Managed realignment

Managed realignment

Controlled inundation of land by setting back the sea defence is an increasingly used method for coastal protection that anticipates to climate change. In the United Kingdom this so-called “managed realignment” is applied widely and considered a cost-effective and sustainable response to loss of salt marsh habitat and sea level rise. It is also applied in other countries such as the United States, Germany and Belgium.

By re-inundating land the coastline is placed backwards and a new intertidal area is created. The area is enclosed by a new dike on the landside to ensure safety of the hinterland. The goal is to create the right circumstances for succession of salt marsh vegetation. Once salt marshes develop, the vegetation will enhance sedimentation, the area will increase in elevation and will thus be able to grow with sea level rise. Furthermore, salt marshes can reduce wave energy and improve the stability of the dike.

>> Read more

Managed realignment can be applied to many different situations that fall within the scope of coastal and flood management. Success is also dependent on local boundary conditions. It is important to be clear on the aim and purpose of the proposed project at the beginning. Without this it may be difficult later to determine the success/failure of the scheme in meeting its objectives. It is also important at the outset of a project to identify any potential opportunities and/or constraints. Managed Realignment presents the opportunity for a variety of benefits, though such opportunities may also have associated constraints.

This Building Solution describes the practice of managed realignment as an approach that combines coastal defense with creation of new intertidal and salt marsh habitat. Managed realignment is mostly used in low lying estuarine and coastal areas to counter-act coastal erosion and coastal squeeze as a consequence of sea level rise or other causes and improve coastal stability. Furthermore it is a method that is used to compensate for loss of intertidal areas (tidal flats and salt marshes) and as water retention area during extreme water levels in narrow river mouths.

5 Basic steps towards Building with Nature

Related Tools

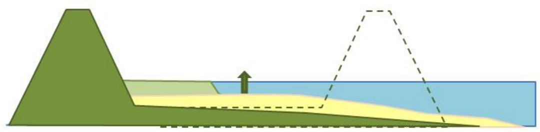
- Fibre-optic distributed temperature sensing for monitoring morphological changes
- Geographical data and knowledge management - OpenEarth
- Including natural value in decision-making - Nature Index
- Interactive Dredge Planning Tool - Singapore
- Interactive group modelling - MapTable
- Monitoring of coastal morphodynamics using satellite imagery
- Monitoring swimmer safety
- Nearshore wave transformation table
- Probabilistic analysis of ecological effects - Cause-effect chain modeling
- Probabilistic effect analysis - The Species Sensitivity Distribution
- Quick model set-up using open databases - DelftDashboard
- Roughness module for sediment dynamic modelling
- Species Response Curves for Seagrass

Related Projects

- Area development for sustainability - Wieringerrandmeer, NL

Areas that are of interest for the application of a coastal buffer zone are mostly low-lying areas where a secondary dike is already present for instance as remnant of former land reclamation. Some of these areas are dominated by salt water seepage which makes the land less valuable for other functions such as agriculture or housing. These areas are suitable for the application of a coastal buffer zone.

Managed realignment means a radical change for landowners, residents and people living in the surroundings of the area. Realignment, therefore, often leads to high controversy. For more information on management of the realignment process and social acceptance see Building with Nature Knowledge Base of Managed Realignment.



A schematic overview of the managed realignment concept. The dashed line represents the old dike.

Related pages

A more elaborate description of managed realignment practices is given in Building with Nature Knowledge Base of Managed Realignment. Two related Building Solutions are Coastal buffer zones and Inland shores. Habitat requirements of salt marshes are further described in the Building Solution Salt marshes.

Required skills

With this Building Solution description, anyone with a basic level of knowledge and/or working experience on coastal systems can make a first order assessment. To fully assess the potential for salt marsh development in the newly created area, one should consult the Building Solution Habitat requirements for salt marshes.

BwN interest

The added value of this Building Solution within BwN-type projects is that it enables the creation of coastal protection systems utilizing the ecosystem services of salt marshes. The Building Solution is mainly applicable in the planning and design phase.

