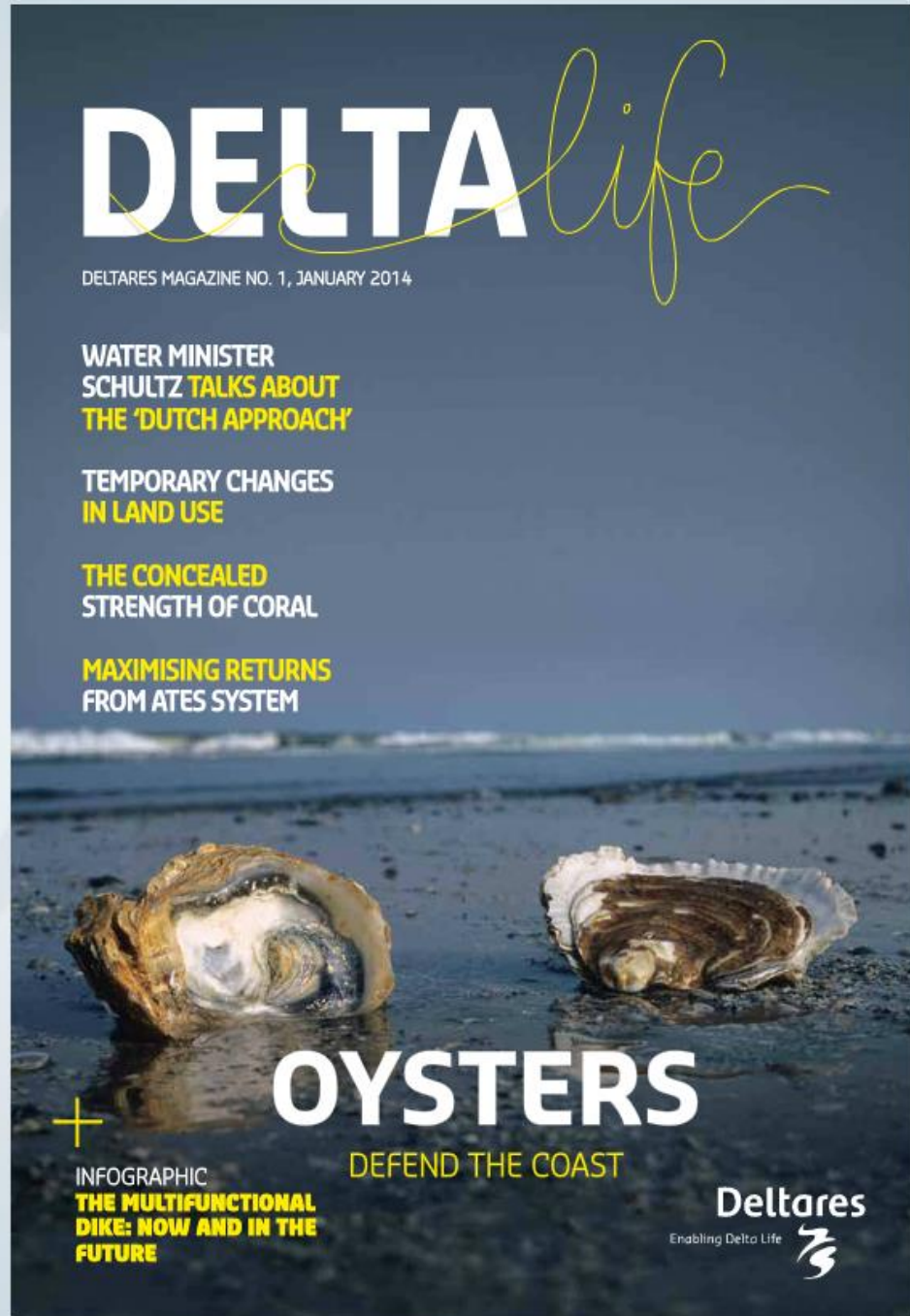




# Integration of ecology and engineering in cost-effective nature-based flood defences

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Bregje van Wesenbeeck, Ellis Penning, Wouter  
van der Star

