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Topic

CATALOG OF TUNNELS

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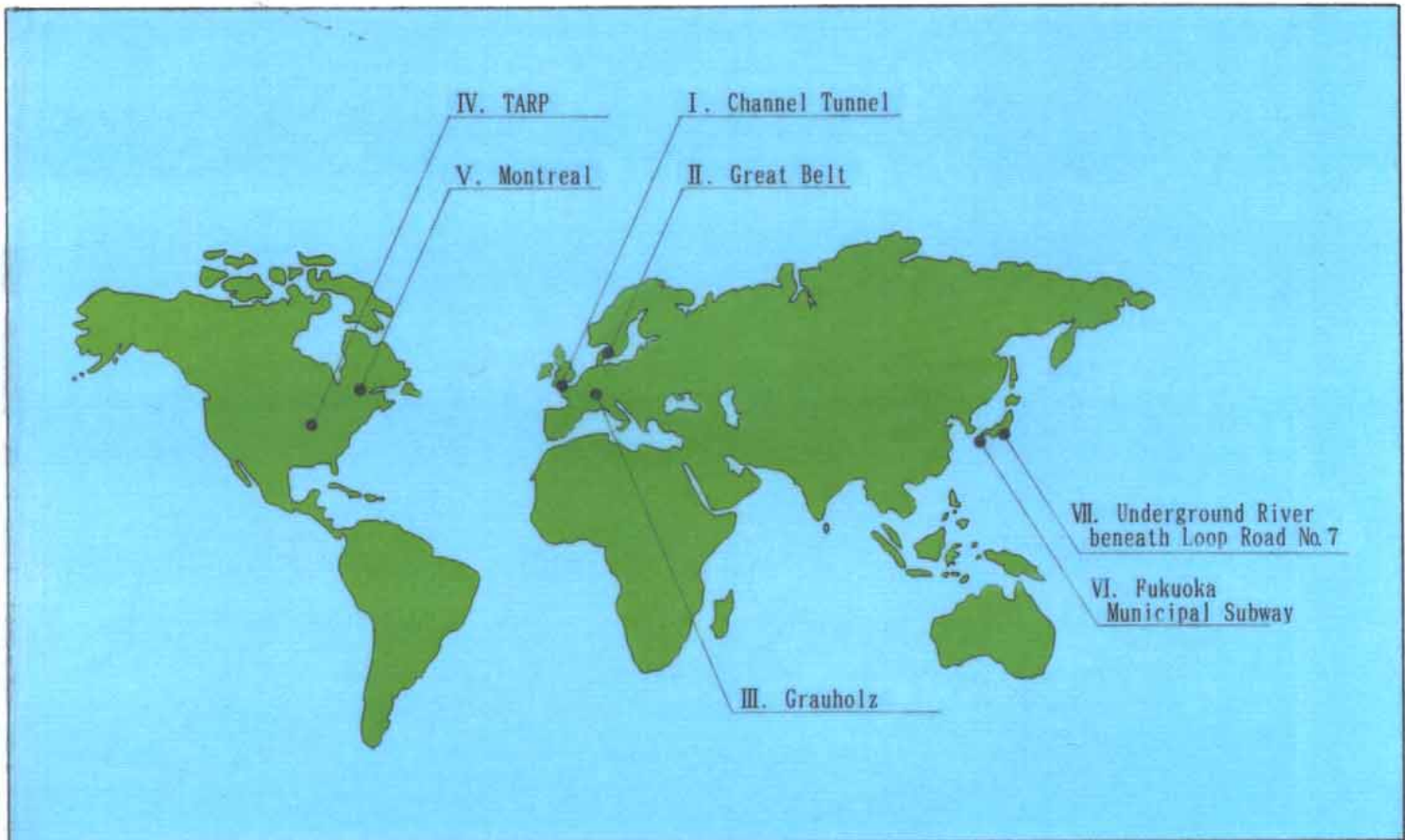
Résumé: -

Remarks: Seven large tunnel projects under construction throughout the world were selected to present in this brochure. Specifications and details of the project and the Tunnel Boring Machine (TBM) used are given for each selected tunnel project. As future tunnel projects will probably be performed using a TBM, we felt this brochure will provide useful information on TBM's and tunnelling. By applying a mechanized tunnel construction method, tunnel engineers will improve quality and safety, while increasing time/cost savings. In addition, this brochure highlights the realization of several large tunnel projects which seemed impossible earlier.

Contents:

- * Channel Tunnel Project (UK / France)
- * Great Belt Link Project (Denmark)
- * Grauholz Tunnel Project (Switzerland)
- * Tunnel and Reservoir Plan (USA)
- * Montréal Interceptor Systems (Canada)
- * Fukuoka Municipal Subway (Japan)
- * Underground Piver beneath Loop Road No7 (Japan)

LARGE TUNNEL PROJECTS IN THE WORLD '91



International Tunnelling Association

Working Group
Catalogue of Tunnel

Preface

It is with great pleasure that we, the Catalogue of Tunnels I.T.A. Working Group, distribute this brochure to the participants of the I.T.A. Congress 1991 in London. Seven large tunnel projects under construction throughout the world were selected to present in this brochure. Specifications and details of the project and the Tunnel Boring Machine (TBM) used, are given for each selected tunnel project. As future tunnel projects will probably be preformed using a TBM, we feel this brochure will provide useful information on TBM's and tunneling. By applying a mechanized tunnel construction method, tunnel engineers will improve quality and safety, while increasing time/cost savings. In addition, this brochure highlights the realization of several large tunnel projects which seemed impossible earlier.

We feel that those people who are planning, designing, engineering, or contracting any type of tunnel project will be encouraged by the information presented. We greatly appreciate the documents supplied by the TBM manufacturers to the Catalogue of tunnels I.T.A. Working Group, to be used in preparing this brochure. Any additional information on the TBM's can be obtained upon request from the manufacturer.

Whenever technical information, such as that presented in this brochure, is required, please feel free to contact our group. We hope we can continue to present you useful information on tunneling activities in the world.

We look forward to seeing you at the next I.T.A. Congress in Mexico in 1992.

12. April 1991



Shoji Kuwahara

Animateur of Working group

Catalogue of Tunnel I.T.A.

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I Channel Tunnel Project

1. Scope of Project

Eurotunnel is the private sector Anglo-French group which has a 55-year concession to operate a rail tunnel under the Channel between Britain and France - the first ever fixed link between the two countries.

The concession has been granted by the British and French governments under a Treaty which was ratified in July 1987. The concession period is due to last for 55 years - until 2042 - and Eurotunnel is free to operate the tunnel according to its own commercial policies. Moreover, the governments will not facilitate a second link built by anyone other than Eurotunnel to open before the end of 2020.

The Eurotunnel System will incorporate two rail tunnels and, running between and linked to them, a service tunnel to provide ventilation and allow routine maintenance. Each of the tunnels will be about 50 kilometres long.

At each end of the tunnels there will be a terminal - near Folkestone in the UK and at Coquelles near Calais in France - with links to each country's motorway network. The terminals will contain toll booths, frontier controls, shops and other facilities for travellers. Each national railway system will be directly connected to the tunnels.

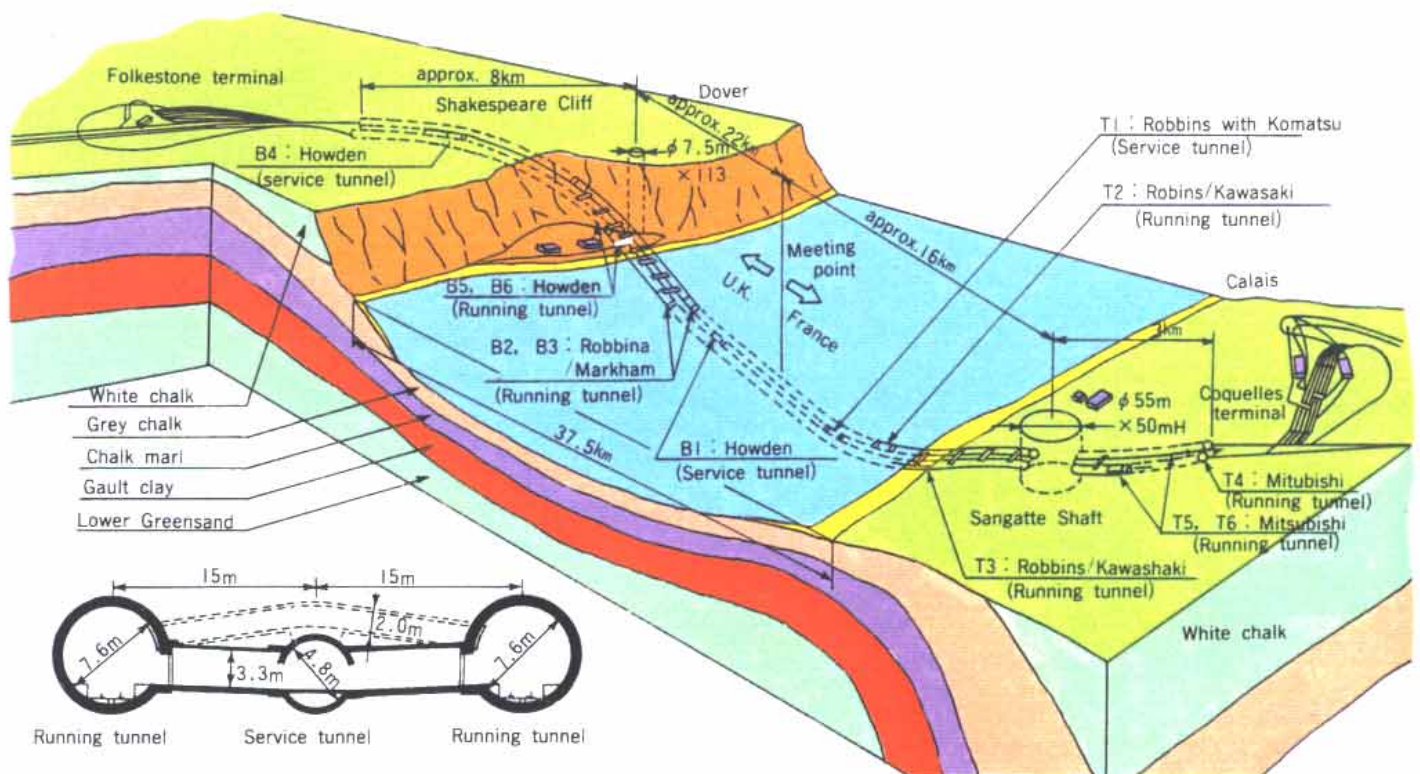


Fig. I -1 Isometric View of Channel Tunnel

2. Outline of Tunnel

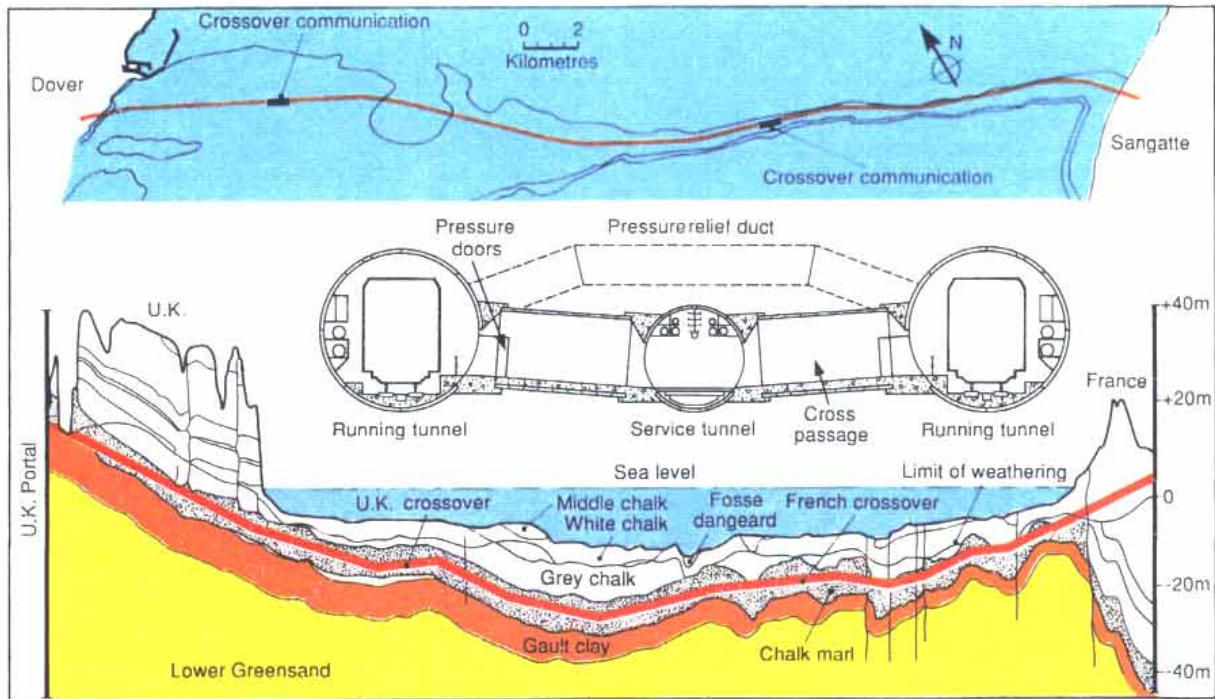


Fig. I-2 Composite diagram showing plan and geological Section of the Channel Tunnel and layout of the three sub-sea tunnels

