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WATERFRONT DEVELOPMENTS IN HARMONY WITH NATURE

ABSTRACT

The main development theme in many coastal countries is to utilise the attractiveness of water in a broad context. The emphasis has shifted from coastal protection to the development of coastal communities, with coastal resorts along existing coastlines. Waterfront developments as such are considered to be artificial pieces of new nature. The artificial beaches and lagoons, however, do not know that they are artificial. Consequently, these landscape elements will follow the natural marine and coastal processes resulting from the characteristics of the hydrodynamic forces on the coastal sediments, flushing and pollution loading to which they are exposed following construction. Therefore, understanding the prevailing natural processes responsible for creating attractive waterfront, beach and lagoon environments as a basis for the design of well-functioning artificial coastal and marine elements is essential.

This article focuses on providing a basic understanding of how to develop well-functioning coastal and offshore developments with regard to the hydraulic issues – for some the most desired elements in the modern waterfront developments, beaches and lagoons. Design guidelines for *artificial beaches* and for *artificial lagoons* will be presented as well as guidelines for *recreational and landscape elements of coastal developments*. A holistic design of the new Amager Beach Park in Copenhagen is presented as an example of how a successful collaboration between the coastal engineer and the architect can lead to a sustainable new coastal landscape. Finally, a new type of offshore development scheme is presented, where the main idea is the development of an exposed crescent-shaped bay with a high quality beach, which could form the backbone for development of a coastal promenade.
All photographs accompanying this article are by DHI or Hasløv & Kjærsgaard.

INTRODUCTION

The art in developing waterfront projects is to utilise the possibilities provided at a specific site to the benefit of the project, i.e., to integrate the possibilities provided by the marine environment with the demands of society. The art is to perceive the marine forces, such as waves and tides, as external opportunities to be used to maintain high quality artificial beaches and lagoons, contrary to the traditional approach of perceiving these external forces as problem generators, against which protection is required. The article is divided in the following sections:

- Characteristics of natural landscape elements
- Design guidelines for artificial beaches
- Design guidelines for artificial lagoons
- Landscape elements of coastal and offshore developments and their hydraulic design
- Example of beach park development
- Presentation of a new concept for an offshore development scheme

Above, Attractive natural, beaches such as the Skaw Spit in Denmark benefit from the natural wave action that keeps them clean and sandy.

CHARACTERISTICS OF NATURAL LANDSCAPE ELEMENTS

Characteristics of natural beaches

Attractive and safe recreational beaches are always characterised by their exposure to moderate wave action, the tide is micro to moderate (tidal range < ~1.5 m), clean and transparent water, no rock outcrops, well sorted medium sand and minimal amounts of natural and artificial debris.

Figure 1. Other examples of attractive natural beaches with exposure to waves. Left: NW Mediterranean coast in Egypt. Right: Sunset Beach in Dubai, UAE.

Examples of attractive natural beaches are presented in Figure 1. These beaches are all characterised by their exposure to waves, their clean beach sand and their clean water. The type and colour of the sand is different, but all types are natural beach sand of great beauty and recreational value. The exposed beaches have a sandy and clean appearance owing to the wave action which prevents settlement of fine sediments and organic matter. However, there are also many examples of good quality beaches along coasts, where the water contains high amounts of suspended sediments, at least during the rainy season and/or during rough weather. This is, e.g., the situation along Malaysia's East coast and along Sri Lanka's entire coastline. These beaches also remain clean and sandy, because they too are exposed to waves.

Natural beaches develop differently when they are lacking wave exposure. This is clearly seen in the examples presented in Figure 2 and Figure 3. These examples of exposed and protected natural beaches demonstrate that wave exposure is of paramount importance for the type of natural beach which develops in an area.

Clearly, one of the main hazards in relation to developing attractive artificial sandy beaches is lack of wave exposure. Lack of wave exposure on an artificial beach will allow settlement of suspended matter on the seabed and on the beach, also in cases where the beaches have been built of clean sand. This will, with time, lead to the seabed being covered with a layer of soft sediment. Though this is a natural process, it is the main reason for poor quality of beaches found in protected environments. Such beaches feel muddy when walking on them, which is unattractive for recreational beaches.

