Standing Committee on Concrete Technology
Annual Concrete Seminar 2019

Harbour Area Treatment Scheme Stage 2A
Long-Distance Concrete Placing

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Nick Gibbs (Gammon Construction)

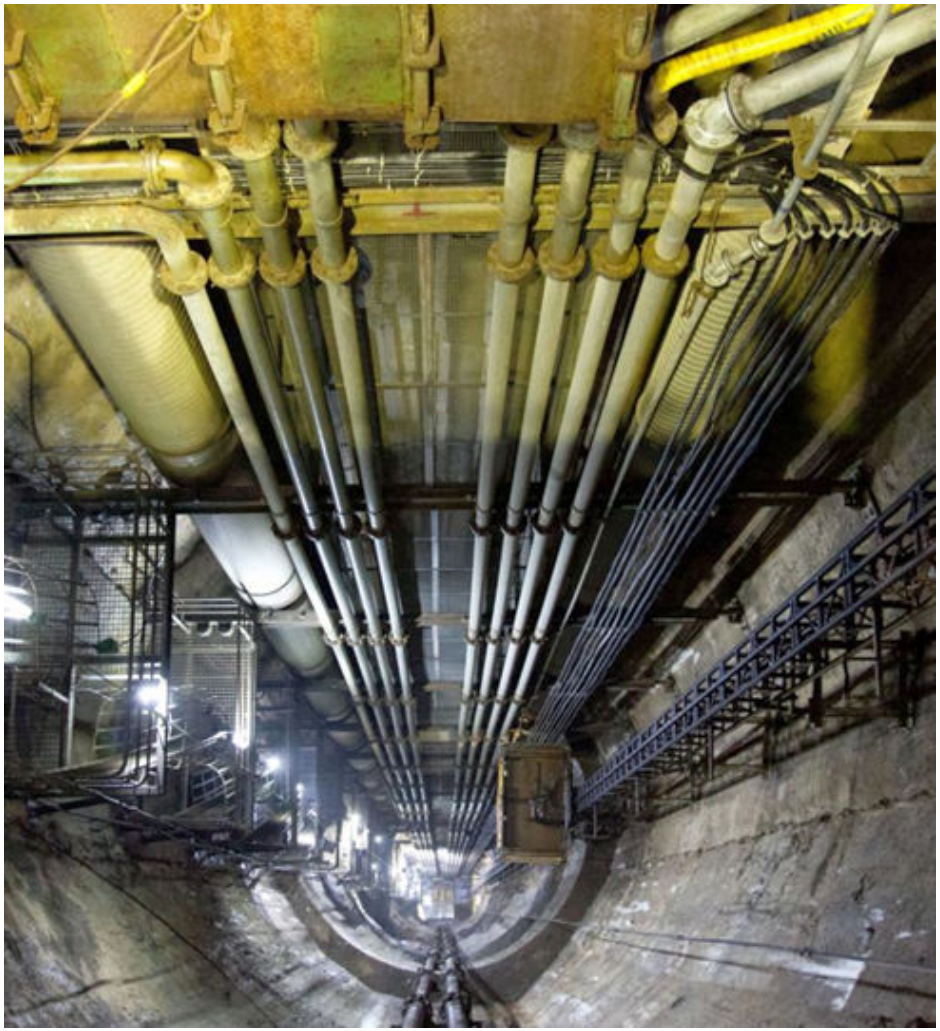
Outline

- 1st part – by Mr. K Y Chan
  - Project Introduction & Background
  - Consideration of choosing long-distance concrete pumping

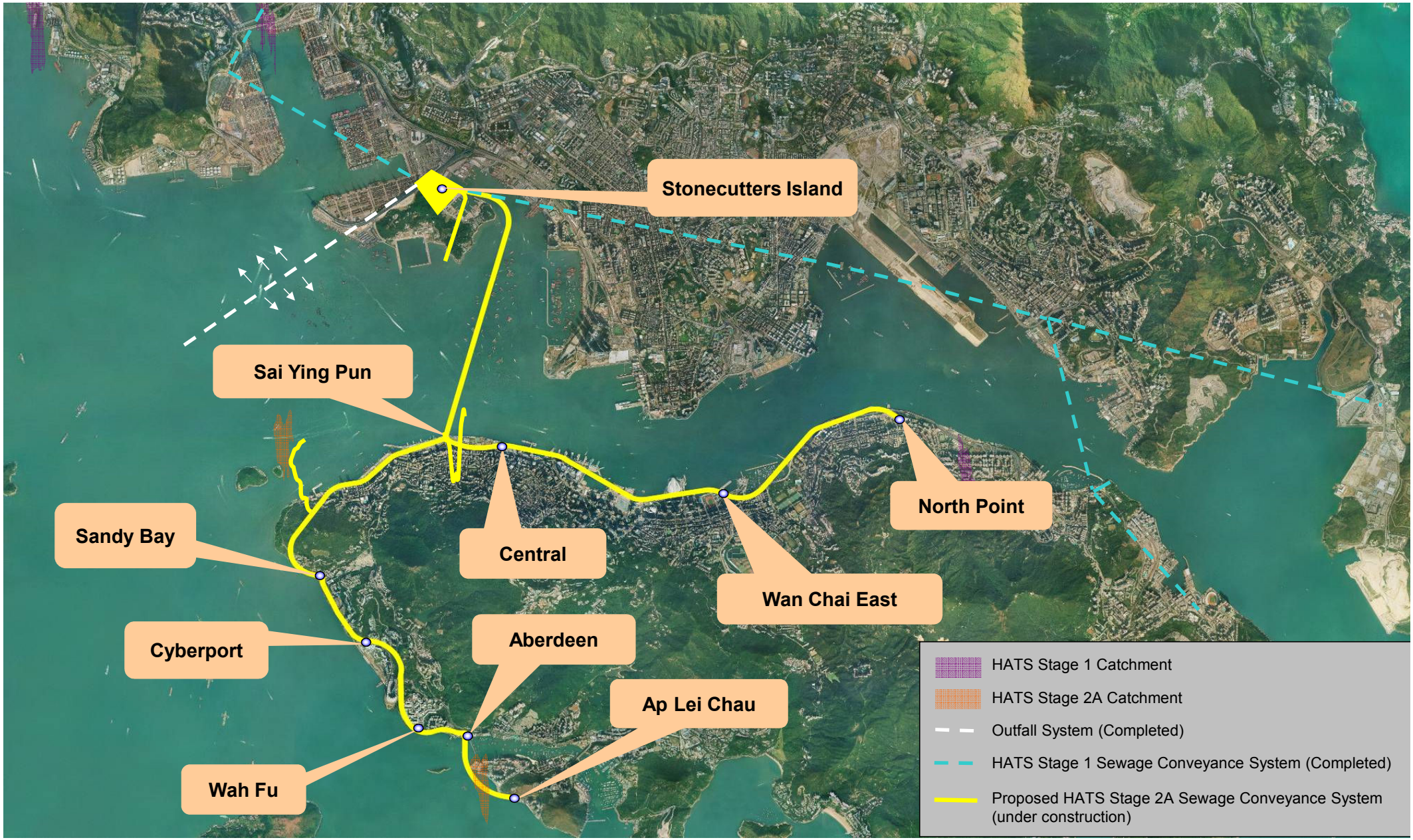
- 2nd part – by Mr. Nick Gibbs on
  - Project delivery including logistics, trial pours, concrete distribution system, high performance concrete mix design etc.

