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Penny’s Bay Reclamation Phase 1: Fairytale in Hong Kong

Abstract
The construction of the new international Theme Park in Hong Kong is well underway, built on a vast area of land which was reclaimed from the sea in only 32 months. This reclaimed land was made to such a high standard that the construction works for the infrastructure and Theme Park were able to commence directly after the completion of the reclamation works. Some of the important technical details of the reclamation works, which were executed under strict environmental conditions, are highlighted in this article.

Martijn van Doorne has been involved in the dredging industry for more than 15 years and has worked on dredging projects around the world in Nigeria, the United Kingdom, India, the Philippines, to name a few. He has been the project manager of the Penny's Bay Reclamation Project in Hong Kong.

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Introduction

After due consideration by the Hong Kong S.A.R. Government, Penny’s Bay on Lantau Island was chosen for the location of an international Theme Park, and the Civil Engineering Department of the government (the Employer) and their Engineer Scott Wilson (Hong Kong) Ltd. prepared the design for the works. An area of new land of some 200 hectares had to be reclaimed from the sea, of which Van Oord’s share of the work represented approximately $500 million. Since environmental management was an essential part of the project, a dedicated team comprising members from Van Oord and independent Maunsell Environmental Management Consultants Ltd. was employed on a full time basis.

The Extent of the Works

Some of the principal quantities for the reclamation project are outlined below, giving an impression of the extent of the works.

Before the actual filling operation for the reclamation could start, some 43 million m^3 of uncontaminated mud and 80,000 m^3 of contaminated mud had to be removed from the site. The sand volume that was needed for the reclamation was approximately 70 million m^3.

The settlement of this sand body was accelerated by deep compaction; the deep compaction volume was about 40 million m^3. In one area the sub-soil treatment was different and the excess pressurised water was drained by means of vertical drains; a total of 2.6 kilometres of prefabricated band drains were installed. This area is the future water pond.

The work also included the removal of silt and overburden from the marine borrow areas, before suitable sand could be extracted, as well as placing and removing surcharges on the reclamation site. This volume amounted to about 6 million cubic m^3.

Finally, the contract required the building of a 2-kilometre seawall along the southern perimeter of the reclamation, a 1.5-kilometre revetment along the eastern perimeter, and a 2-kilometre access road. This part of the work involved some 2 million m^3 of imported rock.

All these works were to be completed within a period of 32 months. The works started in May 2000 and were completed on the scheduled completion date of 7 December 2002 within the strictly proscribed environmental constraints (Figure 1).

Figure 1. Panorama view of Hong Kong's Penny's Bay on Lantau Island.

Clearly, the planning and sequencing of all activities for such a project is of vital importance if the contractual requirements are to be met, especially when a large amount of equipment must be deployed simultaneously in a relatively small area.

A solid foundation for the reclamation was found at levels varying from –10 m PD to –39 m PD, in some spots even –45 m PD. This meant that a mud layer of up to 33 metres thick was to be removed prior to the actual reclamation works.

Monitoring Measures

The Hong Kong S.A.R. Government is very keen on protecting the environment, which resulted in strict regulations and requirements for the dredging work in this project. A considerable amount of time, effort and money went into monitoring the ecological and environmental effects of the work. Water and air quality including noise levels in the surroundings were measured frequently and the well-being of local wildlife was monitored. As this was an essential aspect of the project, a dedicated team from Van Oord and independent Maunsell Environmental Management Consultants Ltd. was employed on a full time basis.

Scanning the Subsoil

No less than 1,200 CCPTs were executed with the intention of determining the top level of the hard clay subsoil, thereby establishing the target dredge levels.

Figure 2. Grab dredgers were used to remove mud to provide access in the bay for the larger trailer dredgers.

Up for Grabs

Work started with the removal of the thick layer of unsuitable mud from the bottom of the bay. The original seabed level at the site varied from –3 m PD to –7 m PD, while the top of the hard clay subsoil was found at between –10 PD and –39 metres PD.

Three grab dredgers were used for mud removal, mainly to provide access for the trailer dredgers and in locations where rock layers were expected close to the surface (Figure 2). The grab dredgers created sufficient depth for the small trailer dredgers like *HAM 312* (Figure 3). The smaller trailers in turn dredged an access channel into the works and lowered the level of the working area for the larger dredging vessels such as *Geopotes 15, Amsterdam and Rotterdam* (Figure 4 and 5).

