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Contaminated Dredged Material: Building Material of the Future?

An Investigation into Building Mounds of Dredged Material in The Netherlands

Abstract

The Dutch Department of Water Management (Rijkswaterstaat) is developing an innovative concept: building mounds (*terpen*) of dredged material. *Terpen* or mounds were common in Holland centuries ago: man-made mounds a few metres high that were placed as a protection against the sea.

Climate change, rising sea levels, and falling land levels mean that The Netherlands is still challenged to keep the country safe and dry. In addition modern water management and water safety must ensure that waterways are deep enough to keep the functionality (shipping, discharge of rain water) of the water systems intact. Maintenance through the removal of dredged sediment from ports, canals, and rivers is an ongoing necessity, with millions of cubic metres of often contaminated dredged sediment being removed annually.

For this reason, the traditional "mound solution" may be ready to make a come back. Modern mounds made of (contaminated) dredged material create a beneficial use: on the one hand, mounds offer protection against flooding and, on the other, they provide a final destination for dredged material which allows dredging to be continued.

At the initiative of the Dutch Department of Water Management several activities are in progress to involve stakeholders, and competitions have been organised to find possible placement sights for the mounds. The article describes the competitions conducted and the studies which have been done to develop the concept.

Introduction

How is it possible to contribute to the beneficial use of contaminated sediment and at the same time offer better protection against flooding? The building of mounds of contaminated dredged material appears to be a promising partial solution. Since 2004 a project team of WINN, the water innovation programme of Rijkswaterstaat, the Dutch Directorate for Public Works and Water Management, has been working with market players with the intention of accomplishing these two things simultaneously by creating new high-lying land in lowland areas.

To this end, they have organised "competitions for the best ideas" amongst market players (e.g. landscape architects), as well as secondary school students. The result is a number of interesting and innovative ideas which merit further investigation. To turn words into actions, Rijkswaterstaat is looking for a location for a pilot mound of at least 25,000 m^3 of dredged material.

The Mound Is Back

For centuries high-lying land has been the ideal protection against flooding. In the event of an emergency caused by high water, damage is limited and there are no casualties. Dyke rings in The Netherlands consist primarily of flood defences – designed to withstand floods with an exceedance probability of 1:1250 to 1:10,000 per year – and high-lying land. Climate change, the rising sea level and tectonic subsidence of the land mean that dry feet can no longer be taken for granted (Figure 1).

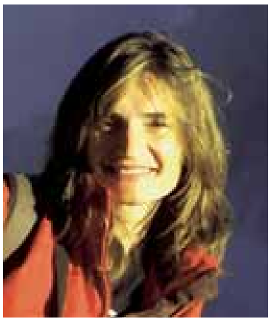

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Figure 1. The mound of Hogebeintum, built in the 5th century BC, with its 8.8 metres above sea level, is officially the highest mound in The Netherlands. The reason for the height of the mound is not quite clear, as a mound half as high would have served the purpose of flood prevention. In the 20th century this mound has been partly dug away as the ground was very fertile and was sold as fertilizer. This has been the fate of many Dutch mounds.

The re-introduction of mounds could provide a means to reduce the risk of flooding. Mounds can be made from clean and contaminated dredged material from waterways and flood plains. Since The Netherlands, like many other countries, is battling against a shortage of destinations, in particular, for contaminated dredging material, the new mounds could solve two problems at one time.

Solutions for contaminated dredged material arouse a great deal of NIMBY (not in my back yard) feelings. The building of mounds by local dredging is a good way of getting rid of sludge in the local area in an economic and lasting manner. In addition, mounds offer the local council a large number of interesting possibilities. In principle, living, working and recreation on the top of a mound are all possible. But the use of *contaminated* dredged material as a building material demands a revolution in thinking.

What is required is a change of attitude from NIMBY to PIMBY (please in my back yard).

