

# World Tunnel Congress (WTC) 2009

## Planning of Deep Sewage Tunnels in Hong Kong

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# CONTENT

Background of Harbour Area Treatment Scheme (HATS)

Rationales for choosing a deep tunnel system

Ground investigation using the specialized technique of horizontal directional coring

Why we have selected the drill-and-blast construction method instead of TBM

Contract strategy for implementation of the construction works.



An aerial photograph of Hong Kong, showing the dense urban landscape of the city and the surrounding Victoria Harbour. The skyline is filled with numerous skyscrapers, and the harbour is filled with water, with several ships visible. The text "Victoria Harbour a Major Asset for the Hong Kong SAR" is overlaid on the image in a large, bold, white font with a black outline. The background shows green hills and a blue sky with scattered white clouds.

# **Victoria Harbour a Major Asset for the Hong Kong SAR**



**Before the implementation of the Harbour Area Treatment Scheme (HATS) Stage 1, sewage discharged into harbour only after screening and degritting.**

**Rapid development and population increase have led to water pollution problems**

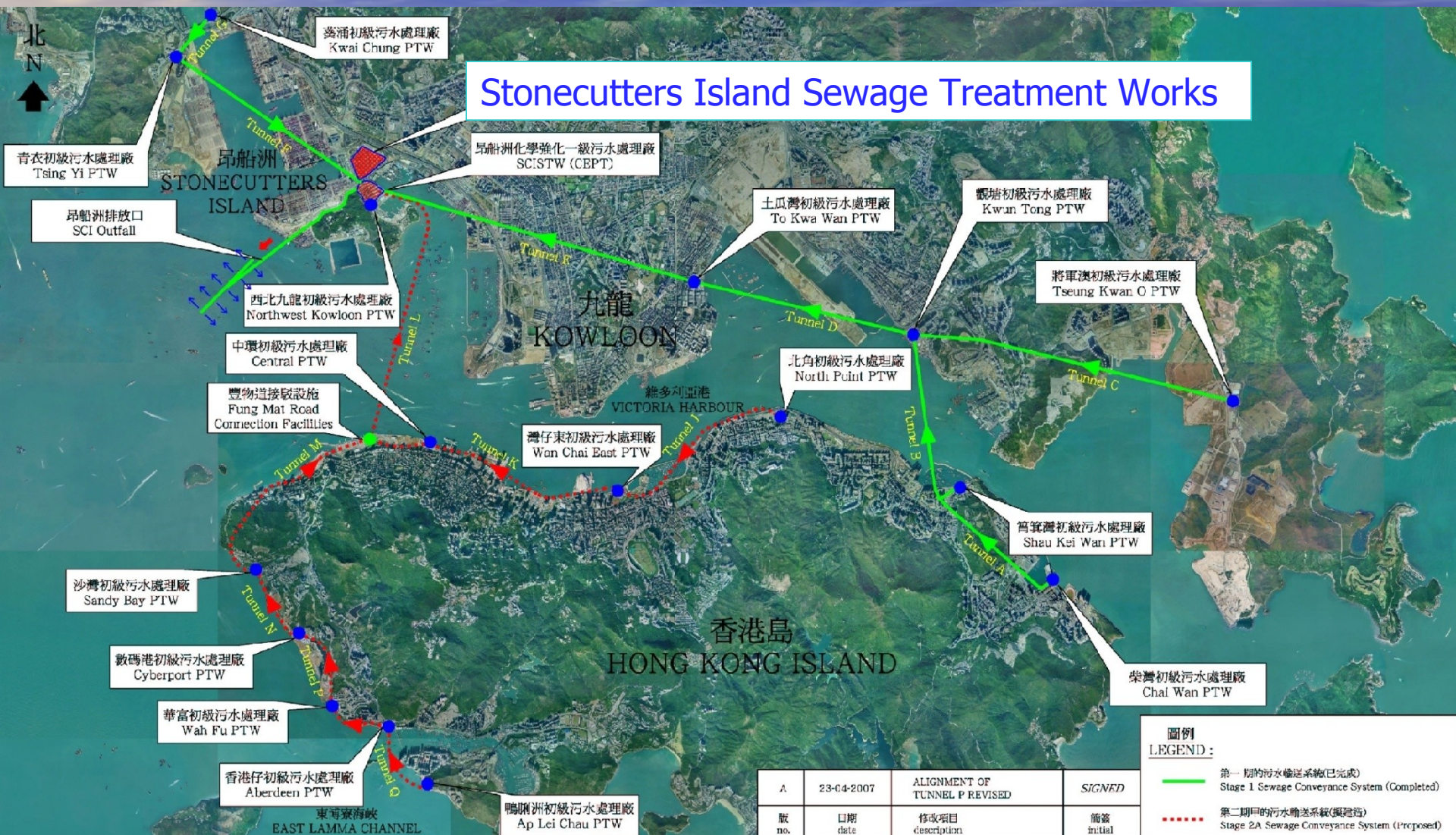