The dredging of the seawall trench was a special case as dredging was required to a foundation level having a strength of 2 mPa. The Engineer, the Employer but in particular the end user had stringent requirements with regards to the differential settlement criteria. Once the grabs and medium size trailers had cleared the way for the new generation jumbo hoppers, with hopper capacities over 20,000 m^3, the speed of mud removal operations was increased making it possible to meet the timetable as specified in the contract.

Designated Discharge Sites

The removed mud was transported to a number of designated discharge sites for which the contractor had to obtain special discharge permits. These areas used for the non-contaminated mud are located North of Lantau, South Chung Chau, near the Nine Pins Islands and in the Peoples' Republic of China (PRC), south of Danggang. A separate permit was obtained for the contaminated mud, which was deposited in the dedicated discharge-pit at East Cha Chau.

Checking the Numbers

A survey launch with a multibeam echosounder verified whether the required dredge levels were actually reached. Apart from these bathymetric surveys, grab dredgers took soil samples to a 25 x 25 m grid and vibrocore samples were taken on a 50 x 50 m grid, followed by a seismic sounding of the dredged area. These surveys were conducted while work on site continued. This meant the survey vessels had to manoeuvre amongst a large number of dredgers and other ships, which was often quite complicated.

Once satisfied that sufficient mud had been removed, pre-cast concrete settlement plates were lowered down onto the dredged surface to a 100 x 100 m grid. The installed positions were accurately recorded as the plates were to be relocated later by drilling through the reclamation, to provide important information on the settlement of the sub-strata.

The filling operation commenced with placing a 3-metre-thick sand blanket. Subsequently, so-called basal vibrocores were carried out at a 50 x 50 m grid to confirm that there were no silt pockets left behind or enclosed. After confirmation that there were no large enclosures, the filling process continued.

Settlement and Surcharges

The reclamation areas had to be raised to levels varying between +6.5 m and +10 m PD. This meant that in some places a sand layer of up to 45 metres thick was required. Allowances had to be made for calculated settlement. For this reason an extra overfill of about 0.6 m on average was placed over and above the required surcharge levels.

Filling Methods

A variety of filling methods were used. In some cases the strict environment constraints dictated the working method deployed. But, broadly speaking, when there was sufficient depth for the trailers to access the working area, the dredger would simply open its bottom doors and discharge its load. This disposal took place in a controlled manner whereby each vessel that entered the site was allocated a disposal spot in accordance with a pre-determined sequence based on actual survey data.

When the disposal area became too shallow for the ships to enter, they reverted to rainbowing, i.e. unloading their sandy cargo by pumping it through a nozzle at the bow of the vessel. However, in Hong Kong the issued Environmental Permit stipulated that this method may not be used for discharging directly in the water.

A third method used was to pump the sand ashore via floating and land pipelines. This method was used to bring the reclamation to the required level above water.

All these methods have the same goal: to get as much sand in place as efficiently as possible. But when accuracy becomes a critical factor, that is, exactly how much sand goes where and when, alternative methods have to be used. For example, in the area beneath the proposed lake, a special zone where soft marine deposits were to be left in place, the sand was deposited in a controlled manner by means of the spreader barge *Tisnix* which was able to place the sand accurately in one metre thick layers. The *Tisnix* received the sand mixture via a floating pipeline from a cutter suction dredger that was located in a rehandling pit.

Figure 3. Ham 312, one of the smaller trailers used for excavations at Penny's Bay.

Figure 4. Large trailing suction hoppers during sand placement.

Borrow Areas

To achieve the land reclamation in this project, a total amount of around 70 million m^3 of sand, originating from various marine borrows areas in Hong Kong S.A.R. and the PRC, was used. Here too special permits had to be obtained by the contractor to excavate sand in these locations.

The sand borrow areas used for the project were: East Lamma Channel and West Po Toi, both in Hong Kong waters, and Wailing Ding near Wanshan Island in the PRC. The mining licences for this last area in the PRC were obtained after lengthy, but successful, negotiations with the Chinese authorities.

Figure 5. Geopotes 15 transporting sand.

In order to check the quality of the sand, a large number of vibrocore samples were retrieved from the reclaimed area on a 100 x 100 m grid and throughout the depth of the sand-fill. The result: 32 m^3 of sampling material and 16,000 sieve analyses.

