CT4491 Fundamentals of Urban Drainage

Urban drainage in lowland areas

Marie-claire ten Veldhuis,
17-9-2013
Living in a delta: polder areas and water management challenges
Water management in delta cities

Rotterdam and Jakarta: two examples of delta cities

A. Influence of river and sea on urban water systems
B. Small ground level variations (almost flat)
C. High groundwater tables, salt water intrusion

Rotterdam: moderate climate, annual rainfall ca. 0.9 m/yr
Jakarta: tropical climate, annual rainfall ca. 2 m/yr
The Netherlands: Rhine, Meuse, Scheldt delta

Darker shades of green indicate higher population density

Source: www.deltanet-project.eu
Greater Jakarta
Jakarta bay
Vulcanos, 2000-3000 meter
Bogor
Depok
Bekasi
Jakarta
Tanggerang
5 m/year
2 m/year
30 km
The Netherlands: Rhine, Meuse, Scheldt delta

Delft: ground level relative to sea level?

A: +10m
B: +5 m
C: 0 m
D: -5 m
E: -10 m
F: Other
The Netherlands: Rhine, Meuse, Scheldt delta

Delft: ground level relative to sea level?

0.5 to 5 meters below mean sea level (!)
Deltas, if dikes do not protect

Influence of sea level

Influence of sea + river levels
Watersystems in the Dutch delta

NAP: Mean North Sea Level

- Dunes: North Sea
- Zoetermeer: NAP - 4.0 m
- Rottemeren: NAP - 4.5 m
- Hollandse IJssel: NAP - 6.0 m
Jakarta
Pluit - February 2011
(Water level 2.28m)

- Jakarta: ground level relative to sea level?
The Netherlands: Rhine, Meuse, Scheldt delta

Delft: ground level relative to sea level?
0.5 to 5 meters below mean sea level

Jakarta: average 7 m + sea level
➢ 40% of Jakarta below sea level
Deltas with protection: dikes and polders
Deltas with protection: dikes and polders

Pumping station

River level
Polder level
Intermediate level
Sea level
Delft area, dikes for flood protection:

- Sea defence works (23 km)
- River dikes (31 km)
- Polder dikes (655 km)

If this were 1 continuous straight line of dikes, what European capitals could we reach?
Delft area, dikes for flood protection:

- Sea defence works (23 km)
- River dikes (31 km)
- Polder dikes (655 km)

Total: 709 km

- Delft-Paris: 463 km
- Delft-Berlin: 702 km
- Delft-London: 492 km

A lot of dikes to maintain or enlarge!
Dikes for flood protection

Delft: 0.5 to 5 meters below mean sea level
709 km of dikes to protect surrounding delta area

Jakarta: 40% or urbanised area below sea level
➢ Should a similar solution be implemented here?
High sea levels are only part of the problem:

Jakarta, Jan 2013: extreme rainfall

Source: www.wunderground.com
Water management challenges in deltas

Water comes from all sides:

Make a list: 7 water problems in deltas
Water management challenges in deltas

Water comes from all sides:
- High sea levels (6, 7)
- High river levels (5)
- Heavy rainfall (1)
- High surface water levels (in polder and regional water system) (4)
- Urban drainage system overloading (3)
- High groundwater levels (2)
Climate change: growing challenges
Climate change: growing challenges

What growing challenges due to climate change for:

- High sea levels (6, 7)
- High river levels (5)
- Heavy rainfall (1)
- High surface water levels (in polder and regional water system) (4)
- Urban drainage system overloading (3)
- High groundwater levels (2)
Climate change: growing challenges

What growing challenges due to climate change for:

- Sea levels?
- River levels?
- Rainfall?
- Surface water levels?
- Urban drainage?
- Groundwater levels?
Climate change: growing challenges

- Rising sea levels (6,7)
- Rising river levels (5)
- More extreme rainfall (1)
  - High surface water levels (in polder and regional water system) (4)
- Urban drainage system overloading (5)
- Longer droughts
- Subsiding soils
- Salt water intrusion (2)
The challenge: coping with more extreme rainfall in cities

Jakarta, Jan 2013: extreme rainfall

Source: www.wunderground.com
Aerial view of Delft and elevation levels

Dark blue is level of main surface waters (water level Schie: NAP-0.43)
Delft city centre: canals

Note: street level only cm-s above water level
Street level only cm-s above water level: susceptible to flooding
Deltas, an additional challenge: land subsidence
Land reclamation: subsidence

Historical development of water and ground levels in polders
Land reclamation

Historical development of water level and ground levels in polders

-4 m
Subsidence in polders

Expected subsidence
(Flevopolders: range 0 to 1.2 m)

Amsterdam: Settlement rate in mm/yr
Scale: -20mm/yr (dark blue) to 0mm/yr (red)
Subsidence in polders

Amsterdam: Settlement rate in mm/yr: Up to 2 cm/year

Jakarta: Settlement rate in mm/yr: Up to 25 cm/year

So... we build higher and higher buildings and will be safe?
Well, only if you do not want to go anywhere...
Water management challenges in deltas

Water comes from all sides:

- High sea levels (6, 7)
- High river levels (5)
- Heavy rainfall (1)
- High surface water levels (in polder and regional water system) (4)
- Urban drainage system overloading (3)
- High groundwater levels (2)
Sewer systems in lowland areas, where there is no natural slope
Sewers in flat urban catchments

Small distance between ground level and surface water level:

Sewer outflow below surface water level!

