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Input database for the Bretschneider wave calculations for narrow river areas

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In preparation for the WTI-2017 production runs

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Title
Input database for the Bretschneider wave calculations for narrow river areas

Client	Project	Reference	Pages
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Summary
In this report the method of the determination of hydraulic boundary conditions for WTI-2017 for narrow river areas in the Netherlands has been described. The following regions were studied:

- Meuse (in Dutch: Maas)
- Rhine Branches (in Dutch: Rijntakken)
- Vecht-IJssel delta
- Mouth of the Rhine-Meuse (in Dutch: Rijn-Maas-monding, or simply RMM)

In the narrow parts of these river areas, the hydraulic boundary conditions for WTI-2017 will be determined with the empirical Bretschneider wave growth curves. The Bretschneider curves need various inputs:

- Wind velocity;
- Effective fetch;
- Representative water depth.

These inputs have to be determined for a large number of locations in the regions of interest and for 16 wind directions. Use is made of two tools and Baseline schematizations of the regions to calculate the effective fetch and representative water depth. The fetches are calculated from the river contours, following the crest height (in Dutch: buiten kruinlijn) of the primary water defence of a dike ring. As a starting point dry areas and obstacles were not taken into account in the fetch determination.

Various checks on the input for the Bretschneider production runs and the results of the Bretschneider calculations were performed to make sure that correct results are delivered for the WTI-2017 production runs. The results of the Bretschneider runs have been stored in a structured matlab format and a *.kmz file to be used in the determination of HR2017 and for further processing in follow-up studies.

Versie	Datum	Auteur	Paraaf	Review	Paraaf	Goedkeuring	Paraaf
1	Nov. 2015	A. Camarena Calderon et al.		J. Groeneweg		M. van Gent	
2	Dec. 2015	A. Camarena Calderon et al.		J. Groeneweg		M. van Gent	
4	Apr. 2016	A. Camarena Calderon A. Smale J. van Nieuwkoop J. Morris JCM		J. Groeneweg	[signature]	M. van Gent	[signature]

State
final

Contents

Bijlage(n)

Samenvatting (summary in Dutch)

Dit rapport beschrijft de methode waarmee de hydraulische randvoorwaarden voor WTI-2017 voor de smalle riviersystemen in Nederland bepaald zijn. De volgende gebieden zijn bekeken:
- Maas
- Rijntakken
- Vecht-IJssel delta
- Rijn-Maas-monding (of afgekort RMM)

De hydraulische randvoorwaarden voor WTI-2017 voor de bovenstaande riviergebieden zullen worden bepaald met behulp van de empirische golfgroeiformules van Bretschneider. Voor de Bretschneider formules is de volgende invoer benodigd:
- Windsnelheid;
- Effectieve strijklengte;
- Representatieve waterdiepte.

De bovenstaande invoer is voor een groot aantal locaties in de interessegebieden en voor 16 windrichtingen bepaald. Ter bepaling van de effectieve strijklengte en representatieve waterdiepte, is gebruik gemaakt van twee rekenprogramma's en van Baseline schematisaties van de betreffende gebieden. De strijklengtes zijn bepaald met behulp van de shapes, waarbij de buiten kruinlijnen zijn gevolgd. Daarbij is als uitgangspunt gehanteerd om hoogwatervrije gebieden en obstakel niet te verdisconteren.

De invoer voor de Bretschneider productieberekeningen en de resultaten van de Bretschneider testberekeningen zijn op verschillende manieren gecontroleerd om er zeker van te zijn dat de opgeleverde resultaten voor de WTI-2017 productieberekeningen correct zullen zijn. De resultaten van de productieberekeningen zijn opgeslagen in een gestructureerd matlab formaat en in een *.kmz bestand, zodat de resultaten gebruikt kunnen worden in de bepaling van de HR2017 en gemakkelijk verder verwerkt kunnen worden in toekomstige studies.

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1 Introduction

Reader's Note:

This report was generated based on the information available in July 2015. It describes the Bretschneider procedure as it was at that moment. Some changes have been made to this procedure prior to the final Bretschneider computations. Therefore, there are some differences between the results presented in this report and the final results contained within the hydraulic databases (see Deltares, 2016).

These changes include:

1. Changes made to the RMM shape file, which are described in Appendix D of the present report.
2. In this report only one schematization is mentioned for the Maas region. There are actually two schematizations for this area, one with and one without infinitely high quays. For the final databases, the Baseline schematization with infinitely high quays "maas-hr2017_mknov_5-v2" was also used, but only to extract the relevant output locations (uitvoerlocaties) for the Maas mknov database. For the rest, the "maas-beno14_5-v2" Baseline schematization, which is mentioned in this report, was used.
3. Additional locations were added to the Rijnmaasmonding 'uitvoerlocaties' location set to get the required coverage for the database generation.
4. Changes were made to the ShapeLib-fetch-tool in January 2016. This was because the ShapeLib-fetch-tool described in the present report had issues when the river contour was composed of multiple polygons. The fetch was often shorter than it should be because it was cut off at the 'ghost' lines that connected the multiple polygons.

The KMZ files attached to the report contain the Bretschneider input that was used to generate the final databases from Deltares (2016). They take into account the changes mentioned above.

1.1 Framework

In compliance with the Dutch Water Act ("Waterwet, 2009") the strength of the Dutch primary water defences must be assessed periodically for the required level of protection, which, depending on the area, varies from 300 to 100,000 year loads in the assessment round of 2017. These loads are determined on the basis of Hydraulic Boundary Conditions (HBC). The HBC and the Safety Assessment Regulation ("Voorschrift op Toetsen op Veiligheid", VTV), play a crucial role in the assessment of the primary water defences.

With the aim of delivering legal assessment instruments to be used in the fourth assessment period, starting in 2017, DGRW is funding the long-term project WTI-2017, with Rijkswaterstaat – WVL as executive client for Deltares.

1.2 Motivation

The HBC consist of water levels and wave conditions in terms of significant wave height, peak or mean wave period and mean wave direction, corresponding to a maximum probability of failure of a dike/dune trajectory. The HBC are being determined with the software tool Hydra-Ring. Here the statistical distributions of basic random variables and their correlations are combined with a so-called transformation matrix. The matrix translates values of (combinations of) random variables to local hydraulic loads.

Numerical models are used to determine the values in the transformation matrices. Computations with the hydrodynamic model WAQUA provide the water levels. The wave conditions in coastal regions, at lakes and at the broader parts of the tidal river areas and Vecht-IJssel delta are determined with the phase-averaged wave model SWAN. For the non-tidal rivers (Meuse and Rhine branches) and the narrow parts of the Vecht-IJssel delta and the mouth of the Rhine-Meuse, the wave conditions are determined with the empirical Bretschneider wave growth curve. The wave conditions that can be determined with the Bretschneider formulation are the significant wave height and the peak wave period.

One of the starting points of the WTI-2017 projects is that new HBC are being determined for all regions, but that underlying transformation matrices of WAQUA, SWAN and Bretschneider results are only renewed for those areas that are affected by the “Ruimte voor de Rivier” measures and “Maaswerken”. That implies that new hydrodynamic and wave computations have only been carried out for the tidal and non-tidal rivers and the Vecht-IJssel delta, see Figure 1.1. The model set-up, results and checks on the results of WAQUA and SWAN computations have been described in other WTI-2017 reports. Here we will only consider the preparations needed to produce the Bretschneider calculations for WTI-2017. The final Bretschneider production runs will be described Deltares (2016).

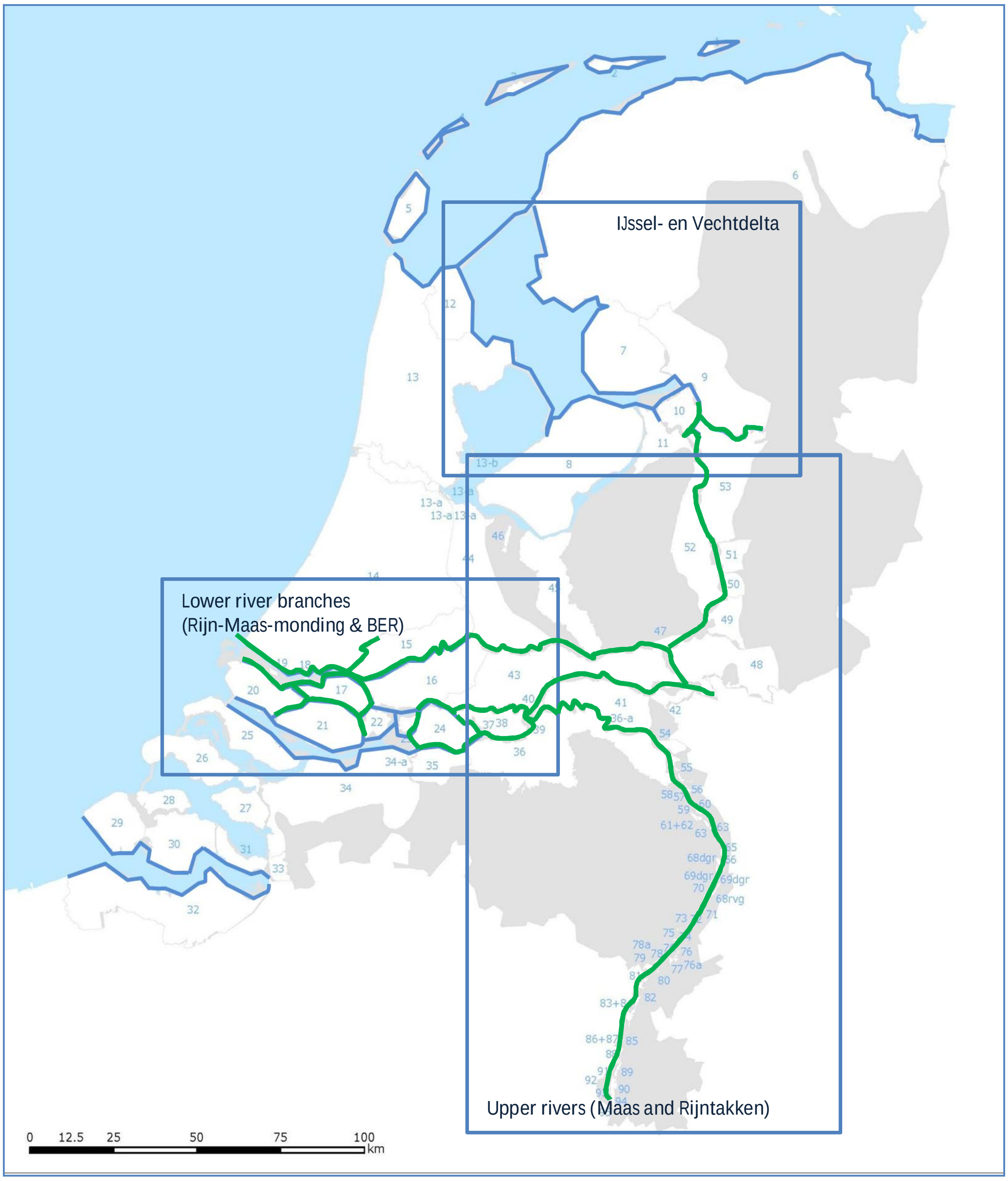


Figure 1.1 Water systems that require new WAQUA, SWAN or Bretschneider runs. The areas where Bretschneider calculations will be carried out are indicated in green.

Bretschneider wave conditions are needed for a combination of wind velocities, wind directions and water depths. One essential step in the Bretschneider calculation is to determine the fetches and bottom levels for every location and wind direction.

In the WTI-2017 project is was decided that Bretschneider wave conditions will be supplied for the assessment of water defences, in contrast to former practice that water managers could influence the wave conditions by adjusting fetches and water depths. A disadvantage of this WTI-2017 decision is that local knowledge and information is not used anymore in the determination of the fetches and water depths and this could lead to a too conservative or optimistic approach. However, the advantage is that the Bretschneider wave conditions will be determined in a consistent (with the rest of WTI-2017) and reproducible way. More information about this decision is reported in De Waal (2014). It should be noted that water managers are still able to influence the Bretschneider wave conditions 1) by using the foreshore (in Dutch: voorland) module and 2) in the advanced safety assessment (in Dutch: 'Toets op Maat').

1.3 Objectives

The aim of the present study is to provide a database of input that is needed for the empirical Bretschneider calculations at:

- Meuse (in Dutch: Maas; the name used in the remainder of the report)
- Rhine Branches (in Dutch: Rijntakken)
- the narrow parts of the Vecht-IJssel delta
- Mouth of the Rhine-Meuse (in Dutch: Rijn-Maas-monding, or simply RMM)

The database of Bretschneider results will be used for the HBC determination in the WTI-2017 project (see Deltares, 2016). This database will be made available as a *.kmz file, which can be loaded in an Earth browser such as Google Earth.