Seventeen Trailers

For a sand-fill operation of this magnitude, a large number of trailing suction hopper dredgers are necessary and some seventeen trailers were deployed during the course of the project. Besides these trailing suction hopper dredgers, other dredgers, such as a cutter suction dredger, a water injection dredger and various units of grab dredgers, were employed.
In order to maintain a safe marine environment at the site, Van Oord had their own vessel control centre at the site office that co-ordinated all vessel movements, day and night, via telephone and VHF radio.
The necessity for such a department is evident in the light of the number of vessels on site; besides the above-mentioned dredgers there were survey vessels, vibrocore barges, stone delivery derrick-lighter/tug combinations, many barge/tug combinations for the grabs, launches from the Engineer, tender boats for site personnel, multicats for pipeline and anchor handling and so on.

Other Disciplines

Apart from the actual marine works, such as demudding, dredging and sand-filling, there were a number of associated activities carried out under the same contract. They included:

- deep compaction;
- installation of geotechnical instrumentation;
- surcharge removal;
- vertical drain installation;
- seawall construction; and
- access road construction.

Deep compaction

The deep compaction works were carried out by subcontractor Bachy Soletanche Group Ltd. A sand body with a volume of about 40 million m^3 had to be treated by this method. The objective here was to meet the contractual requirement of close to zero differential settlement after delivery, which was an essential requirement to the end user of the new land.

The deep compaction method used in this case was the vibro-floatation method. Under this process, a so-called poker is jetted into the sand to the required depth and energy is applied to the vibrating tip of the poker. This causes the sand grains to reposition into a more compact configuration. Based on time and the energy consumption of the tip, the process is monitored to ascertain if the required degree of compaction has been achieved. This process continues from the starting level up to the proposed final surface, with the poker raised in one-metre increments, with additional sand poured in from the top to fill the void around the poker.
On average, a compaction of 6% by volume was achieved with this method (the specified requirement was 5%).

Not all areas of the sand body were deep compacted. In some zones only limited deep compaction was stipulated, whereas in others full depth deep compaction was carried out. Pre- and post- CPPTs were taken to monitor the works and to confirm that the specified contract requirements were met.

Installation of geotechnical instruments

The installation of geotechnical instrumentation in the reclamation area was another activity carried out by specialist subcontractor Bachy Soletanche. The types of instrumentation installed were:

- standpipes;
- Casagrande piezometers;
- vibrating wire piezometers; and
- magnetic extensometers.

The instruments were installed in 33 instrumentation clusters throughout the site. In addition to these clusters, almost 1,200 settlement markers were installed, partly at the dredged surface and partly just below the finished reclamation level. The instruments were monitored throughout the project duration according to the specific requirements of the end user.

Figure 6. Land formation and infrastructure for the theme park on Lantau Island, Hong Kong. Theme park is situated at bottom of drawing.

Surcharge removal

An entirely different method used to increase the speed of the settlement process was the placement of a surcharge on top of the reclamation thereby adding extra weight onto the subsoil. This surcharge was later removed after a pre-determined period to bring the reclamation to the design final levels. The removal of the 6 million m^3 of surcharge was also carried out by Van Oord. Large land-based earth-moving equipment, able to move about 110,000 m^3 per week, was used for this activity; special haul roads were constructed and maintained in order to separate this heavy equipment from other site vehicles.

Installation of vertical drains

In some cases soils are drained by using vertical drains. These are usually prefabricated strips of woven material that are installed, through the reclaimed sandbody into the sub-soils, by specialised equipment.

For Penny's Bay two such specialised rigs were mobilised to execute this part of the works. The two rigs had the capacity to install about 40 km of drain per day. This meant they had to work around the clock to install the total of 2.6 million metres of drains needed on this project. The vertical drains were installed in the special area W3, a future recreational area. The installation of vertical drains in this zone was a very critical activity, causing considerable changes in the working sequence.

