Master's thesis

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Modeling offshore basin as deep water and shallow water part.

2 Wave run-up in shallow water

2.1 Introduction

Introduction.

2.2 Mathematical model

The wave run-up in the shallow water part of the domain is modeled by the shallow water equations. The quasi-linear formulation of the shallow water equations in one spatial dimension is given by:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + g\frac{\partial h}{\partial x} = -g\frac{\partial b}{\partial x}, \tag{2.1}$$

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} = 0, \tag{2.2}$$

where $h(x,t)$ is the depth of the fluid, $u(x,t)$ the velocity, $g = 9.81m/s^2$ the acceleration of geavity and $b(x)$ the topografy defined from a certain reference level. The term $-g\frac{\partial b}{\partial x}$ in the first equation is the source term.
The domain of consideration is $x \in (0, L)$, see figure ??? for a sketch of the domain.
The dimensional equations (2.1)-(2.2) are scaled using the following scalings:

$$u = Uu', \quad x = L_s x', \quad t = \frac{L_s}{U}t', \quad h = Hh', \quad b = Hb' \quad \text{and} \quad g = g'\frac{U^2}{H},$$

where U is the velocity scale, L_s the horizontal scale and H the vertical scale. The dimenionless quasi-linear formulation of the shallow water equations in one spatial dimension then read as:

$$\frac{\partial u'}{\partial t'} + u'\frac{\partial u'}{\partial x'} + g'\frac{\partial h'}{\partial x'} = -g'\frac{\partial b'}{\partial x'}, \tag{2.3}$$

$$\frac{\partial h'}{\partial t'} + \frac{\partial (h'u')}{\partial x'} = 0, \tag{2.4}$$

The dimensionless quasi-linear formulation (2.3)-(2.4) can be written in a form, conservative for b,

$$\frac{\partial u}{\partial t} + u\frac{\partial f(u)}{\partial x} = S \tag{2.5}$$

with $u = (hu, h)^T$ and $S = (-gh\frac{\partial b}{\partial x}, 0)^T$, topographic term S, and transpose $(.,.)^T$

2.2.1 Variational formulation

The Lagrangian functional of the non-linear 1D shallow water equations is given as:

$$\mathcal{L}(\phi,\eta) = \int_{t_0}^{t_1}\int_0^L \Big\{ -\Big(\frac{1}{2}h(\partial_x\phi)^2 + \frac{1}{2}g((h+b)^2 - b^2)\Big) + \phi\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t, \tag{2.6}$$

with $\phi = \phi(x,t)$, $\eta = \eta(x,t)$ for the case of one-dimensional case, $h = h(x,t) = D(x) + \eta(x,t)$ and L the length of the domain in the x direction.

The equations of motion can be obtained by determining the critical point(s) of the Lagrangian using the first variation around ϕ and h:

$$\delta\mathcal{L}(\phi;k) = \frac{d}{d\varepsilon}\mathcal{L}(\phi+\varepsilon k)\Big|_{\varepsilon=0} = 0, \quad \text{and} \tag{2.7}$$

$$\delta\mathcal{L}(h;l) = \frac{d}{d\varepsilon}\mathcal{L}(h+\varepsilon l)\Big|_{\varepsilon=0} = 0. \tag{2.8}$$

Writing (2.7) out:

$$\begin{aligned}
\delta\mathcal{L}(\phi;k) &= \frac{d}{d\varepsilon}\mathcal{L}(\phi+\varepsilon k)\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\int_0^L \Big\{ -\frac{1}{2}\Big(h(\partial_x(\phi+\varepsilon k))^2 + g((h+b)^2 - b^2)\Big) + (\phi+\varepsilon k)\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\int_0^L \Big\{ -\frac{1}{2}h\Big((\partial_x\phi)^2 + 2\varepsilon\partial_x k\partial_x\phi + \varepsilon^2(\partial_x k)^2\Big) - \frac{1}{2}g\Big((h+b)^2 - b^2\Big) + \\
&\quad \phi\partial_t h + \varepsilon k\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \int_{t_0}^{t_1}\int_0^L \Big\{ -\big(\partial_x k\partial_x\phi + \varepsilon(\partial_x k)^2\big) + k\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \int_{t_0}^{t_1}\int_0^L \Big\{ -\partial_x k\partial_x\phi + k\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1}\Big[-k\partial_x\phi\Big]_0^L\,\mathrm{d}t + \int_{t_0}^{t_1}\int_0^L \Big\{ -k\partial_{xx}\phi + k\partial_t h\Big\}\,\mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1}\Big[-k\partial_x\phi\Big]_0^L\,\mathrm{d}t + \int_{t_0}^{t_1}\int_0^L k(-\partial_{xx}\phi + \partial_t h)\,\mathrm{d}x\,\mathrm{d}t = 0
\end{aligned}$$