1.4 Assumptions

The most important assumptions that were used in this study are:

- The fetch is determined based on shape files from Baseline, consistent with SWAN and WAQUA.
- The WTI-2017 output locations are used as defined in Deltares (2014a).
- The fetch is determined based on the distance between output location and the crest height (in Dutch: buitenkruinlijn). Dry areas and obstacles are not taken into account in the fetch determination.
- The input for the Bretschneider calculations is stored in a *.kmz file, to make the Bretschneider calculations reproducible and to give water managers insight into the input that is used for the Bretschneider results and the eventual HBC.

1.5 Approach

Three steps can be defined in the approach:

1 *Gathering of geographical information and output points*
In order to determine the effective fetch and representative bottom height as input for the Bretschneider wave growth curve (step 2) the following information is required for all regions considered:
   – the rivercontour (line delimiting the area) of each region;
   – the output locations;
   – the bottom level.

2 *Determination of Bretschneider model input*
Based on the geographical data the direct fetch length, effective fetch length and mean bottom level are derived for each location and each wind direction.

3 *Determination of wave conditions to check the Bretschneider model input*
For each location the significant wave height and peak wave period are derived, given a combination of water depth, wind speed and wind direction, to be able to test the Bretschneider model input database. The results of the Bretschneider model input have been stored in '.mat' files that are organized by regions and location datasets and in a *.kmz file, which can be loaded in an Earth browser such as Google Earth.

The Bretschneider model input will be used for the Bretschneider production runs. The Bretschneider production runs are not described in this study, but will be described in a follow-up study/project, see Deltares (2016). The wave conditions of these production runs will be stored in a sql-database, combined with the water levels determined with WAQUA.

1.6 Contents of the report

The outline of the report is as follows: in chapter 2 the geographical information, that was used to determine hydraulic boundary conditions, has been reported. Subsequently, in chapter 3 it has been described how the input for the Bretschneider calculations was determined. Finally, in chapter 4 the Bretschneider calculations have been detailed and the various checks of the Bretschneider results have been illustrated with a few examples.

2 Geographical information and output locations

2.1 Introduction

To prepare the input required for the Bretschneider calculations, geographical information from different Baseline/WAQUA schematizations was used. The following information had to be extracted from the Baseline/WAQUA schematizations for each region:

- The river contour (line delimiting the river edges) of each region;
- The output locations, for which wave conditions need to be calculated;
- The bottom level of each region.

The river contour of each region (defined in Section 2.2.1) and the output locations were extracted from the different Baseline schematizations, which is described in Section 2.2. In Section 2.3 it is described how the file containing the bottom schematization of each area was extracted from the WAQUA schematizations of these regions.

2.2 Baseline

Baseline is a GIS database and application that can be used to make spatial model schematizations for the hydrodynamic models WAQUA, Delft3D and SOBEK. In Baseline, river data is stored in a structured way in geodatabase format ('.gdb').

For each area that was studied in this report, a Baseline schematization exists. The following Baseline schematizations were used:

- Maas: *maas-beno14_5-v2*, which includes:
  - the schematization of the Maas, updated for the 2014 situation;
  - plus all permits until 2014;
  - the Maaswerken;
  - the 'Stroomlijn-project' (with vegetation of 1997);
  - an update for Ooijen-Wanssum;
  - an update for the bottom level near weirs.

  A more detailed list of all updates that were included in this Baseline version can be found in AHA (2014).
- Rijntakken: *beno14_5-v2*, which includes:
  - the schematization of the Rijntakken, updated for the 2014 situation;
  - plus all permits until 2014;
  - all 'Ruimte voor de Rivier' (RvdR) projects;
  - the 'Stroomlijn-project' (with vegetation of 1997);
  - an update for RvdR project 'Uiterwaardvergraving Bolwerksplas, Worp en Ossenwaard';
  - an update with the roughness of the Ketelmeer and Vossemeer from the IJVD model.

  A more detailed list of all updates that were included in this Baseline version can be found in RHDHV (2014).
- Vecht-IJssel delta: *ijvd-hr2017_5-v1*, which includes:
  - the schematization of the Vecht-Ijssel delta, updated for the 2014 situation;

- plus all permits until 2014;
- all ‘Ruimte voor de Rivier’ (RvdR) projects;
- the ‘Stroomlijn-project’ (with vegetation of 1997).

A more detailed list of all updates that were included in this Baseline version can be found in Deltares (2014b).

- RMM: *beno14_5-v1*, which includes:
  - the schematization of the Rijnmaasmonding, updated for the 2014 situation;
  - plus all permits until 2014;
  - all ‘Ruimte voor de Rivier’ (RvdR) projects;
  - the ‘Stroomlijn-project’ (with vegetation of 1997).

  A more detailed list of all updates that were included in this Baseline version can be found in Deltares (2015a).

An overview of these schematizations is given in Figure 2.1. Note that Bretschneider calculations are only done for parts of the schematizations (see Figure 1.1) and that there is a strong overlap of locations belonging to the different schematizations. After the normative hydraulic loads are determined, a strict separation between the locations from different regions can be made, e.g. in Figure 2.1 all output locations in Lake IJssel are included in the Vecht-IJssel delta schematization (Lake IJssel acts as a water reservoir for Vecht-IJssel delta in the WAQUA computations), and there is a large overlap of Rijntakken and Maas on the one hand and the Vecht-IJssel delta and RMM on the other hand.

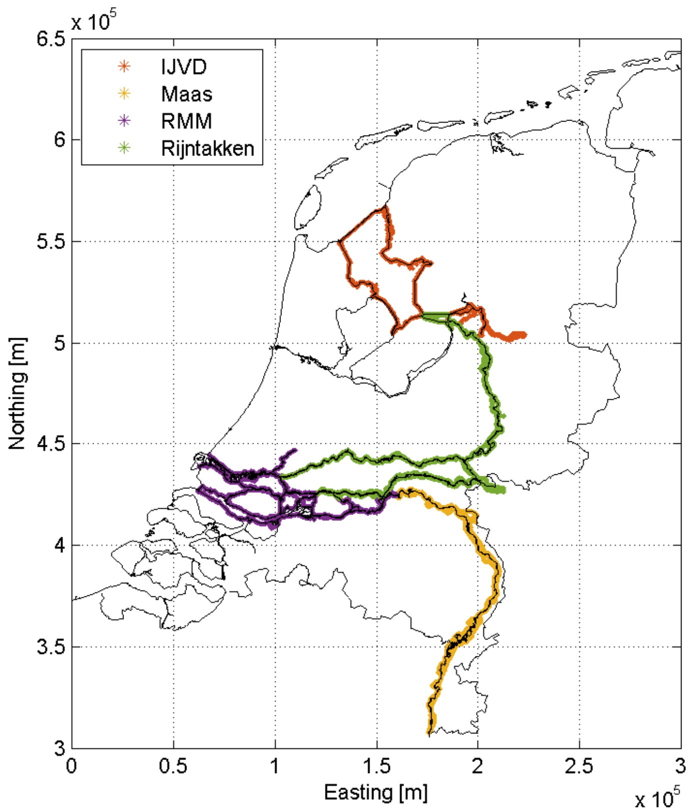


Figure 2.1 The four Baseline schematizations that are being considered for this study.

2.2.1 River contour

For the fetch calculations, the river contour of each region is needed. The contour that was used in this study is the contour following the crest height (in Dutch: buitenkruinlijn) of the primary water defence of a dike ring. As a starting point dry areas (in Dutch: hoogwatervrije gebieden) and obstacles were not taken into account in the fetch determination.

The contour of each region was extracted from the different Baseline schematizations and saved in a shape ('*.shp') format. The river contour will be used to calculate the fetch, as described in chapter 3. The following steps were followed for each of the 4 regions:

1. The layer of the contour line (in the layer 'Hoogtemodel': layer 'secties_terrain', which includes the contour of the crest height of the primary water defence) of one of the 4 regions was opened in ArcMap 9.3.1. Examples of the river contour lines are shown in Figure 2.2 for the Rijntakken, in Figure 2.3 for the RMM and in Figure 2.4 for the Maas.
2. Subsequently, the layer ('secties_terrein') was exported to a shapefile format (geospatial vector, '.shp') and called "Shape.shp" for each region, and saved correspondingly.

The shapefile format is read directly by the tools described in chapter 3.

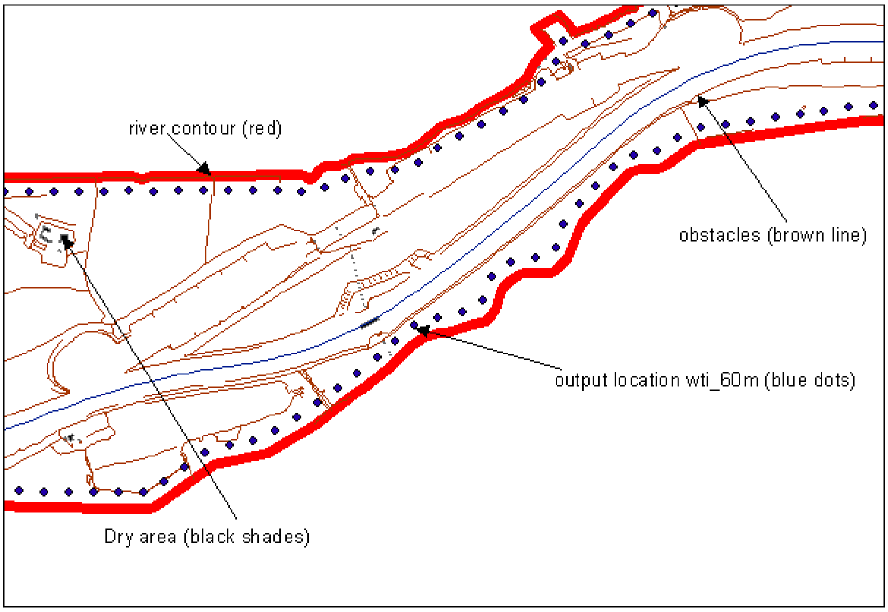


Figure 2.2 An example of the river contour of the Baseline Rijntakken schematization near Arnhem shown in ArcMap 9.3.1.

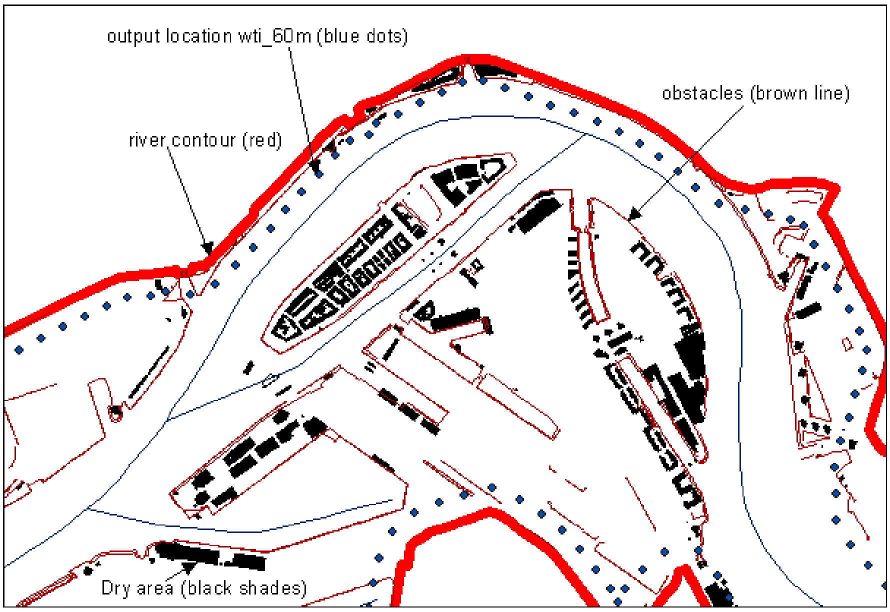


Figure 2.3 An example of the river contour of the Baseline RMM schematization of the Noordereiland of Rotterdam shown in ArcMap 9.3.1.

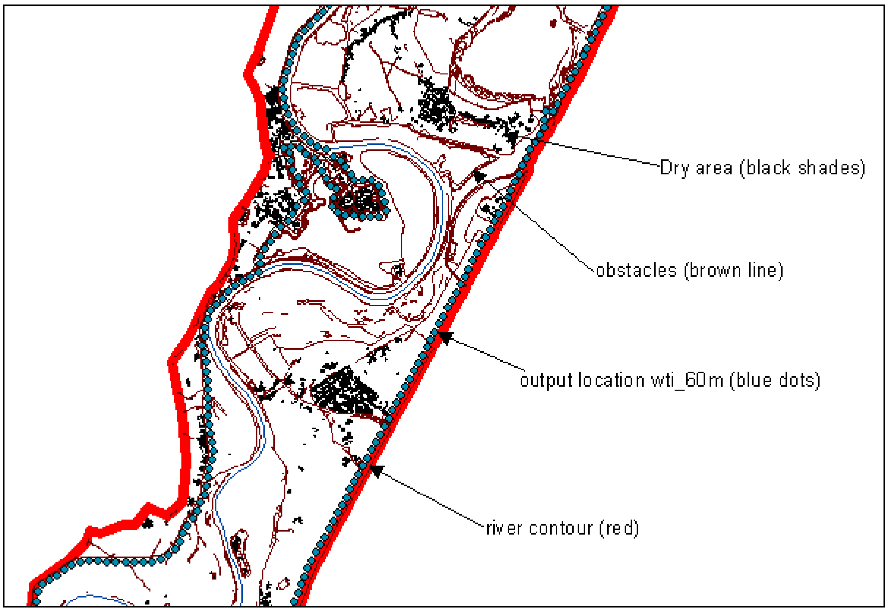


Figure 2.4 An example of the river contour of the Baseline Maas schematization near Roosteren shown in ArcMap 9.3.1.

