ABSTRACT

Hong Kong is a highly urbanized metropolitan. The dense population (about 4.5 million people) on both sides of the Victoria Harbour demands an efficient and effective sewerage system to collect and convey about 1.85 million cubic metres of sewage generated daily to a centralized plant for treatment. A sewage conveyance system in the form of deep tunnels was chosen to suit the local urban environment. Hong Kong has completed 23.6km of deep sewage tunnels in 2001 which formed part of a major sewage collection and treatment scheme known as the Harbour Area Treatment Scheme (HATS) Stage 1. Construction of another 21km of deep tunnels of depths up to 160m below sea level under HATS Stage 2 to extend the sewage conveyance network is scheduled to commence in the second half of 2009.

This paper gives a description of the planning and design of the HATS Stage 2 deep sewage tunnels. It covers topics including the rationales for choosing a deep tunnel system, ground investigation using the specialized technique of horizontal directional coring, the selection of the drill-and-blast construction method and the contract strategy for implementation of the construction works.

KEYWORDS

sewage tunnel, deep hard rock sub-sea sewage tunnels, horizontal directional coring, drill-and-blast

INTRODUCTION

The Hong Kong Special Administration Region (Hong Kong) is a highly urbanized metropolitan. The dense population (about 4.5 million people) on both sides of the Victoria Harbour demands an efficient and effective sewage collection and treatment system.

In the past, sewage collected from both sides of the Victoria Harbour only underwent preliminary treatment, i.e. screening and grit removal, at preliminary treatment works located along the shoreline before being discharged via submarine outfalls to the Victoria Harbour. However, with the increase in population and economic activities on both sides of the harbour, the water quality of the harbour has deteriorated over the years. To improve the water quality of the harbour, the Government has decided to implement the Harbour Area Treatment Scheme (HATS), which is one of the most important environmental protection programmes ever undertaken in Hong Kong. HATS, when completed, will collect and treat all sewage collected from both sides of the harbour in an efficient, effective and environmentally sustainable manner.
LAYOUT FOR HARBOUR AREA TREATMENT SCHEME

The HATS is implemented in two stages. Stage 1 of HATS was completed in 2001 with a capacity to collect and treat about 1.7 million cubic metres a day of sewage generated around the harbour (i.e. from Kowloon and the north-eastern parts of Hong Kong Island). A system of about 24 kilometres of deep tunnels transfers the collected sewage to the sewage treatment works at Stonecutters Island (SCISTW) for chemically-enhanced primary treatment. HATS Stage 2 is the next phase in the programme to further improve the water quality of the harbour. It will collect the remaining harbour area sewage and transfer it via deep tunnels for centralized treatment at the SCISTW and cater for future growth in sewage flows of the entire HATS catchment. Eight preliminary treatment works along the route of the tunnels will also be upgraded. The ultimate combined capacity of HATS Stage 1 and Stage 2 will reach 2.44 million cubic metres per day. The overall layout of the HATS sewage conveyance system is shown in Figure 1 below.

In this paper, we will discuss about the planning and design for the deep sewage tunnels for HATS Stage 2.

SCOPE OF THE HATS STAGE 2 SEWAGE CONVEYANCE SYSTEM

The total length of the sewage conveyance system under HATS Stage 2 (the SCS) is about 21km. The vertical profile of the SCS is shown in Figure 2. Similar to Stage 1, a deep tunnel system going into the rock stratum is chosen for the SCS. The depth of the SCS tunnels ranges from 75m to about 160m below sea level.
Table 1 below summarises the size, length and depth of the tunnels, and the size of conduits to be installed within the tunnels.