Because $k\Big|_{t=t_0} = k\Big|_{t=t_1} = k\Big|_{x=0} = k\Big|_{x=L} = 0$, the final result is:

$$\partial_t h - \partial_{xx}\phi = 0. \tag{2.9}$$

Writing out (2.9):

$$\begin{aligned}
\delta\mathcal{L}(h;l) &= \frac{d}{d\varepsilon}\mathcal{L}(h+\varepsilon k)\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \left\{ -\frac{1}{2}\Big((h+\varepsilon l)(\partial_x\phi)^2 + g\big(((h+\varepsilon l)+b)^2 - b^2\big)\Big) + \phi\partial_t(h+\varepsilon l)\right\} \mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \left\{ -\frac{1}{2}\Big(h(\partial_x\phi)^2 + \varepsilon l(\partial_x\phi)^2 + g\big((h+\varepsilon l)^2 + 2(h+\varepsilon l)b + b^2 - b^2\big)\Big) + \right. \\
&\qquad \left. \phi\partial_t h + \varepsilon\phi\partial_t l \right\} \mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \int_{t_0}^{t_1}\!\!\int_0^L \left\{ -\frac{1}{2}l(\partial_x\phi)^2 - \frac{1}{2}g\big(2\varepsilon lh + 2\varepsilon l^2 + 2lb\big) + l\phi\partial_t \right\} \mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \int_{t_0}^{t_1}\!\!\int_0^L \left\{ -\frac{1}{2}l(\partial_x\phi)^2 - glh + glb + l\phi\partial_t \right\} \mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1} \Big[-\phi\partial_t l\Big]_0^L \mathrm{d}x + \int_{t_0}^{t_1}\!\!\int_0^L \left\{ -\frac{1}{2}l(\partial_x\phi)^2 - glh + glb + l\partial_t\phi \right\} \mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1} \Big[-\phi\partial_t l\Big]_0^L \mathrm{d}x + \int_{t_0}^{t_1}\!\!\int_0^L l\big(-\frac{1}{2}(\partial_x\phi)^2 - gh + gb + \partial_t\phi\big)\,\mathrm{d}x\,\mathrm{d}t = 0
\end{aligned}$$

$q\Big|_{t=t_0} = q\Big|_{t=t_1} = q\Big|_{x=0} = q\Big|_{x=L} = 0$, which leads to:

$$\partial_t\phi - \frac{1}{2}(\partial_x\phi)^2 - gh + gb = 0 \tag{2.10}$$

2.3 Finite volume scheme

Describe the finite volume scheme.
- Godunov method
- Method of Audusse et al for bottom topography
- CFL condition
- Accuracy

2.3.1 Riemann problem

Show results of the FV discretisation by comparing exact and numerical solutions for the Riemann problem, for several cases.
- derivation exact solution Riemann problem
- describe cases
- numerical solutions for cases
- exact solutions for cases

2.3.2 Results

Numerical results of the FV Shallow Water code with the implemented topography of the Offshore Basin at MARIN.
Refer to appendix for geometry beach.

2.4 Discontinuous Galerkin scheme

Describe the discontinuous Galerkin scheme.

2.4.1 Riemann problem

Show results of the DG discretisation by comparing exact and numerical solutions for the Riemann problem, for several cases.

2.4.2 Results

Numerical results of the DG Shallow Water code with the implemented topography of the Offshore Basin at MARIN. Refer to appendix.

2.5 Conclusion

Conclusion(s) of chapter 2.

3 Potential flow model

3.1 Introduction

The modeling of the offshore basin at MARIN considered in this report consists of a shallow water part and a deep water part. In the previous chapter the shallow water part was treated. In this chapter a potential flow model for the deep water part is presented. This chapter begins with a description of the mathematical model and gives analytical solutions for some cases. Subsequently the numerical scheme for the potential flow model is presented. This chapter ends with a comparison between the numerical solutions and the analytical solutions