The WINN Project "Mounds of Dredged Material"

The "Mounds of dredged material" project is managed by WINN, an innovative programme of Rijkswaterstaat. Within WINN (www.waterinnovationbron.nl), Rijkswaterstaat (RWS) together with the public in general, is looking for ingenious, long-term solutions for the optimal use of water and the Dutch water-based infrastructure. This innovative programme aims to give impulse to new land use, while at the same time guaranteeing the safety of waterway systems.

Dialogue and co-operation are sought with external partners, such as waterway users, lobbying organisations, market players, experts, architects, people in the advertising and art world, and secondary school and university students. The working method of the programme involves consideration of concrete test projects and demonstrations on the basis of long-term perspectives. Apart from offering the chance for technical innovations, this also provides an opportunity to discuss how RWS is to carry out its functions in the future.

Feasibility of Mounds of Dredged Material

In an in-house preliminary study RWS examined the technical, environmental and legal consequences of building mounds of dredged material. An exploratory investigation was also carried out into the perceptions and opinions of citizens and organisations in the Gelderland (a province of The Netherlands) river area.

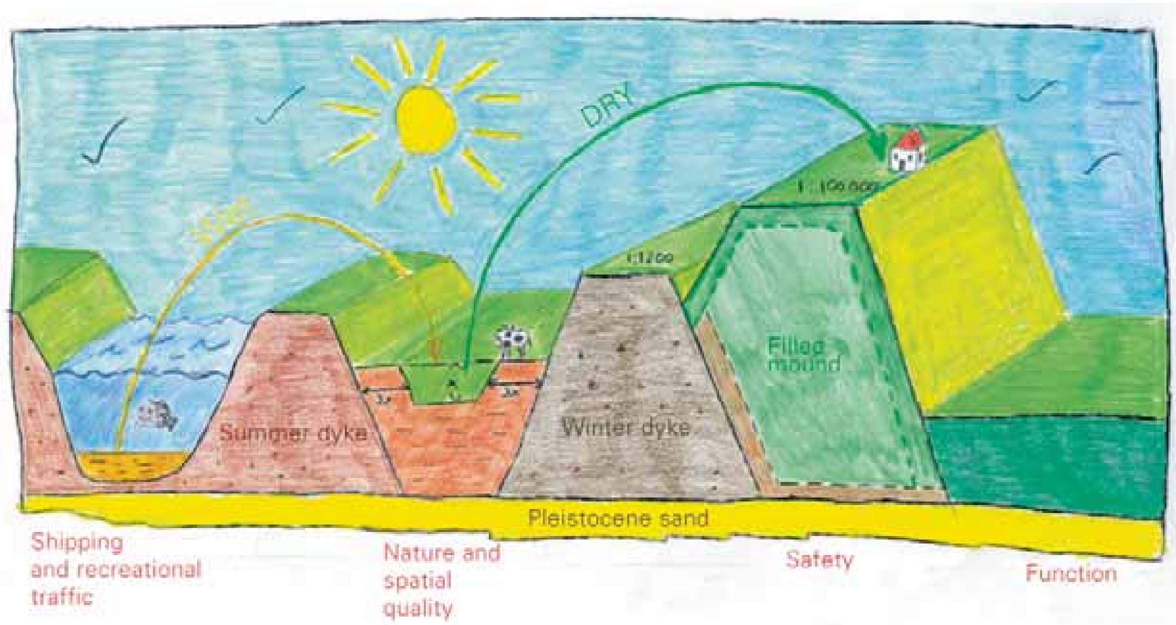

Figure 2. The filled mound (omputterp) drawn adjacent to the winter dyke.

Alternatives
A number of technical alternatives have been investigated and selected based on defined stipulations. These stipulations are divided into "must have" requirements, with which every alternative has to comply, and "desirable" aspects, for which the alternative concepts can win extra points to variable degrees. The "must have" requirements and other desirable aspects are listed below.