Seawall construction and access road

Hong Kong Construction Ltd., Van Oord's joint venture partner, executed the construction of the various seawalls, both vertical and sloping, revetments and access road. This part of the contract involved the

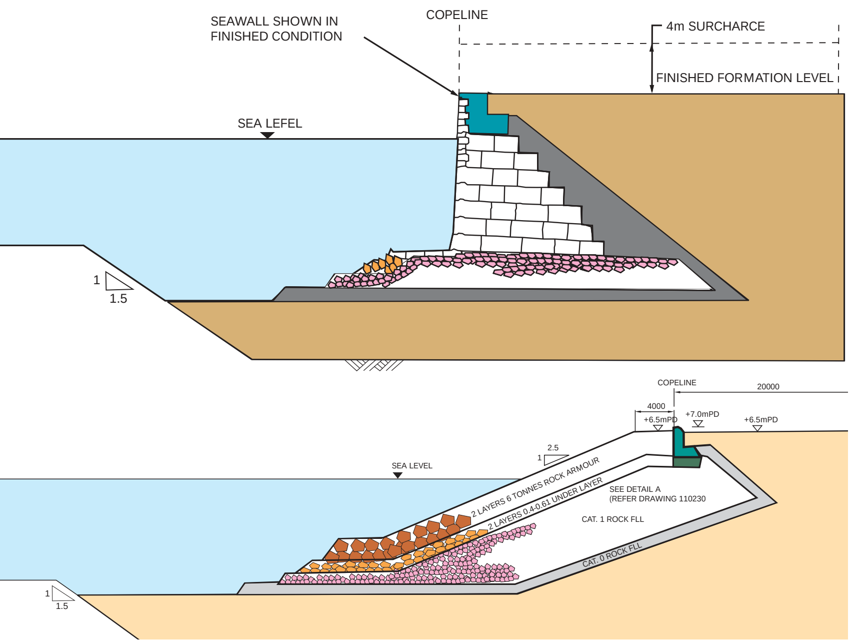


Figure 7. Two seawall designs were used: above, the vertical seawall and below, the sloping seawall.

supply and placement of about 1.9 million tonnes of rock. The rock was procured from Chinese quarries in the PRC. Two large box culvert outfalls were also constructed, through the sloping seawall, in order to drain surface water from the area.
The seawall was constructed along the southern perimeter of the reclamation, about two kilometres long and consisting of two sections; a vertical seawall and a sloping seawall. The designs used for the seawalls are fairly classic, well proven and often used in Hong Kong (Figure 7).

Along the eastern perimeter of the reclamation a 1.5-kilometre revetment, consisting of heavy rock imported from the PRC, was constructed. A two-kilometre access road to the China Light & Power's power station was also constructed and included three culverts underneath the road.

Environmental Efforts

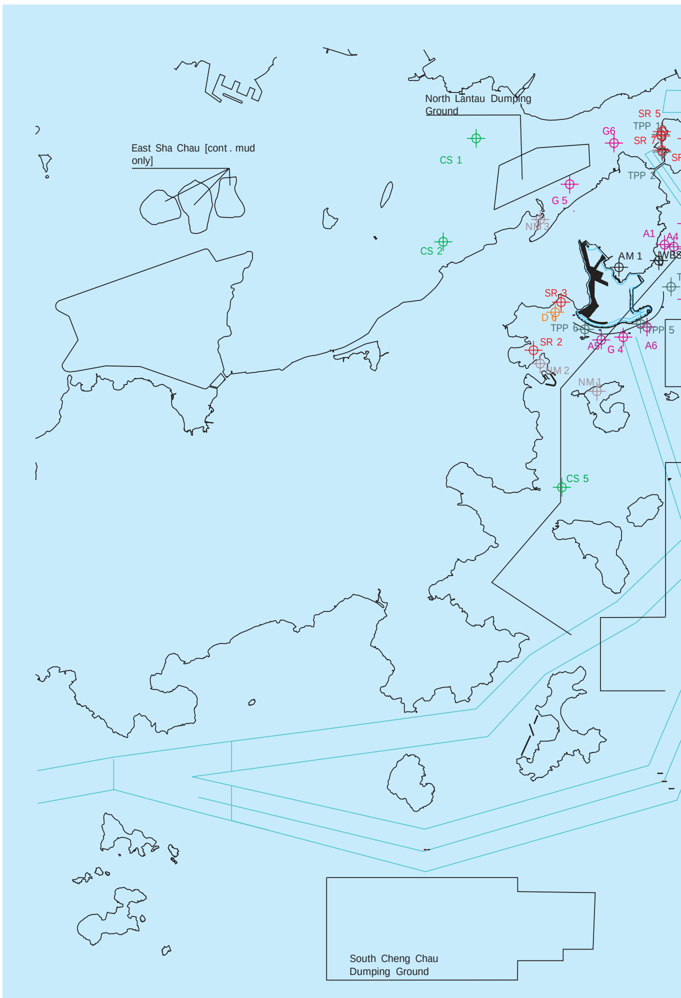
Hong Kong is very keen to protect its environment and has various ordinances in place stipulating the environmental requirements under which a project of this size must be executed. Under such an ordinance, an Environmental Impact Assessment (EIA) was produced by the client and approved by the Environmental Protection Department (EPD) of the Government. As a result, the EPD granted an Environmental Permit (EP) to the client for the construction of the project.