Characteristics of natural lagoons

Natural lagoons are attractive from a recreational point of view owing mainly to the open water body they offer and not their beaches, which are normally of poor

Figure 2. Beaches lacking wave exposure. Left: Beach in a natural lagoon in the UAE, which suffers from algae and deposition of fine sediments. Right: "Beaches" in Dubai Creek.

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quality. Coastal lagoons are characterised by the following elements:

- One or more so-called tidal inlets which connect the lagoon and the sea.
- Tidal exchange of water between the lagoon and the sea known as the tidal volume.
- Rich flora, such as sea grass beds, mangroves and meadows.
- Rich fauna such as mussel banks, nursery areas for many fish species and rich bird life.
- The openings are sometimes stable and sometimes suffering from sedimentation; this is dependent on the balance between the tidal range and the wave exposure.
- The lagoon environment is protected and is therefore often characterised by the settlement of fines, which in many cases leads to the formation of mudflats.

These natural conditions offer the following attractions:

- Protected water environment, which are traditionally used by coastal societies as a natural location for communities based on natural harbour facilities.
- Possibilities for a great number of commercial activities such as fishing, hunting, aquaculture, location for water intakes/outlets of different kinds and salt production for example.
- Recreational activities such as water sports, navigation in protected waters, fishing, bird watching and so on.

On the other hand, however, these communities as well as the many associated activities in the lagoons also contribute to the high risk of impacts on the lagoons, such as:

Figure 3. Examples of correlation between type of beach and wave exposure. Below left: Location "Map", North Beach in Doha, Qatar. Note, the southern part is protected by an island and associated reefs and has a muddy tidal flat beach (photo lower right) whereas the northern part is exposed and has a sandy beach (photo upper right).

Figure 4. Above: Marsa Matrouh Lagoon, NW Mediterranean coast of Egypt; red dot is photo location for photos below. Lower left: Semi-exposed sandy beach looking towards NW. Lower right: semi-exposed beach towards SE.

- Pollution leading to degradation of the water quality and associated degradation of flora and fauna.
- Installation of sluices leading to changes in the salinity and such.
- Reclamations leading to changes in the tidal volume.
- Regulation of inlets and dredging of navigation channels leading to changes in the tidal volume, which may lead to local erosion or general siltation.
- Navigation, which may lead to pollution and erosion and other impacts.

An example of an attractive lagoon environment is the semi-open Marsa Matrouh lagoon located at the NW Mediterranean coast of Egypt (Figure 4). This lagoon offers attractive sandy beaches because of the wide opening towards the sea, which allows some wave penetration and good water quality. The breaking waves over the reef and shoals ensure a good exchange of waters.

DESIGN GUIDELINES FOR ARTIFICIAL BEACHES

The most important landscape elements in many waterfront developments are *attractive sandy beaches*. An artificial beach is the construction of a new beach by the supplying of sand, so-called beach fill. The design requirements for a good quality recreational beach are outlined below.

Beach exposure to waves

A beach will be exposed to waves in order to obtain a good quality beach. However, a recreational beach should not be too exposed, as this endangers bathing safety. This means that there are two opposing requirements:

- A certain degree of exposure to ensure a self-cleaning beach.
- The exposure should not be too great in order to ensure safe bathing conditions.

In order to safeguard an attractive sandy beach the yearly wave exposure should be moderate to exposed, which means that the significant wave height ($H_{s,\ 12h/y}$), which is exceeded 12 hours per year, should be higher than 1.0 m. This consistent movement of the sand during rough conditions by the wave action is what naturally maintains a nice sandy beach and shoreface by preventing settlement of the content of fines, which are often present in seawater, on the beach and shoreface. Furthermore, the wave exposure prevents sea grasses from growing on the shoreface.

The difference between two artificial beaches in a beach park in the UAE area, where the first beach is exposed to waves and the second beach is a protected lagoon beach, can be seen clearly in Figure 5.

No internationally agreed criteria exist as related to wave height relative to safe bathing conditions. Bathing safety is mainly related to the occurrence and type of breaking waves and the wave-generated currents in the breaking zone. These conditions are discussed below.