Advantages

- Attenuation of wave energy by intertidal habitats. Waves reaching the shore are less powerful and sea defence can therefore be of reduced height and strength or even be absent
- Possible reduction of coastal defence costs mainly due to decreased maintenance and a lower allowable safety standard
- Provide long term reduced risk of flooding and coastal erosion, because salt marshes are able to grow with the sea level, given sufficient sediment is available
- Prevention of “coastal squeeze”, the reduction of foreshore as result of sea level rise, by removal of the sea defence; salt marshes are able to migrate shore wards with the rising sea level
- Provide a wide range of ecosystem services besides coastal protection like mitigation of CO_2 emissions, nutrient cycling, improvement of air and water quality, support of fish population for fisheries and contribution to an attractive landscape for visitors (Barbier et al., 2011)
- Creation of new intertidal habitats which are valuable from a conservation point of view for birds, fish, macrobenthos and the support of the estuarine food web
- Potential for recreation and aquaculture or cultivation of saline crops

Disadvantages

- Former land use has to give way. This is a radical change for landowners, residents and people in the surroundings that recreate in the area. Often realignment causes high (social and

Knowledge - Managed Realignment Schemes

Pioneer salt marsh restoration for coastal protection - Eastern Scheldt, NL

Sustainable development - Perkpolder ferry port, NL

Wetland Restoration - Wallasea, GB

political) controversy because of the resettlement that is involved and (agricultural) land is intentionally flooded by the sea. The choice of this measure therefore deserves careful consideration
- Relocation of houses, buildings and infrastructure is very costly
- Loss of agricultural land
- Managed realignment is a relatively young concept. There is little experience and knowledge on best practices and feasibility

How to Use

Once the dike is breached and the managed realigned area is subject to tidal influence, the area will start to develop. Development of salt marshes is crucial for two reasons. First, once salt marshes develop, large scale erosion is unlikely to occur. Salt marsh vegetation will enhance sedimentation and creation of the area that will reduce waves and improve safety. The second reason is that managed realignment is often used as nature development and compensation measure. This is aimed at creation of salt marshes because they are a valuable habitat that can support biodiversity and ecosystem services. The practice of managed realignment should therefore by aimed at the development of salt marsh vegetation. Several boundary conditions need to be met in order to be successful.

>> Read more

In the table below important boundary conditions as elevation, sediment load etc. for development of a managed realigned area are described. These boundary conditions can serve as guidance for area selection and design.

Criteria	Threshold	Habitat	Comments	References
Site selection	Location	Salt marsh	Formerly reclaimed land where salt marshes were present before embankment and where there is limited erosion (relatively sheltered) are most suited for managed realignment.	(French, 2006)
Site selection	Land use	Salt marsh	Areas which are relatively undisturbed in terms of geo-chemical soil conditions. For example a former meadow area is more likely to develop into a salt marsh than a ploughed field	(French, 2006)
Elevation	Mean High Water Spring-Mean High Water Neap	Salt marsh	Minimum of 400-500 inundations per year. From 1 m below MHWN colonization by pioneer vegetation takes place.	(Toft & Maddell, 1995; French, 2008)
	Mean High Water Neap-Mean Low Water Spring	Intertidal flat		
Slope	Possible:0-7% (1:0-1:18) Optimal: 1-2% (1:0-1:64)	Salt marsh	Slope determines the drainage. A gentle slope in seawards direction reduces flow velocity and enhances sedimentation.	(Burd, 1995)
Size	Fetch < 2000 m	Salt marsh Intertidal flat	The "fetch" (length or width) and depth are determining for the degree in which waves can develop and cause resuspension of sediment. A study by French et al. (2000) describes erosion of 10 mm/year in realignment areas with a fetch of 2000 m and sedimentation of 7-16 mm/year with fetch 400 m.	(French et al., 2000)
Shape	Length/width ratio	Salt marsh Intertidal flat	An elongated area that is far more deep than wide supposedly has a lower initial accretion, because most of the sediment has settled by the time the tide has traveled to the back of the area.	(Van Oevelen et al., 2000)
Suspended sediment	1-10 mg/l survival 10-100 mg/l growth	Salt marsh	Survival of salt marshes depends on the degree of sea level rise. Besides the suspended sediment concentration the sedimentation rate also depends on elevation of the area which determines the water depth and plant characteristics/age of the salt marsh and estuarine characteristics (river discharge and tide).	(Borsje et al., 2011; Li & Yang, 2009; Temmerman et al., 2004)

Safety standards

The coastal buffer zone can face a higher flood risk. Where flood risk standards for inhabited areas are set to 1/4000 year or even 1/10.000 year, a standard of 1/100 or even 1/50 is allowable in the buffer zone. This will reduce costs on dike maintenance and strengthening considerably.