Requirements:
- The mound must be realised within 1 year.
- The mound must have a recreational function within 3 years after construction.
- The mound must have a living function within 5 years after construction.
- The mound must be constructed with wet contaminated (class III as minimum) dredged material.
- The costs must be less than Euro 30 per tonne dry material. This amount is a reference amount based on cost estimation where dredging, transport, engineering, and construction costs, including VAT, of a mound of 150.000 m^3 are included; real estate costs are excluded.
- The mound must be safe with respect to flooding and to the contaminated dredged material.

Desirable aspects:
- The effects on LNC-values (landscape, nature and culture values) during the execution and the exploitation should be as minimal as possible.
- Potential for scale up, large volume of contaminated dredged material should exist.
- The mound should have a self-cleaning effect.
- After 5 years, the pumping of the water consolidation should no longer be necessary.
- It should be possible to construct the mound with all types of material, i.e. a specific fixed degree of sand content or degree of contamination should not be fixed.
- The mound should be construct in one go, wet material should be processed in the mound in one step.

All alternatives are based on the assumption of a mound with a net volume of 150,000 m^3.

The technical investigations demonstrated that the so-called filled hill or mound (*omputterp*) was the best alternative by far.

The central thought is that the (relatively solid) material from the flood plains can be built up into a mound in one go. This material can be heaped up easily to a height above that of a dyke and therefore contribute to safety conditions (probability of flood: 1/100.000 per year) and also be used for the function of housing immediately. The "hole" in the flood plain will be not deeper than 10 metre, according to Dutch legislation (Ontgrondingwet) and not wider than the stability of the summer and winter dykes allow. The "hole" is filled with material from the river. This material is wet and, depending on the intended spatial quality and nature, should be built up in varying heights to ground level.

In Figure 2, the filled mound (*omputterp*) is drawn adjacent to the winter dyke.

The second alternative is "Concentric Sedimentation Basins". Sand, silt and water deposits are formed into concentric rings. Wet sludge is pumped into the heart of the mound and the sand (the coarse fraction) is deposited in the inner ring. The coarse fraction

