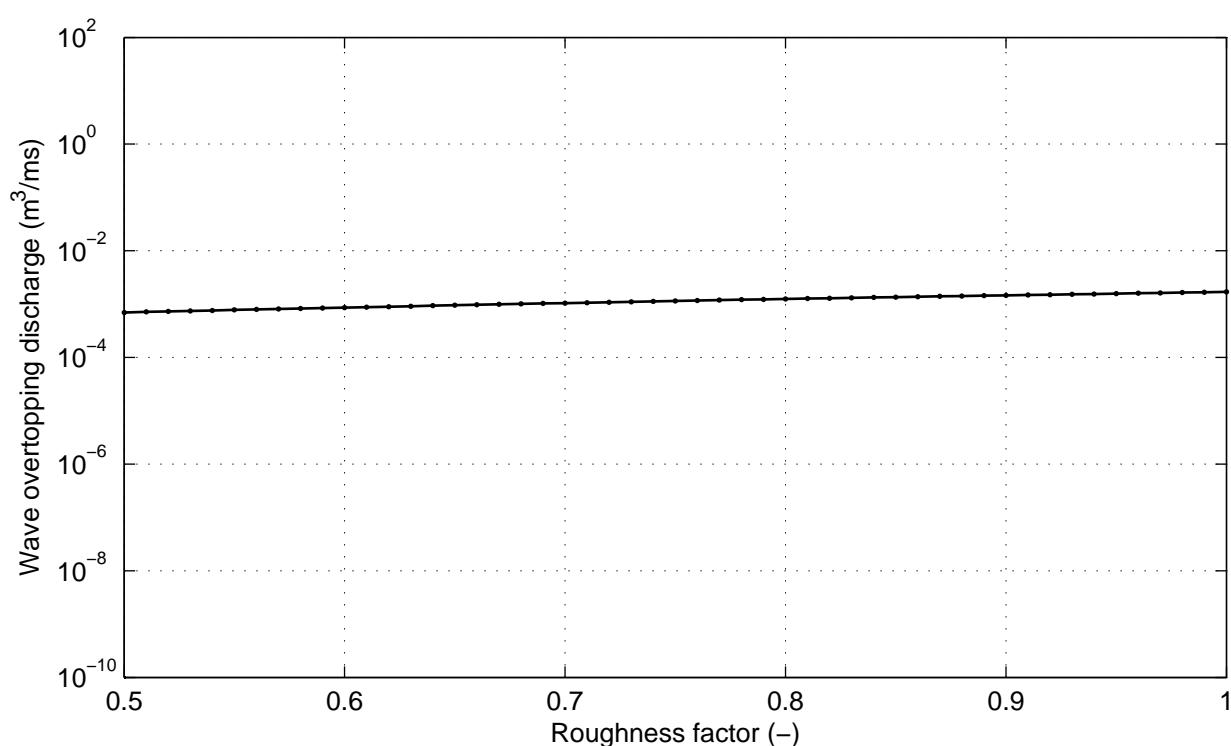
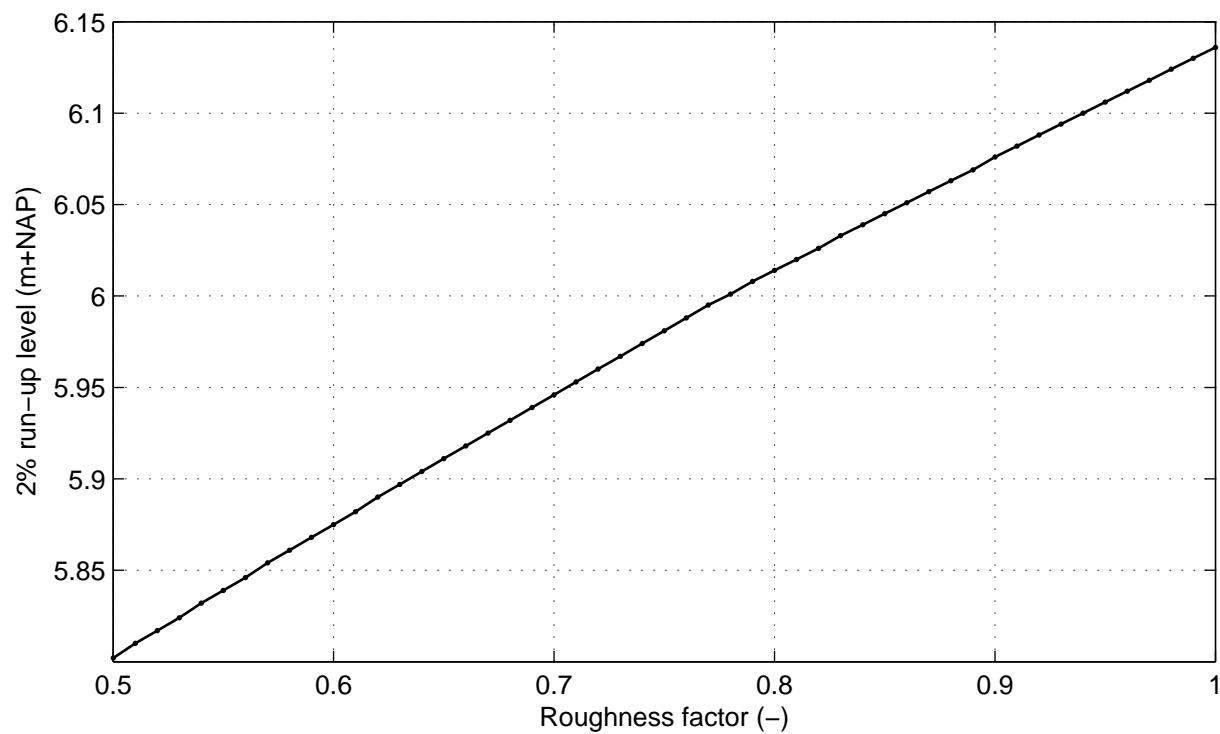
Cross section nr 5; series nr 11; Wave angle: 85 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.13



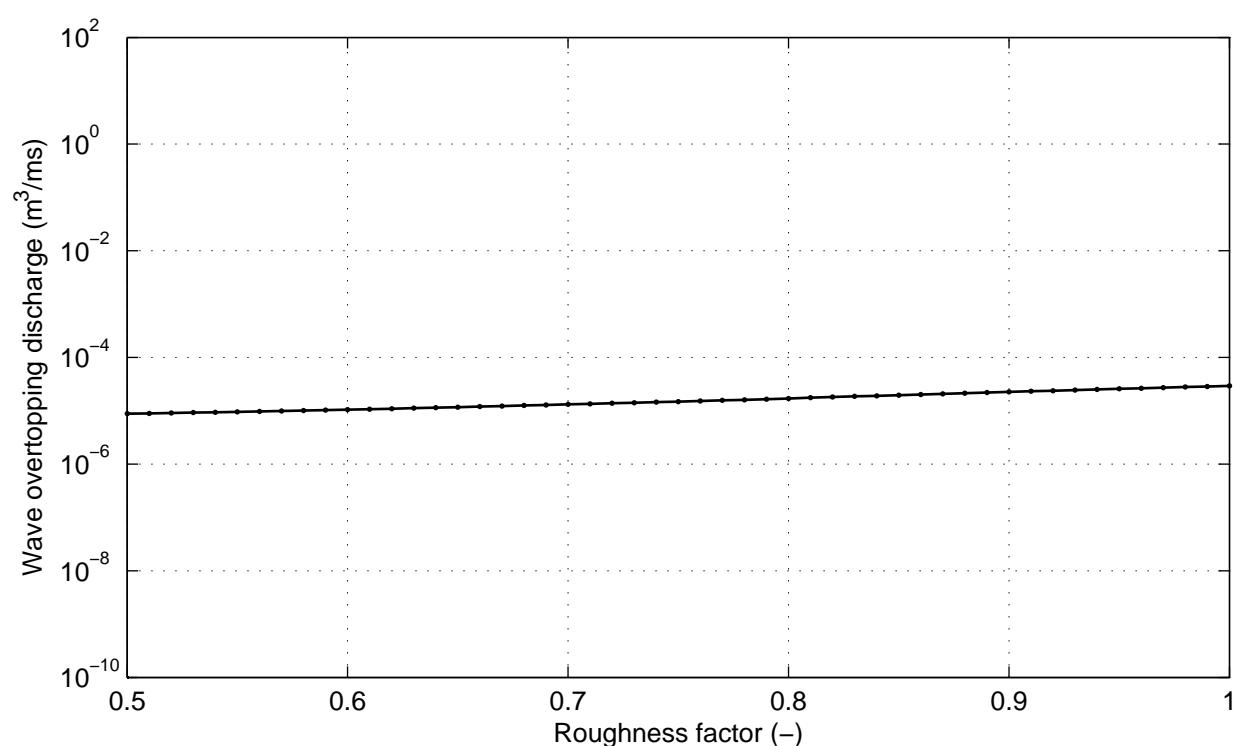
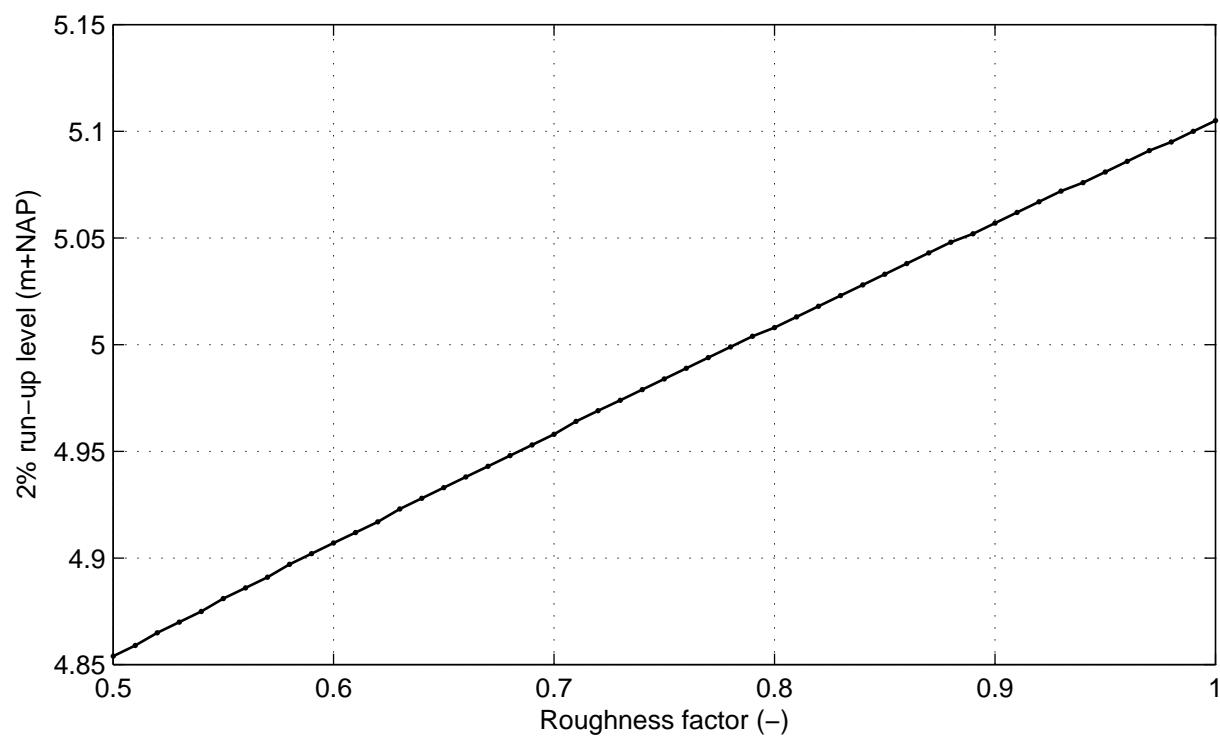
Cross section nr 5; series nr 12; Wave angle: 0 °
Varying roughness of segment 2

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.14



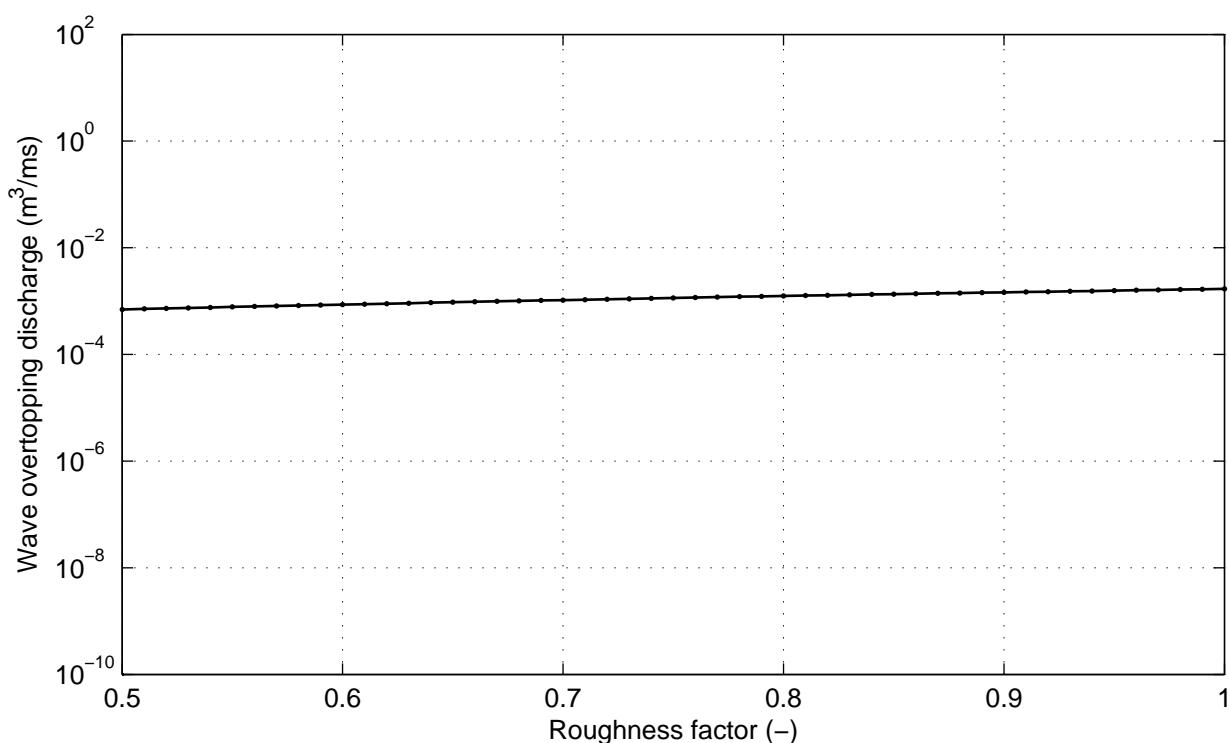
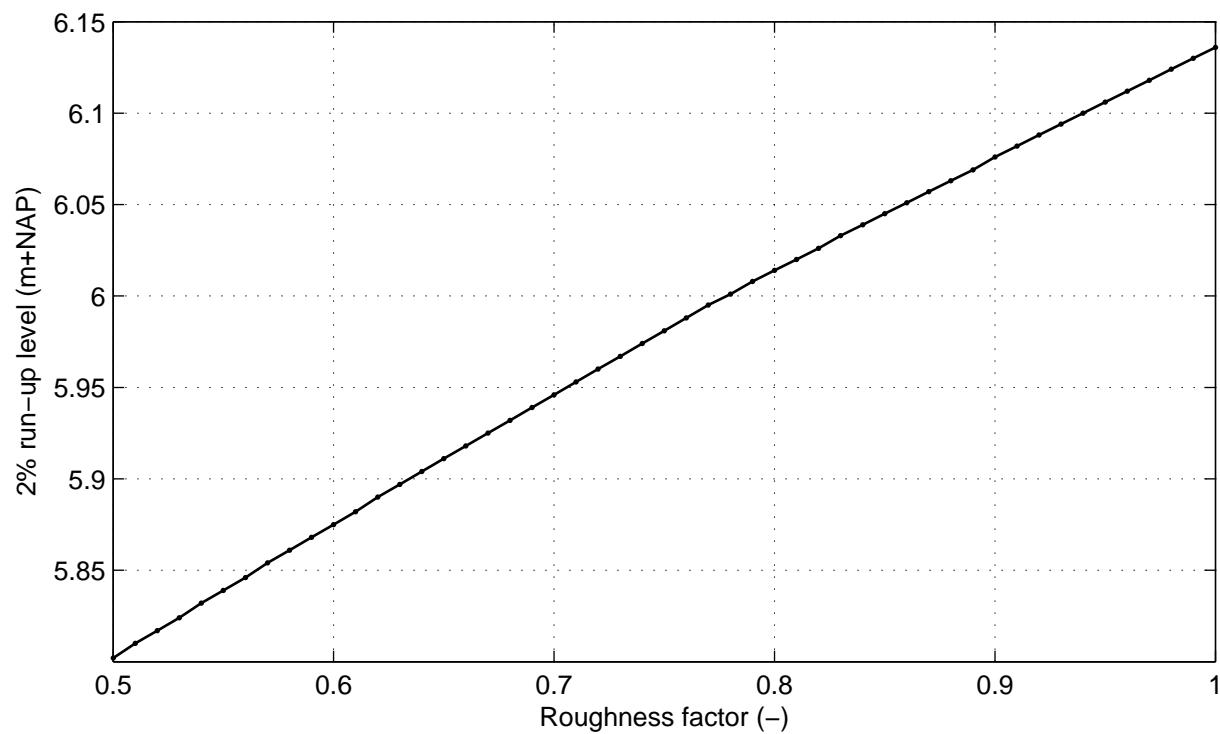
Cross section nr 5; series nr 13; Wave angle: 85 °
Varying roughness of segment 2

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.15



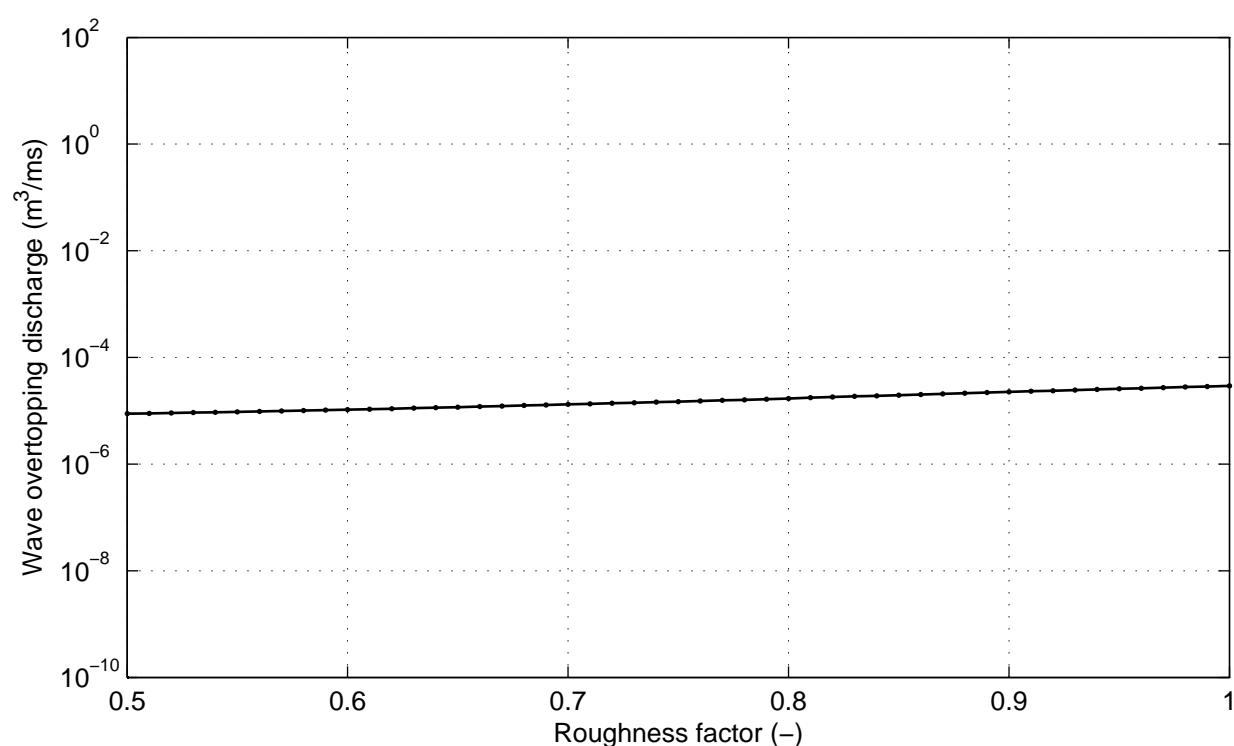
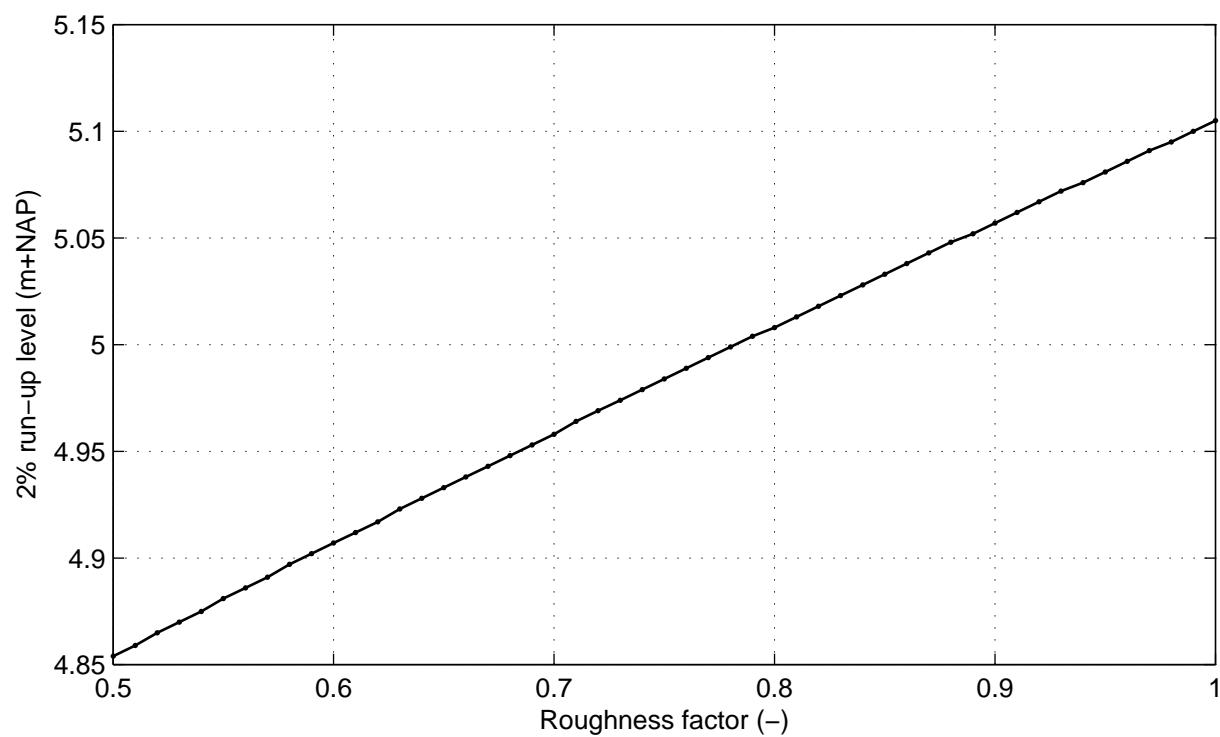
Cross section nr 5; series nr 14; Wave angle: 0 °
Varying roughness of segment 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.16



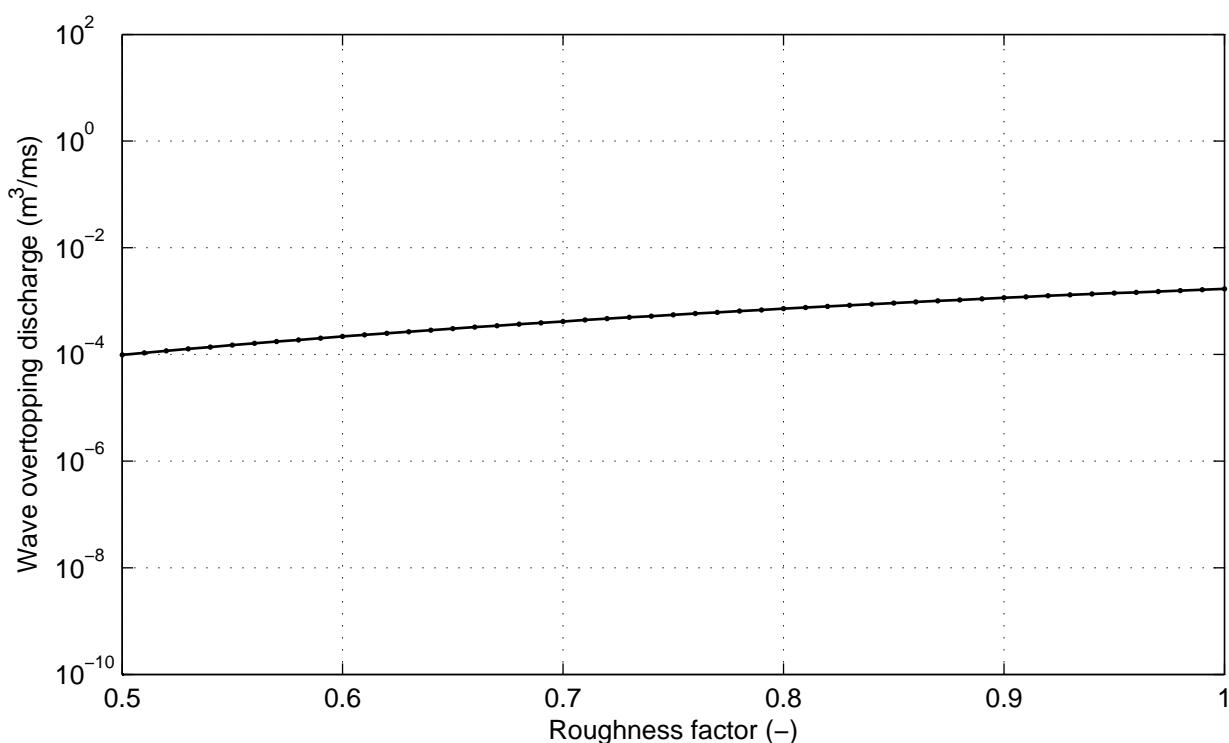
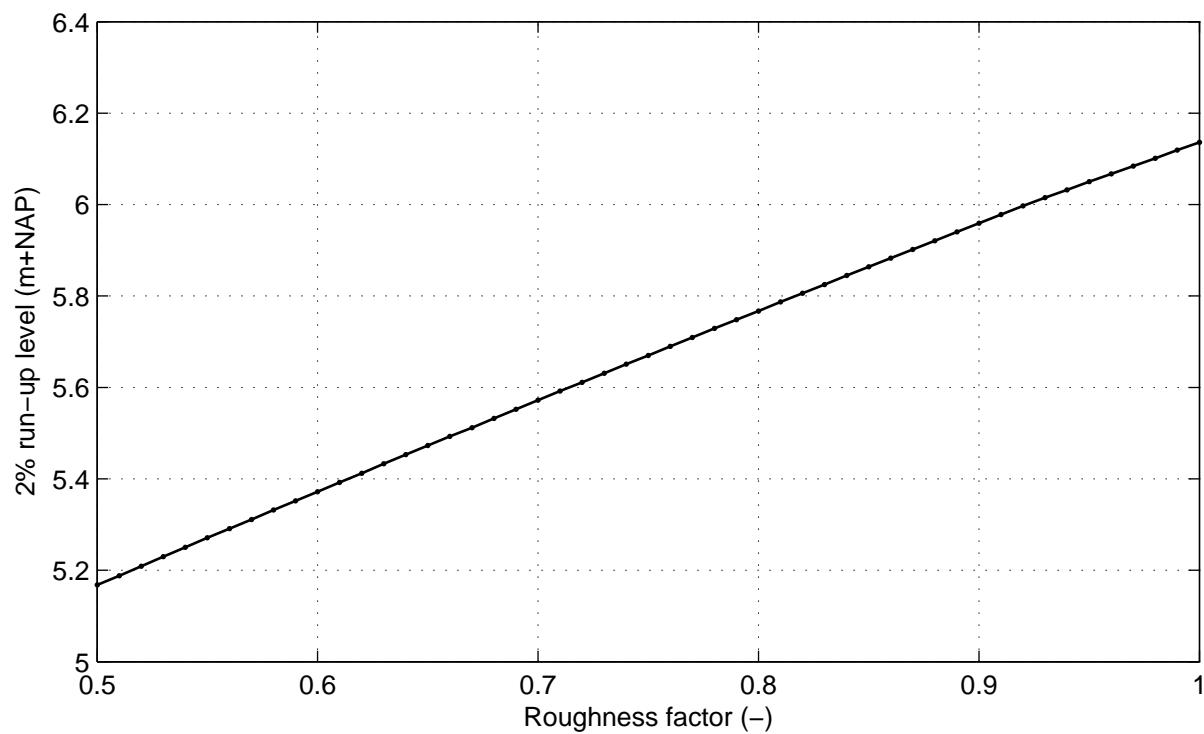
Cross section nr 5; series nr 15; Wave angle: 85 °
Varying roughness of segment 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.17



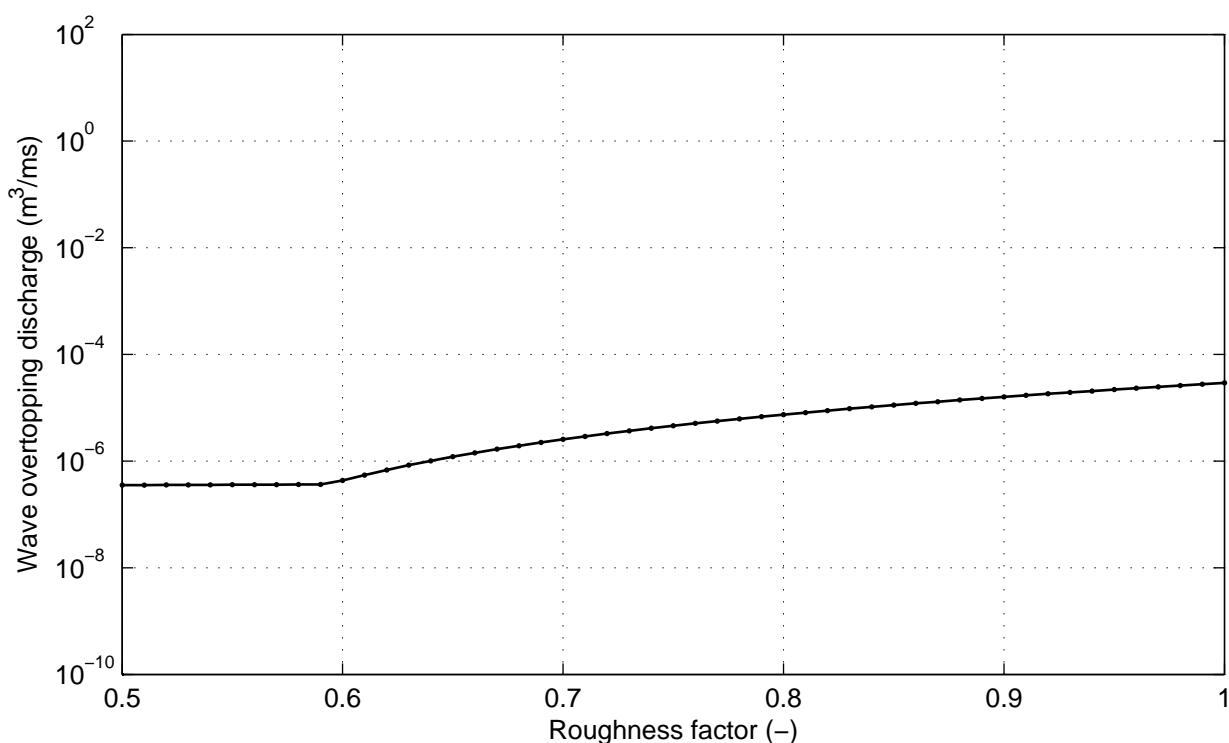
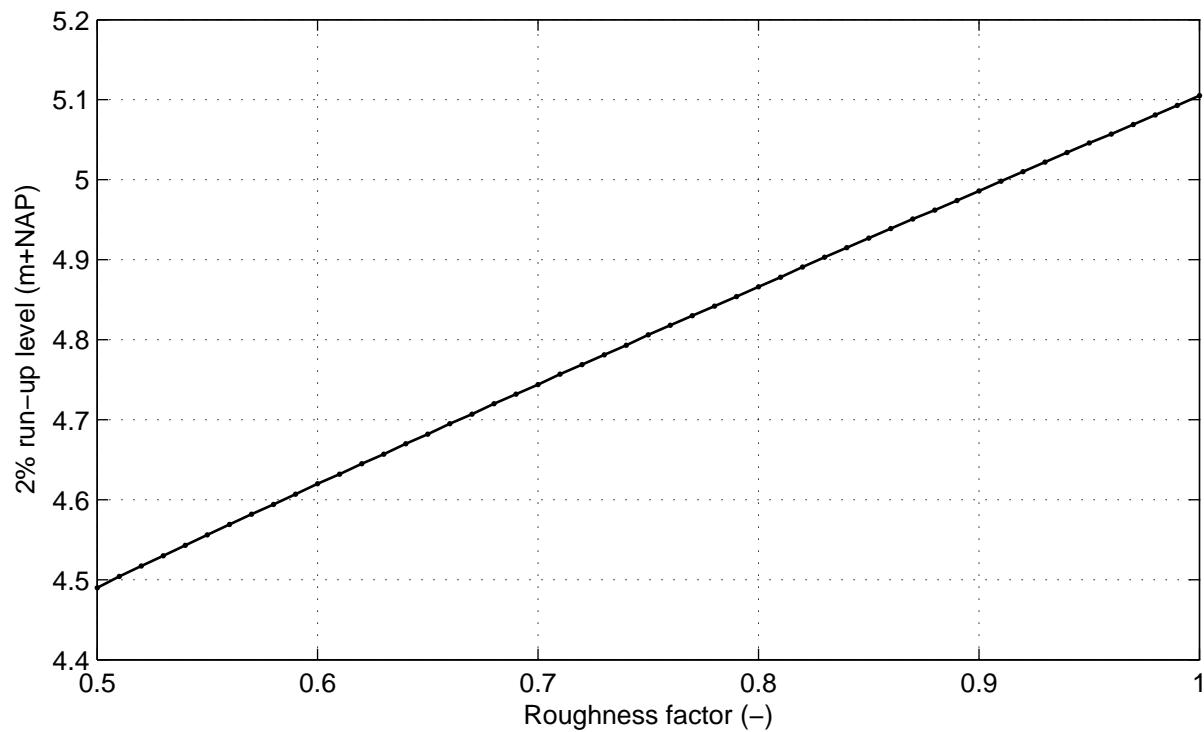
Cross section nr 5; series nr 16; Wave angle: 0 °
Varying roughness of segments 1 and 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.18



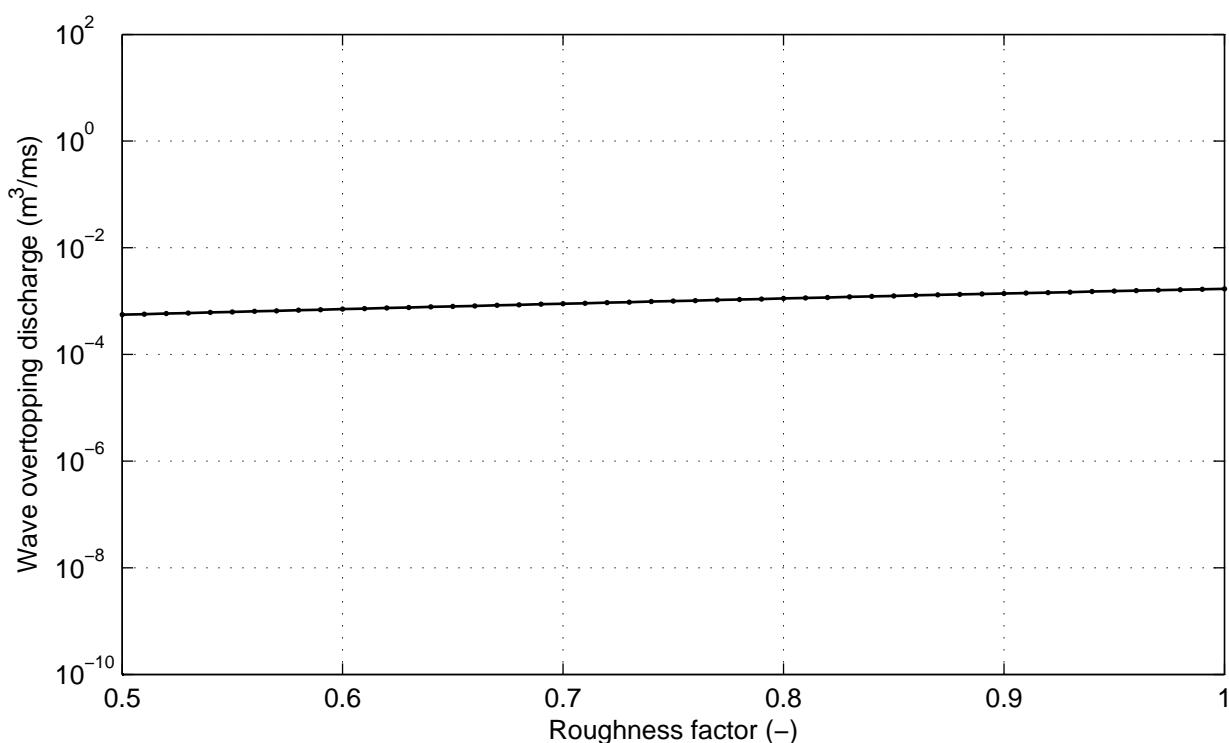
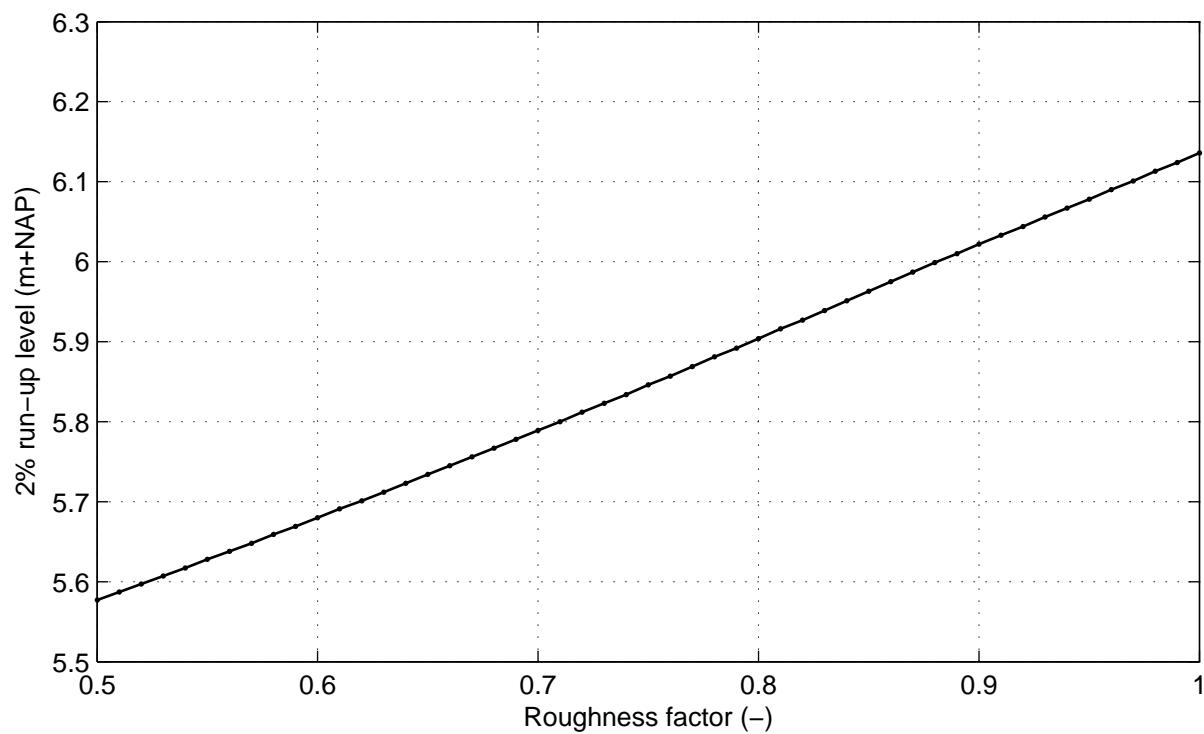
Cross section nr 5; series nr 17; Wave angle: 85 °
Varying roughness of segments 1 and 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.19