Breaking waves

Spilling breakers are often associated with the formation of bars and rip currents, which can carry both adults and children out into deep water. This situation is typical for strong wind and storm conditions at sandy (ocean) coasts. Plunging waves are dangerous because the violent breaking can hit a person who is swimming. Plunging breakers typically occur on ocean coasts with moderate wave conditions, such as under monsoon and trade wind conditions on coasts with relatively coarse sand. Based on the above, obviously ocean coasts are

Figure 5. Left: An exposed artificial beach in the UAE is a nice clean beach owing to the wave action. Right: At an artificial beach in an artificial lagoon in the UAE, note the muddy seabed, which is caused by the lack of wave exposure. The lack of freshness can be clearly seen.

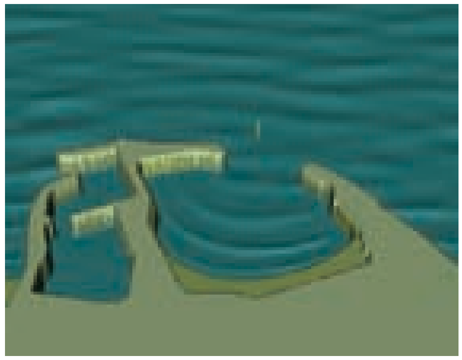

Figure 6. Modelled wave conditions at an artificial beach in Alexandria, Egypt. The design is made by DHI, Hasløv & Kjærsgaard and ECMA.

the most dangerous. However, if an upper limit for wave heights were to be recommended in relation to safe bathing conditions, an estimated criterion will be $H_s < 0.8$-1.2 m during the swimming season. The low limit is valid for long period waves (swell) and the high limit for steep waves (wind waves). This means that protective measures are required if a site is more exposed during the bathing season than given in the above rough criteria, e.g. in the form of specially designed coastal structures.

Rip currents generated as a result of the presence of coastal structures can also be very dangerous. This danger occurs because during a storm situation waves will be partially sheltered behind the coastal structure, but in the same area strong currents, which can carry poor swimmers out into deep water, will arise owing to eddy formation. Such areas with partial shelter provided by coastal structures generate a false sense of safety and such arrangements should consequently be avoided.

The principle of providing safe partial shelter and shoreline stability at an exposed coast is presented in Figure 6, which shows a project for an artificial beach and a marina in Alexandria, Egypt:

- Large breakwaters provide partial shelter; the width of the opening has been adjusted to provide suitable wave exposure to fulfil the requirements of moderate exposure for securing a good beach quality and semi-sheltered conditions for providing safe swimming conditions.
- The beach is designed to be stable under the resulting wave conditions, and a nice curved shape is obtained by the diffracting waves.
- No dangerous rip currents are created because of the long distance between the breakwaters and the beach and because of the equilibrium shape of the beach.

Minimum wave exposure

A recreational beach should have an active profile out to a water depth of about 2.0 m relative to low tide. This recommendation of a depth of 2.0 m relative to low tide results from the requirement that swimmers walking on the seabed should experience an attractive clean sandy seabed without deposition of fines, which causes a muddy seabed. The clean and active seabed is ensured by the requirement that the active coastal profile should extend out to a water depth of 2.0 m, that is, $d_l \geq 2.0$ m or in terms of wave height: $H_{s,12h/y} \geq 1.0$ *m.* This means that the seabed out to this water depth will regularly be exposed to waves which will prevent fine sediments from settling on the shoreface. Furthermore, the growth of sea grasses will also be prevented.

If the natural shoreface does not allow these requirements to be fulfilled, e.g., if the shoreface is shallower than the equilibrium profile, then two possibilities may fulfil the requirements:

- The beach is shifted seaward.
- The existing coastal profile is excavated to accommodate the equilibrium profile.

Beach exposure in relation to tidal range

A certain tidal range and storm-surge activity will cause a wide beach. However, a tidal flat may develop if the mean spring tidal range is much larger than the yearly average breaker wave height H_b. A high tidal range may also cause a danger to bathers. Thus, a good quality recreational beach is normally characterised with a micro to moderate tidal regime, which means a tidal range smaller than approx 1.5 m.