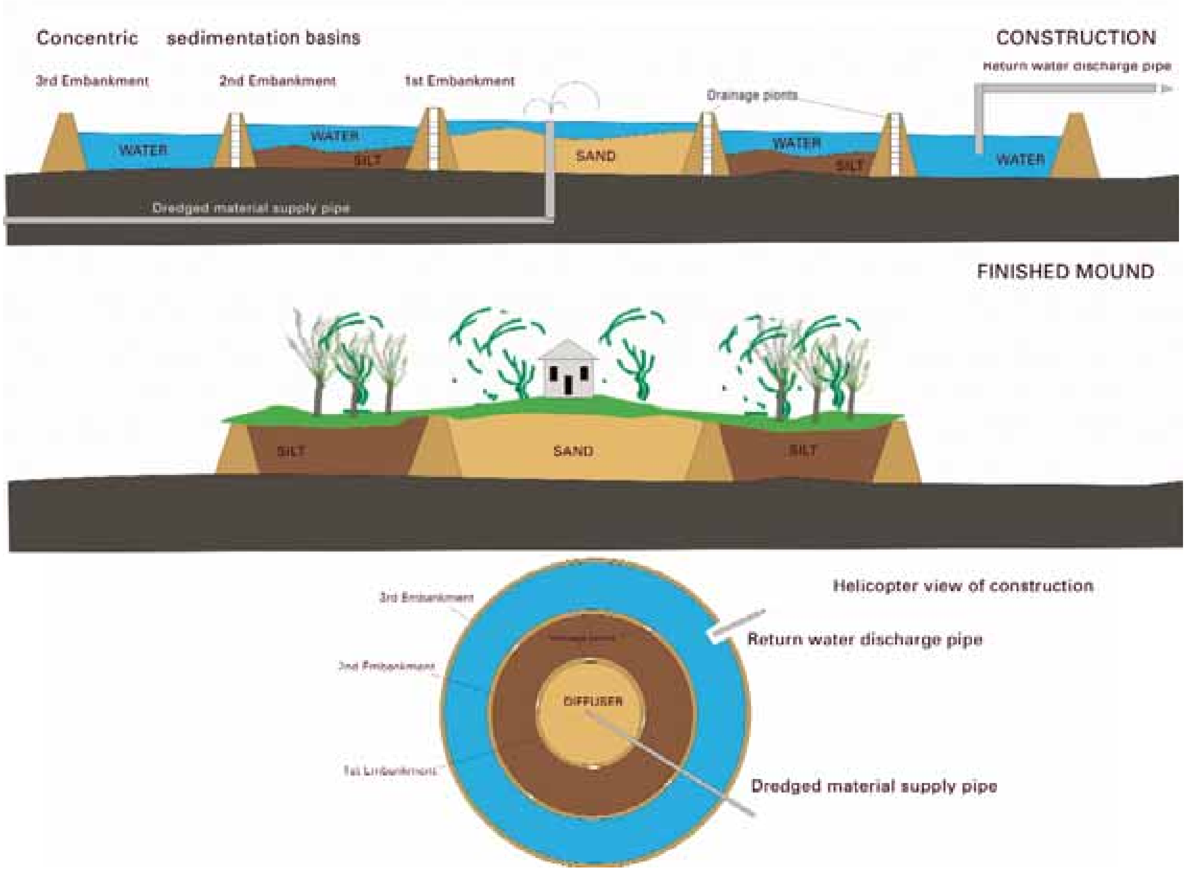

Figure 3. Concentric Sedimentation Basins (not in scale).

consolidates fast and quickly reaches the bearing power for functions as living and recreation. Next to the improvement of the physical quality, an improvement of the chemical quality occurs as well, because the contaminated material sticks more to fine than to coarse parts. Via the drainage points in the sand dump the sludge moves into the next ring where it can sink and consolidate. Here, the consolidation process is longer because the silt contains water binding parts (see Figure 3).

The dewatering process can be accelerated by means of plants. By aeration and plantation, the organic contamination can break down. The anorganic pollutants (heavy metals) stick to the fine parts (clay minerals), as a result of that the emission in the ground decreases. The process water flows over into the provisional outermost ring and can be purified with helofytes. The water, then, will be pumped out the ring and deposited into the surface water. For the process to work well a sand fraction of 50% is required.

This alternative can be optimalised depending on the quality of the material. For example, if the dredged material is rich in silt then the silt ring can be divided in two or three zones (rings). Per zone, the thickness of the layer and the planting can be decided based on the specific requirements: how fine the silt, how thin the layer.

The investment costs of these two types of mound (in Figures 2 and 3) are comparable with the cost of a traditional mound built with primary material such as sand and clay. The benefits of both alternatives are:

- non-use of primary materials;
- no transport and dumping costs of dredged materials; and
- the possibility of subsidies.

Another innovative alternative which was considered is a mound of geotextile tubes. A series of tubes in layers are filled with dredged material (see Figure 4).

During filling, the geotextile tube is pressurised with the soil-water mixture, allowing discharge of the liquid through the fabric pores but retaining the solid particles. The result is a "soil sausage" with lower water content and correspondingly higher percent solids. Succeeding layers of geotextile tubes are placed parallel to the lower layer. The upper layer geotextile tubes can be placed along the gap of the lower layer in a brick-laying pattern or a pyramid pattern. This results in a solid compartmented volume of dredged material.

During the filling, bacteria can be added to the dredged material to break down the organic pollutions. This alternative, although very interesting, cannot compete with the above described two other alternatives because of its higher costs.

Legislation

An important factor in the creation of a mound of dredged material is the question of which legal framework is applicable. For dredged material there is a limited order of destinations:

- sustainable relocation;
- beneficial use (directly and by treatment); and
- confined disposal.