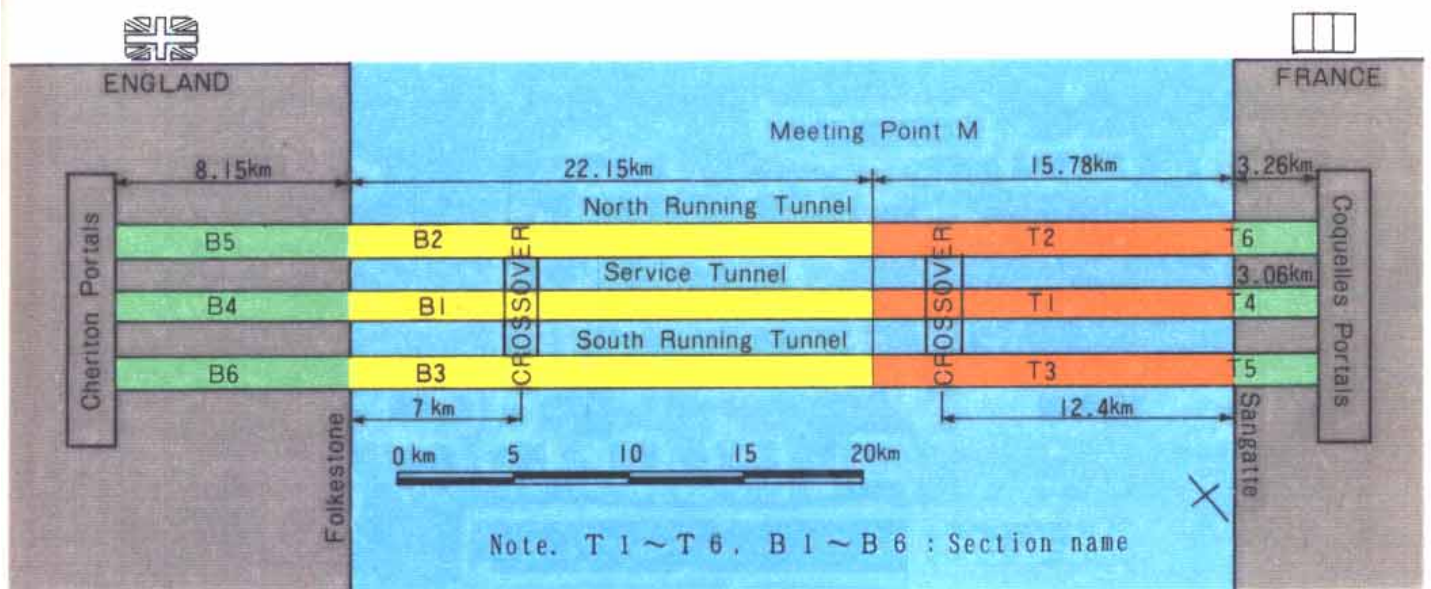


Fig. I-3 Sections of Channel Tunnel Project

3. TBM

① T 1 Section

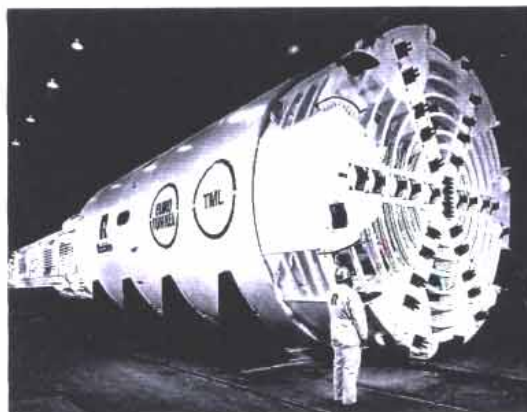
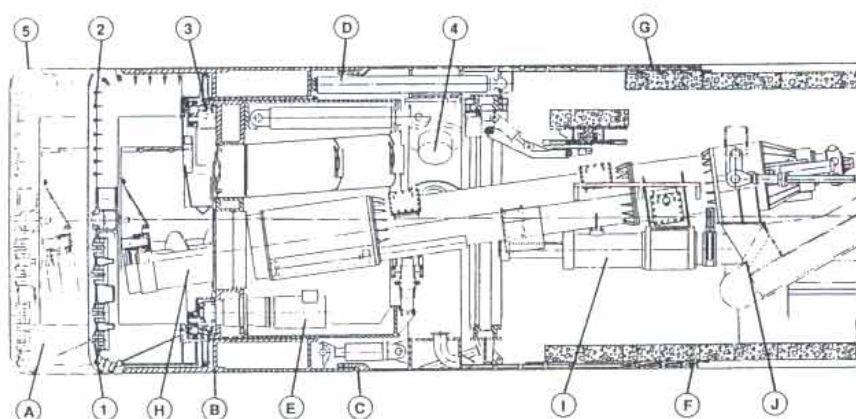


Photo. I-1 TBM used T 1 Section



1. Cutterhead
2. Gril bars
3. Main bearing
4. Gripper
5. Extensible telescoping cutterhead
- A. Two-way bucket
- B. Pressure bulkhead
- C. Articuration joint
- D. Shield jacks
- E. Bi-directional drive
- F. Tail seals
- G. Backfill grouting system
- H. Screw conveyor
- I. Twin piston discharger
- J. Alternative slurry system

Fig. I-4 TBM used in T 1 Section

Table. I-1 Specifications of TBM used in T 1 Work

Machine Specifications		Back-up Specifications	
Diameter	5.6m (18tf 4in)	Description	17 gantries plus switch
Power	880Kw (1180 hp)	Weight	647 m tons(713 tons)
Thrust	Cutterhead(7 Cylinders): 1,200,000Kg (2,645,547 lbs) Shield(20 Cylinders): 4,000,000Kg (8,818,490 lbs)	Length	298 m(978 ft)
Weight	412m tons(454 tons)		
Cutters	39-330 mm(13 in)discs or 78 drag picks		

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② T 2 , T 3 Section

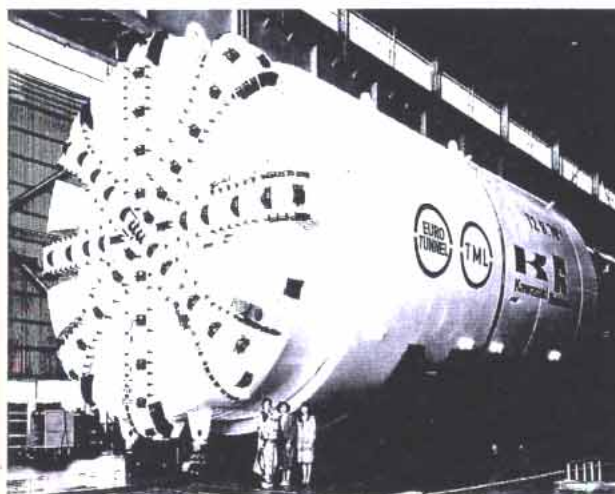


Photo. I -2

T B M Uesd in T 2 , T 3 Sections

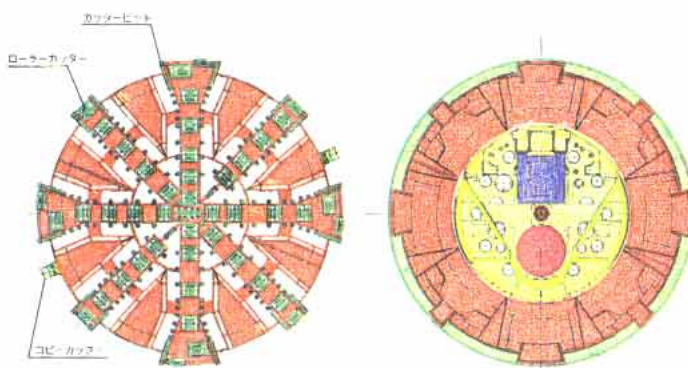


Fig. I -5 T B M used in T 2 , T 3 Sections

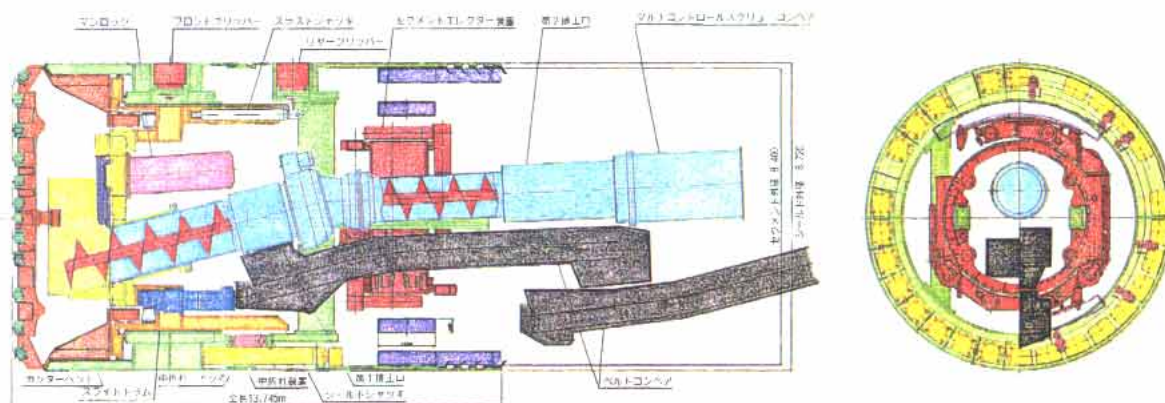


Fig. I -6 T B M used in T 2 , T 3 Sections

Table. I -2 Specifications of T B M used in T 2 , T 3 Sections

Diameter	ϕ 8.780m	Thrust Force of Thrust Cylinders	2.000ton
Length	13.745m	Thrust Force of Shield Jacks	11.500ton
Installed Capacity	約4.650Kw	Gripper Reaction	3.800ton
Cutterhead Torque	650/1,300t-m	Minimum Radius of Curve	500mR
Cutterhead Rotation	3.0/1.5 r.p.m		

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③ T 4 Section

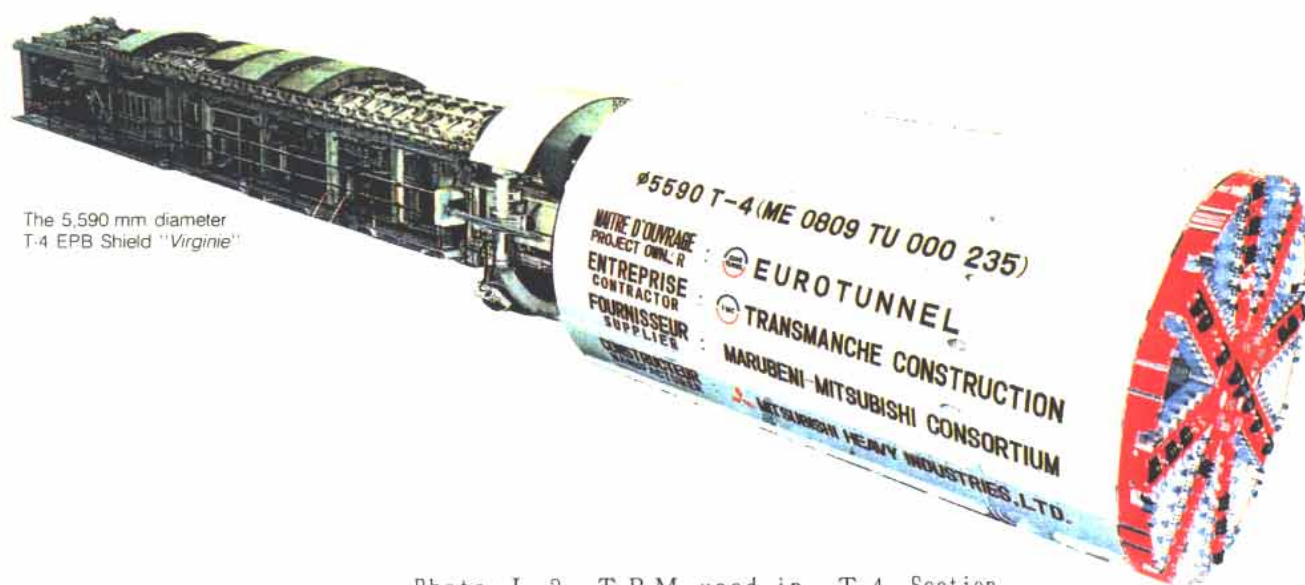


Photo. I-3 TBM used in T 4 Section

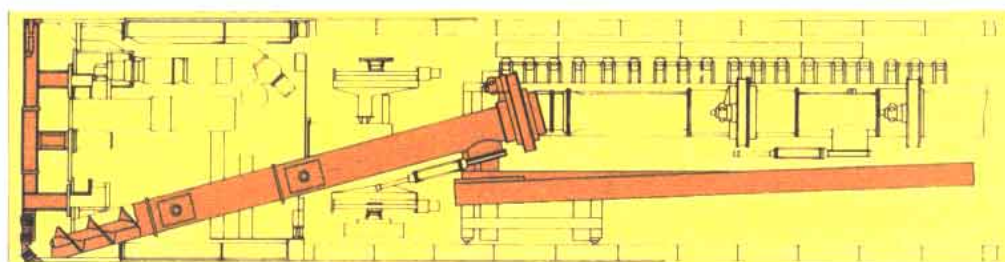


Fig. I-7 TBM used in T 4 Section

Table. I-3 Specifications of TBM used in T 4 Section

Outer Diameter	φ 5,590mm	Cutter Ignition Motor	75Kw × 6/12P × 10No
Length	10,595mm	I.D. of Screw	φ 750mm
Shield Jack	200ton × 3,000st × 20No	Screw Pitch	750mm
Full Propulsion Force	4,000ton	Screw Torque	4.5ton-m
Cutter Torque	407ton-m	Screw Rotation	0~20 r.p.m
Cutter Rotation	0.89/1.79 r.p.m	Installed Capacity	約 2,350Kw