# Stage 1 tunnels (completed)

## Stage 2 tunnels (being planned)

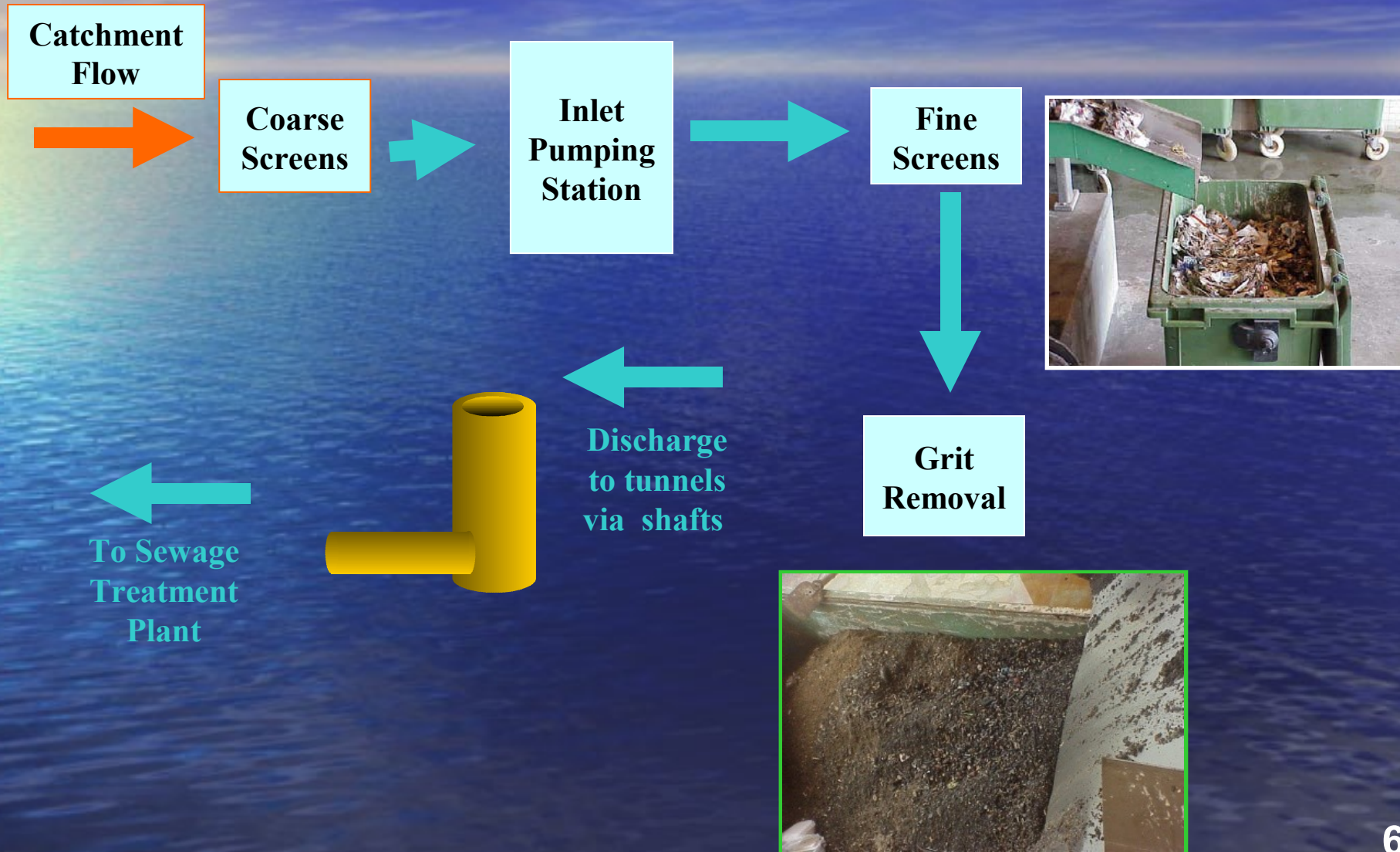
24 km

21 km

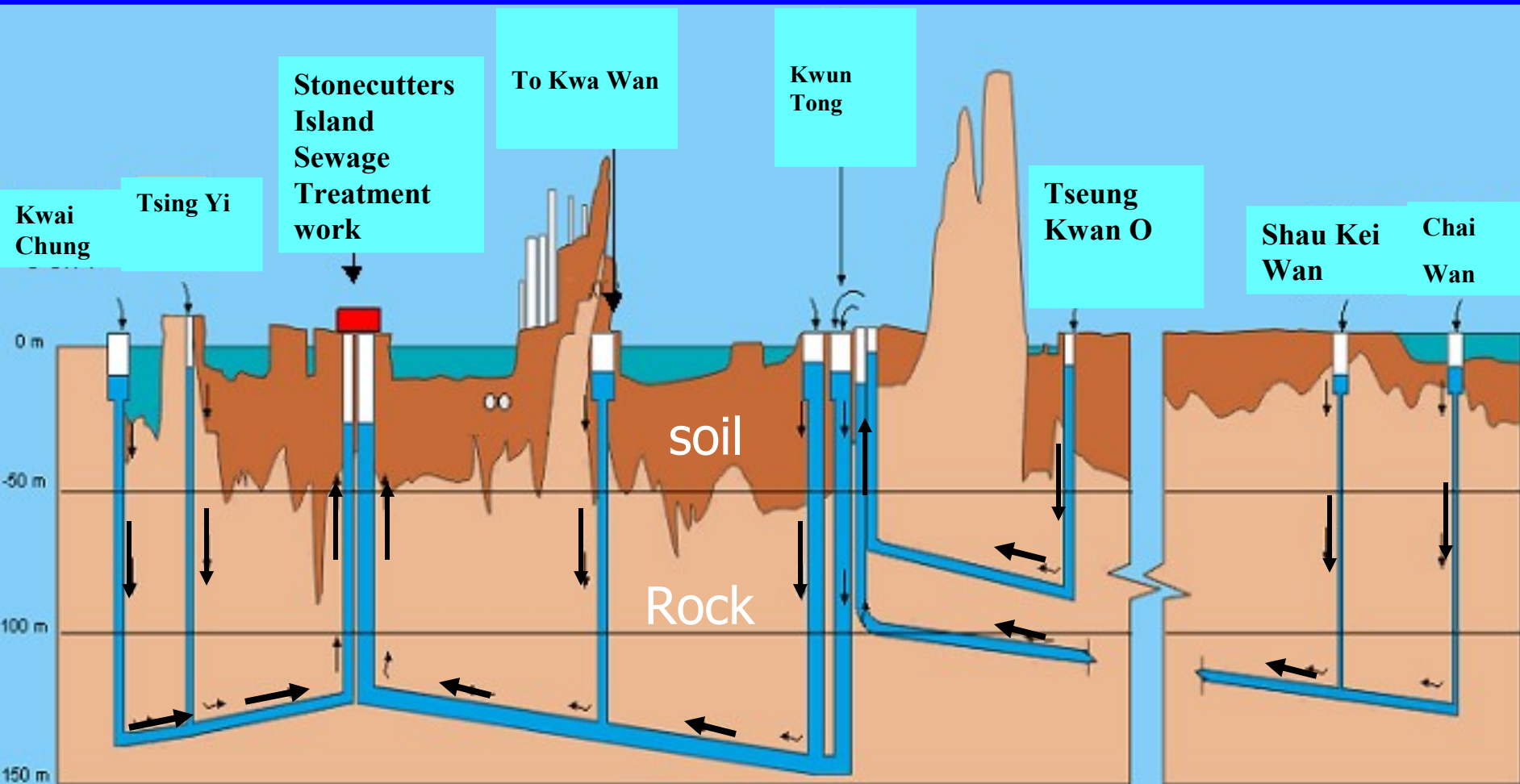




# HATS - Sewage Conveyance System



# HATS Stage 1 - Sewage tunnels system – vertical profile



Mostly Inverted siphons



# **HATS Stage 1 - Stonecutters Island Sewage Treatment Works**

**Preventing 600 tonnes of sludge from entering into harbour each day**



**Capacity: 170 million cu.m  
of sewage per day**



# Harbour Area Treatment Scheme Stage 2

Total tunnel length about 21 km



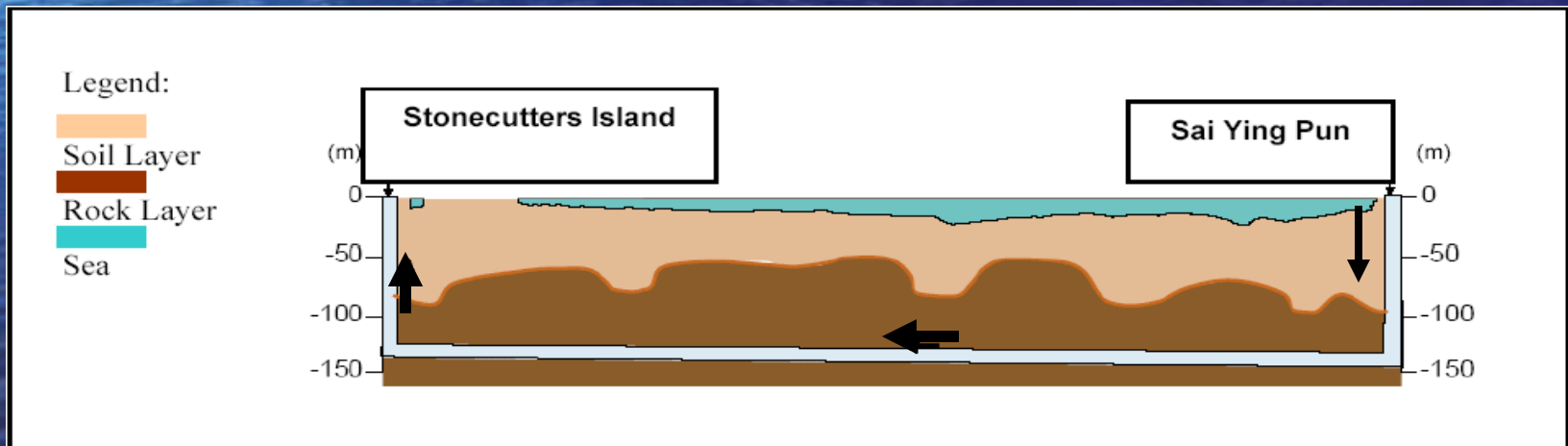
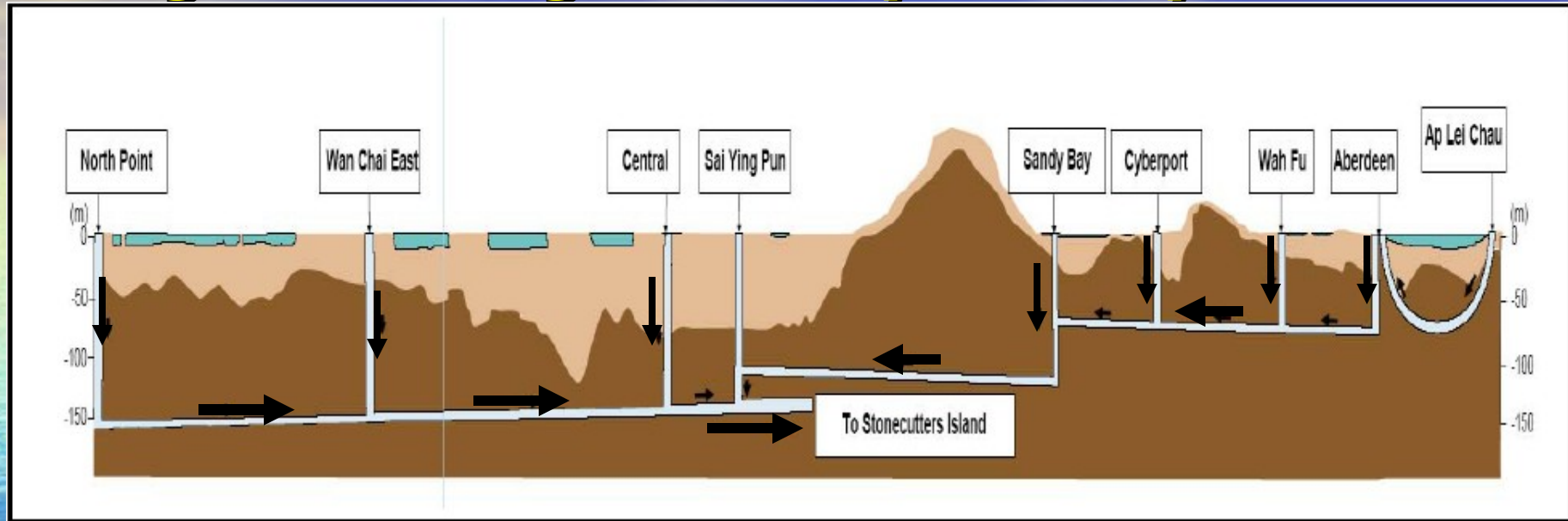
**Stage 1 + 2:**