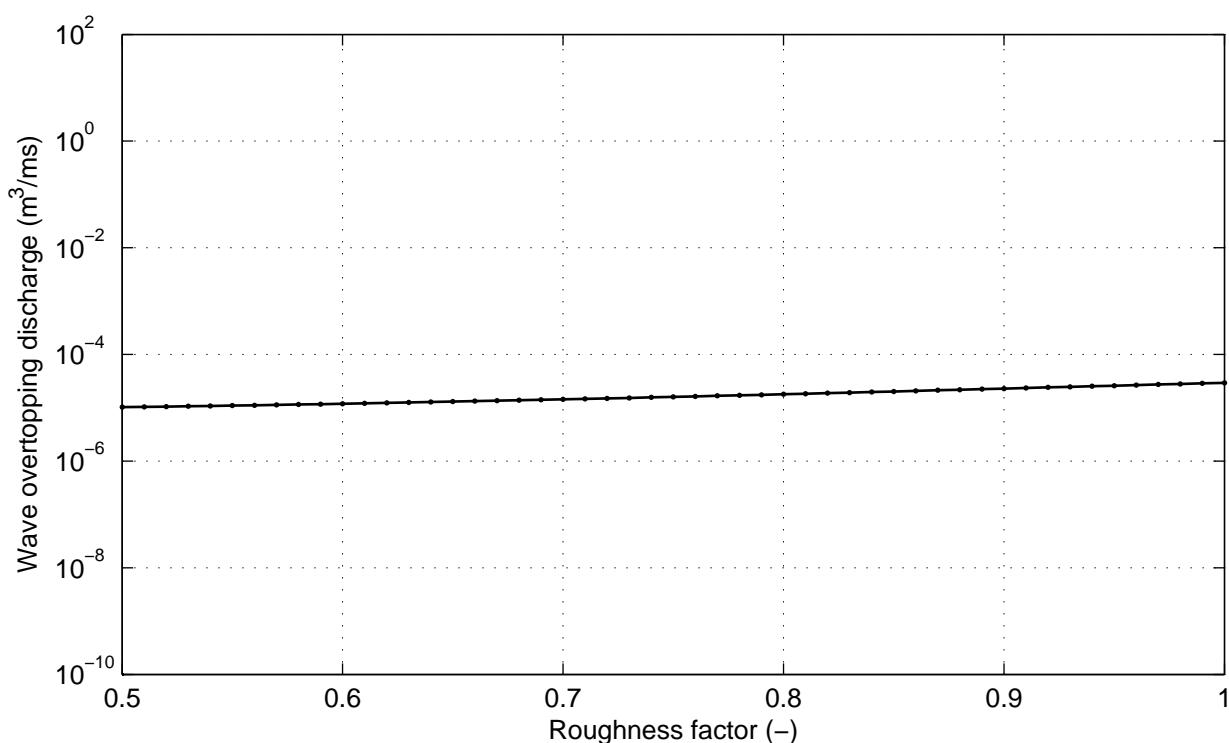
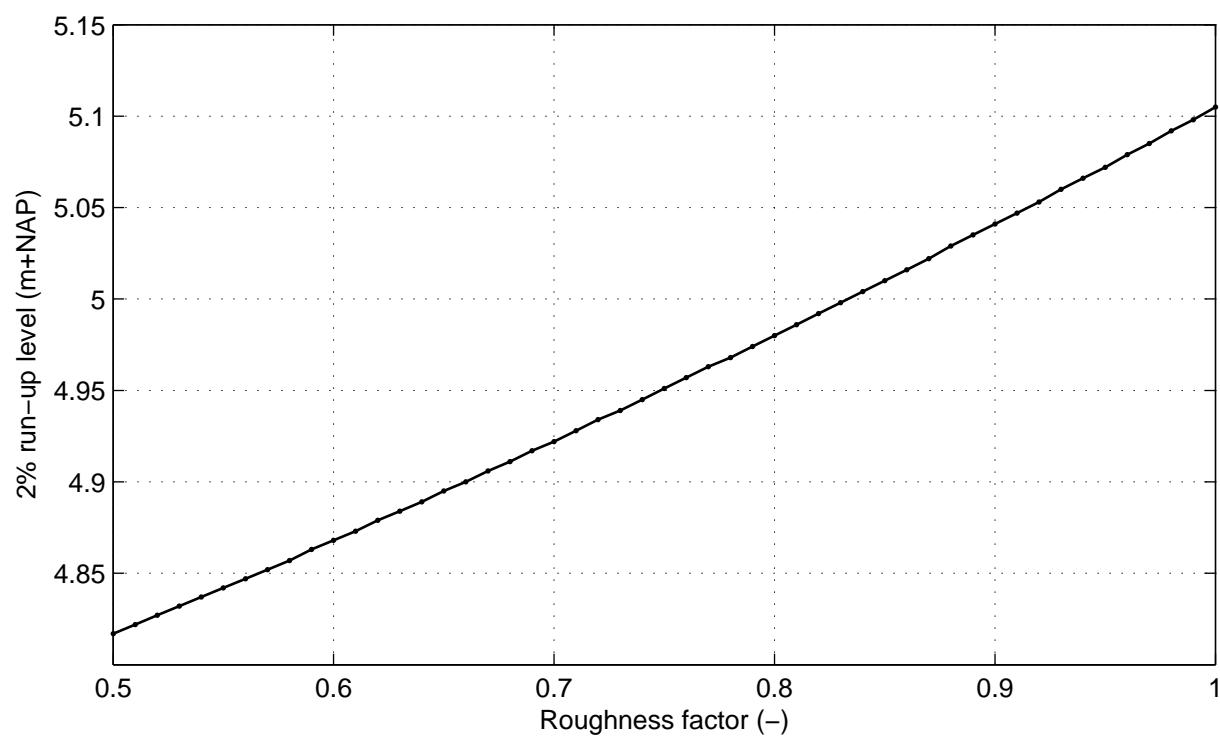
Cross section nr 5; series nr 18; Wave angle: 0 °
Varying roughness of segments 2 and 4

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.20



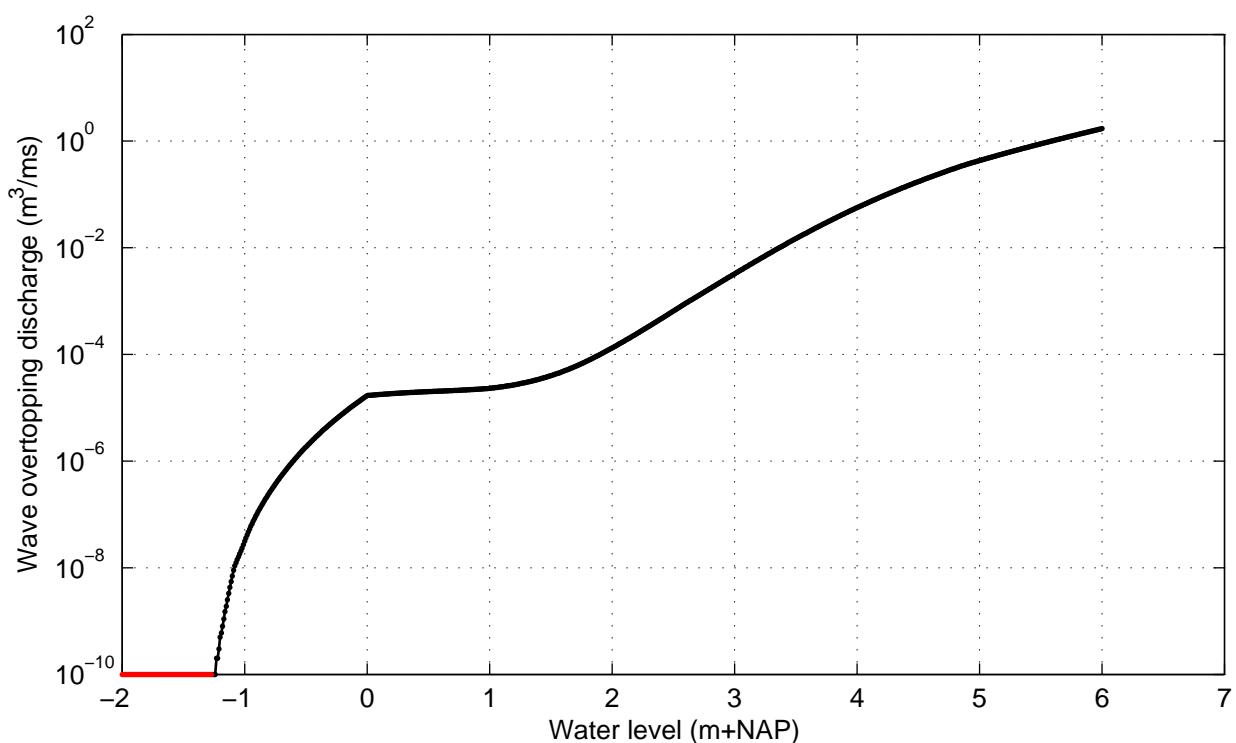
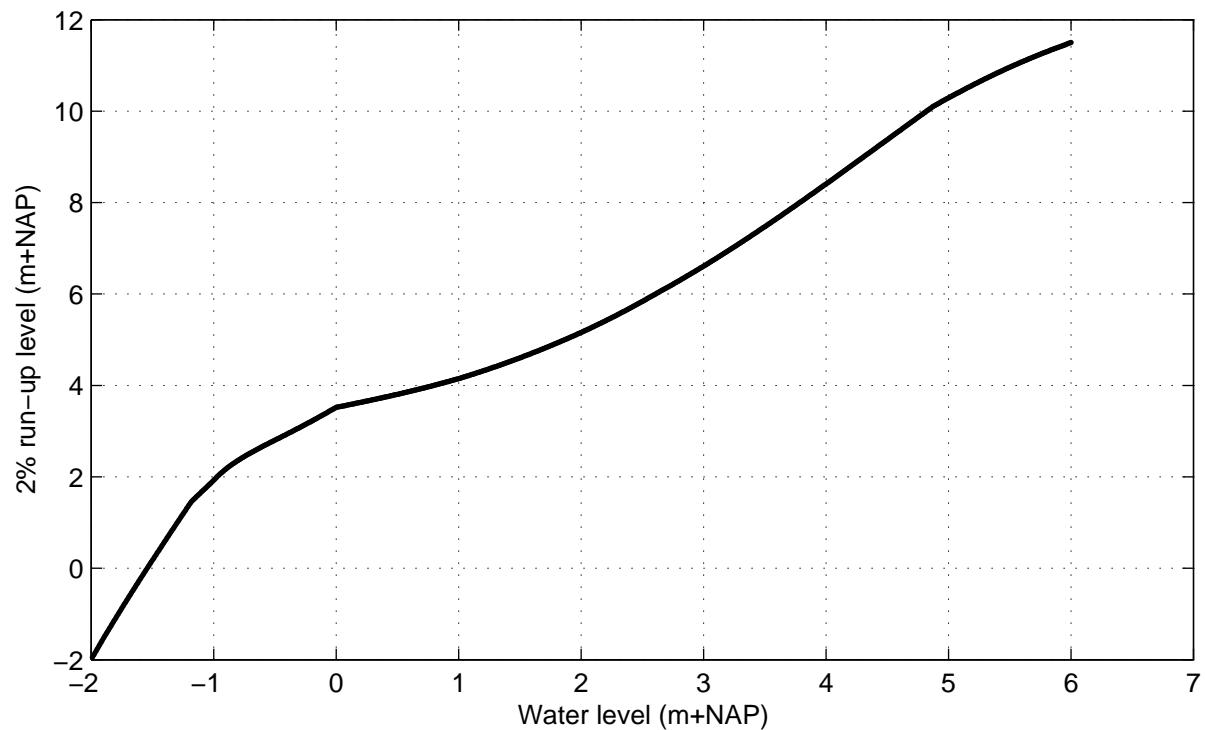
Cross section nr 5; series nr 19; Wave angle: 85 °
Varying roughness of segments 2 and 4

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 5.21



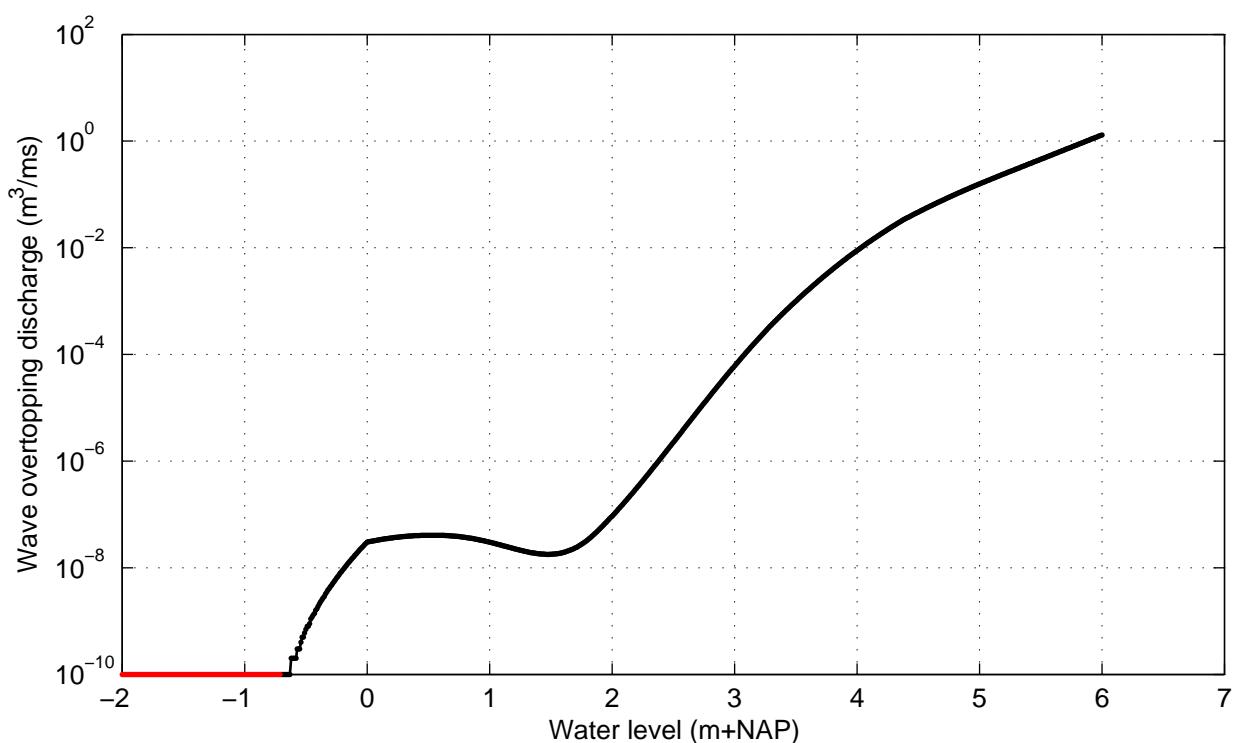
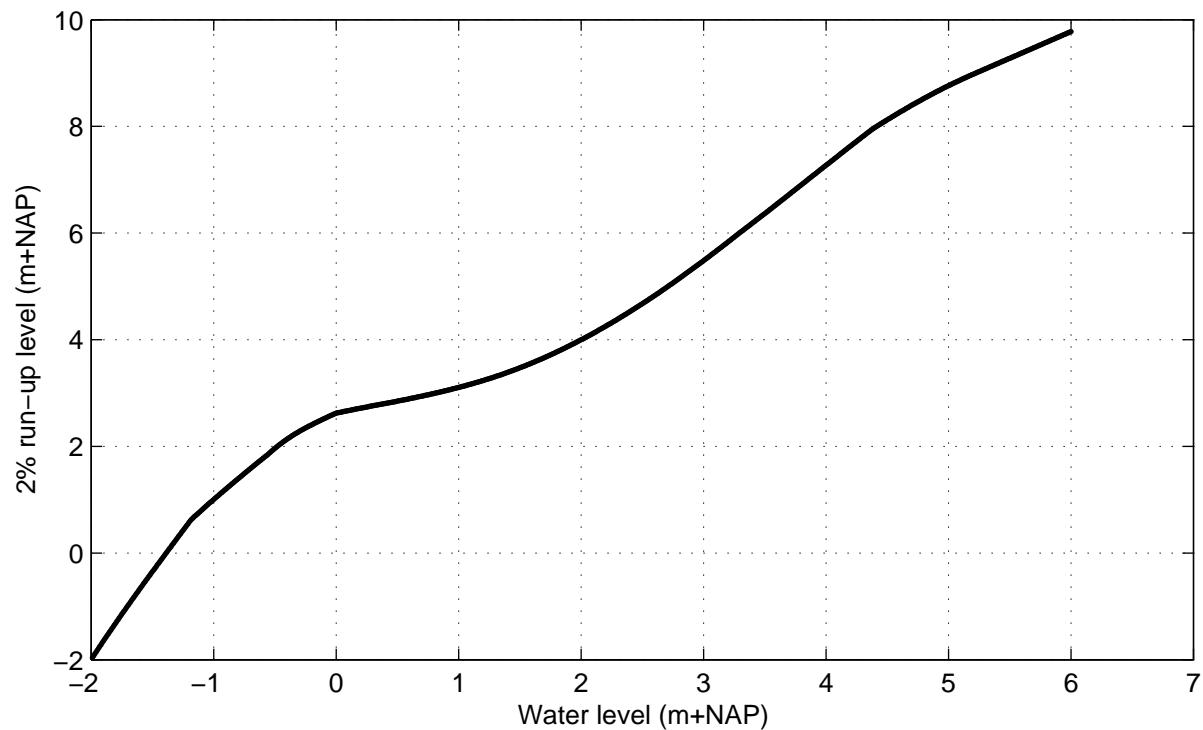
Cross section nr 6; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.1



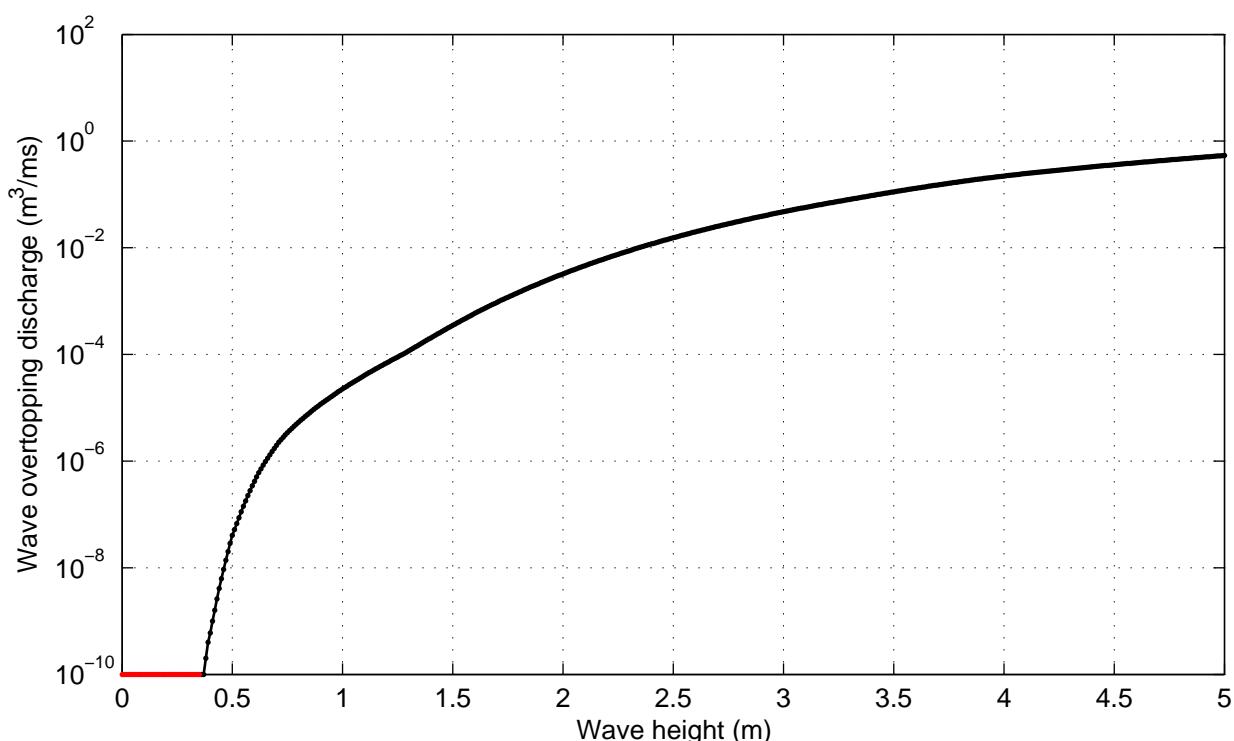
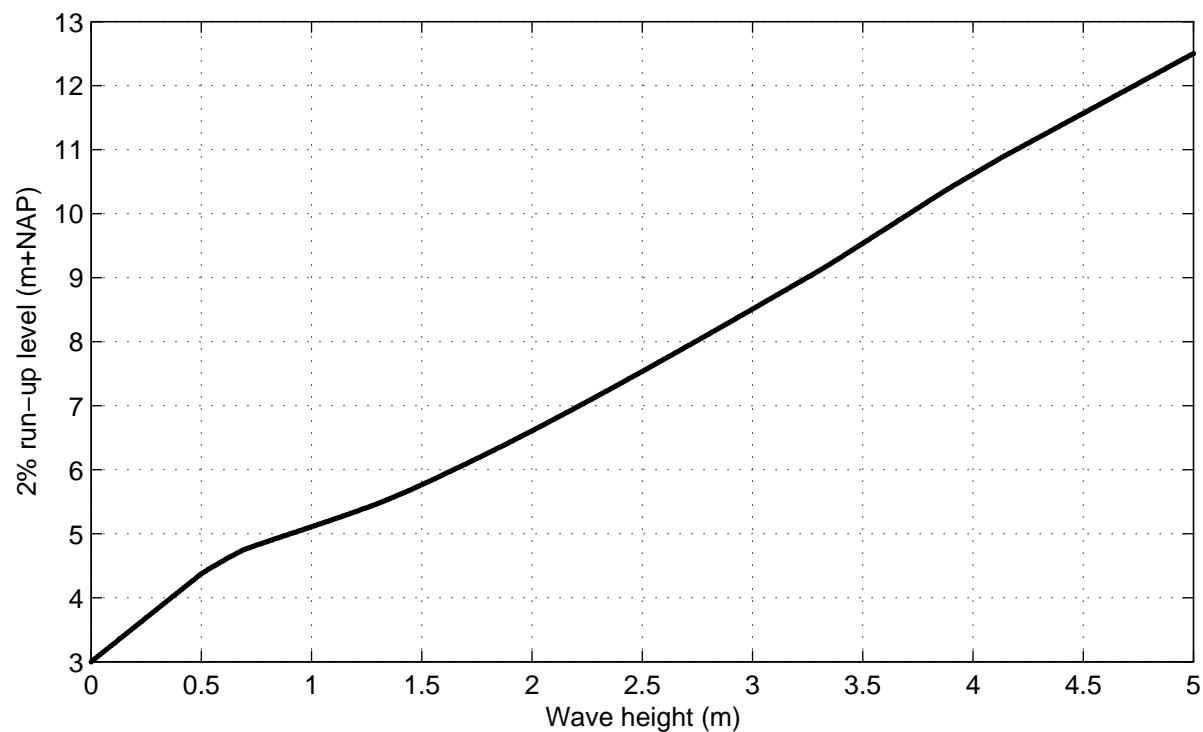
Cross section nr 6; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.2



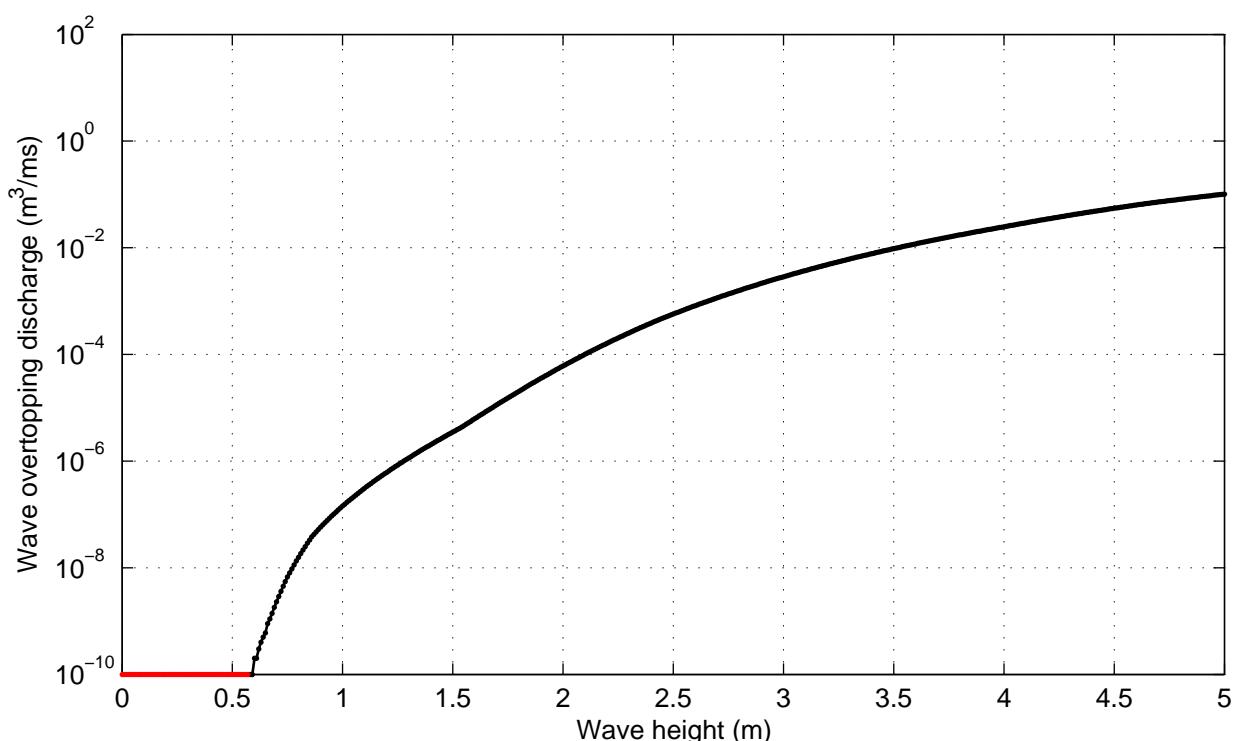
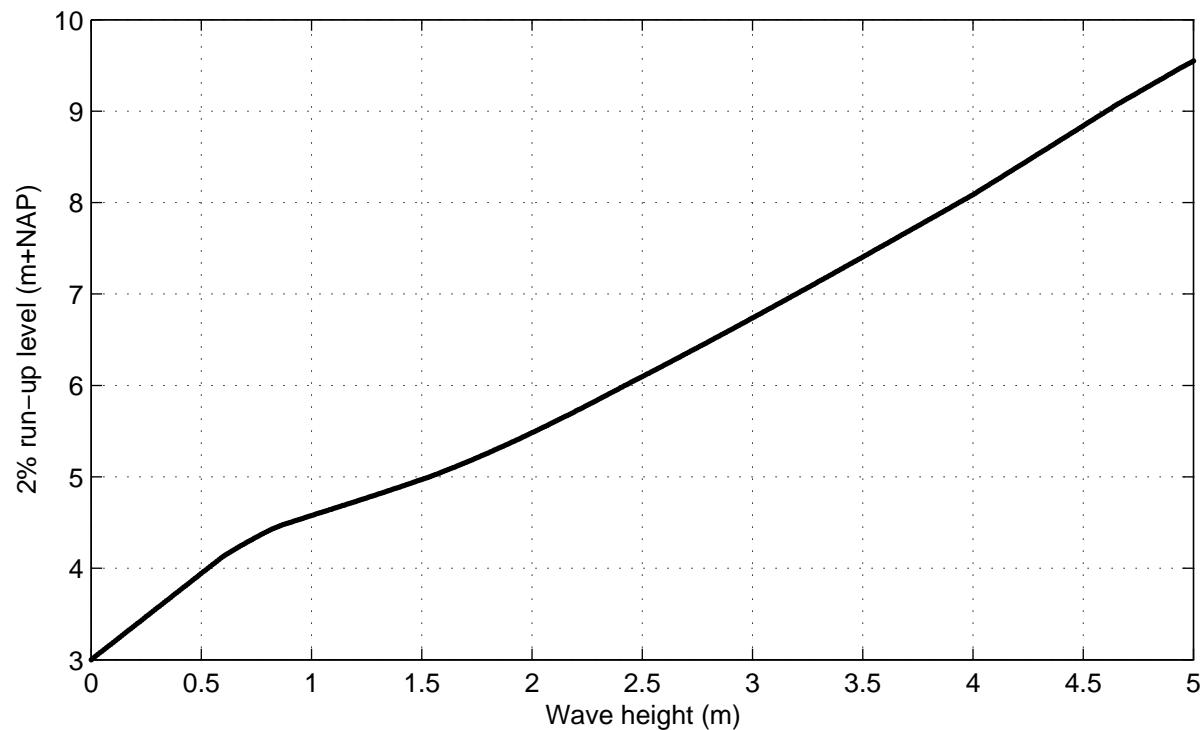
Cross section nr 6; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.3



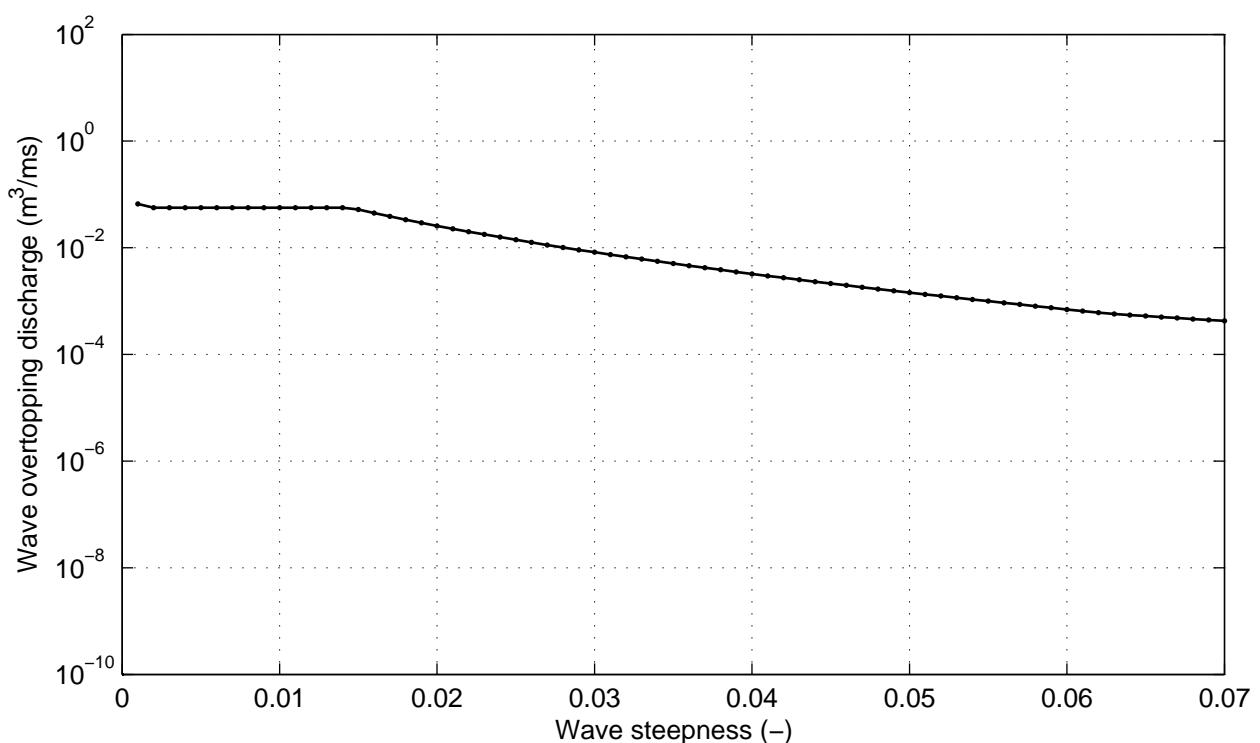
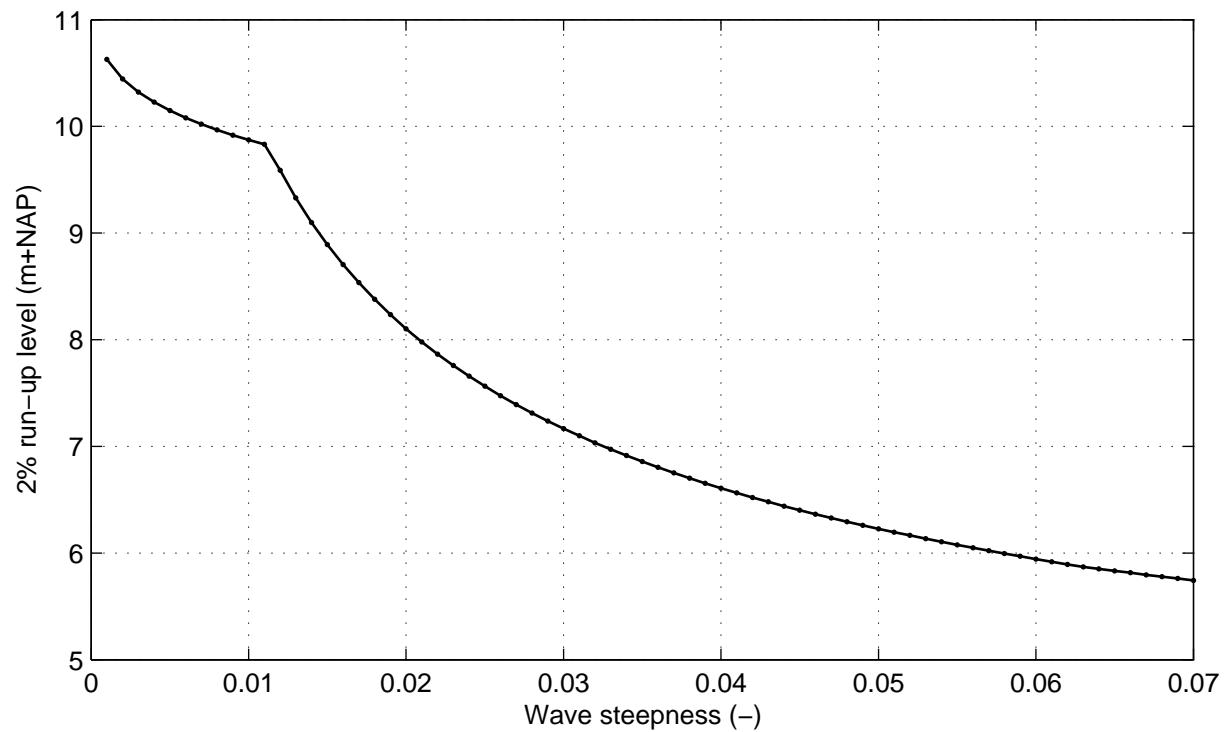
Cross section nr 6; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.4



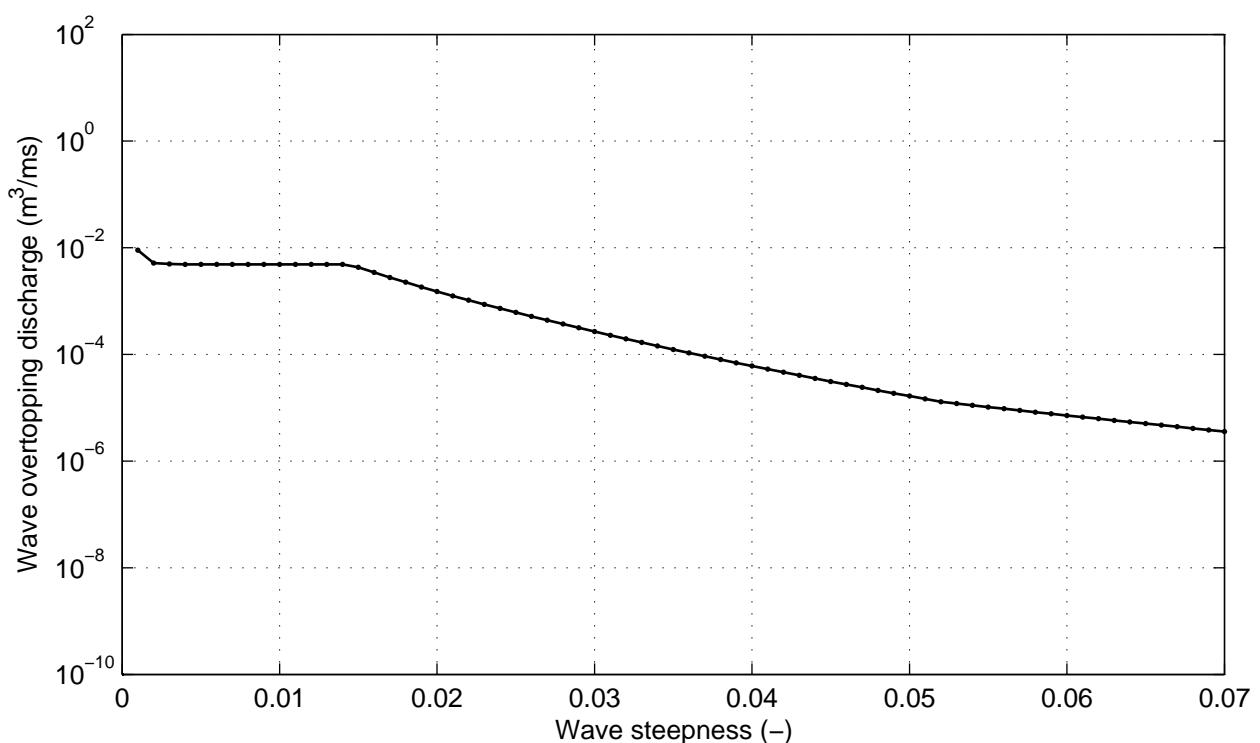
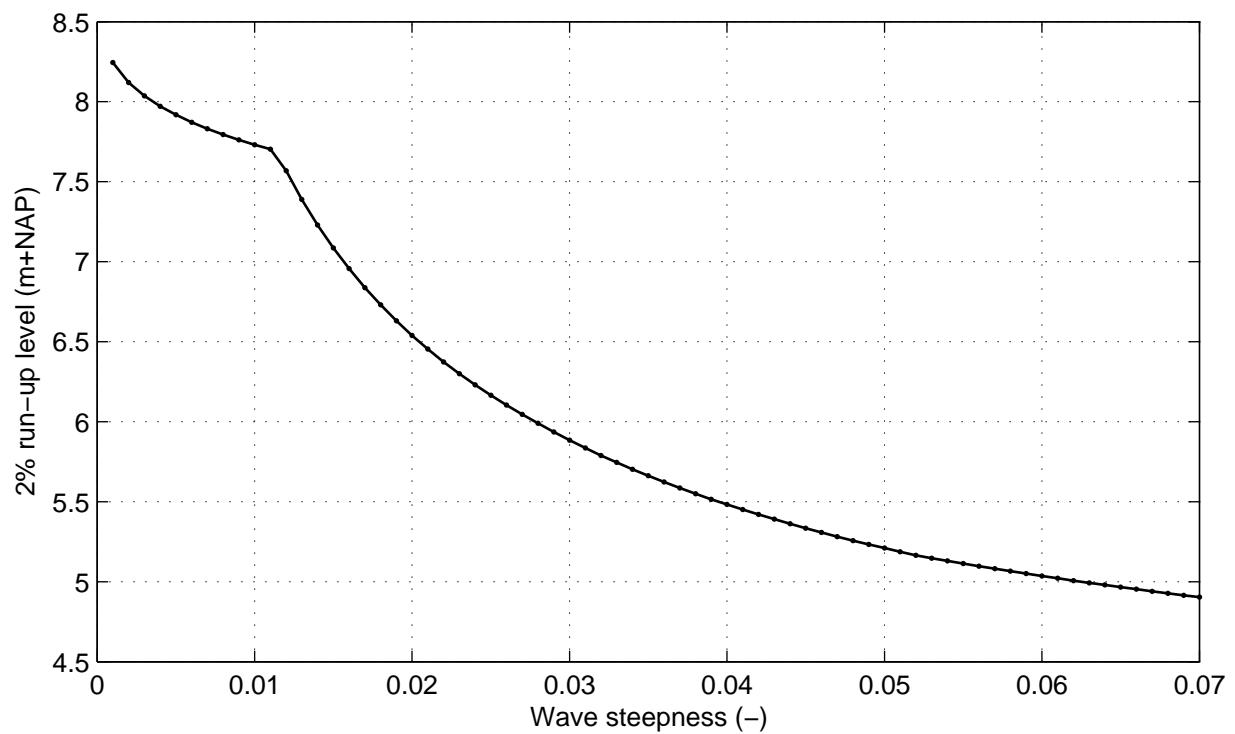
Cross section nr 6; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.5