Based on the recommendation of the EIA, an Environmental Monitoring and Audit (EM&A) Manual was written, specifying the scope of environmental monitoring and mechanisms to avoid and mitigate any negative impact to the environment (Figure 8).

Besides the monitoring schemes, the EP and EM&A Manual imposed various necessary restrictions and limitations in respect of the methods of construction. As a result, the work done by the Joint Venture was subject to many environmental regulations with a large scope of environmental monitoring works.
The following measures were taken:
– installation of a 4 km silt screen and a temporary rock bund around the worksite;
– installation and data collection at 66 water quality monitoring stations;
– installation and data collection at 3 noise measurement station;
– installation and data collection at 1 air quality measurement station;
– installation of 13 coral monitoring stations including data collection dives; and
– ecological monitoring of wildlife around the site.

Silt screen

A silt screen was installed around the entire working area. The screen kept suspended solid particles, stirred up by the dredging operations, within the site boundaries. It was installed by hand from workboats, a labour-intensive operation, with regular assistance



from a diving team. The screen received daily maintenance work, which was intensified after periods of heavy weather. Also the navigation lights as fixed to the screen needed attention from the maintenance team. Maintenance often meant replacement since these lights were frequently stolen. An unintended consequence of the silt screen was that the site became a collection point for floating rubbish, brought in by the tidal currents. During the weekly cleanup of the shoreline, up to two container loads of rubbish were collected.

Water quality

The water quality was monitored around the site and especially at sensitive areas like the fish farms in Ma Wan, the water intakes of the marine life park of Ocean Park, and the residential area at Discovery Bay.

Three times per week and during certain periods daily, dedicated monitoring teams sailed out to the measurement locations to take water samples for analyses onboard and in the laboratory. In addition to visual monitoring, the parameters that were measured during these sessions were: temperature, salinity, turbidity, suspended solids, dissolved oxygen, and chemical components. At the most sensitive areas around the site, continuous monitoring systems were installed that measured various parameters and sent the data "online" to computer systems onshore.

Noise measurements

At three locations outside the site, noise measurements took place to monitor whether the noise produced by the construction activities was below the allowable limits. In this respect it must be noted that the site, as a producer of noise, was required to have a Construction Noise Permit, issued by EPD that stipulated a maximum permissible noise level. The monitoring of noise levels demanded close attention since passing cars or air conditioners from nearby residences could easily influence the monitoring results.

Air Quality Monitoring

One air quality monitoring station was erected directly next to the site. This station was mainly meant to monitor the dust emissions from the site. Measures taken to reduce the emissions consisted of spraying all site roads using water tank wagons and covering all stockpiles of materials.

Coral monitoring

Around the site, but especially near the West Po Toi marine borrow area, various types of coral are found. In order to monitor and protect these corals, a monitoring scheme was devised consisting of regular dives by a marine biologist accompanied by a diving team. During these dives a fixed route over the coral colonies was set out and the condition of the corals was recorded in writing, with photographs and on film.

