PM

CONCEPT DESIGN COST ESTIMATE AVLOPPSTUNNEL KÄLLBY-SJÖLUNDA

1-T01-PM-01

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VÄLJ DATUM

1 INTRODUCTION

This document provides an estimate of the costs for the construction of the wastewater tunnel (AVLOPPSTUNNEL) between KÄLLBY and SJÖLUNDA, known as the Lund Avloppstunnel or LAT. The basis for the cost analysis is the Concept Design for the wastewater solution as described in document *CONCEPT DESIGN REPORT WASTEWATER TUNNEL (AVLOPPSTUNNEL) KÄLLBY-SJÖLUNDA ref: 1-T01-CDR* together with the locations of the connections to the existing sewer system that have been defined by WSP, most recently in an interface meeting between Tyréns and WSP held on the 26th Feb 2020.

The cost estimates are based on international experience, and in particular, recent experience from similar projects carried out for the utility owner HOFOR in Copenhagen. These provide a robust basis for the cost estimate as the final costs of these projects are known as well as their initial cost estimates.

The cost estimate includes a contingency of fifteen percent to cover for unforeseen costs and changes in the design the design that may occur during the further development of the design from the current concept design level. Such a contingency is normal for major construction projects.

Such a deep gravity wastewater tunnel is fundamentally different from a conventional pressure pipe/gravity pipe solution for conveying waste water over long distances. The deep gravity solutions have higher investment cost than the conventional pipe solutions but these investment costs are balanced by significantly better operational benefits, such as a large storage capacity, lower power consumption and lower operation and maintenance costs. The deep tunnel can be design for a 100 year maintenance free structure which is more than double the assumed service life of the conventional pipe solutions. These differences needs to be considered when comparing the construction costs between the deep tunnel and a conventional pipe system.

2 BACKGROUND

The wastewater tunnel between Källby and Sjölunda is a deep gravity sewer approximately 10 km in length, 3 m in diameter located at a depth of approximately 30 m below ground level. There is a total of nine shafts on the tunnel alignment, formed by a drop shaft at Källby, a receiving shaft at Sjölunda and seven intermediate shafts in order to give a maximum shaft spacing of 1.5 km which is required by the tunnelling method.

Four of the intermediate shafts are used as connections to existing wastewater pumping stations that will pick up wastewater flows along the tunnel alignment and bring them into the deep gravity tunnel. The other three shafts could also be constructed to allow for future connections, enabling future upgrading of the wastewater system for the communities between Lund and Malmö at minimal cost. The tunnel has been dimensioned based on the hydraulic models to provide a large storage capacity (82,000 m^3) in order to attenuate heavy rainfall events and minimise untreated wastewater discharges (overflows).

The tunnel is intended to work together in the long term with the Malmö Avloppstunnel (MAT). Their storage capacities will be combined as both tunnels will share the same pumping shaft at Sjölunda. The storage capacities, i.e. size of the two tunnels can be adjusted to provide the optimal solution for the overall system storage capacity and optimal design of the treatment works.

Similar deep gravity wastewater or stormwater systems having been constructed in many countries, a selection of such projects is listed below. Seven such projects have been constructed or are under construction in Copenhagen.