The mound as a beneficial use
At the moment there is a great deal of discussion and difference of opinion about in which order destinations should be implemented. The question of whether a layer of dredged material in a mound should be seen as soil, beneficial use or dumping is an urgent matter of discussion. The challenge is to consider mounds not as dumping sites, but as a beneficial use. This assumption must then be tested against the Building Materials Decree.

Building Materials Decree
In the Dutch situation all dredged material is regarded as waste if there is a need for disposal. Based upon the quality, the dredged material is divided into classes. The quality of the diffusive contaminated aquatic soils is judged by comparing total amounts of contaminants in the sediment with target levels. Depending on the most abundant contaminant the contaminated aquatic soil is categorised as class I, II, III or IV. If all contaminant-concentration are below the target level the sediments are not polluted and categorised as class 0. Class 0 is then clean material (target-values are not exceeded); Class I and II are regarded as slightly polluted and classes III and IV are heavily polluted.

The use (on land and in water) of secondary construction materials (excavated soil included) is regulated by means of the "Building Materials Decree (BMD, Bouwstoffenbesluit)". According to the existing legislation, it is currently only possible to build a mound with clean (class 0) or slightly contaminated (classes I and II) and solid (not fluid) dredged material. If sludge with a higher contamination rate can comply with the requirements of the Building Materials Decree, then it may be considered for the building of a mound.
In practice this is most often class III based on metals.

Although the introduction of the categorisation of dredged material by class has proven to be very useful in the development of water soil management, at present the relation between classes and the order of destinations needs to be revised.

Dredged materials have been categorised based on toxic aspects but the characteristics of the ground and the environmental conditions influence the behaviour of substances. With present-day knowledge, a risk approach should be found based on toxicity in relation to function: in other words look at the absolute measured contents of the dredged material and add other characteristics such as the percentage of sand, the level of acidity and the redox potential of the system. A similar approach (dynamic approach) allows bottlenecks to be removed at a policy level.

Broad Social Discussion Through "Best Ideas" Competition

In order to use the creativity and inventiveness of the marketplace in the development of the concept of mounds of dredged material, RWS organised a "best ideas" competition. The competition attracted some 38 entries. Participants included engineering companies, architects, landscape architects and private individuals. An external commission was formed consisting of experts from outside RWS and representing the most relevant disciplines such as engineering, landscape architecture, architecture and civil administration. The external commission chose the three best entries from ten entries selected by an internal commission. Prizes were awarded in the categories of most technically innovative, the most promising with respect to future expectations and finally the one with the highest PIMBY content. The latter stood for aspects that made the mound attractive and desirable with respect to environmental impact, good integration into the landscape and functionality of the mound.

Three Winners of the Competition

Watertight
The prize for the idea with the most technically innova-

Figure 4. Refillable geotextile tubes used to build a mound.

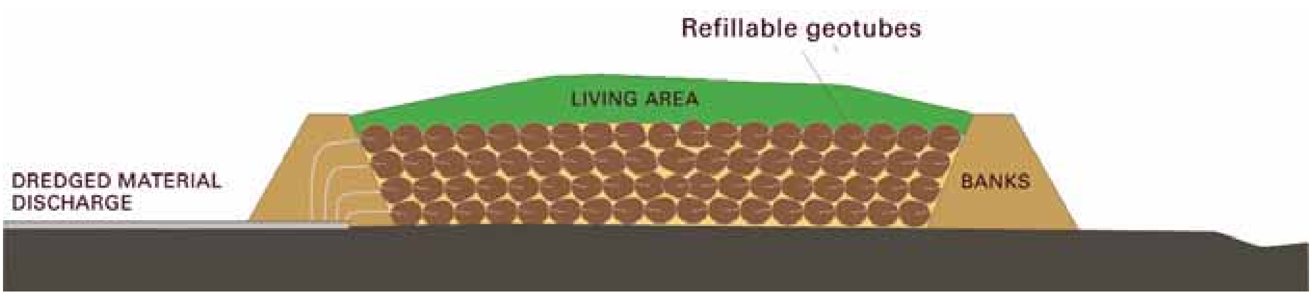

Figure 5. The "Watertight" design includes layered, compartmentalised embankments, partially made from dredged materials. These embankments allow better control of flood zones.