2.2.2 Output locations

In each of the Baseline river schematizations sets of point files containing data of output locations are available. For each area the available location datasets are shown in Table 2.1. For all location datasets, Bretschneider calculations were made. It should be noted that a few locations (less than 1% of the locations) fall outside the river contour. Consequently, for these locations no calculations have been made. An example of the output locations for the Rijntakken is shown in Figure 2.5. It can be seen that the locations of the various location datasets are very close to each other, or identical.

Maas	Rijntakken	Vecht-IJssel delta	RMM
Meetpunten	Meetpunten	HRbackup_Rijn	HR50m_Maas_in_RMM
Uitvoerlocaties	Uitvoerlocaties	HRbasis_OV	HR50m_Rijn_in_RMM
Uitvoerlocaties_ori	Uitvoerlocaties_ori	HRbasis_Rijn	HR50m_RMM
Uitvoerlocaties_basis	WTI_60m	HRbasis_YM	HRbasis_Maas_in_RMM
WTI_60m	WTI_BU	HRbasis_ZW	HRbasis_Rijn_in_RMM
WTI_BU		HRextra_YMKM	HRbasis_RMM
WTI_HK		HRextra_ZW	HRextra_RMM
		Meetpunten	Meetpunten
		Uitvoerlocaties	Uitvoerlocaties
		Uitvoerlocaties_basis	Uitvoerlocaties_basis
		Uitvoerlocaties_hr2017	Uitvoerlocaties_hr2017

Table 2.1 River areas and their corresponding location datasets.

The output locations need to be converted from a layer format (the layer that includes all location datasets is called 'Meetpunten'[1]) to a matlab format to be able to use the output locations in the Bretschneider input and Bretschneider calculations. The following steps were followed for each of the 4 regions and each location dataset:

1 The layer 'Meetpunten' of one of the 4 regions was opened in ArcMap 9.3.1. The X and Y coordinates of each location were extracted and saved to an attributes table for each of the location datasets of the selected region (as shown in Table 2.1). This was done using the Data Management Tools from ArcMap 9.3.1 (in the "Data Management→Features" tab).
2 After saving the X and Y coordinates of each location to an attribute table, the layer was exported to a shapefile format (geospatial vector, '.shp') and subsequently saved to an excel format.
3 Finally, the excel file was read into Matlab and all available data was saved into a '.mat' file by region.

[1] *Note that the layer 'Meetpunten' in Baseline includes various sublayers (the location datasets), of which one is also called 'Meetpunten'.*

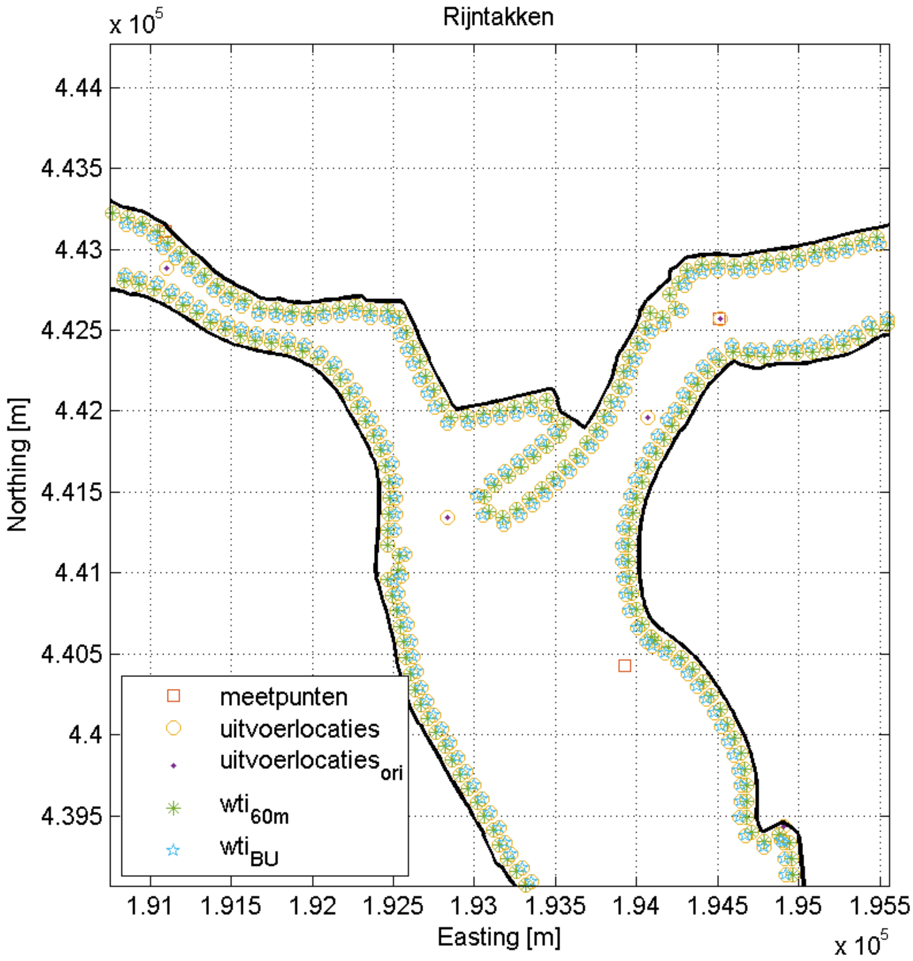


Figure 2.5 Output locations for a part of the Rijntakken region. Here the black line shows the river contour of the Rijntakken. The markers show the various output locations.

2.3 WAQUA

A WAQUA model conversion exists for every Baseline schematization of each region. In this conversion Baseline information like for example bottom level and obstacles is translated to a WAQUA input format, see for example Figure 2.6 and Figure 2.7. To determine the input for the Bretschneider production runs, use is made of the WAQUA bottom level. It should be noted that dry areas have not been taken into account in this conversion and therefore dry areas will be not present in the WAQUA bottom level. This means that the bottom level at the dry areas is either based on the surrounding bottom levels (this is the case for buildings), or it will be influenced by obstacle heights (in case of roads). The resolution of the bottom level varies with the WAQUA grid resolution. An example of the WAQUA bottom level for the Rijntakken schematization near Arnhem is shown in Figure 2.7.

The WAQUA bottom level information needs to be converted to an ASCII format (see Appendix B and chapter 3) for usage in one of the preprocessing tools for Bretschneider. Therefore, the WAQUA grid and bottom level information of each region was read into matlab using the ‘wlsettings’ toolbox. The ‘wlgrid’ matlab function was used to read the grid data, while the ‘boxfile’ matlab function was used to read the bathymetric data of the bottom files.

The bottom information was saved as '.xyz' files with an ASCII format. Each bottom file contains a X,Y,Z combination per line separated by a single space.

Figure 2.6 Example of the bathymetry of the Rijntakken schematization near Arnhem from in Baseline.

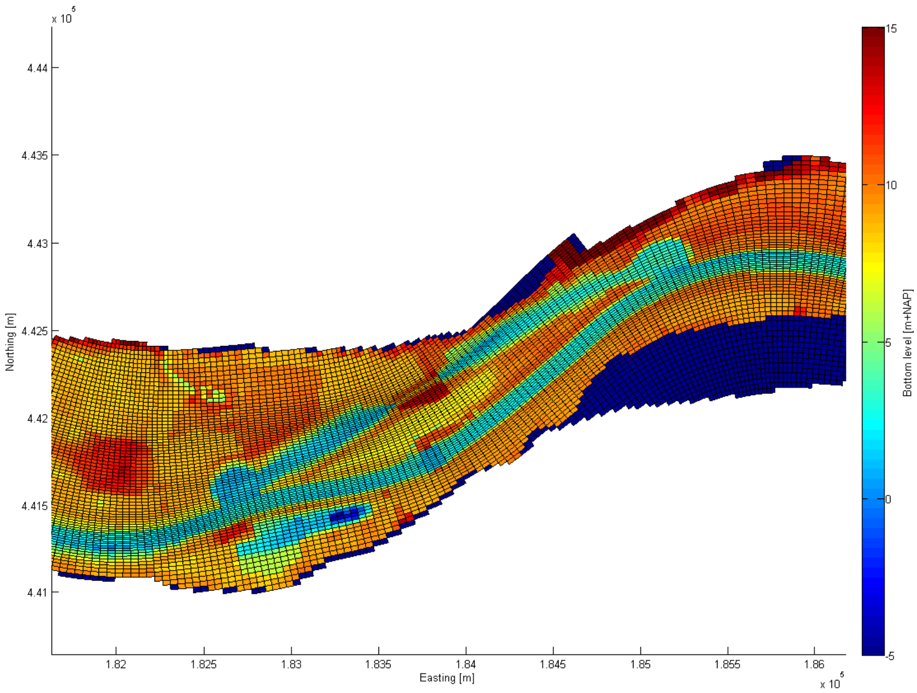


Figure 2.7 Example of the bathymetry of the Rijntakken schematization near Arnhem from the WAQUA model.

3 Bretschneider input variables

3.1 Introduction

To compute the significant wave height and peak wave period with the Bretschneider equations, various inputs are needed:

- Wind velocity at 10m height;
- Fetch
- Water depth.

In this chapter it is described how these input variables were determined to be used in the Bretschneider production runs.

3.2 Wind velocity

For every output location in the Bretschneider production runs a large range of wind velocities, varying from 0 m/s up to 40 m/s, was used in order to cover mild wind conditions up to very extreme storms. The value of 0 m/s was included as a quick way to confirm that the Bretschneider equations were providing correct results. The wind was varied in steps of 5 m/s.

As the random variable in Hydra-Ring is the potential wind speed U_p, the wind speed had to be transformed to open water wind speed U_{10} to be used in the Bretschneider equation. The transformation of U_p to U_{10} was done using the conversion table from De Waal (2003), shown in Table 3.1 for the selected wind velocity range. For the narrow parts of the Vecht-IJssel delta and the Mouth of the Rhine-Meuse, the potential wind of Schiphol was used. For the upper rivers Rhine and Meuse, the potential wind of Deelen was used. The transformation from potential wind speed to open water wind speed, as presented in Table 3.1, was used for all regions.

Table 3.1 Wind conversion table. Potential wind to U_{10}

U_p (m/s)	U_{10} (m/s)
0	0
5	5.61
10	11.14
15	16.44
20	21.62
25	26.69
30	31.67
35	36.56
40	41.39

3.3 Fetch

Fetch is the distance from an output location to the upwind river edge (the so-called direct fetch) and is one of the determining factors in the wave growth of wind waves. To determine the fetch for one output location and wind direction, information about the river edges (the intersection with the water defence) is needed. In this study the river contour line from Baseline has been used, as described in Section 2.2. An example of the fetch rays for different wind directions (every 22.5°) at an output location inside a river harbour is given in Figure 3.1.

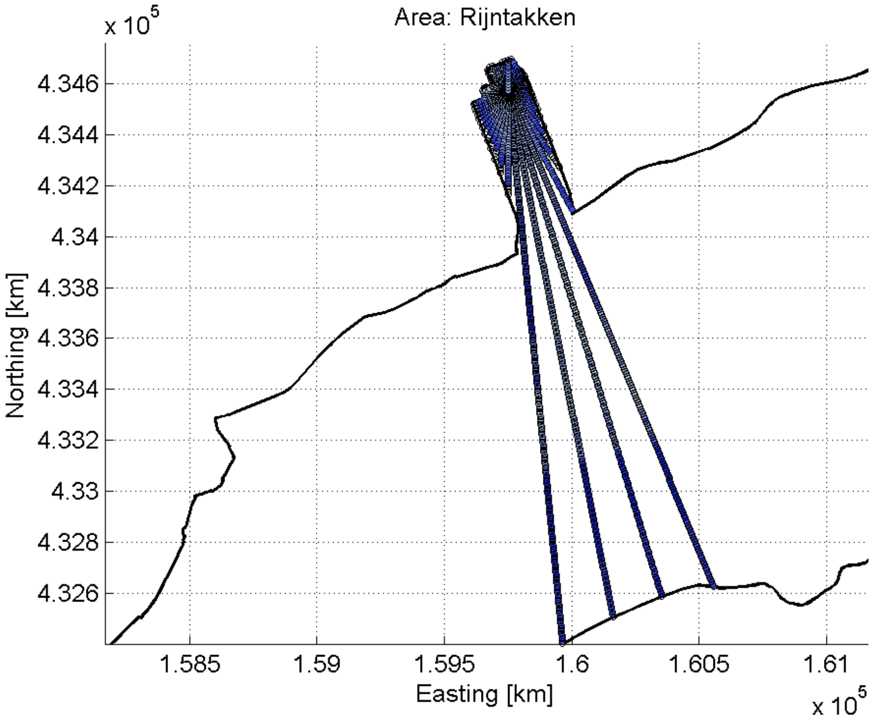


Figure 3.1 Example of the fetch rays for wind directions at a 22.5° interval for an output location inside a river harbour.