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④ T 5, T 6 Sections

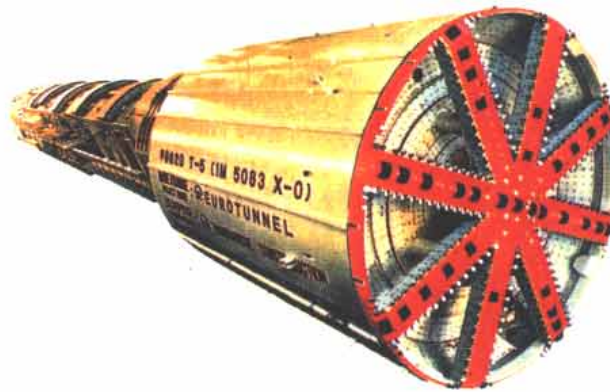


Photo. I-4 TBM used in T 5, T 6 Sections

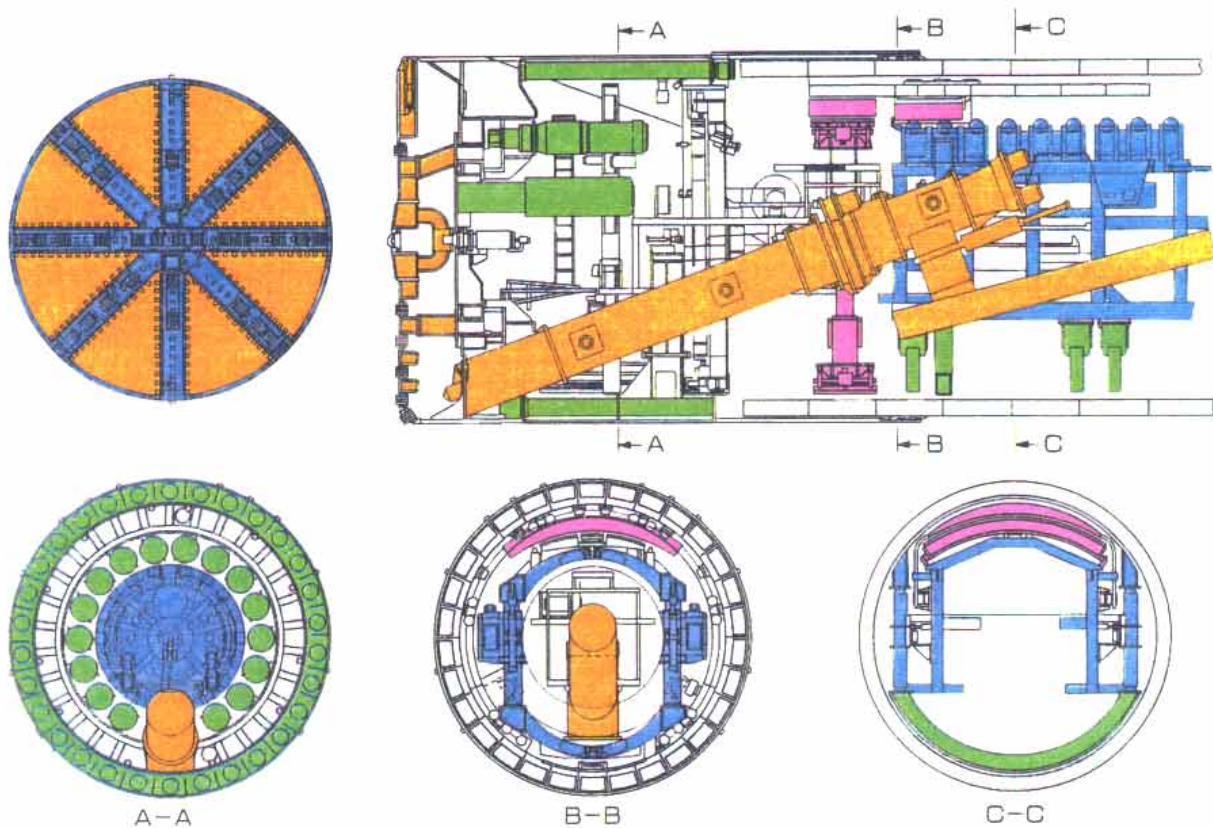


Fig. I-8 TBM used in T 5, T 6 Sections

Table. I-4

Outer Diameter	$\phi 8,620\text{mm}$	Cutter Ignition Motor	$90\text{Kw} \times 6/12\text{P} \times 16\text{No}$
Length	$12,610\text{mm}$	I.D. of Screw	$\phi 1200\text{mm}$
Shield Jack	$300\text{ton} \times 3.500\text{st} \times 30\text{No}$	Screw Pitch	1200mm
Full Propulsion Force	$9,000\text{ton}$	Screw Torque	30ton-m
Cutter Torque	$664/1.304\text{ton-m}$	Screw Rotation	$0 \sim 15 \text{ r.p.m}$
Cutter Rotation	$1.0/20 \text{ r.p.m}$	Installed Capacity	約 $4,110\text{Kw}$

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⑤ B 1 Section

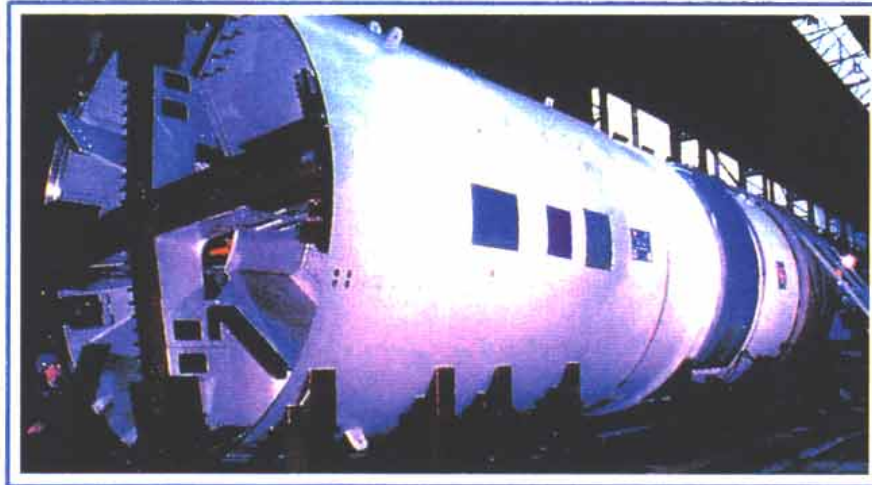


Photo. I-5 TBM used in B 1 Section

Table. I-5 Specifications of TBM used in B 1 Section

MACHINE SPECIFICATIONS	SERVICE MACHINES	MACHINE SPECIFICATIONS	SERVICE MACHINES
	MARINE	Number of Operators	15
Diameter of Cutting Face	5.380m	Voltage Supply to Machine	11kVA
Speed of Cutting Head	3rpm~4.5rpm	Thrust of Main Rams	130 tonnes each
Number of Cutting Picks	75 + 4 Profile	Number of Main Push Rams	8 Auxilliary 8 Main
Hourly Removal of Loose Spoil	355 cu.m/hr	Rating of Emergency Water Pumps	150 l/s × 2
Power of Drive Motors (each)	190kW	Travel of Machine before laying fixed services	400m
Number of Drive Motors	4	Weight of Machine	600 tonnes
Tunnel Advance Rate(Design)	8m/hr	Segment Thickness(and Width)	270mm (1.5m)
Length of Machine	220m		

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⑥ B 2, B 3 Section

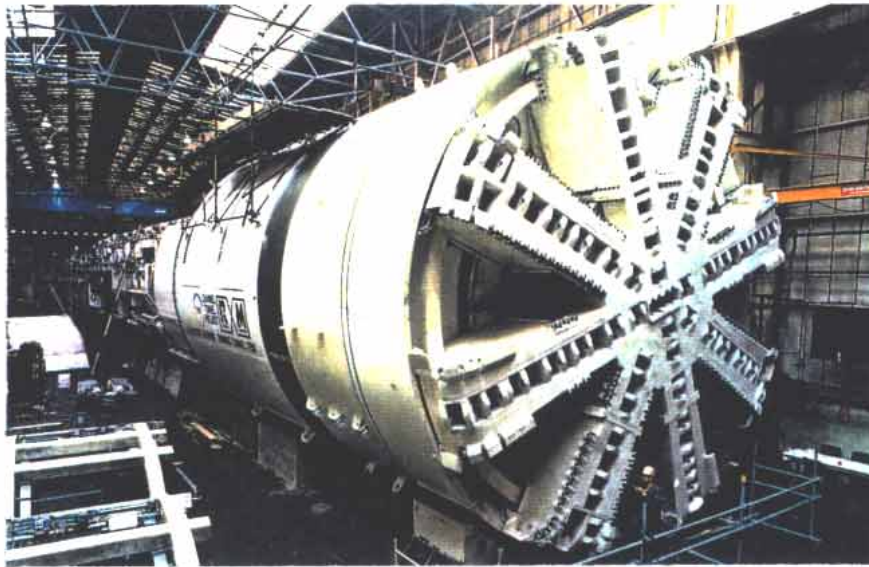
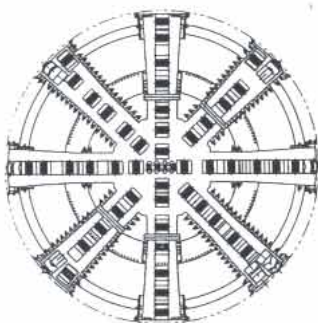
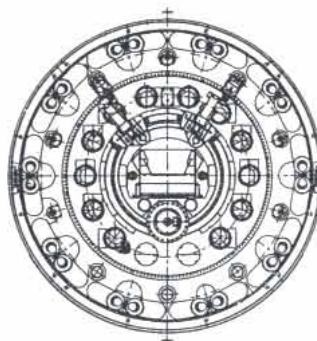


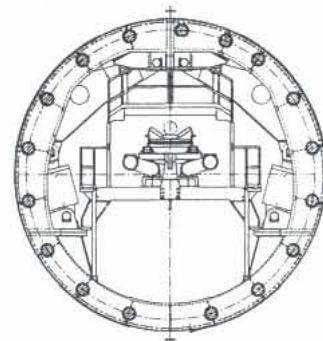
Photo. I-6 TBM used in B 2, B 3 Sections



A-A



B-B



C-C

Table. I-6 Specifications
of TBM used in B 2, B 3 Sections

Type	Double Shield
Diameter	8.36m(27 ft.-5in.)
Power	1.320 kW(1,760 hp)
Thrust	6,717,000 kg(14,810,978 lbs.)
Weight	800 metric tons (880 t)
Cutters	57×330 mm(13 in.) disc cutters or 196 drag picks