Costs

Costs of managed realignment sites widely differ and there is no standard guideline that indicates costs. This is because the concept is still young and few data are available but also because of many variables that influence costs. Breached realignment is the most frequently used method and is therefore elaborated here. Numerous factors can influence costs of a breached realignment site, for example:

- Land of construction (costs of realignment in development countries are lower than in developed countries)
- Costs of the inland area that will be re-inundated
- Compensation to land owners
- Costs for dismantling buildings, roads etc.
- Costs for a new inland sea defence

The table below gives an indication of costs of managed realignment sites in the Humber estuary. Based on these examples costs of a breached realignment site are roughly €100.000 per hectare on average. These costs include the construction of a new inland sea defence.

Costs of breached realignment sites in the Humber estuary (UK) according to IECS (2008)

Breached realignment sites	Area (ha)	Costs (€)	Costs per hectare (€/ha)
Chowder Ness (2006)	18,5	1.253.552	67.759
Paul Home Strays (2003)	45	8.855.541	198.789
Alkborough (2006)	440	12.20.286	27.741

Salt marshes attenuate wave energy, therefore the new inland dike can be less strong and high and maintenance costs are reduced. Maintenance cost savings will vary from site to site according to wave climate, coastal topography and consequent defence works (Turner et al., 2007). The table below shows how salt marshes before the sea defence influence dike height and costs involved based on a report by the English Environment Agency (2006).

Relation between salt marshes and dike costs in the UK, based on EA (1996)

Salt marshes before dike (m)	Dike height (m)	Costs of sea wall (€/m)
0	12	6000
6	6	1800
30	5	960
60	4	600
80	3	480

A study by Hillen et al. (2010) describes the costs for heightening dikes in the Netherlands based on several studies:

- 9-11 M€/km for 1 metre higher in rural areas
- 13,8-21,6 M€/km for 1 metre higher in urban areas

Maintenance costs of dikes are estimated at 0,1 M€/km/year in the Netherlands (ACPM, 2006).

Benefits: ecosystem services and multifunctional use

Besides sea defence, managed realignment sites also provide other goods and services (ecosystem services) and have potential for multifunctional use as recreation, aquaculture and cultivation of saline crops. A study by De Mesel et al. (2013) describes several forms of aquaculture and cultivation of saline crops that are possible in a re-inundated saltwater tidal area. As the main goal of a realigned area is elevation increase by sedimentation, land use forms should be extensive without hampering the sedimentation process. The potential benefits of aquaculture is described in the Building Solution Coastal Buffer Zone.

Practical Applications

Design can greatly differ amongst managed realignment sites, depending on goals (coastal protection, nature development, retention) and specific local conditions. Pontee (2007) distinguishes three main categories:

1. banked realignment
2. breached realignment
3. regulated tidal exchange

Two other related applications are described in separate Building Solutions:

1. Coastal buffer zones, or "inlaag", as traditionally used in the Southwest Delta of the Netherlands
2. Inland shores, recently applied along the coast of Lake IJsselmeer in the Netherlands.

>> Read more

Banked realignment

Banked realignment concerns complete dike removal. With this measure a fully open connection with the estuarine or marine environment is restored. It is also helpful in creating more water storage capacity, for example in narrow river mouths. However this design is not often used because of the high costs involved in dike removal. Also lack of shelter can cause erosion that prevents salt marsh development and a higher wave attack on the new inland dike. The Welwick site along the Humber Estuary in North England is one of the few examples where complete dike removal took place (Pontee, 2007) and 1400 m dike was removed. This was done to enhance and maintain mudflat formation which was the main goal. Banked realignment enables higher water movement levels within the site with the absence of the formal sea defence, thereby improving the probability that mudflat habitat will be maintained (Institute of Estuarine & Coastal Studies, 2008).