3.3.1 Effective fetch

In river systems often the effective fetch is used as input for the Bretschneider equations. The principle of effective fetch is based on the assumption that wind transfers energy to the water surface in the direction of the wind and in all directions within a certain directional sector on either side of the wind direction. For off-wind directions, the amount of energy transferred is modified by the cosine of the angle between the off-wind and wind directions. The effective fetch F_e, as described by TAW (1985) is defined as follows:

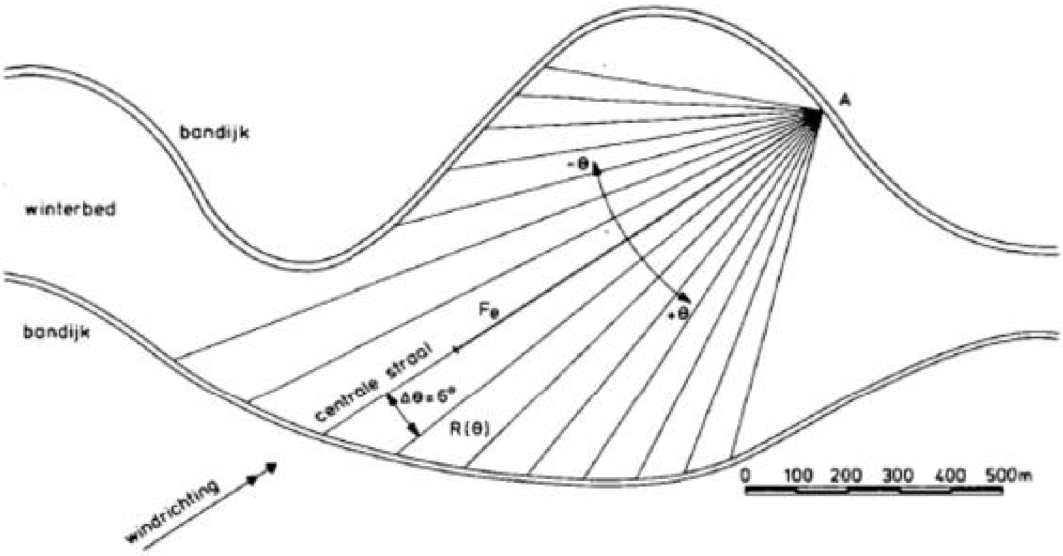
$$F_e = \frac{\sum R_i(\theta_i) \cdot \cos^2 \theta_i}{\sum \cos \theta_i}$$

Here θ is the angle between a certain fetch ray with a length R and the wind direction, see also Figure 3.2. How many fetch rays are considered, depends on the directional sector that is chosen (θ_{max}) and the directional step size ($\Delta\theta$). Table 3.2 shows the settings that were chosen to calculate the effective fetches that were input for the Bretschneider production runs. This means that for every output location 16 effective fetches are calculated. For every wind direction considered ten direct fetches are considered (1+ $\theta_{max}/\Delta\theta$).

Different to the direct fetch, the effective fetch does not end directly on the edge of the river. An example of the effective fetches, calculated for every 22.5°, is shown in Figure 3.3.

Table 3.2 Selected settings to calculate the effective fetches for the Bretschneider computations.

Variable	Value
Directional step size $\Delta\theta$	5.625^{o}
Maximum angle θ_{max}	47.8125^{o}
Directional step size wind direction	22.5^{o}



θ in degrees	cosθ	$\cos^2\theta$	R(θ) in meters	$R(\theta).\cos^2\theta$
- 42	0,743	0,552	520	287
- 36	0,809	0,654	570	373
- 30	0,866	0,750	640	480
- 24	0,914	0,835	720	601
- 18	0,951	0,904	830	750
- 12	0,978	0,956	1340	1281
- 6	0,995	0,990	1240	1228
0	1,000	1,000	1140	1140
6	0,995	0,990	1050	1040
12	0,978	0,956	980	937
18	0,951	0,904	920	832
24	0,914	0,835	880	735
30	0,866	0,750	830	623
36	0,809	0,654	780	510
42	0,743	0,552	730	403

$\Sigma \cos\theta = 13{,}512$ $\quad \Sigma R\theta.\cos^2\theta = 11220$

The effective fetch F_e is calculated as follows:

$$F_e = \frac{11220}{13{,}512} = 830 \text{ m}$$

Figure 3.2 Effective fetch background information and an example of an effective fetch calculation.

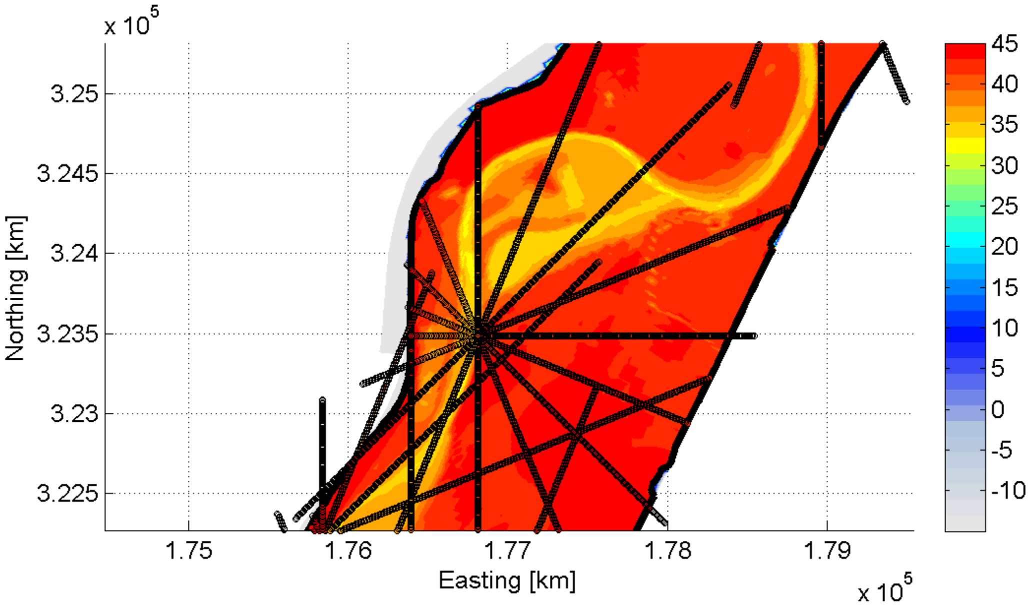


Figure 3.3 Example of effective fetch plotted with the local bathymetry, in rays of 22.5 degrees.

3.3.2 Fetch calculation tools

Two different tools were available to determine the effective fetch in the different regions (Maas, Rijntakken, Vecht-IJssel delta and RMM). These are:

- Original-fetch-tool (described in appendix A);
- ShapeLib-fetch-tool (described in appendix B).

With both tools the effective fetch can be calculated using:

- The X- and Y-coordinates of the output locations;
- And the river contours.

This input was determined from the Baseline schematizations of the different areas, as has been discussed in chapter 2. A description of how the tools calculate the effective fetch can be found in Appendix A and B.

The ShapeLib-fetch-tool provides besides the effective fetch also the representative bottom level for every effective fetch ray and information about the direct fetches that were used to calculate the effective fetch. Therefore, the ShapeLib-fetch-tool was used to determine the effective fetch for the Bretschneider calculations. The Original-fetch-tool was only used as a double check for the ShapeLib-fetch-tool results. No differences were found between the effective fetches determined with the Original-fetch-tool and the ShapeLib-fetch-tool.

3.3.3 Checks of the calculated fetch lengths

In the previous section it was explained that the effective fetches that were calculated with the ShapeLib-fetch-tool were checked with the Original-fetch-tool. No differences between the two tools were observed.

Additionally, the fetch results were checked by plotting the direct fetch rays for a large number of output locations in all four regions and confirming that each ray ends directly at the edge of the contour file that is loaded, see for example Figure 3.1. This validates that the fetch length calculated with the ShapeLib-fetch-tool is correct.

3.4 Water depth

One single water depth is needed to calculate the wave conditions along one ray with the Bretschneider equations. This water depth is calculated using bottom level information along the fetch ray and adding a water level. In the Section 3.4.1 it is explained how one representative bottom level was extracted from an effective fetch ray with a varying bottom profile. For the production runs water levels determined with WAQUA will be used to calculate the local water depths, in combination with the determined representative bottom levels used for the Bretschneider production calculations. As these water levels were not yet available during this study, in Section 3.4.2 it is explained how the representative bottom levels were combined with different water levels to provide water depth input for the Bretschneider test calculations in this report.

3.4.1 Bottom level data processing

To calculate the representative bottom level of the different effective fetch rays of every output location, the ShapeLib-fetch-tool is used (see Appendix B for a description of the tool). As described in Section 3.3.2, the ShapeLib-fetch-tool needs the X- and Y-coordinates of the output locations and the river edge contours to calculate the effective fetch and the direct fetches. In addition, the ShapeLib-fetch-tool needs bathymetry information to determine the representative bottom level. This bathymetry information was extracted from the different WAQUA model bathymetries in the different areas, see Section 2.3 for more details.

After calculating the direct fetch rays for every wind direction at each output location, the ShapeLib-fetch-tool interpolates the WAQUA bottom level to the direct fetch rays with 1 m steps along the fetch ray. Subsequently, the representative bottom level is calculated by taking the average of all bottom levels determined along the direct fetch rays.

A small percentage of locations presented errors and these were saved in order to be identified later. It was found that the errors with the ShapeLib-Fetch-tool occur when the output location is located outside the contour of the river edges. These locations, where this occurs, were excluded from the results.

The ShapeLib-fetch-tool only calculates one representative bottom level per wind direction for each output location. To be able to further analyse and check the calculated representative bottom levels, the bottom level profiles along the direct fetch rays were determined by interpolating the WAQUA bathymetry to the different direct fetch rays. The X- and Y-coordinates of the different direct fetch rays were found using the ShapeLib-fetch-tool.

3.4.2 Conversion bottom levels to water depths

The representative bottom levels were combined with water level information to provide representative water depths for the Bretschneider test calculations of this report. For every output location a selection of water levels was considered. The lowest water level was defined as the lowest minimum bottom level over all 16 fetch directions for one X, Y-coordinate pair rounded down to the nearest half integer. The highest water level was determined by the Load level obtained in the reference runs with Hydra-Zoet (Deltares, 2014c) for a return period of 1,250 years and the failure mechanism wave overtopping. On top of the Load level an extra 2 meters was added to make sure all depths are covered by the Bretschneider computations. The water level was varied in steps of 0.5 m between the lowest and the highest.

In order to combine the results from the reference runs and the ShapeLib-fetch-runs all x,y locations were compared and the results were merged, hence, all x,y coordinates from the ShapeLib-fetch-runs at the output locations (defined in Table 2.1) were supplemented by adding the corresponding Load level, for the locations that did not have an exact match in coordinates the Load level of the closest location was assigned.

4 Bretschneider test calculations

4.1 Introduction

Bretschneider test calculations were carried out for the four regions Maas, Rijn, Vecht en IJssel delta and RMM. In this chapter first a short description is given of the empirical wave growth model in Section 4.2. Subsequently, the input combinations of the Bretschneider test calculations have been described in Section 4.3. The checks that were performed on the test calculations have been presented in Section 4.4, followed by a description of how the results were stored in Section 4.5.

4.2 The empirical wave growth model

4.2.1 Bretschneider equations

The Bretschneider equations for significant wave height and significant wave period are shown below.

$$\bar{H} = 0.283 \tanh\left(0.530\bar{d}^{0.75}\right) \tanh\left[\!\left[\frac{0.0125\bar{F}^{0.42}}{\tanh\left(0.53\bar{d}^{0.75}\right)}\right]\!\right]$$

$$\bar{T} = 2.4\pi \tanh\left(0.833\bar{d}^{0.375}\right) \tanh\left[\!\left[\frac{0.077\bar{F}^{0.25}}{\tanh\left(0.833\bar{d}^{0.375}\right)}\right]\!\right]$$

$$\bar{d} = \frac{dg}{u^2}, \bar{F} = \frac{Fg}{u^2}$$

$$\bar{H} = \frac{H_s g}{u^2}, \bar{T} = \frac{T_s\, g}{u}$$

Where:

g = gravity acceleration [m/s^2]
u = wind speed at 10m height [m/s]
d = water depth [m]
F = fetch length [m]
H_s = Significant wave height [m]
T_s = Significant wave period [s]

The T_s value that is used in the equation for the wave period corresponds to the significant wave period and is transformed to T_p (peak wave period) by multiplying by a 1.08 factor.