Beach plan form

The beach should be stable in plan form (horizontally) in order to ensure minimum maintenance. This means that the orientation of the beach must be perpendicular to the direction of the prevailing waves, or in other words, the orientation of the beach will be in the equilibrium orientation, which is the orientation providing net zero littoral transport. This often leads to the requirement of supporting coastal structures for stabilising the beach in an orientation, which is different from the natural orientation of the coastline in the area of interest.

At an exposed beach with oblique wave attack, the supportive coastal structures for an artificial beach should be designed to fulfil the following conditions:

- Provide support for a stable lateral shape of the beach and prevent loss of sand out of the artificial beach area.
- Provide partial protection against wave action.

- Must not lead to dangerous currents near the beach.
- Structures will have a streamlined form to minimise trapping of floating debris.
- All coastal structures should also have recreational functions.

Beach profile form

The beach profile should be stable, which means that a beach will be built in the form of the equilibrium profile. A beach adjusts to the equilibrium profile in the active littoral zone. The shape of the profile is mainly dependent of the grain size characteristics of the sand. The equilibrium shape, Dean's Equilibrium Profile, follows the shape $d = A\ x^{2/3}$ where d is the depth in the distance x from the shoreline, both d and x in metres. A is Dean's constant, which is dependent on the grain size of the sand according to the directions given in Table I.

The equilibrium profile concept is valid only for the active littoral zone, i.e., out to the Closure Depth d_l. As a rule of thumb $d_l \sim 2H_{s,\ 12h/y}$ can be used for normal wind waves.

Beach fill material

The beach fill material for artificial beaches should fulfil the following criteria in order to provide a high quality recreational beach:

- Characteristics of the fill sand should be similar to that of the natural sand in the area if the new artificial beach is connected to an existing beach, however, as a rule slightly coarser.
- Sand should be medium, i.e., 0.25 mm $< d_{50} <$ 0.5 mm, preferably coarser than 0.3 mm, which minimises wind loss.
- Minimum content of fines, i.e., silt content less than 1-2%.
- Gravel and shell content less than 3%.
- Well-sorted sand, $u = d_{60}/d_{10}$ less than 2.0.
- Colour shall be white, light grey or yellow/golden.
- No content of organic matter.
- Thickness of sand layer will be at a minimum1 m, preferably thicker.

The reason for the requirement for the beach sand to be medium, well-sorted sand with minimum content of fines is discussed below. If this requirement is not fulfilled, i.e., if the sand is graded (the opposite of well sorted) with some content of fines, the permeability is low, which means that the beach will drain very slowly at falling tide. This implies that the beach will be wet at all times and will have a tendency to be swampy, and thereby unpleasant to walk on. This criterion is especially important for artificial beaches built at protected locations, as there will not be enough wave action to wash the fine sediments out of the beach. Furthermore, algae may grow on the beach, which makes it greenish in colour and un-aesthetic. Finally, in such environments the beach will attract beach crabs and their pellets. Especially at protected sites, the use of clean sand with zero content of organic matter is important, because the combination of lack of wave exposure and content of organic matter may lead to anoxic conditions resulting in formation of hydrogen sulphide, which causes a bad smell and dark colouring of the sand (see examples in Figure 7).

The requirement for a small content of gravel and coarse fractions is important for the quality of the beach surface as the action of the waves will wash away the fine fractions leaving the beach armoured with the coarse fractions. Such a beach surface is unpleasant to walk on (see examples in Figure 8).