25 september 2014



Deltares is a leading institute in R&D for Building with Nature

Fitting in our motto: *'Enabling Delta Life'*

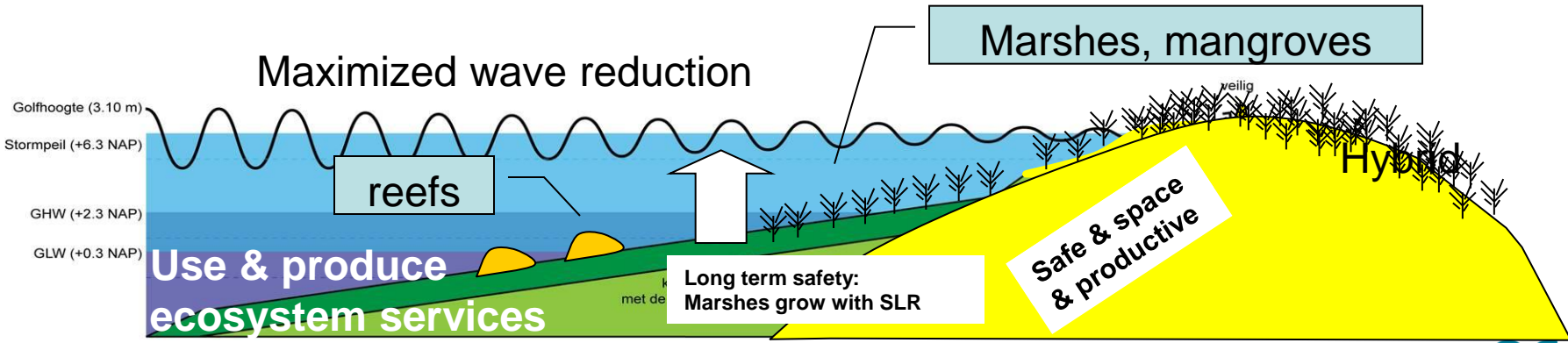
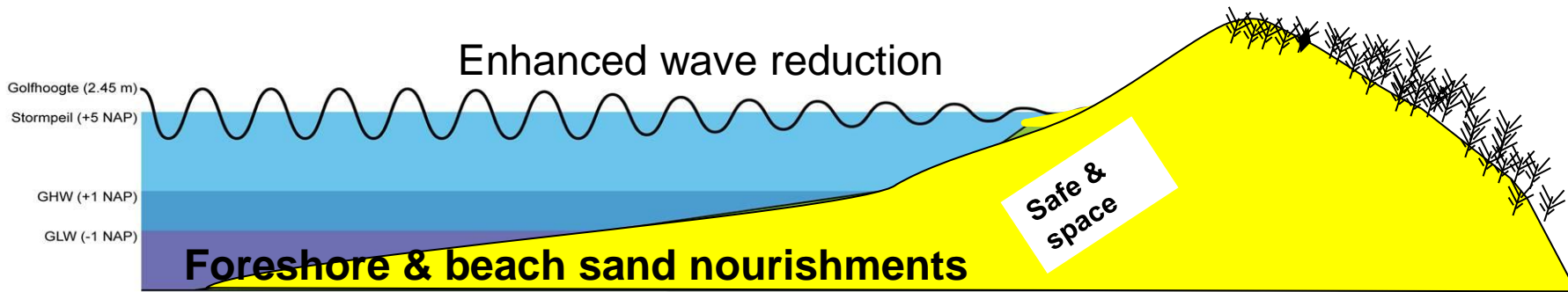
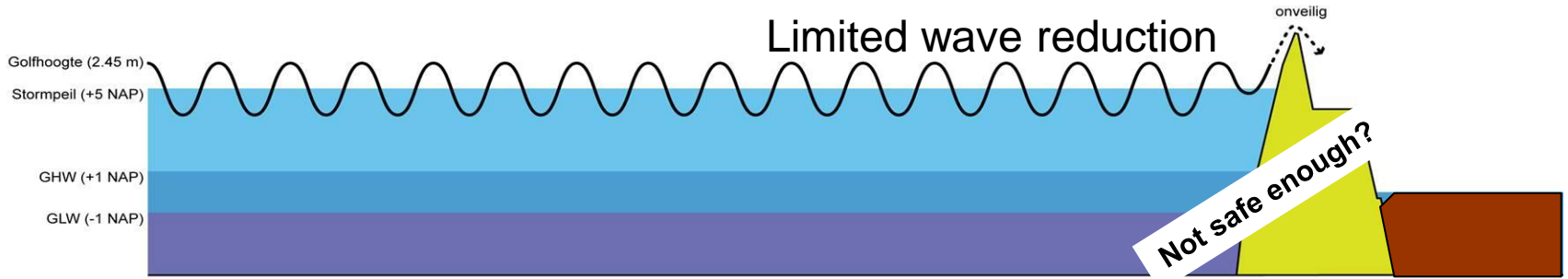


# Ecosystem services relevant for flood safety

- Reduction of wind speed
- Stabilisation of sediment
- Increase in sedimentation
- Reduction of erosion
- Wave attenuation
- Reduction of currents
- Physical barrier



# Traditional knowledge and BWN integrated to build safe soft eco levees by reef, marsh, dune, dike combinations



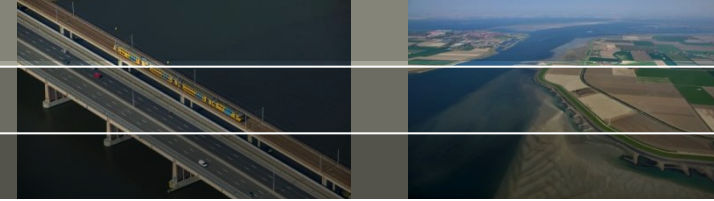
# Why should we use nature based flood defense

Why should we make use of natural processes and ecosystem services in flood risk mitigation in combination with hard engineering?