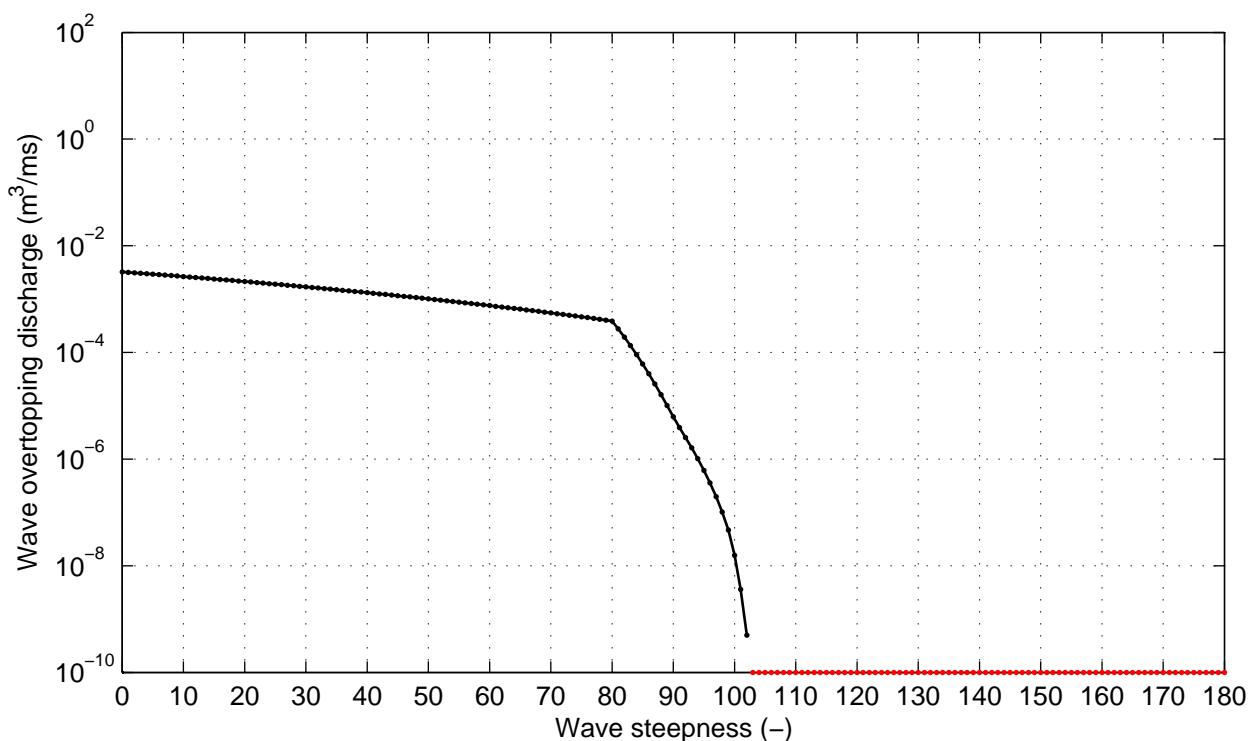
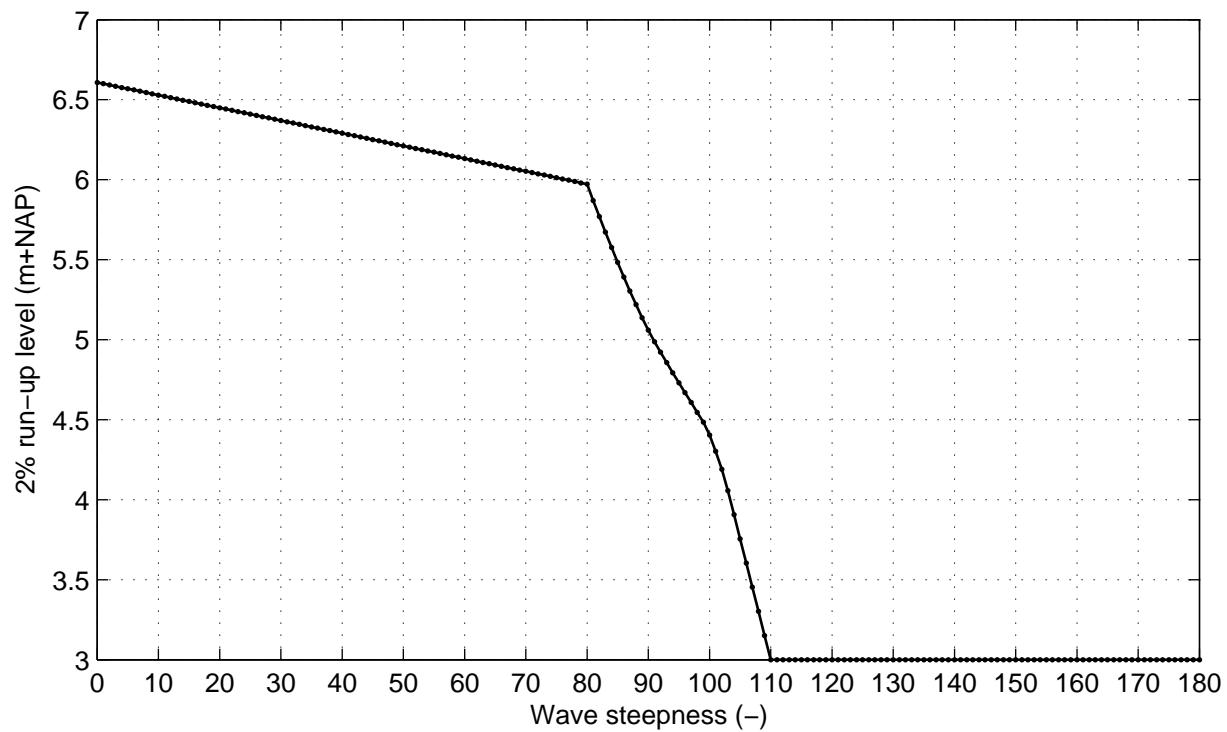
Cross section nr 6; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.6



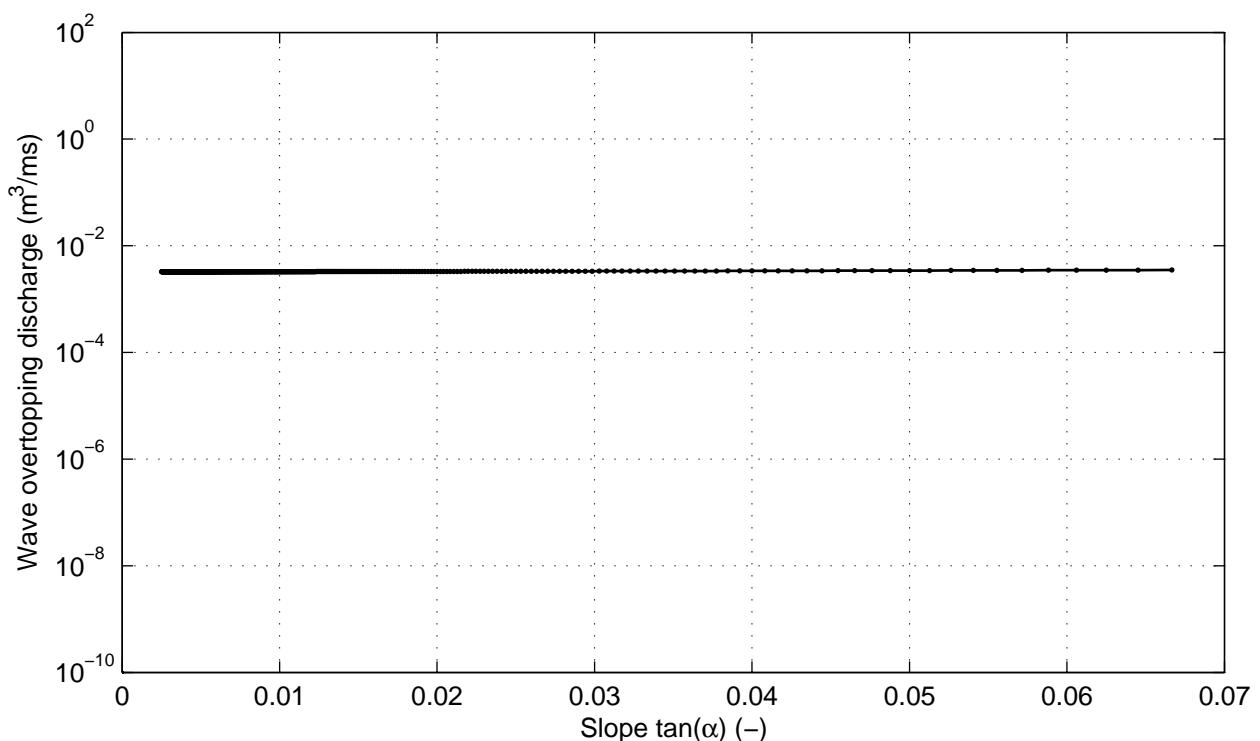
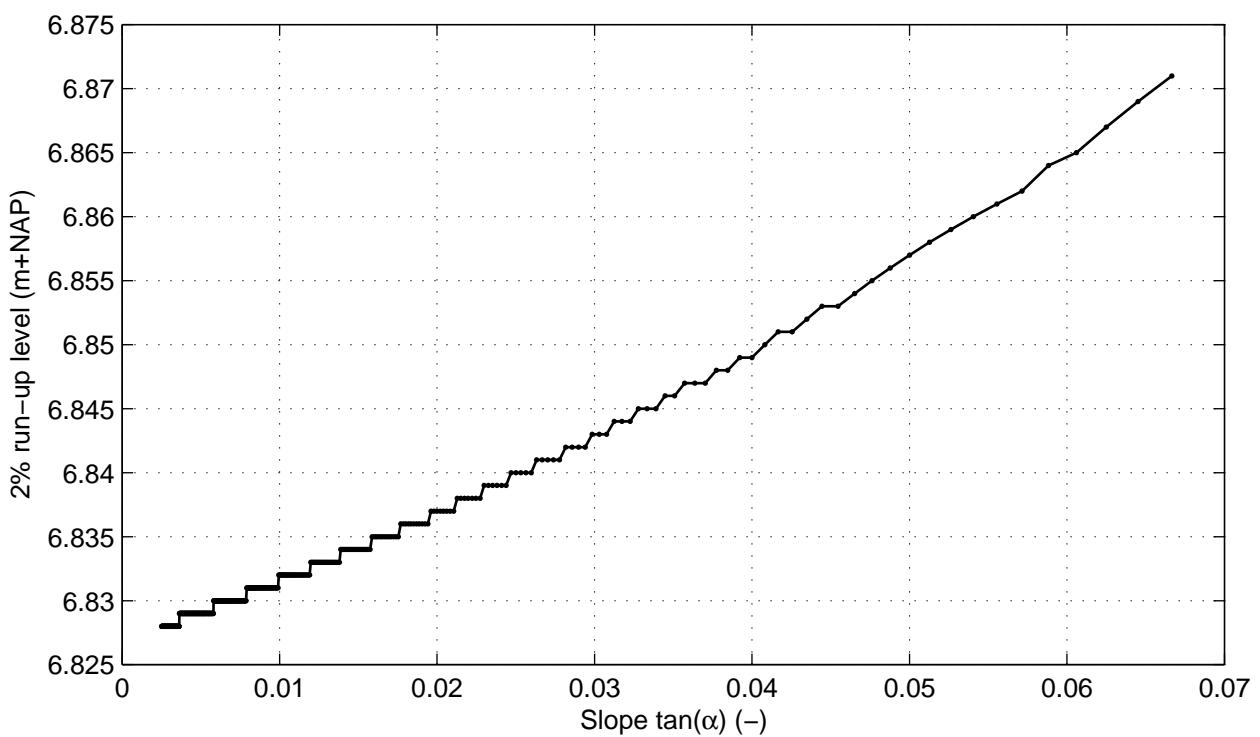
Cross section nr 6; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.7



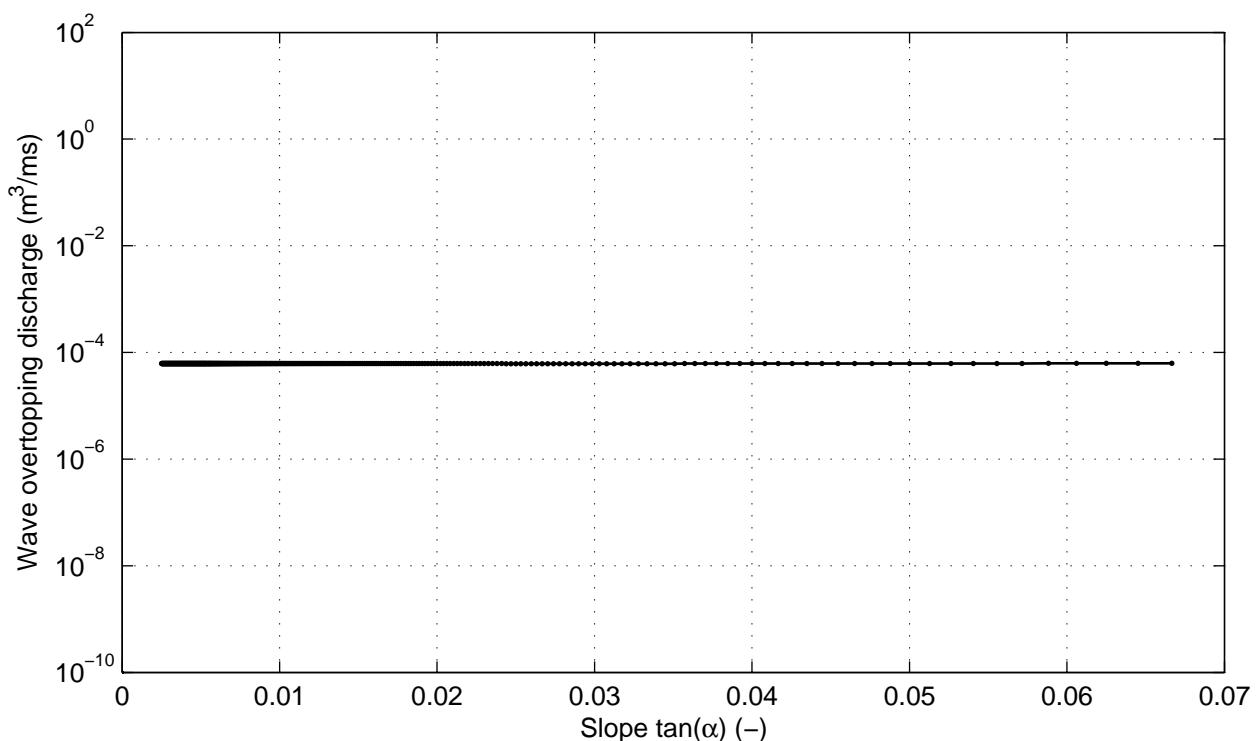
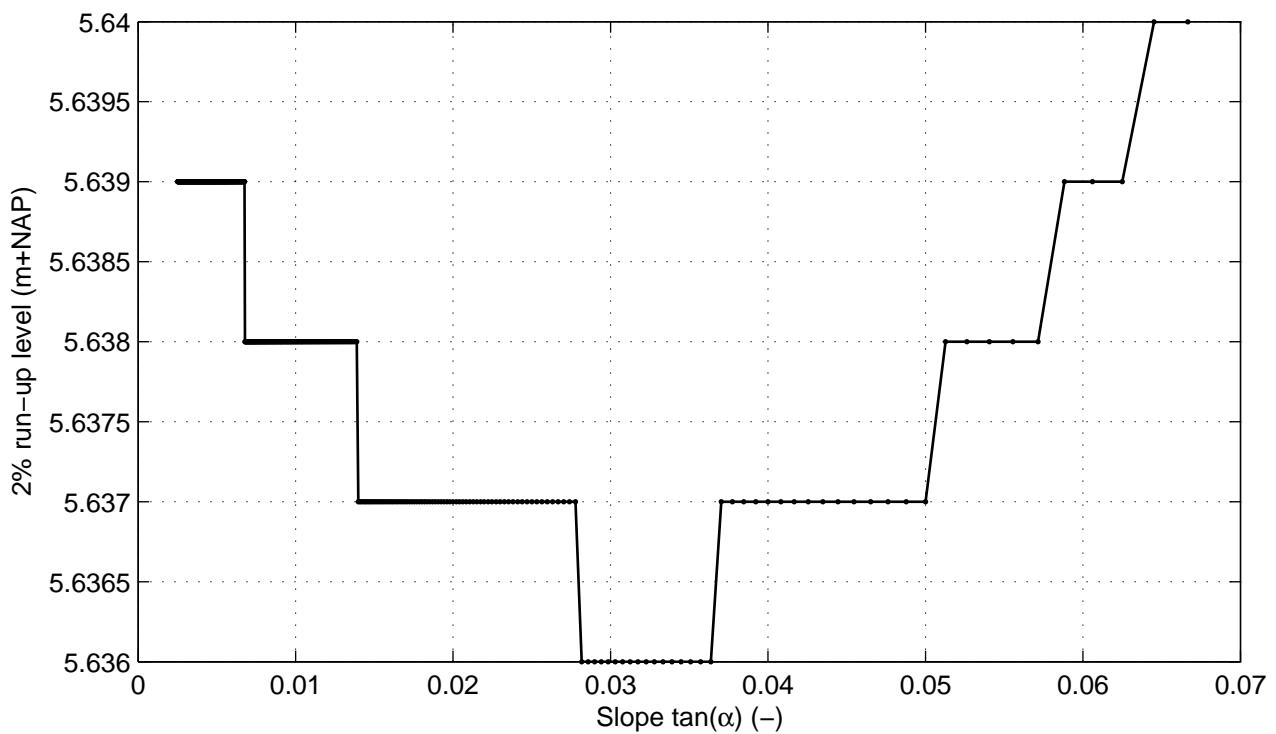
Cross section nr 6; series nr 8; Wave angle: 0 °
Varying slope second (higher) berm segment as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.8



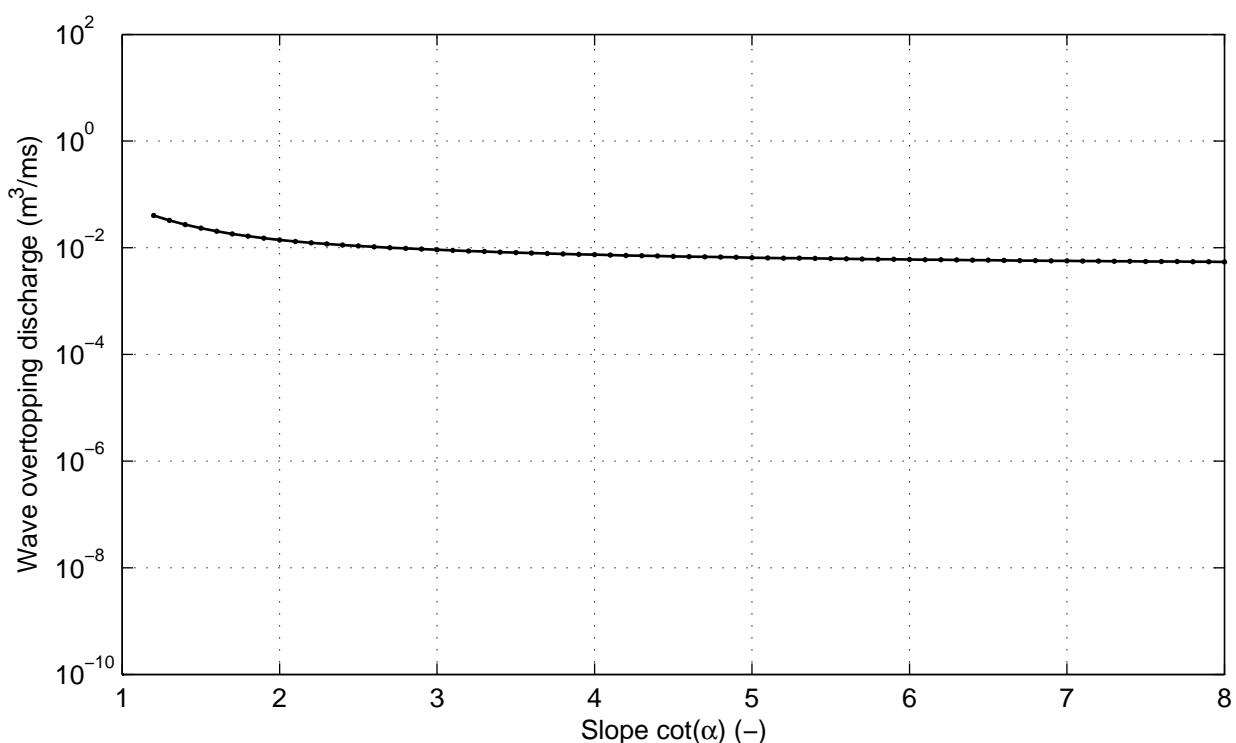
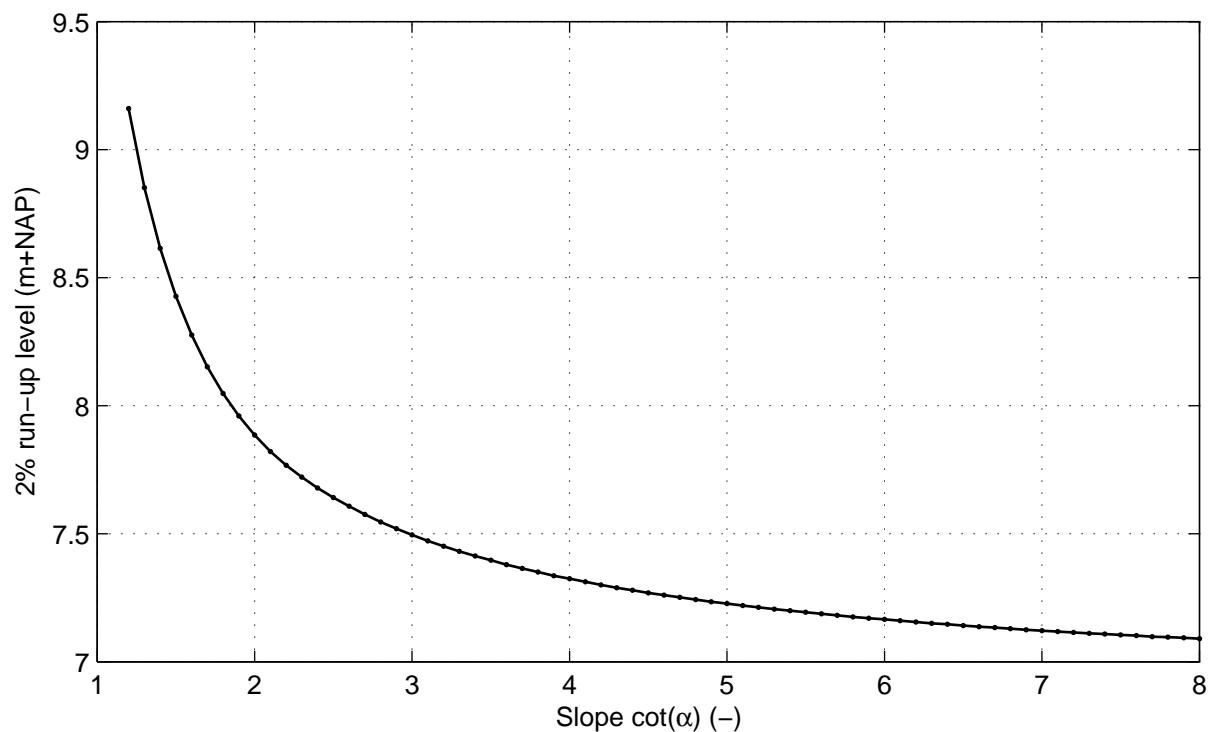
Cross section nr 6; series nr 9; Wave angle: 85 °
Varying slope second (higher) berm segment as a berm

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.9



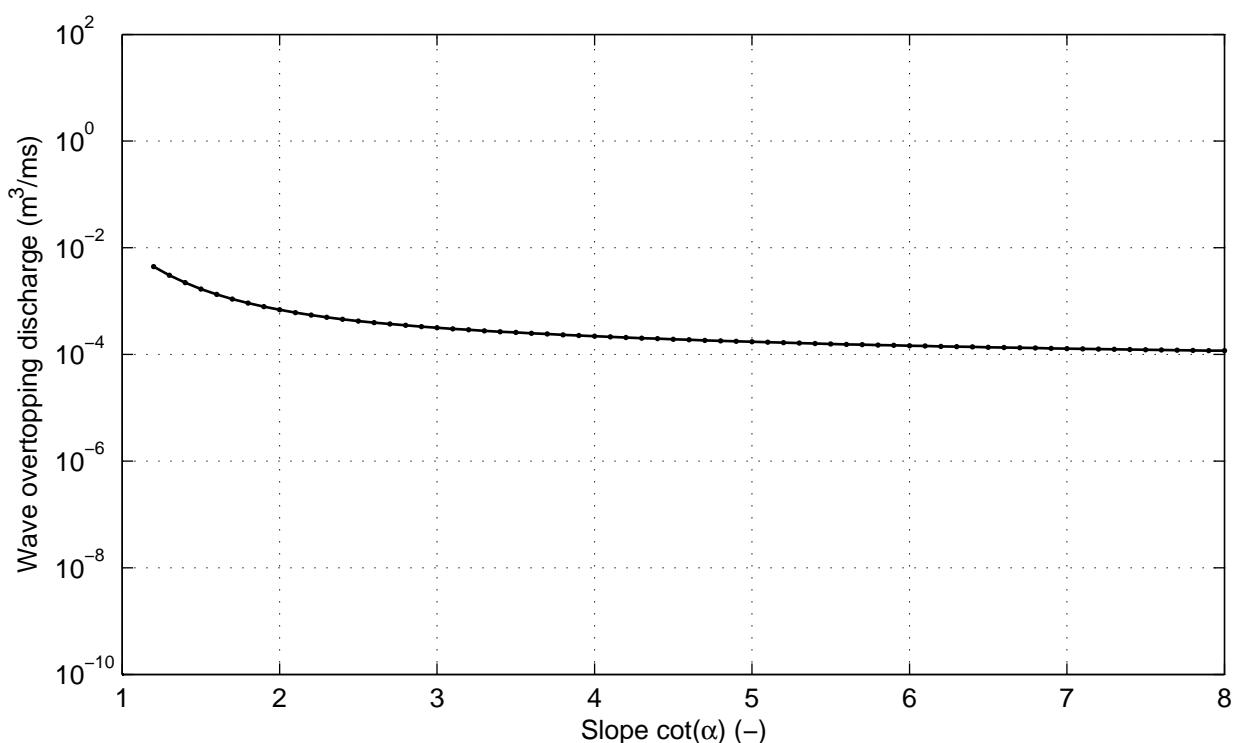
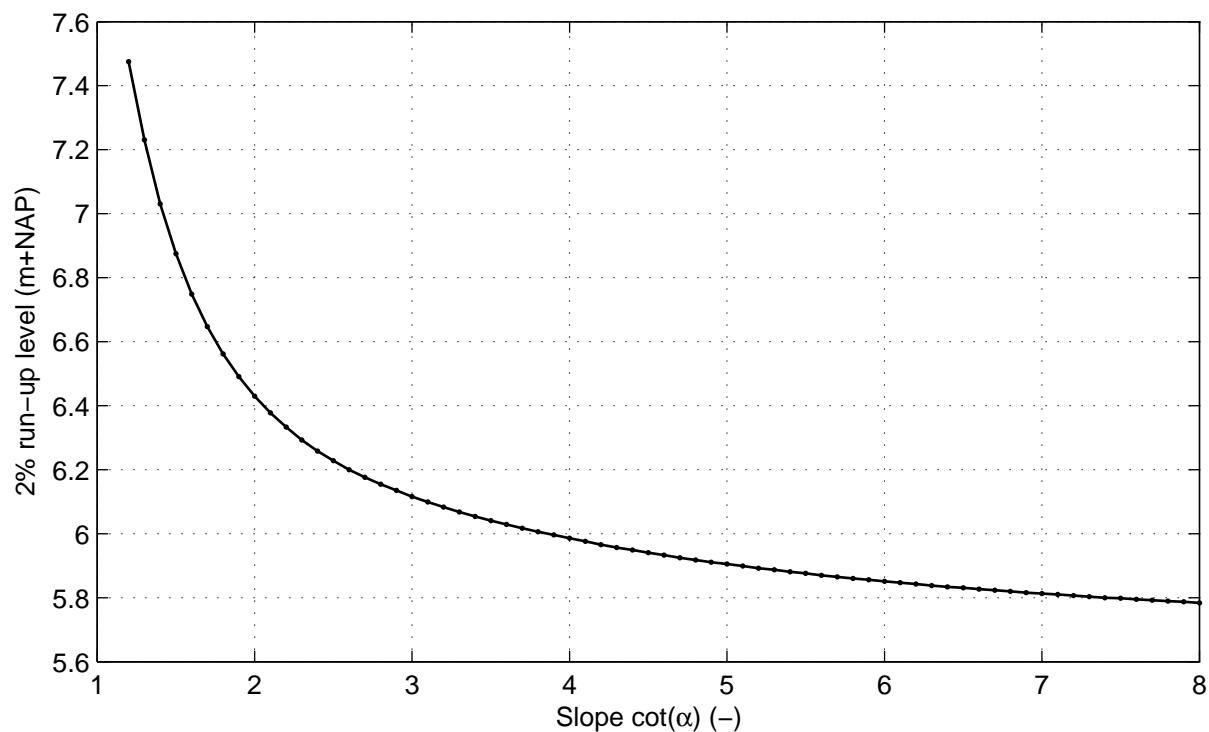
Cross section nr 6; series nr 8; Wave angle: 0 °
Varying slope second (higher) berm segment as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.10



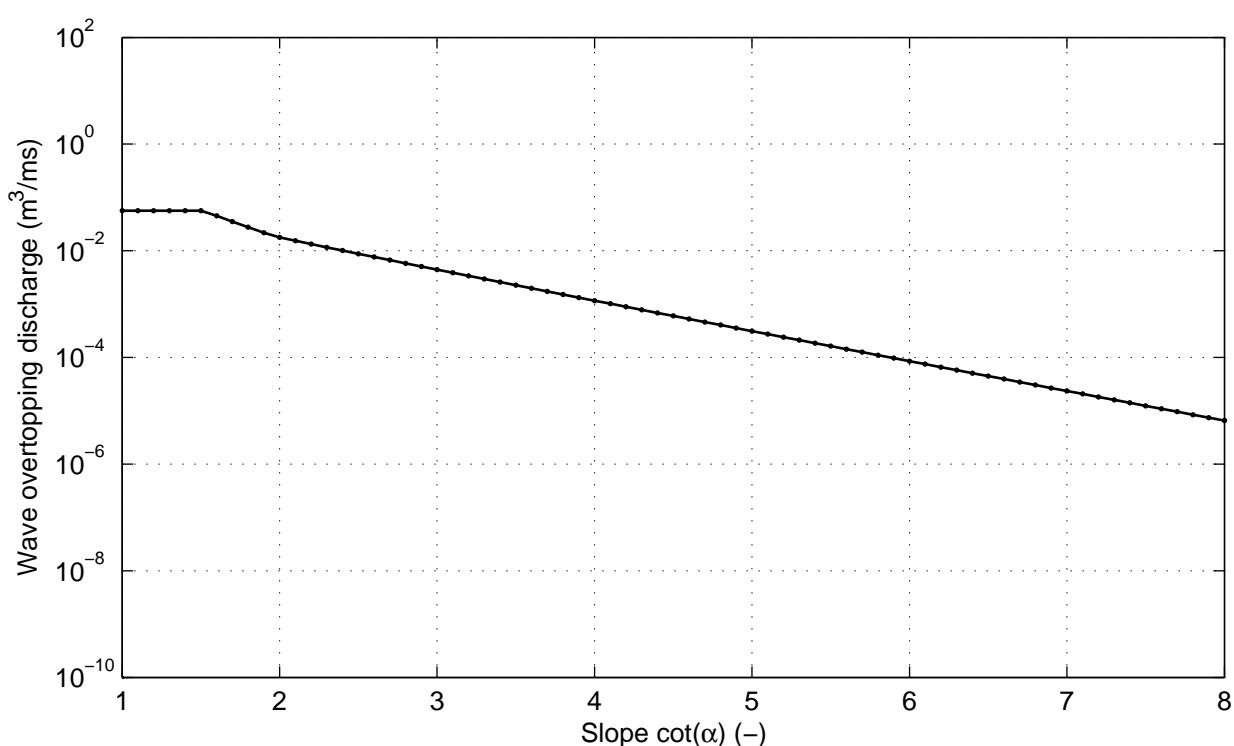
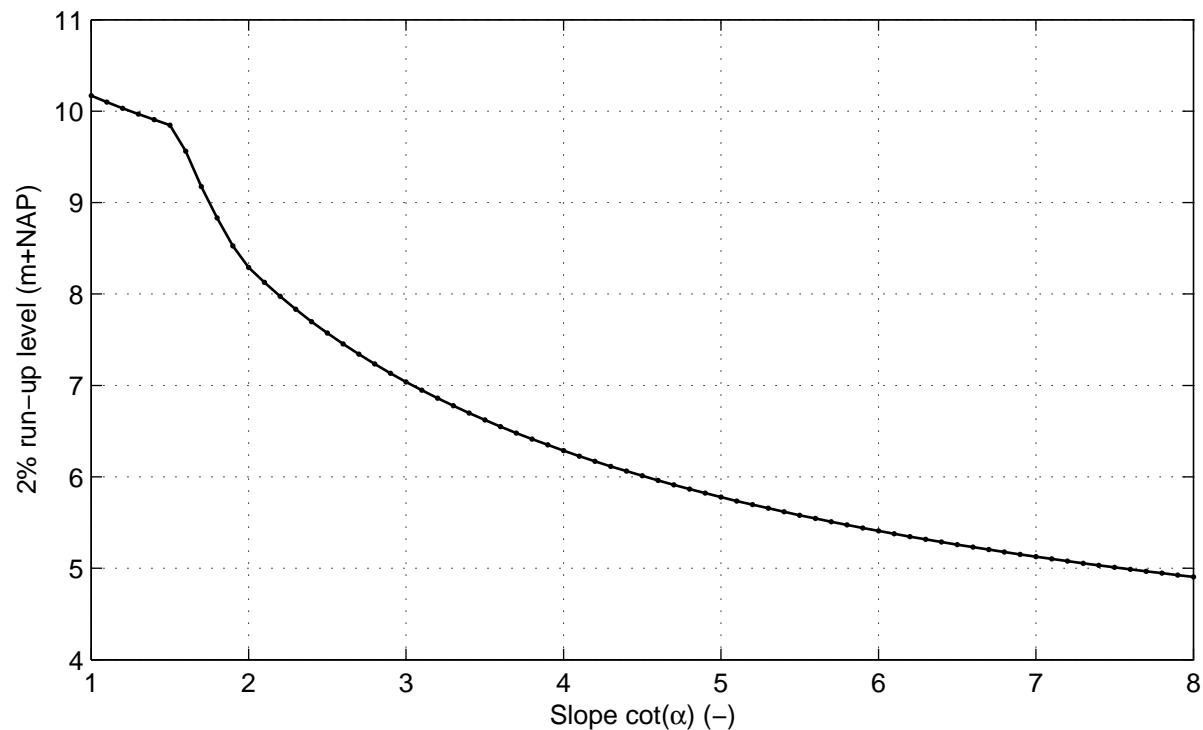
Cross section nr 6; series nr 9; Wave angle: 85 °
Varying slope second (higher) berm segment as a slope

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.11



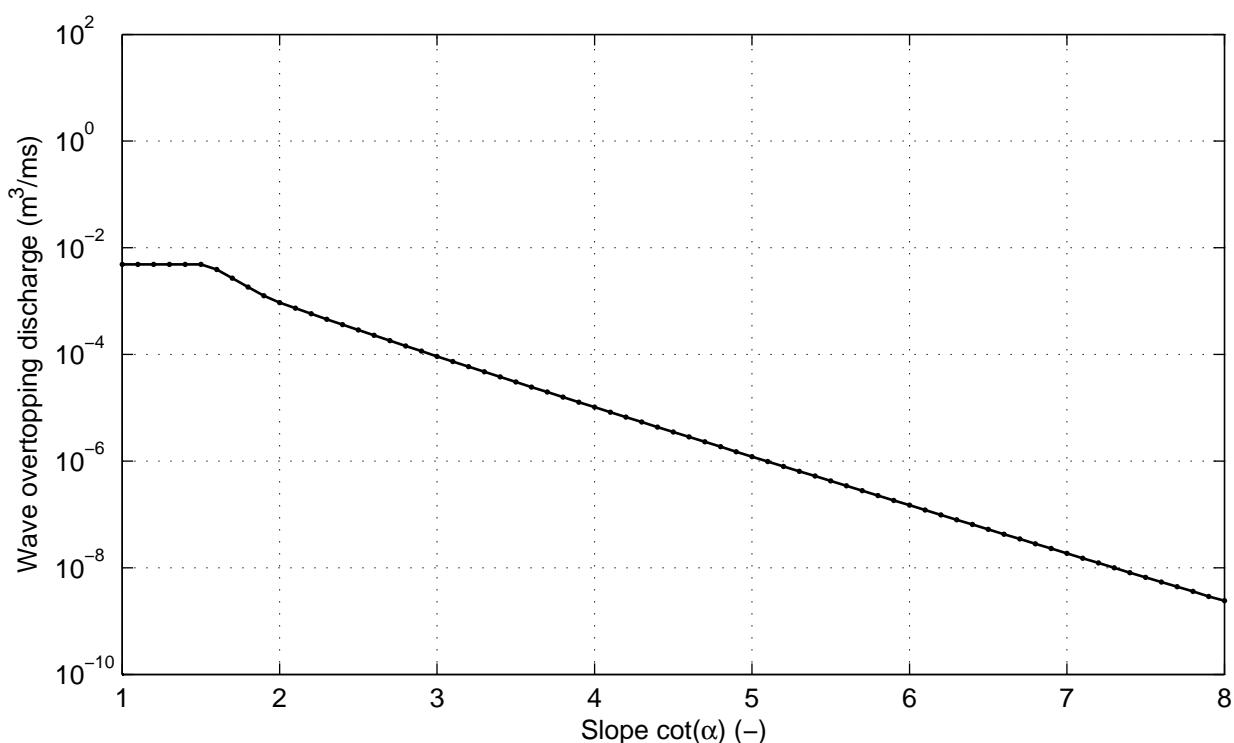
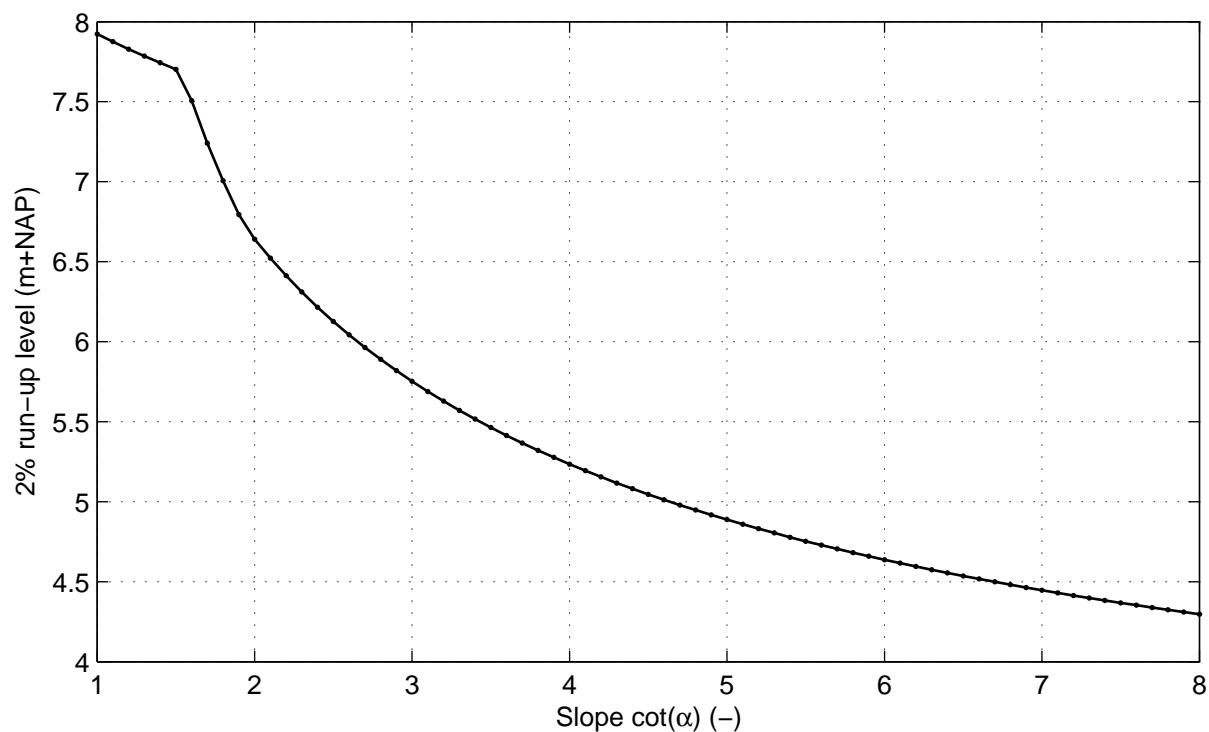
Cross section nr 6; series nr 10; Wave angle: 0 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.12