4.2.2 Wave growth for different input values

The Bretschneider equations consist of three input variables: depth, fetch and wind speed. A sensitivity run was completed in order to understand the impact of each input variable. Figure 4.1 shows the results. It can be observed that in case the water depth is large enough, the wind speed is the most relevant input variable in relation to the wave growth. Of course it is important to keep in mind that if the depth is limited, then the wave growth is also strongly related to the water depth. As expected, the wave growth induced by the wind forcing is also larger when the fetch length increases.

As expected when the water depth is equal or lower (in the situation that the bottom level exceeds the considered water level, both with respect to the reference level NAP) than 0 m the wave height is equal to 0 m, same holds when the wind speed is equal to 0 m/s.

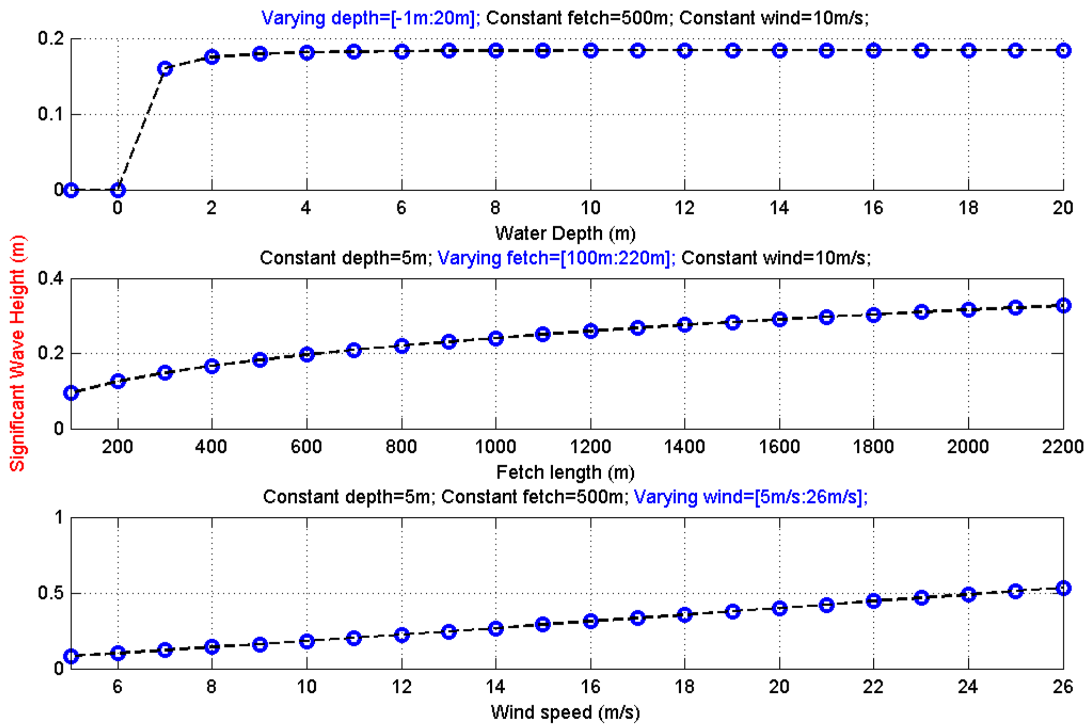


Figure 4.1 Schematization of results obtained with Bretschneider when varying each input variable separately.

4.3 Input combinations of test calculations

The test calculations were done for various input values, as described in Chapter 3. Table 4.1 summarizes the input values that are used at every output location. It depends on the representative bottom level of an output location and the wind direction, for how many water depths the wave growth is calculated (see also Section 3.4). Per output location 16 different fetches (the effective fetch, see Section 3.3) are used in the Bretschneider calculation. The values of the fetches are depending on the wind direction.

Wind speed [m/s]	Wind direction [^oN]	Water depth [m]	Fetch [m]
0	0	Lowest water level – bottom level	Depending on location
5.61	22.5	Steps of 0.5 m	
11.14	45	Hydraulic load + 2m	
16.44	67.5		
21.62	90		
26.69	112.5		
31.67	135		
36.56	157.5		
41.39	180		
	202.5		
	225		
	247.5		
	270		
	292.5		
	315		
	337.5		
	360		

Table 4.1 Input for the Bretschneider test runs. The wind speed is the open water wind at 10 m height.

4.4 Checks on results

Reality checks (H_s, T_p and wave steepness for various input values) were done for a number of locations. These checks are described in Section 4.4.1. Furthermore, it has been described in Section 4.4.2 how missing results were handled.

4.4.1 Reality checks

In order to check in a comprehensive and effective way the results per location the significant wave height and wave peak period were plotted, as a relation of wind speed, water depth and wind direction, has been illustrated in Figure 4.2 for a Rijn location.

The y-axis represents the significant wave height, x-axis the varying water depth for which Bretschneider computations were carried out, and finally the colour of the dots represent the wind speed. Figure 4.2 contains 16 sub-plots; each of these corresponds to a different fetch direction with its corresponding fetch length.

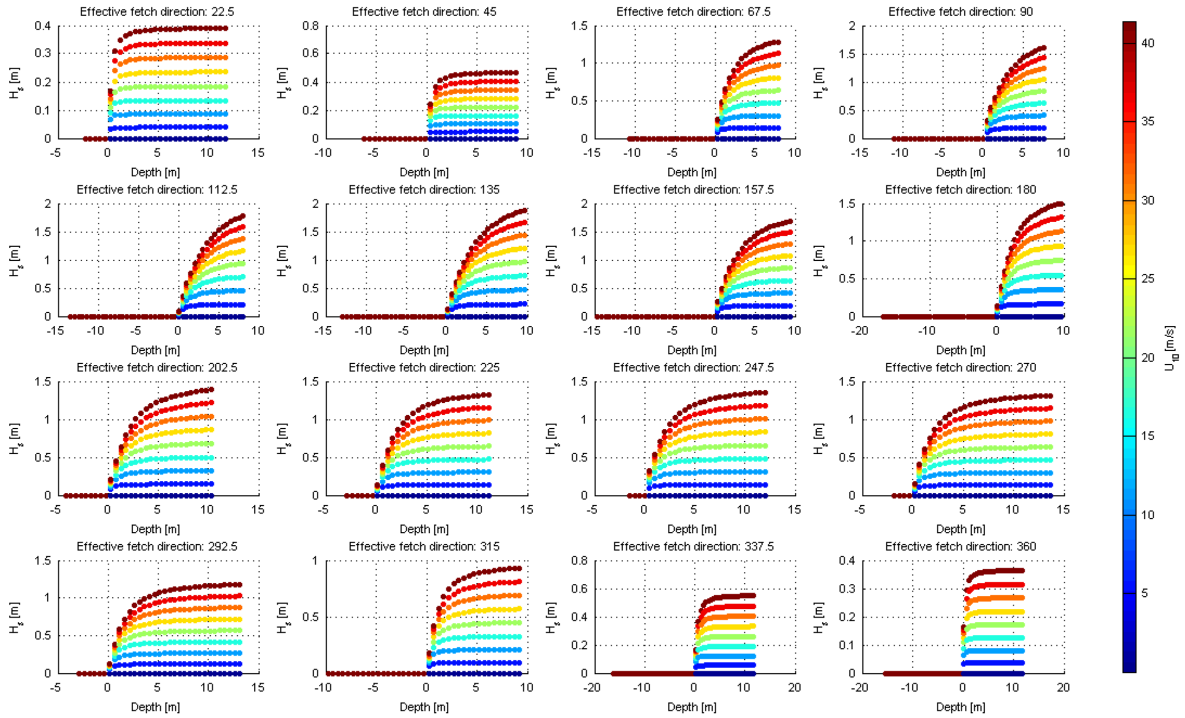


Figure 4.2 Rijn: Significant wave height variation with respect to water depth and wind speed.

It can be observed in Figure 4.2 that when the water depth is equal or smaller than zero there is no wave growth. Moreover, the same finding holds for the cases where the wind speed is equal to zero. As expected for higher winds, higher waves are found, it can also be concluded that the water depth has a much larger influence on the wave height when winds are stronger and the limitation of wave growth becomes the water depth. On the other hand when winds are mild, in the order of 5-10 m/s, there is hardly any effect by the water depth.

Figure 4.3, represents results in the same manner as Figure 4.2, the only difference is that for this case the significant wave height is replaced by the peak wave period. In general the significant wave height and the peak wave period follow very similar trends.

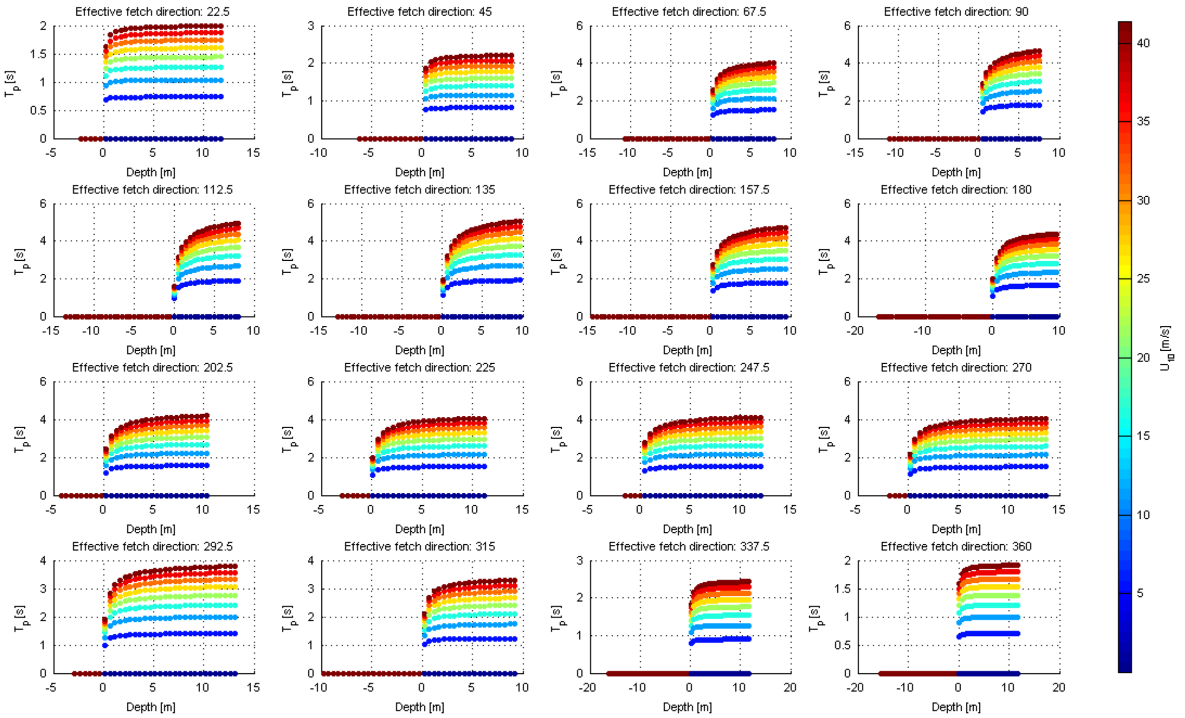


Figure 4.3 Rijn: Peak wave period variation with respect to water depth and wind speed.

Also the behaviour of the relative wave steepness has been checked, as illustrated in Figure 4.4. Once again, each subplot represents one specific fetch length and direction, x-axis the water depth, and in this case the y-axis represents the relative wave steepness. The relative wave steepness was calculated as follows.

$$Relative\ wave\ steepness = \frac{Hs}{1.56\,Tp^2}$$

It can be seen that maximum relative wave steepness is in the order of 0.065. In the example location shown in Figure 4.4 the largest values for relative wave steepness correspond to the locations with the milder wave conditions, thus, the relative value is easily influenced by small absolute variations.