3.2 Mathematical model

The waves in the deep water part of the offshore can be described by a linear potential flow model, which is given by Laplace's equation

$$-\nabla^2\phi = 0 \text{ on } \Omega, \tag{3.1}$$

and boundary conditions at the free surface $\partial\Omega_S$

$$\partial_t\phi + g\eta = 0 \text{ and} \tag{3.2}$$

$$\partial_t\eta - \partial_z\phi = 0, \tag{3.3}$$

and a no normal flow boundary condition on the rigid bed $\partial\Omega_b$:

$$\mathbf{n}\cdot\nabla\phi = 0 \tag{3.4}$$

The wave maker is located at the left boundary, which involves a boundary condition with a prescribed normal velocity. The modeling of the wave maker is explained in detail in the next paragraph.
Depending on the application of interest, the boundary condition at the right of the domain can be a Neumann (fixed wall) or periodic boundary condition.
domain
assumptions: irrotational, incompressible, inviscid flow

3.2.1 Variational formulation

The Lagrangian functional for the modeling of potential flow is stated as:

$$\mathcal{L}(\phi,\eta) = \int_{t_0}^{t_1}\int_0^L \left\{ -(\frac{1}{2}D(x)(\partial_x\phi)^2 + \frac{1}{2}g\eta^2) + \phi\partial_t\eta \right\} \mathrm{d}x\,\mathrm{d}t, \tag{3.5}$$

with $\phi = \phi(x,t)$, $\eta = \eta(x,t)$ for the case of one-dimensional potential flow, $h = h(x,t) = D(x) + \eta(x,t)$ and L the length of the domain in the x direction.

The equations of motion can be obtained by determining the critical point(s) of the Lagrangian, using the first variation around ϕ and η,

$$\delta\mathcal{L}(\phi;p) = \frac{d}{d\varepsilon}\mathcal{L}(\phi+\varepsilon p)\Big|_{\varepsilon=0} = 0, \quad \text{and} \tag{3.6}$$

$$\delta\mathcal{L}(\eta;q) = \frac{d}{d\varepsilon}\mathcal{L}(\eta+\varepsilon q)\Big|_{\varepsilon=0} = 0. \tag{3.7}$$

Writing (3.6) out:

$$\begin{aligned}
\delta\mathcal{L}(\phi;p) &= \frac{d}{d\varepsilon}\mathcal{L}(\phi+\varepsilon p)\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -(\frac{1}{2}D(x)(\partial_x\phi+\varepsilon p)^2 + \frac{1}{2}g\eta^2) + (\phi+\varepsilon p)\partial_t\eta \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -\frac{1}{2}(D(x)(\partial_x\phi)^2 + 2\varepsilon D(x)\partial_x p\partial_x\phi + \varepsilon^2 D(x)(\partial_x p)^2 - g\eta^2) + \\
&\quad \phi\partial_t\eta + \varepsilon p\partial_t\eta \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -(\partial_x p\partial_x\phi + \varepsilon(\partial_x p)^2) + p\partial_t\eta \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -\partial_x p\partial_x\phi + p\partial_t\eta \Big\}\,\mathrm{d}x\,\mathrm{d}t = \int_{t_0}^{t_1} \Big[-p\partial_x\phi \Big]_0^L \mathrm{d}t + \\
&\quad \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -p\partial_x x\phi + p\partial_t\eta \Big\}\,\mathrm{d}x\,\mathrm{d}t = \int_{t_0}^{t_1} \Big[-p\partial_x\phi \Big]_0^L \mathrm{d}t + \\
&\quad \int_{t_0}^{t_1}\!\!\int_0^L p(-\partial_{xx}\phi + \partial_t\eta)\,\mathrm{d}x\,\mathrm{d}t = 0
\end{aligned}$$

Because $p\Big|_{t=t_0} = p\Big|_{t=t_1} = p\Big|_{x=0} = p\Big|_{x=L} = 0$, the final result is:

$$\partial_t\eta - \partial_{xx}\phi = 0. \tag{3.8}$$

Writing out (3.7):

$$\begin{aligned}
\delta\mathcal{L}(\eta;q) &= \frac{d}{d\varepsilon}\mathcal{L}(\eta+\varepsilon q)\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -(\frac{1}{2}D(x)(\partial_x\phi)^2 + \frac{1}{2}g(\eta+\varepsilon q)^2) + \phi\partial_t(\eta+\varepsilon q) \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \frac{d}{d\varepsilon}\int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -\frac{1}{2}(D(x)(\partial_x\phi)^2 + g(\eta^2 + 2\varepsilon q\eta + \varepsilon^2 q^2)) + \phi\partial_t\eta + \varepsilon\phi\partial_t q \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \\
&= \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -g(q\eta + \varepsilon q^2)\phi\partial_t q \Big\}\,\mathrm{d}x\,\mathrm{d}t\Big|_{\varepsilon=0} = \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -gq\eta\phi\partial_t q \Big\}\,\mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1} \Big[-\phi q \Big]_0^L \mathrm{d}x + \int_{t_0}^{t_1}\!\!\int_0^L \Big\{ -gq\eta - q\partial_t\phi \Big\}\,\mathrm{d}x\,\mathrm{d}t = \\
&= \int_{t_0}^{t_1} \Big[-\phi q \Big]_0^L \mathrm{d}x + \int_{t_0}^{t_1}\!\!\int_0^L q(-g\eta - \partial_t\phi)\,\mathrm{d}x\,\mathrm{d}t = 0
\end{aligned}$$