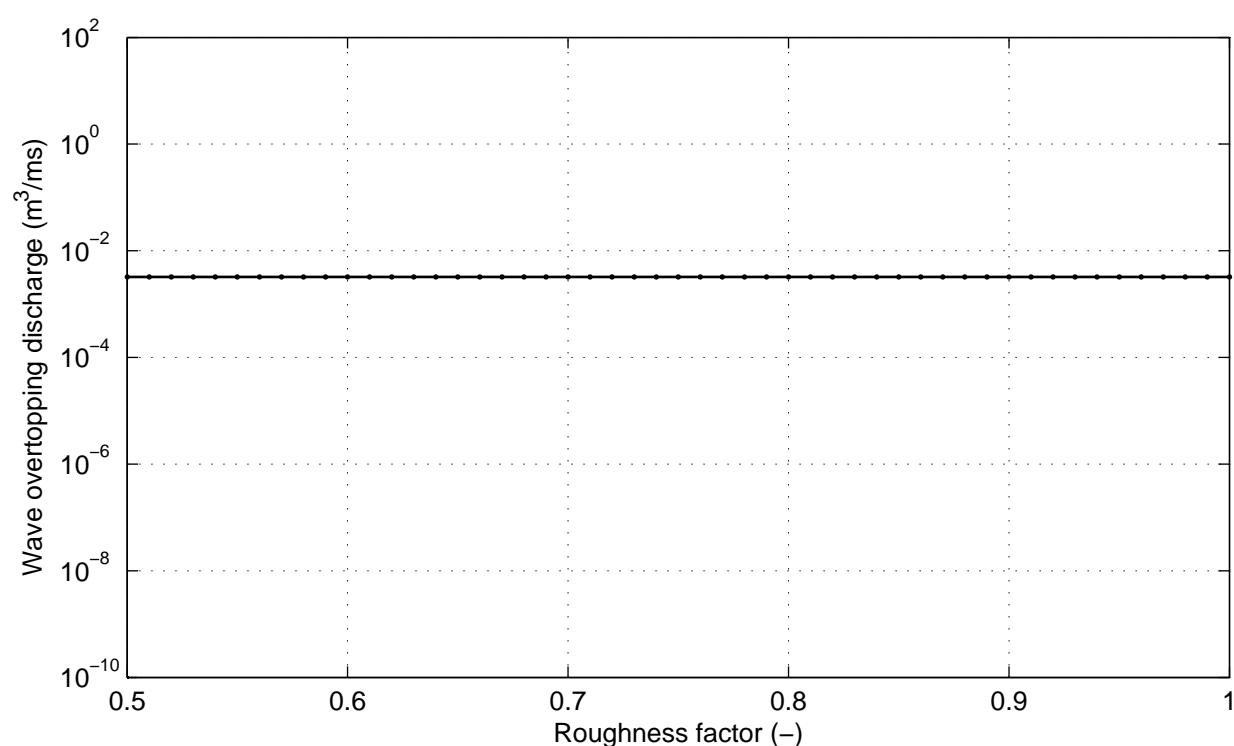
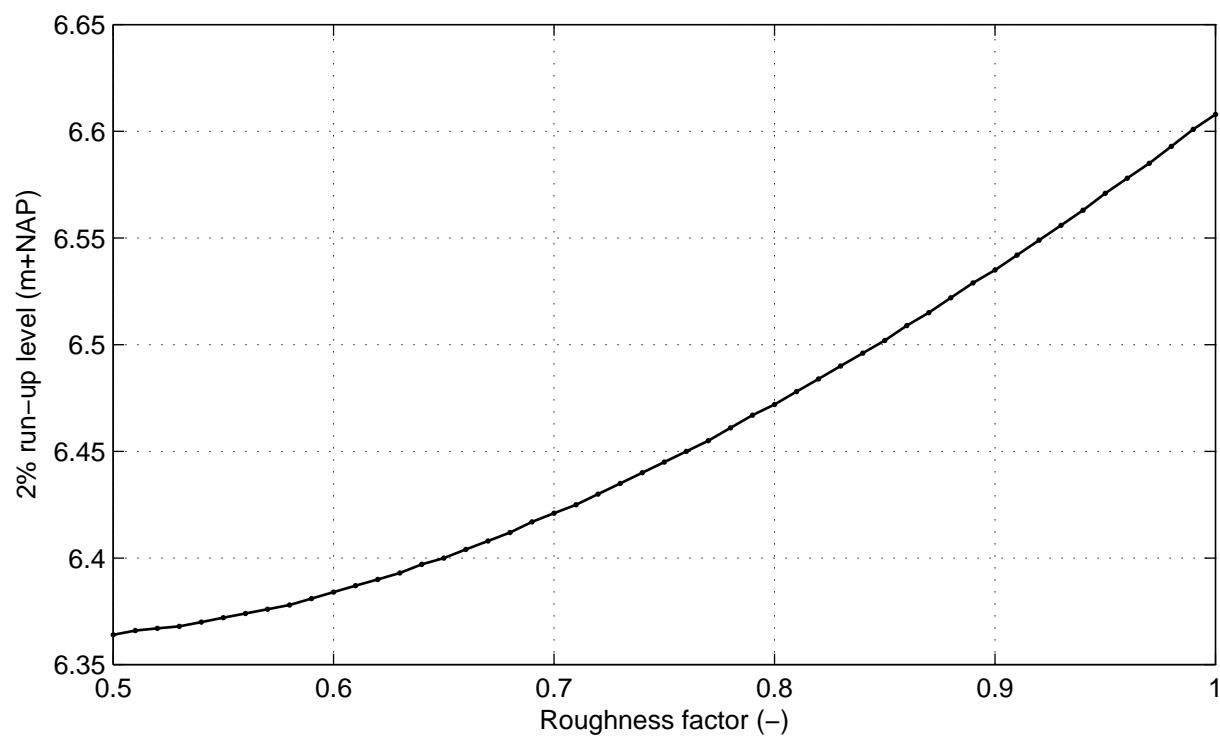
Cross section nr 6; series nr 11; Wave angle: 85 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.13



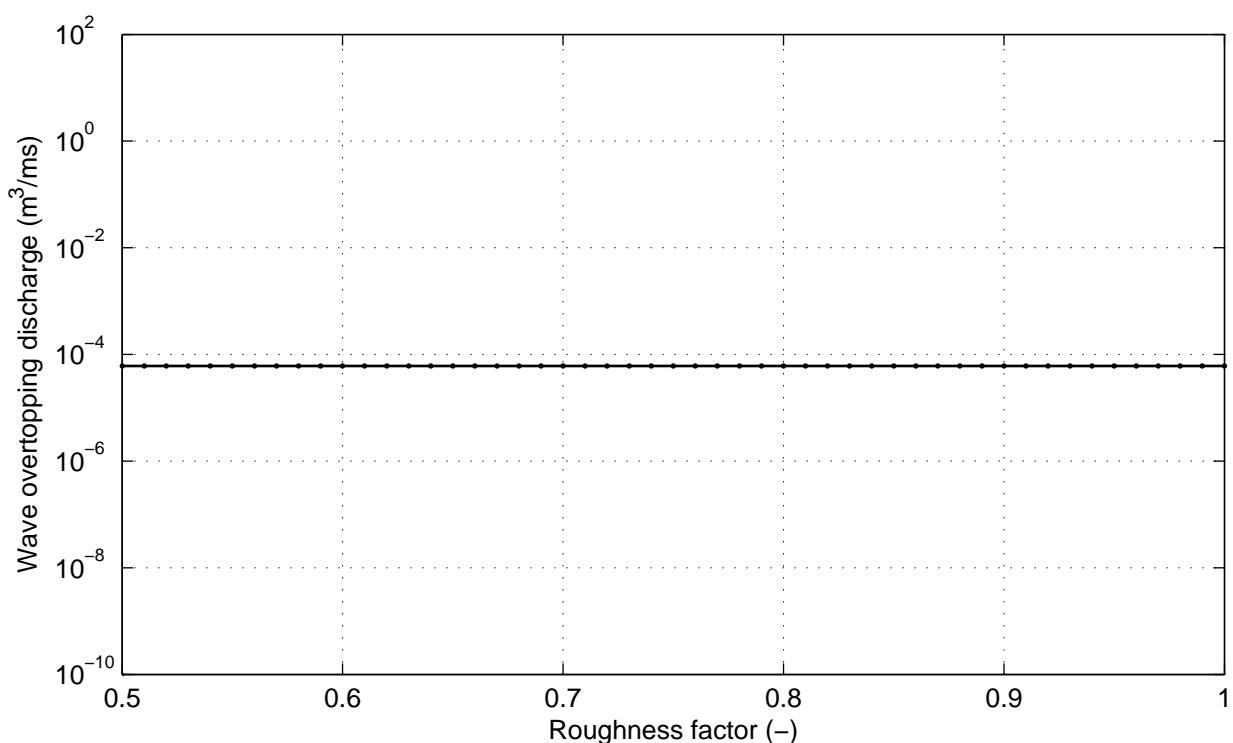
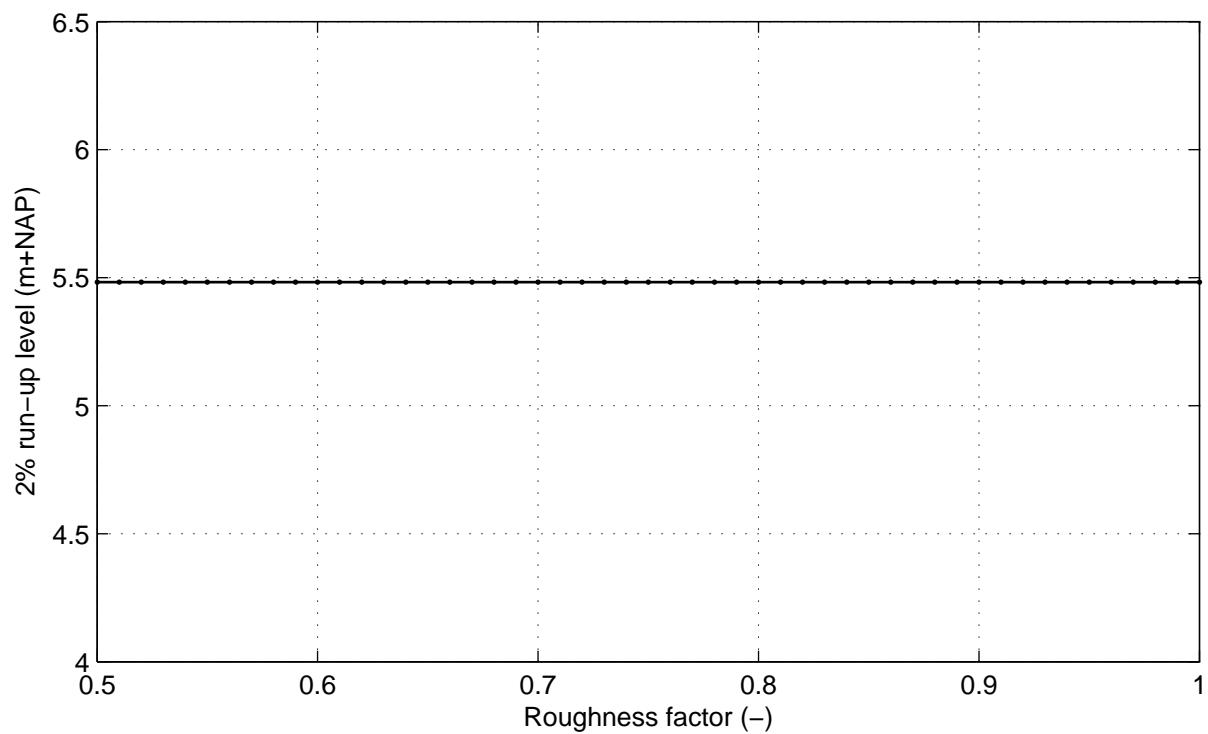
Cross section nr 6; series nr 12; Wave angle: 0 °
Varying roughness of segment 2

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.14



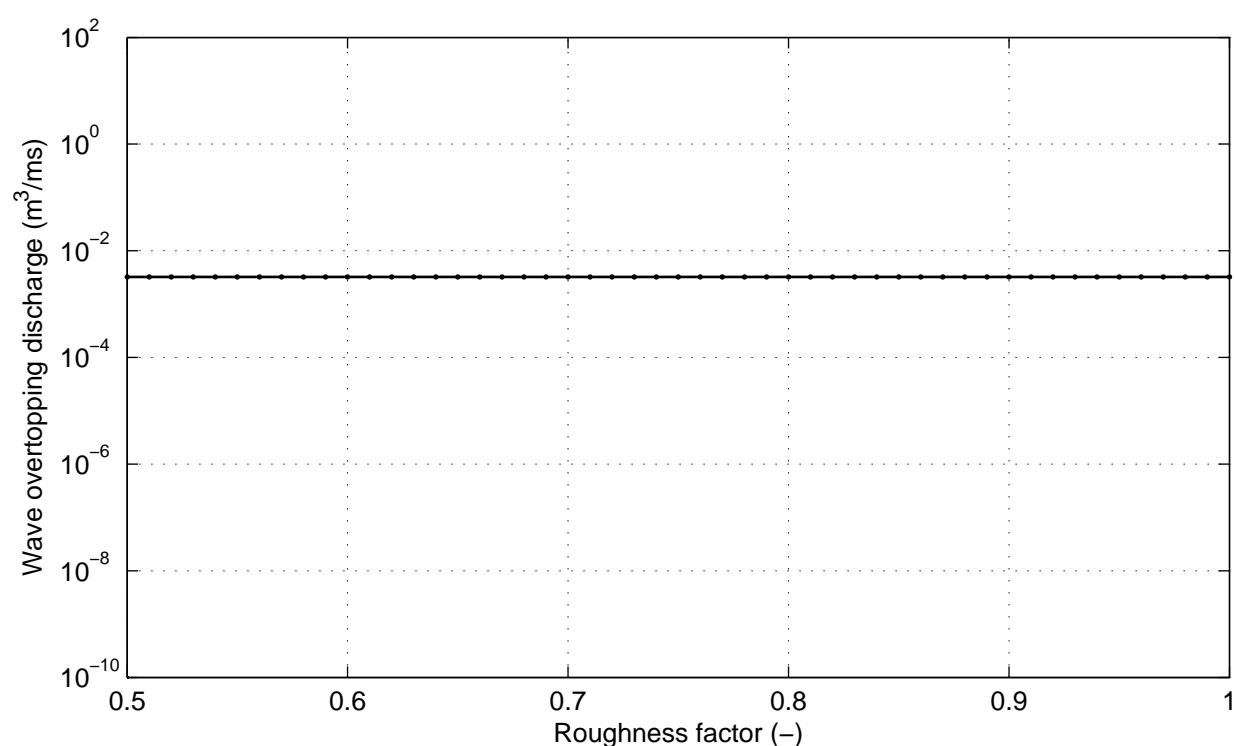
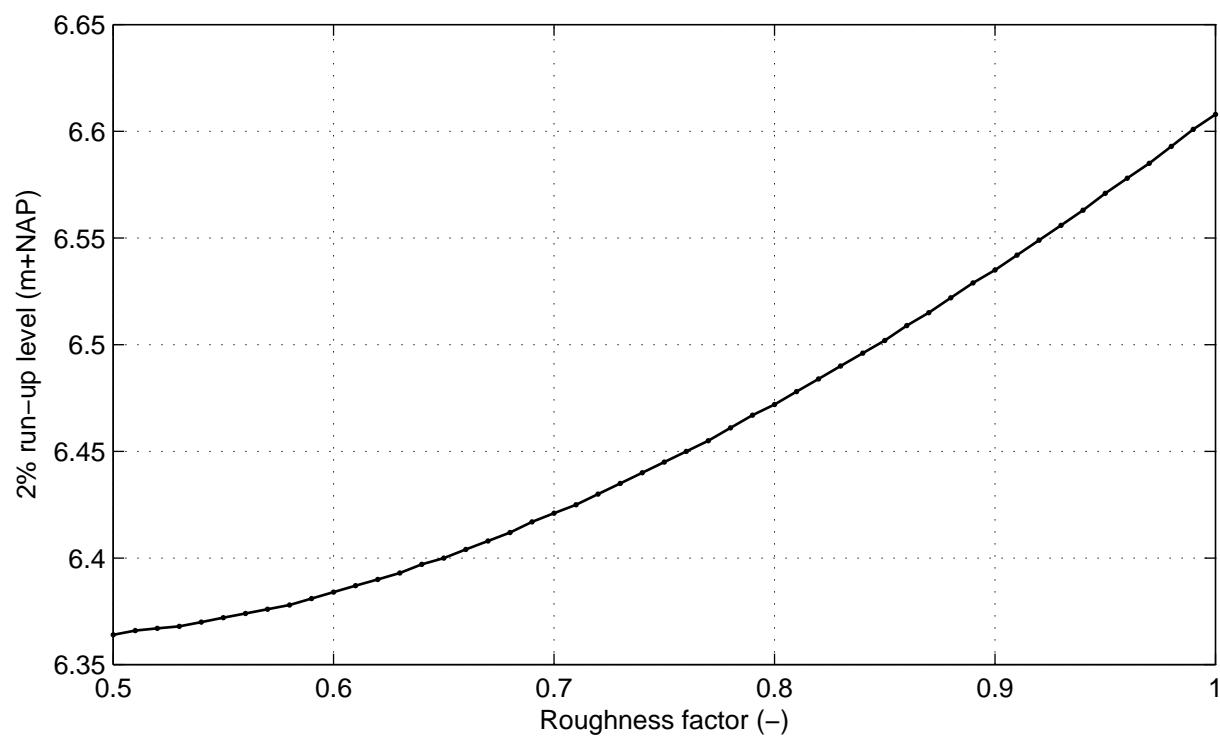
Cross section nr 6; series nr 13; Wave angle: 85 °
Varying roughness of segment 2

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.15



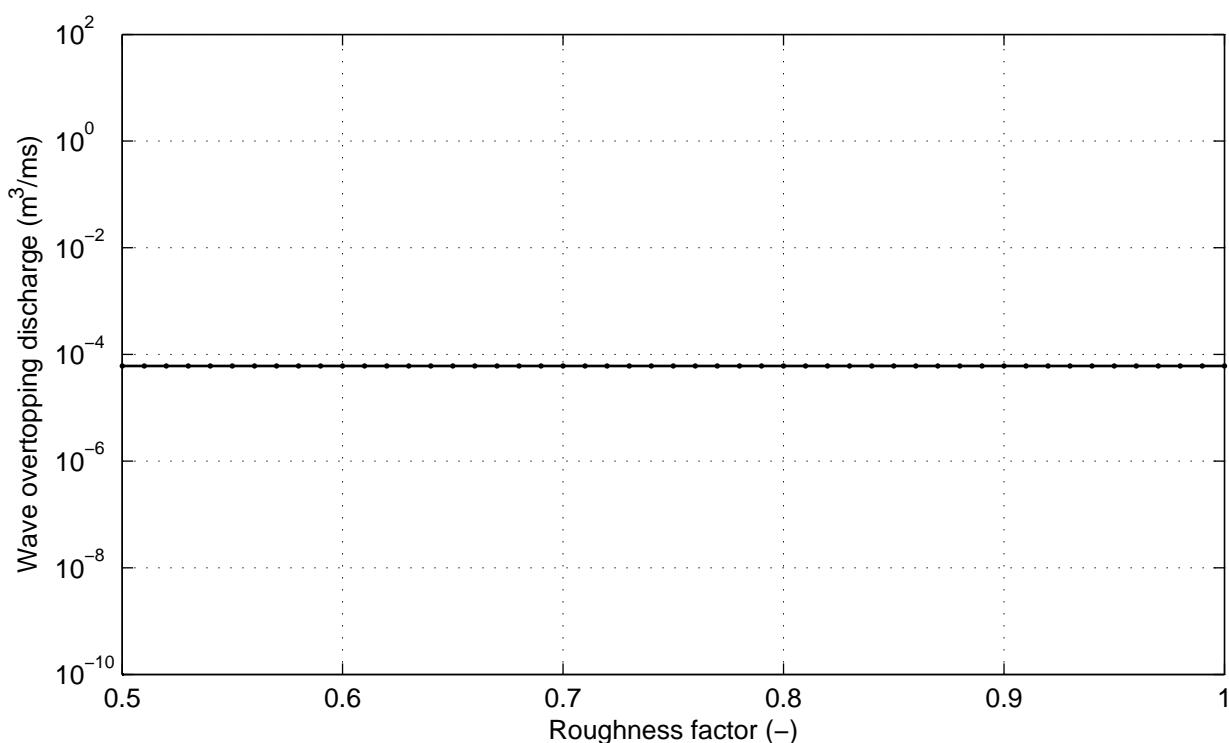
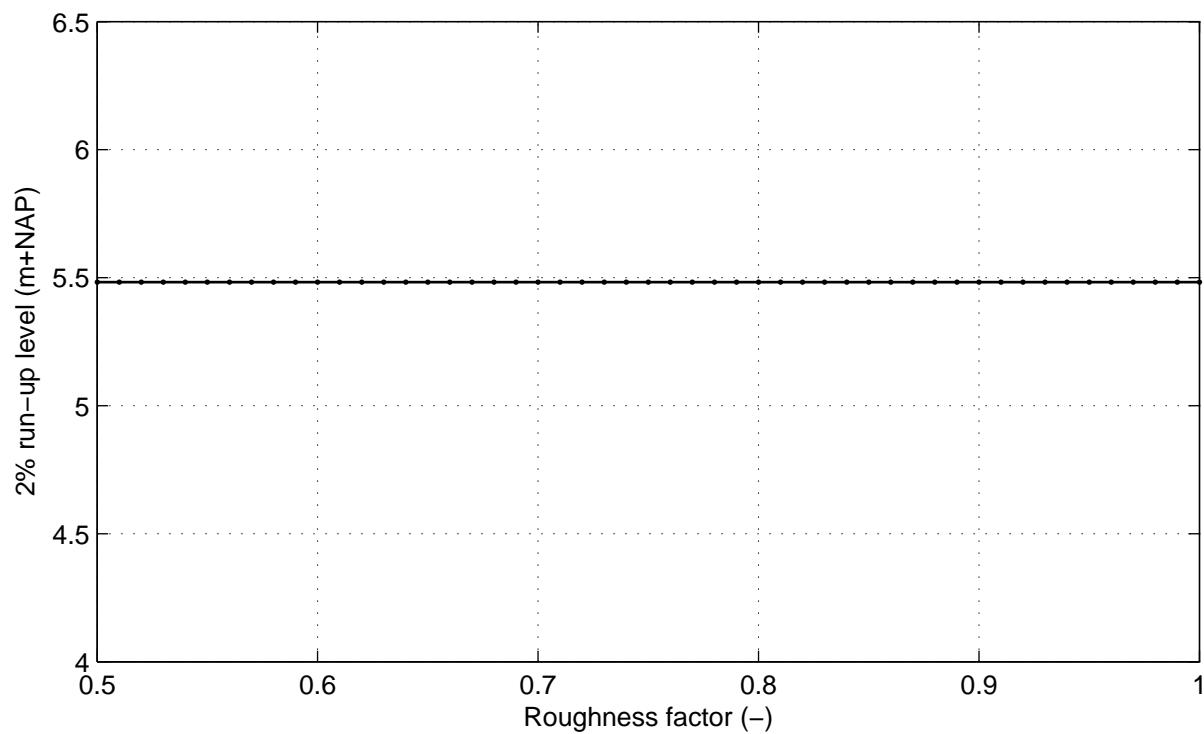
Cross section nr 6; series nr 14; Wave angle: 0 °
Varying roughness of segment 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.16



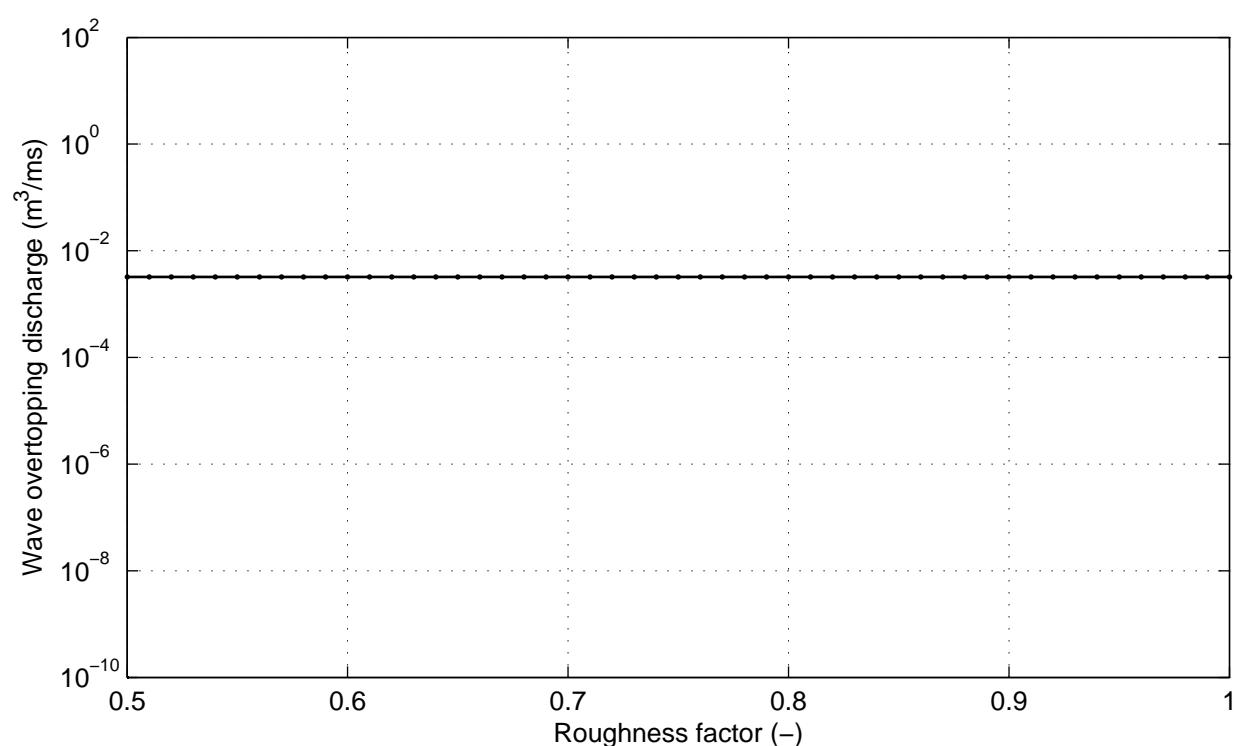
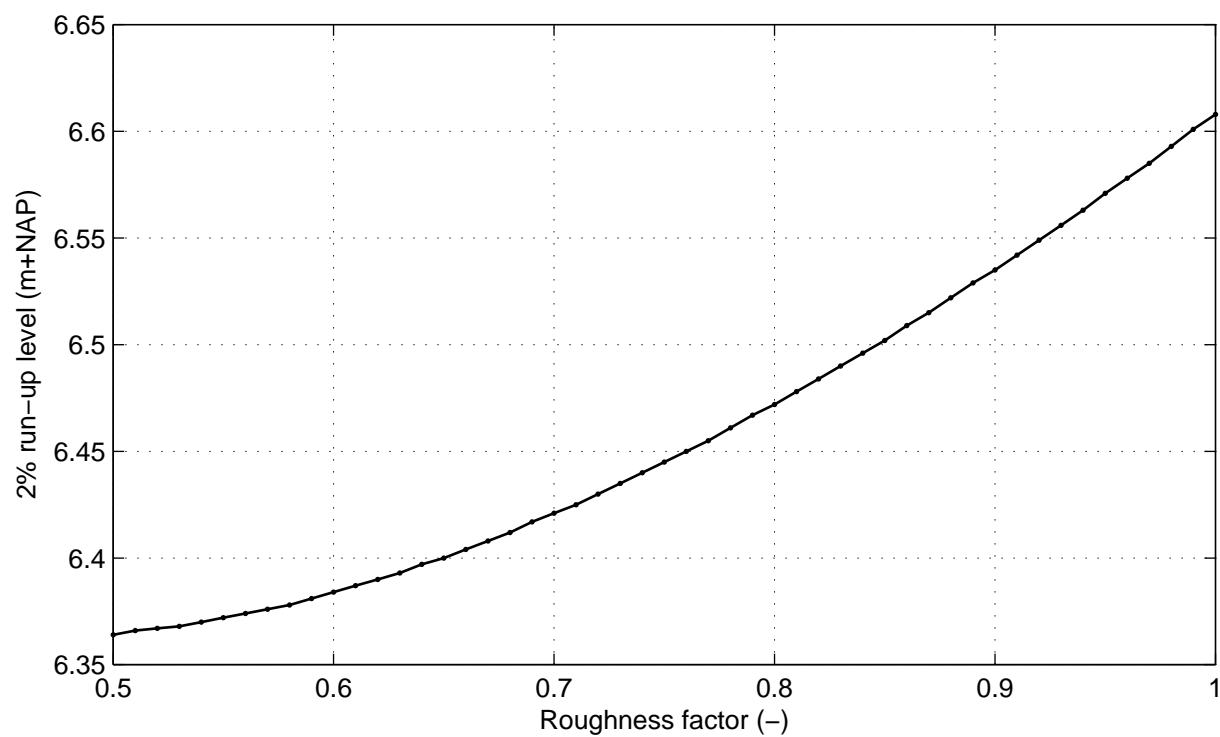
Cross section nr 6; series nr 15; Wave angle: 85 °
Varying roughness of segment 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.17



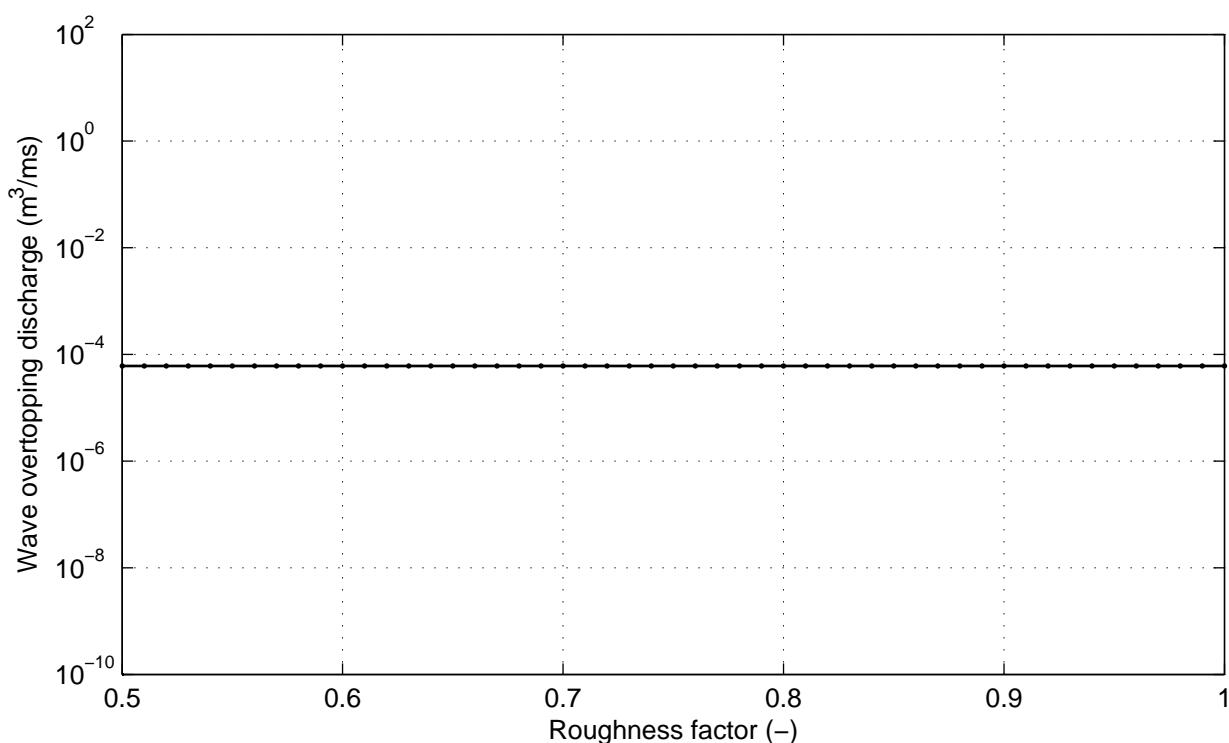
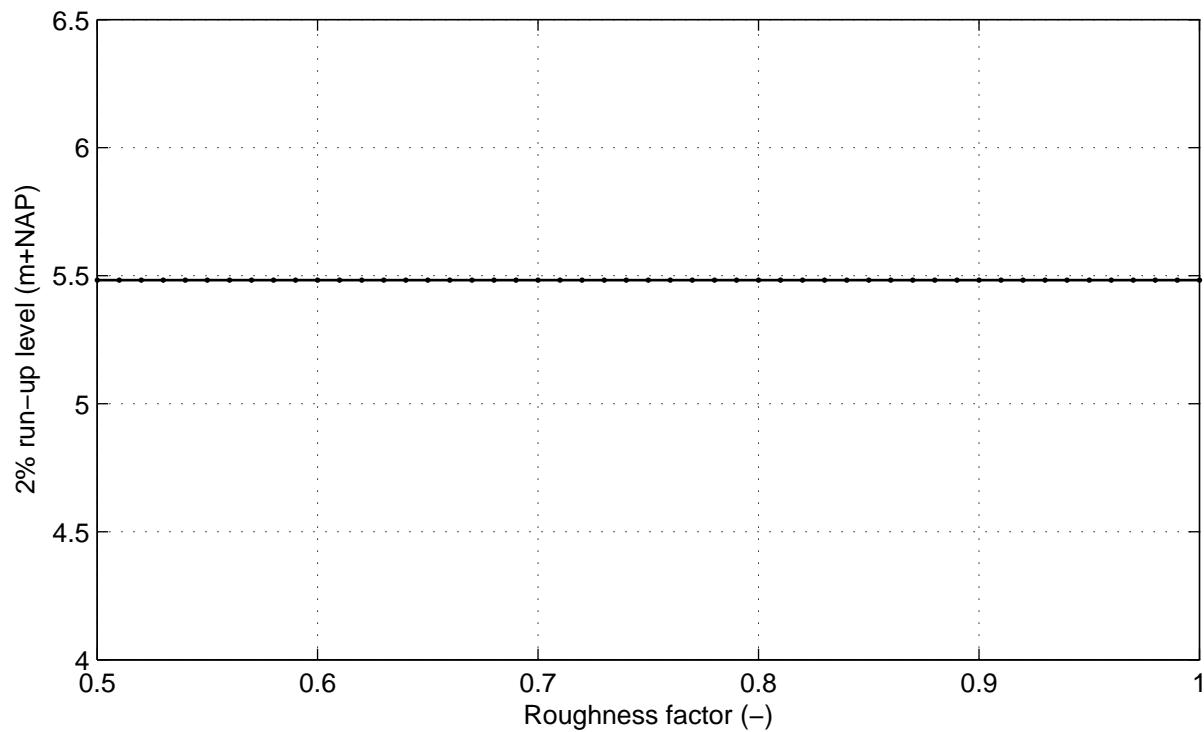
Cross section nr 6; series nr 16; Wave angle: 0 °
Varying roughness of segments 1 and 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.18