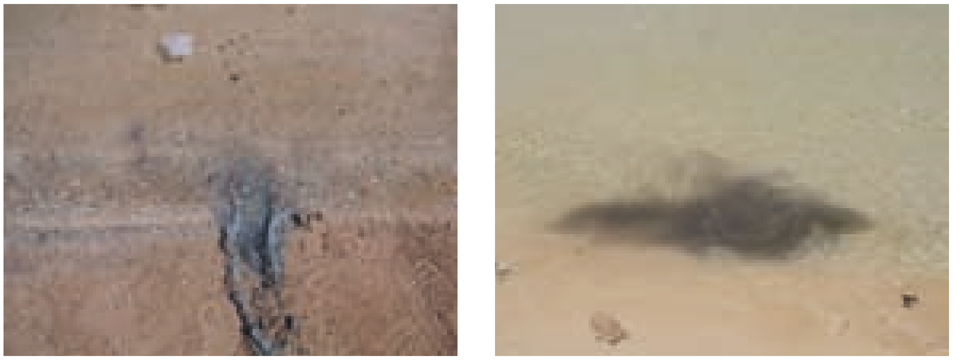

Figure 7. Examples of anoxic conditions and the formation of hydrogen sulphide at protected artificial beaches. Left: Dark substance suspended in the water when seabed at shallow water is disturbed, artificial beach in lagoon environment at the Egyptian NW coast. Right: Dark substance at beach in artificial lagoon in the Red Sea.

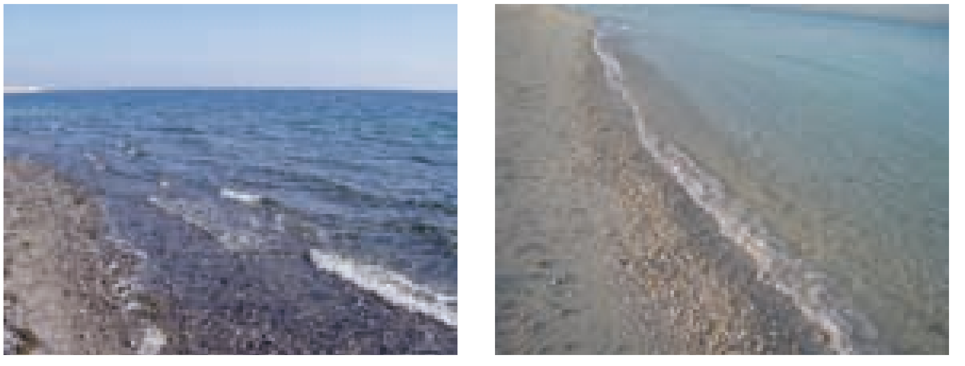

Figure 8. Artificial beaches with too much coarse material. Left: Beach Park in Copenhagen. Section where the content of gravel and pebble is too high. Right: Artificial beach in the UAE where the content of shells and coral debris is too high.

Table I. Correlation between mean grain size d_{50} in mm and the constant A in Dean's Equilibrium profile equation. For typical beach sand.

d_{50}	0.20	0.25	0.30	0.50
A	0.080	0.092	0.103	0.132

Clearly, from the examples in Figures 7 and 8, the use of very good quality fill sand for the construction of artificial recreational beaches is very important.

DESIGN GUIDELINES FOR ARTIFICIAL LAGOONS

The most important landscape elements in many coastal development schemes are attractive tidal lagoons. Such lagoons provide an attractive protected marine environment – but also major technical challenges. Design guidelines for elements of artificial lagoons are discussed below.

Lagoon mouth and channel sections
The stability of tidal inlets is a science in itself, which is not be discussed in detail here. Suffice it to say that at littoral transport coasts the stability of tidal inlets is a major issue, which means that careful studies are needed. The required cross sections will be dependent on the tidal volume in the lagoon. No specific criteria can be given. However, the cross section area of mouth and channel sections of artificial lagoons should be large enough that peak tidal current velocities are less than ~ 0.8 m/s. The width and depth should also be designed according to guidelines for safe navigation if the lagoon is to accommodate boating by motor and sailing yachts.

Open water body
The main purpose of introducing artificial lagoon and channel elements is to add attractive landscape elements adjacent to an urban development area. The lagoon may be designed to accommodate water sports, navigation and swimming, but swimming in a lagoon will never be as attractive as in the sea. The most import function is to provide the inherent attraction of water to an area which does not have this in its native condition. The lagoon therefore should be properly designed as an important landscape element.