**Capacity to serve  
population of over  
6 million**



# Vertical Profile of HATS

## Stage 2 Sewage Conveyance System





# Why use the Deep Tunnel System?

Planning considerations: Options and Evaluations

## Options considered:

- **Shallow sewers by open trench method**
- **Shallow sewers by trenchless method: e.g pipe jacking, HDD**
- **Mixed ground tunnelling (20-50m)**
- **Deep hard rock tunnelling by TBM or D&B**



# Why use the Deep Tunnel System?

## Factors considered in evaluation of options:

- **Constructability**
- **Cost**
- **Environmental and social impact**
- **Programme**
- **Risks**
- **Hydraulic performance**
- **Maintenance**



# Why use the Deep Tunnel System?

Open Trench Method for sewers





# Why use the Deep Tunnel System?

## **Evaluation - Open trench method:**

- practically ruled out - unacceptable by the public**
- difficult and lengthy utility diversions**
- environmental & traffic impacts difficult to mitigate**
- strong objections from local bodies and legislature**



# Why use the Deep Tunnel System?

Evaluation – trenchless method (pipe jacking):

- Very few possible locations for jacking pits
- Inevitable road opening works -- similar problems as open trench
- costs comparable with mix ground / deep hard rock tunnelling for this project's situation
- Programme risks due to likely strong public objections
- Experience: trunk sewers by pipe jacking in urban areas: "more than 4 years"



# Why use the Deep Tunnel System?

Evaluation – mixed ground tunnelling (20 –50m):

- Cost similar to deep hard rock tunnelling
- Ground settlement risks exist as for deep hard tunnel
- Lack of above ground space for support, for e.g. slurry plant, TBM set up.
- Impact on existing/future land development
- Conflicts with existing piles from buildings and existing road and railway tunnels



# Why use the Deep Tunnel System?

**Deep hard rock tunnelling is selected mainly because:**

- 1. Disturbance to public is minimized**
- 2. Conflicts with existing foundations/utilities minimized**
- 3. Acceptance by public**
- 4. Cost and programme: comparable/ better than other options**
- 5. Future land developments not constrained**