Tabell 1 Reference Projects

Project	Description
Damhusledningen, Copenhagen, HOFOR	3.4km ID3000 stormwater and basin tunnel 1 large pumping station
Strandvejsområdet, Hellerup, NOVOFOS	3.4km ID 3000 stormwater and basin tunnel 1 large pumping station
Østerbro skybrudstunnel, Copenhagen, HOFOR	0.58km ID 2500 stormwater tunnel 1 pumping station
Strandboulevarden, Copenhagen, HOFOR	1.1km ID 2000 stormwater tunnel (currently uder construction)
Kalvebod Brygge Skybrudstunnel, Copenhagen, HOFOR	1.26km ID 2000 and ID 3000 stormwater and basin tunnel 1 large pumping station (currently in the design phase)
Valby Skybrudstunnel, Copenhagen, HOFOR	2.5km ID 3200 stormwater and basin tunnel 1 large pumping station (currently in the design phase)
District Heating Tunnel Copenhagen HOFOR	0.32km ID 3000 district heating tunnel
District Heating Tunnel Copenhagen HOFOR	4km ID 4200 district heating tunnel
STEP, Abu Dhabi	45km of deep gravity wastewater tunnel
Abu Hamour, Doha	10km of deep drainage tunnel
IDRIS, Doha	45km of deep wastewater tunnel and 70km of linking sewers, built in stages and currently under construction
Lee Tunnel UK	7km of deep wastewater tunnel
Tideway UK	25km of deep wastewater tunnel
Dubai stormwater tunnel	10km of deep drainage tunnel which is the 1st stage of a larger stormwater drainage project stages
Singapore DTSS	40km of deep wastewater tunnel and 60km of linking sewers, under construction

Deep gravity wastewater and stormwater tunnels have a number of advantages over conventional pumped/shallow pipe systems particularly for conveying waste water over long distances. They are inherently sustainable and have significant advantages as discussed below:

- They can provide large storage capacity to attenuate overflows without taking large areas of land.

- The large gravity tunnels have low head losses, and the single pumping station has high efficiency pumps. The system has lower energy costs than a conventional solution.
- The tunnel will be designed for a maintenance free service life of in excess of 100 years with sufficient storage capacity for long term heavy rainfall events and provisions for additional connections to the existing systems which could further reduce overall operational costs of the wastewater system
- The long service life means that the tunnel has more than double the assumed service life of a conventional pipe solution.
- It is inherently better from an operations and maintenance point of view than a conventional system, with pumps only at a single location at the main pumping shaft. The pumping shaft will have sufficient redundancy to allow pumps to be taken out of commission without affecting the operations.
- The system therefore has a much lower maintenance requirement and a much higher reliability than a conventional system.
- The majority of the works is undertaken underground (approx. 30 m BGL) and thus has minimal impact on the environment during construction compared to a conventional pipe system that is constructed in a continuous trench approximately 14 km in length. Also the shaft works take place only at a number of discrete locations where the disturbance will be minimal.
- The connections to the existing pumping stations can be largely made as gravity connections, thereby taking out the local pumping stations and greatly simplifying operations, this also provides additional energy savings. This would remove the need for the investments in these old local pumping stations.
- The gravity tunnel will not impact the infrastructure at ground level when crossing rail or roads, during construction there is minimal influence on the surface. In comparison the conventional pipe solution which has a large number of road and rail crossing.
- The deep tunnel will be able relieve capacity in parts of the existing pipe system and thus providing potential for saving ess future investments in the system.
- The need for expropriations is significantly less with the deep tunnel than the conventional pipe solution.
- The deep sewer reduces the risk of damage from third parties to the waste water system and improves its reliability.
- The deep tunnel is largely independent of future land developments, thus providing less constraints on development.
- The deep tunnel allows for future urban development by enabling connections to the deep tunnel to be made either to the planned shafts or additional drop shafts could be constructed in the future and the large daily sewer capacity of the 3 m diameter tunnel could be further utilised.

In the present studies no Life Cycle Analysis (LCA) has been carried out, however it is expected that the deep tunnel would have a service life far in excess of 100 years and at such a time when the tunnel would need maintenance it could be relined at modest cost. Therefore if such an analysis is carried out, the sustainability benefits of the deep gravity tunnel could be robustly documented, showing how this would fit into VA-SYD's overall sustainability goals.

3 COST ESTIMATES

The cost estimates shown below are primarily derived from similar projects in Copenhagen, these have also been verified based on international experience. For some of the Copenhagen projects which are completed the final costs are known and the uncertainty from the early estimates and tender prices are known, thus providing robust estimates. The ground conditions in Copenhagen are similar to those in the project area and therefore the uncertainties in terms geotechnical risks, tunnelling and shaft construction are broadly similar, which gives further confidence in using cost estimates based on experience from Copenhagen.