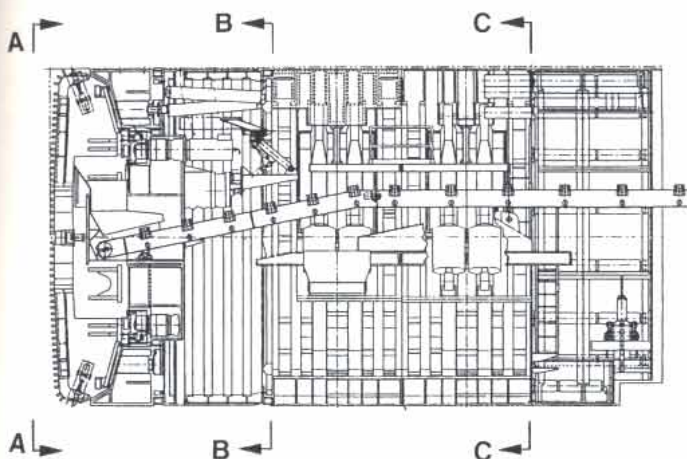


Fig. I-9 TBM used in B 2, B 3 Sections

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⑦ B 4 , Section



Photo. I -7 T B M used in B 4 Sections

Table. I -7 T B M used in B 4 Section

MACHINE SPECIFICATIONS	SERVICE MACHINES	MACHINE SPECIFICATIONS	SERVICE MACHINES
	LAND	Number of Operators	15
Diameter of Cutting Face	5.760m	Voltage Supply to Machine	11kVA
Speed of Cutting Head	3rpm~4.5rpm	Thrust of Main Rams	130 tonnes each
Number of Cutting Picks	81 + 4 Profile	Number of Main Push Rams	8 Auxilliary 8 Main
Hourly Removal of Loose Spoil	355 cu.m/hr	Rating of Emergency Water Pumps	110 l/s
Power of Drive Motors (each)	190kW	Travel of Machine before laying fixed services	400m
Number of Drive Motors	4	Weight of Machine	625 tonnes
Tunnel Advance Rate(Design)	8m/hr	Segment Thickness(and Width)	460mm (1.5m)
Length of Machine	237m		

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⑧ B 5, B 6 Sections



Photo. I-8 TBM used in B 5, B 6 Sections

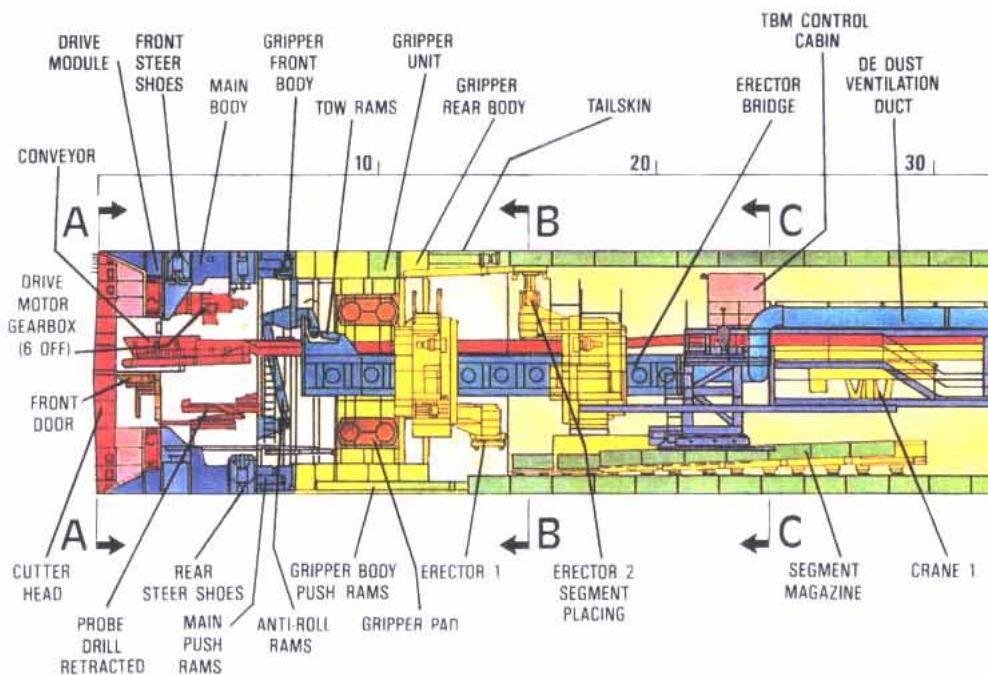


Fig. I-11 TBM used in B 5, B 6 Sections

Table. I-8 Specifications of TBM used in B 5, B 6 Sections

MACHINE SPECIFICATIONS	RUNNING MACHINES	MACHINE SPECIFICATIONS	RUNNING MACHINES
	LAND	Number of Operators	16
Diameter of Cutting Face	8.720m	Voltage Supply to Machine	11kVA
Speed of Cutting Head	1.9rpm~2.86rpm	Thrust of Main Rams	130 tonnes each
Number of Cutting Picks	227 + 4 Profile	Number of Main Push Rams	8 Auxilliary 16 Main
Hourly Removal of Loose Spoil	700 cu.m/hr	Rating of Emergency Water Pumps	None
Power of Drive Motors (each)	190kW	Travel of Machine before laying fixed services	400m
Number of Drive Motors	6	Weight of Machine	1000 tonnes
Tunnel Advance Rate(Design)	6m/hr	Segment Thickness(and Width)	540mm (1.5m)
Length of Machine	270m		

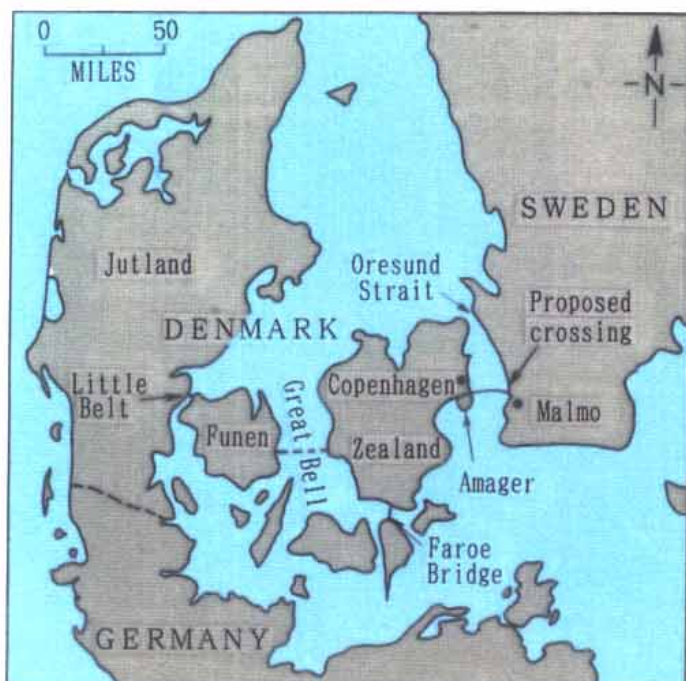
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II Great Belt Link Project

1. Scope of Project



The fixed tunnel and bridge link across the Storebaelt (the Great Belt) is one of the most important contributions to the infrastructure of Denmark in recent times and after its completion, it will fully integrate Denmark's road and railway network. The Storebaelt Fixed Link is financed by loans raised in Denmark and abroad, and will be repaid via toll charges levied on motorists and the Danish State Railways.

Fig. II -1 Location Map of Great Belt Link Project

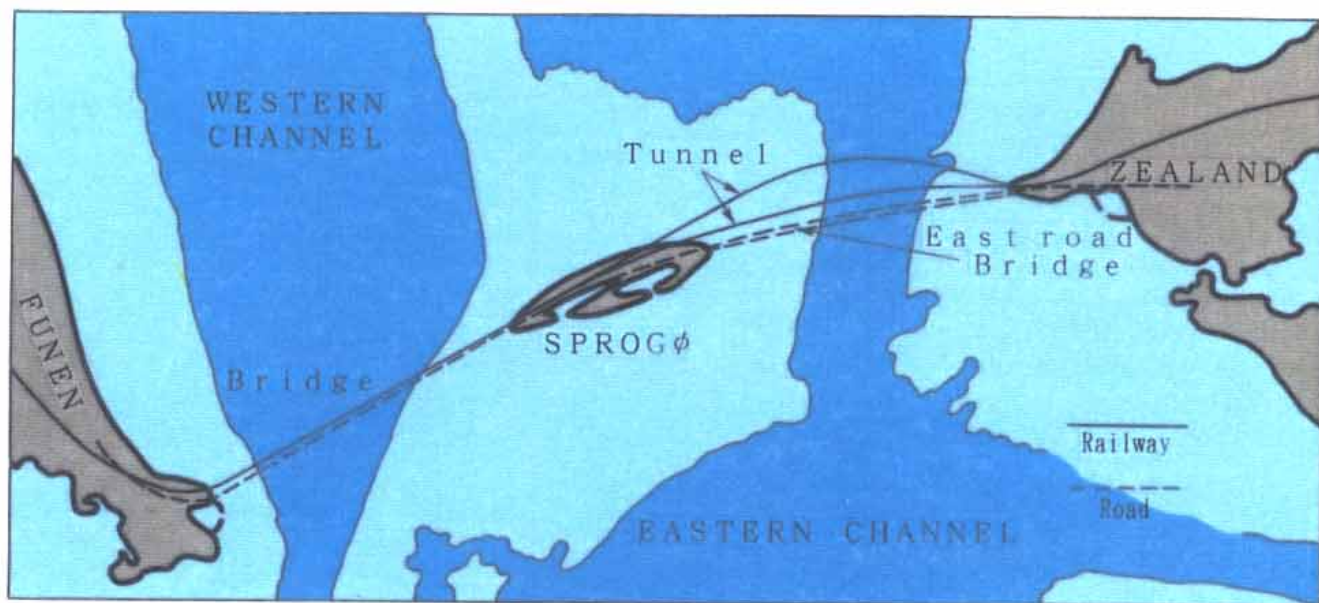


Fig. II -2 Plan of Great Belt Link Project

The establishment of the Great Belt Link has been divided in such a way that the railway link will be built first. The railway link consists of a tunnel from Zeeland to a point 80 to 200 meters north of Sprogø. A bridge completes the remaining distance from Sprogø to Funen. The railway will be completed in 1993. The construction on the road link will begin no later than one year prior to the completion of the railway link. The roadway link from Funen to Sprogø will be across the same bridge as the railway link. From Sprogø to Funen, either a high-level bridge or a tunnel will be used to complete the link. The road link is expected to be completed in 1994.

The railway link will be carried under the Eastern Channel in a bored tunnel. The Eastern Channel is 6km wide and up to 60m deep.