$q\Big|_{t=t_0} = q\Big|_{t=t_1} = q\Big|_{x=0} = q\Big|_{x=L} = 0$, which leads to:

$$\partial_t\phi + g\eta = 0, \tag{3.9}$$

or, when differentiating (3.9) with respect to x:

$$(\partial_x \phi)_t - g\partial_x \eta = 0. \tag{3.10}$$

3.3 Modeling of the wave maker

How to model the wave maker.

3.4 Analytical solutions

For the potential flow model (3.1)-(3.4) analytical solutions can be obtained. Suppose the solution is of the form

$$\phi(x,z,t) = \hat{\phi}(x,z)e^{iwt} \tag{3.11}$$

Then because of (3.1) we have on Ω:

$$\nabla^2(\hat{\phi}(x,z)e^{iwt}) = 0,$$

or

$$\hat{\phi}_{xx}e^{iwt} + \hat{\phi}_{zz}e^{iwt} = 0,$$

so

$$\nabla^2\hat{\phi}(x,z) = 0. \tag{3.12}$$

Boundary conditions (3.2) and (3.3) on $\partial\Omega_S$ can be written as a single boundary condition, by differentiating (3.2) with respect to t and substituting (3.3) into (3.2), resulting in:

$$\partial_{tt}\phi - g\partial_z\phi = 0 \text{ on } \partial\Omega_S. \tag{3.13}$$

Putting (3.11) into the free surface boundary condition (3.13) gives

$$i^2\omega^2\hat{\phi}e^{iwt} + g\partial_z\hat{\phi}e^{iwt} = 0 \text{ on } \partial\Omega_S,$$

or

$$e^{iwt}(g\partial_z\hat{\phi} - \omega^2\hat{\phi}) = 0 \text{ on } \partial\Omega_S,$$

resulting in

$$g\partial_z\hat{\phi} - \omega^2\hat{\phi} = 0 \text{ on } \partial\Omega_S. \tag{3.14}$$

Substituting (3.11) in (3.4) leads to:

$$\partial_z\hat{\phi}e^{i\omega t} = 0 \text{ on } \partial\Omega_b,$$

or

$$\partial_z\hat{\phi} = 0 \text{ on } \partial\Omega_b, \tag{3.15}$$

Now we apply the method of separation of variables for (3.12), (3.14) and (3.15). Suppose

$$\hat{\phi}(x,z) = f(x)h(z),$$

Then because of (3.12) we have on Ω:

$$\nabla^2(\hat{\phi}(x,z)) = \nabla^2(f(x)h(z)) = 0,$$

or

$$\frac{\partial^2 f}{\partial x^2}h + \frac{\partial^2 h}{\partial z^2}f = 0$$

Deviding by fh gives:

$$\frac{\partial^2 h}{\partial z^2}\frac{1}{h} + \frac{\partial^2 f}{\partial x^2}\frac{1}{f}.$$

Because $\frac{\partial^2 h}{\partial z^2}\frac{1}{h}$ depends only on z and $\frac{\partial^2 f}{\partial x^2}\frac{1}{f}$ only on x, we have:

$$\frac{\partial^2 h}{\partial z^2}\frac{1}{h} = k^2 \text{ and } \frac{\partial^2 f}{\partial x^2}\frac{1}{f} = -k^2 \text{ , with } k \text{ a constant.}$$

Shorter notated as:

$$f'' = -k^2 f \text{ and } h'' = k^2 h \text{ , with } k \text{ a constant.} \tag{3.16}$$