# Details of Stage 2 Sewage Tunnels by Drill and Blast

**Total Length of tunnels: 20 km**

**Length of tunnels between shafts: 3.2km to 4.6km**

**Estimated excavated size of tunnel:**

**horse-shoe shape**

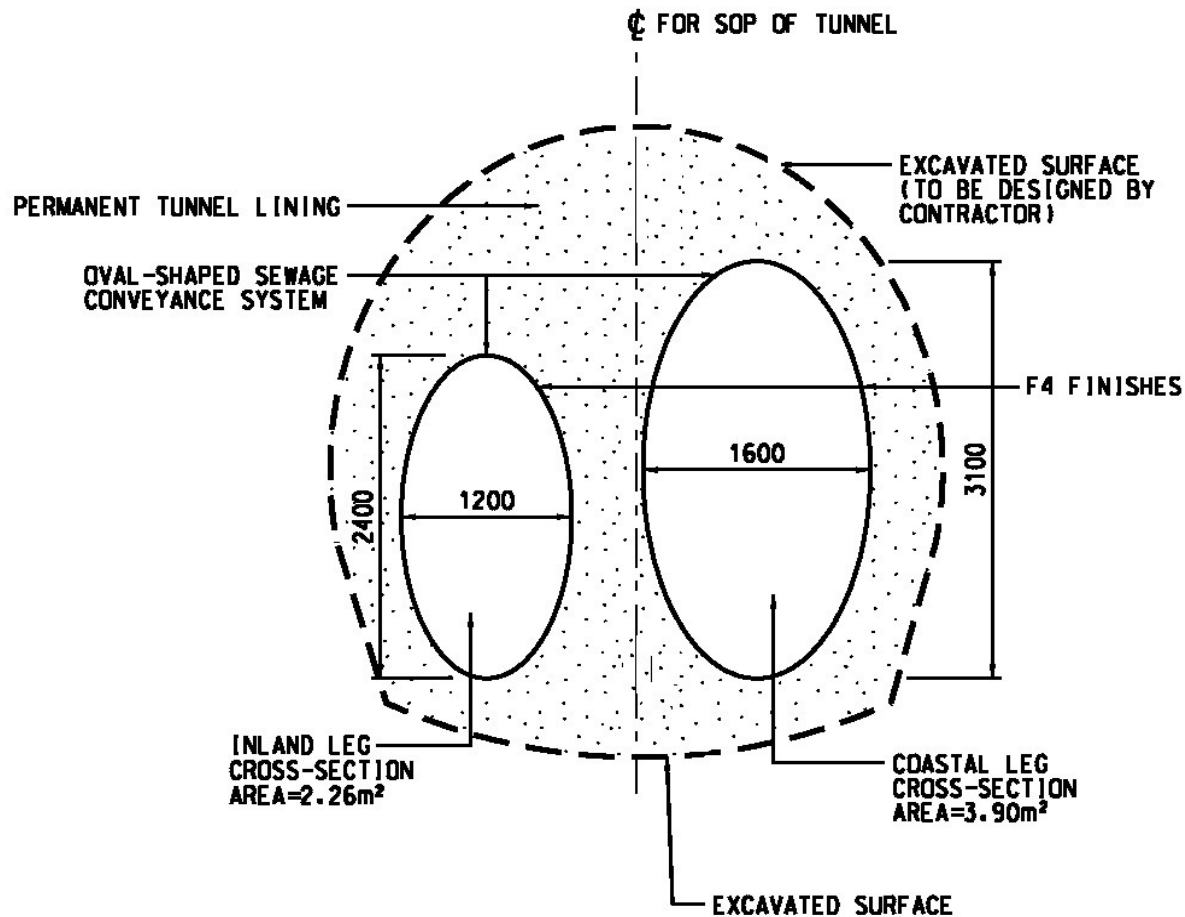
**width: 3.5m ~ 4.5m**

**Height: 3.5m ~ 4.5m**

**Depth: ~ 75m to 165m below sea level**



# Cross Section (Oval Conduits) of Sewage Tunnel



**TUNNEL K : WAN CHAI EAST TO CENTRAL**





**Tunnel Construction mostly by Hard  
Rock TBM in Stage 1**



# Problems experienced in HATS Stage 1

- Water Inflow