2. Outline of Tunnel

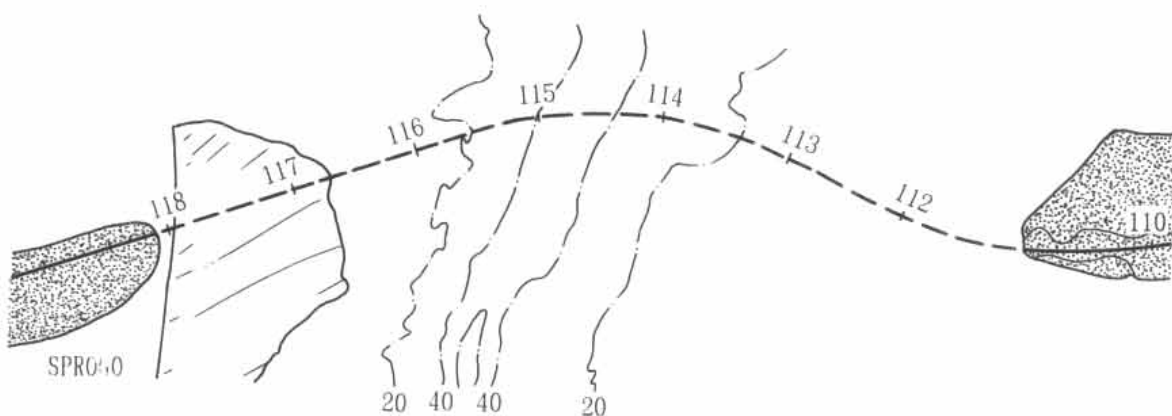


Fig. II -3 Plan of Eastern Tunnels

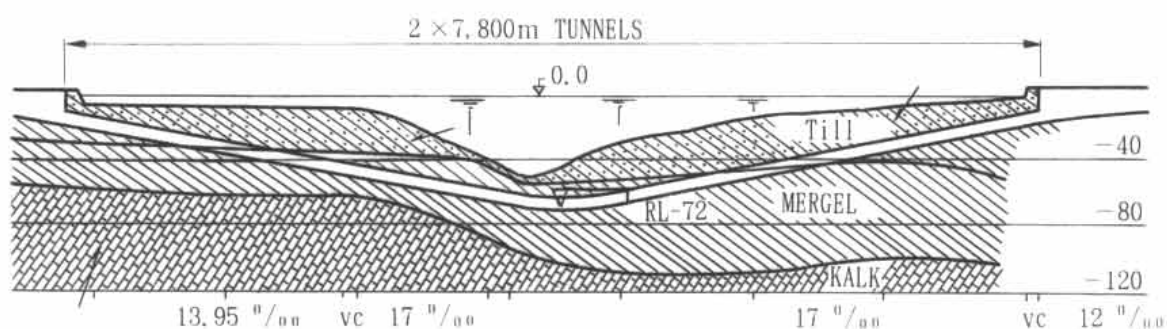


Fig. II -4 Geological Section

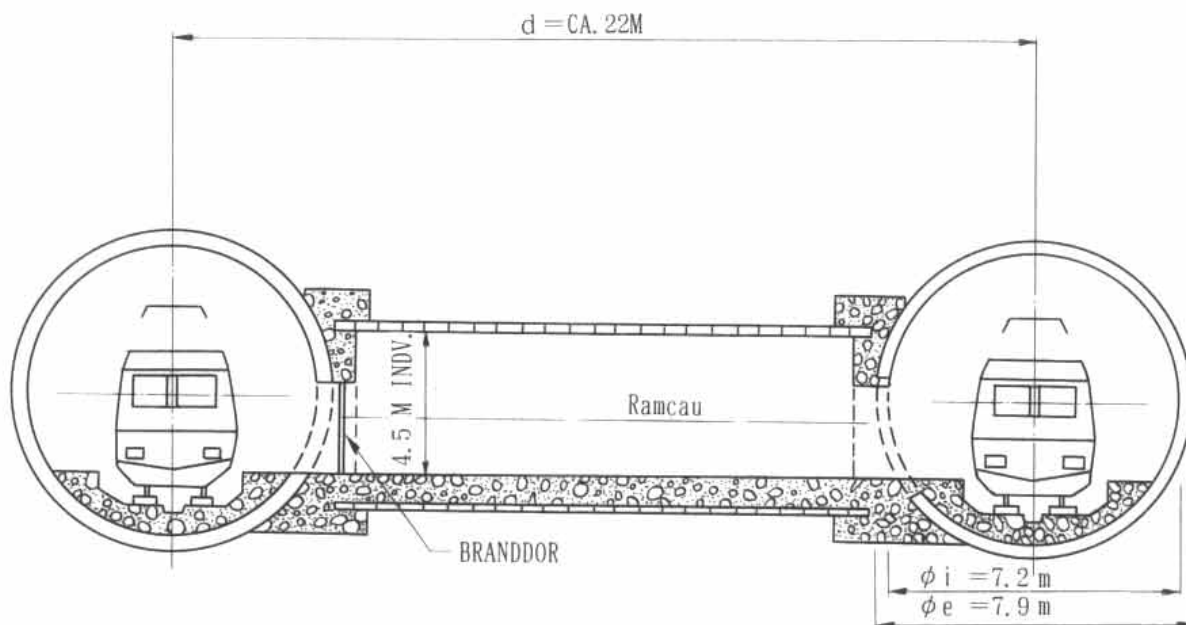


Fig. II -5 Section of Eastern tunnels

The railway tunnel will have a northerly curve with a total length of 8km. The bored tunnel can not follow a direct route due to allowances which must be made for the soil layers through which the tunnel will be bored. The tunnel will be a minimum of 10 - 15m under the seabed and the greatest depth under the sea surface will be approximately 80m. The railway tunnel will carry one rail track in each direction. At frequent intervals along the tunnel there will be emergency passages linking the two tracks. When the Link is completed safety and surveillance installations will be established for road and railway traffic.

3. Т В М

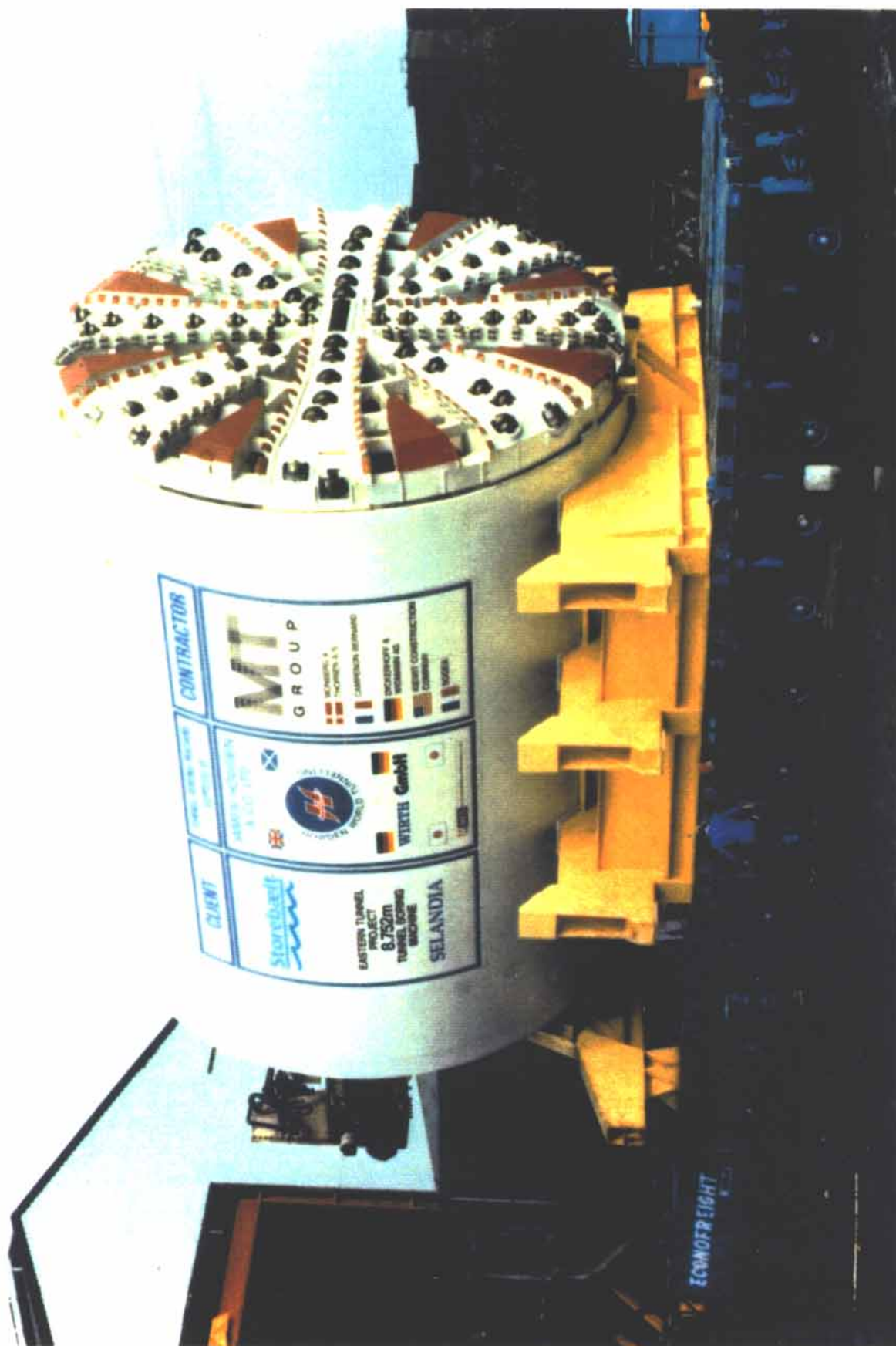


Photo. II-1 TBM used in Eastern Tunnels

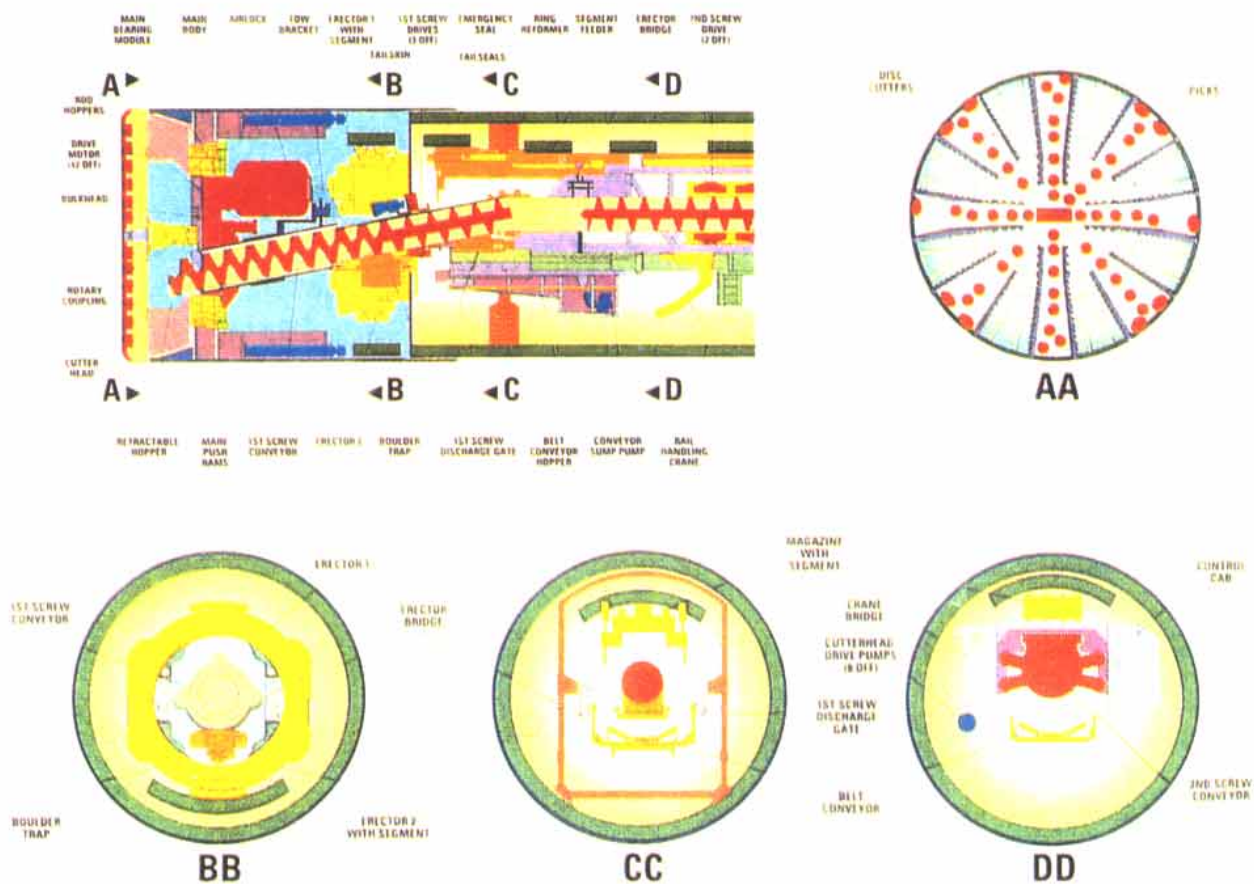


Fig. II -6 T B M used in Eastern Tunnels

Table. II -1 T B M used in Eastern Tunnels

Outer Diameter	Φ8,752mm	Torque Maximum	1,500 ton-m
Length	3,475mm	Hydraulic Pumps	8No.
Thrust Rams	36No. (4 with digital stroke measurement) 0 ×stroke 2,220	Hydraulic Motors	(A6 VM355 HD2)12No.
Cutterhead Rotational Speed	0 to 2.5 r.p.m		