The design of the wastewater tunnel Källby to Sjölunda (LAT) is at an early stage with the project currently at Concept Design level. However this concept design has fixed the major design assumptions and parameters and these are not expected to change during the design development, as a robust process has been gone through to establish the concept design.

The cost estimate, provides three prices for the major construction elements and for the main Client costs, these are defined below:

- Most likely cost
  This represents the most probable (or likely) final cost based on similar projects. i.e. the 50 % percentile
- Maximum cost,
  This represents the maximum cost that could occur if a number of risks to the project materialise, these risks include the normal risks associated with major construction projects and underground construction such as the risks of unforeseen ground conditions, major breakdowns of the tunnel boring machines, groundwater handling etc. i.e. the 90% percentile.
  It does not incorporate the Owners risk such as permits and permissions or for major changes in the project. In appendix 2 a list of the major risk included in the uncertainties is shown.
- Minimum Cost
  This represents the minimum cost of the project if, market conditions allow competitive prices and that the environmental requirements allow for reasonable construction solutions to be applied and that the ground conditions are as predicted or more favourable, i.e. the most optimistic outcome representing a 30% percentile.

The cost estimate includes the connections to the existing pumping stations, it does not include any upgrading works at the pumping station as these would be limited with the deep tunnel solution. It currently does not include the main pumping shaft at Sjölunda although it includes a final reception shaft at Sjölunda and a short gravity tunnel to connect it with the main pumping shaft. During the design development, the main pumping shaft at Sjölunda will be combined with combined with the reception shaft and the reception shaft for the Malmö tunnel to provide a fully integrated solution.

A number of risks and opportunities are not included in the cost estimate at this stage as they will be considered in the further design development, these are listed below in Tabell 1 which illustrates that whilst there are some risks there are also opportunities for reducing costs.

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Note: + implies a positive effect on the cost estimate, i.e. a reduction in cost.
- Implies an increase in cost

Item	Not part of the cost estimate:	Effect
A	Potensial saving for some shafts by changing the alignment (less tunnel overburden)	++
A-1	Temporary retaining walls: Assumed S-piles -> change to sheet piles	+
B	Temporary retaining walls: Assumed S-piles -> change to Dwalls	-
C	Uncertainty for the GW handling	-
D	Final tunnel length (after placing the shafts) for Southern alignment	-
E	Southern alignmenta llows gravity connections	+
F	Southern alignment reduces connection length	+
G	Construction time - required number of TBMs and equipment to meet the expected construction schedule	-

The cost estimate breakdown is shown in the Appendix and is summarised below:

Scenario	Estimate Cost (SEK)
Most Probable	1,673,000,000
Minimum likely	1,324,000,000
Maximum likely	2,157,000,000

The cost estimate includes a robust estimate of the following:

- The construction costs
- The design costs
- the costs of the connections to the existing system,
- a 15% contingency to incorporate unforeseen costs
- the client's project costs, including project management, expropriations, archaeology, polluted soil and utility diversions.

The cost estimate is therefore considered to represent a robust estimate of the project costs.