# Problems experienced in HATS Stage 1

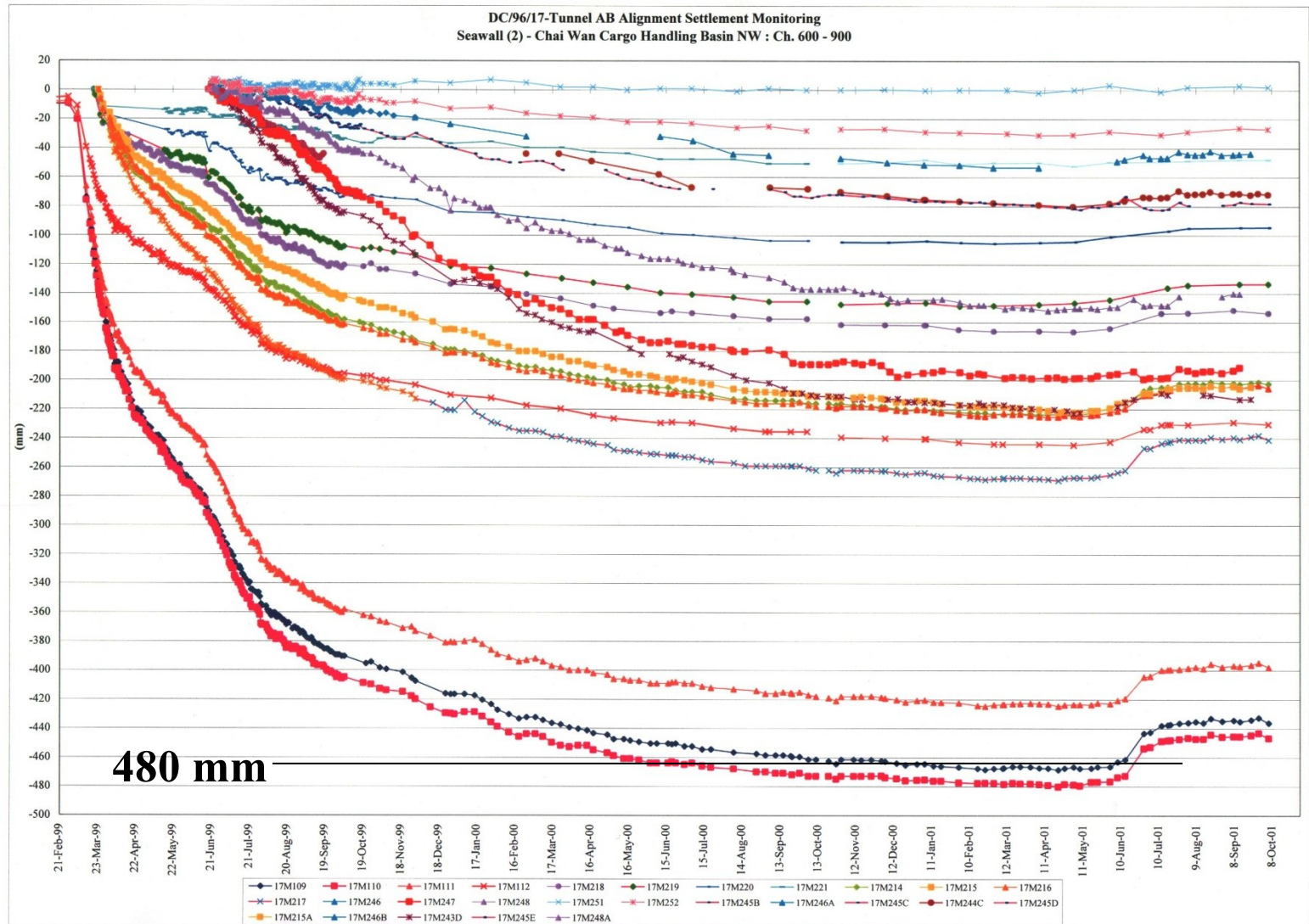
- Water Inflow





# Problems experienced in HATS Stage 1 (Cont.)

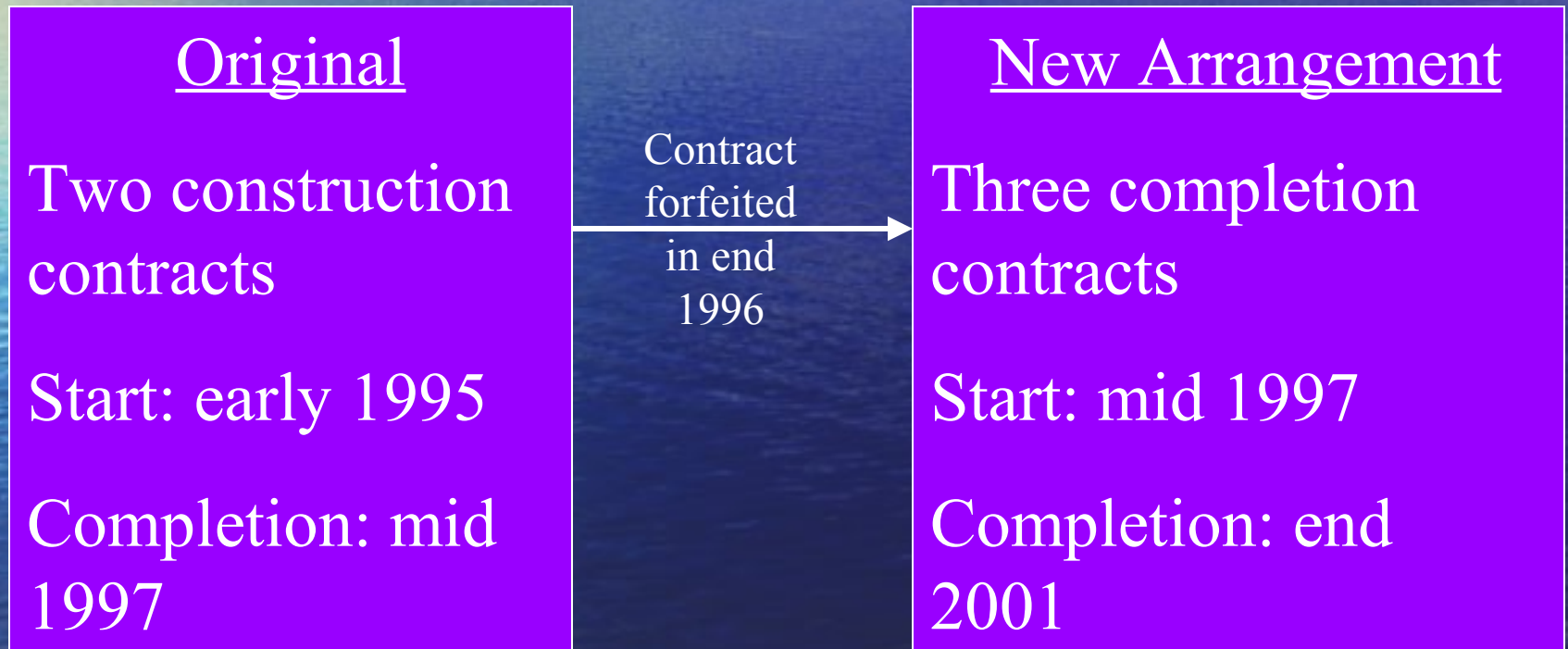
- Settlement





# Problems experienced in HATS Stage 1 (Cont.)

- Forfeiture of Contract



## Measures taken in Stage 2 tunnels:

- Early design input from Experts
- A comprehensive site investigation programme
- Use state-of-the-art site investigation technology : directional coring
- Critical Review of TBM vs Drill-&-Blast
- Contract measures