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III Grauholz Tunnel Project

1. Scope of Project

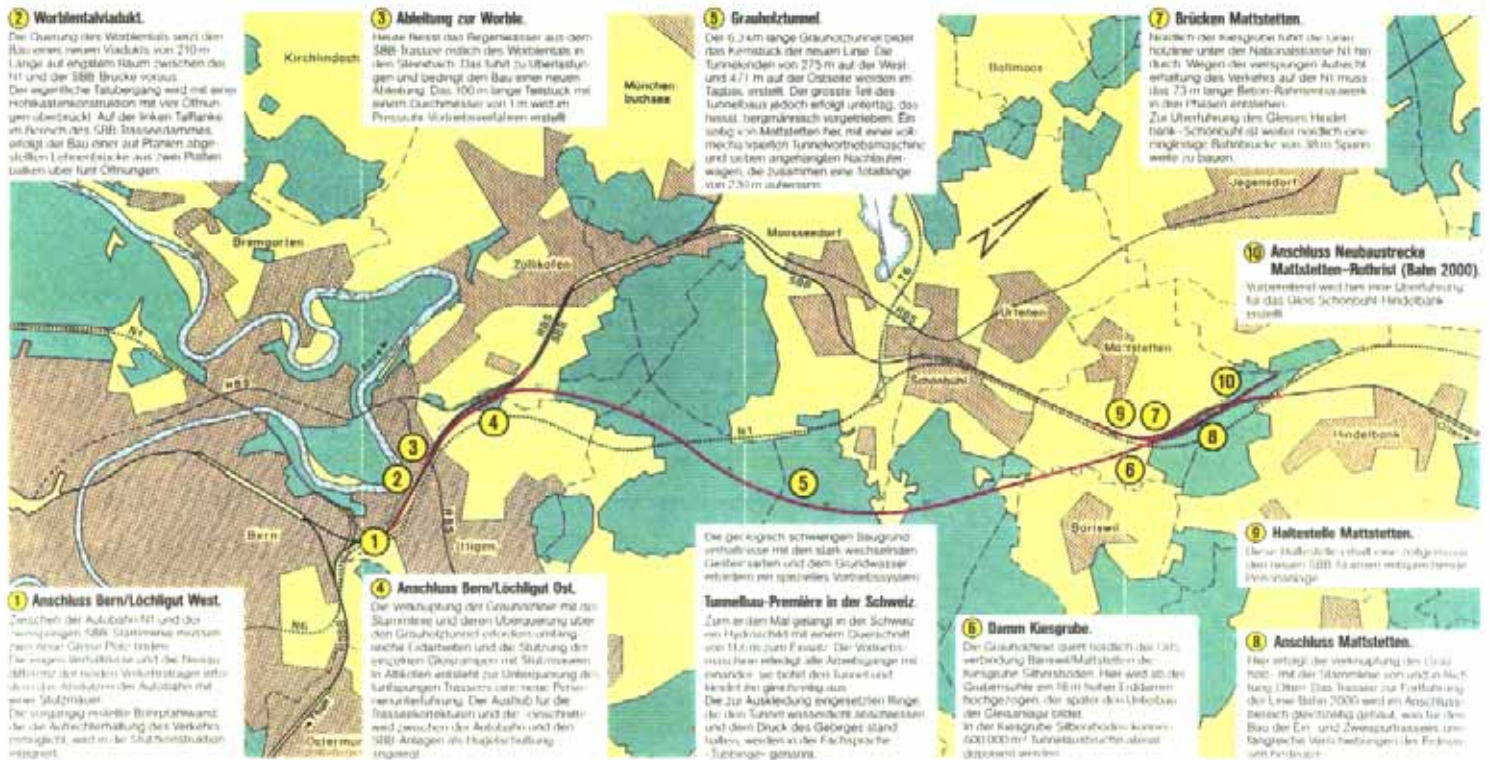


Fig. III-1 Route Map

The increasing trade due to the unification of Europe in 1992 and the modernization of the European railway system have created the need for a new route to bypass the Lochligut Junction-Zollikofen route, which is operating at near to maximum capacity. The Grauholz tunnel is being constructed as part of a scheme to bypass Zollikofen and connect Lochligut with Mattstetten by a direct route. The tunnel is 6.3km long and is equipped with double tracks. Train speeds via Zollikofen are limited to 90 - 120km/hr. The new line will allow the speeds up to 200km/hr. The project is a component in "Railway 2000," a Swiss Government plans to upgrade the country's railway network. The client for the Grauholz tunnel is the Swiss Federal Railroad (SBB). Construction began June 1988 at the east portal open-cut section near Schunbühl. The planned completion date for the tunnel is the end of 1992, with the project commissioning in the first half of 1994.

The Grauholz Hill is a remnant from glaciation, with a bedrock core of Lower Freshwater Molasse, consisting of sandstone and shale and an upper bed of Upper Marine Molasse, a source of building stone. The bedrock is covered by Quaternary glacial deposits and those are covered by complex moraine deposits. The original tunnel alignment was initially a straight route between Lochligut and Mattstetten. However, a major aquifer which supplies drinking water for the region would have been intersected by this alignment and construction would have affected the water supply. It was decided to move the alignment southwards, and an alignment and grade were selected to avoid the aquifer and to intersect as much bedrock as possible.

2. Outline of Tunnel

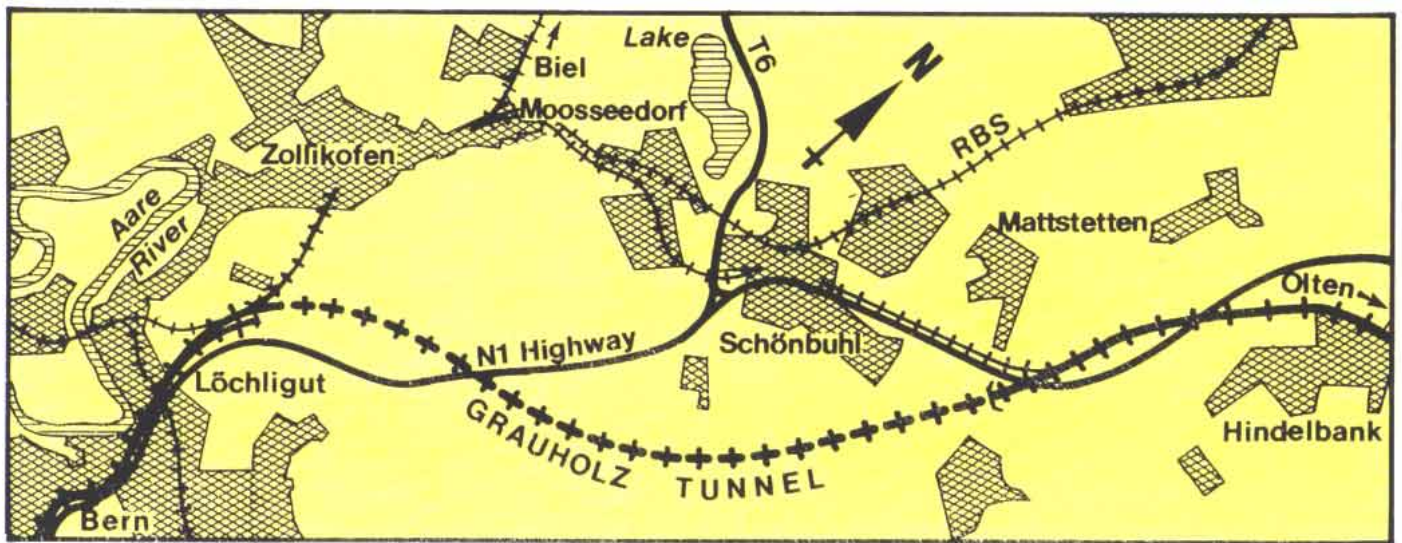


Fig. III-2 Plan of Grauholz Tunnel

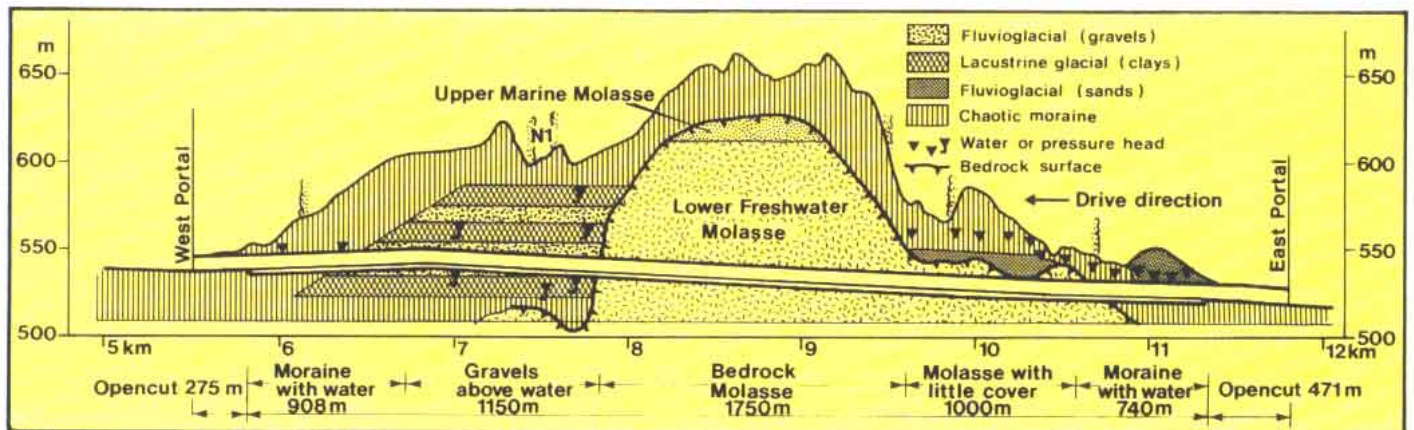


Fig. III-3 Geological Section of Grauholz Tunnel

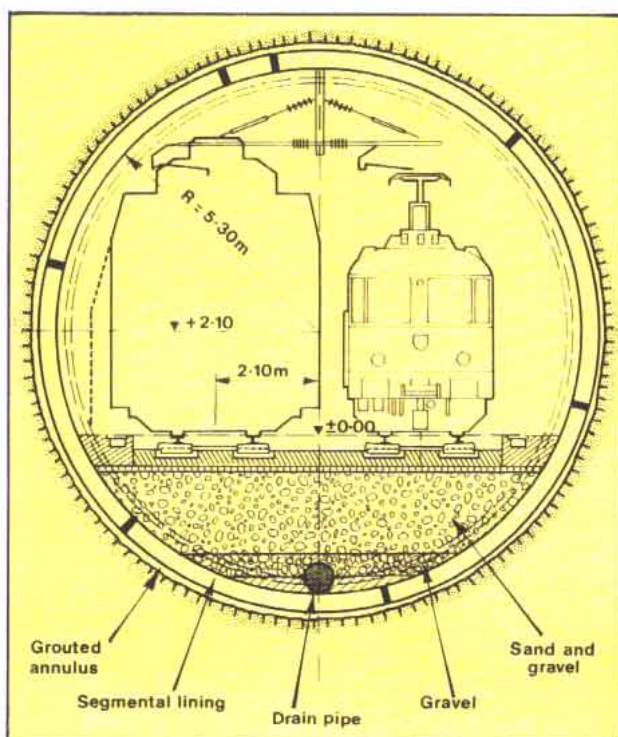


Fig. III-4 Tunnel Section of Grauholz Tunnel

The tunnel will be driven from a 471 meter long open cut at the east portal through 0.7km of water-bearing clays and moraine. Then it will pass through 1km of bedrock with a very shallow cover (up to about 10m) before reaching the central bedrock zone which is 1.8km long in sandstone and shale with a deep cover. Beyond the central bedrock zone, there is 1.1km of silty gravel above the water table, then 0.9m of water-bearing moraine before reaching the west portal and a 275 meter long open cut.

3. T B M



Photo. III -1 T B M used in Grauholz Tunnel

The successful bid proposed driving the entire tunnel from the east portal using a TBM. The TBM uses a slurry system in the water bearing ground, and open boring with dry mucking through the central zone. A "Mixshield Machine" was selected, based on the principles developed by Wayss & Freytag and manufactured by Herrenknecht. The tunnel lining, a single-shell, with watertight linking is installed behind the shield to provide an inside diameter of 10.6m.