APPENDIX 1 COST ESTIMATE BREAKDOWN

	Cost Estimate 2020-03-10			Most likely		Min	Max
		Qty	Unit	Cost (SEK)	**Total SEK**	**SEK**	**SEK**
1.1	**Produktionskostnad inkl projektering**						
1.1.1	**Tunnel**						
	Tunnel 3M ID, pipe jacking & EPB	10,200	m	95,000	969,000,000	726,750,000	1,259,700,000
	Tunnel reception shaft to PS	20	m	200,000	4,000,000	3,000,000	7,000,000
1.1.2	**shafts (9)**	1	sum	261,000,000	261,000,000	208,800,000	391,500,000
1.1.3	**Connections**						
	S2 ABMA P1, Arlöv 317 l/s	400	m	8,000	3,200,000	2,720,000	3,680,000
	Reconnection Åkarp	400	m	4,500	1,800,000	1,530,000	2,070,000
	S3 Lomma	100	m	8,000	800,000	680,000	920,000
	S6 Hjärup	500	m	4,500	2,250,000	1,912,500	2,587,500
	S8 Flackarp (Kävlinge)			included in shaft			
	Källby	250	m	4,037	1,009,250	857,863	1,160,638
1.1.4	**Disposal of excvated material**		m3				
	Tunnel	124,588	m3	250	31,150,000	24,920,000	41,740,000
	shafts (9)	30,791	m3	250	7,700,000	6,160,000	10,320,000
1.1.5	**Other Construction Costs**						
	Construction Site and site roads	9	sum	3,000,000	27,000,000	20,250,000	33,750,000
	Traffic management	9	sum	1,000,000	9,000,000	6,750,000	11,250,000
	Reestablishment of the ground & landscapin	9	sum	2,000,000	18,000,000	13,500,000	22,500,000
	Monitoring	9	sum	500,000	4,500,000	3,375,000	5,625,000
	Geotechnical investigations	1	sum	5,000,000	5,000,000	3,750,000	6,250,000
	Fee for PD and DD (5% of construction)	1	sum		67,270,463	50,452,847	84,088,078
1.2	**Contingencies (15%)**				211,901,957	211,901,957	211,901,957
1.2	**Byggherrekostnad**						
1.2.1	Projektorganisation (40 +/-10 för bägge alt.)				40,000,000	30,000,000	50,000,000
1.2.2	Upphandling				3,000,000	2,250,000	3,750,000
1.2.3	Kontrollprogram tillstånd				3,000,000	2,250,000	3,750,000
1.2.4	Arkeologl				included in Projektorg		
1.2.5	Tillstånd				included in Projektorg		
1.2.6	Fastighetsärenden				not included		
1.2.7	Projektförsäkring (utgår)				not included		
1.2.8	Föberedande arbete tex ledningsomläggningar				2,000,000	2,000,000	2,000,000
1.2.9	Överlämnande/avslut (ingår i 1.2.1)				included in Projektorg		
1.2.11	design included in 1.1.5				n/a		
1.3	**Polluted Soil**	1,000	t		800,000	400,000	1,400,000
	Total cost estimate				1,673,000,000	1,324,000,000	2,157,000,000

APPENDIX 2 MAJOR RISKS

The major risks included in the price uncertainty are as follows:

Risk	Consequence
Unforeseen adverse ground conditions, causing the tunnel construction to be more difficult than expected.	Delay and additional cost
Greater than expected wear on the TBM cutters causing more frequent cutter exchanges	Delay and additional cost
The pipe jacking process goes out of alignment and the pipes become stuck requiring an intervention or other measures to remedy.	Delay and additional cost
In order to do tool changes on the TBM hyperbaric interventions will be required at a pressure of approx. 2.5 Bar. Loss of pressurised air and loss of stability of the tunnel face could occur if the hyperbaric interventions are not properly carried out	Delay and additional cost
Difficulties in getting approval from the authorities for the hyperbaric interventions	delay
Difficulties in finding transport routes and getting permission for transport of the large tunnel pipes	delay
Supply problems for the tunnel pipes due to production or transport problems as they will most likely be fabricated in Germany or Poland.	delay
Higher than expected permeability of the Alnarp formation giving rise to difficulties in controlling the groundwater and higher than expected amounts of water to discharge	Delay and additional cost
Poor quality of the diaphragm wall construction resulting in leakages and soil ingress into the shafts	Delay and additional cost
Unforeseen ground conditions in the form of higher than expected amounts of flint in the Limestone at the KÄLLBY and SJÖLUNDA shafts causes difficulties with the diaphragm wall construction.	Delay and additional cost
A water well is encountered by the TBM which may lose pressure and a ground collapse may occur.	Delay and additional cost