Table 1: Details of the HATS Stage 2A Sewage Conveyance system

<table>
<thead>
<tr>
<th>Tunnels (Estimated Excavated size)</th>
<th>Location</th>
<th>Length on Plan (m)</th>
<th>Depth below Sea Level (m)</th>
<th>Nominal Size of Conduits to be installed in Tunnel (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel J (3.5m x 3.5m horse-shoe shape)</td>
<td>North Point to Wan Chai East</td>
<td>3200</td>
<td>163 to 157</td>
<td>Twin oval pipes: 1100(W) x 2000(H), reserve: 1200(W) x 2400(H) (Note 1)</td>
</tr>
<tr>
<td>Tunnel K (Maximum 4.6m x 4.6m horse-shoe shape)</td>
<td>Wan Chai East to Central</td>
<td>3420</td>
<td>157 to 150</td>
<td>Twin oval pipes: 1600(W) x 3100(H), reserve: 1200(W) x 2400(H) (Note 1)</td>
</tr>
<tr>
<td></td>
<td>Central to Sai Ying Pun</td>
<td>880</td>
<td>150 to 148</td>
<td>Twin oval pipes: 2000(W) x 3600(H), reserve: 1200(W) x 2400(H) (Note 1)</td>
</tr>
<tr>
<td>Tunnel L (4m diameter)</td>
<td>Sai Ying Pun to Stonecutters Island</td>
<td>4550</td>
<td>148 to 139</td>
<td>Circular pipe 3000 dia.</td>
</tr>
</tbody>
</table>

Figure 2: Vertical Profile for the Harbour Area Treatment Scheme Stage 2 Sewage Conveyance System.
### Tunnels (Estimated Excavated size)

<table>
<thead>
<tr>
<th>Tunnels</th>
<th>Location</th>
<th>Length on Plan (m)</th>
<th>Depth below Sea Level (m)</th>
<th>Nominal Size of Conduits to be installed in Tunnel (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel M (3.5m x 3.5m horse-shoe shape)</td>
<td>Sandy Bay to Sai Ying Pun</td>
<td>3680</td>
<td>123 to 116</td>
<td>Twin oval pipes: 1260(W) x 2160(H), 1000(W) x 1900(H)</td>
</tr>
<tr>
<td>Tunnel N (3.5m x 3.5m horse-shoe shape)</td>
<td>Cyberport to Sandy Bay</td>
<td>1180</td>
<td>75 to 73</td>
<td>Twin oval pipes: 1260(W) x 2160(H), 1000(W) x 1900(H)</td>
</tr>
<tr>
<td>Tunnel P (3.5m x 3.5m horse-shoe shape)</td>
<td>Aberdeen to Wah Fu</td>
<td>1090</td>
<td>80 to 78</td>
<td>Twin oval pipes: 1100(W) x 2040(H), 1000(W) x 1900(H)</td>
</tr>
<tr>
<td></td>
<td>Wah Fu to Cyberport</td>
<td>1510</td>
<td>78 to 75</td>
<td>Twin oval pipes: 1260(W) x 2160(H), 1000(W) x 1900(H)</td>
</tr>
<tr>
<td>Tunnel Q (2 x 0.9m dia.)</td>
<td>Ap Lei Chau to Aberdeen</td>
<td>1310</td>
<td>0 - 76</td>
<td>Twin 600 dia.</td>
</tr>
</tbody>
</table>

Note 1: W and H denote the dimension of the minor axis and major axes of the oval pipes.

### PRELIMINARY DESIGN OF THE SEWAGE CONVEYANCE SYSTEM

Traditionally, sewerage networks are constructed by open trench method. Other construction methods such as pipe jacking, micro-tunnelling, etc. are also adopted nowadays depending on the site situations. Under this project, a deep tunnel system going into the rock stratum is chosen with the following key considerations:

- (a) Major traffic and social disruptions in busy urban district will be minimized;
- (b) Environmental nuisances such as dust and noise problems will be minimized;
- (c) Conflicts with very congested underground utilities, the underground mass transit railways, and the cross harbour road and rail tunnels will be avoided;
- (d) Foundations of existing buildings will not be affected; and
- (e) Constraints to developments in the future above the sewage tunnels will be minimized.

In compliance with local statutory requirement for obtaining legal rights for the tunnels to go underneath private lands, the tunnels are required to have a minimum of 30 metres of bedrock cover.