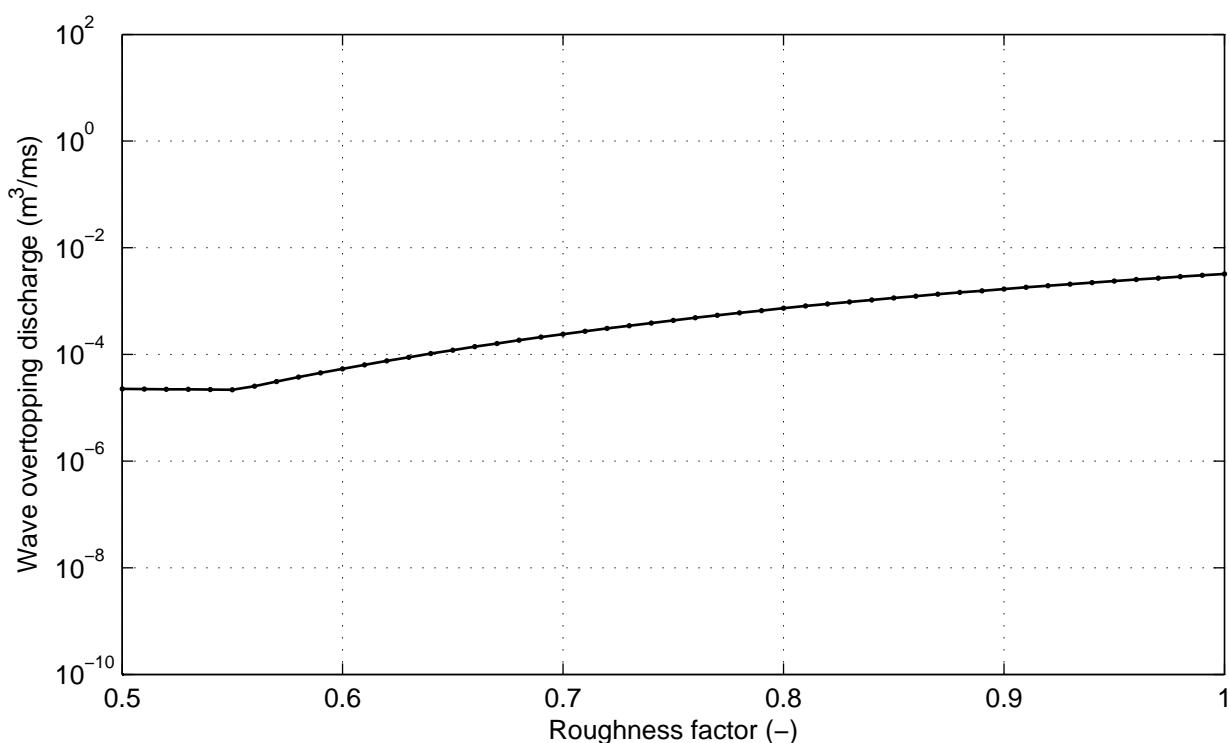
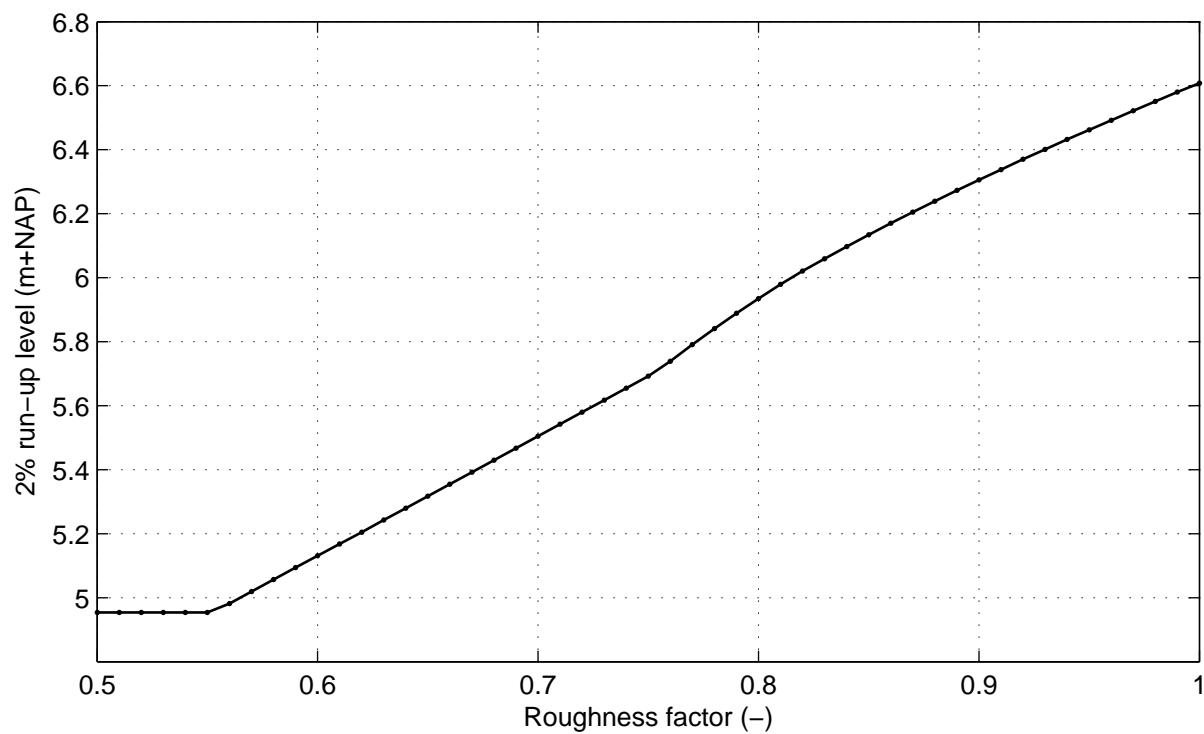
Cross section nr 6; series nr 17; Wave angle: 85 °
Varying roughness of segments 1 and 3

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.19



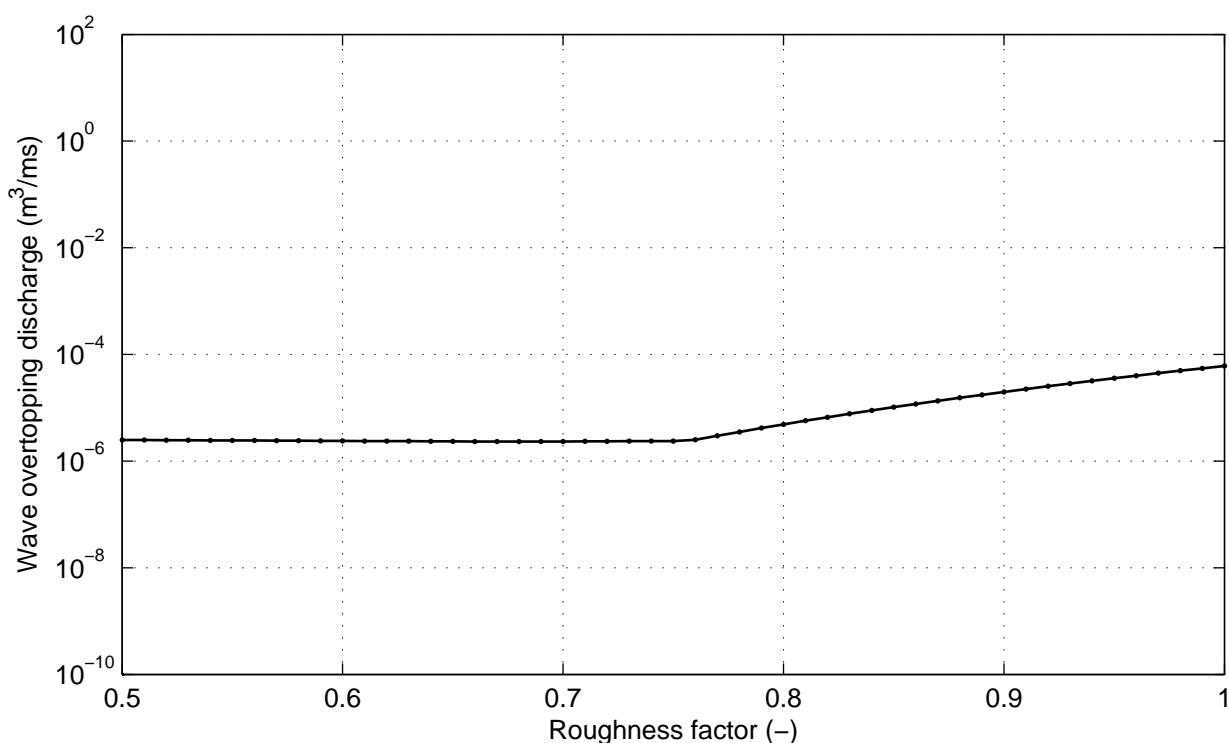
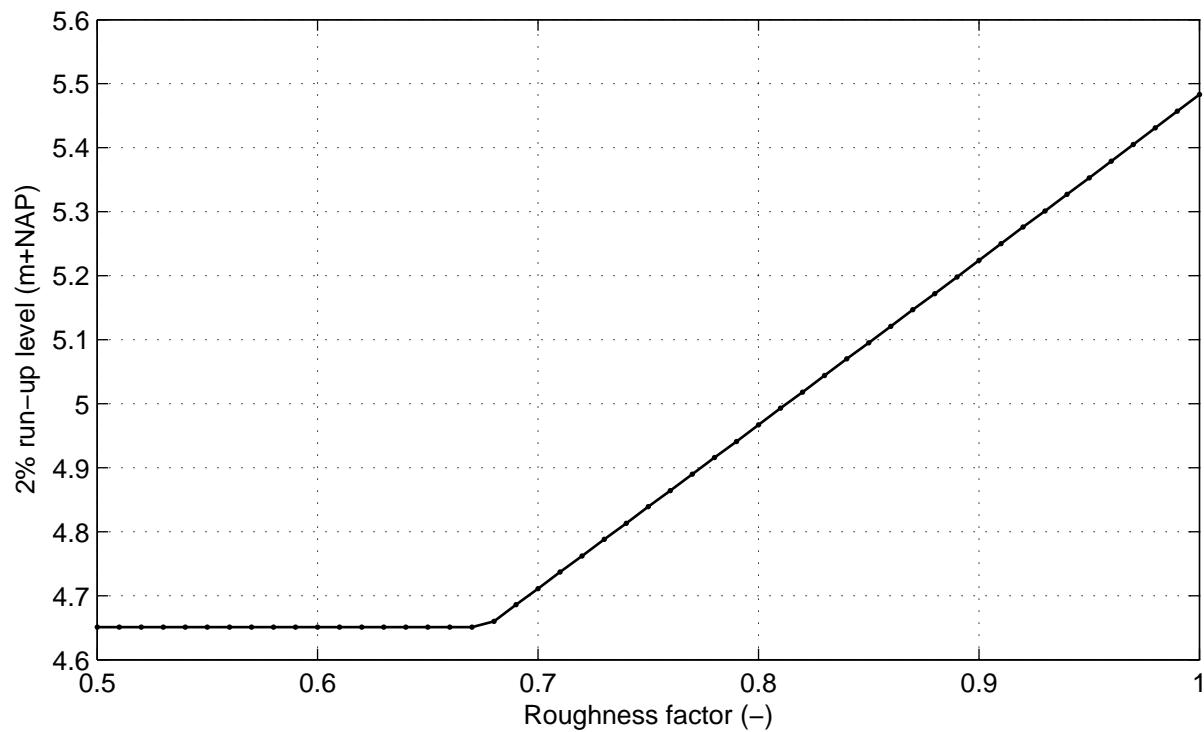
Cross section nr 6; series nr 18; Wave angle: 0 °
Varying roughness of segments 2 and 4

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.20



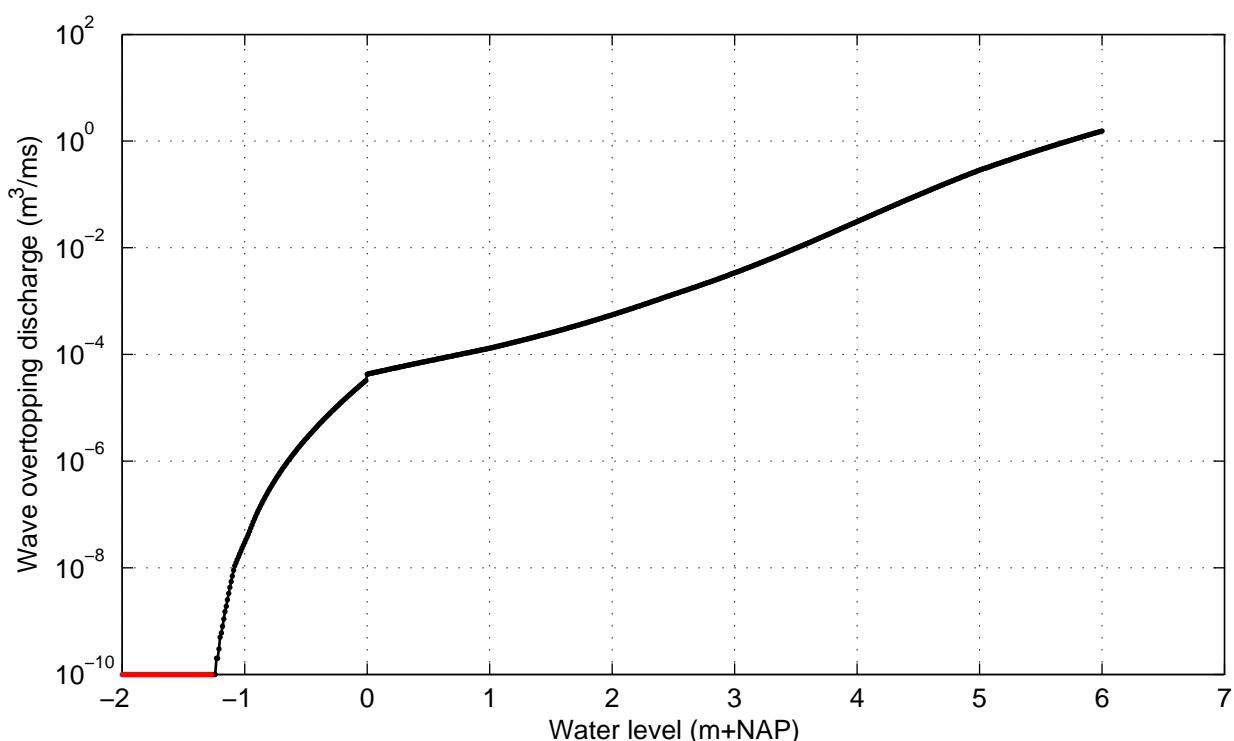
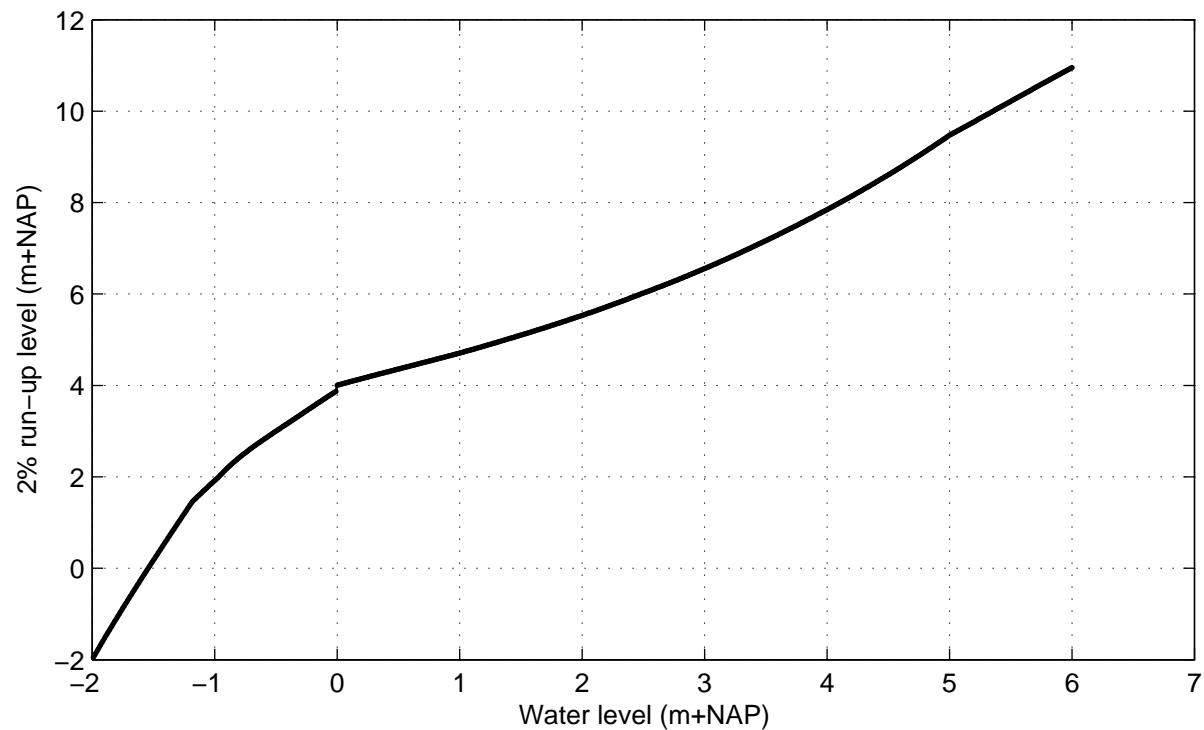
Cross section nr 6; series nr 19; Wave angle: 85 °
Varying roughness of segments 2 and 4

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 6.21



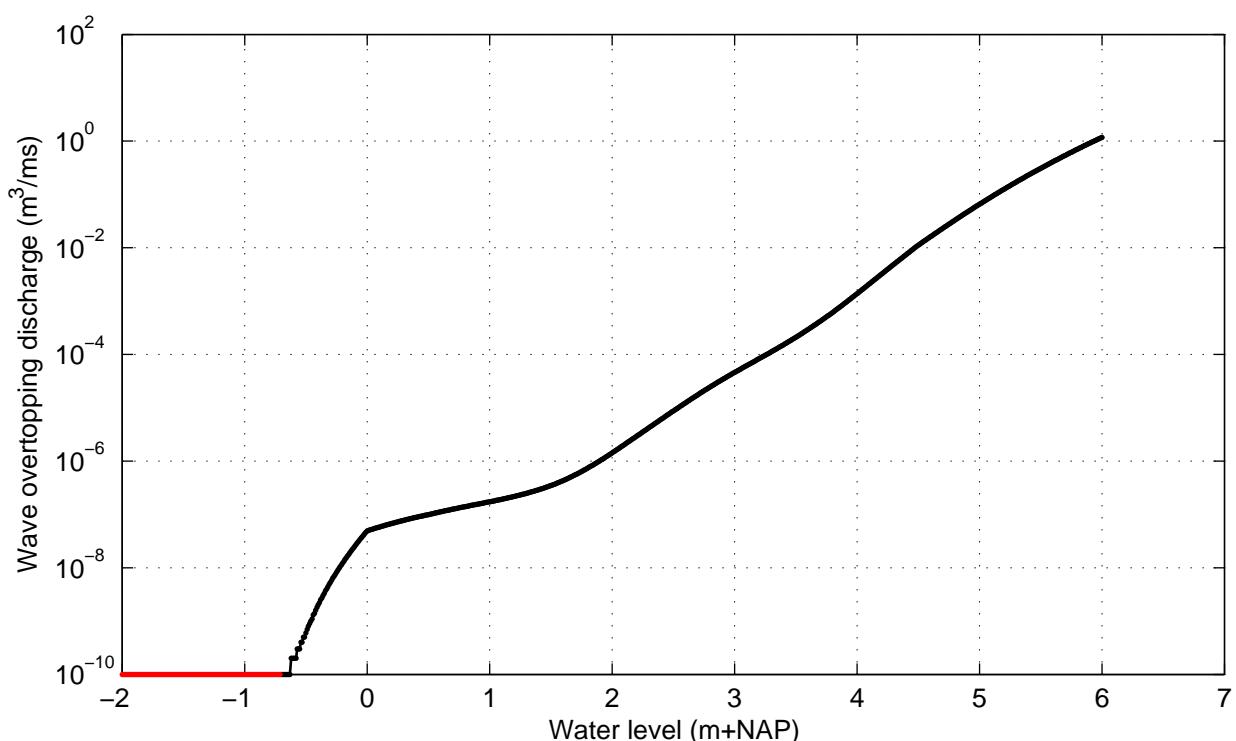
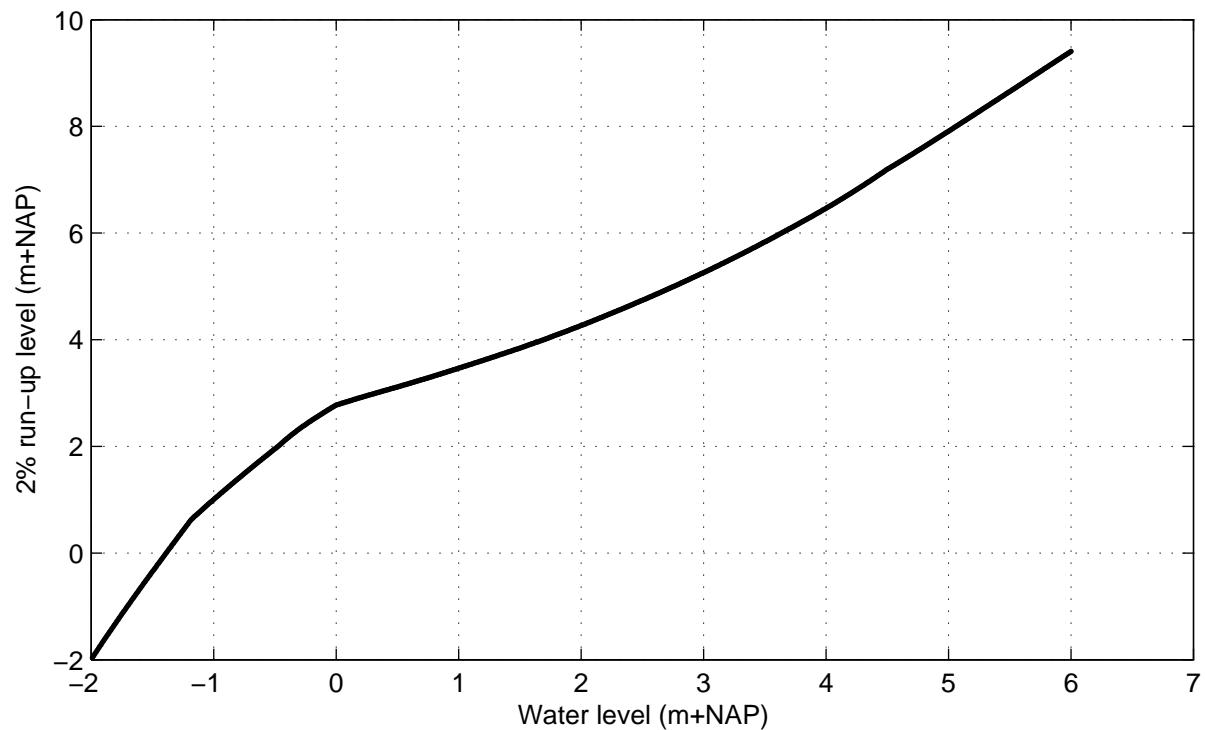
Cross section nr 7; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.1



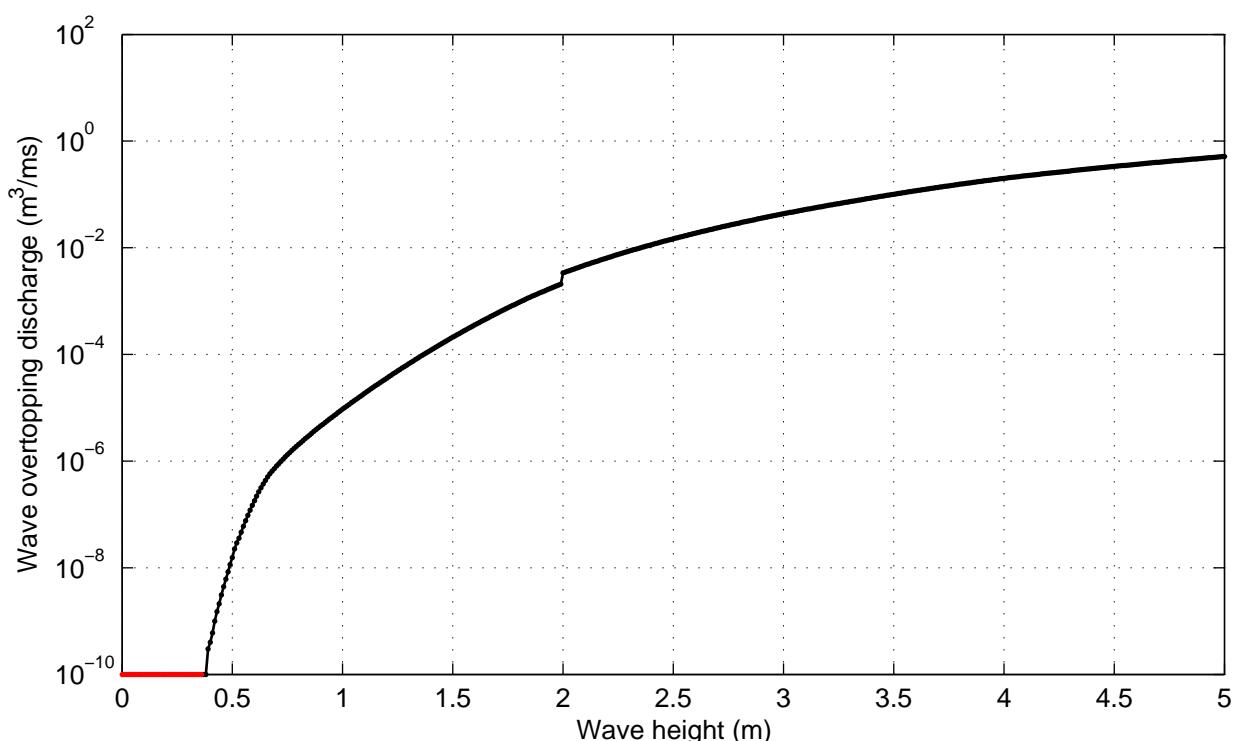
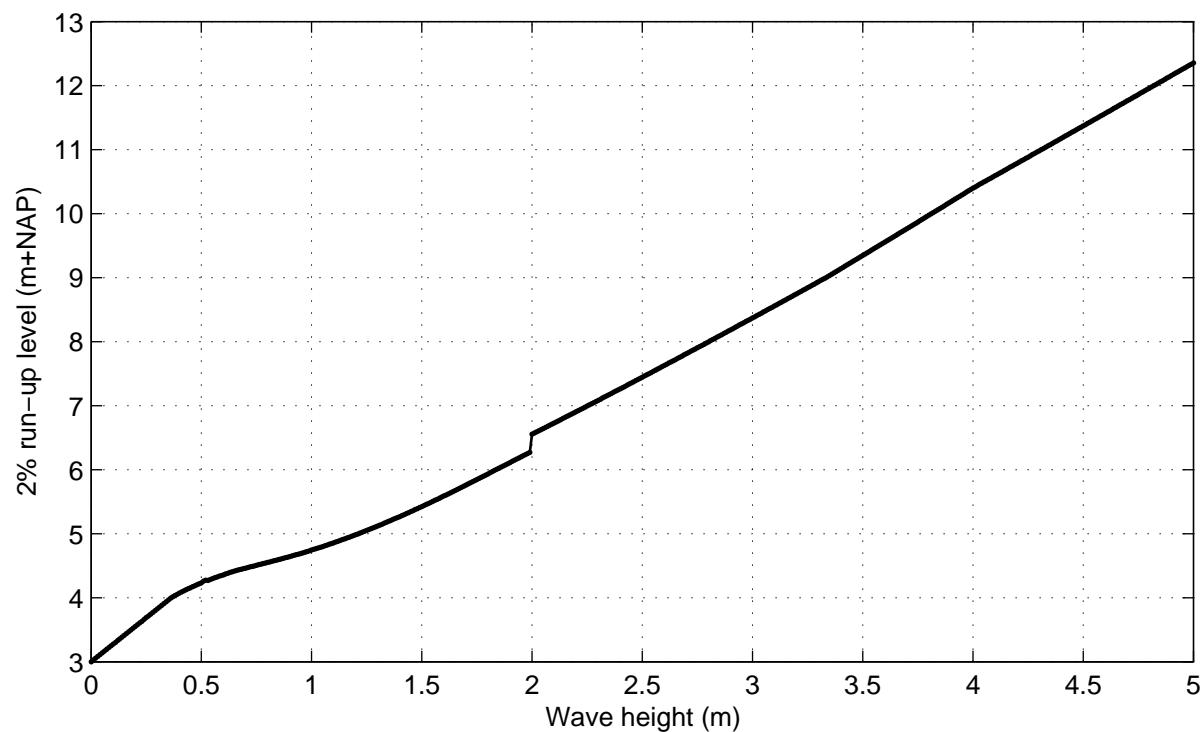
Cross section nr 7; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.2



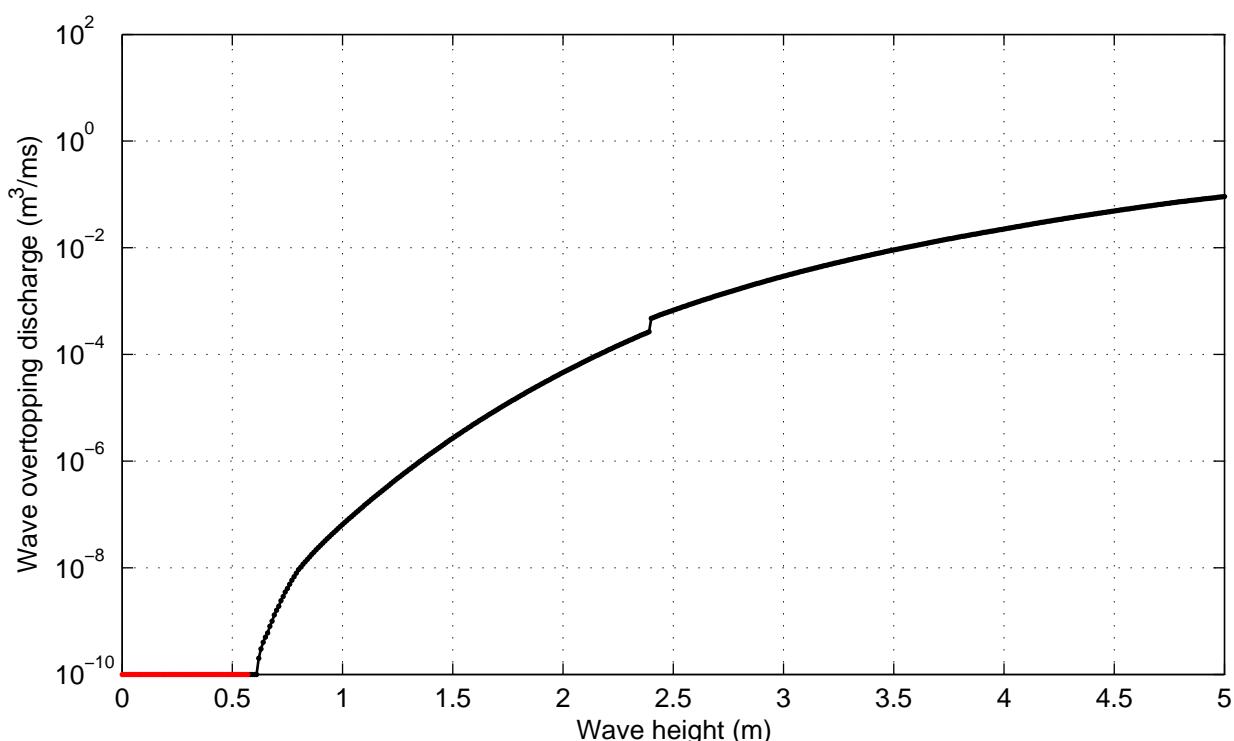
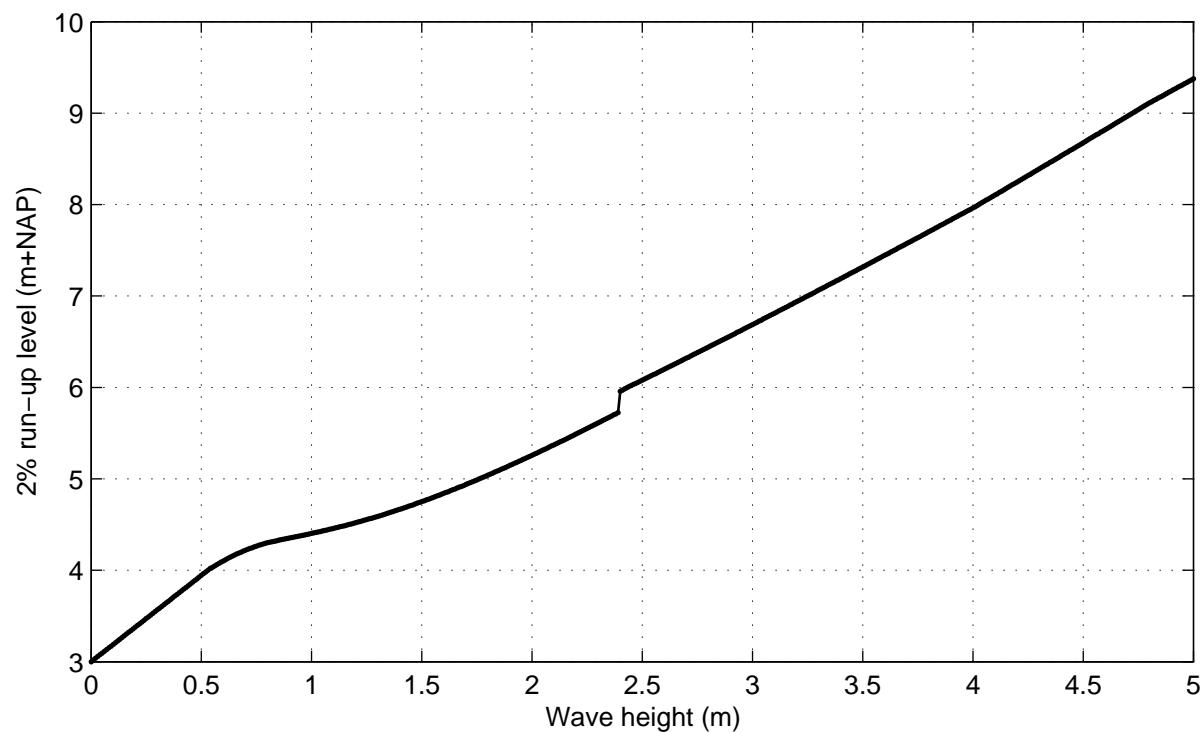
Cross section nr 7; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.3



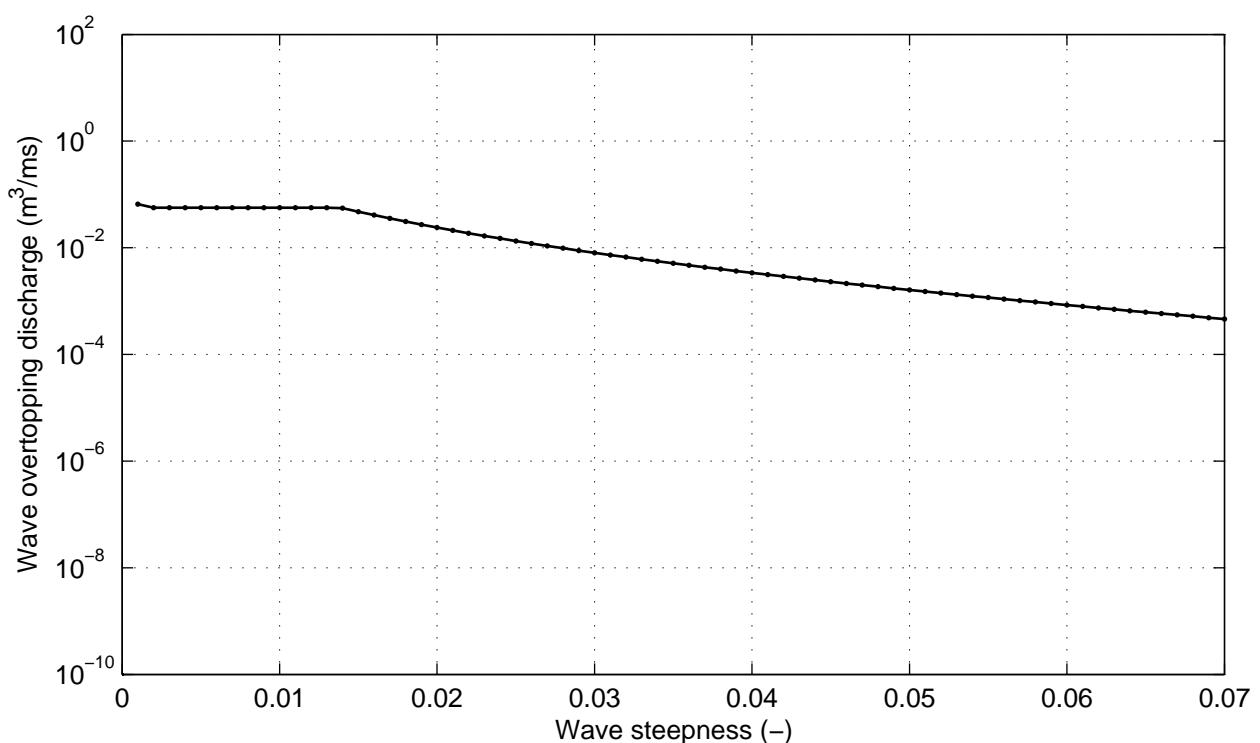
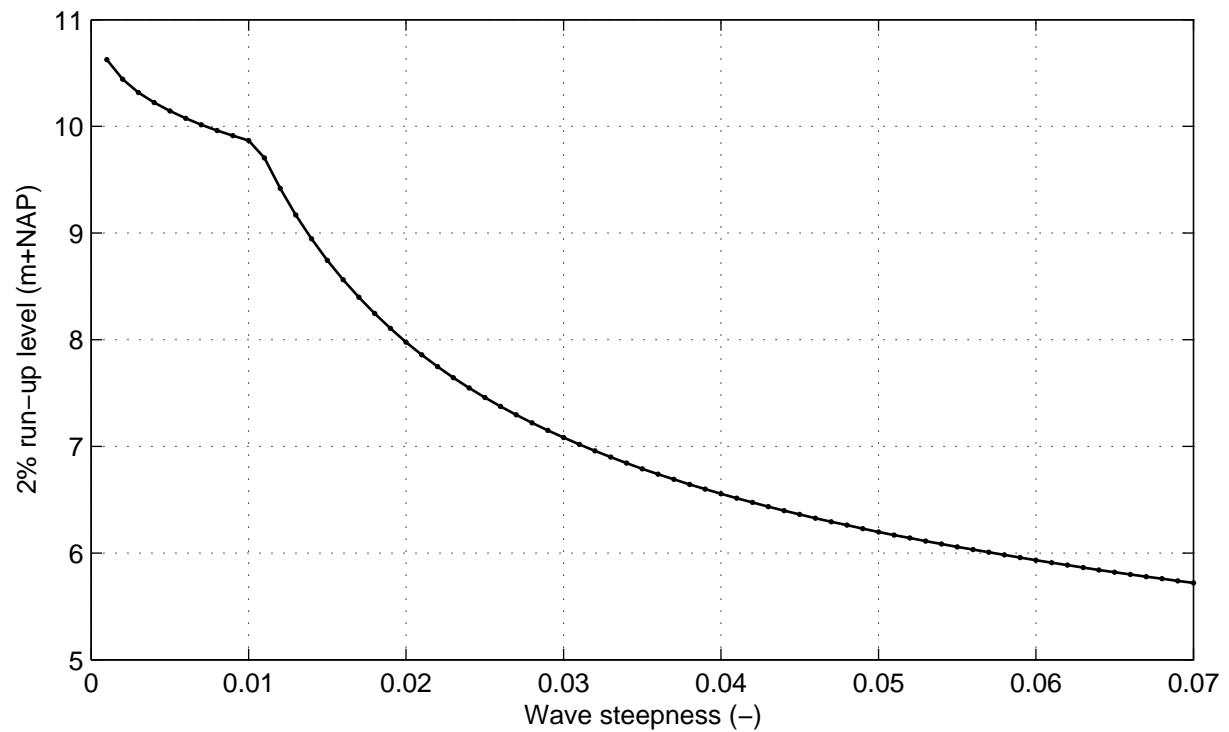
Cross section nr 7; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.4