Welwick Realignment Scheme

Paul Holme Strays Managed realignment

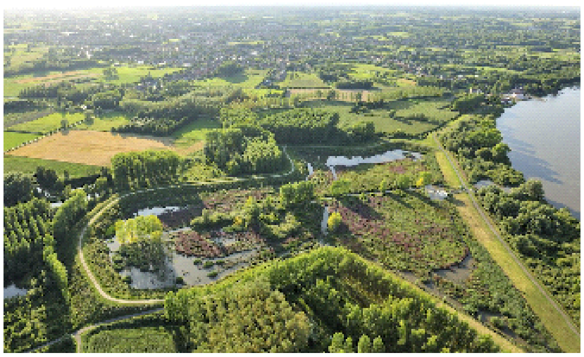
Breached realignment

With this method the coastal defence is maintained and foreseen with one or more inlets depending on the size and shape of the area. This method concerns less excavation then banked realignment and provides more shelter to the re-inundated area which limits erosion and impact on the secondary dike by reducing wave energy. In the Humber estuary coastal management applies breached realignment at several sites to enhance coastal protection and mitigate for coastal squeeze. The interaction with the estuarine ecosystem, however, is more limited. The inlet design is determining water flow and volumes. The width of the inlet should at least be broader than the width of the main ebb tidal gullies in the area. Previous experience showed that if inlets are too narrow, high flow velocities occur which can damage the breached dike (Dixon et al., 2008). A study by Townsend (2008) describes a method for inlet design that is based on the maximum allowed flow velocity before erosion occurs, the elevation of the area in regard to sea level and current conditions. Also the orientation of the inlet can influence the tidal energy and flow velocities coming into the area (Van Oevelen et al., 2000).

Case - Wetland Restoration Wallasea

Case - Perkpolder

Regulated tidal exchange



Lippenbroek Regulated Tidal Exchange

Use of a culvert/sluice system in the coastal defence enables regulated tidal exchange to the re-inundated area. A high level and low level sluice in the dike enable inflow during high tide and discharge during low tide. The position of the sluices in the dike determines the tidal regime in the area. In a river mouth where fresh as well as salt water influence is present the sluice positioning and design can also determine water quality (salinity and nutrient) inflow (Maris et al., 2007) and determines the amount of water and sediment inflow. Regulated tidal exchange is mainly used for water retention motives, for example along the freshwater tidal zone of the Scheldt estuary (Belgium), where more retention is created by allowing reduced tide and dike overflow at several sites along the estuary. The potential of these sites concerning sedimentation and the ability of the area to grow with sea level rise also looks promising. By limiting currents and wave action, limited erosion occurs (Peeters et al., 2009). Because water depth is not determined by the natural feedback (increase of elevation means decrease in water depth when inundating) but remains constant, continuous high sedimentation rates are possible (Vandenbruwaene et al., 2011). Vandenbruwaene et al. (2011) calculated that an area with regulated tidal exchange could grow up to 2-2,5 times faster than a natural salt marsh over 75 years. Drawbacks are high construction costs due to the sluices and limited exchange with the estuarine ecosystem.

>> References

Literature

- ACPM (2006), Tussensprint naar 2015 – advies over de financiering van primaire waterkeringen voor de bescherming van Nederland tegen overstromingen., Advisory Committee Primary Waterdefences.
- Barbier, E.B., Hacker S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R. (2011), The value of estuarine and coastal ecosystem services. Ecological Monographs 81(2): 169-193.
- Borsje, B.W., Van Wesenbeeck, B.K., Dekker, F., Paalvast, P., Bouma, T.J., Van Katwijk, M.M., De Vries, M.B. (2011), How ecological engineering can serve in coastal protection. Ecological Engineering 37: 122.
- Burd, F.H. (1995), Managed retreat: a practical guide. Peterborough, English Nature.
- De Mesel, I., Ysebaert, T., Kamermans, P. (2013), Klimaatbestendige dijken: het concept wisselpolders. IMARES Wageningen UR C072/13. (in Dutch)
- Dixon, M., Morris, R.K.A., et al. (2008), Managed realignment: lessons from Wallasea, UK. Proceedings of the Institution of Civil Engineers 161(2): 61-71.
- EA (1996), East Anglican salt Marshes - The meadows of the Sea. Peterborogh, Environment Agency.
- French, C.E., French, J.R., Clifford, N.J., Watson, C.J. (2000), Sedimentation-erosion dynamics of abandoned reclamations: the role of waves and tides. Continental Shelf Research 20: 1711-1733.