# Site Investigation

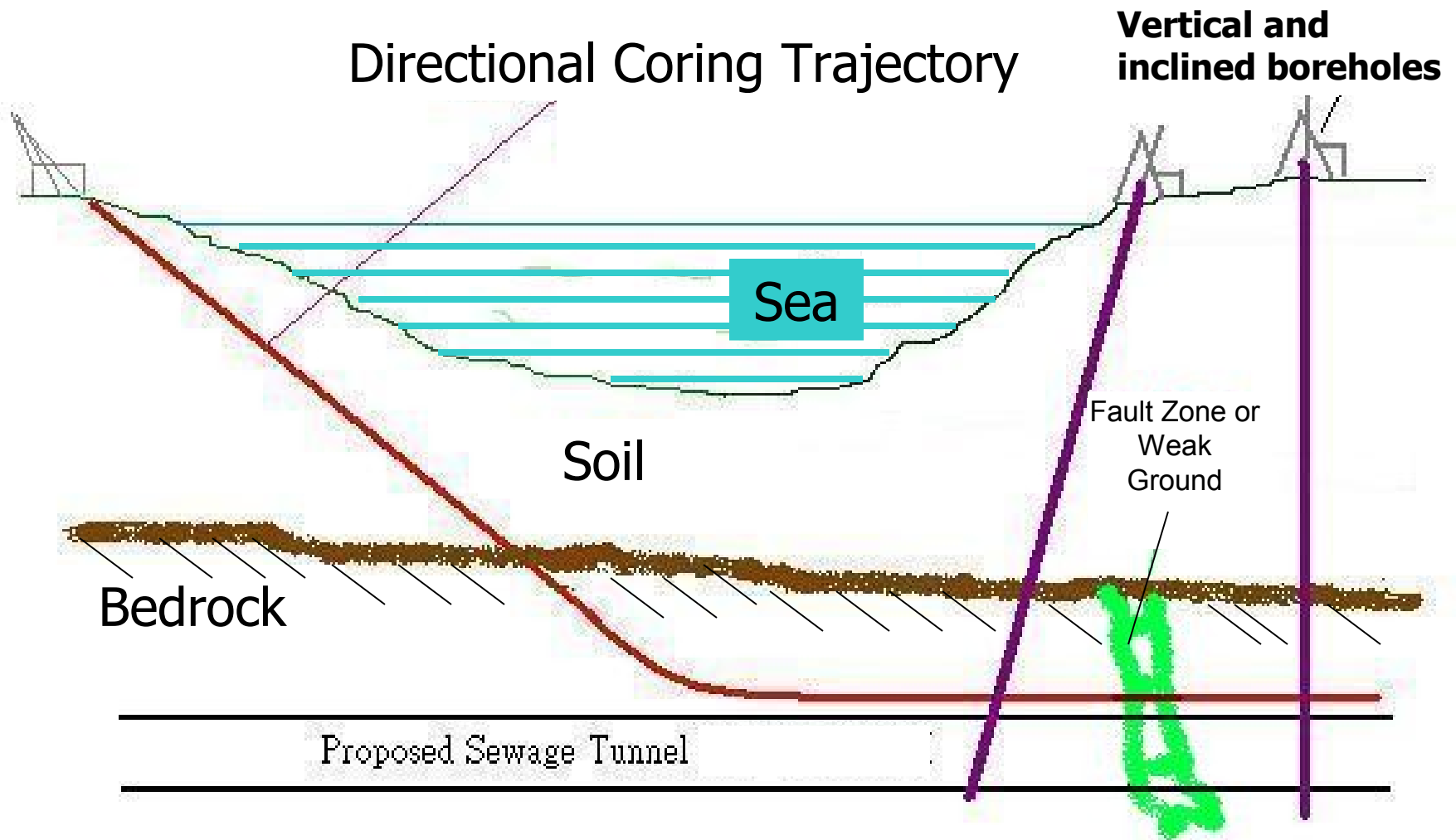
		<b>Rough costs in Euros (based on 1 Euro = 10 HK\$)</b>
<b>Total length of directional coring</b>	<b>about 5 km</b>	<b>4.7 Million</b>
<b>Number of vertical/inclined boreholes</b>	<b>about 150 numbers</b>	<b>5.3 Million</b>
<b>Total length of vertical/inclined boreholes</b>	<b>about 18 km</b>	
<b>Total cost of ground investigation works</b>		<b>10 Million</b>

# Horizontal Directional Coring

- **The first use of this technology in obtaining geological information at such depth in Hong Kong**



# Horizontal Directional Coring Trajectory



# Advantages of using Directional Coring for Site Investigation

- Continuous geological information at tunnel level can be obtained
- Tests can be carried out at tunnel level to obtain information for control of groundwater ingress and grouting design