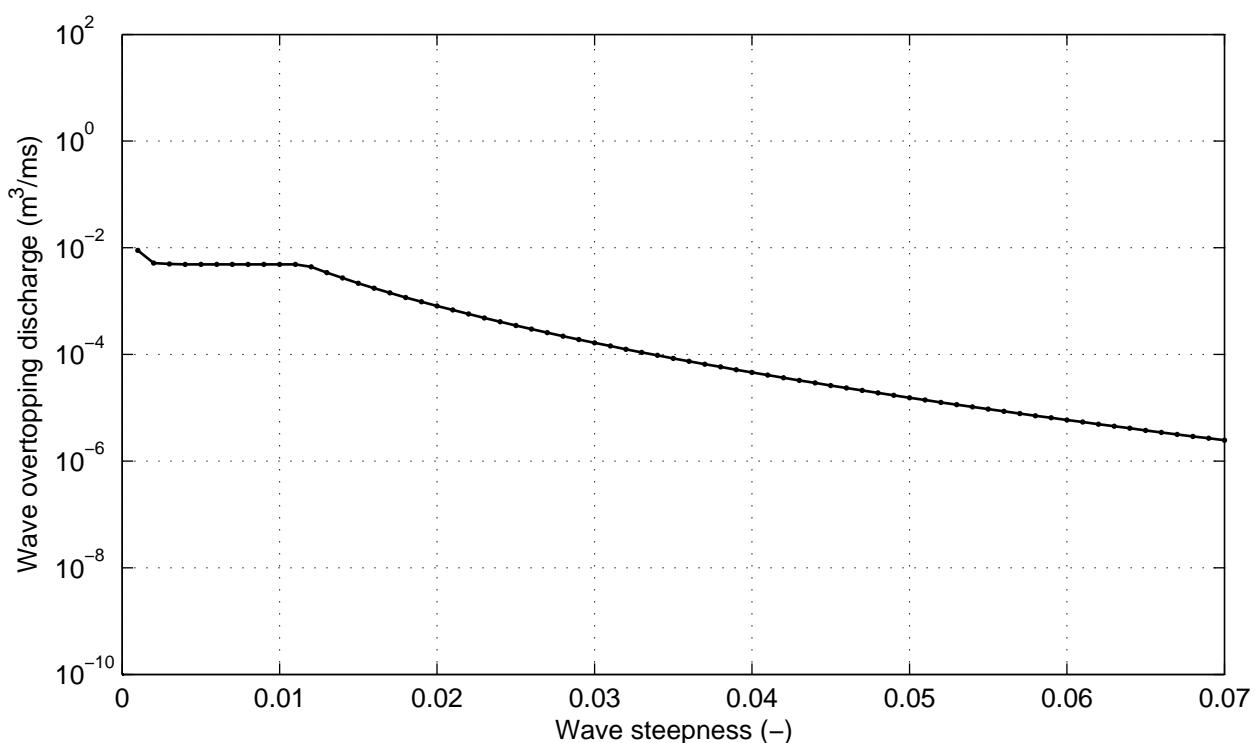
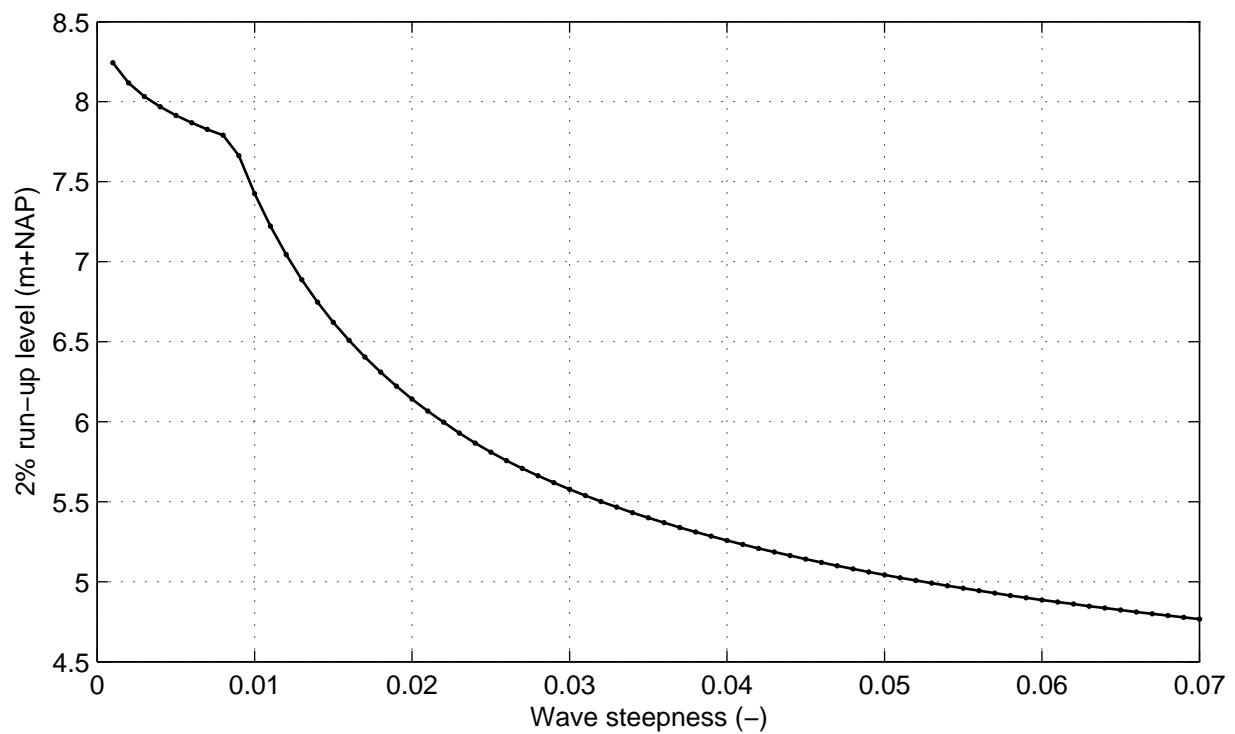
Cross section nr 7; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.5



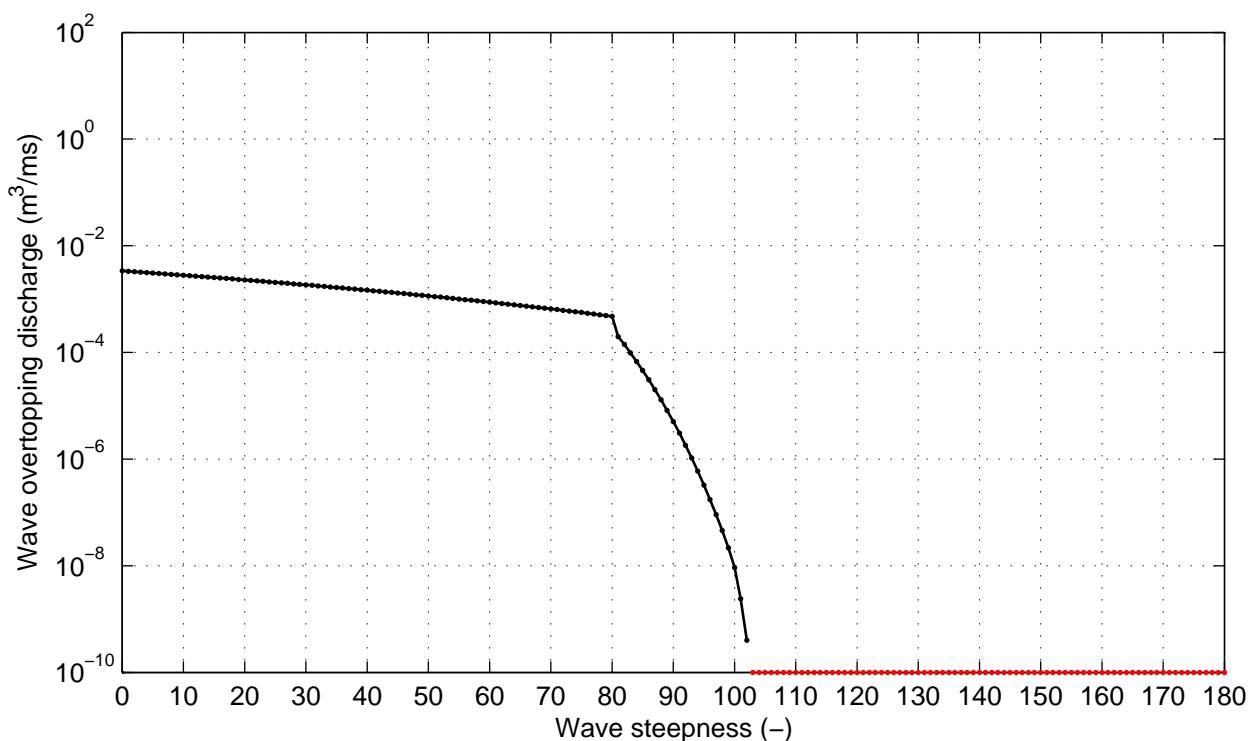
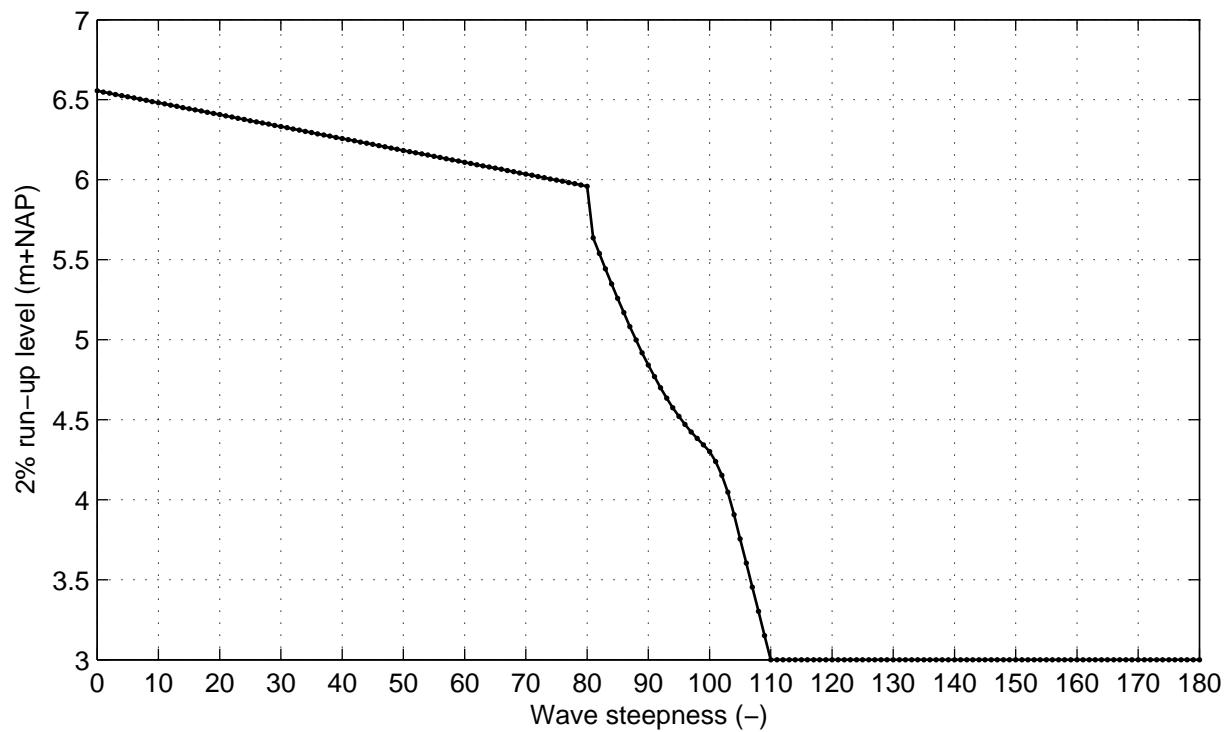
Cross section nr 7; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.6



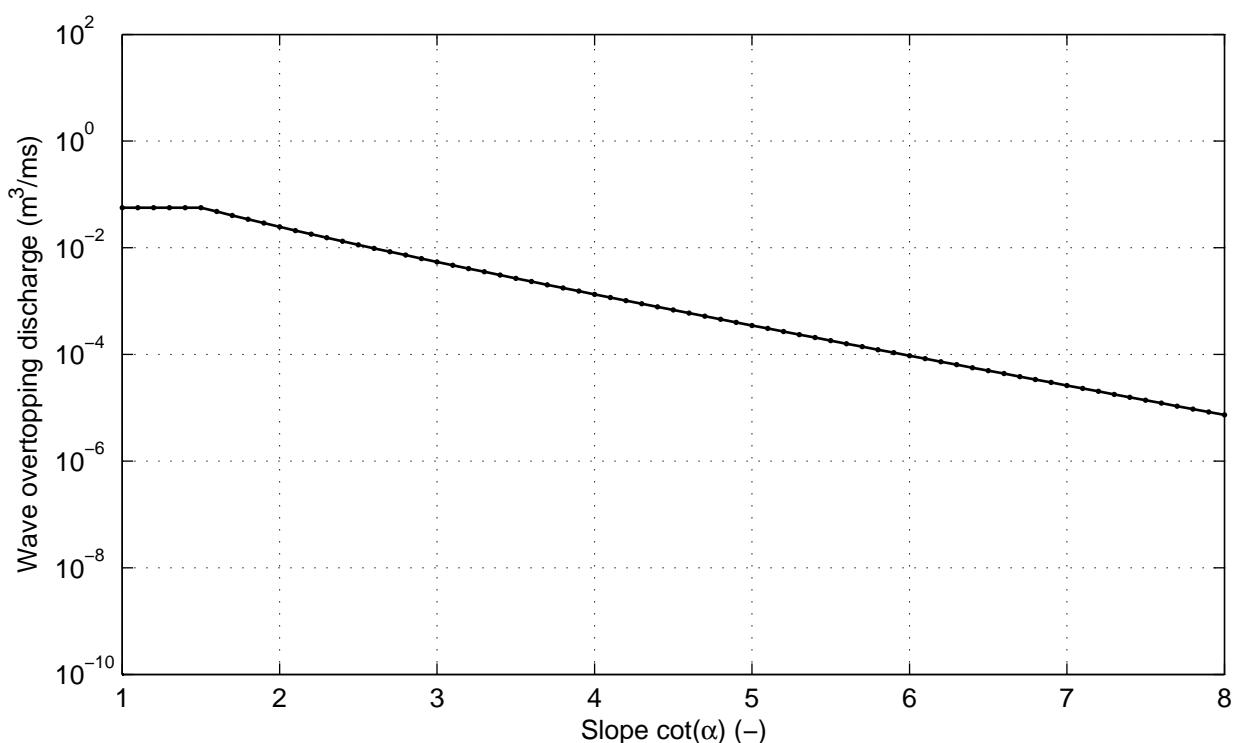
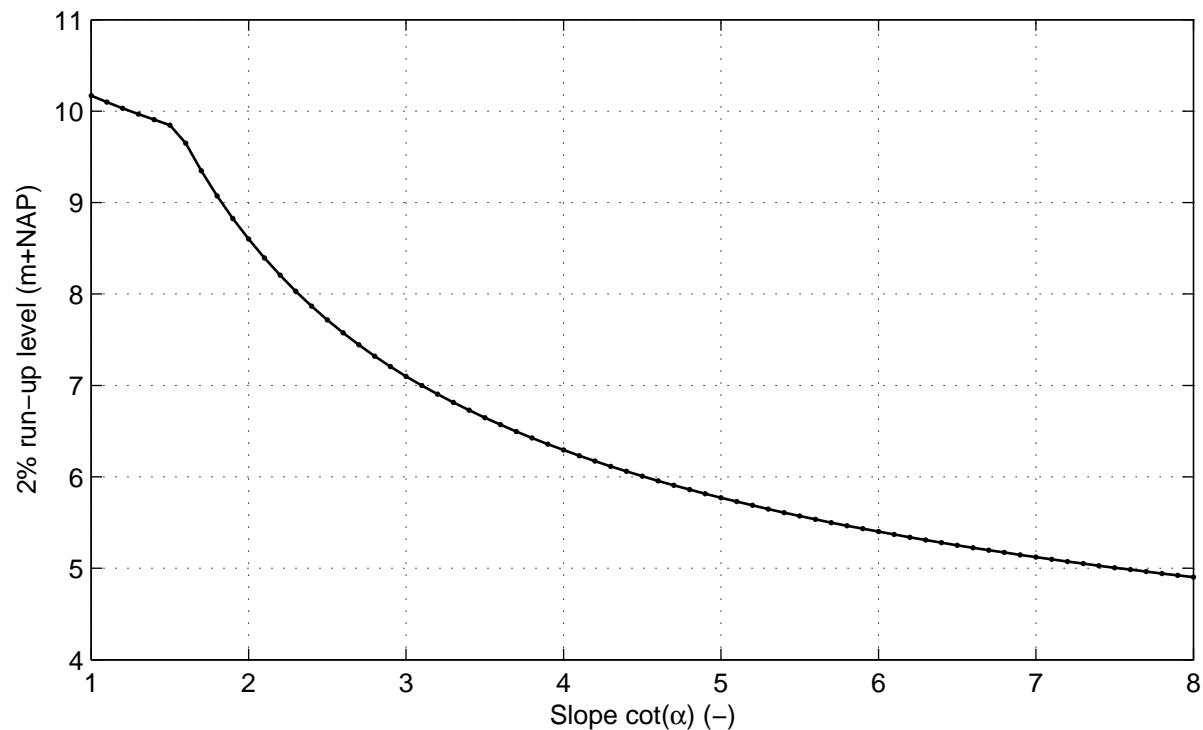
Cross section nr 7; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.7



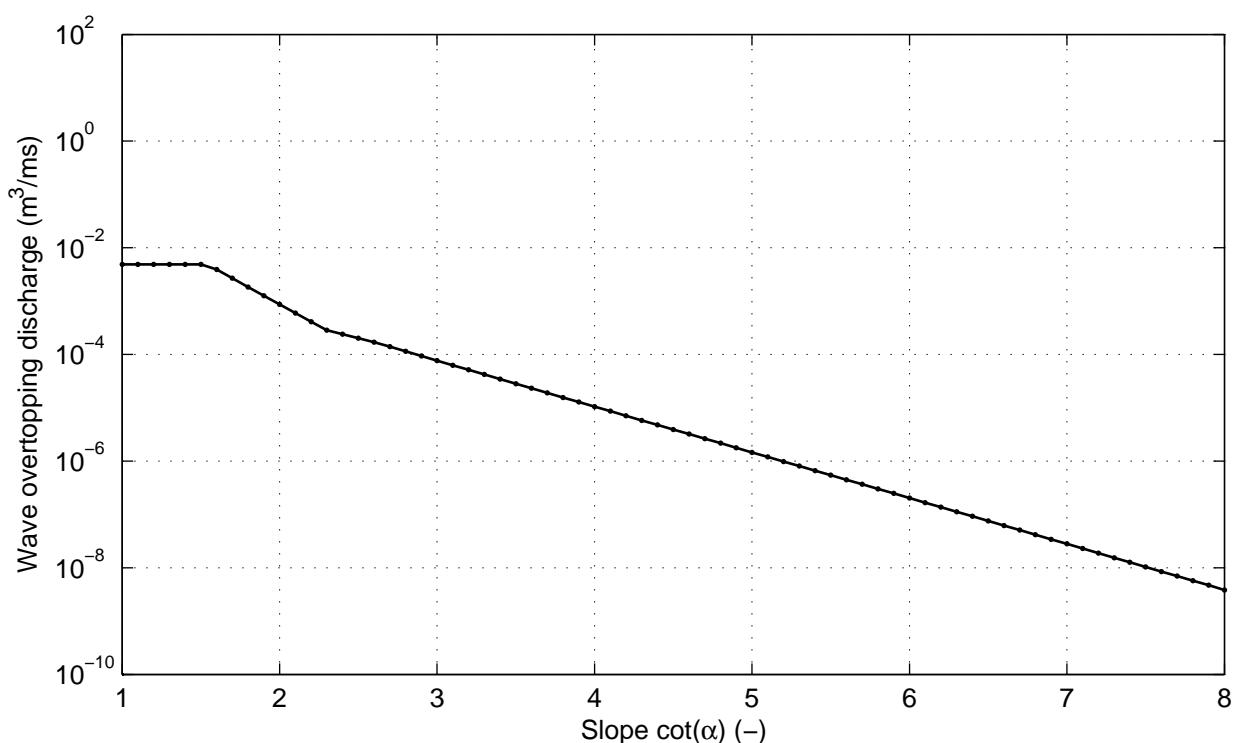
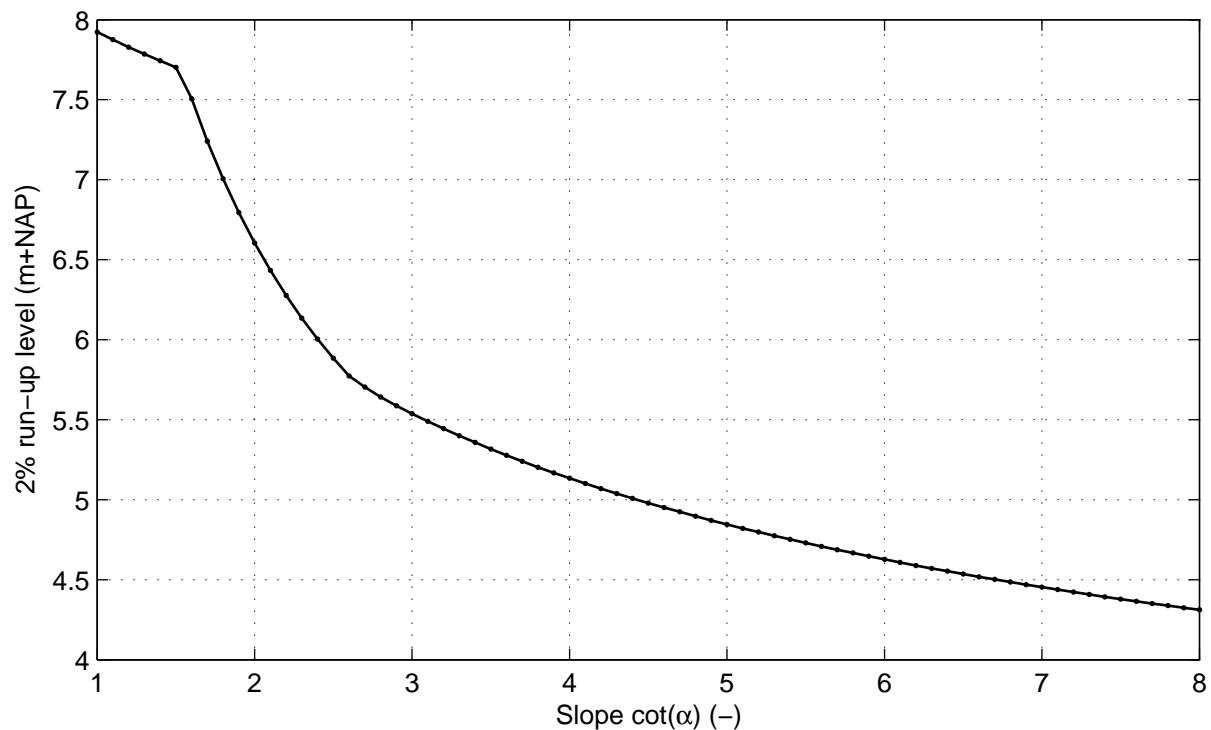
Cross section nr 7; series nr 8; Wave angle: 0 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.8



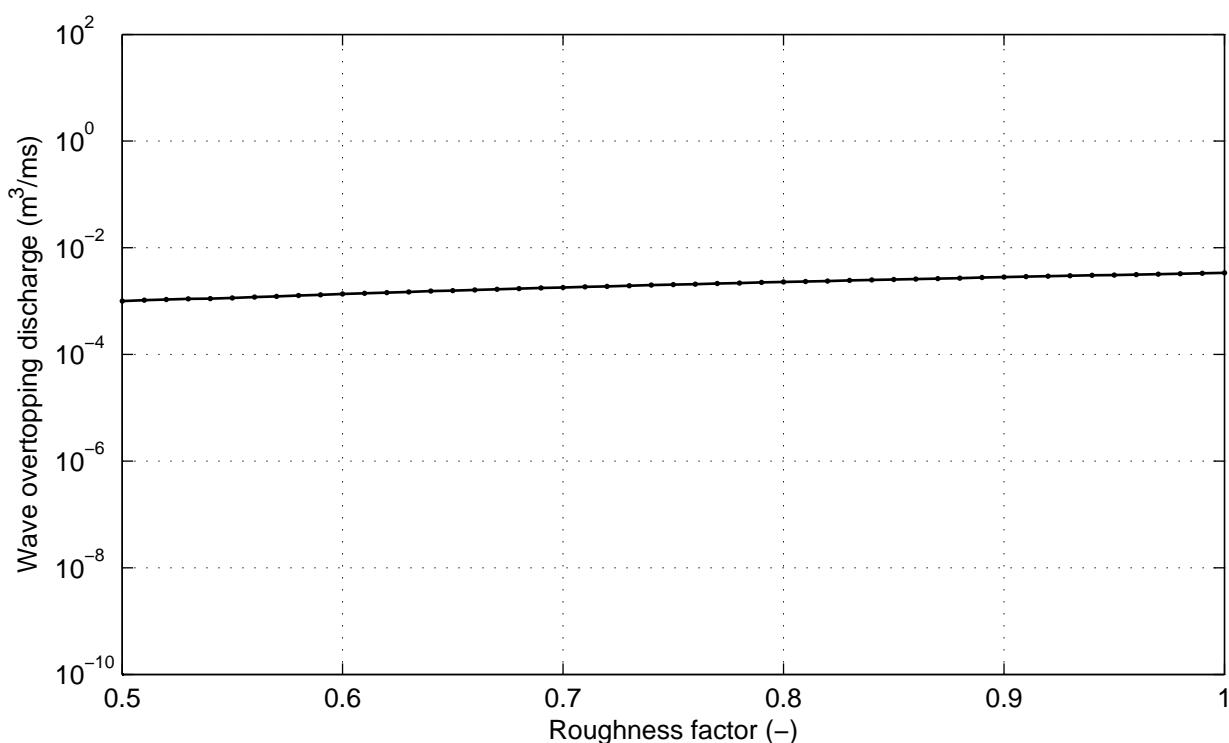
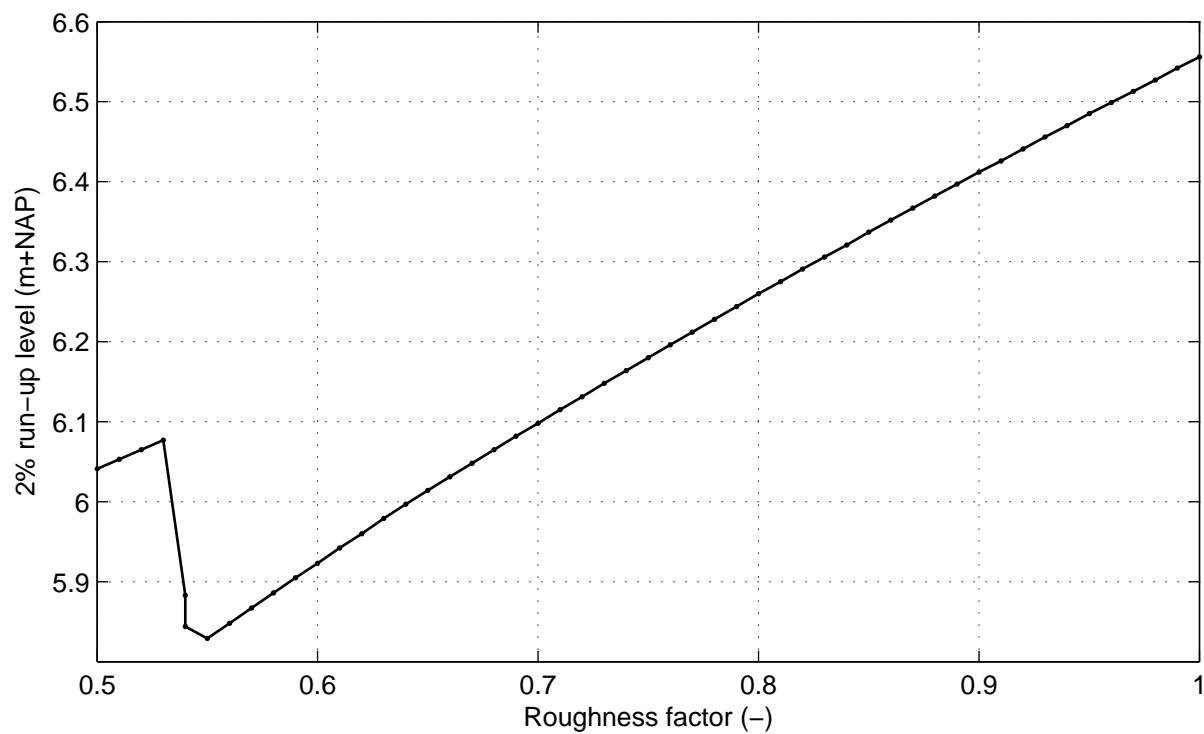
Cross section nr 7; series nr 9; Wave angle: 85 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.9



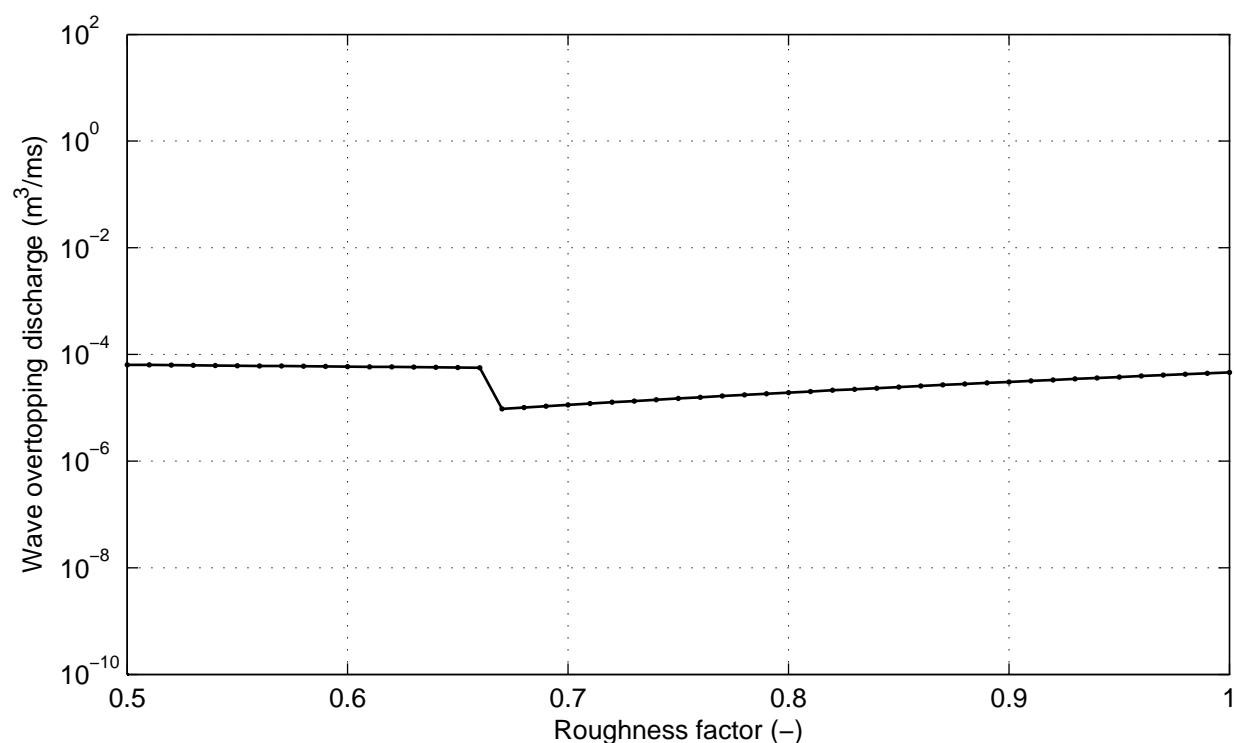
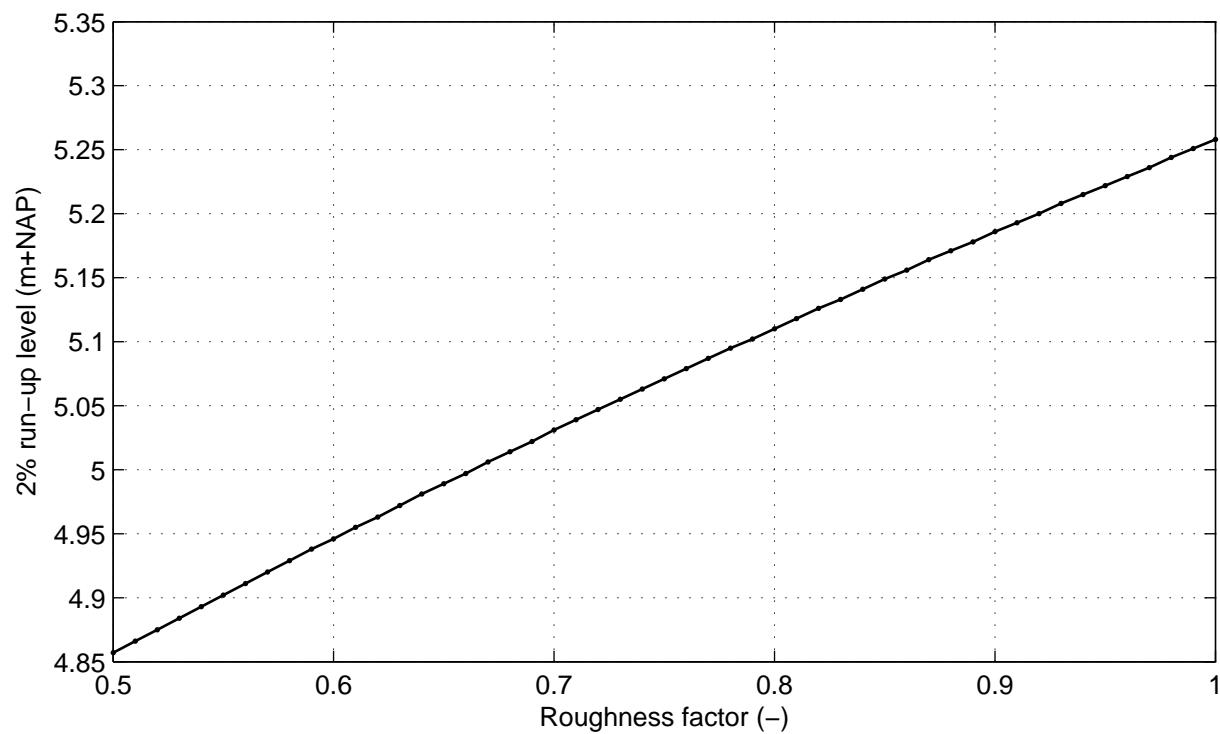
Cross section nr 7; series nr 10; Wave angle: 0 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.10



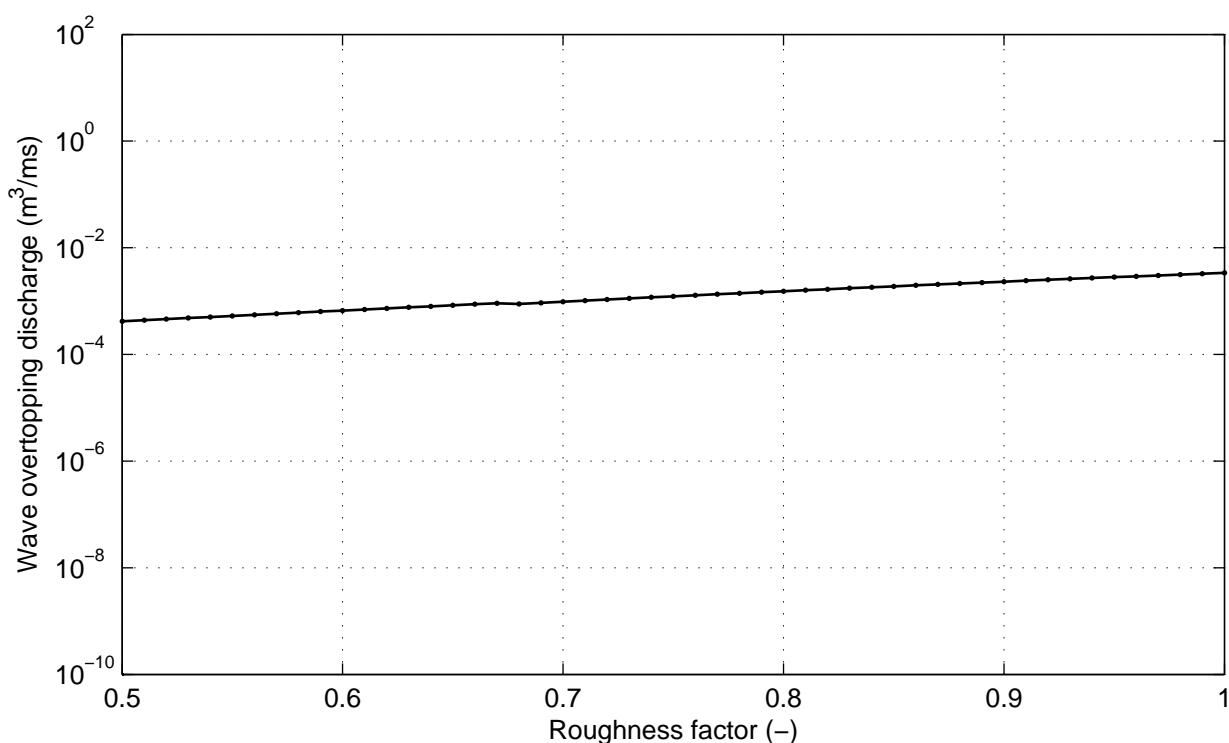
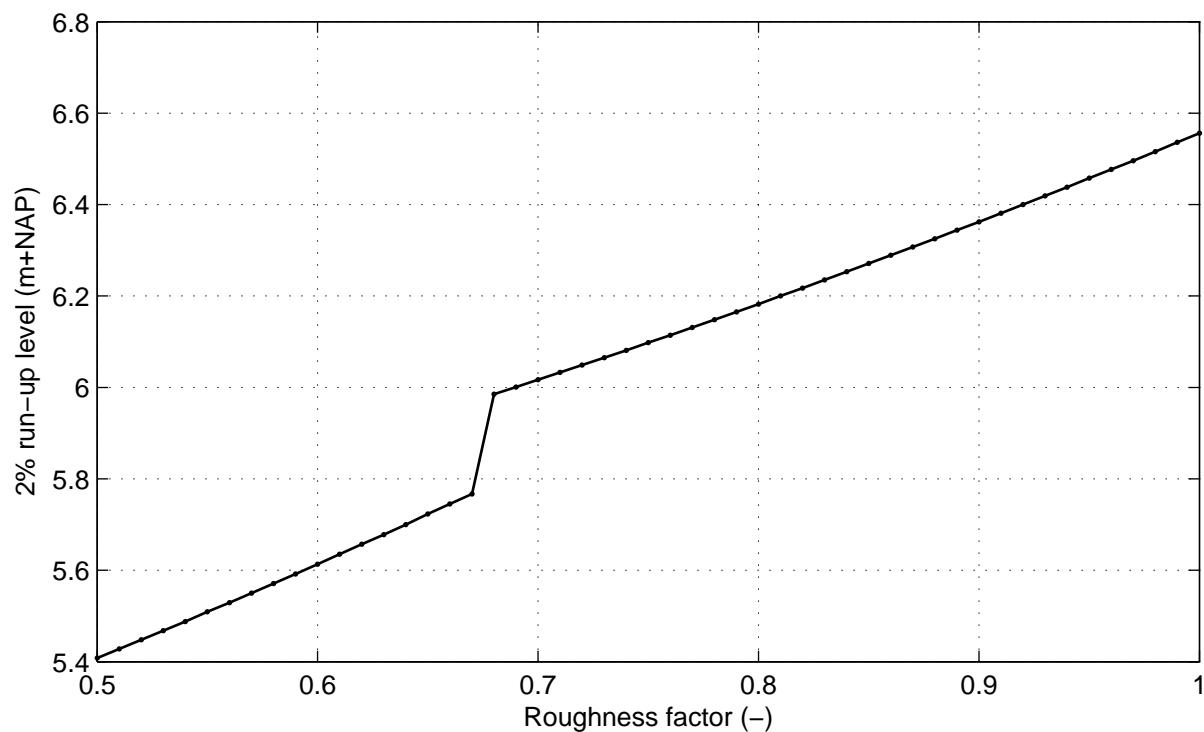
Cross section nr 7; series nr 11; Wave angle: 85 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.11