tive content was for the "Watertight" idea from the consortium of Robbert de Koning landscape architect, DIN Arch, Dura Vermeer and Alterra Wageningen. The idea, which was found to be intellectually innovative, includes the adaptation of layered compartmentalised embankments in areas likely to be flooded such as flood plains. These embankments are partially made from dredged material from flood plains and ditches. The embankments have a useful function in that flooding can be better controlled and the river area will fill up more slowly. On these embankments houses or a recreational area can be built. According to the commission the idea would contribute to making the inhabitants more aware of the flood risk in The Netherlands.

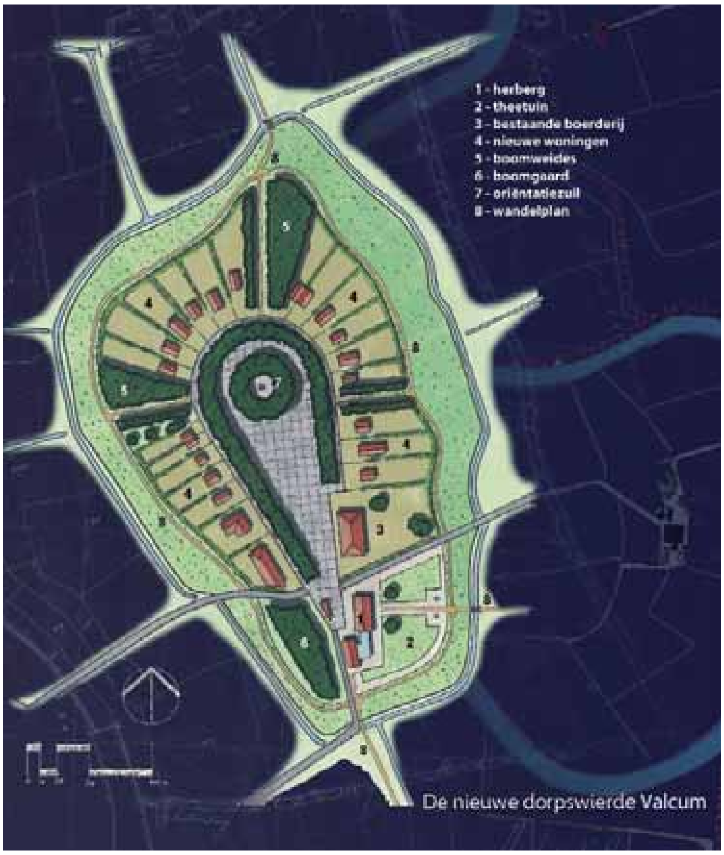

Figure 6. The "Werk met werk" idea creates a village on a mound, higher than the flood line, instead of living at a low level inside the protection of dyke walls.

"Werk met werk in het kwadraat" (Work with work squared)

The commission found that the most promising entry for the future was 'Werk met werk in het kwadraat' by Grontmij Nederland BV. This idea comprises the construction of a village on a mound where it would integrate easily into the Groningen (eastern Netherlands) landscape. The idea was found attractive most of all because it could be fully adapted as a solution for the high water problem. This plan changed the concept of "living in an area protected by dykes" to "living safely high on a mound and be less dependent on the height of the dyke". In view of the agreement made with local parties in the province of Groningen the idea has considerable promise. It offers the opportunity for a concrete project to act as an example for other areas of The Netherlands.

"Spaarkaart"

"Spaarkaart" (Savings card) by Arcadis, Attika, Attika & Park was the winning entry in the PIMBY category. The idea was appealing because it contained two complementary concepts – living mounds and a multi-functional mound landscape – which differ according to scale and time horizon. The living mound concerns the implementation of earth-wall homes with a back garden in which the function of nature is central.
An existing dyke is widened into a mound that is filled with local sludge in phases. The mound with housing is developed over a period of three to ten years. There is room for approximately 85,000 m^3 sludge.

