The large scale development of land subsidence in northwest Jakarta and north Tangerang, Indonesia

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Abstract A large area of approximately 10 000 ha is being developed along the northwest shore of Jakarta (Indonesia). Approximately 50% of the area is located onshore and 50% offshore. The future number of inhabitants amounts to approximately 500 000 to 600 000. The upper soil layer onshore and under the seabed consists, in large parts of the area, of soft marine sediments, overlaying medium stiff to stiff clay and silts. During recent years (1974/1978 until 1989/1990), along the entire northern coast of Jakarta, subsidence due to groundwater mining has been monitored, and found to range between 0.2 and 0.7 m. The present development plan needs to take account of this land subsidence. Because the area will be developed as a polder, the sea defence is of major importance. Also the drainage requirements of the upstream area are under pressure.

SITUATION

General description

Along the northwest coast of the Indonesian capital Jakarta and the westerly, neighbouring city of Tangerang, large-scale land reclamation is planned (Fig. 1). The area is partly located onshore and partly offshore (Fig. 2). The onshore area consists of typical coastal wetlands, at present mainly in use as fish pond areas. The offshore area stretches to the 5 m depth contour (i.e. LLWS − 5 m). The area comprises approximately 10 000 ha and runs approximately 29 km along the coast with a width ranging between 2 and 6 km.

The tidal levels range between MSL − 0.5 m (LLWS) and MSL + 0.5 m (HHWS). Storm surges, with an occurrence frequency of $10^{-4}$ per year, can add up to 1.2 m, depending on the wind direction. The future sea level rise over a period of 50 years is assessed at 0.3 m.

The future land levels range between MSL − 5.5 m and MSL + 3 m. The main onshore area lies at approximately MSL + 0.5 m.
REGIONAL SUBSIDENCE

Soil

From available soil data it is concluded that the coastal zone is composed of a basin fill of predominantly clay and clayey sediments with a thickness of several hundred metres. The depth of the upper marine sediment layer is about 10 m, on some places overlain by coastal swamp deposits and humic flood plain clays. It covers a late Pleistocene layer of volcanic origin with a thickness of more than 35 m.

Below this layer a distinction in soil profile has to be made between the area east and west of the Cisadane River, more or less following a deeper fault. At the eastern side of the Cisadane River a thick complex of Pleistocene deltaic, coastal and alluvial clays and silts are present up to 200 m below ground level. Only minor beds of intercalated sands are present. Below the Pleistocene basin fill impermeable Tertiary rock formations are found. At the western side of the Cisadane, west of the Cisadane fault, where the Pleistocene basin fill is missing, permeable Tertiary rock is present. Below the permeable Tertiary rock impermeable Tertiary rock formations are found, belonging to the same geological formation. The upper silty clayey marine soils are very soft and compressible.

Geohydrology

The stratigraphy cannot easily be characterized by clearly distinguishable high permeable layers (aquifers) and low permeable layers (aquitards). Groundwater mining
in the upper layers, mainly for domestic use, takes place over large areas of Jakarta by means of shallow wells, causing a decline of the groundwater head. Deep wells (up to more than 100 m below land level) are mainly used for industrial purposes. The hydraulic head declined more than 30 m in a period of 75 years.

Subsidence

Studies indicate that the coastal zone suffers from subsidence due to the extraction of groundwater from a depth between 40 and 120 m. The results of these studies have been converted to the offshore and nearshore reclamation areas. In future about 0.2-0.3 m of subsidence might be expected from the influence of urbanization.

POLDERS

Conceptual design

The land development design foresees the division of the area in six separate polders. A polder is a reclamation area, surrounded by a closed loop of flood protection elements (sea defences, dikes, water management system) to separate the water regime inside the polder areas from the water regime outside and to control the water table inside the area.
A partial landfill is applied to improve the accessibility in the polder area.

The concept of a polder comprises the following elements:

- A macro drainage system that consists of canals and outlets to intercept the runoff from the adjacent areas and the discharge of the rivers, and to divert this runoff towards the rivers and macro drainage outlets between the polders.