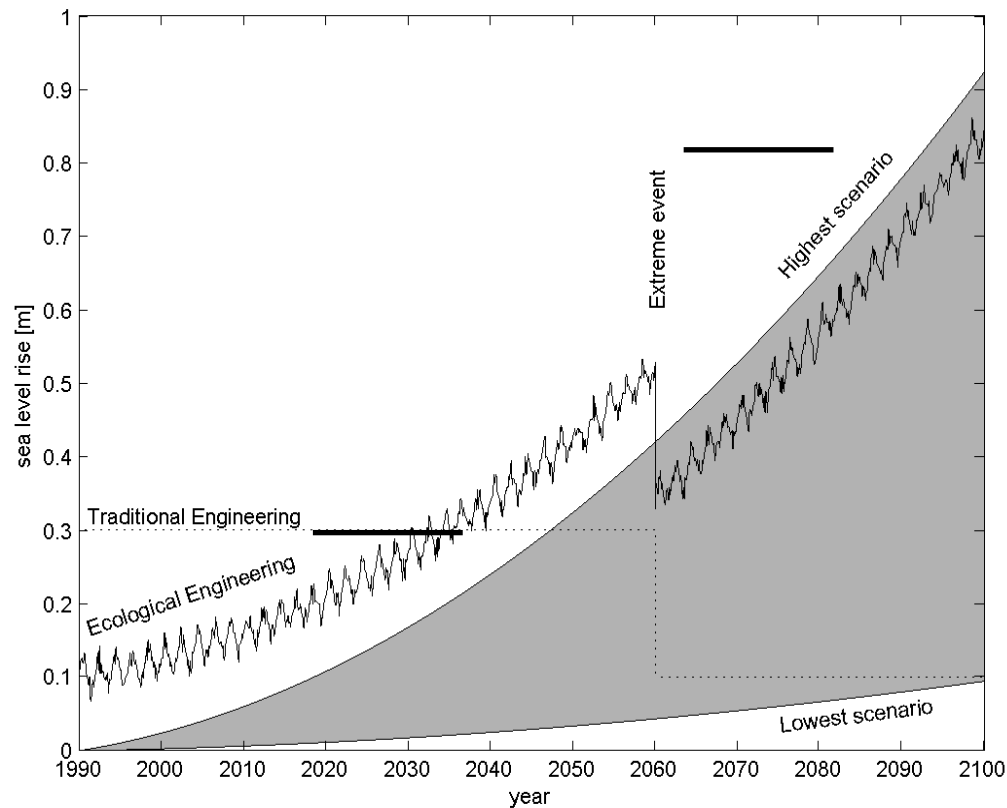
1. Adaptable
2. Cost reduction
3. Provides benefits



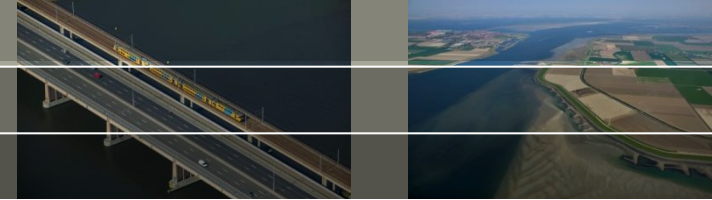
# Adaptable



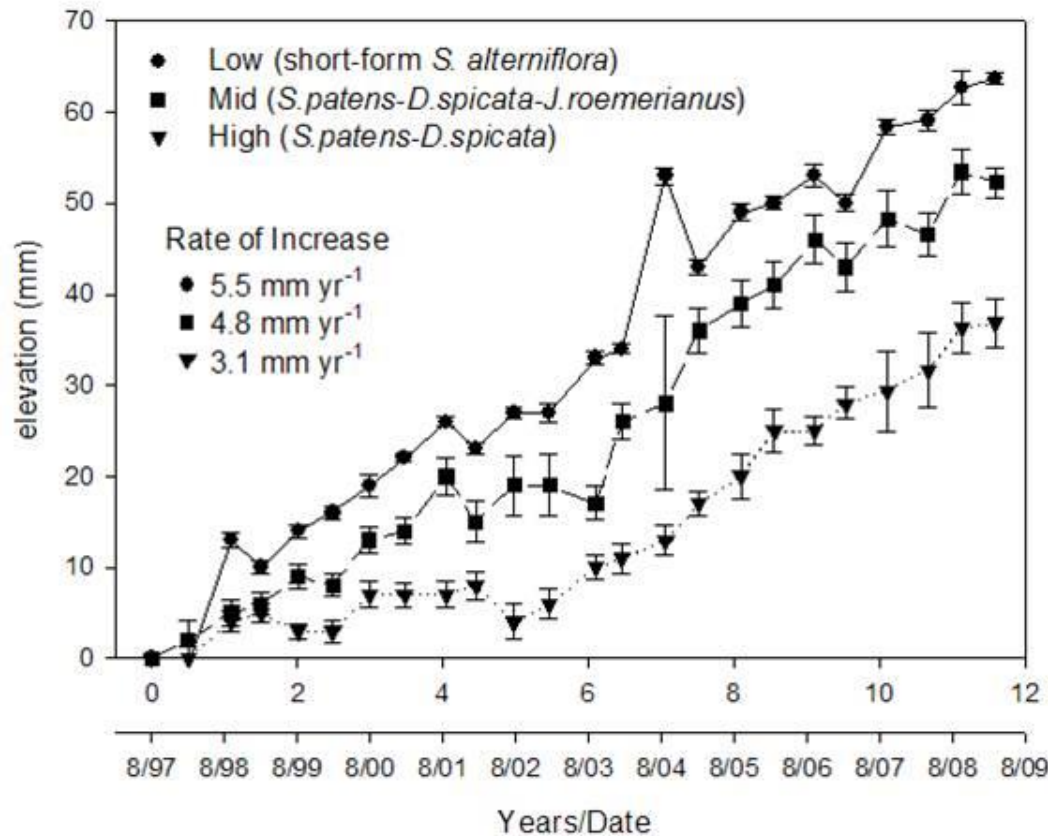
1. Self-sustaining and self-repairing
2. Accretes with rising water levels (peat or sediment)
3. Dampens waves independent on wave height