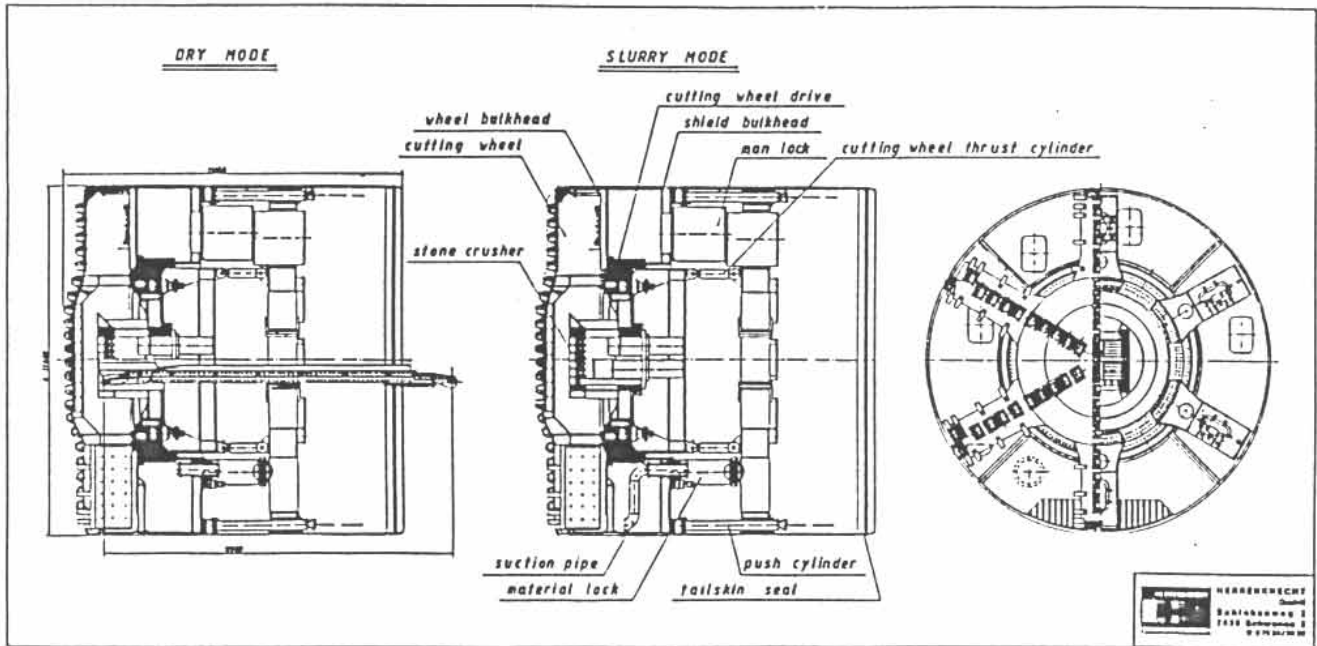


Fig. III -5 T B M used in Grauholz Tunnel

Table. III -1 Specifications of T B M used in Grauholz Tunnel

Shield:	Trailing section in seven units:	Lining:
<p>Total weight:1.350t</p> <p>Diameter:11.6m</p> <p>Maximum cutting dia:11.68m</p> <p>Length:10.4m</p> <p>Cutter speed:2.7rev/min</p> <p>Torque maximum:1,300mt</p> <p>Cutterhead power:1,250kw</p> <p>Thrust by 48 cylinders:8,640t</p> <p>Stroke by cylinders:2.5m</p> <p>Cutters:74 roller cutters 17 in diameter 80 ripper teeth</p> <p>Water pressure protection:4 bar maximum</p> <p>Boulder breaker opening:1.1m×1.2m</p>	<p>Length:235m</p> <p>Weight without material:1.800t</p> <p>Bentonite slurry supply:1,300m³/h maximum</p> <p>Maximum grain size in slurry:250mm</p> <p>Installed power:4,600kw at 16kv (3 compressors,hydraulic pumps for shield, slurry pumps,ventilation,separation plant, conveyor)</p> <p>Compressed air capacity:around 190m³/min</p> <p>Ventilation capacity:25m³/s</p> <p>Conveyor belt capacity:540t/h maximum</p> <p>Conveyor belt speed:3.2m/s</p> <p>Conveyor belt width:800mm</p>	<p>Six elements+key,od 11.4m, id 10.6m thickness 400mm.Neoprene seals in tonque-and-groove joint</p> <p>Width of elements:1.8m</p> <p>Weight of elements:about 10t</p> <p>Shift manpower:18-20</p>

HERRENKNECHT INTERNATIONAL,LTD.: 32 West Common Drive, Haywards Heath, West Sussex RH16 2AW, UK.
TEL: (+44) 0444 452963 FAX: (+44) 0444 457336 TELEX:87515

IV Tunnel and Reservoir PLAN (TARP)

1. Scope of Project

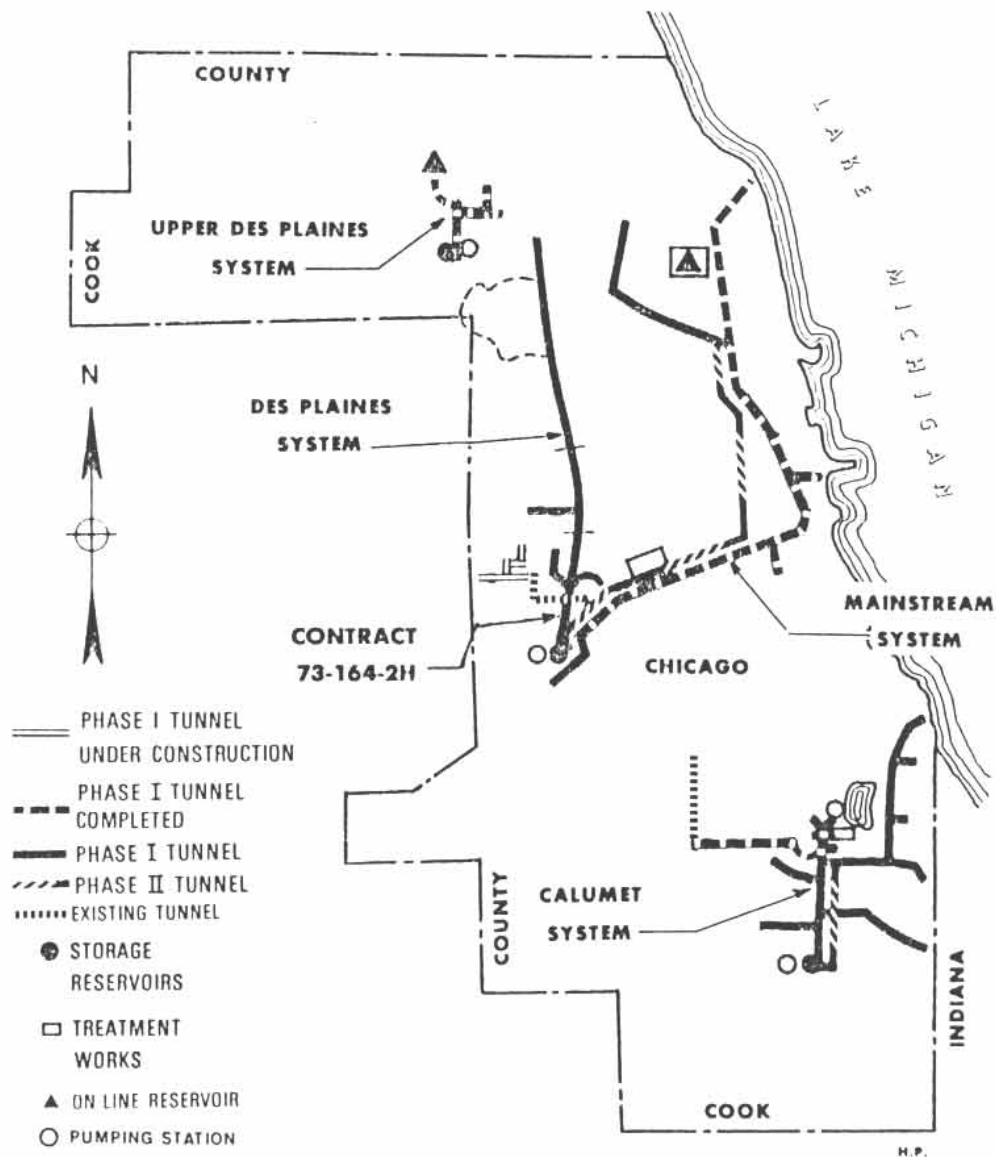


Fig. IV-1 Plan of T A R P

Combined stormwater and sewage systems have caused pollution problems in the Calumet region of Illinois. Since 1930, the State of Illinois has not allowed the construction of combined sewers. Separate sewer systems, one for stormwater runoff and one for sewage, are now required. There still remains all the combined sewers built before 1930. Because older municipalities, such as many of those which make up the Calumet region, have sewer systems that must handle both sewage and stormwater, about 100 storms per year cause a combination of raw sewage and stormwater to discharge into Chicagoland waterways, causing a pollution problem. The need to end the pollution caused by these overflows gave birth to the Metropolitan Sanitary District of Greater Chicago's MSD) innovative Tunnel and Reservoir Plan (TARP).

2. Outline of Tunnel

The total TARP Project is divided into four systems: Main stream, Calmet, Desplaines and Upper Des Plaines. Contract 73-164-2H, which is a part of Desplaines systems, is shown below.