HATS Stage 2A Project Background

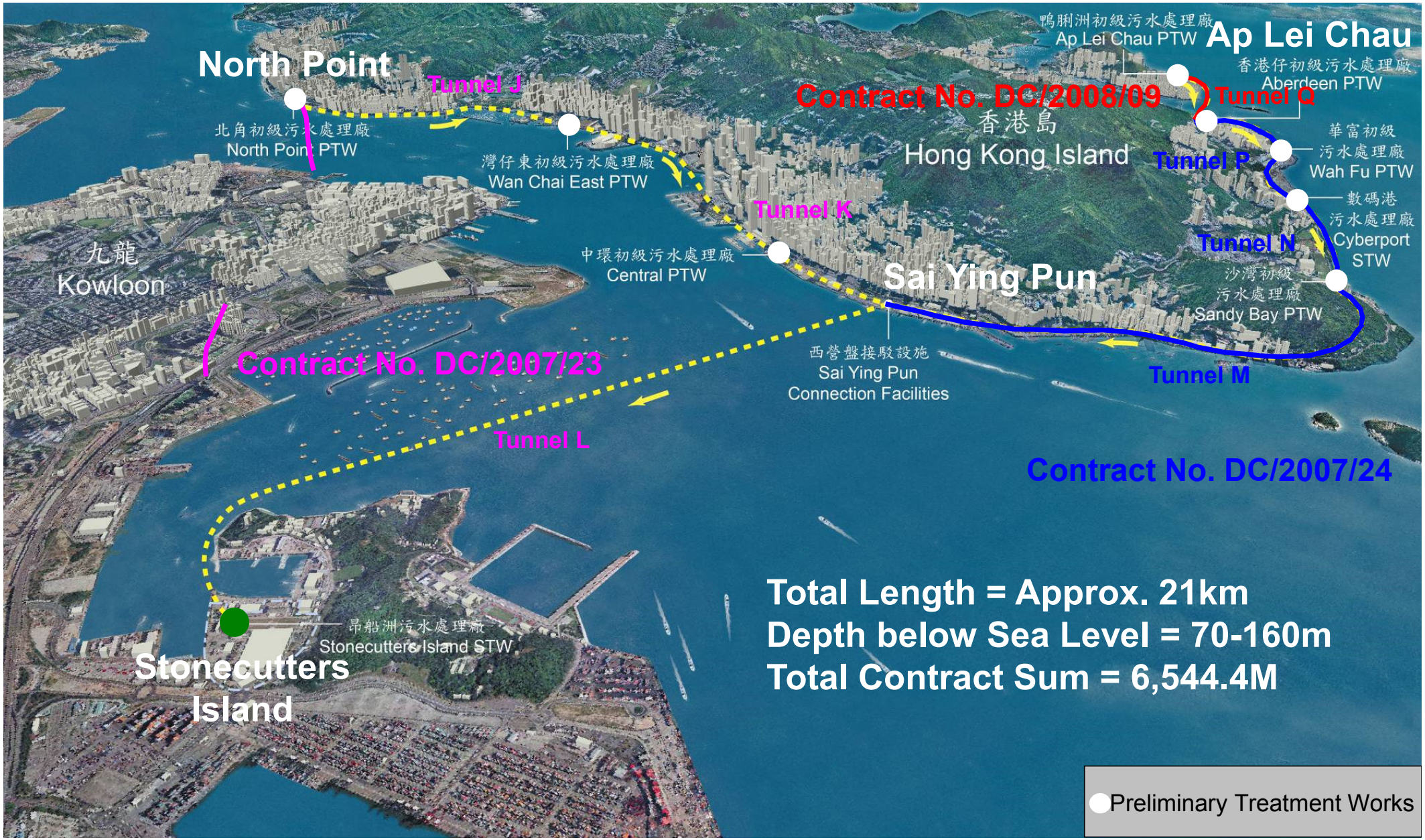
Harbour Area Treatment Scheme (HATS)
Stage 2A Sewage Conveyance System (SCS)