Ground level

Pressure gradient

Ground cover: ±1m

Surface water level

Side-view of underground sewer pipe
Sewers in flat urban catchments

Side view of small-gradient sewer

Gradient: 0.5 m over 1000 m: 0.05%
Sewers in flat urban catchments

- Small ground level gradient; small sewer pipe gradients
- Low flow velocities
- Subcritical flow

Gradient: 0.5 m over 1000 m: 0.05%

Pressure gradient

Ground level

Sewer pipelines
Sewers in steep urban catchments

- Steep ground level gradient;
- High flow velocities
- Occurrence of supercritical flow

**Surface water level**

**Ground level**

(gradient: 6m over 200m: 3%)

**Water level gradient**

**Side-view of steep drainage channel**
Water management in delta cities

Main differences between urban water systems in sloping versus flat catchments:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sloping</th>
<th>Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First, a few questions:
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?

Q: How deep are sewers below ground level?
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?

Q: How deep are sewers below ground level?

A: typically 1 m to 4 m below ground level
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?

Q: How deep are sewers below ground level?

A: typically 1 m to 4 m below ground level

Q: What is distance between ground level and surface water level?
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?

Q: How deep are sewers below ground level?

A: typically 1 m to 4 m below ground level

Q: What is distance between ground level and surface water level?

A: Typically 0.5 m – 2.5 m
Water management in delta cities

Q: What is level of sewer outflow (bottom level pipe) compared to surface water level?
A: typically 0.3 m to 1 m below surface water level

Q: How deep are sewers below ground level?
A: typically 1 m to 4 m below ground level

Q: What is distance between ground level and surface water level?
A: Typically 0.5 m – 2.5 m
Water management in delta cities

Main differences between urban water systems in sloping versus flat catchments:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sloping</th>
<th>Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance ground level to surface water level</td>
<td>0 – 10s of meters Pipe outflow point above surface water level Pipes above groundwater</td>
<td>0 – 10s of centimeters Pipe outflow point below surface water level Pipes below groundwater</td>
</tr>
<tr>
<td>Water conveyance gradient</td>
<td>Natural gradient</td>
<td>Create gradient by digger deeper+adding pumping stations</td>
</tr>
<tr>
<td>Flow velocities</td>
<td>High flow velocities</td>
<td>Low flow velocities</td>
</tr>
<tr>
<td>Design conditions</td>
<td>Pipes partially filled</td>
<td>Pipes surcharged =pressurised flow</td>
</tr>
</tbody>
</table>
Example: Longitudinal profile of a combined sewer pipeline

Sketch the hydraulic gradient in the sewers during design rainfall

Rainfall intensity: 60 l/s/ha
Connected surface per manhole: 4 ha; 50/50 paved/unpaved
Distance between manholes: 400 m

Surface water level: NAP 0.0m

Ground level
Manhole 1: NAP+0.5m
Manhole 2: NAP+0.4m
Manhole 3: NAP+0.3m
Example: Longitudinal profile of a combined sewer pipeline

Sketch the hydraulic gradient in the sewers during design rainfall

Rainfall intensity: 60 l/s/ha
Connected surface per manhole: 4 ha; 50/50 paved/unpaved
Distance between manholes: 400 m

Surface water level: NAP 0.0m

Ground level
Manhole 1: NAP+0.5m
Manhole 2: NAP+0.4m
Manhole 3: NAP+0.3m
Example: Longitudinal profile of a stormwater sewer line

Same question:

Sketch the hydraulic gradient in the sewers during design rainfall

Ground level
Manhole 1: NAP+0.5m
Manhole 2: NAP+0.4m
Manhole 3: NAP+0.3m

Surface water level:
NAP 0.0m
Example: Longitudinal profile of a stormwater sewer line

Same question:
Sketch the hydraulic gradient in the sewers during design rainfall

Ground level
Manhole 1: NAP+0.5m
Manhole 2: NAP+0.4m
Manhole 3: NAP+0.3m

Surface water level:
NAP 0.0m
Example: Longitudinal profile of a stormwater sewer line

Same question:

Sketch the hydraulic gradient in the sewers during design rainfall

Surface water level: NAP 0.0m

Ground level
Manhole 1: NAP+0.5m
Manhole 2: NAP+0.4m
Manhole 3: NAP+0.3m