For the development of a multifunctional mound landscape 30 years is required. The sludge is required for the construction of an arbitrary area, whether it is deep polders or water-rich landscapes with mounds. The focus is directed towards areas where flooding is unavoidable. In 20 years new use of space will be created with about 1,000,000 m^3 sludge. In the opinion of the commission the idea would fit in very well with a project such as "Room for the River", which is a project directed towards finding new approaches to give rivers the space they need to handle larger volumes of water while improving surrounding land areas. Instead of continuing to raise and strengthen dykes the project is

Figure 7. The two-stage idea of "Spaarkaart" is (left) over 3 to 10 years widening an existing dyke into a mound with earth-wall homes; and (right) a longer term (20 to 30 years) multifunctional mound where some 1,000,000 m^3 sludge are utilised.

concerned with the possibility of giving water more room by shifting dikes farther away from riverbanks, lowering flood plains, removing obstacles, even houses, from the flood plains, and creating new inundation areas.

Youth and Opportunities for Mounds

In order to involve tomorrow's citizens in a public discussion about dredged sediment as a new building material, RWS organised a competition for 15 and 16 year old high school pupils. They were asked to act as project developers and design their own PIMBY mounds from contaminated dredged material.
Before their participation in the school competition to design a mound made of dredged material, the majority of pupils reacted with "No way".

Thirteen school classes took part in the RWS competition. The pupils concentrated on thinking about the functions of the mounds such as a shopping mall, ski slope and a children's farm. The competition generated publicity that contributed to the discussion about mounds made from dredged material. In addition the participants increased their knowledge about mounds. Opinion was divided about how they expected social support to be created for the mounds of dredged material. It ranged from consideration of the necessity to give local sludge a useful application to secrecy about the use of the sludge.

Further information about both these "best ideas" competitions can be found on the web site of WINN, the water innovation programme of Rijkswaterstaat: www.waterinnovatiebron.nl or by contacting the authors [p.bernardini@bwd.rws.minvenw.nl] and [j.d.vduijvenbode@bwd.rws.minvenw.nl]

2005/2006 Pilot Mound

As a follow-up to these competitions for generating new ideas, RWS now needs to get practical experience with the construction of dredged material mounds. This includes adapting the ideas derived from the marketplaces competition into building a pilot mound and by investigating all sorts of technical aspects such as working with wet sludge. RWS is therefore looking for suitable locations. There is currently a list of potential locations where both aspects of the PIMBY mound could be implemented. This would mean a solution to possible flooding as well as the use of locally dredged material as building material for the mound. Recently RWS signed a letter of intent with Zeeland to start implementation of a pilot project in 2005/2006. Other locations are also being sought.

Conclusions

An exploratory investigation was carried out amongst the public and organisations in the Gelderland river area, in which the idea of mounds of dredged material was proposed. This included competitions for new ideas of how to build mounds from dredged materials. In view of the limited scope and restricted area of the study it is difficult to come to firm conclusions. However, since mounds have been a feature of the Dutch landscape for a long time, the idea of building mounds in general was well received by the population. The location, size, height and the use of the mound must be precisely defined. Some respondents thought that living on a mound would afford them a good view over the land. Local councils and the water authority expect a great deal of opposition from the population, based amongst other things on the fear of contamination.

The effort of RWS to find solutions to the continuing problem of disposal of contaminated dredged materials is a significant step in the right direction. Given the new EU Water Frame Directive, similar problems exist throughout Europe. The public relations efforts of RWS to involve the population, engineers and others in related disciplines, as well as the youth, to find future solutions should set an example for other nations facing similar disposal situations, where maintenance dredging through the removal of sediment from ports, canals, and rivers is an ongoing necessity.