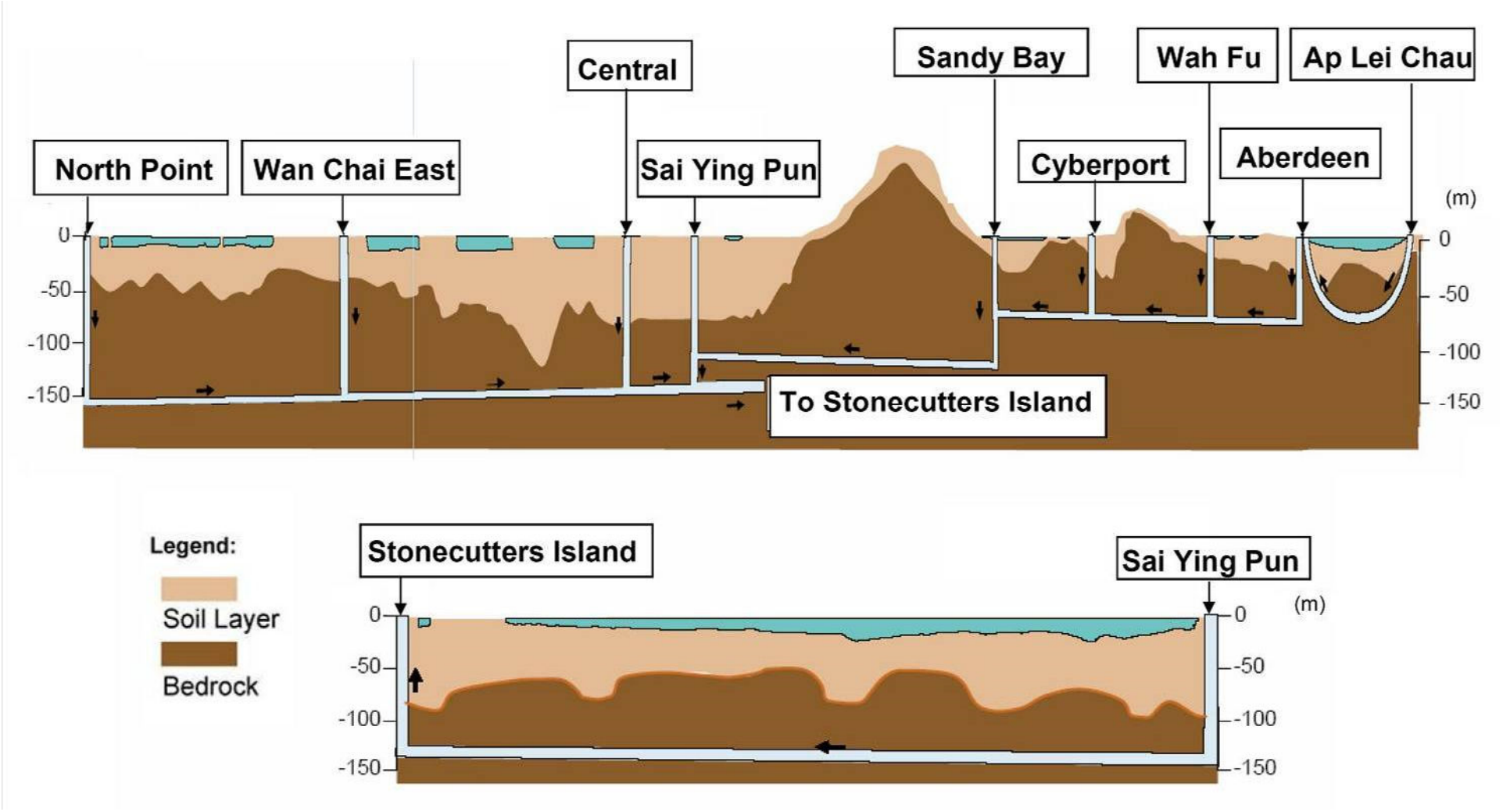


Harbour Area Treatment Scheme – Stages 1 and 2A

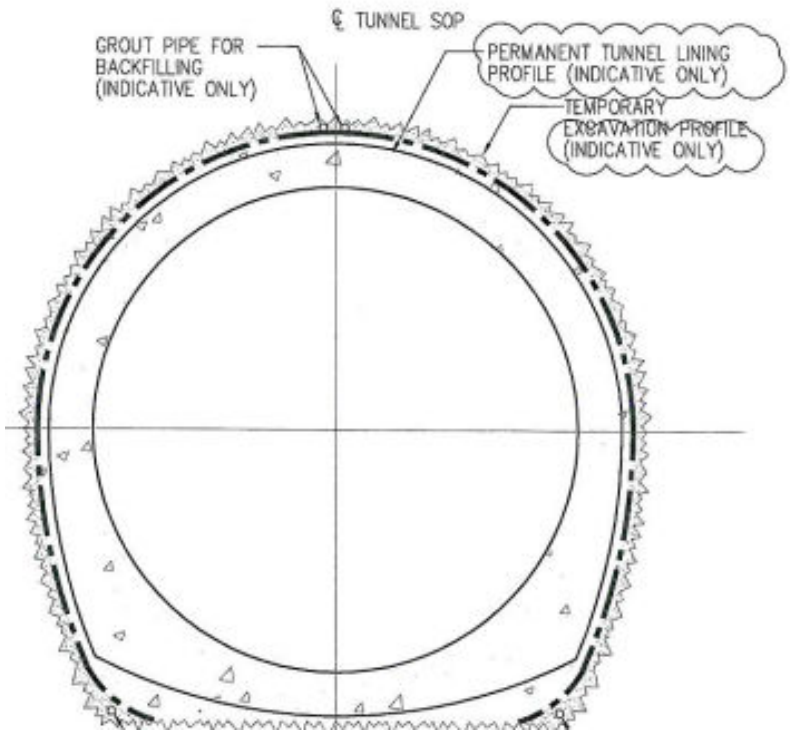


HATS Stage 2A Sewage Conveyance System - Alignment

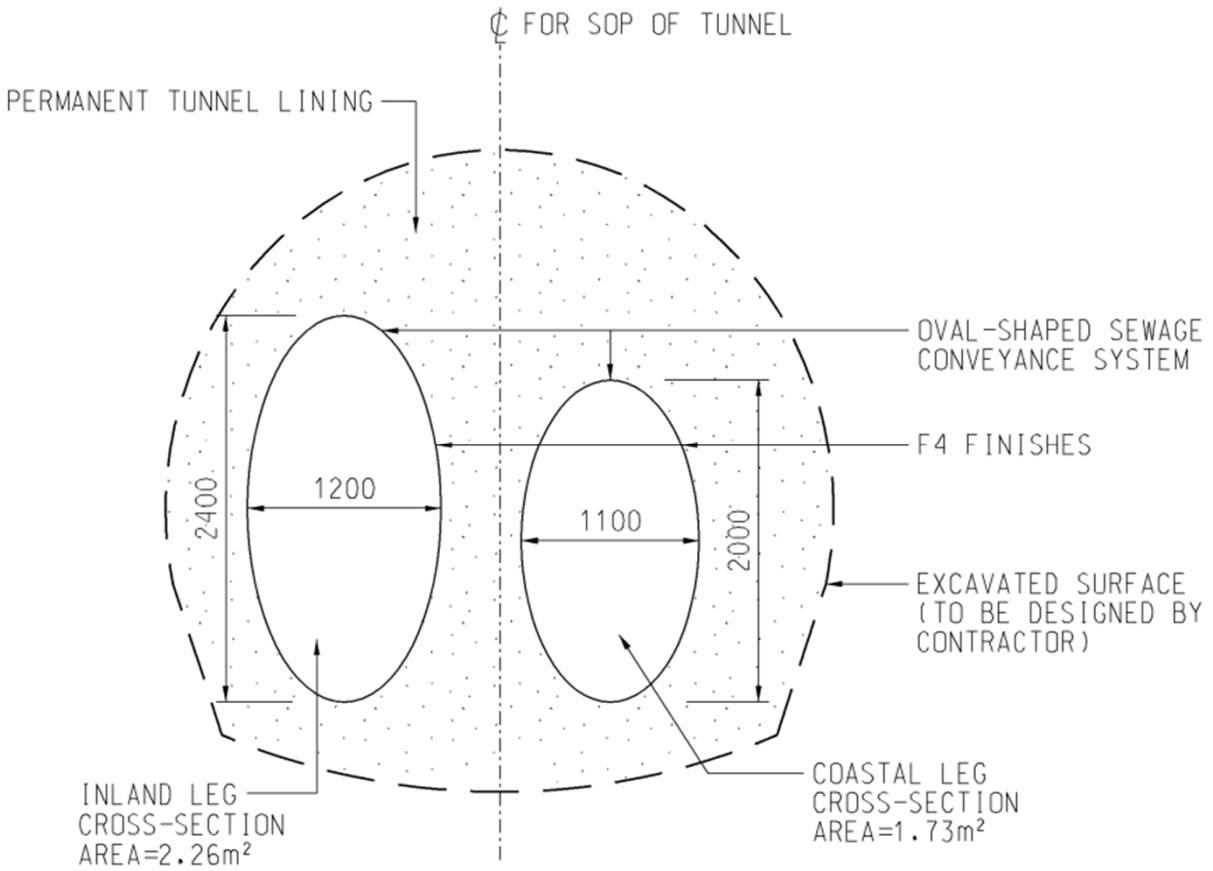



North Point
Wan Chai East
Central
Sai Ying Pun
Sandy Bay
Cyberport
Wah Fu
Aberdeen
Ap Lei Chau
(m)
0
-50
-100
-150
To Stonecutters Island
Legend:
Soil Layer
Bedrock
Stonecutters Island
Sai Ying Pun