# Layout plan for HDCs

STONECUTTERS ISLAND  
SEWAGE TREATMENT WORKS  
昂船洲污水處理廠

HDC

Target high risk areas with potential deep  
weathering and/or major fault zones

SAI YING PUN CROSS  
HARBOUR TRANSFER SHAFT  
西營盤海底轉運豎井

CENTRAL PRELIMINARY  
TREATMENT WORKS  
中環污水隔濾廠

NORTH POINT PRELIMINARY  
TREATMENT WORKS  
北角污水隔濾廠

WAN CHAI EAST PRELIMINARY  
TREATMENT WORKS  
灣仔東污水隔濾廠

LITTLE GREEN ISLAND

CHAMNEL

SULPHUR

TUNNEL M

HD05

隧道 L  
TUNNEL L

HD04

HD01

HD02

HD03

HD03a

HD03b

HD03c

HD03d

HD03e

HD03f

HD03g

HD03h

HD03i

HD03j

HD03k

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HD03hl

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HD03hp

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HD03js

HD03jt

HD03ju

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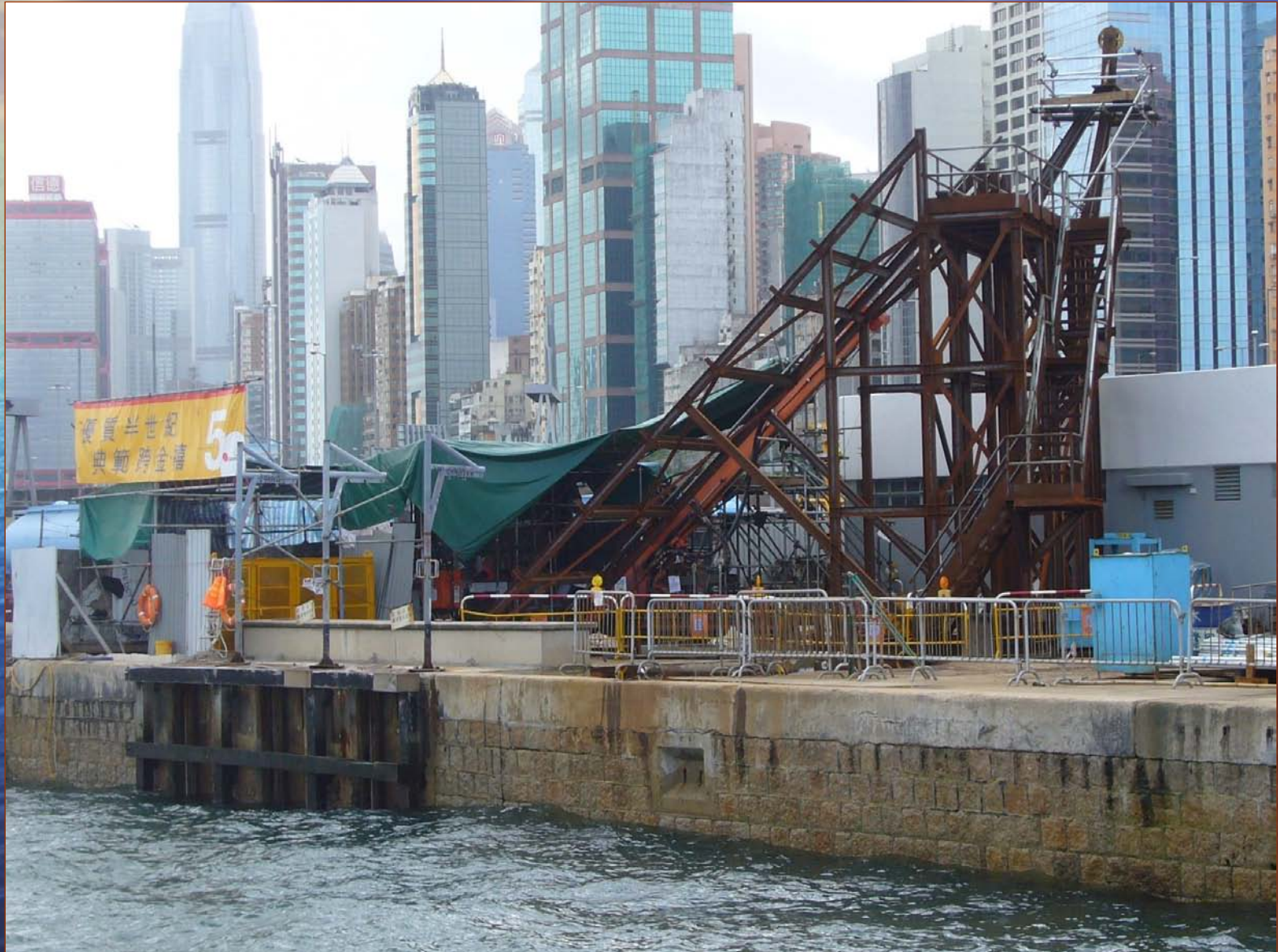
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# Set Up for Directional Coring









# DIRECTIONAL BARREL





# Rock Cores from Directional Coring



Central PTW 30/07/07 (DV = 32 Ø)

# Geological Information

- **Faults and dykes are likely to be encountered at tunnel depth**
- **Deep weathering and/or gouge materials expected at Faults and dykes**
- **Fractured rock in fault zones and areas other than fault zones**
- **Localised weathering in fault zones and dykes**
- **Extensive treatment to limit water inflows and ground supports required**



# Critical review on construction method: TBM vs Drill-and-Blast



## Why Drill-and-Blast is selected:

- **Variable Geological conditions – extensive grouting and ground support expected; TBM excavation rates more susceptible to adverse ground conditions**
- **Relatively small tunnel sizes for efficient drilling and grouting equipment for TBM. Fully automated drilling jumbo available for size range.**



## Why Drill-and-Blast is selected:

- **Extensive grouting to control groundwater inflow**
- **Limited surface works area is available for the use of TBM**
- **Few proven experiences in TBM tunnelling at such depth (-160 mPD)**

# Measures taken in Stage 2

- Risk Management Approach
  - A comprehensive risk management plan has now been developed
  - Risks are allocated to the most appropriate parties to deal with



# Measures taken in Stage 2

- Contract Strategy to reduce risk
  - Contract Form with Re-measurement of Major Works Items: drilling of probe holes, pre-excavation grouting, shotcreting, rock bolts, steel ribs, etc.
  - Divide into two drill-and-blast contracts with manageable size
  - Restriction that a contractor cannot take both drill-&-blast contracts
  - Requirement for parent company guarantee and a performance bond

## Measures taken in Stage 2

- **Mechanism for Selecting the Contractors**

- Prequalify contractors who are capable (both financially and technically)
- A marking scheme tailor-made for the tendering exercise is devised and made known to all prequalified tenderers
- Award based on both technical score and price



# Public Consultation

- A continuous public involvement approach
  - Consult the public and stakeholders at various stages of project implementation

# **HATS Stage 2 Tunnels – Costs**

**Capital cost of sewage tunnels: ~ 600 million Euros**

## **Project Update**

Approval of Environmental Assessment Study	End 2008
Commencement of contracts	2nd half of 2009
Completion of the whole system	2014



**Thank you!**