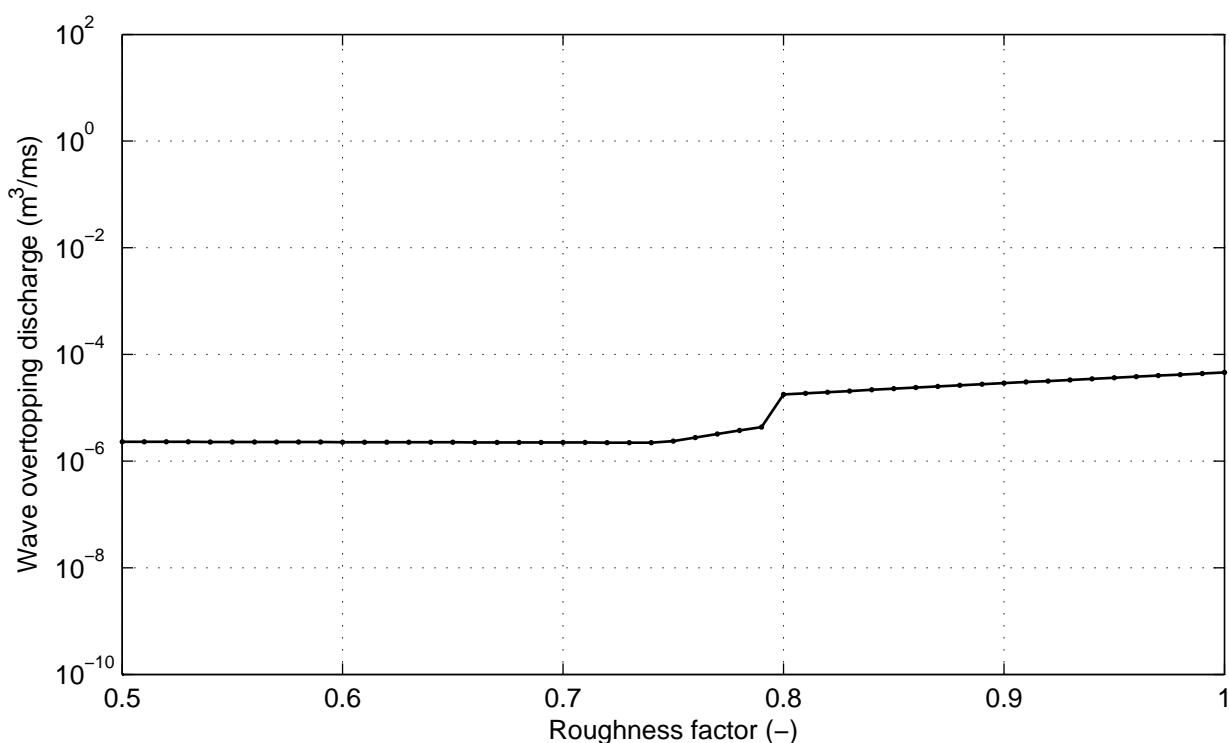
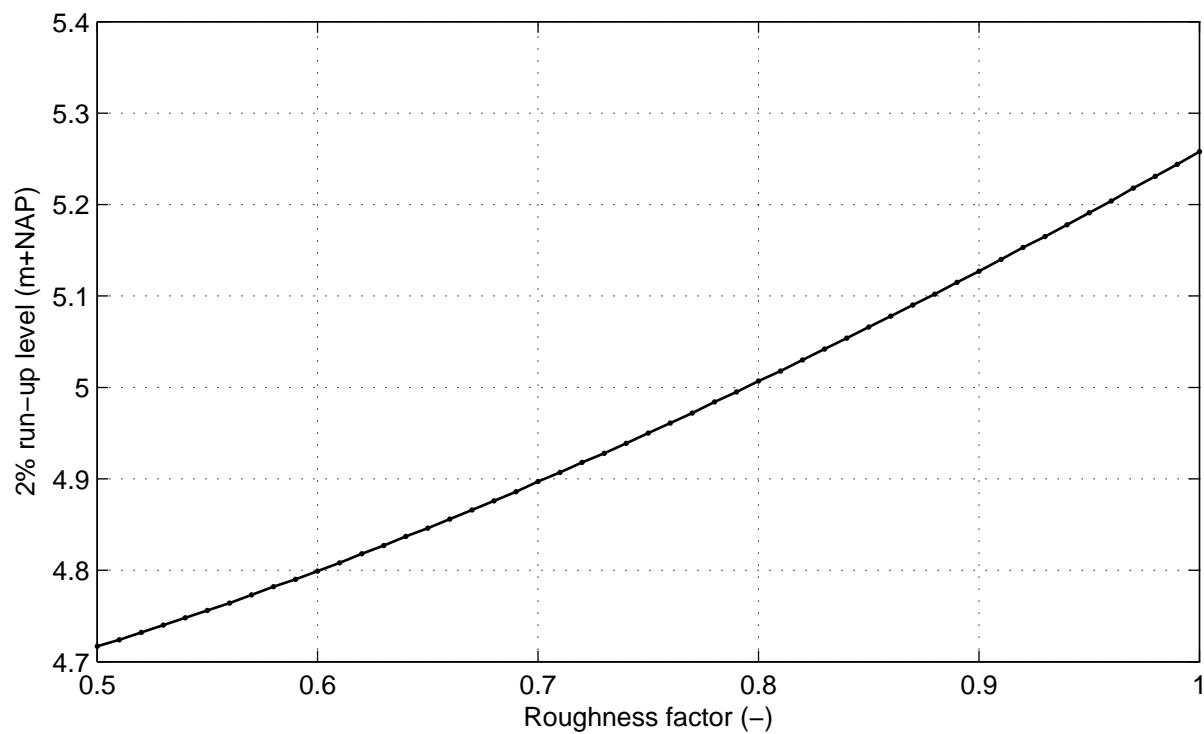
Cross section nr 7; series nr 12; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.12



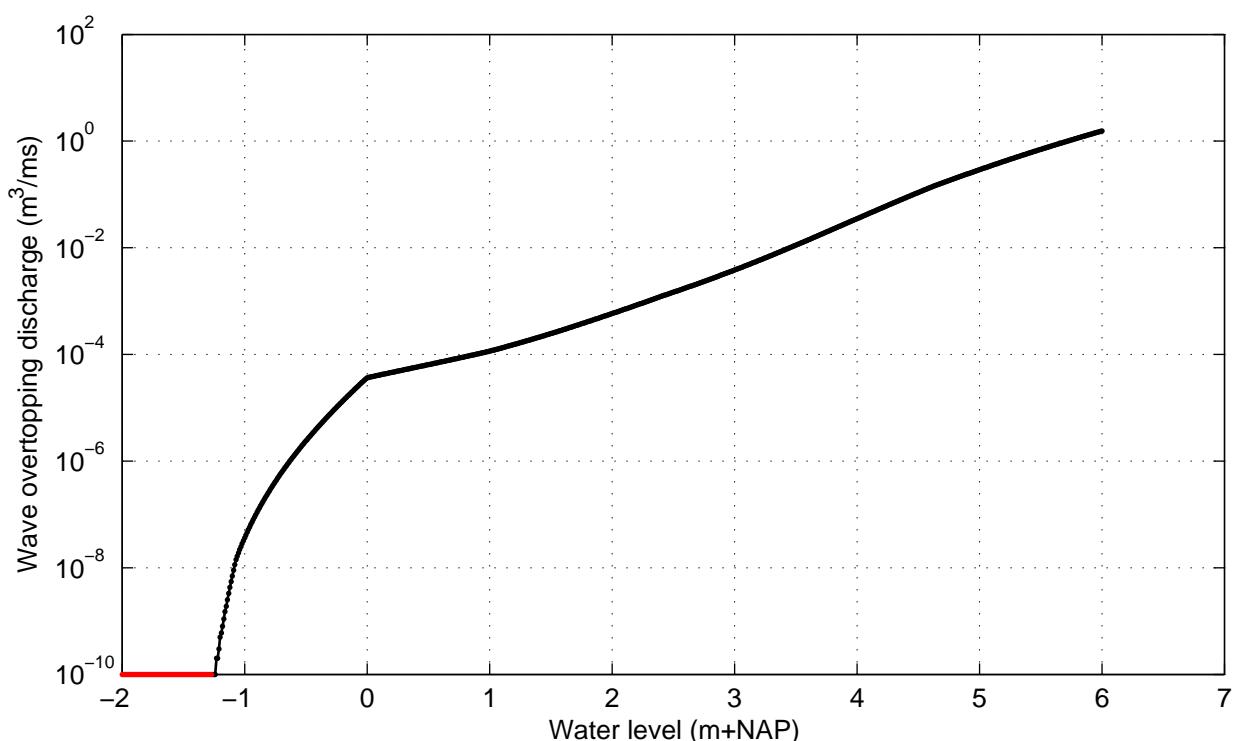
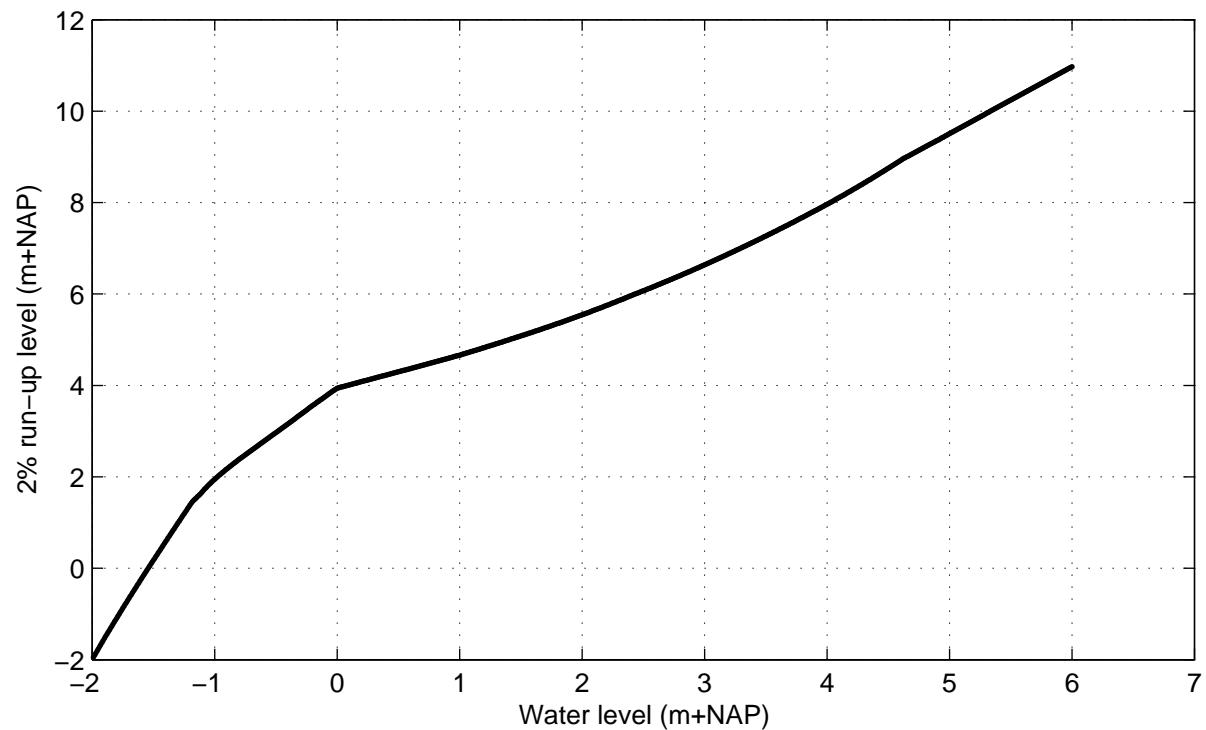
Cross section nr 7; series nr 13; Wave angle: 85 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 7.13



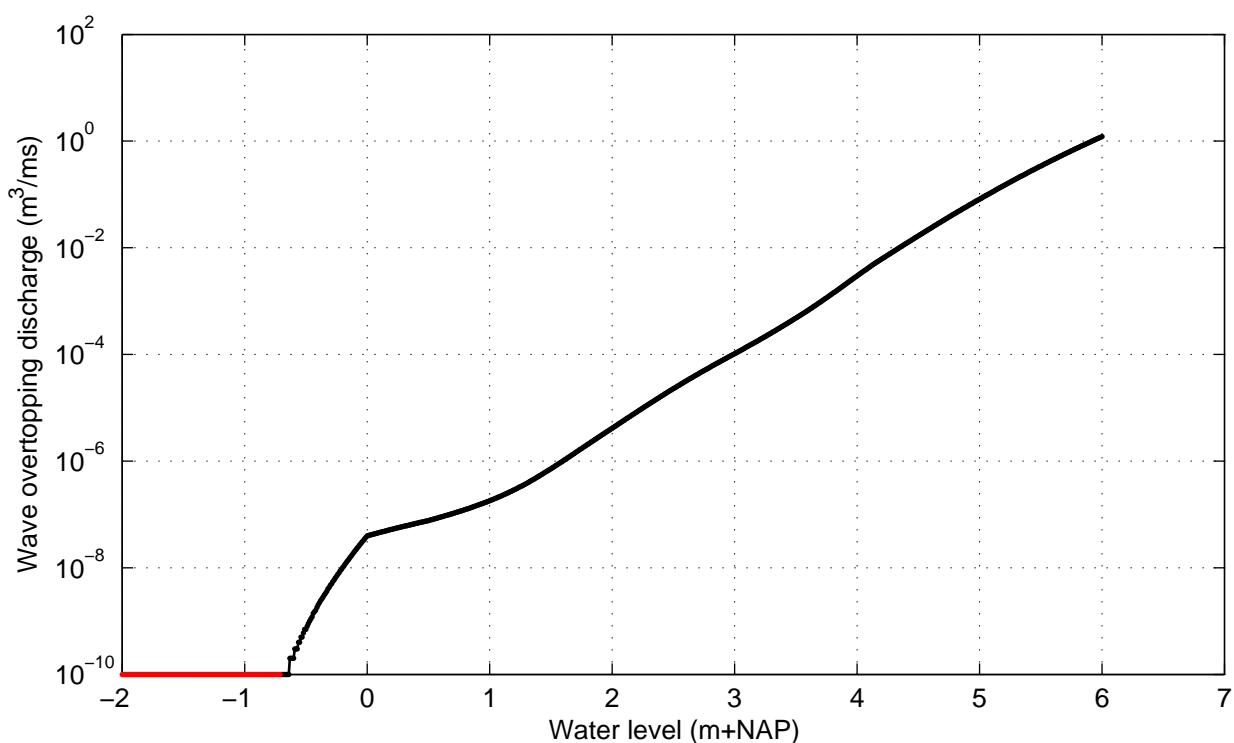
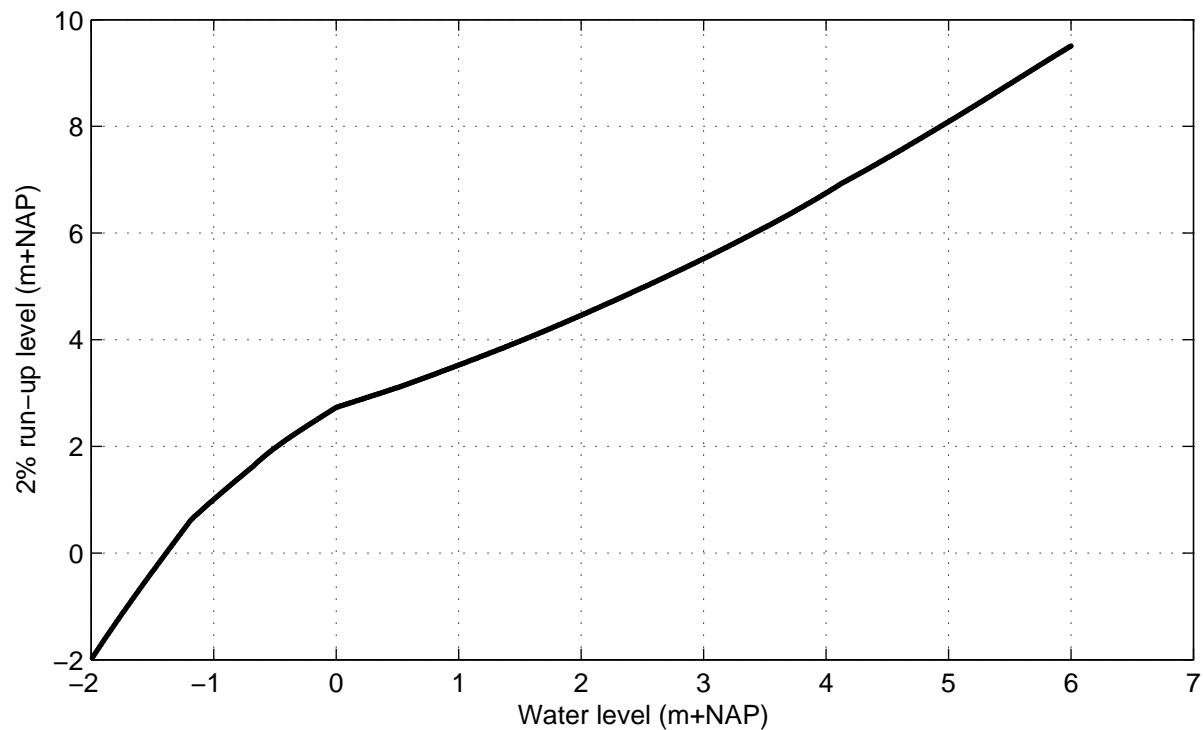
Cross section nr 8; series nr 1; Wave angle: 0 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.1



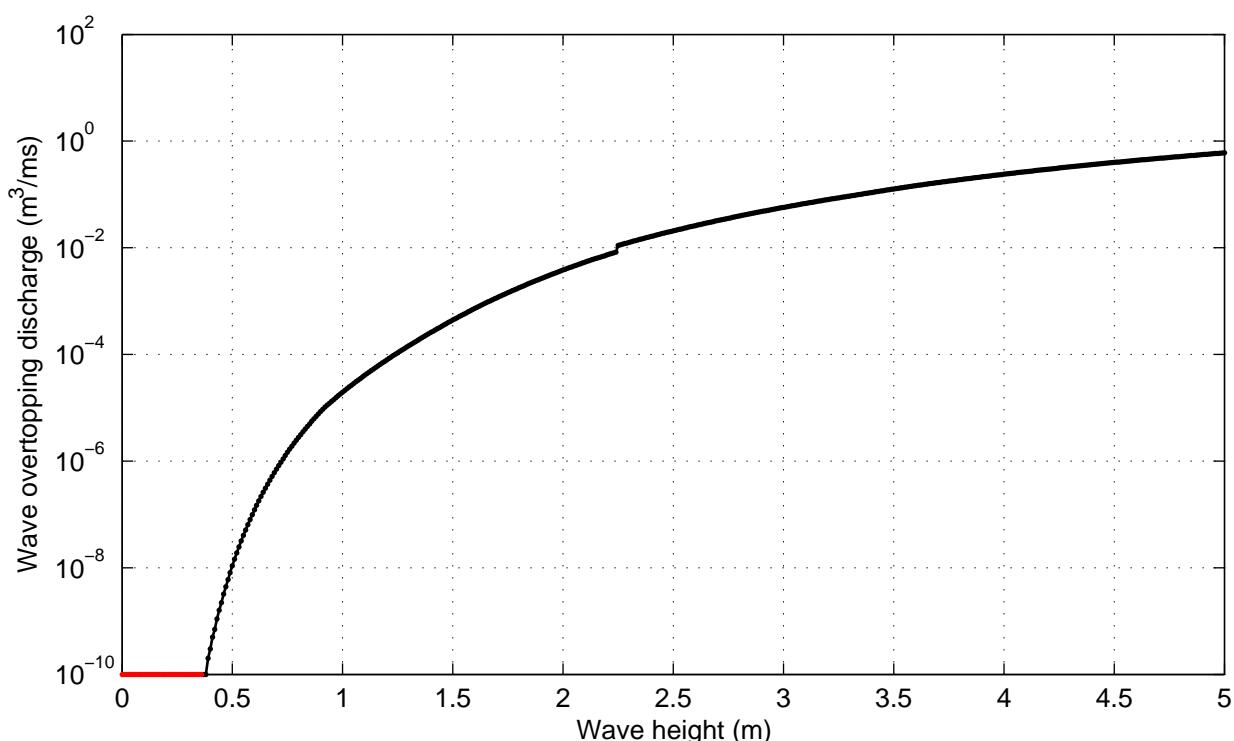
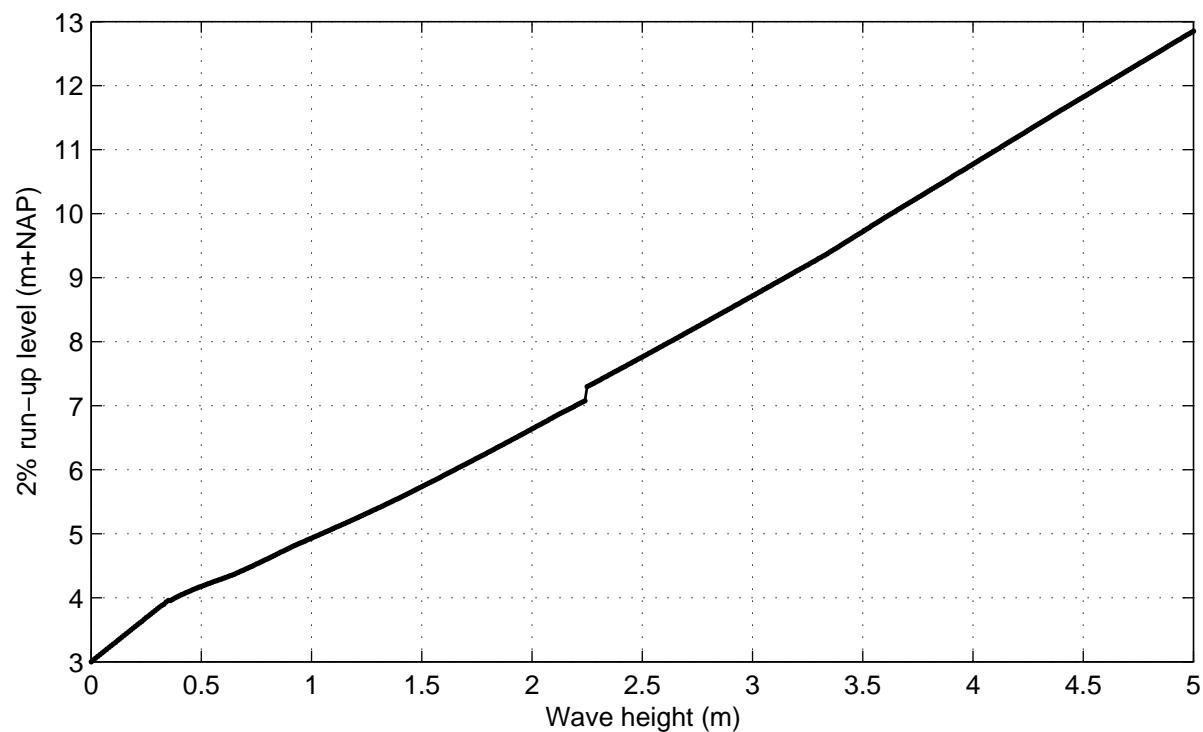
Cross section nr 8; series nr 2; Wave angle: 85 °
Varying water level

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.2



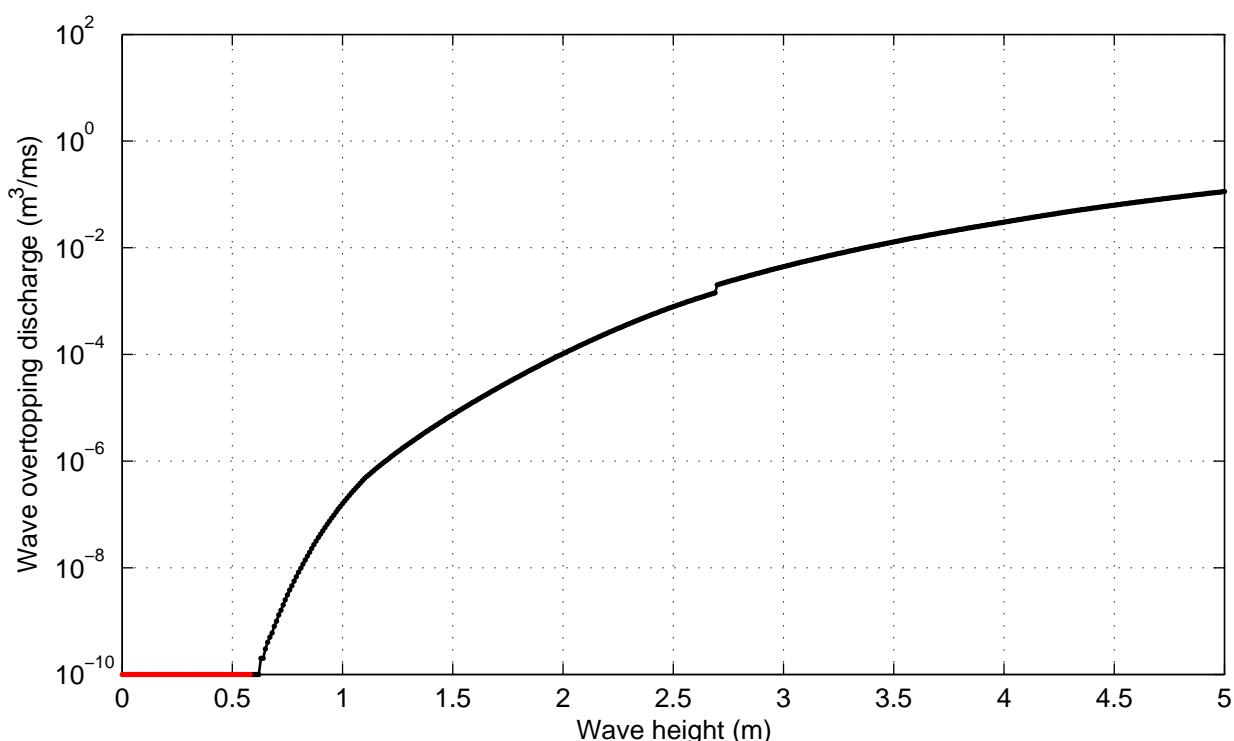
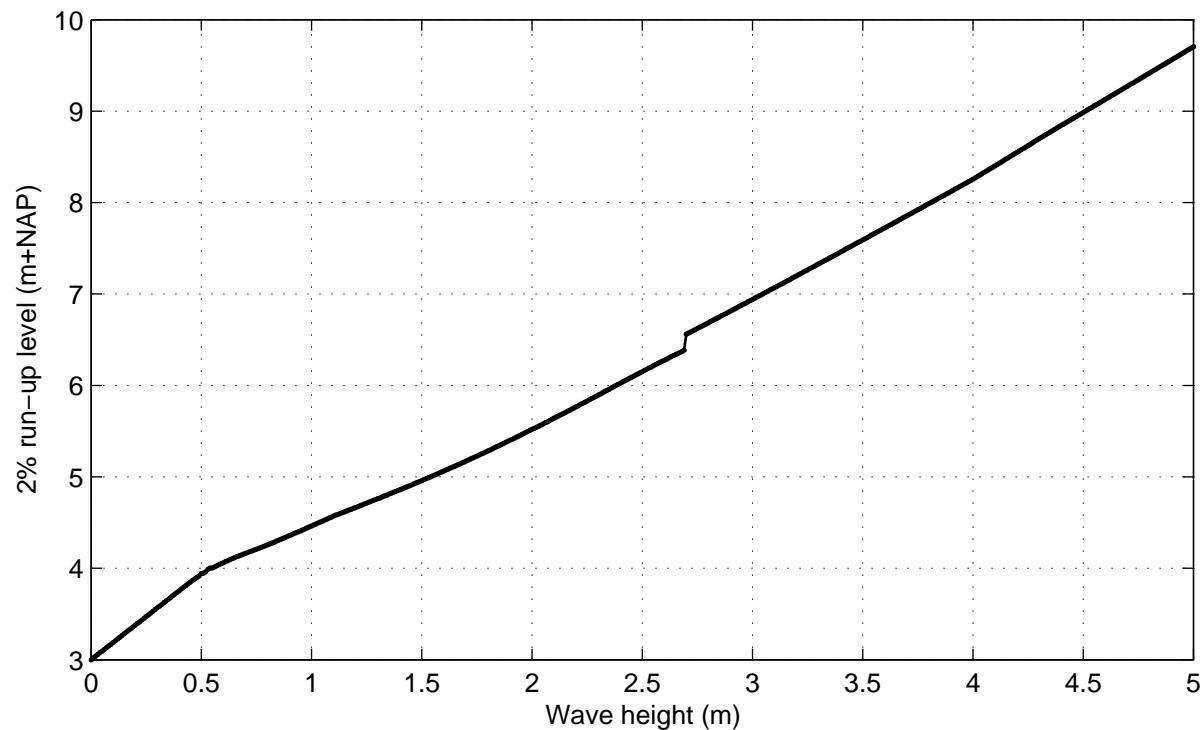
Cross section nr 8; series nr 3; Wave angle: 0 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.3



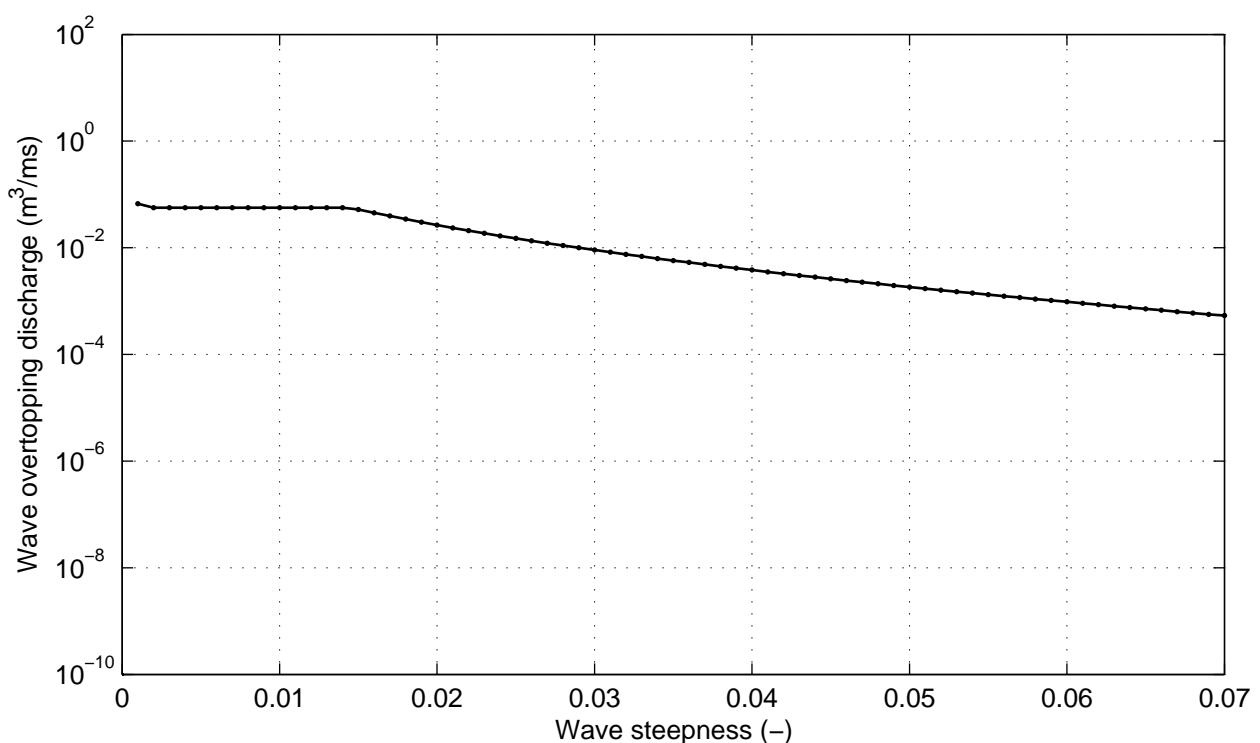
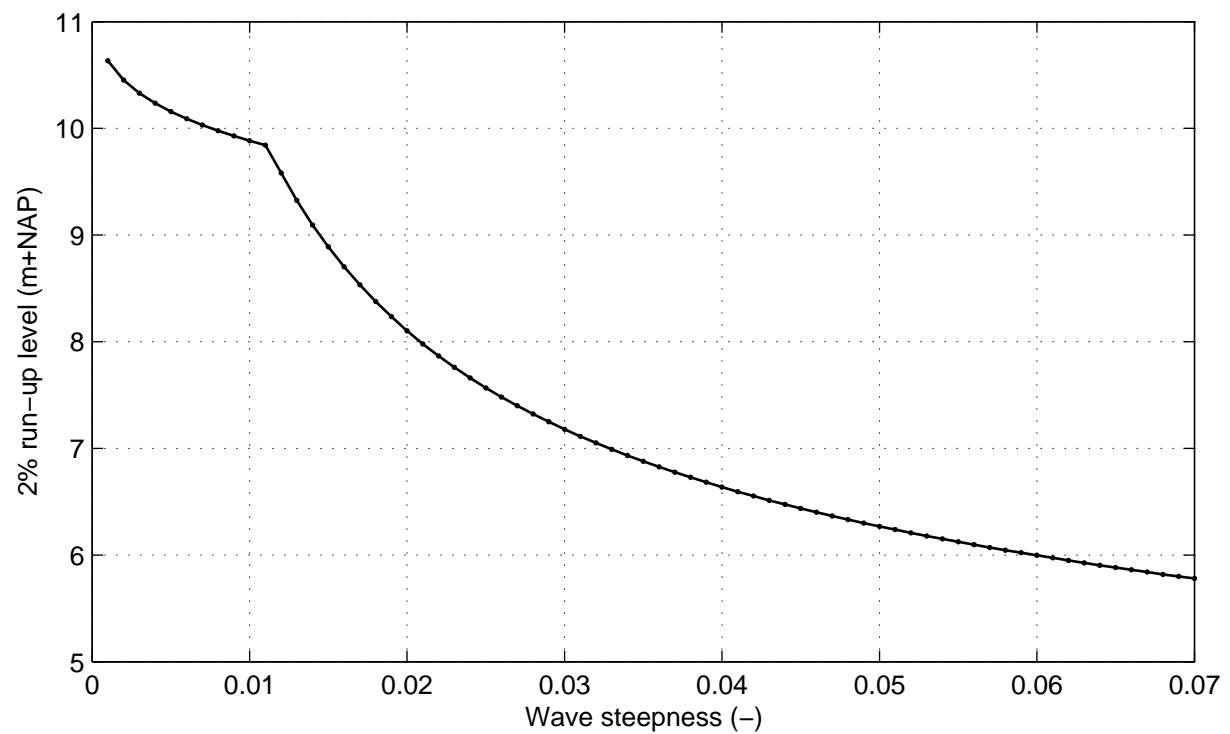
Cross section nr 8; series nr 4; Wave angle: 85 °
Varying wave height

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.4



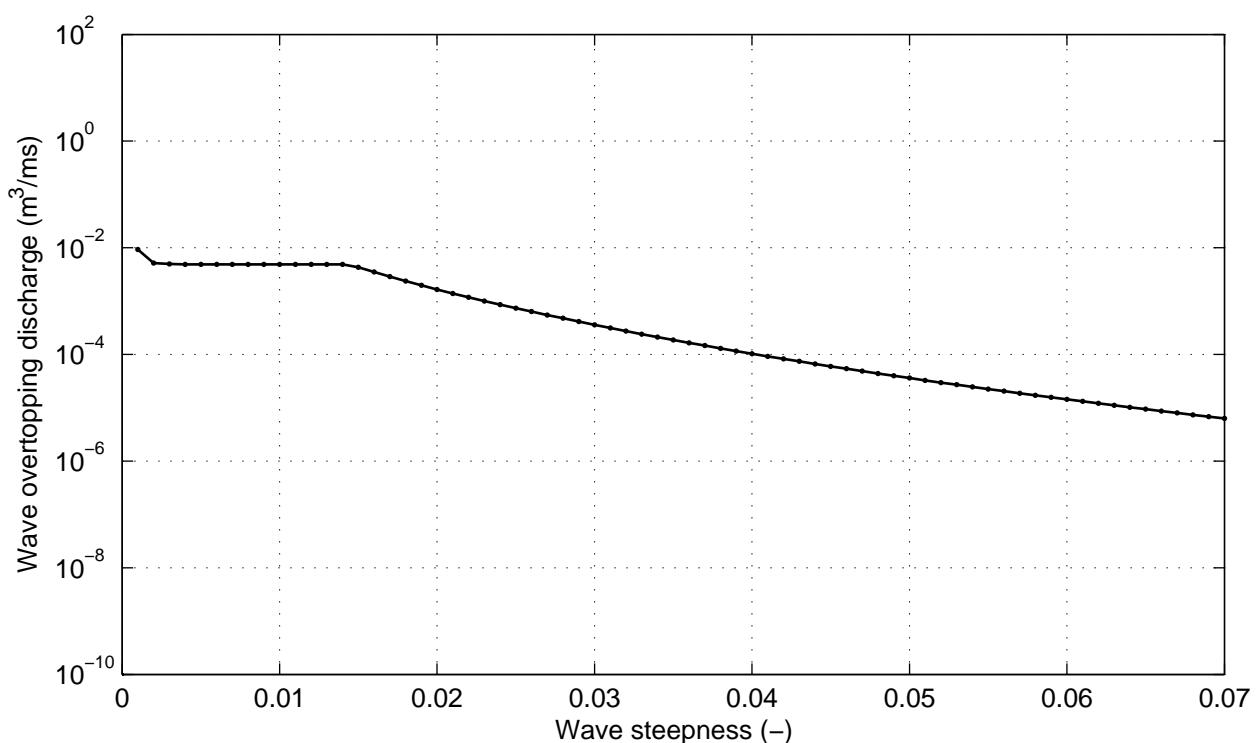
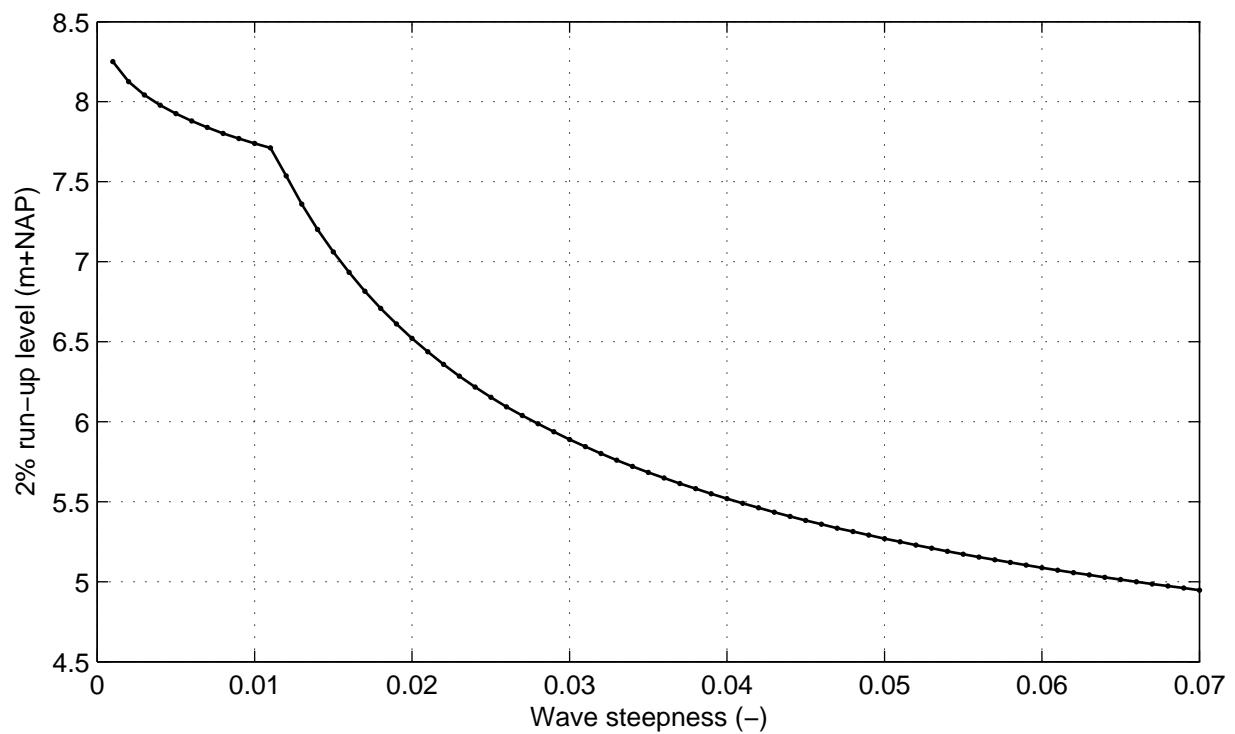
Cross section nr 8; series nr 5; Wave angle: 0 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.5