Typical Cross Section



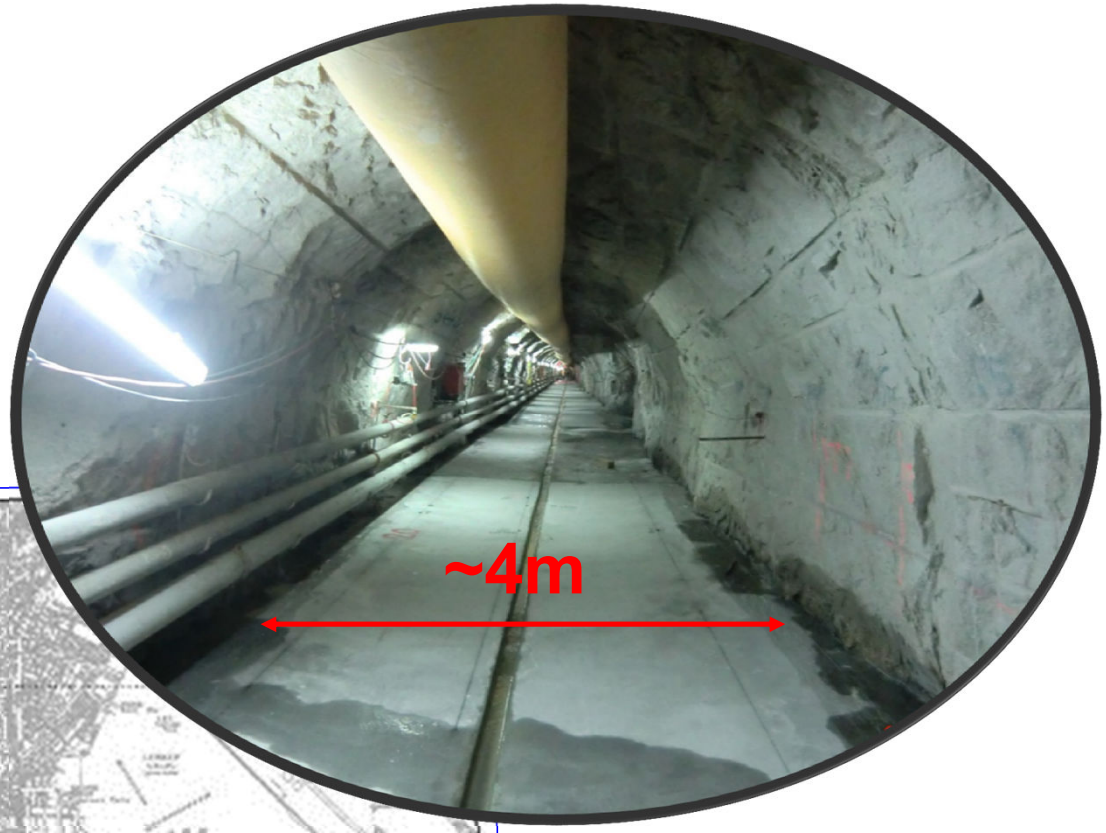
Tunnel L
(3000 diameter)

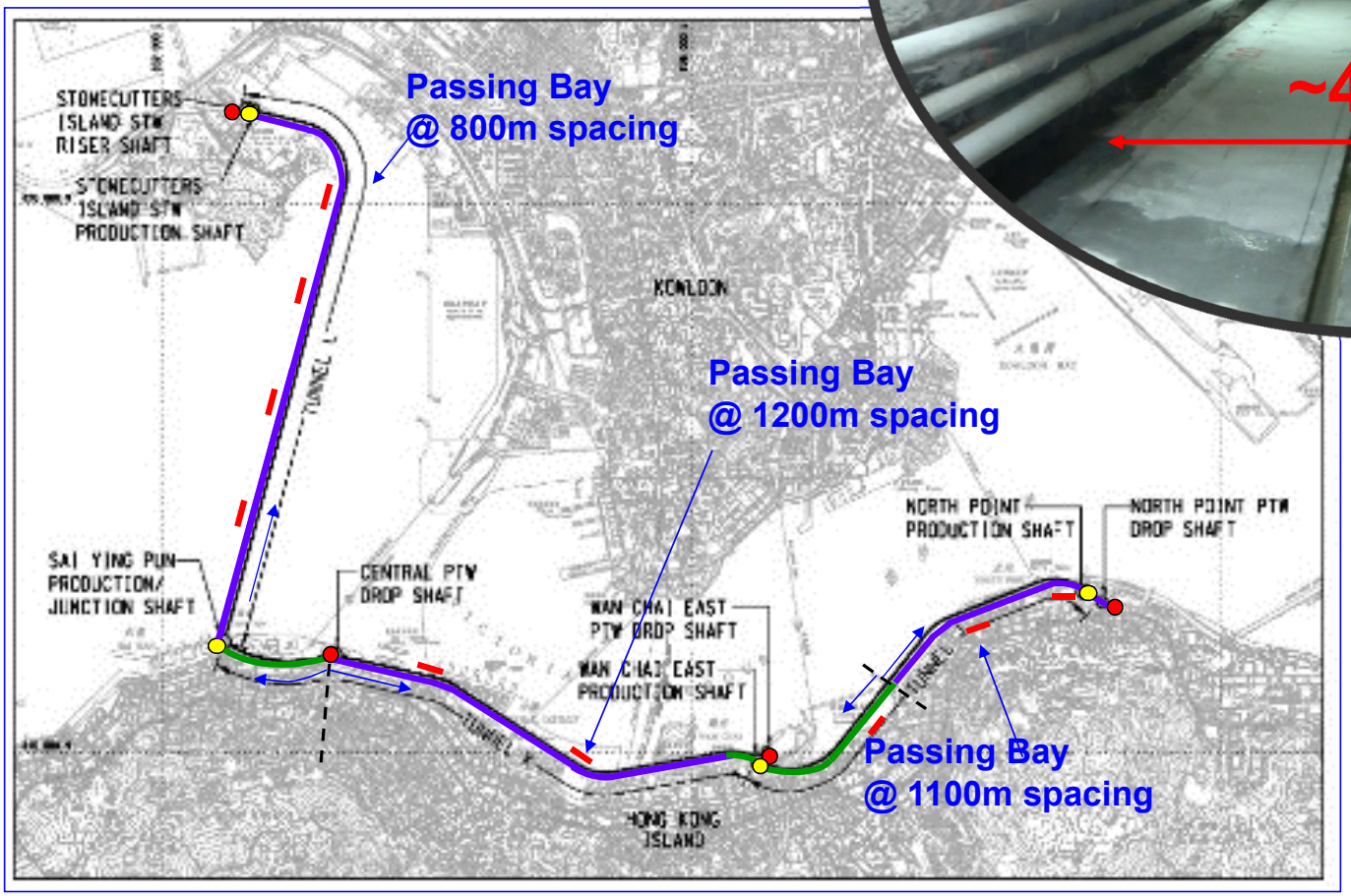


Tunnel K
(1200x2400 + 1100x2000)