A requirement for maintaining good water quality is the proper flushing of the lagoon. Flushing can be expressed in terms of a characteristic "flushing time" T_{50}, which is the time it takes before 50% of the water in the lagoon system has been exchanged with clean water from the sea outside the lagoon during a design scenario. The design scenario should be a calm and warm period, as this is most critical for flushing and water quality. No required criteria are specified for the flushing time. An acceptable flushing time for a natural lagoon will normally be 5–7 days but the flushing time for artificial recreational lagoons should preferably be shorter.

Under many conditions, more than one opening is recommended in order to accommodate sufficient flushing; sometimes forced flushing circulation by gates or additional pumping may be required. Other rules of thumb are:

- Water depths shall not be larger than 3–4 m.
- There must be no local depressions in the seabed.
- There must be no discharge of pollutants to the lagoon, such as sewage, storm water, brine, cooling water, pesticides and nutrients.

The above-mentioned flushing guidelines are imperative for obtaining good bathing conditions. Fulfilment of international bathing water quality standards must be ensured, e.g. the EU Standard, Ref. /2/.

Perimeters
Normally it is difficult to obtain a good quality beach inside a lagoon for the reasons discussed in the previous section. The following guidelines should be followed to obtain the best possible lagoon beaches if lagoon beaches are embarked on despite the above "warnings":

Figure 9. Pictures from Amager Beach Park, Copenhagen. Right: Middle pier functions as terminal structure for the two beach sections and as viewing and bathing facility. Below: Seawall along the southern beach section has multiple functions: Coast protection, separation between promenade and beach and sitting furniture.

Figure 10. Aerial photo of Amager Beach Park, Copenhagen (courtesy of Jan Kofod Winther), which consists of the following main elements: Island with terminal structures north and south and a separating headland between northern and southern beaches and a lagoon. Designed by DHI, Hasløv and Kjærsgaard and NIRAS.

- Use only high standard beach sand as explained under the design guidelines for beaches.
- Construct the desired beach profile from the beginning.
- Build only beaches at exposed locations in "large" lagoons with dimensions preferable > 2–5 km and water depth not less than 2 m.
- Build only beaches if the amount of suspended substances in the lagoon water is very small, say in the order of less than 5–10 mg/l.

It is strongly advised to consider other alternatives than beaches inside lagoons.

LANDSCAPE ELEMENTS OF COASTAL AND OFFSHORE DEVELOPMENTS

The recreational and landscaping requirements in relation to design of the marine elements of waterfront developments are discussed below.

The characteristic elements are:
- Beaches
- Other types of shoreline perimeters
- Landscape behind the shoreline perimeter
- Lagoon areas/body lines

Far too many coastal projects are developed without a clear understanding and respect for the natural hydraulic and coastal processes which are decisive for the overall layout of the marine elements of a development. Consequently, many projects are developed without a clear idea of which layouts are feasible and of how the different elements can support each other.

This may lead to unsuitable shoreline perimeter solutions of poor quality and consequently major expenses for maintenance – often resulting in poor results.

The planning process for a waterfront development should consequently ensure a balance between the objectives of the developer and the possibilities that the specific development site offers in terms of artificial marine elements, taking environmental impacts into consideration. The main objectives of the developer, being a public authority or a private company, are typically some of the following:
- Enhancing of economic development possibilities in an area.
- Expanding the length of water perimeter through establishment of artificial water bodies.
- Developing recreational and service facilities.
- Providing balanced public and private access.
- Providing sandy beaches and other shoreline perimeters types.
- Establishing optimum internal functionality and causing minimum environmental impacts.

These objectives must be balanced against the possibilities and constraints offered by the natural conditions in the development area: Where can beaches be located and how should they be orientated? How can good flushing and water quality be ensured in artificial lagoons and so on? These conditions are already discussed in the previous sections where design guidelines for artificial beaches and artificial lagoons are presented.

It is especially important to ensure that necessary coastal structures are planned and designed as multifunctional facilities. Examples of such layouts could be:

- A terminal structure is designed as a viewing headland.
- A groyne structure is designed as a headland which can be utilised for recreational facilities.
- A lagoon opening can be designed as a marina.
- A seawall can be designed as an integrated part of the beach furniture (see Figure 9).

Landscaping principles for the layout of artificial beaches should focus on as long and uninterrupted beach sections as possible, with a minimum number of structures, as this will enhance the natural appearance of a beach section.