Boundary condition (3.14) (at the free surface $\partial\Omega_S$) then becomes:

$$gf\partial_z h - \omega^2 fh = 0 \text{ on } \partial\Omega_S,$$

or

$$f(g\partial_z h - \omega^2 h) = 0 \text{ on } \partial\Omega_S.$$

Because $f \neq 0$ (trivial solutions not allowed):

$$g\partial_z h - \omega^2 h = 0 \text{ on } \partial\Omega_S. \tag{3.17}$$

Boundary condition (3.15) then becomes:

$$f\partial_z h = 0 \text{ on } \partial\Omega_b,$$

because $f \neq 0$:

$$\partial_z h = 0 \text{ on } \partial\Omega_b. \tag{3.18}$$

Take $f(x) = e^{-ikx}$ and $h(z) = e^{kz}$, then (3.16) holds. Substituting these in (3.17) gives:

$$gke^{kz} - \omega^2 e^{kz} = 0 \text{ on } \partial\Omega_S \text{ or at } z = 0,$$

or

$$gke^0 - \omega^2 e^0 = 0,$$

or

$$gk - \omega^2 = 0,$$

so

$$\omega = \sqrt{gk}.$$

Substitution of $f(x)$ and $g(z)$ in (3.18) gives:

$$ke^{kz} = 0 \text{ on } \partial\Omega_b \text{ or at } z = -H,$$

or

$$ke^{-kH} = 0,$$

and because $k = 0$ results in $\hat{\phi} = 1$, we take $h(z) = e^{k(z+H)} + e^{-k(z+H)}$, then (3.18) becomes

$$ke^{k(z+H)} - ke^{-k(z+H)} = 0 \text{ at } z = -H,$$

or

$$ke^0 - ke^0 = 0,$$

so (3.18) holds. With the new f and h boundary condition (3.17) gives:

$$gke^{k(z+H)} - gke^{-k(z+H)} - \omega^2\big(e^{k(z+H)} + e^{-k(z+H)}\big) = 0 \text{ at } z = 0,$$

or

$$gke^{kH} - gke^{-kH} - \omega^2\big(e^{kH} + e^{-kH}\big) = 0,$$

or

$$\omega^2\big(e^{kH} + e^{-kH}\big) = gk\big(e^{kH} - e^{-kH}\big),$$

so

$$\omega^2 = \frac{gk(e^{kH} - e^{-kH})}{(e^{kH} + e^{-kH})} = gk\frac{2\sinh kH}{2\cosh kH} = gk\tanh kH \quad \text{or} \quad \omega = \sqrt{gk\tanh kH}.$$

Summerizing, we have $f(x) = e^{-ikx}$ and $h(z) = e^{k(z+H)} + e^{-k(z+H)} = 2\cosh k(z+H)$, resulting in

$$\begin{aligned}\phi(x,z,t) = \hat{\phi}(x,z)e^{i\omega t} &= f(x)h(z)e^{i\omega t} = 2\cosh\big(k(z+H)\big)e^{-ikx}e^{i\omega t} = \\ &= 2\cosh\big(k(z+H)\big)e^{i(\omega t - kx)} = A\cosh\big(k(z+H)\big)e^{i(\omega t - kx)}.\end{aligned}$$

Analytical solutions for certain boundary conditions and initial conditions, with and without wave maker.

3.5 Numerical scheme

Description of the numerical scheme used in the potential flow code.

3.6 Results

Comparison between analytical and numerical solutions for certain (test) cases.

4 Coupling of the potential flow and shallow water schemes

4.1 Introduction

Introduction of chapter 4.

4.2 Theory of coupling of domains

Describe basic principles of coupling. Describe different mehthods of coupling from the literature.

4.3 Method of coupling of domains

Describing the method of coupling that is used in the situation of the offshore basin at MARIN.

4.4 Analysis of the coupled domains

(Stability) analysis of the coupled domains.

4.5 Numerical results

Numerical results for differents (test) cases.

4.6 Conclusion

Conclusion(s) of chapter 4.

5 Wave dampening in the offshow basin

5.1 Introduction

Introduction of chapter 5.

5.2 Situations of interest

Describe situation(s) at MARIN, for which the wave dampening is analysed.
Type of waves, depth of basin.

5.3 Methods of wave dampening

Describing different methods for wave dampening.

5.3.1 Geometry of the beach

Analysis of different geometries for the beach.

5.3.2 Method 2?

Analysis of method 2 for wave dampening in the offshore basin at MARIN.

5.3.3 Method 3?

Analysis of method 3 for wave dampening in the offshore basin at MARIN.

5.4 Conclusion

Conclusion(s) of chapter 5.
How do the waves for an/some specific situation(s) in the offshore can be dampened most effectively?

6 Conclusions and recommendations

6.1 Introduction

Introduction of chapter 6.

6.2 Conclusions

Conclusion(s) of the report.

6.2.1 Recommendations for MARIN

Recommendations for wave dampening in the offshore basin at MARIN.

6.2.2 Future research

Recommendations for future research with respect to the research done in this report.