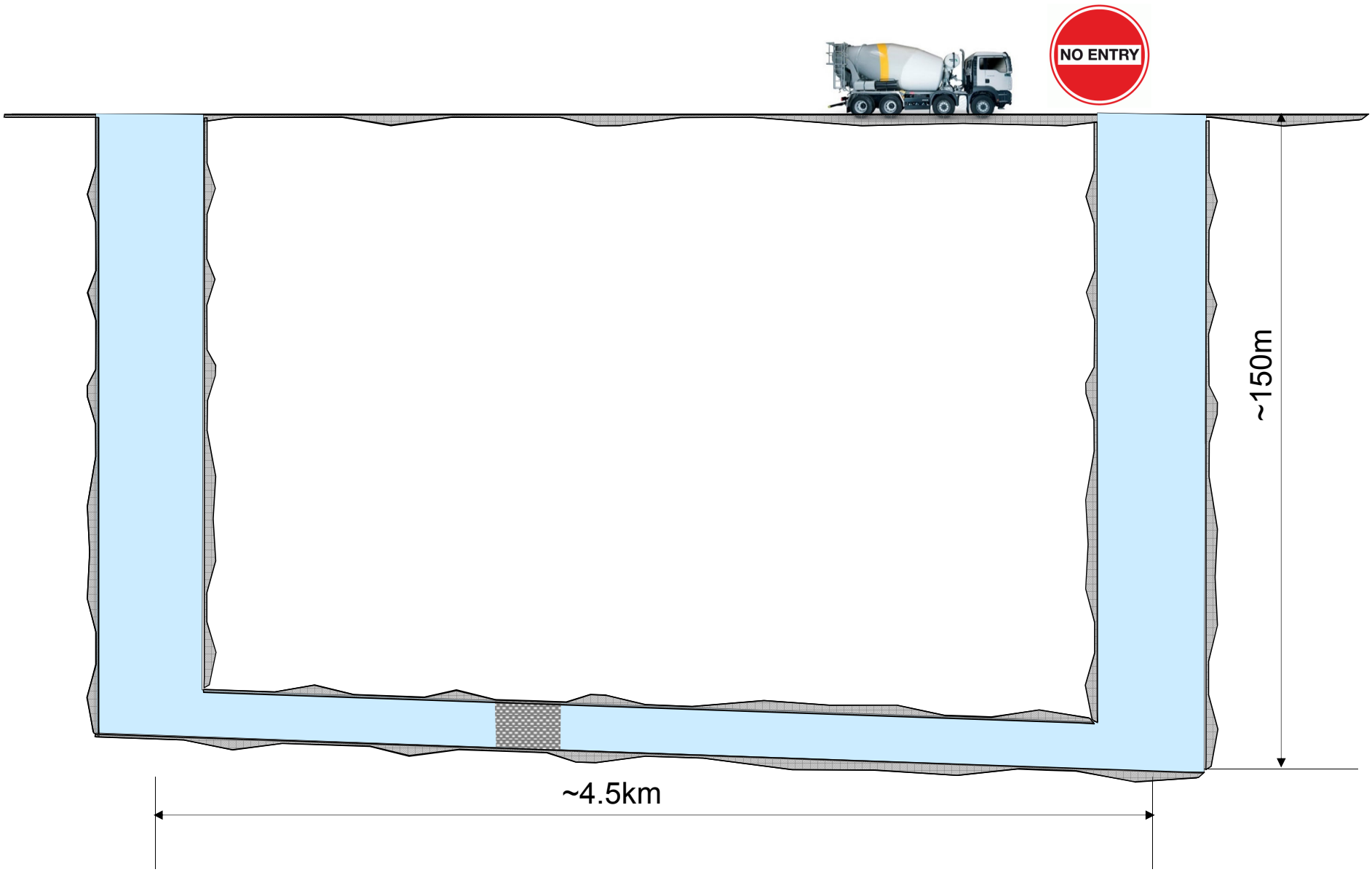
Access constraints

- Access via deep shafts (>150m)
- Small diameter (~4m)
- One way traffic
- Passing bays at ~800 to 1200m