**Hydraulics**

Due to the great depth of the tunnels, the sewage conveyance system is designed to operate as an inverted siphon where the sewage collected is discharged into the tunnels via drop shafts at the preliminary treatment works and the sewage is pumped out for treatment at the downstream end of the tunnel system at Stonecutters Island. This inverted siphon design compares favourably with a gravity system design in minimizing long term pumping costs which is very significant for handling the large quantity of sewage flow of over 2 million cubic metres each day. To prevent accumulation of sediments along the tunnels, the conduits are sized to ensure that there is sufficient velocity in the flow for scouring and keeping grit particles and other solids pollutants in the sewage.
in suspension. **Figure 3** shows two typical cross sections for the deep tunnel conveyance system. The choice of oval shape pipes for some tunnels is to accommodate the dual pipes within a optimized size of the tunnel excavation.

![Figure 3: Typical cross sections for the deep tunnel conveyance system](image)

- **Alignment of Tunnels**

  Extensive reviews of archives and databases on existing geological information including those obtained during construction of the Stage 1 tunnels have been undertaken. More than 300 ground investigation reports and 50 laboratory reports covering some 1,700 boreholes have been studied. Upon completion of these desktop studies and with due consideration given to various constraints including the need to avoid known difficult grounds and encroachment into private lands as far as possible, a preliminary alignment of the deep tunnels is selected for planning further site specific ground investigation works and for early consultation with local bodies and interested groups.

**GROUND CONDITIONS OF THE HATS STAGE 2 TUNNELS**

In the planning of the site investigation programme, a review of the information obtained during the construction of similar tunnels under the HATS Stage 1 and other available geological data was carried out. This indicates the following general characteristics of the ground conditions that are expected to be encountered in the HATS Stage 2 tunnels.

(a) The tunnels will be constructed mainly in hard granitic and volcanic rocks. Common in tunnelling projects, the actual conditions along the tunnel alignment cannot be fully investigated irrespective of any costly site investigation. Direct information on ground conditions at the depth of the alignment is also difficult to obtain and there will be an inevitable degree of uncertainty regarding the conditions that will be encountered including, in particular, the hydrogeological conditions.

(b) The geological information available (both generally and from local and international experience of similar works) indicates that the ground conditions are likely to be variable and that water inflows are likely to be encountered from discontinuities in the rock at and around tunnel depth including joints, faults and dykes. For significant lengths of the alignment, inflows of ground water into the excavated tunnel during construction are likely to occur from joints of narrow aperture in the form of general seepage. In addition to such background seepage, there is a likelihood of significant ground water inflows from comparatively wider
conductive joints in the rock. Such random conductive joints with significant ground water inflows are likely to be present and can occur anywhere along the alignment. Moreover, as a result of the location of the tunnels both under and adjacent to the Victoria Harbour, the groundwater encountered therein is likely to have a high saline content and will not diminish with time.

(c) If not properly controlled, seepage and water inflows into the tunnels during construction can lead to lowering of ground water table and result in ground settlement. The Specification for the HATS Stage 2 tunnels will have to limit the allowable seepage and water inflows into the tunnels within prescribed levels and those limits will have to be tight. The seepage and water inflows referred to in sub-paragraph (b) above are likely to be in excess of the levels permitted by the Specification and will require to be controlled by ground treatment by drilling and injection of grout around the whole perimeter of the tunnels ahead of the excavation face. The amount of such treatment required is likely to be significant.

(d) The geological information available also indicates a variety of ground conditions including a number of areas where the ground conditions are likely to be poor and/or problematic for tunnelling. The conditions indicated are:

- Fractured rock in or near known or suspected and/or possible fault zones;
- The presence of fractured or highly fractured rock in areas other than fault zones;
- Localised weathering in the known, suspected and/or possible fault zones and dykes;
- Areas of closely spaced joints at rock heads; and
- Faults and dykes are likely to be encountered at tunnel depth in a number of areas and deep weathering and/or gouge material are characteristic conditions of such features. Where encountered, such areas are likely to require extensive treatment to limit water inflows and/or ground supports.