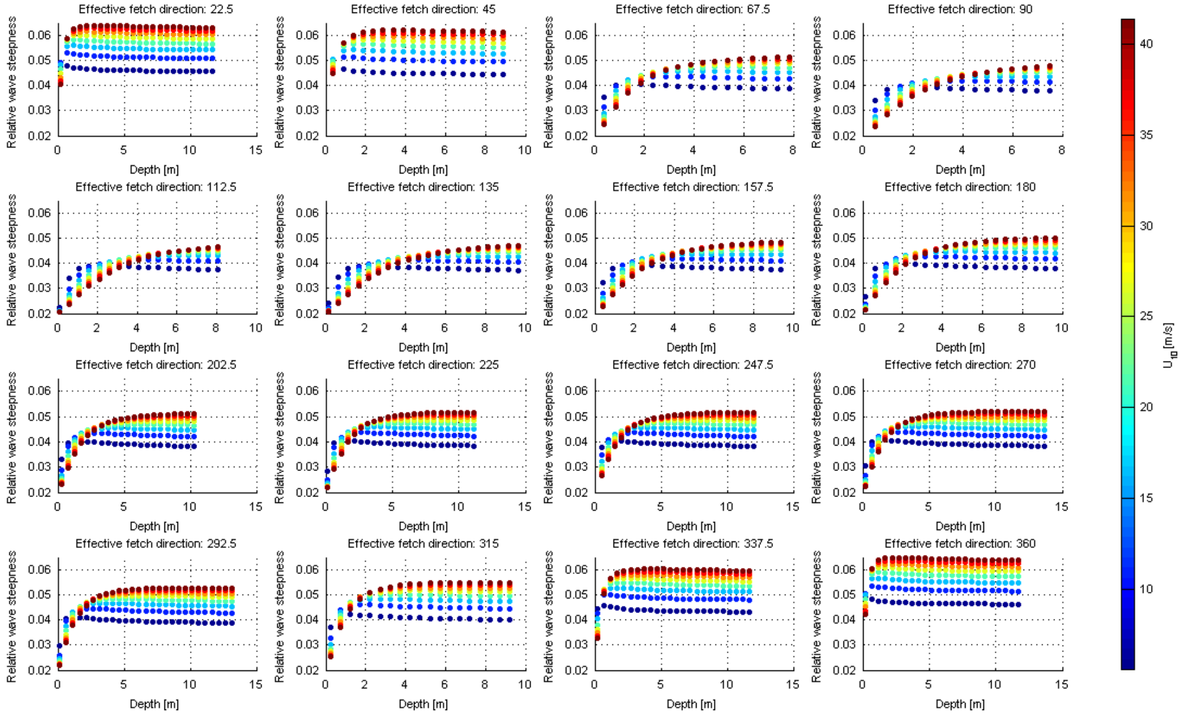


Figure 4.4 Rijn: Relative wave steepness variation with respect to water depth and wind speed.

The figures shown above represent the results for one location in the Rijntakken region. The same checks were performed for multiple locations (>600 locations) in all river areas in order to check that results were consistent and that similar trends occur. In all output figures the ranges for which wave heights and wave periods were calculated appear to be realistic and within a possible range given the depths and the fetches of the different river areas as seen in Figure 4.2 to Figure 4.4.

Regarding the bottom height schematization from the ShapeLib-fetch-tool it is also visible from the plots that the values that were calculated are within realistic limits, meaning that no cases with extremely large bottom heights were found.

In most cases wave steepness is within a range of 0.02 (at very shallow depths) to 0.06, which can also be considered as a realistic range. Showing that the calculated wave periods and wave heights, have a good correlation.

4.4.2 Missing results

The very limited amount of results from the ShapeLib-fetch-tool that had errors were excluded, and not considered for the Bretschneider computations.

The errors that were encountered when using the ShapLib-fetch-tool were related to points that lay outside of the contour of the river, or at locations that were in the edges and therefore no bathymetry data was available from the WAQUA models.

From the RMM river area in the “HR50m Maas in RMM” file, 12 locations were excluded. Also in RMM, from the “HR50m Rijn in RMM” 20 locations were taken out. From the “H50m RMM” location file 3 locations were not considered. Lastly for the “HRbasis Mass in RMM” file 12 locations were excluded.

For the rest of the river areas no errors were found and therefore all locations were included in the computations. As mentioned before the number of locations containing errors is considerably less than 1%. Therefore it does not influence the final results of this study.

4.5 Storage of results

4.5.1 Matlab structure

All output was saved in separate MATLAB files per river area. For each combination of location (x,y), wind speed, water depth and wind direction the following output is saved.

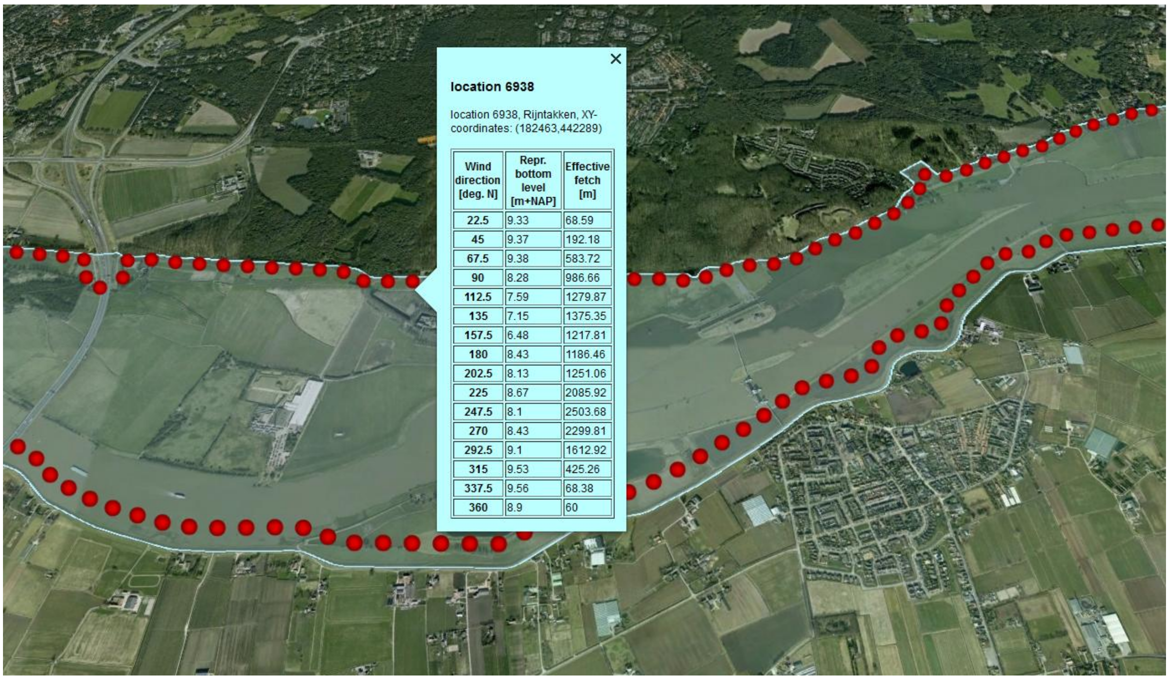
Output variables
Location ID
X coordinate
Y coordinate
Wind direction
Fetch length
Average bottom level obtained with the ShapeLib-fetch-tool
U_p
U_{10}

Table 4.2 Output variables stored for each location

4.5.2 Kmz file

The output variables Wind direction, Fetch length and Average bottom level of Table 4.2 have been stored in a *.kmz file, which can be loaded in an Earth browser such as Google Earth. An example of the *.kmz file for one location in the Rijntakken schematization is shown in Figure 4.5. The river contour that was used in the determination of the Bretschneider input is shown as a polygon (light blue).

Within Google Earth the bottom profile over one fetch ray can be presented. A step by step description how to do this is given in Appendix C. An example of the bottom profile for one location is shown in Figure 4.6.



Wind direction [deg. N]	Repr. bottom level [m+NAP]	Effective fetch [m]
22.5	9.33	68.59
45	9.37	192.18
67.5	9.38	583.72
90	8.28	986.66
112.5	7.59	1279.87
135	7.15	1375.35
157.5	6.48	1217.81
180	8.43	1186.46
202.5	8.13	1251.06
225	8.67	2085.92
247.5	8.1	2503.68
270	8.43	2299.81
292.5	9.1	1612.92
315	9.53	425.26
337.5	9.56	68.38
360	8.9	60

Figure 4.5 Example of the Bretschneider input representative bottom level and effective fetch, for different wind directions at one location near Arnhem (region Rijntakken). The river contour that was shown in the determination of the Bretschneider input is shown as a polygon (light blue).

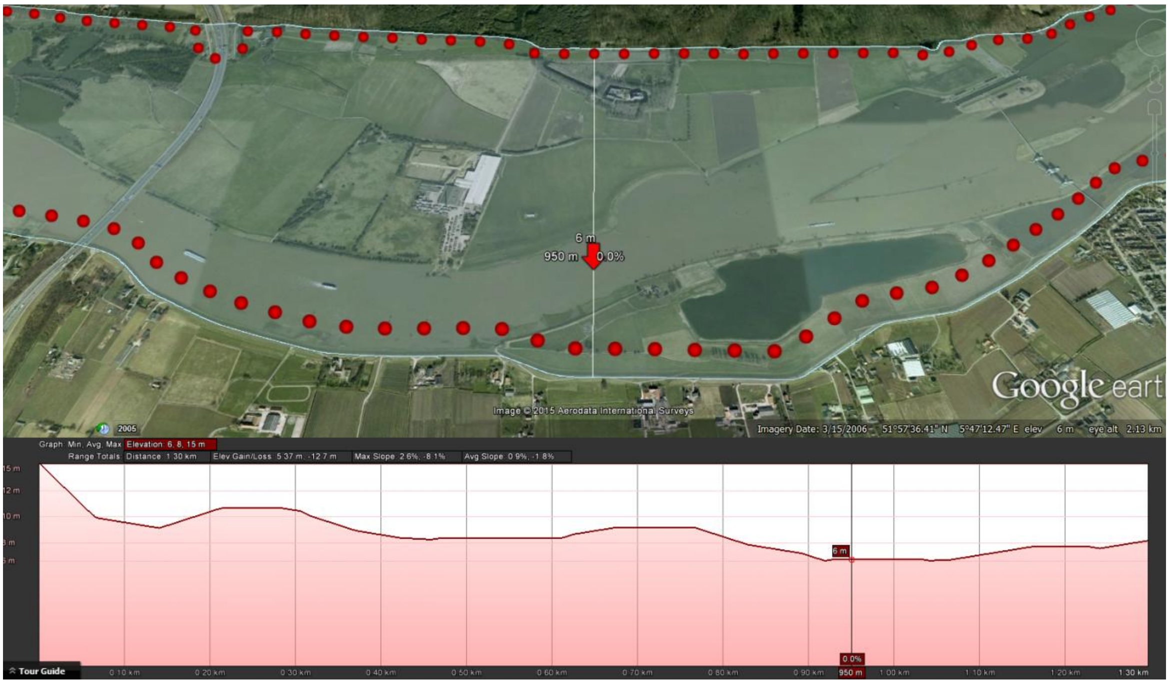


Figure 4.6 Example of the Google Earth bottom level representation over a fetch ray for a wind direction of 180 ^{o}N.

4.5.3 WTI-2017 production runs

The output stored in the MATLAB files will be used to determine for each location the significant wave height and wave peak period for many combinations of wind speed, wind direction and water level for WTI-2017. These local water levels are determined by WAQUA. The storage of local water levels and wave conditions into databases, which are input to Hydra-Ring, is not reported here, but will be reported in Deltares (2016).

5 Recommendations for future assessment rounds

For WTI-2017 choices have been made regarding the determination of the effective fetch and the representative bottom level. In this approach obstacles and dry areas were neglected and no use was made of local geometric knowledge, which is in line with WTI-2011. It should be noted that water managers are still able to influence the Bretschneider wave conditions 1) by using the foreshore (in Dutch: voorland) module and 2) in the advanced safety assessment (‘Toets op Maat’).

In future assessment rounds the WTI-2017 approach for the determination of the effective fetch and the representative bottom level should be reconsidered, as it could lead to too conservative or optimistic results. As no dry areas and obstacles were taken into account in the determination of the fetch length, fetch lengths may be overestimated, which could lead to an overestimation of the wave conditions. An example is shown of a situation in Rotterdam, where wave growth is limited due to the Noordereiland, see Figure 5.1.

Additionally, for the estimation of the representative water depth, neglecting dry areas and taking into account the whole fetch length when the bottom level highly varies could either lead to too conservative wave conditions or to too optimistic wave conditions. However, it should be noted that during normative conditions, high water levels in the rivers are expected. Therefore, the representative water depths will be most likely high and this means that the wave conditions will not be depth dominated. For this reason, it is expected that the effect of a method, which takes into account more details, will be limited. This has also been concluded by HKV (2010).