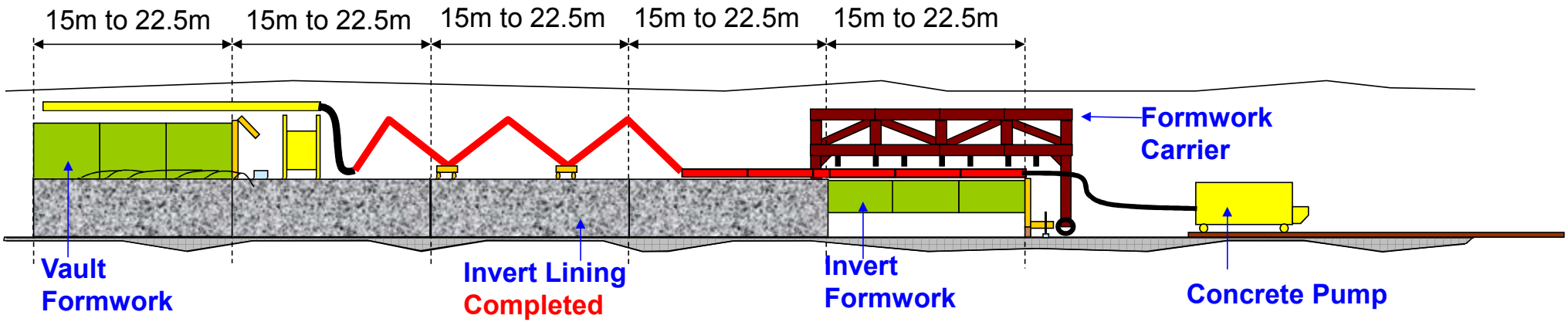




Concrete Delivery Arrangement


NO ENTRY
~150m
~4.5km

Formwork Concreting Operation

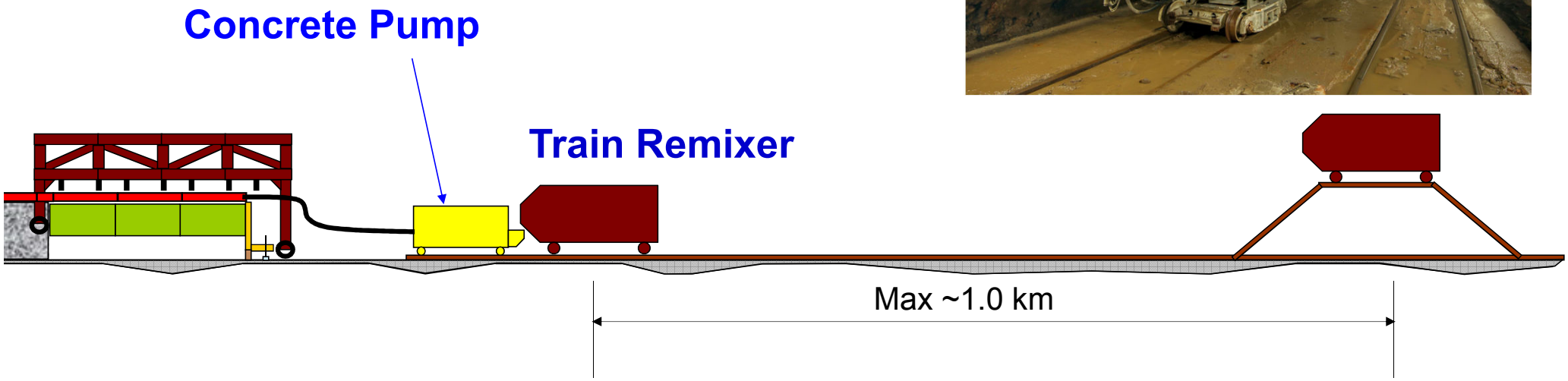


Vault Formwork

Scissor pipes

Formwork Carrier with Invert Formwork

Delivery by Train Remixer



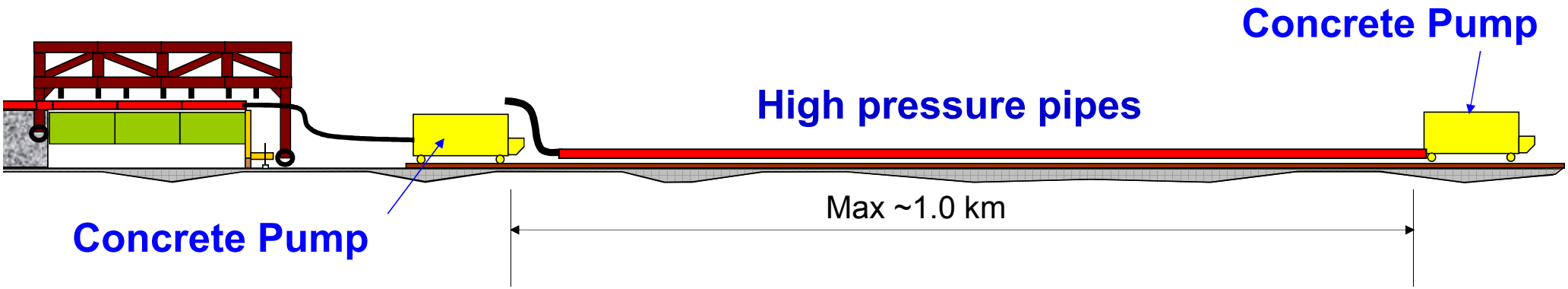
Train speed	=	6km/hr
Average Travelling Time (round trip)	=	10min
Average Time to discharge	=	15min
Capacity of each train remixer	=	7m^3
Concreting rate	=	16.8m^3/hr

Means to enhance concreting rate

Method	Concerns
Increase train speed	Risk of de-railing, safety concerns
Twin track	Time and cost for increased excavation and backfilling
Closer passing bays	Time and cost for increased excavation and backfilling

Delivery by LDPC
(Long Distance Pumping of Concrete)

Concrete Delivery by LDPC



Concrete Pump at Formwork

Concrete Pump at Shaft Bottom

Discharge Rate of LDPC

Pipe diameter	=	150mm
Area	=	0.018m^2
velocity	=	0.5m/sec
Pumping rate	=	31.8m^3/hr
		(>16.8m^3/hr by train remixer)
Time to travel 1 km	=	33min

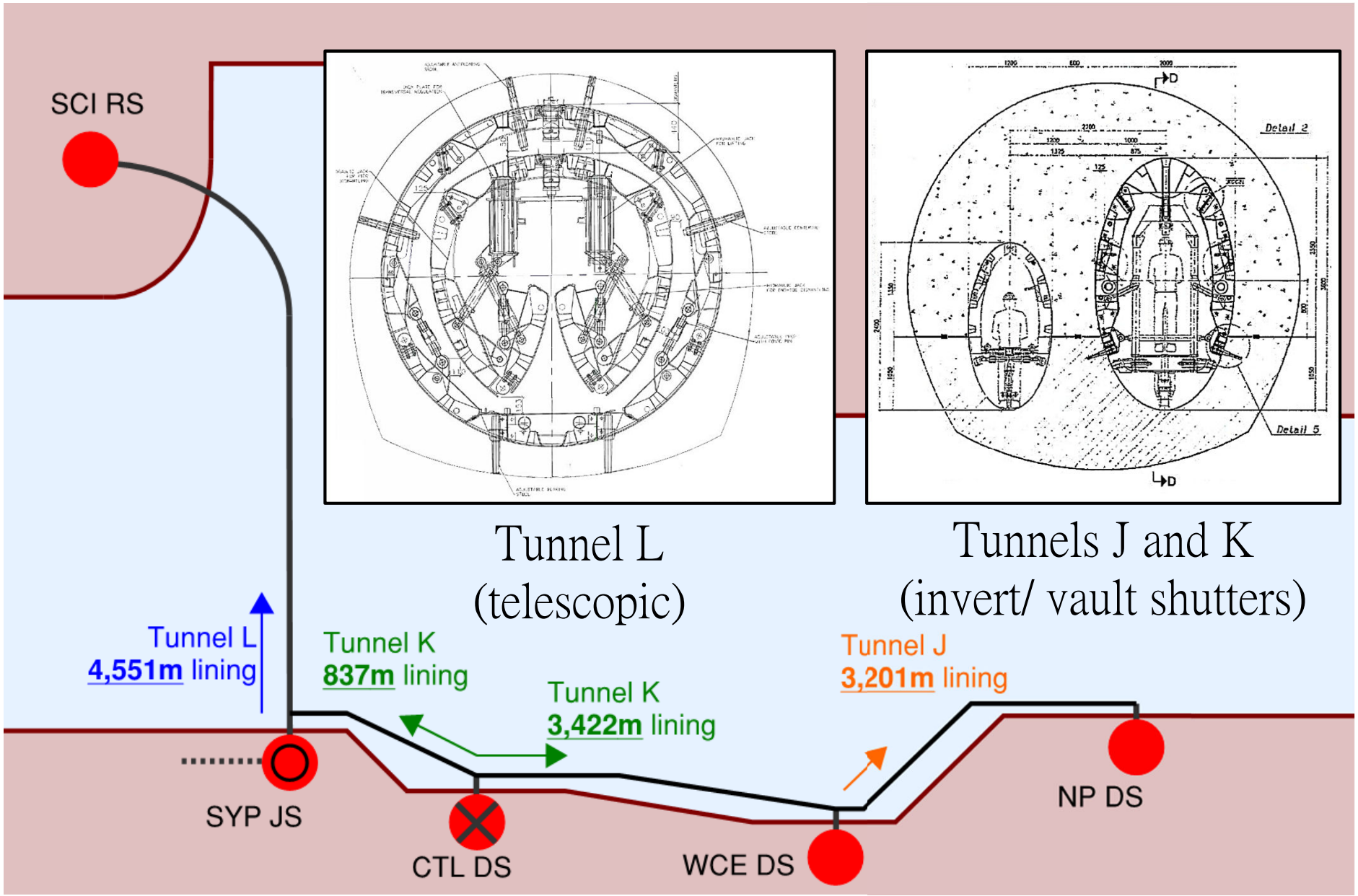
Compare LDPC with Train Remixer

Advantages	LDPC	Train Remixer
Higher concrete delivery rate	~32m^3/hr	~17m^3/h
Occupy less space	150mm diameter pipe	Train remixers
Steady supply of concrete at face	Continuous	Break after discharge each train
Potential Problems / Limitations		
Longer travelling time	0.5 m/sec = 1.8 km/hr	6 km/hr
Risk of pipe blockage	Yes	No
Limited distance	Up to 1.2 km in HATS experience	Up to 4.5 km in HATS

Specification and Design Mix Requirements

Category	GS (2006) - Marine Concrete (Grade 45/20D)	DSD HATS2A (Plain marine concrete Grade 45/20D)
Concrete mix		
	(i) Min grade 45 MPa (ii) Max 0.38 w/c ration (iii) 375-450 kg/m3 cementitious materials with 25-40% PFA and 5-10% condensed silica fume	
	PC, SRPC, PFAC, PBFC, CSF	Sulphate Resisting Portland Cement
Concrete Performance		
Temperature	Placing temp < 30°C	(i) Placing temp < 32°C (ii) Peak ≤ 70°C (iii) Max difference ≤ 20°C
Strength	same as normal concrete	Any consecutive 40 results of 28d cube strength: - **Coefficient of variation ≤ 8%** - **Average strength ≥ Grade + 2x standard deviation**
Durability	not specified	- **28d AASHTO chloride diffusion (6 hour hour test) ≤ 1,000 coulumbs** - **28d water sorptivity ≤ 0.07 mm/min$^{0.5}$**