- Flood protection measures to retain the high water levels outside the polder and to protect the coastline against erosion. The flood protection measures comprise the dikes facing the sea, the dikes along the rivers, a landward dike bordering the interception drain and a separation dike between the shallow polders on the existing land and the deeper polders in the present offshore area (Fig. 3).

- A water management system to control the water table inside the polder. It comprises collector drains, retention basins, pumping stations and subsurface drainage to control the open water and the groundwater table.

![Fig. 3 North-south cross section over a polder.](image)

**Flood protection**

The polders are surrounded by one of the following types of dike:

- Sea defence dikes along the new shoreline, that is the present 5-m depth contour. These dikes are subject to tidal water level fluctuations, and attack and run-up of waves from the Java Sea.

- River dikes along the seaward part of the drains, intersecting the subsequent polders, between the present shoreline and the sea defences. These dikes are protecting the lower part of a polder. The river dikes are under the influence of fluctuations of the water level due to tides and due to the backwater effects of river and drain discharges, but wave attack is only minor. The dikes will therefore differ in type of outer slope protection and in crest level.

- River dikes along the landward part of the intersecting drains. These dikes are also under attack from both tides and backwater effects, but the dikes protect the upper part of a polder.

- Dikes along the boundary drains. These dikes are along the southern project boundary of the polders.

- Separation dike. This is a dike along the present coastline that protects the lower section against flooding from the upper reclamation section.

The dike structures are subject to consolidation settlement of the order of 1.5-2.5 m due to compression of the marine topsoil. Dike construction along the 5-m depth contour
will be phased to allow a substantial part of the settlements to occur before finalizing the crest structure of the sea defence dike. Still, between 0.5 and 1 m of residual settlement has to be considered. In the settlement predictions a semi-probabilistic approach has been chosen, taking into account the variation coefficient of the consolidation parameters.

**Earthworks inside the polder areas**

The local topsoils at the future reclamation area mainly consist of soft silty clay, plant remains and debris. Beyond the present shoreline the topsoils mainly consist of very soft organic silty clay with shells. These topsoils are not very desirable for a future housing/commercial area and have poor drainage properties. Therefore the sector will be filled by a sand layer approximately 1.5 m thick. This sand layer serves as a foundation for roads and the housing/commercial area, and also as a drainage layer. Due to the low permeability of the local soils, the settlement process may take several months.

For the onshore area, settlement analysis was carried out assuming no groundwater lowering. The present groundwater table ranges from 0.5 to 1.5 m below ground level. After filling and the construction of settlements the groundwater table will lie between 1.5 and 3.0 m below the future ground level. The mean characteristic values with a probability of exceedance of 5% have been used for the settlement analysis to avoid underestimating the future ground level.

The retention basin plays an important role in the drying of the reclamation area. Until 1 m above the sea bed the water can be easily pumped out, but below this level the retention basin has to be used as the main drainage provision.

First, the retention basin will be excavated by grab dredgers. The slopes that will form under water are about 1:4. Along the future basin embankment at the north side a sand fill will be placed under water over a width of about 20 m. The excavated material from the retention basin will be deposited between the sand fill and the landward slope of the sea defence on top of a 1-m-thick sand fill. The lowest part of the future reclamation area, at the landward foot of the sea defence, is thus effectively reduced. After the reclamation area has been pumped dry, the retention basin can be further deepened and the embankment slopes protected against erosion.

**Settlement of grab dredged soil from the retention basin**

The *in situ* properties of the material from the retention basin will change due to the excavation by a grab dredger. The material is loosened by the dredging process and will absorb additional water. The excavated material will reduce in volume due to the drying process after filling. It is estimated that the disposed local soil will reduce 60% in volume.

The analysis reported here has been based on soil borings spaced about 1000 m apart. Additional borings will be made to upgrade the soil data. In 1995 the conceptual designs will be worked out. A more detailed construction schedule will be prepared. It is envisaged to build a test section of the sea defence structure to confirm the estimates and to optimize the design.