- French, J.R. (2008), Hydrodynamic Modelling of Estuarine Flood Defence Realignment as an Adaptive Management Response to Sea-Level Rise. Journal of Coastal Research 24(2B): 1-12.
- French, P.W. (2006), Managed realignment - The developing story of a comparatively new approach to soft engineering. Estuarine, Coastal and Shelf Science 67: 409-423.
- Garbutt, A. (2008), Restoration of intertidal habitats by the managed realignment of coastal defences, UK. ‘Dunes and Estuaries 2005’ – International Conference on Nature Restoration Practices in European Coastal Habitats, Koksijde, Belgium.
- Goosen, H. (1999), Toward a saline alternative; using halphytes for sustainable agriculture. Amsterdam, Institute for Environmental Studies, Vrije Universiteit Amsterdam.
- Hillen, M.M., Jonkman, S.N., et al. (2010), Coastal Defence Cost Estimations. Case Study of the Netherlands, New Orleans and Vietnam., TU Delft.
- Institute of Estuarine & Coastal Studies (2008), Managed Realignment in the Humber Estuary, UK. UK, University of Hull.
- Li, H., Yang, S.L. (2009), Trapping Effect of Tidal marsh Vegetation on Suspended Sediment, Yangtze Delta. Journal of Coastal Research 25(4): 915-924.
- Maris, T., Cox, T., Temmerman, S., De Vleeschauwer, P., Van Damme, S., De Mulder, T., Van den Bergh, E., Meire, P. (2007), Tuning the tide: creating ecological conditions for tidal marsh development in a flood control area. Hydrobiologia 588: 31-43.
- Peeters, P., Claeys, S. et al. (2009), Sediment behaviour within a flood control area with a controlled reduced tide - pilot project Lippenbroek. Congrès SHF-31ième Journées de l'hydraulique: "Morphodynamiques et débits solides dans les estuaires, les baies et les deltas" Paris: 1-15.
- Pontee, N.I. (2007), Realignment in Low-lying coastal areas. Proceedings of the Institution of Civil Engineers 160(4): 155-166.
- Temmerman, S., Govers, G., Wartel, S., Meire, P. (2004), Modelling estuarine variations in tidal marsh sedimentation: response to changing sea level and suspended sediment concentrations. Marine Geology 212: 1-19.
- Toft, A.R., Maddell, R.J. (1995), A guide to the understanding and management of salt marshes. Peterborough, NRA.
- Townsend, I.H. (2008), Breach design for managed realignment. Proceedings of the Institution of Civil Engineers 161(1): 9-21.
- Turner, R.K., Burgess, D., Hadley, D., Coombes, E., Jackson, N. (2007). A cost-benefit appraisal of coastal managed realignment policy. Global Environmental Change-Human and Policy Dimensions 17(3-4): 397-407.
- Van de Voort, M.P.J., Dekking, A.J.G., et al. (2005), Scenariostudie Zuidwestelijke Delta IV-V: Perspectieven alternatieve bedrijfsvormen, Praktijkonderzoek Plant & Omgeving, Wageningen UR: 54.
- Van Oevelen, D., Van den Bergh, E., et al. (2000), Literatuuronderzoek naar ontpolderingen: 50 pp.
- Vandenbruwaene, W., Maris, T., Cox, T.J.S., Cahoon, D.R., Meire, P., Temmermans, S. (2011), Sedimentation and response to sea-level rise of a restored marsh with reduced tidal exchange: comparison with a natural tidal marsh. Geomorphology 130(3/4): 115-126.