# Adaptable

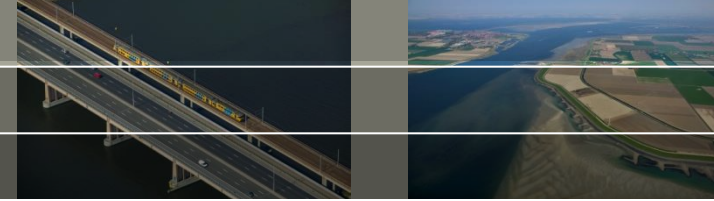


1. Self-sustaining and resilient
2. Accretes with rising water levels (peat or sediment)
3. Dampens waves independent on wave height

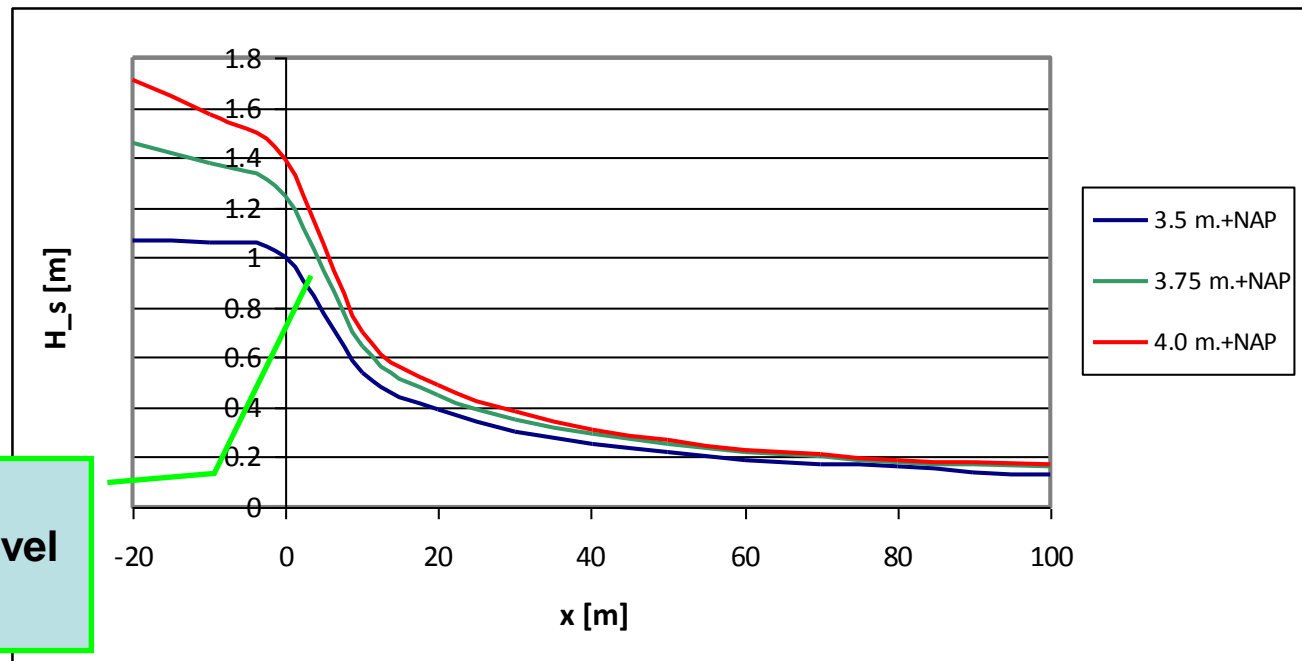


Blum 2011

# Adaptable



1. Self-sustaining and resilient
2. Accretes with rising water levels (peat or sediment)
3. **Dampens waves independent on wave height (forest)**



Wave reduction is insensitive to water level increase.

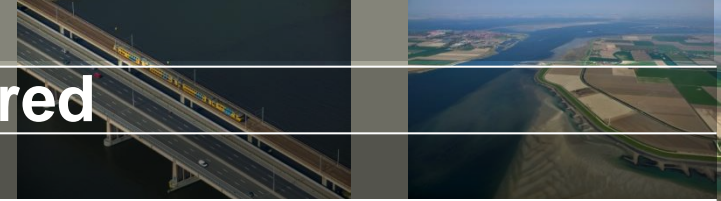


# Design of hybrid and soft NBF D solutions depends on energy and slope (=space)



Figure 1: Range of potential BwN applications along the main axes of given bed slope and hydrodynamic energy. Of course factors like salinity and geo-climatic region also determine potential solutions.