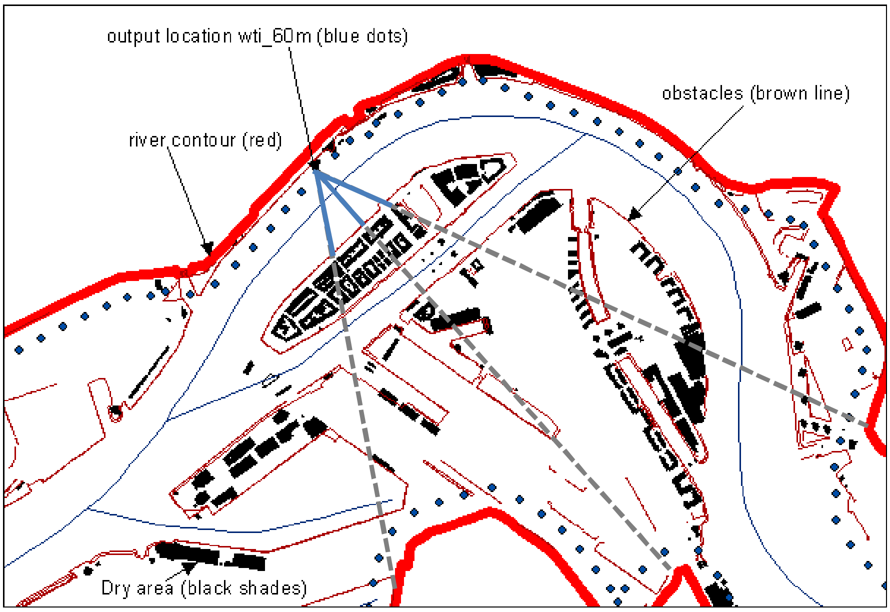


Figure 5.1 Example of the Noordereiland in Rotterdam. Wave growth is limited due to the dry areas of the island. Three fetches are shown, in gray the fetch with the current method is shown, in blue if dry areas are taken into account.

Nonetheless, future studies are recommended to investigate the possibilities to take into account dry areas and obstacles in a consistent way.

6 References

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TAW (1985). Leidraad voor het ontwerpen van rivierdijken. Deel 1 – Bovenrivierengebied. September 1985.

A Original-fetch-tool

In order to determine the effective fetch for each output location the Original-Fetch-tool can be used. This is a tool developed by HKV for Rijkswaterstaat (RIZA), see HKV (2002). In this appendix a short description of the tool is given and it has been described how it was used for the production runs.

A.1 Input

The following input is needed to use the fetch tool:

- Shape file of river contour (see Section 2.2.1);
- Output locations in X- and Y-coordinates (see Section 2.2.2);
- Number of directions for which the fetch has to be calculated.

The Original-fetch-tool determines the maximum angle θ_{max} and the directional step size $\Delta\theta$ (as specified in Section 3.3.1) based on the number of directions for which the fetch has to be calculated. The effective fetch for every direction is based on 17 direct fetch lengths. For the production runs 16 directions were used and this means that the settings as presented in Table 3.2 were used.

The input files for the Original-fetch-tool were created with Matlab. These input files contain in the first line the name of the shape file of the river contour. In the second line the number of directions for which the fetch has to be calculated is specified, and lastly the set of X,Y coordinates of each output location. An example of the input file is shown in Figure A.1.

```
.\Shape.shp
16
204360.0000;429320.0000
200010.0000;431530.0000
186930.0000;429440.0000
171747.0000;434694.0000
159750.0000;434575.0000
145140.0000;425160.0000
129440.0000;426000.0000
120503.0000;425535.0000
194525.0000;438466.0000
193930.0000;440430.0000
191090.0000;443108.0000
184060.0000;441980.0000
183570.0000;441700.0000
168929.0000;440123.0000
```

Figure A.1 Example input file for Original Fetch tool.

A.2 Effective fetch calculation

The Original-fetch-tool calculates the fetch with the effective fetch formula given in Section 3.3.1. The fetch length of every fetch ray (R) is determined by the length between the output location and the location where the fetch ray (for a certain wind directions) intersects the river contour.

To run the Orignal-fetch-tool for all output locations of all regions, a batch file was made. This batch file calls the executable of the fetch tool, reads the appropriate input and saves the output into a corresponding '.out' file for each output location.

A.3 Output

The following output is created using the fetch tool for every output location and wind direction:

- Effective fetch length in meters;
- X- and Y coordinates of the intersection location with the river contour (Xs,Ys);
- The distance from the output location (X,Y) to the intersection with the river contour (Xs,Ys).

This output has been processed into histograms of the fetch lengths to identify outliers and unrealistically long fetches. Histograms for all location datasets of every region were created. An example of these histograms is shown in Figure A.2.

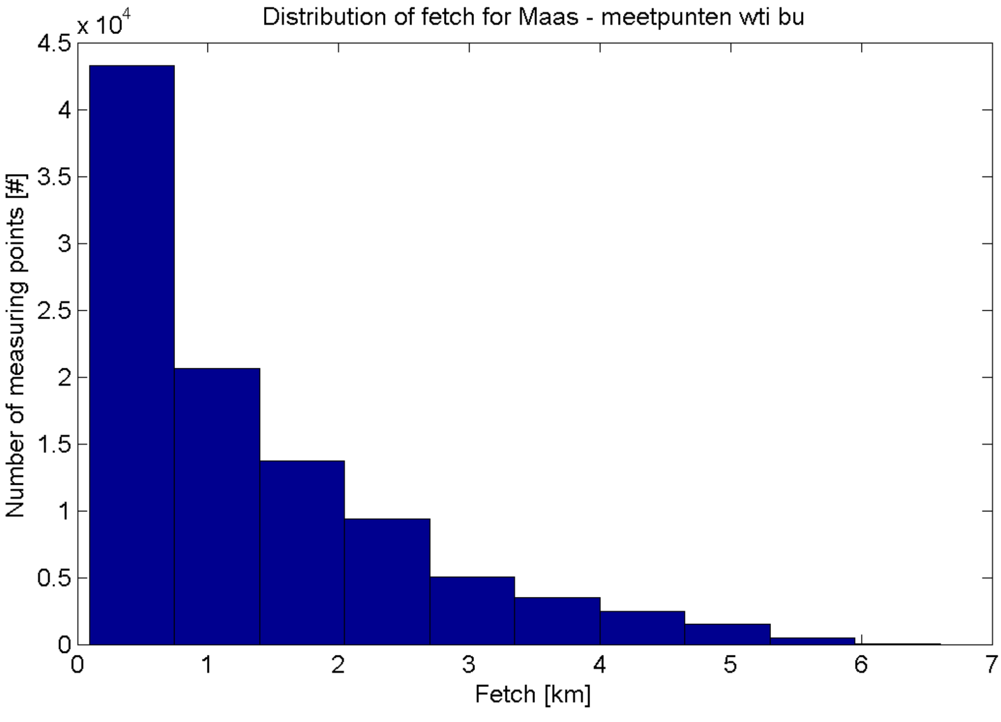


Figure A.2 Distribution of effective fetch lengths at the Maas river area at the location dataset 'meetpunten wti bu'.

B ShapeLib-fetch-tool

In order to determine the effective fetch for each output location the Shape Lib fetch tool can be used. This is a tool developed by Deltares and was developed as part of the Deltamodel-Waterveiligheid (see Deltares, 2012[2]). The ShapeLib-fetch-tool is largely based on the Original-fetch-tool and a tool to determine the representative bottom level available in Hydra. In this appendix a short description of the tool is given and it has been described how it was used for the production runs.

B.1 Input

The following input is needed to use the fetch tool:

- Shape file of river contour (see Section 2.2.1);
- Output locations in X- and Y-coordinates (see Section 2.2.2). For each region and locations dataset an locations file was prepared, containing the X- and Y- coordinates of every output location, see Figure B.1;
- Settings (the most important settings have been specified in Section 3.3.1, Table 3.2)
- Bottom level information in *.txt format (see Section 2.3)

```
# locations by x,y
177123.6564,309539.2135
177027.4521,309569.2501
176972.4227,309655.1261
176985.7917,309756.1435
177027.3074,309848.3041
177061.9481,309942.9754
177112.6552,310027.2465
177142.4281,310120.4376
177164.8211,310215.8880
177176.1955,310315.7468
177196.5659,310411.6704
177200.2460,310513.7044
177287.1208,310572.6874
177389.2837,310553.8079
177482.4478,310518.5804
```

Figure B.1 Example locations file for ShapeLib runs.

All the input mentioned above was specified in an input file. An example is shown in Figure B.2.

[2] *An updated version of the ShapeLib tool was made January 2016 However, this version was not used for this report.*

```
# Input file for program HdW
# Give the shape file containing one or more dike rings
# Use file name including .SHP extension.
shape_file = .\data\poly_Shape.shp
ring = ALL POLYGONS

# The bottom level in the study area can be given either by an ascii file or a shape file.
#
# An ascii file can be an ordinary text file or a .csv file.
# For ascii and .csv file, the first line should be a comment line and
# for a .csv file the separator must be a comma.
# Ascii and .csv files contain x, y, z values
# NOTE that the program expects pos/neg values for the bottom level!!!!
# So you must give the current sign of the bottom value

bottom_file = .\data\bottom_XYZ.txt
z_column = DEPTH

# Locations in the water (output locations) has to be given in a file.
# The first line on the file should be a comment line.
# All next lines should contain a x, y co-ordinate.
# The file may be an ascii file or a .csv file. In case of a .csv file the separator
# must be a comma.

locations_file = .\meetpunten_HRextra_YMKM.txt

# For the calculations view directions and wind directions are needed.
# View directions are given as an angle delta_phi and delta_pi must be a multiple of 360 degrees.
# So you get a set of view directions from 0 till 360 degrees.
# Wind directions must be given as a multiple of the angle delta_phi. It is delta_alpha
# Wind directions are also from 0 till 360 degrees.
#
# In the program angles for wind directions are according the wind, so 0 degree is North.
# Both delta_phi in [degrees]

delta_phi_view = 5.625

delta_phi_wind = 22.5

# Give a delta X along the effective fetch. The bottom level of the effective fetch will be
# calculated for each step delta X. Delta x in [m]

delta_x = 60.0

# Give a buffer size around a fetch, which will be used during interpolations of the bottom levels.
# This buffer size has a relation to the positions of the bottom points (e.g. a grid, unstructured)
# dxBuffer in [m]

dxBuffer = 210.0

# 2 * Maximum angle is a sector around the wind direction(s) while calculating the effective fetch
# Value for max-angle (n+0.5) * delta_phi

max_angle = 47.8125

# Value of the power (exponent) in the weight function for calculating average of fetches in
# view directions.

exponent = 1.0

result_file = .\out\meetpunten_HRextra_YMKM.csv

# Intermediate results (ascii) of all locations, all view angles and the fetches.
# If the keyword is omitted or the file name is blank, then no intermedeiate file.

vieuw_results = .\out\meetpunten_HRextra_YMKM.out

end data
```

Figure B.2 Example of the ShapeLib-fetch-tool input file.

B.2 Effective fetch calculation and representative bottom level calculation

The ShapeLib-fetch-tool calculates the fetch with the effective fetch formula given in Section 3.3.1. The fetch length of every direct fetch ray (R) is determined by the length between the output location and the location where the fetch ray (for a certain wind directions) intersects the river contour.

After calculating the direct fetch rays for every wind direction at each output location, the ShapeLib-fetch-tool interpolates the WAQUA bottom level to the direct fetch rays with 1 m steps along the fetch ray. Subsequently, the representative bottom level is calculated by taking the average of all bottom levels determined along the direct fetch rays.

It should be noted that for the calculation of the fetches and the representative bottom level, no dry areas (hoogwatervrij terrain) or obstacles were taken into account.

To run the ShapeLib-fetch-tool for all output locations of all regions, a batch file was made. This batch file calls the executable of the fetch tool, reads the appropriate input and saves the output.

B.3 Output

The following output is created using the fetch tool for every output location and wind direction:

- Effective fetch length in meters;
- Representative bottom level in meters.

This output is given in *.csv format.
In addition, the information of the fetch rays that were used to calculate the effective fetch is also saved in a *.out file. This file contains for every step size $\Delta\theta$:

- The X- and Y-coordinates of the output location (X,Y);
- The X- and Y-coordinates of the intersection location with the river contour (Xs,Ys);
- The direct fetch, which is the distance between (X,Y) and (Xs,Ys).

The bottom profile of each fetch ray was separately (without the Shape Lib Fetch tool) determined by interpolating the WAQUA bottom level information to each of the direct fetch rays.

C How to use the *.kmz files

C.1 Introduction

The *.kmz database is intended for water managers to be able to check the Bretschneider input (effective fetch and representative bottom level). In case the water manager finds that the Bretschneider input is incorrect, the water manager is able to raise his concern about this with Rijkswaterstaat. In this appendix a short manual is given how water managers can use the *.kmz Bretschneider data input databases.

C.2 Importing a *.kmz file into Google Earth

*.kmz Bretschneider data input databases have been made for the four regions:

- Meuse (Maas_BretschneiderInput.kmz, Maasmknov_BretschneiderInput.kmz, and Maasmknov_hk_BretschneiderInput.kmz)
- Rhine Branches (Rijntakken_BretschneiderInput.kmz)
- the narrow parts of the Vecht-IJssel delta (IJVD_BretschneiderInput.kmz)
- Mouth of the Rhine-Meuse (RMM_BretschneiderInput.kmz)

The river contour of each of these regions has also been converted to a *.kmz file and can be loaded separately.