Site Investigation

Based on the understanding of the basic characteristics of the ground conditions that are expected to be encountered, a comprehensive ground investigation programme is then planned and carried out to obtain more information on geological features such as faults, fractured rocks zone, etc. and the hydrogeology. In addition to using traditional vertical and inclined boreholes, and geophysical survey technique such as seismic refraction for investigation, we have employed a state-of-the-art technology called horizontal directional coring technique to obtain continuous rock cores at strategic locations along the tunnel alignment. This technique uses an eccentric coring bit that can be precisely steered. The drilling angle is around 45 degrees at entry and once the drilling has entered into bedrock, directional steering is applied in accordance with the planned trajectory, which targets the drilling and coring at about 7m above the designed crown level along the tunnels. The longest length of directional coring completed is 1,247m which is a new record for Hong Kong. A total of 5km of horizontal directional coring were completed successfully. Tests were also carried out along the core holes for estimating the likely water inflow during the construction of the tunnels. The information obtained from this technique is very valuable for subsequent design. The cores and relevant ground investigation data are made available for inspection by the tenderers. A brief summary of the ground investigation works carried out under HATS Stage 2 for the planning of the SCS is shown in Table 2 below.
Table 2: Details and Costs of Site Specific Ground Investigation Works

<table>
<thead>
<tr>
<th></th>
<th>Rough costs in Euros (based on 1 Euro = 10 HK$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length of directional coring</td>
<td>about 5 km</td>
</tr>
<tr>
<td>Number of vertical/inclined boreholes</td>
<td>about 150 numbers</td>
</tr>
<tr>
<td>Total length of vertical/inclined boreholes</td>
<td>about 18 km</td>
</tr>
<tr>
<td><strong>Total cost of ground investigation works</strong></td>
<td></td>
</tr>
</tbody>
</table>

From the existing and newly acquired ground investigation data and subsequent analyses, a geological model in 3-dimensions and a hydrogeological model are developed. Water inflow into different sections of the tunnels during excavation is estimated, and the likely ground settlement due to groundwater drawdown is also predicted. Measures, such as pre-excavation grouting, are then devised to mitigate the extent of ground settlement problem.

The investigation also involves visual inspection, photographic survey and thermographic imaging of structures that may be sensitive to the tunnel construction works. Such surveys provide a baseline for future measurement and monitoring during construction stage.

The site investigation programme confirms and enriches the understanding of the expected characteristics of the ground conditions for the HATS Stage 2 tunnels as mentioned in the preceding paragraphs. With the newly acquired ground investigation data and taking into accounts of comments received from the public, the tunnel alignment was fine-tuned and finalised.

**CONSTRUCTION METHODS**

Hard rock tunnels are commonly constructed either by using a tunnel boring machine (TBM) or by the drill-and-blast method. The latter construction method has been selected for construction of the HATS Stage 2 tunnels except a relatively smaller section (Tunnel Q) which would be constructed by the horizontal directional drilling method. The choice is based on several factors:

(a) **Geological condition:** If the geological condition along the tunnel alignment is homogeneous and requires little pre-excavation grouting to control water ingress into the excavated tunnel, the use of a properly selected TBM may be able to achieve very high excavation rate. However, due to the variability of the geological conditions, extensive pre-excavation grouting is expected to be required during excavation of the tunnels. An extensive system of temporary ground supports is also expected to be required in areas of fault zones and fractured ground. Under such conditions, it would be difficult to fully harvest the excavation capacity of an open TBM.

In addition, due to hydraulic considerations in achieving self-cleansing requirement, the final pipe sizes in most of the tunnels are considerably less than the excavated size of the tunnels. This would mean that the benefit of using a shielded TBM with precast segment linings for high speed tunnelling could not be fully reaped because a further operation will have to be carried out to line down the tunnel to its final sizes after completion of excavation and installation of precast segments. On the other hand, the drill-and-blast method is a proven method which allows an efficient pre-excavation grouting programme to be carried out to control groundwater ingress into the excavated tunnel. It allows flexibility for installing various kinds of temporary ground supports to stabilise fault zones and fractured ground.

(b) **Size of the tunnels:** Efficient drilling equipment will be required to carry out extensive pre-excavation grouting during excavation. Typical excavated sizes of the HATS Stage 2 tunnels are in the range of [3.5 to 4.6m wide and 3.5m to 4.6m high]. For TBM in this size range, the
installation of efficient drilling equipment near the cutter head area would be very difficult. If a shielded TBM is selected to deal with the expected difficult ground conditions in fault zones and fractured ground, the situation will be further aggravated because of very congested space near the cutter head area. In comparison, state-of-the-art fully automated drilling jumbos are available for the relevant size range to allow an efficient pre-excavation grouting programme to be carried out during drill-and-blast operation.