# Species specific approach is required



Coastal systems	Subtidal	Intertidal	Supratidal
	Reefs, kelp and seagrasses	Reefs, seagrasses, mudflats, saltmarsh Vegetation	Saltmarsh and dune vegetation
<b>Lakes&amp; rivers</b>	<b>Fully inundated</b>	<b>Frequently Inundated</b>	<b>Rarely inundated</b>
	Submerged vegetation	Reeds	Floodplain forest/shrub grasses

# Learn from implemented test cases



Some examples of hybrid and soft solutions provide information on additional benefits and costs:

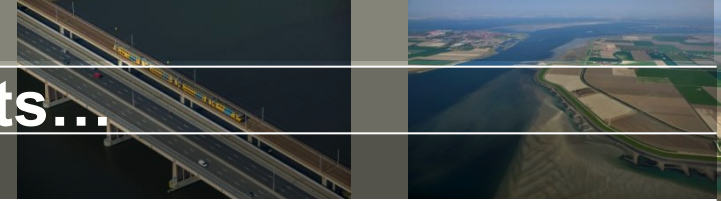
- Coast (sand+reefs):
  - Sand-Engine & Oesterdam Safety Buffer
- Lake (sand+reeds):
  - Houtribdijk sandy foreshore
- River (forest):
  - Noordwaard forest-dike combination

# Soft solution, coast: Sand-Engine, upscale proven technology...

- Dutch sandy coasts is centuries old
- Coastline is maintained by regular sand nourishments



and apply it for multiple benefits...



Sand engine along Dutch coast 2012



Large sand nourishment=>  
+Nature  
+Tourism  
+Safety



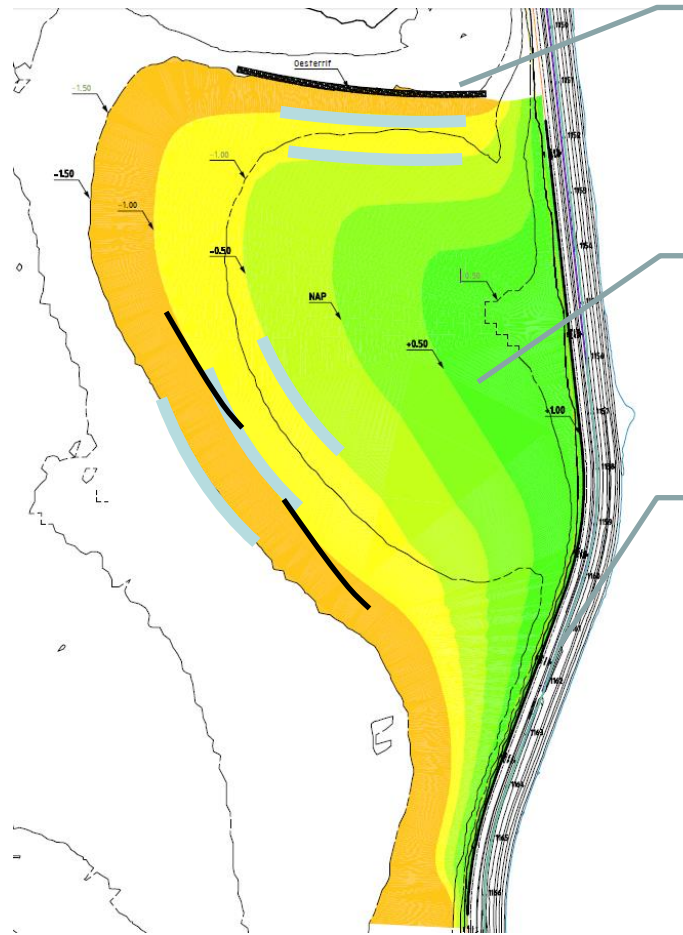
# Hybrid solutions in estuary: foreshore protection with oyster reef