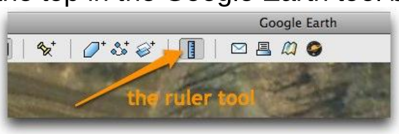
To import the *.kmz file into Google Earth the following steps can be followed:

- Open Google Earth;
- Select File > Open and choose the *.kmz file;

C.3 Checking the Bretschneider input of one location

To check the Bretschneider input at one output location:

- Zoom into the area of interest and choose one output location. The location ID's are shown when the mouse is moved over the location;
- Click on the selected output location. A table with the effective fetch and representative bottom level will pop-up;
- The fetch length can be roughly checked by also importing the river contour of the area of interest into Google Earth: fetch lengths can be measured by choosing the Ruler at the top in the Google Earth tool bar.



- To check the representative bottom profile, the water manager can present the bottom profile over a certain fetch ray, by following these steps:

1 Load the *.kmz file with the output locations and Bretschneider input tables.
2 Choose one location and one wind direction for which a bottom profile is needed
3 Draw the fetch ray, for which a bottom profile is needed, in Google Earth. This can be done by using the Tool Bar at the top of Google Earth: click  (Add Path).
4 To show the bottom profile, choose the path that was drawn from the Places panel and either go to Edit > Show Elevation Profile, or right-click on the path from the Places panel and select Show Elevation Profile. A bottom profile of the fetch ray will appear in the lower half of the 3D Viewer as shown in Figure 4.6.

D Updated Shape Files for Rijnmaasmonding

Some changes were made to the shape file used by the ShapeLib tool (FetchBottom.exe) for the Rijnmaasmonding region. The original shape file can be seen in Figure D.1.

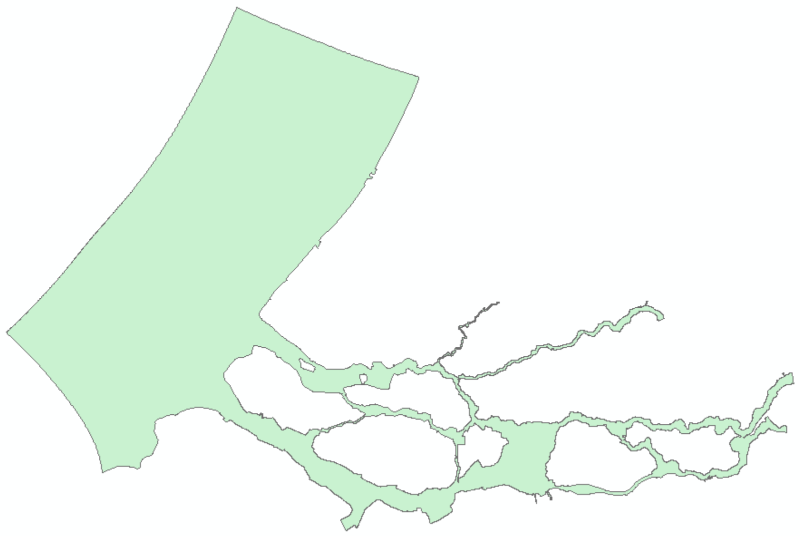


Figure D.1 Original Shape File

The adapted shape file can be seen in Figure D.2 below.

Figure D.2 Adapted Shape File

The main reason for adapting the Shape file was to include the Maasvlakte and the dam separating the Hartelkanaal and the Nieuwe Waterweg. By not including these features in the shape file, fetches were larger than they should be for locations in this area. However, there were also some other changes made to the shape file (e.g. near the Beerenplaat Basin).

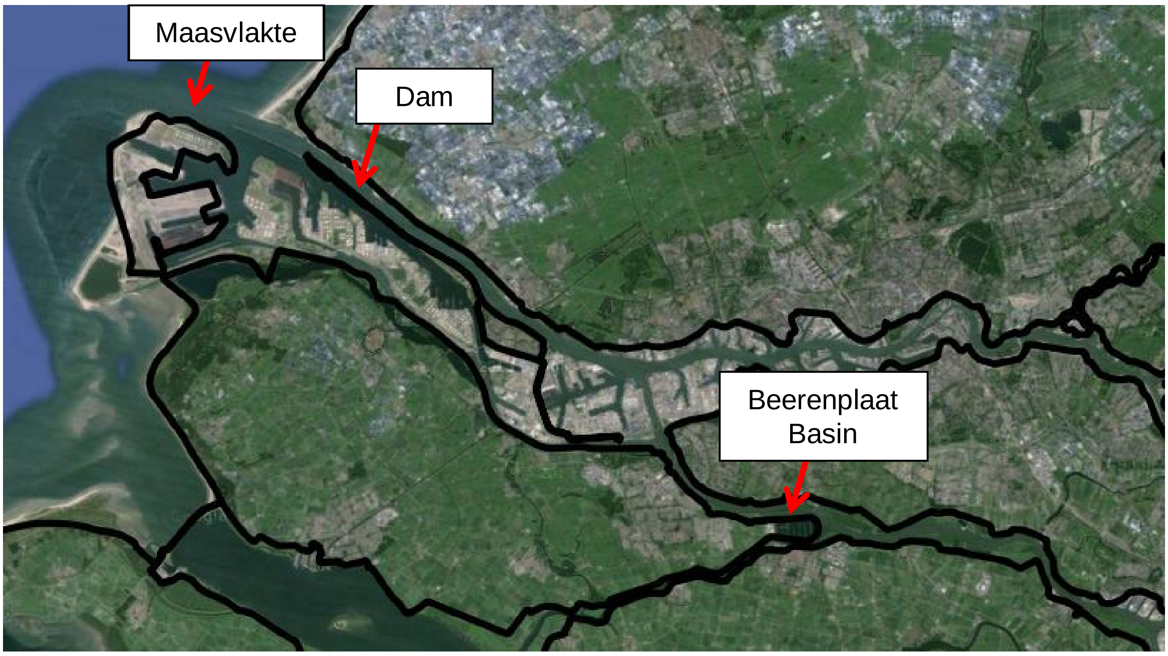


Figure D.3 Updated Shape File with Maasvlakte, the dam separating Hartelkanaal and Nieuwe Waterweg, and the Beerenplaat Basin indicated

One issue that was realized after updating the shape file was that locations appeared to be outside the boundary of the shape files. This occurs at the Beerenplaat Basin, which is seaward of the primary water defence. As a consequence the fetches at these output locations are larger than they should be (see Figure D.3 for location, and Figure D.4 for fetch lengths given a direction of 180 degrees-Left, 270 degrees-Right).

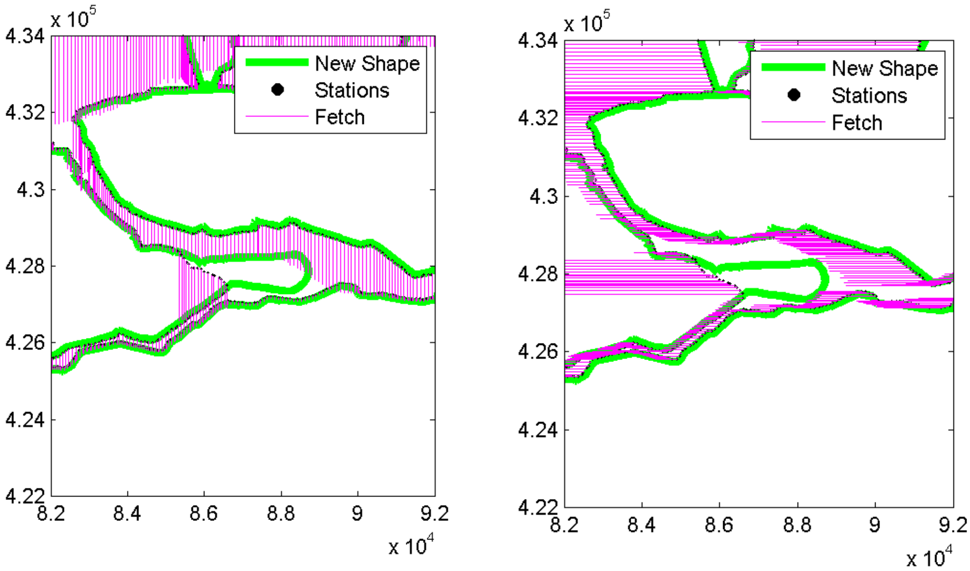


Figure D.4 Fetch length for a direction of 180 degrees-Left and 270 degrees-Right near Beerenplaat Basin.

The bed levels for the locations in this area are in Figure D.5. The bed level for all locations outside of the shape file (black line), are greater than 5m+NAP, with the exception of OM_60m_L_20_536, located just south of the shape file, which has a bed level of 1.305m+NAP.

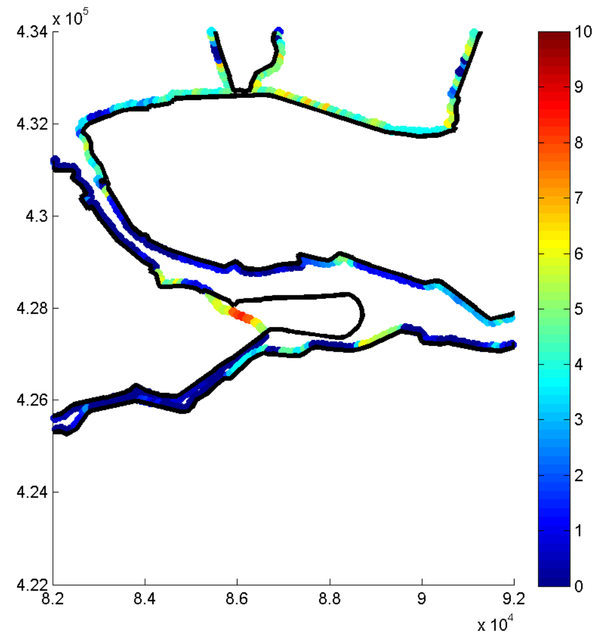


Figure D.5 Bed Level at output points (m+NAP)

The present normative water level (with normative exceedance probability of 1/4000 per year) is about 3m+NAP for this area, so these locations (exception OM_60m_L_20_536) should be dry. However, for WBI 2017 a higher exceedance probability of 1/50 000 per year will be considered, resulting in water levels that may flood the area. The resulting wave conditions may be unrealistic due to the large fetches.

Hydra-Zoet computations were done for locations in this area for an exceedance probability of 1/50 000.The two locations (see Figure D.6) available for Hydra-Zoet computations are DR20 Spui km 998-999 Locatie 01 (Right), and DR20 Oude Maas km 999-1000 Locatie 08 (Left).

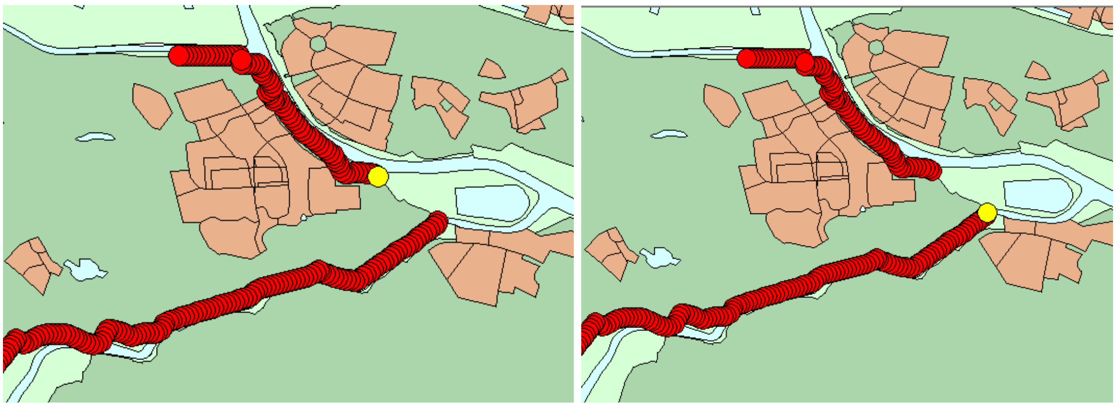


Figure D.6 Locations used for reference calculations. DR20 Spui km 998-999 Locatie 01 (Right), and DR20 Oude Maas km 999-1000 Locatie 08 (Left)

For an exceedance probability of 1/50 000 the water levels are 3.326m and 3.576m for locations ‘DR20 Spu km 998-999 Locatie 01’ and ‘DR20 Oude Maas km 999-1000 Locatie 08’ respectively. This is still lower than the bed level for most of the locations. However, location OM_60m_L_20_536 will be wet, and therefore wave conditions can be unrealistically high for some wind directions.