(c) **Length of the tunnels:** The lengths of the five tunnel sections for the HATS Stage 2 are in the range of 3.2km to 4.6km. With one excavation face from each end, the lengths for each drill-and-blast face are in the range of 1.6km to 2.3km. In favourable ground conditions and with a suitably selected TBM, TBM tunnelling from one end of a tunnel section may result in better rate of progress. However, as TBM excavation rates could be quite susceptible to ground conditions encountered and for the range of lengths in question, the better excavation rate will unlikely deliver significant overall programme advantage. Besides, as the drill-and-blast method is robust and well proven in meeting variable ground conditions, the reliability of this less risky construction method is considered outweighing the potential advantages in excavation rates that may be brought about by TBM tunnelling. For tunnelling in drives of longer lengths (e.g. 7km or above) and above sea levels, the considerations may be different.

(d) **TBM capability:** The analysis of the Stage 1 tunnel excavation rates using open hard rock TBM indicates a typical average excavation rate of around 50m/week. However, the excavation rates were much lower in fault zones mainly because of the need to carry out pre-excavation grouting and installation of temporary ground supports. In other words, a progress rate of 25m/week/face for excavation from 2 faces using the drill-and-blast method may be comparable to the progress rates achievable for TBM tunnelling for the HATS tunnels. TBM technology is developing very fast. It is reckoned that a suitably designed TBM may be able to achieve even better excavation rates. For instance, a tailor-made slurry-shield or earth-pressure-balancing TBM with precast segments may provide support against weak ground and even inflow of water to achieve better progress. However, experience on the use of these machines under similar geological and ground water pressure conditions (up to 16 bar) is very limited. Therefore, there are considerable uncertainties with the use of those state-of-the-art TBM tunnelling techniques for HATS Stage 2 deep tunnels. For the comparatively short length of the HATS Stage 2 tunnels, the drill-and-blast method is considered to provide a robust and comparatively low risk solution.

(e) **Availability of steady supply of explosives:** The HATS Stage 2 tunnels will be constructed in highly populated urban areas. Local social aspiration dictates that it is almost impossible to establish an on-site magazine to supply explosive for maintaining a steady and effective blasting cycle. However, through extensive pre-construction liaison with the authorities and project planning, we have established the arrangement for steady supply of explosive from an existing magazine on the other side of the harbour. While further detailed logistics arrangements will still have to be implemented during the construction stage, the pre-construction planning works have laid down the cornerstone for using the drill-and-blast method by allowing the contractor to proceed with a maximum of two blasts per day to achieve better progress.

(f) **Sensitivity of the surrounding areas to vibration:** If the surrounding area is highly sensitive to vibration, there may be constraints in the amount of explosive that can be used for each blast cycle. This may limit the rate of progress if drill-and-blast method is adopted. However, the problem is much alleviated with latest advance in drill-and-blast technology and with the great depths at which the tunnel excavations are to be carried out.
(g) **Availability of surface works areas at production shafts**: The areas required as works sites for supporting drill-and-blast tunnelling is comparatively smaller than that required for TBM tunnelling which requires very extensive logistic back-up. For the drill-and-blast method, the provision of sufficient surface areas at production shafts at each end of the tunnel sections is generally feasible. On the other hand, if TBM tunnelling is adopted, the available surface works areas will be very tight or perhaps insufficient bearing in mind that equipments such as slurry plant and large stock-piling areas for precast segments will be required depending on the type of machinery to be adopted.

After balancing the effects on construction programme and construction risks for using TBM and drill-and-blast method for the tunnelling works under this project, the drill-and-blast method is selected as the preferred method of construction for the deep tunnels under this project.