Reduce erosion,  
maintain habitats and  
protect the dike

# Hybrid: Safety Buffer Oesterdam (2013), Dike, sand nourishment and oyster reefs

- Oyster reefs will
  - Reduce erosion
  - Create habitat diversity



Oyster reef

Sand  
nourishment

Existing dike

# Oesterdam case was implemented in December 2013



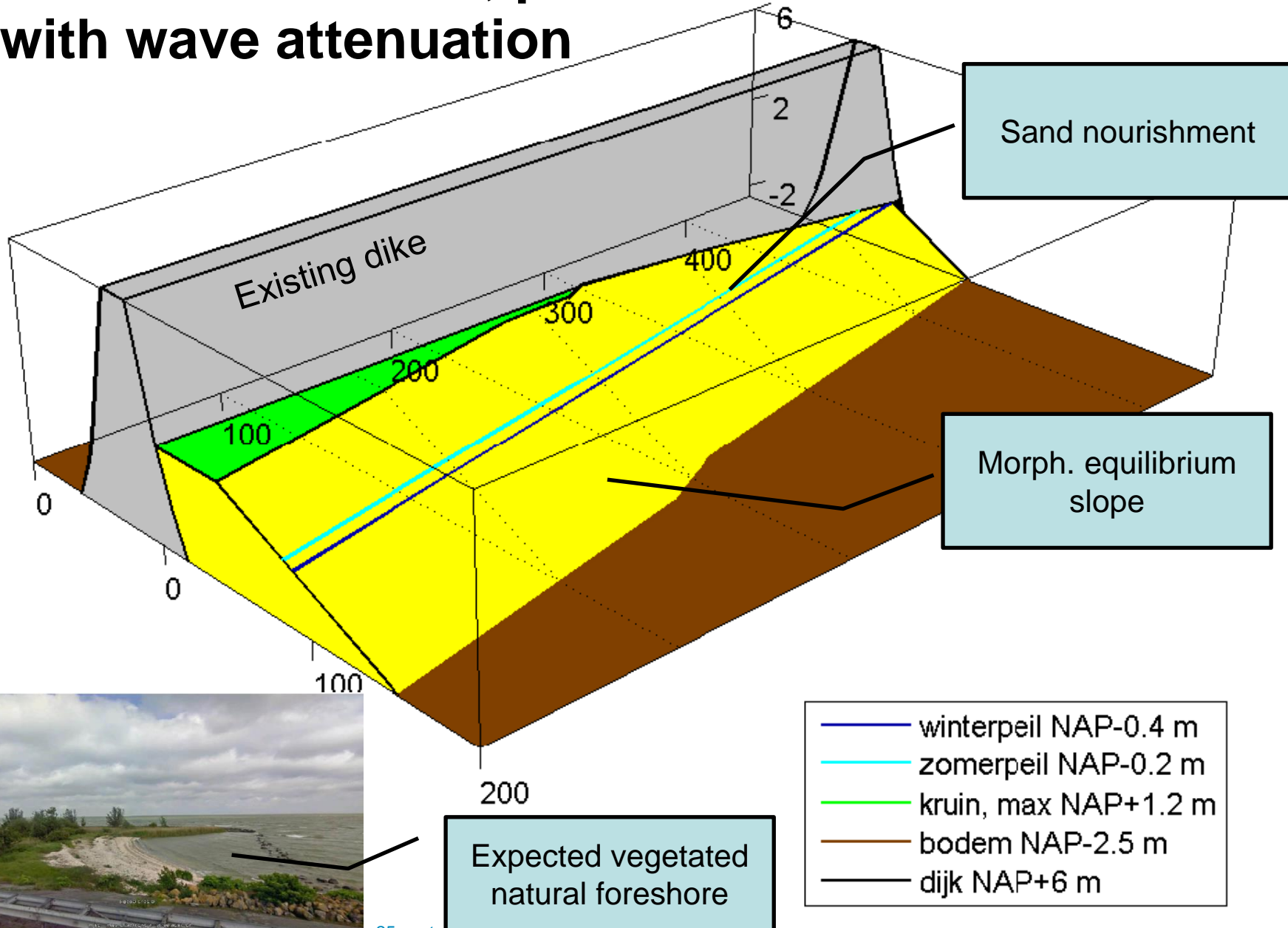


# Hybrid solution in lake system

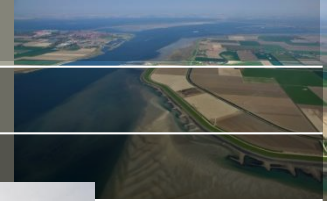
Houtribdijk, Markermeer side  
Present situation...