Figure 8. Overview of environmental monitoring locations

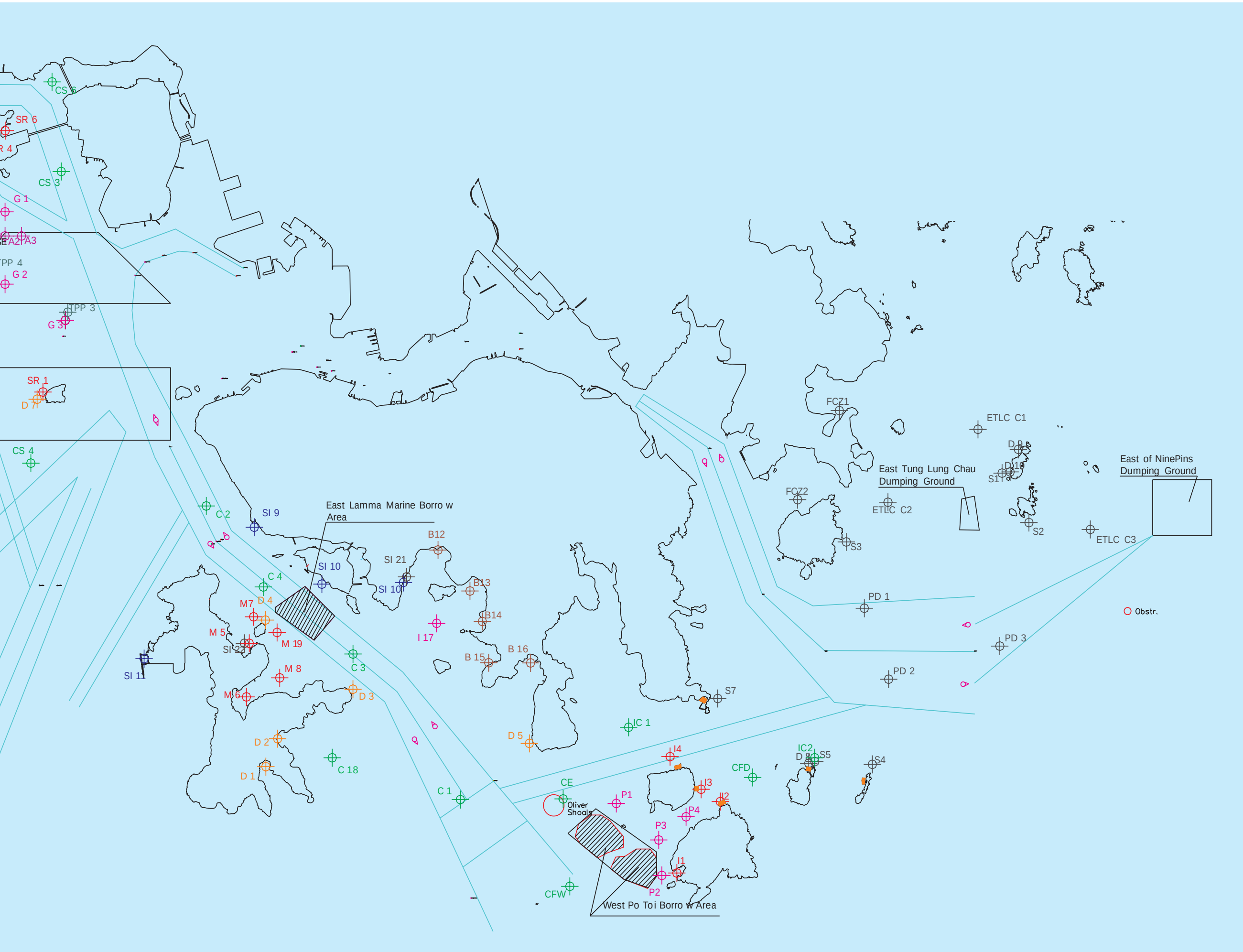


Figure 9. Dolphins liked to socialise with the observers.

Figure 10. White bellied sea eagles were amongst the animals monitored.

Eagles and dolphins

Environmental observers kept track of the movements of local wildlife, and two species in particular: the pink dolphin and the white-bellied sea eagle. They reported twice a month. The observers spotted the dolphins near the silt screen, where they tried to socialise with the observer's vessel. A magnificent bird and one of the most interesting creatures on site was the white-bellied sea eagle. The birds did not seem to be negatively influenced by the construction works and new chicks were spotted during the sessions (Figure 9 and 10).

In general, it is important to note that environmental monitoring sessions and reporting produced a tremendous amount of data and constituted a significant aspect of the execution of the project. Environmental reports alone provided a full-time job for ten staff and used up some ten tonnes of paper per year.

Conclusion

As in many projects of this size and nature, the work for the reclamation of new land for the international Theme Park in Hong Kong was divided into phases. Each phase had its own delivery date, defined in the contract, involving a number of milestones and hand-over dates.

The work on the future Hong Kong Disney Theme Park was divided into six phases (Figure 11). Each was completed and handed back to the client within its contractual period. As was the case for most of the works executed in Hong Kong, the next contractor started work on the newly reclaimed land only hours after handover of each of the areas.

Figure 11. The six phases of the development of the Hong Kong theme park area.