**RISK MANAGEMENT**

The construction of these deep tunnels in highly urbanised environment is technically very complicated and involves risks that need to be managed systematically during the planning, design and construction stage. We have made reference to the Code of Practice for Risk Management of Tunnel Works published by the International Tunnelling Insurance Group and adopted a risk management approach for this project. A comprehensive risk management plan has now been developed. Risk management workshops are held regularly, the identified risks are assessed, mitigation measures are proposed, and the most appropriate parties for dealing with the risks are assigned. For example, the risks in ground conditions are first mitigated by implementing a comprehensive ground investigation programme by the employer at the planning stage. At the construction stage, some of the risks will be shared between the employer and the contractors by appropriate reimbursement of payment for works in dealing with ground conditions. The specification of the drill-and-blast method and the water inflow limit in the contract also serves as a risk mitigation measure to ensure proper control of water ingress by systematic pre-excavation grouting at the tunnel face hence managing the flood risks in the tunnel as well as the ground settlement risk. The risk in the construction programme will also be controlled due to the stipulation of the more robust and flexible drill-and-blast method in dealing with different types of ground conditions as mentioned above and hence more certainty in the excavation progress. All these details are summarised in a risk register which is being continually updated and to be carried through to the construction stage.

**CONTRACT STRATEGY**

We have conducted a detailed study on the contract strategy for implementation of the construction works. We have looked at, among others things, various types of contract form and the contract provisions that are being used both locally and overseas, in particular, those adopted in the Scandinavian countries where a lot of deep hard rock sub-sea tunnels have been successfully completed. The contract form, the contract packaging options and the mechanism for selecting the contractors are discussed below:

- **Contract Form**

Factors considered in selecting the contract form include whether the contract form allows proper sharing of risks between the employer and the contractors, whether the contract form has been used successfully and whether the local industry is familiar with it. After detailed considerations, the design-bid-build type of contract with re-measurement of major works items is chosen over other
forms of contract such as the traditional design-bid-build contract with lump sum payment, design and build contract with lump sum payment with or without contractual geotechnical baseline for assessing differences between the actual and assumed geological conditions. As the tunnel alignment has already been designed and that the horizontal alignment is fixed within the boundary gazetted under the Sewage Tunnels (Statutory Easement) Ordinance\textsuperscript{Note 2}, there is little room for alternative proposals involving significant changes in the alignment. Also, the final configuration of the size and shape of the conduits to be formed have been designed according to the hydraulics requirements and hence, the scope for design of permanent works by the contractor is quite limited. On these considerations, a design-bid-build type is preferred over the design-build type of contract. It is also considered that a re-measurement type of contract with bills of quantities of works can provide an appropriate mechanism for proper risk sharing between the employer and the contractor. In general, items with relatively fixed quantities, such as the Engineer’s accommodation, and element of temporary works designed by the contractor, such as the temporary ventilation and lighting in the tunnels, will be paid in lump sum, while works related to ground conditions and with uncertain quantities, such as drilling of probe holes, pre-excitation grouting, shotcreting, rock bolts, steel ribs, etc. will be re-measured and paid. There will also be provisions in the contract for extension of time for completion of the works and reimbursement of costs if the actual quantities increase significantly from the quantities stated in the contract. This again will contribute to a sharing of risk on time and costs with the contractor.

\* Contract Packaging

We have split the construction of the deep tunnels to be constructed by the drill-and-blast method into two contracts. The tunnels to be constructed by the horizontal directional drilling will be let in another contract. Before deciding on adopting this approach, the benefits have been balanced against possible demerits such as the reduction in economy of scale and the greater management effort to deal with contract interface problems.

For the two drill-and-blast tunnel contracts, restriction has been imposed that a maximum of one contract is to be awarded to one single contractor. The advantages of adopting such restriction are as follows:

(a) The employment of more than one contractors means that a larger pool of skilled labour resources will be available for the works.

(b) Tunnel construction works are high-risk works. This approach allows the risk to be shared. The maximum risk that a single contractor will be allowed to take will be reduced and hence there will be increased certainty of completion of the works within time and budget.

(c) If two different contractors undertake the two contracts, there could be competition in reputation and the effectiveness of construction methods. Such sense of “professional pride” and hence competitiveness may be introduced with two contractors working concurrently on similar contracts.