Lining Logistics



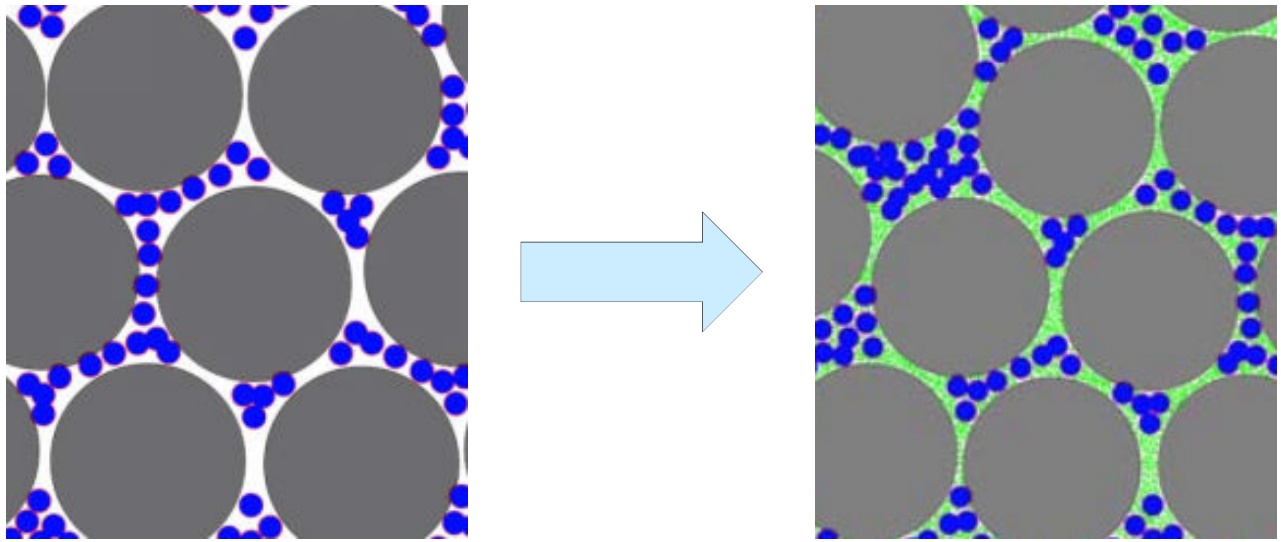
Lining Logistics

		1 hour		2 hours		3 hours		4 hours		5 hours		6 hours	
Activity	**Duration**	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins	30 mins
Mixing at barching plant and transport to site	1 hr												
Queuing at site	0.25 hrs												
Vertical discharge via slickline	0.25 hrs												
Convey to face by train mixer / pump	0.5 hrs												
Placed in final position (earliest / latest)	0.5 - 2.5 hrs												
Contingency	1.5 hrs												

Slump ≥ 200mm at 6 hours after mixing with water
Early strength ≥ 1 Mpa at 6 hours for Tunnels J and K
Early strength ≥ 3 Mpa at 8 hours for Tunnel L

- Tunnels J and K shutter length 15m
- Tunnel L shutter length 60m
- Careful balance between appropriate admixture dosing and operational control onsite (truck queuing, pump line static times)

Concrete Design Mix



- Particle packing optimised through replacement of cementitious material with inert fines
- Water also reduced and superplasticisers added to maintain workability
- Result is good workability, high performance concrete that satisfies durability requirements

Concrete Design Mix

ID	Type	Designation	Workability	w/cm	CSF content	PFA content	CM (kg/m3)	Fine (kg/m3)	Coarse (kg/m3)	Admixtures (L/m3)
1	Self-compacting	15/10D	680mm SF	0.42	0%	58%	440	820	830	6
2		45/10D	700mm SF	0.37	6%	31%	435	780	950	8
3	High-performance	45/20D	200mm slump	0.38	6%	31%	435	730	1000	11
4		45/20D		0.37	6%	31%	435	750	1000	11
5		60/20D		0.35	6%	30%	450	765	1000	8
6		60/20D		0.35	6%	30%	450	765	1000	8
7		80/20D		0.31	5%	25%	450	770	1020	11
8	Very early strength	45/20D	225mm slump	0.38	6%	31%	435	780	950	17
9		60/20D		0.34	6%	28%	450	810	940	17

CSF	Condenses Silica Fume	10 microns
PFA	Pulverised Fly Ash	50-100 microns
CM	Cementitious Materials	100-150 microns
	Fine Aggregates	~0.5-2mm
	Coarse Aggregates	~20mm

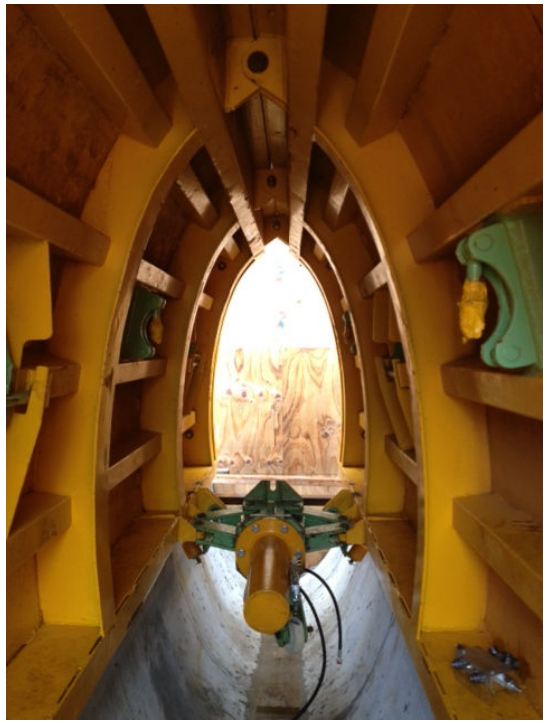
Mix 1 - 2 used for shaft backfilling where needed
Mix 3 - 7 used for tunnel lining
Mix 8 - 9 used as contingency

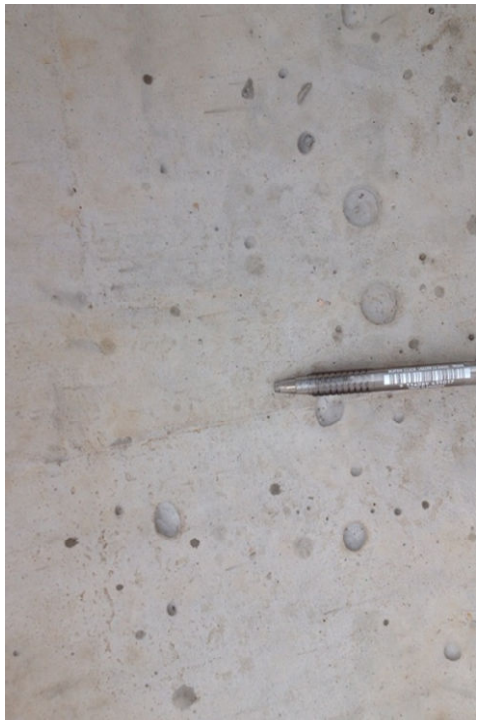
Thermal shrinkage control for 60m length, +500m^3 placement
Controlled by:

- Low cementitious material content to reduce thermal shrinkage effects including cracking
- Early age strength targeted to resist shrinkage in plain concrete lining

Formwork Systems and Logistics

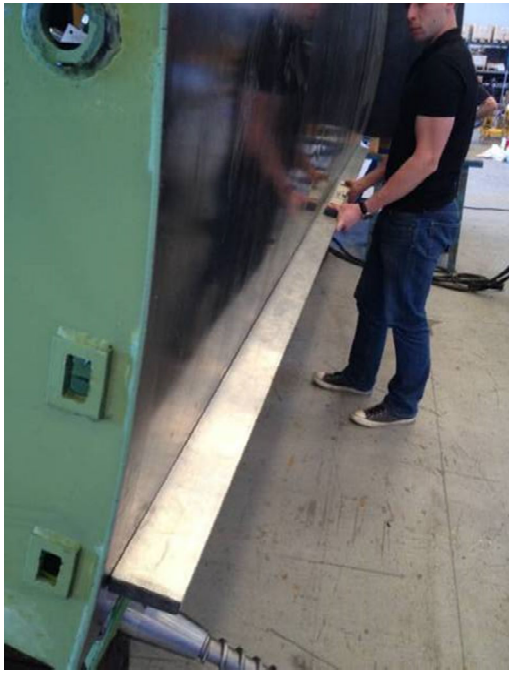
Trial Pour and Design Mix Review





- Extensive honeycombing in early trials due to high viscosity of concrete and cement/ admixture reaction
- Design mix adjusted to include additional inert material and use of superplasticisers to maintain workability

Tunnel L – Telescopic Formwork System



- Formwork systems hand made in Italy
- Fabricator inspection and pre-assembly
- Repeat pre-assembly in HK before lowering to tunnel for lining construction

Tunnels J and K – Invert and Vault Shutters

Concrete Distribution System

Tunnel L - Telescopic Formwork System

Tunnel L – Telescopic Formwork System

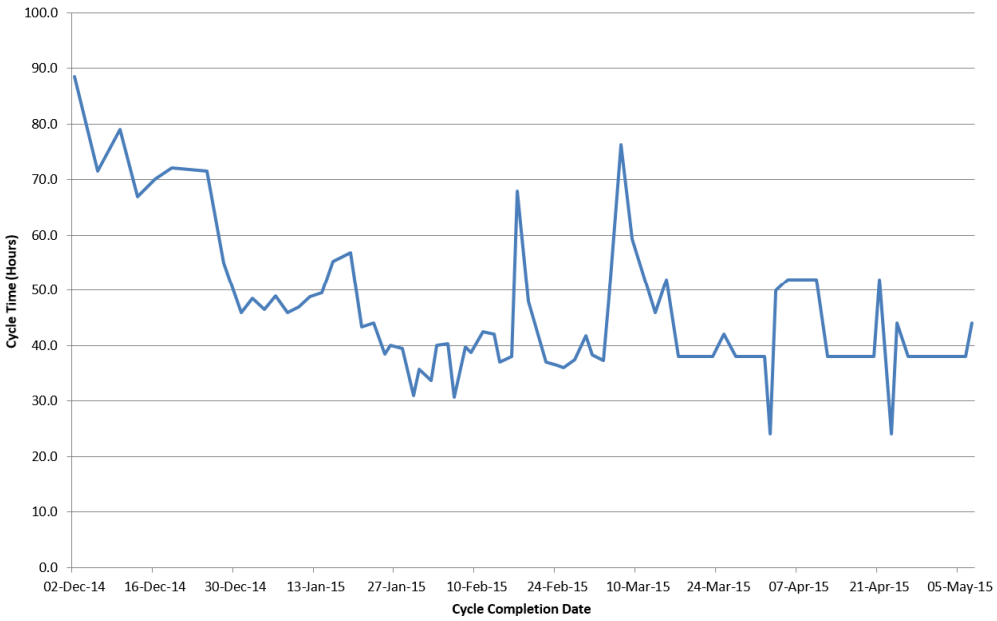
Tunnels J and K – Invert and Vault Shutters

When things go wrong…

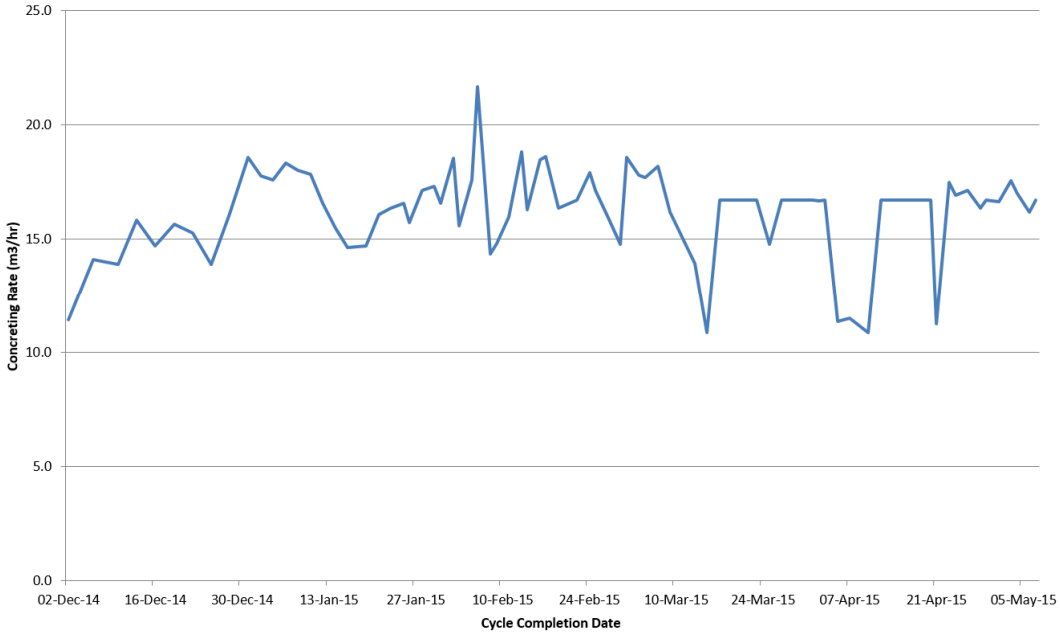
Tunnel L - Lining Production

Month	Cycles	Start Chainage	Finish Chainage	Lining Completed (m/ month)
Dec-14	10	8	438	430
Jan-15	16	438	1+350	912
Feb-15	16	1+350	2+319	969
Mar-15	17	2+319	3+288	969
Apr-15	18	3+288	4+222	934
May-15	6	4+222	4+478	256
Total	**83**			**4,470**

HATS2A - Tunnel L Cycle Time



HATS2A - Tunnel L Concrete Placing Rate



Conclusions

- Stringent strength and durability requirements achieved through innovative design mix with consideration to long distance placing method and QA/QC processes
- High production and reduced plant for safer delivery
- Concrete design, control on manufacturing and quality processes important to delivery

Conclusions

- 2011 cross harbour swim resumed at Lei Yue Mun, first time since 1978!
- 2017 sees return to centre of Victoria Harbour for first time in nearly 40 years


Thank you