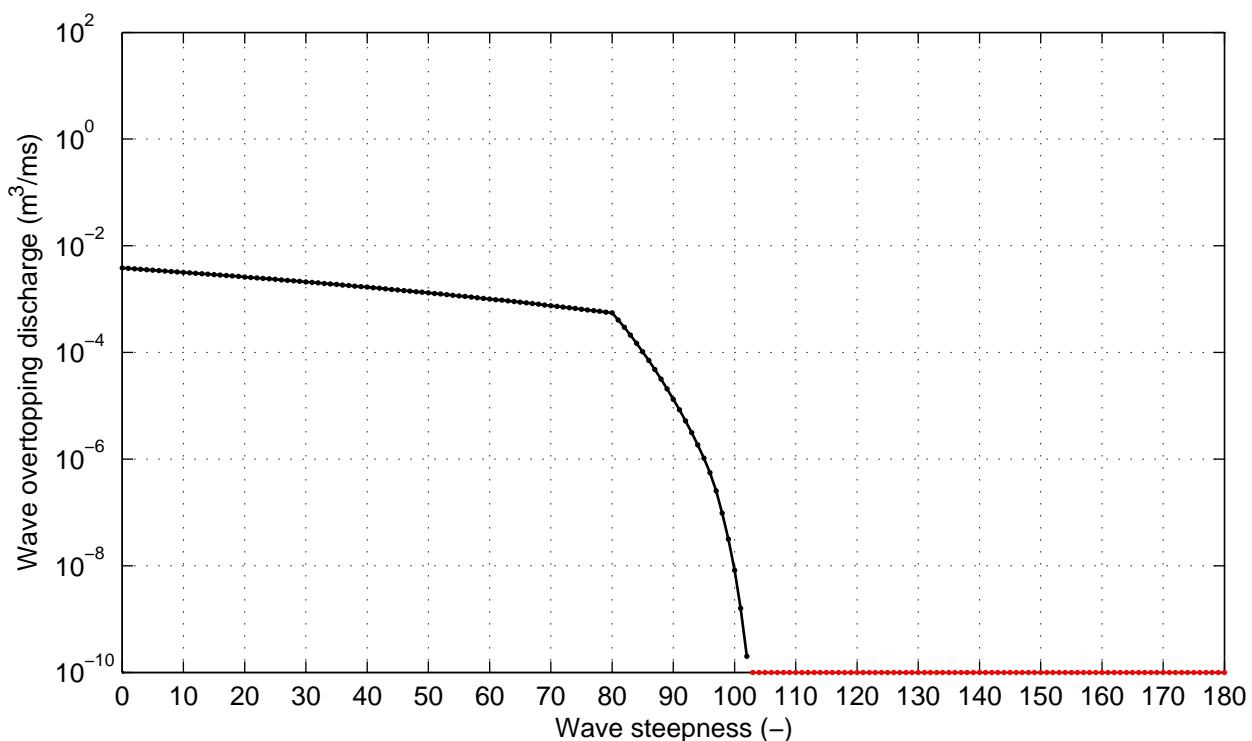
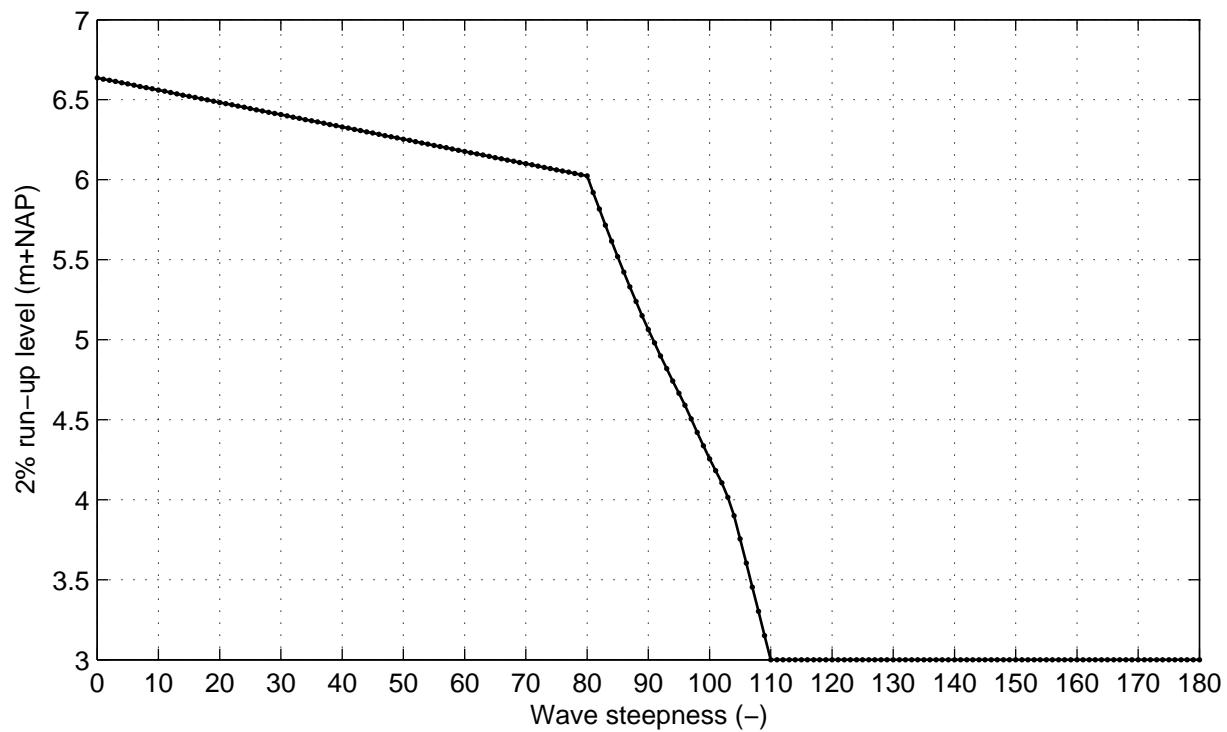
Cross section nr 8; series nr 6; Wave angle: 85 °
Varying wave steepness

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.6



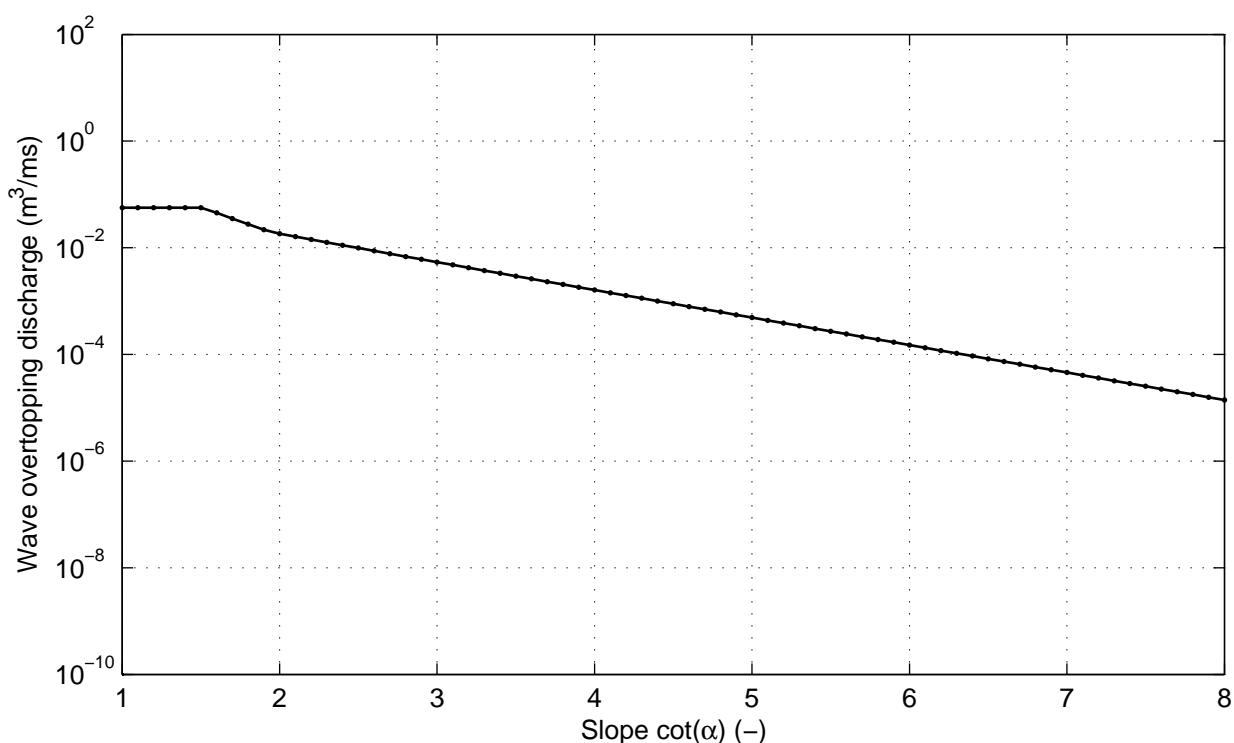
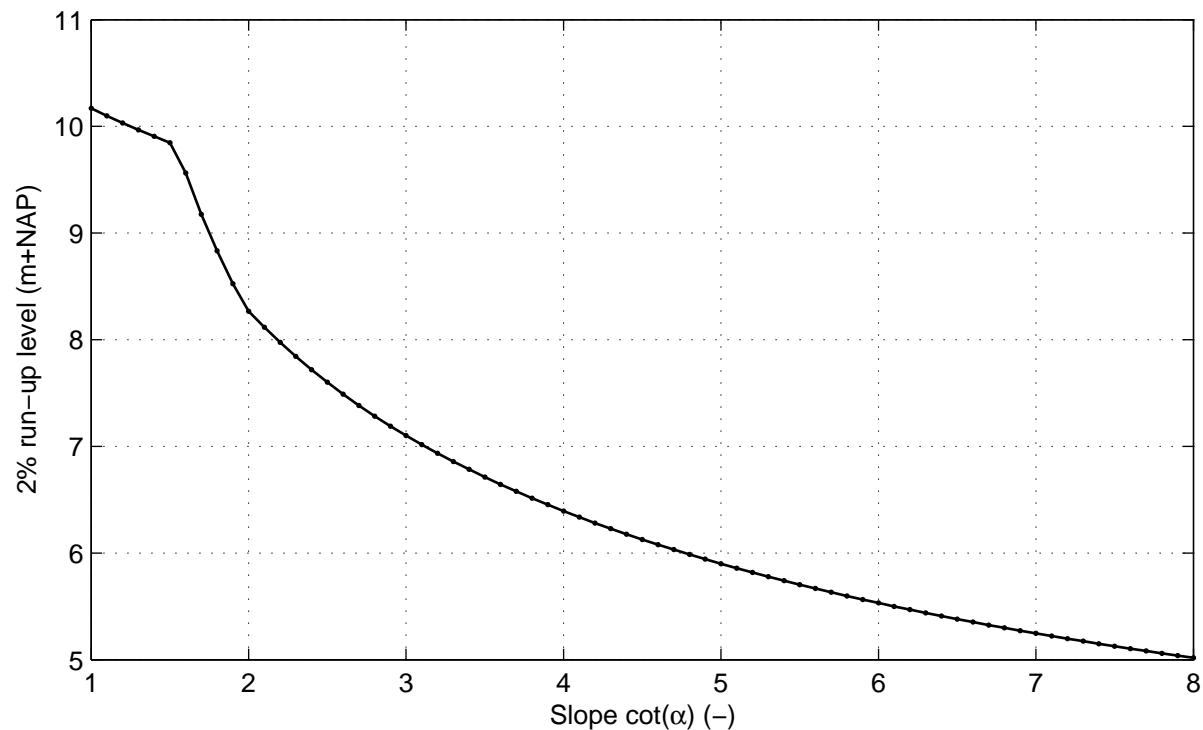
Cross section nr 8; series nr 7;
Varying wave angle

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.7



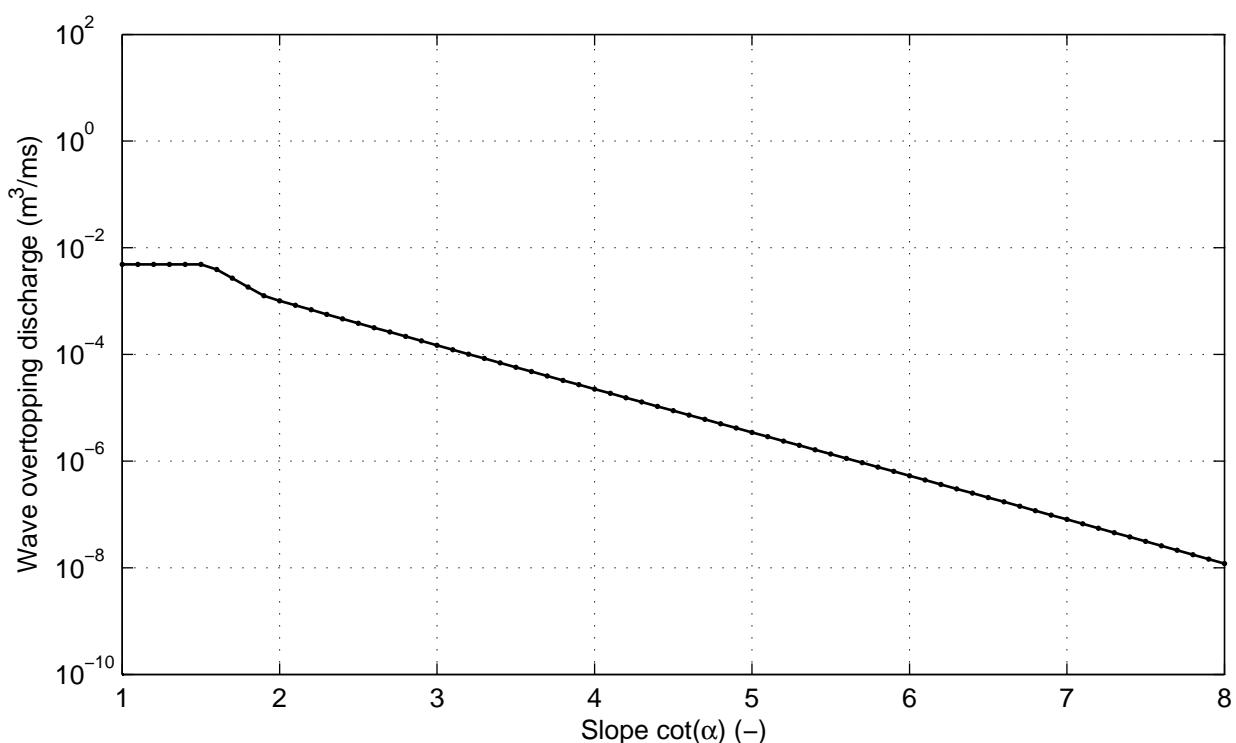
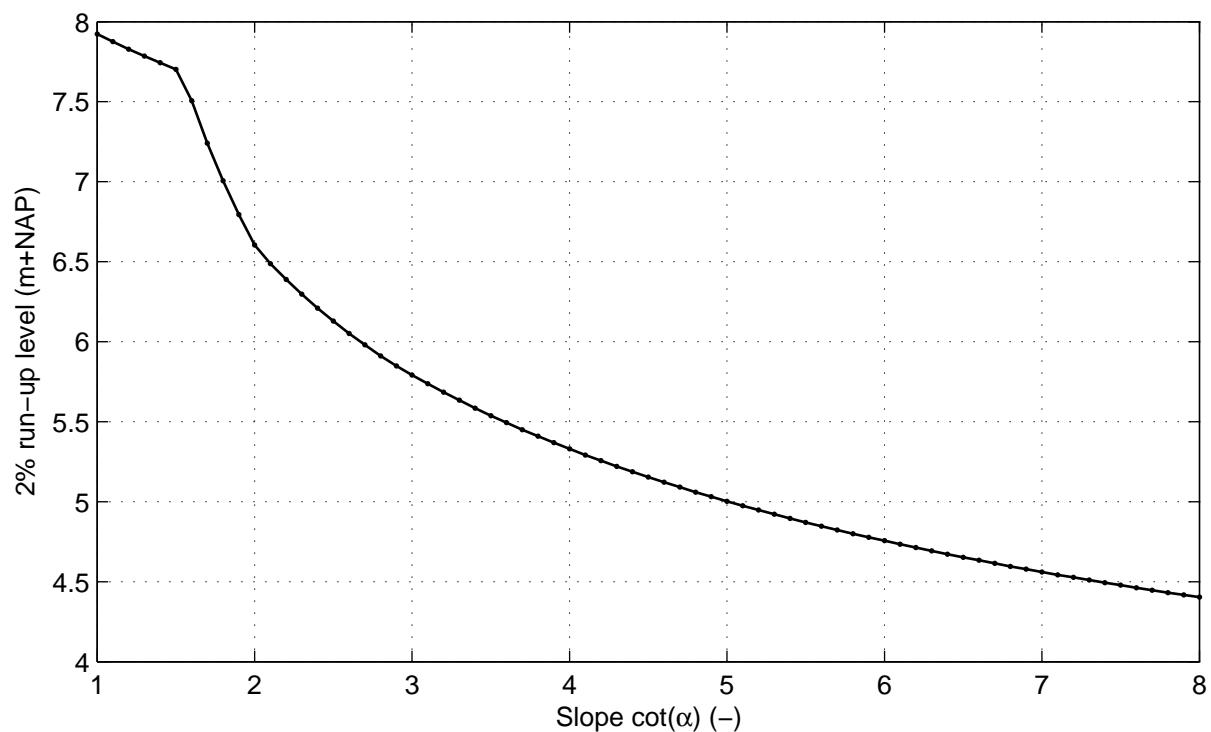
Cross section nr 8; series nr 8; Wave angle: 0 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.8



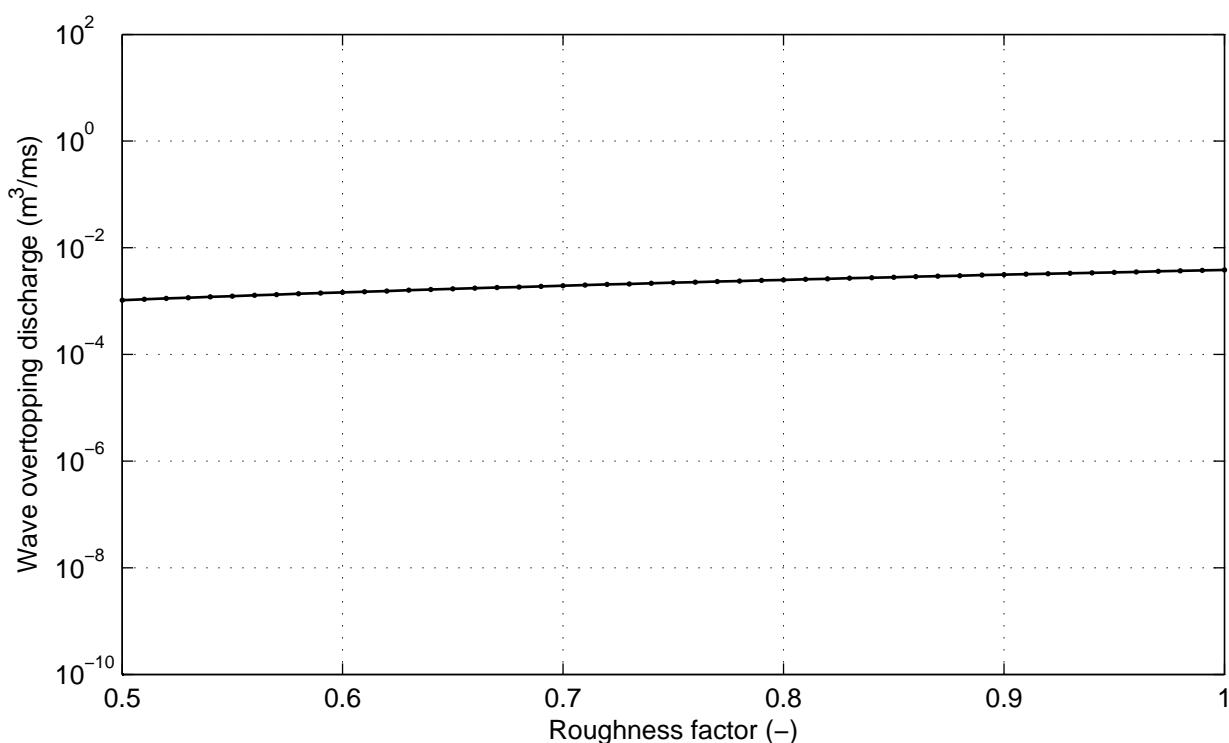
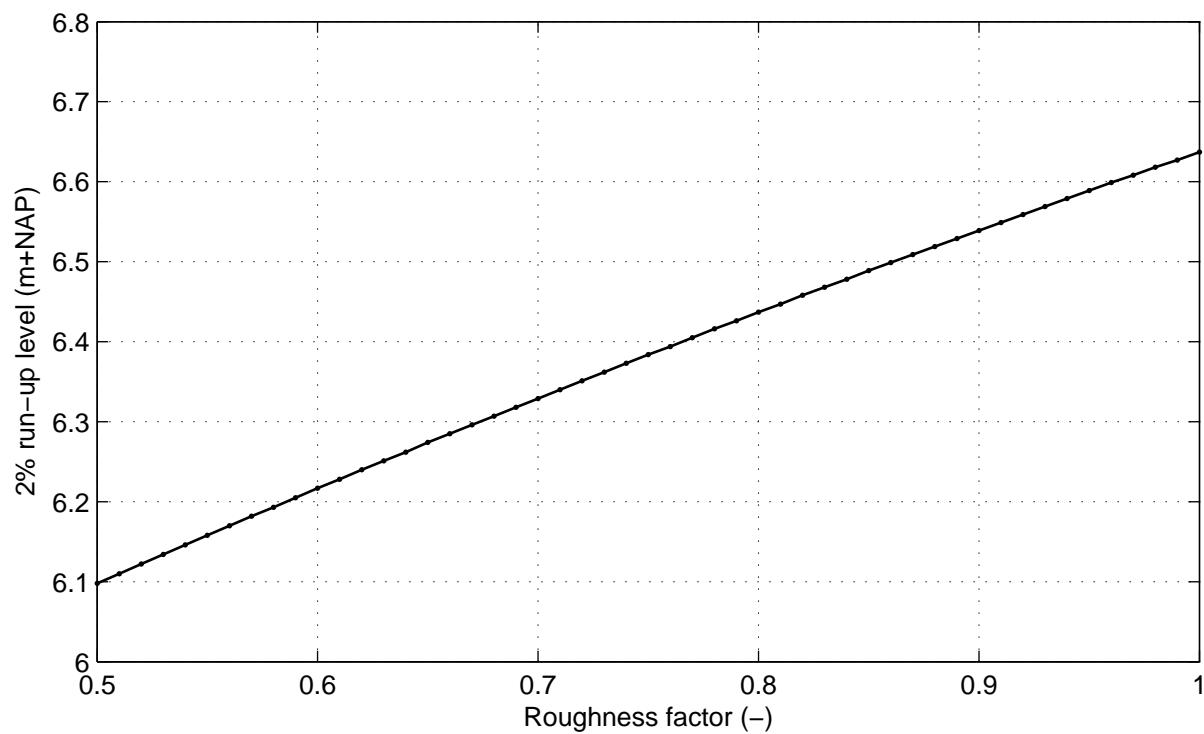
Cross section nr 8; series nr 9; Wave angle: 85 °
Varying slope of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.9



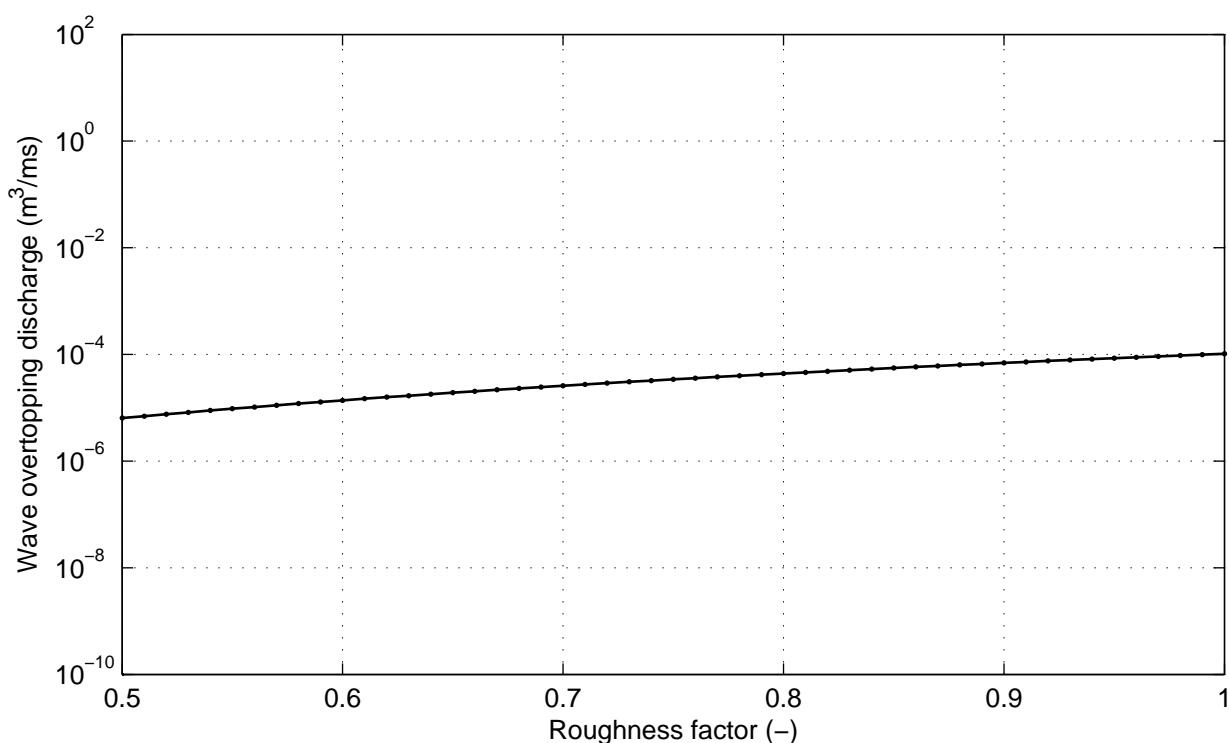
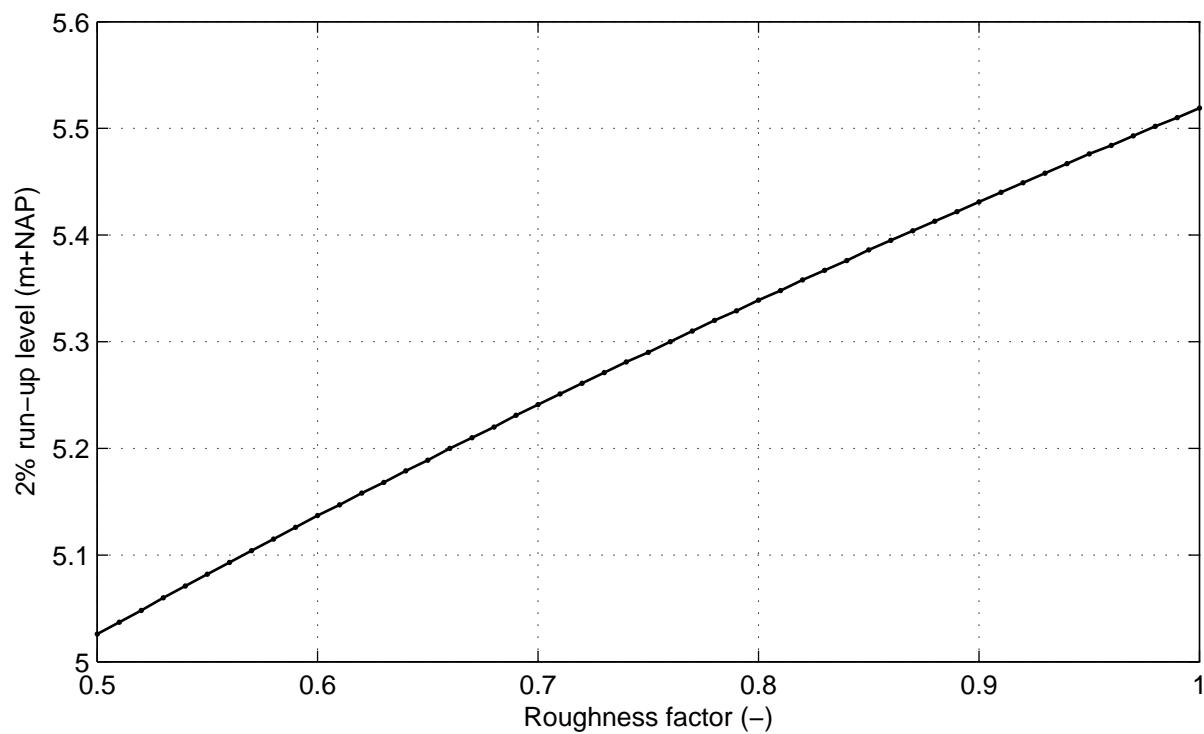
Cross section nr 8; series nr 10; Wave angle: 0 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.10



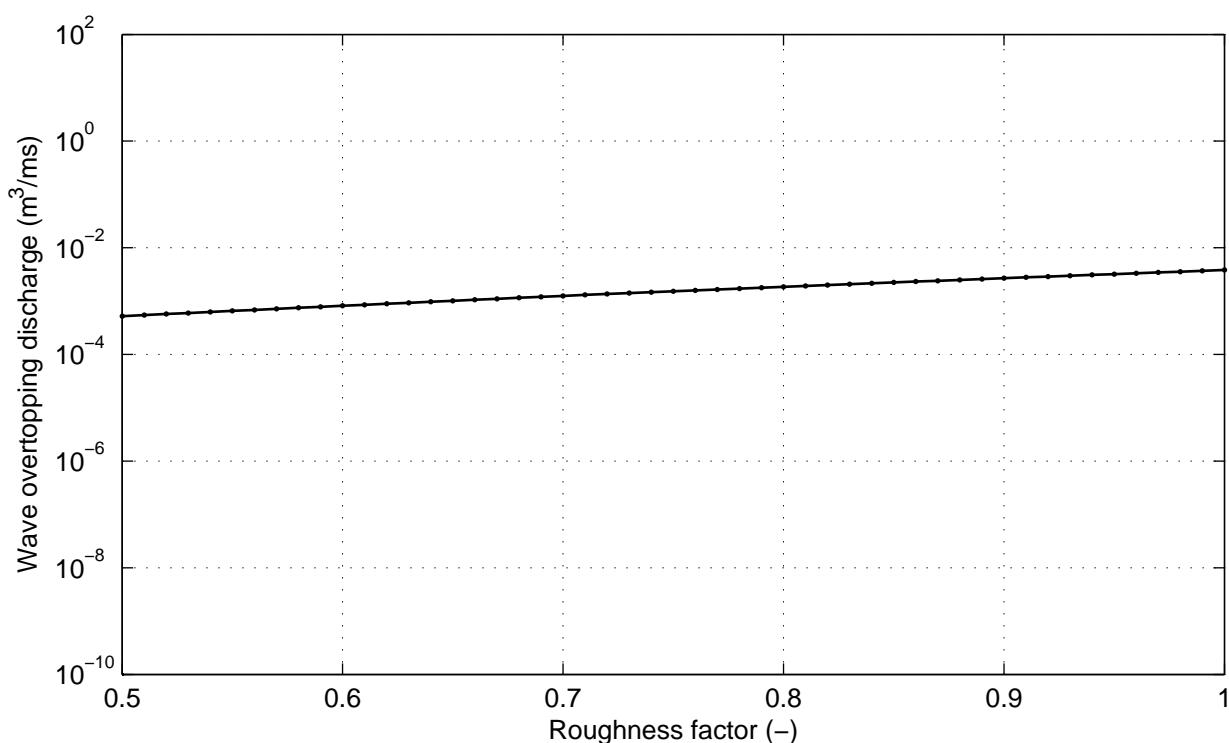
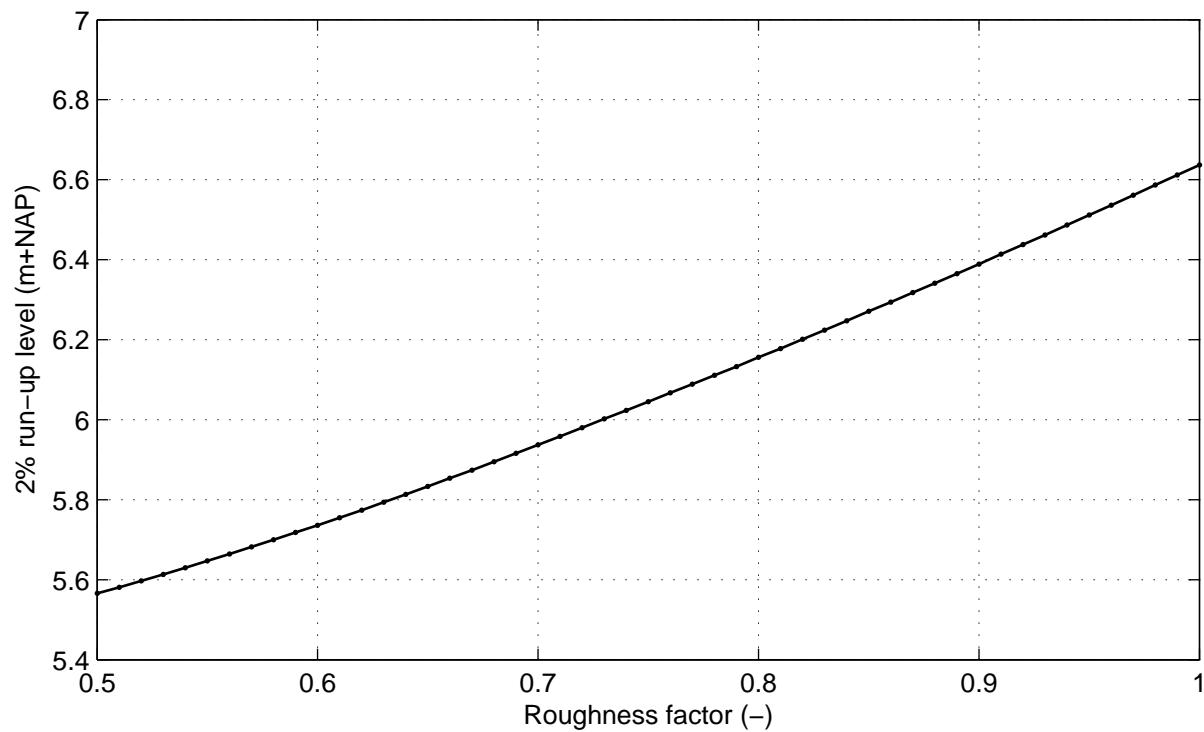
Cross section nr 8; series nr 11; Wave angle: 85 °
Varying roughness of all berm segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.11



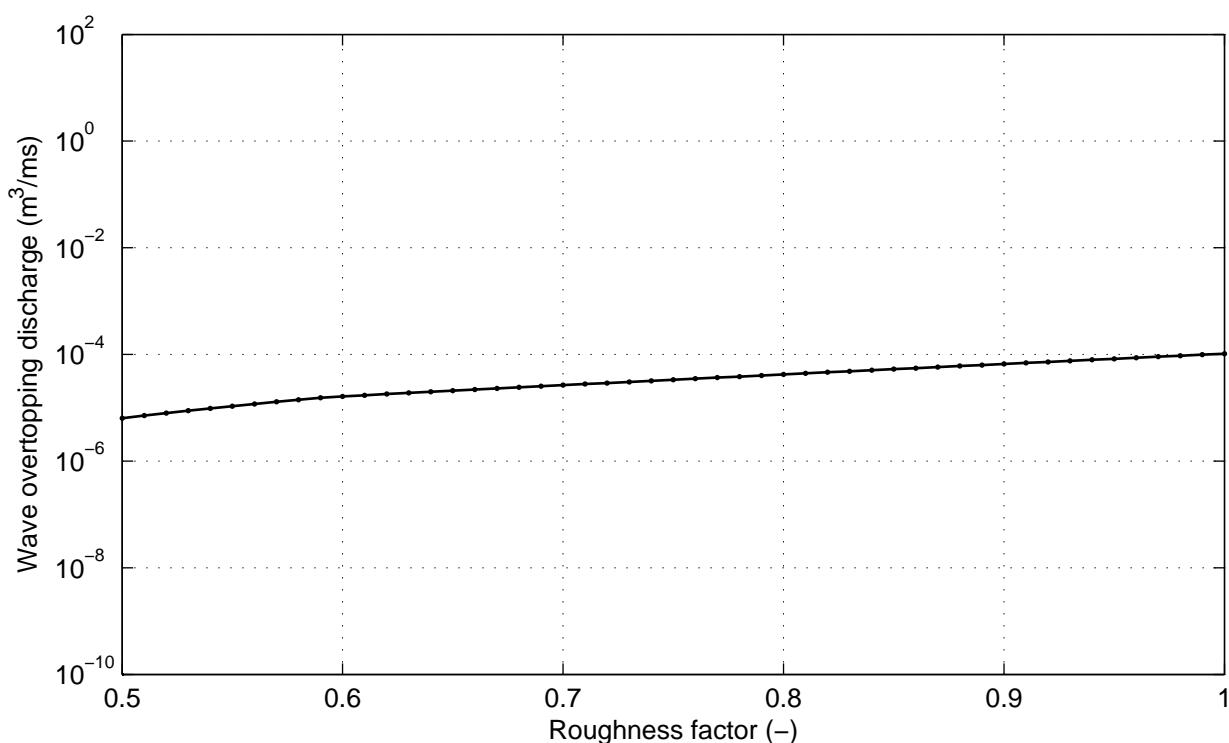
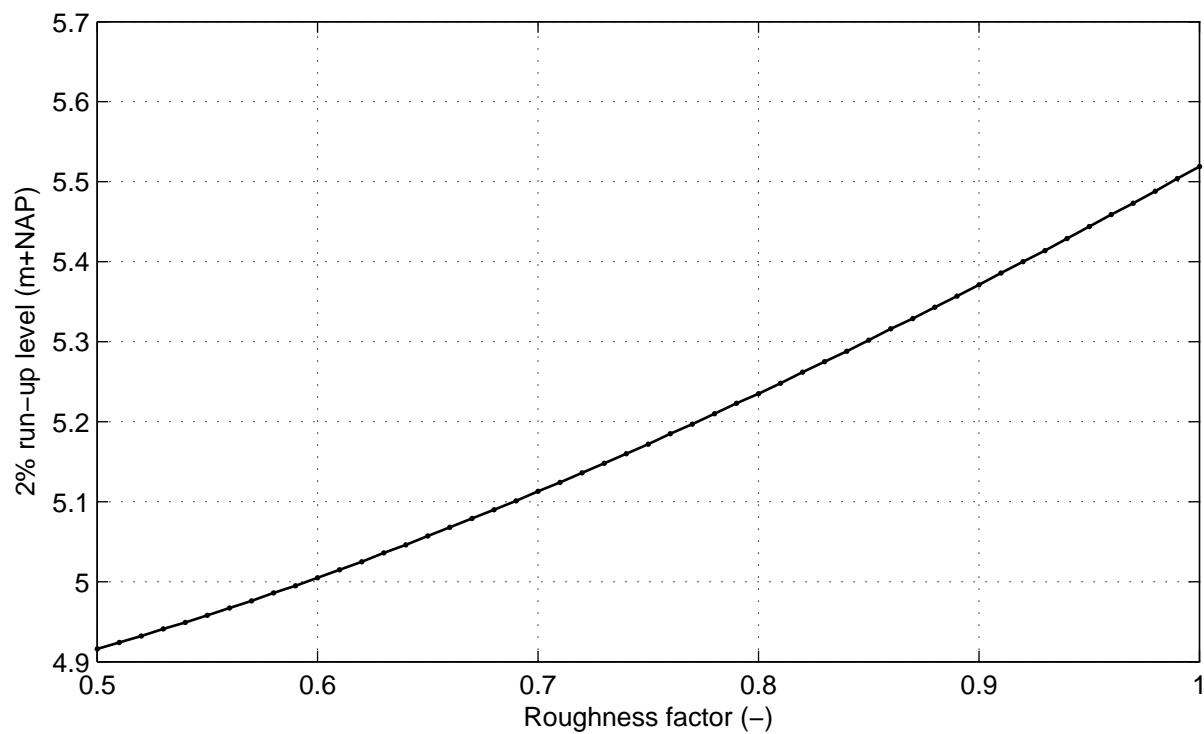
Cross section nr 8; series nr 12; Wave angle: 0 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.12



Cross section nr 8; series nr 13; Wave angle: 85 °
Varying roughness of all ordinary segments

Wave overtopping kernel tests

DELTARES

1220043.002

Fig. 8.13