(d) The risk of more than one contractor defaulting will be less than that of one single contractor defaulting. As a result, the chance of a contractor being able to successfully raise major disputes with the Government will be reduced if a competitor is progressing satisfactorily with similar works on an adjacent site.

\* Inclusion of Parent Company Guarantee and Performance Bond

\textsuperscript{Note 2}: An ordinance enacted in Hong Kong to provide for the creation of easements and other rights over land in favour of the Government for the purpose of the construction, maintenance and operation of sewage tunnels, and for connected matters.
The construction of such deep and sub-sea tunnels is by nature very risky. Although a suitable contract form has been devised to attain a fair share of risks through re-measurement of items with uncertain quantities, the construction risk is still considered high compared with other general civil works contracts. Moreover, completion of the sewage tunnels is also critical for the commissioning of the overall scheme. Delay in completing the tunnels will delay the system integration of the PTWs and the SCISTW, which may attract contractual claims from the contracts for the upgrading of the PTWs and SCISTW, which form essential parts of scheme. As a result, we have stipulated the requirement for the contractors for the two major tunnel contracts to provide both a parent company guarantee and a performance bond. This hopefully will increase the commitment of the contractor and the contractor’s corporate group as a whole, and reduces the risk of the contractor from defaulting.

Mechanism for Selecting the Contractors

(a) **Prequalification of Tenderers:** The two major tunnelling contracts are contracts of very large scales and require expertise in tunnel and shaft construction. We consider that it is necessary to prequalify contractors who are interested and capable (both financially and technically) of undertaking the contracts. In the prequalification exercise, emphasis has been placed on the contractors’ experience in hard rock tunnelling with pre-excavation grouting as the primary means of controlling groundwater ingress, their past performance records where available, the qualification and experience of proposed key staff, their appreciation of the geology and hydrogeology and their implications, and their proposed method statement for construction of shaft and tunnels. The exercise has also provided an opportunity for contractors to give their views on the design and the contractual arrangements.

(b) **Tender Evaluation:** A marking scheme tailor-made for the tendering exercise was made known to the prequalified tenderers for preparing their technical submission. The technical submissions are assessed by a panel consisting a number of senior professionals. For the award of the contract, a set of predetermined rules which is also made known to the tenderers has been set based on both the tendered prices and the scores obtained for their technical submissions. In general, the proposed staff and plant resources and the method statements given in the technical submissions which exceed the requirements or specification of the contract in terms of quality and quantity are binding under the contract.

The prequalification and the tender evaluation mechanism is a risk mitigation measure against incompetent contractors who wish to submit a very low bid betting on a favourable ground condition during construction.

PUBLIC CONSULTATION

For public project of size and complexity like the HATS involving huge capital and recurrent costs, public support is important for the successful implementation of the project. A continuous public involvement approach has been adopted.

Before Government decided to proceed with HATS Stage 2, a five-month extensive public consultation exercise on the way forward for HATS Stage 2 was conducted in 2004. The Government organised a series of in-depth technical briefings, discussion forums and public hearings with a broad spectrum of the community including the environmental affairs panel of the legislature, political parties, advisory committees, professional bodies, academia, special interest
groups, and various business/trade organisations. In general, the public is supportive on this environmental project.

In 2006, after identifying the potential works sites and the preliminary alignment of the project, we consulted the relevant advisory committees on the proposed tunnelling works. These early consultations have proved to be fruitful as some views obtained from the public could be input into the design. For example, a request for minimizing disruption to local residents has led to a design change of the tunnel alignment and from a shallow no-dig construction method to a deep tunnel section. This has helped to avoid potential abortive work in case strong objections were received when the design was near completion. In 2008, after we have finalized the design, we consulted these committees again and sought their support to our project, which is important for subsequent seeking of funds from the publicly elected legislature.

PROJECT UPDATE

A key statutory requirement was fulfilled when the comprehensive environmental impact assessment study for the HATS Stage 2A was successfully completed and approved by the authorities in end 2008. Tenders for the two deep tunnels have been received and should be under assessments at the time of presentation of this paper. Construction of the deep sewage tunnels is anticipated to commence in the second half of 2009 for completion in 2014.

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