# Sand nourishment, provide natural foreshore with wave attenuation



# Work in progress..(August 2014)

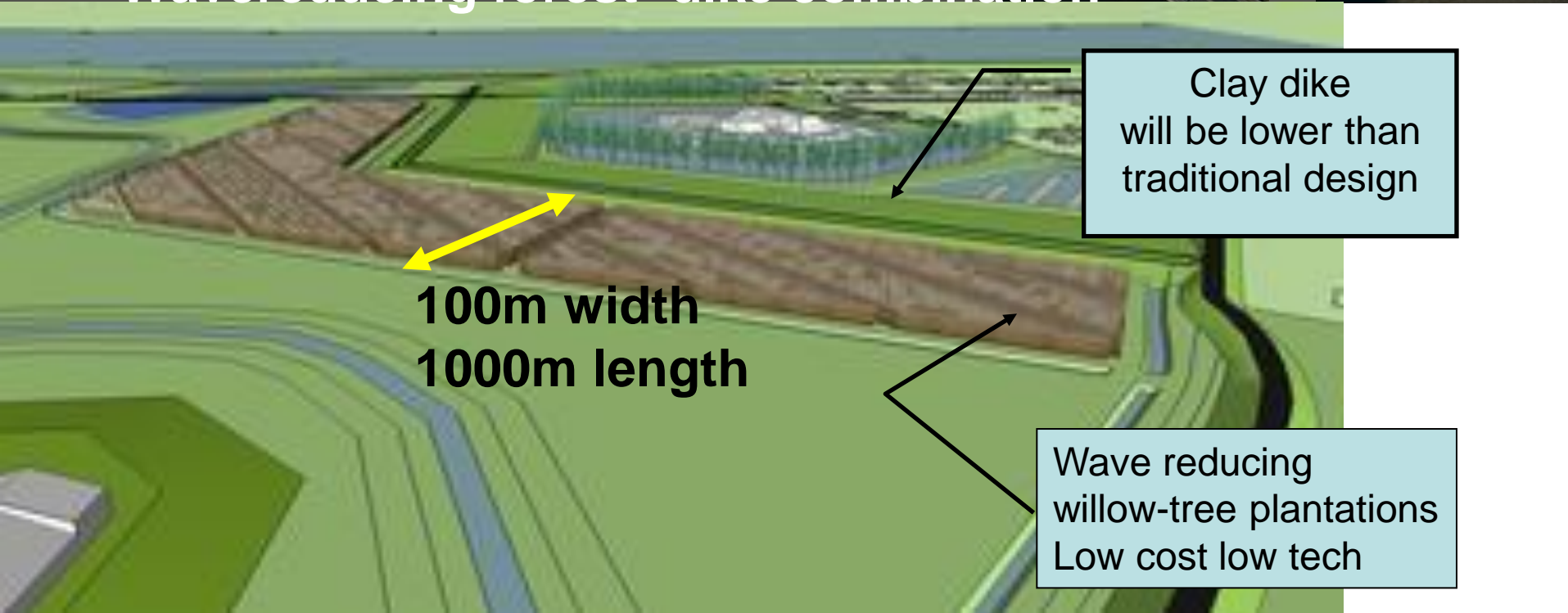


Willow mats will prevent beach erosion until vegetation appears



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# Hybrid Solution, river system: Wavereducing forest- dike combination



- >70% reduction of wave height in healthy willow forest
- Deltares/RWS design achieves required 1/2000 safety standards
- now under construction.



Two year old willow forest



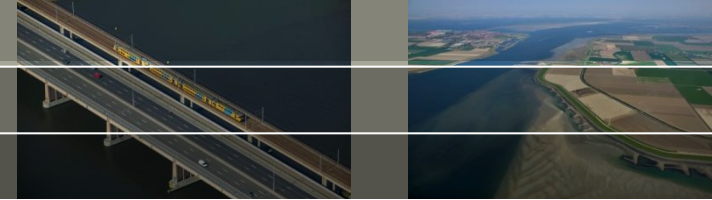
8 jaar oud griend, twee jaarlijks gemaaid



**Grienddijk – ‘willow forest dike’ under construction (August 2014)**

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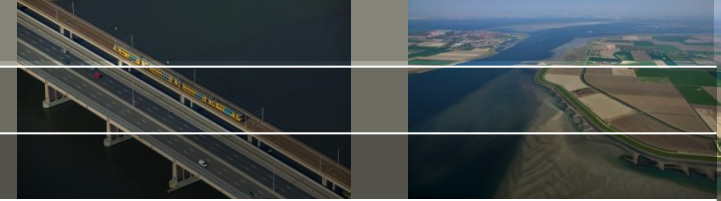
# Cost comparisons



Note: traditional hard solutions are build 'maintenance free' for 50 years.

Case	Ecosystem	Net present value (€/km)	Management and maintenance (€/km/year)	Investment (€/km)	Sensitivity
Lake sand-reed foreshore	Freshwater reed marsh	2.000.000 – 3.500.000 less	2500 – 10.000 more	2.250.000 – 3.550.000 less	40%
River Willow levee	River floodplain	1.500.000 less	2000 more	1.550.000 less	25%
Coastal Sand/marsh levee (hybrid)	Salt marsh and dune	160.000 – 875.000 less	5000-10.000 more	414.000 less to 540.000 more	25%

# What we learned about costs



	Coastal and Lake (soft and hybrid)	River (hybrid)
<b>Construction</b>	<b>In NL competitive against 'hard' solutions</b>	<b>Cheaper than hard solution but only relevant if wave overtopping is significant</b>
	Sediment dominates 80-90% of costs.	Low sediment requirement,.
	Cost dependent on bathymetry, sand availability, and scale of operation	Within sediment budget of standard dike works
<b>Maintenance</b>	<b>Maintenance cost is estimated to be somewhat higher due to nourishments and nature management.</b>	<b>Maintenance cost may be higher due to forest management</b>
	Cost of upgrade is lower.	Cost of upgrade is lower.
	Cost will depend on morphodynamics and scale.	Cost will depend on morphodynamics and scale.
	Sediment trapping and stabilization will reduce maintenance cost (coastal). Design can be self sustaining & accreting	Robust and adaptable against increasing wave energy and SLR. Sediment trapping & stabilization