An integrated plan based on workable marine elements will make it possible for developers and planners to create unique and sustainable coastal developments where the possibilities and requirements of nature are utilised optimally according to the needs of society.

AN EXAMPLE OF A SUCCESSFUL BEACH PARK DEVELOPMENT

A new beach park was recently built in Copenhagen using the principle of making the new beaches exposed to waves by moving them out to deep water thereby avoiding the shelter provided by the existing shallow shoreface. An aerial photo of the new beach park just after finalisation of the civil works is presented in Figure 10. The main wave directions at the site are NE and SE, which have been utilised to make two sections of beach separated by a headland, one facing towards NE and one facing towards SE. Note the Y-shape of the headland structure providing a smooth transition between the structure and the beaches, which secures minimum trapping of floating seaweed and debris in the transition areas. The new beaches have been constructed on an island and a new lagoon (excavated) has been built between the island and the old shoreline. There is always a good current just off the beach park as it is located in the Sound, the strait between Denmark and Sweden, where the water exchange between the Baltic and the North Sea takes place. This results in a good flushing of the lagoon.

The beach park has been very well received by the residents of Copenhagen and in an opinion poll it was nominated as the best beach in the Copenhagen area. It has also received a reward from the "Society for the beautification of the Capital", and people are enjoying all the facilities in the park (see Figure 11).

A NEW CONCEPT FOR AN OFFSHORE DEVELOPMENT SCHEME

A new concept for an offshore development plan utilising the principles presented in this article has been developed by DHI and Hasløv & Kjærsgaard, Planners and Architects, Copenhagen. The plan is universal because it can be implemented at any location where a coastal development is

Figure 11. Recreational activities in Amager Beach Park, Copenhagen. Upper: Beach activities. Lower: Kayaking and kite surfing on the Lagoon; the beach islandis in the background (courlesy Adrian Saly).

needed and where wave exposure is present. The plan has been created under the motto, "Work with Nature", meaning that the wave exposure at the site should be considered a valuable natural gift, to be utilised for developing a significant recreational facility, namely a high-quality exposed beach.

The centre of the plan is the unique half-moon-shaped ocean bay providing an excellent sandy beach. The plan thus offers the possibility for developing an extremely high quality urban beach which can be equipped with an attractive cornice along which most of the important recreational and leisure functions of the new city can be developed, such as promenades, retail downtown areas, advanced apartment schemes, hotels, marine sport facilities, entertainment facilities, parks and other amenities.

Figure 12. "The Universe" concept for an offshore development scheme. Artist's impression of the beach in "The Universe" and a possible concept for a marina. © DHI and Hasløv & Kjærsgaard. All rights reserved.

CONCLUSIONS

It is clearly crucial for a successful design of beach and lagoon elements in waterfront developments that the hydraulic, coastal and environmental aspects are included in the planning from the earliest planning stage. The design of these elements has to follow the "rules of nature", which imposes certain restrictions on the design. The main issues to observe are:

Artificial beaches:
- Good quality recreational beaches should be moderately exposed to waves; they should be orientated towards the direction of the prevailing waves to be stable and terminal structures should be constructed to prevent loss.
- Artificial beaches should be constructed by good quality beach sand: medium, i.e. 0.25 mm < d_{50} < 0.5 mm, well sorted, attractive colour, minimum content of fines and minimum content of coarse fractions and no content of organic matter.
- Coastal structures adjacent to beaches should be designed so that no dangerous currents are generated.

Artificial lagoons:
- High water quality standards should be ensured in recreational lagoons; the "flushing time" T_{50} should be better than 5 to 7 days, which may require special precautions.
- The lagoon mouths should be stable and free of sedimentation.
- Water depths should be between 2 m and 4 m.
- There must be no local depressions in the seabed.
- There must be no discharge of pollutants to the lagoon, such as sewage, storm water, brine, cooling water, pesticides and nutrients.

Waterfront developments in general:
- A thoroughly planned location and layout of the urban elements integrating recreational demands with the natural dynamics of artificial beaches and lagoons are important.
- Coastal structures should also have recreational functions.

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