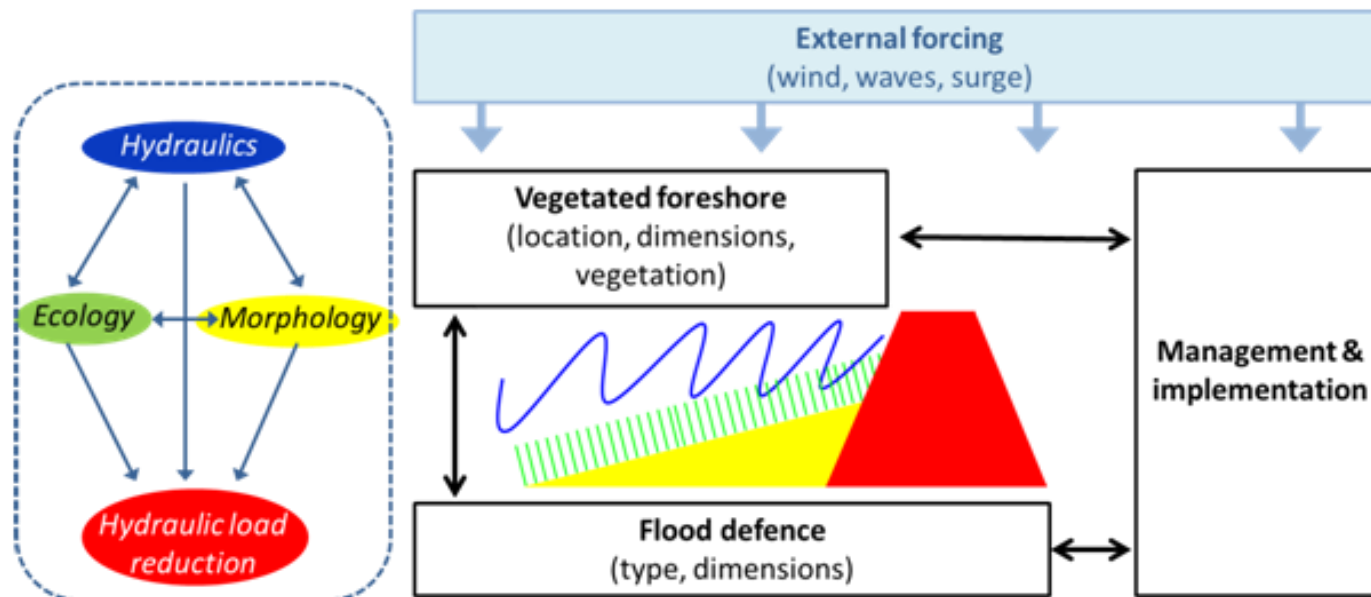


# Additional benefits (= ecosystem services)

	Coastal (saltmarsh, mudflat)	Lake (reeds)	River (forest)
Breeding grounds and nursery for fish, birds and many other species	<b>X</b>	<b>X</b>	<b>X</b>
Biodiversity	X	X	X
Food provisioning (fruits, fish, waterfowl, etc.)	X	X	X
Firewood, biomass production	X	X	X
Carbon sequestration	x?	x?	x?
Water purification	X	X	
Water retention	X (in dunes)		
Tourism & Recreation	<b>X</b>	<b>X</b>	X

# Research project BE-SAFE (2014-2017) amongst many others..

- **Focus op dynamic behaviour of foreshores in time, this relates to the maintenance issue**
- Develop new methods to assess how, and how much vegetated foreshores can contribute to flood risk reduction.



Partners: NIOZ, TUDelft, UTwente, HKV, Deltares  
End users: RWS, NGO's, Waterboards

# Ministry of Infrastructure and the Environment endorses BWN

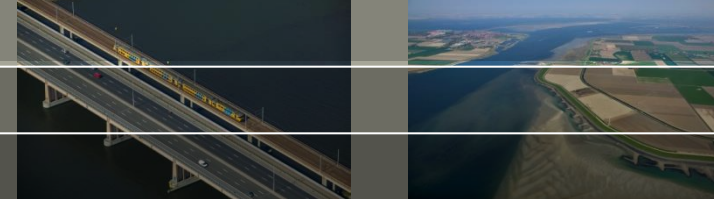


26-04-2013

Minister Schultz van Haegen: wil 'werken met de natuur'. "Eeuwenlang hebben we de natuur met dammen en dijken proberen in te perken. Maar we kunnen de oplossing niet alleen blijven zoeken in het ophogen of verbreden van dijken. Ik wil bouwen mét de natuur.

***Our minister Ms. Schultz van Haegen (+Deltacommission, +speakers at plenary session of DTCC14) promotes the application of Building with Nature principles in the flood safety solutions of this century***

# Thank you!



Contact us at:

- [mindert.devries@deltares.nl](mailto:mindert.devries@deltares.nl)
- [www.ecoshape.nl](http://www.ecoshape.nl) (download the book!)
  
- Wesenbeeck, B.K. van, J. Mulder, M. Marchand, M. de Vries, H. De Vriend, P. Herman, 2014. **Damming deltas: A practice of the past? Towards nature-based flood defences.** Estuarine, Coastal and Shelf Science 140:1-6 (2014).
- E. van Slobbe, H.J. de Vriend, S. Aarninkhof, K. Lulofs, M. de Vries, P. Dircke, 2012. **Building with Nature: in search of resilient storm surge protection strategies.** Natural Hazards (2013) 66:1461-1480. DOI 10.1007/s11069-013-0612-3. Natural Hazards special issue in on storm surges.
- Borsje, B.W., B. K. van Wesenbeeck, F. Dekker, P. Paalvast, T. J. Bouma, M. M. van Katwijk, M. B. de Vries, 2011. **How ecological engineering can serve in coastal protection.** Ecological Engineering, V37: 113–122