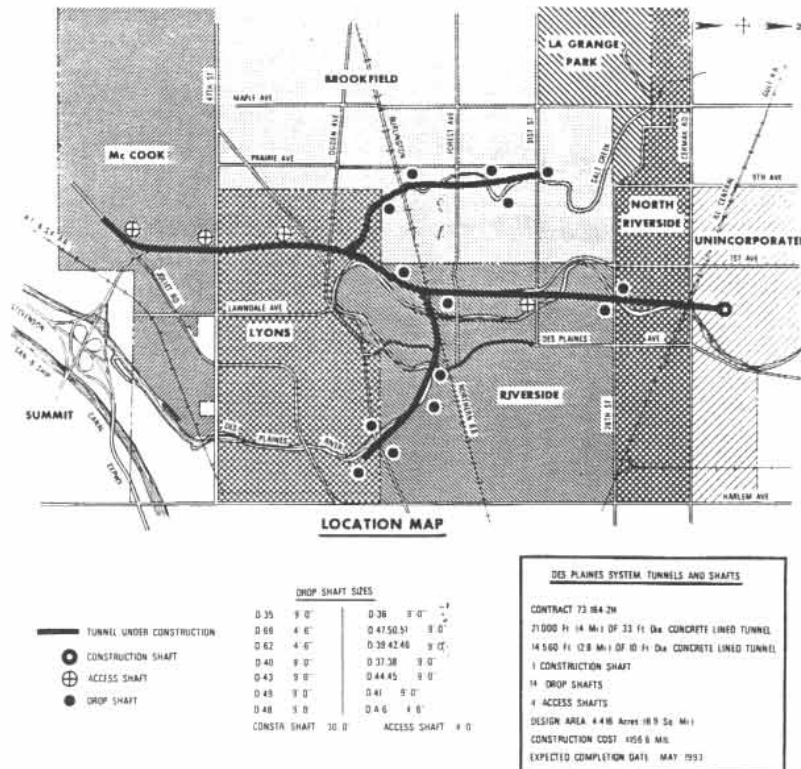


Fig. IV-2 Plan of Desplaines System

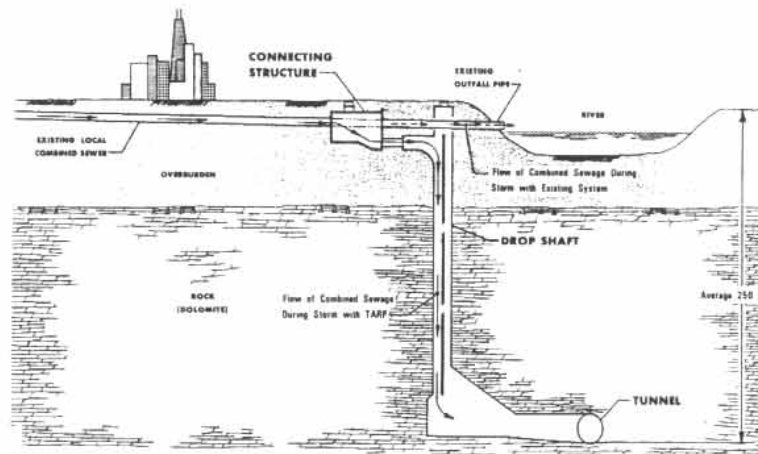


Fig. IV-3 Flood and pollution control

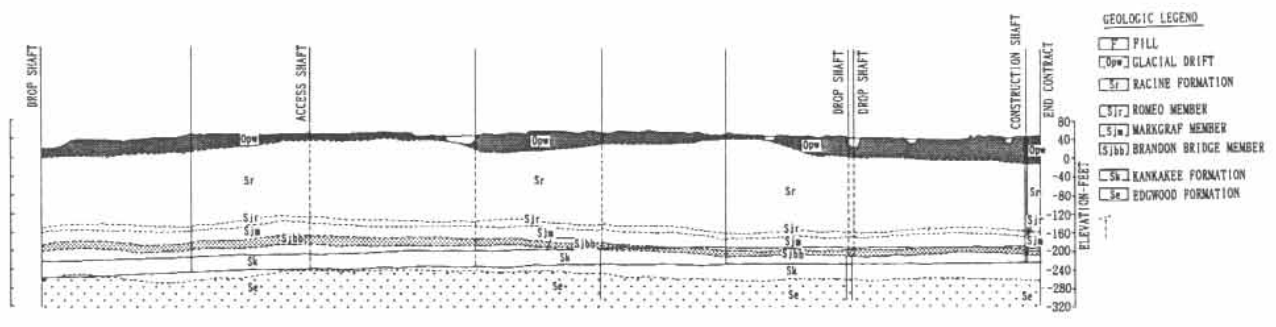


Fig. IV-4 Geological Profile

3. T B M

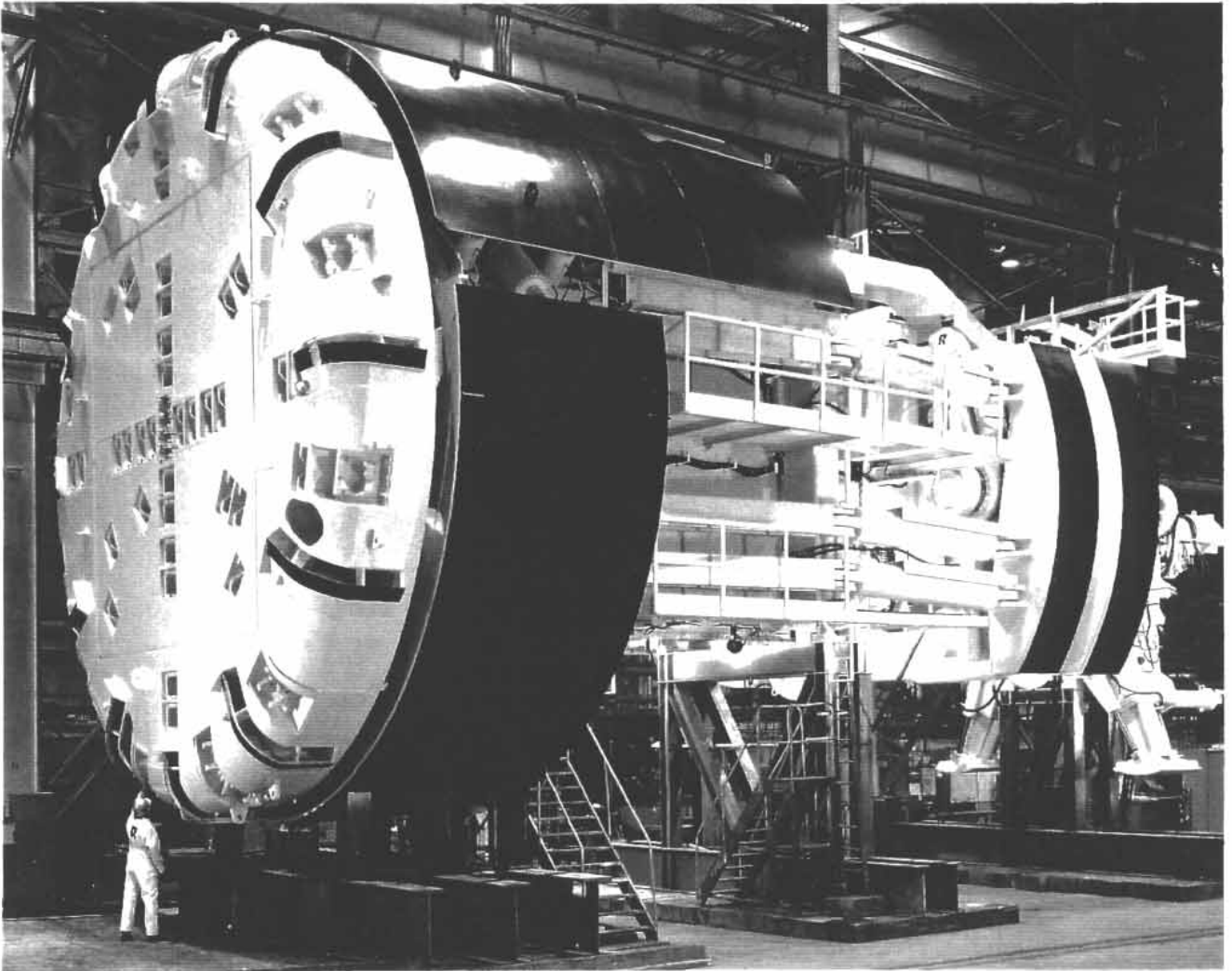


Photo. IV-1 T B M used in T A R P Contract 73-164-2H

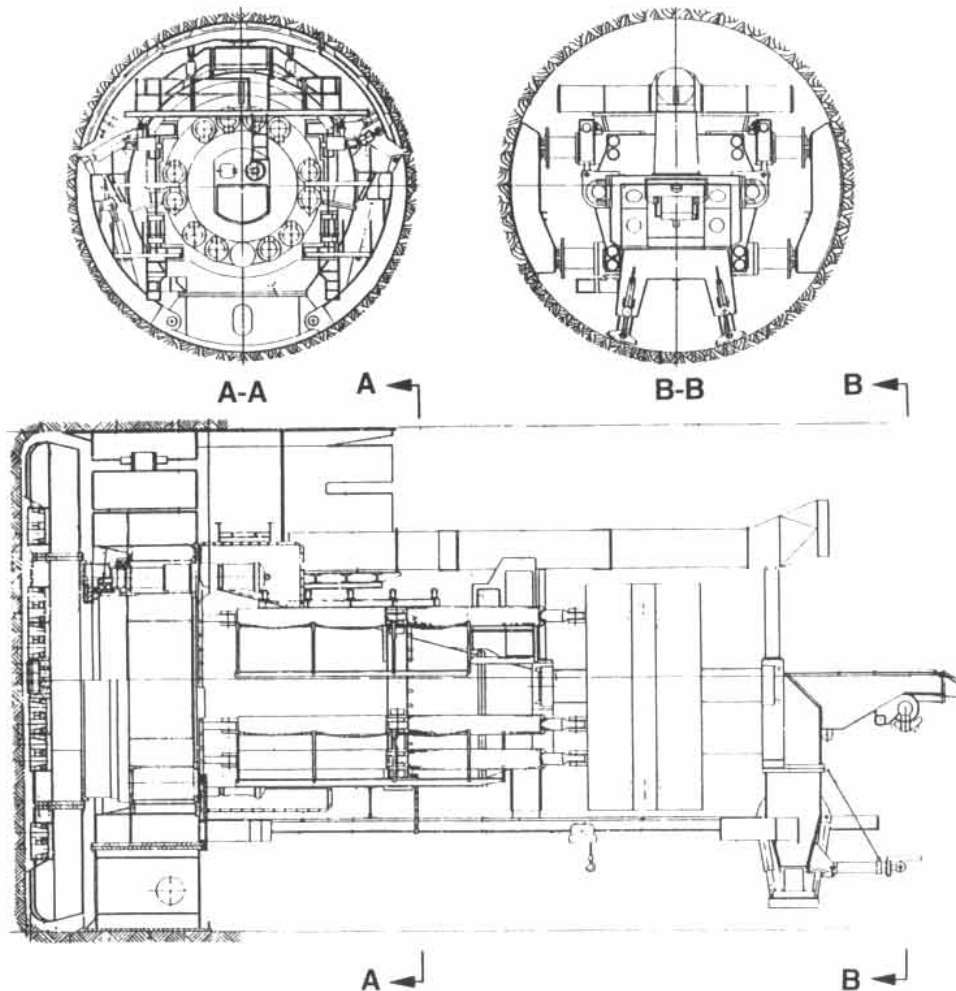


Fig. IV-5 TBM used in TARP Contract 73-164-2H

Table. IV-1 TBM used in TARP Contract 73-164-2H

TYPE	HARD ROCK ROTARY	THRUST	1,327,000Kg (2,925,000 lbs)
DIAMETER	10.8m (35 ft.-4 in.)	WEIGHT	740 metric tons (810 t)
POWER	2237Kw	CUTTER	63×432 mm (17 in.) disc cutters

THE ROBBINS COMPANY. ✓ : Box 97027, Kent, Washington 98031 U.S.A. ✓
 TEL:206-872-0500 FAX:206-872-0199 TELEX:4740083

V M o n t r é a l I n t e r c e p t o r S y s t e m s

1. Scope of Project

The territory of the Communauté Urbaine de Montreal, which covers an area of about 50,000ha, is drained by 180 outfalls varying from 300 to 5,200 mm in diameter. The system of interception makes it possible to collect and channel the wastewater of all the municipalities to the single wastewater treatment plant under construction.

The system of interception is designed in such a way that wastewater from the sanitary and combined networks are directly discharged into the interceptors. The tunneling program includes the construction of about 100km of interceptor for the northern and southern watersheds of the territory. The interceptors vary from 1,800 to 6,100 mm in diameter. The northern interceptor was completed in 1984. The southern interceptor was scheduled to be finished in 1990.

Studies undertaken by the environmental services have made it possible to establish the advantages of building these interceptors by tunneling into rock, at great depth, mainly because of the level and nature of the rock, the proximity of water ways and the problems involved in building such works in urbanized areas. Under these conditions, use of a TBM was considered advisable since this method of construction minimizes the drawbacks inherent in traditional blasting excavation. To promote the use of TBM's, the Communauté divided the construction of the interceptors into sections at least 4,500m in length.

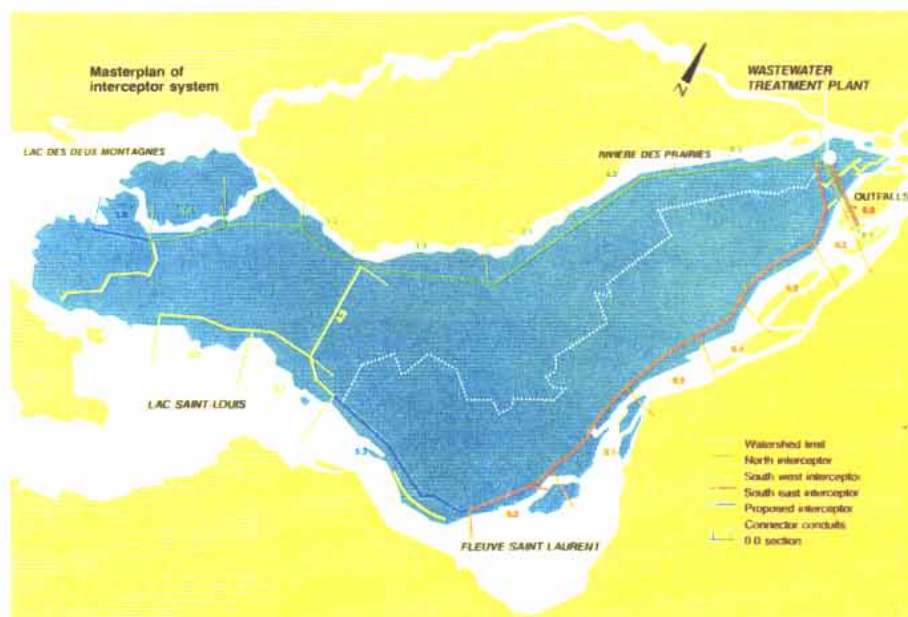


Fig. V -1 Masterplan of Interceptor Systems

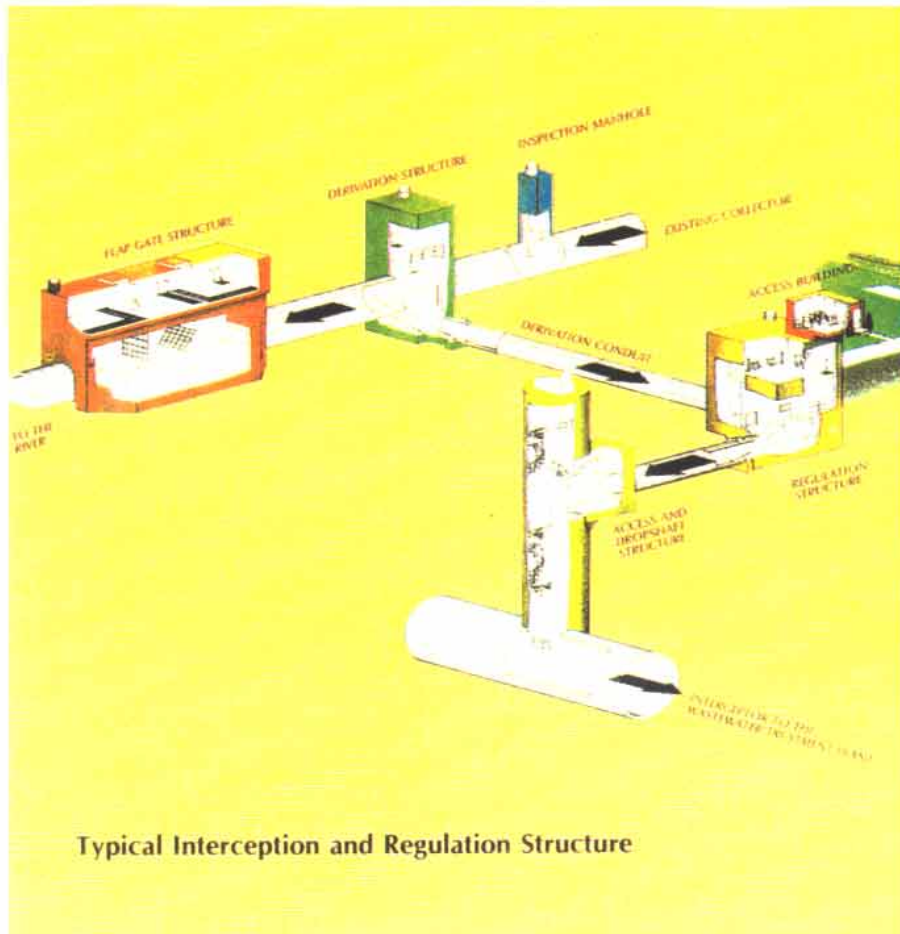


Fig. V-2 Typical Interception and Regulation Structure

2. Outline of Tunnel

The outlet tunnel between Wastewater Treatment Plant and St-Laurent River is introduced here.

Table. V-1 Outline of Tunnel and Shafts

Tunnel	Inner Diameter	5,486mm
	Length	4,349m
Entrance shaft	Diameter	6.1m
	Depth	55m
Intermediate shaft	Diemeter	61m
	Depth	79m

3. TBM



Photo. V-1 TBM used in Outlet Tunnel

Table. V-2 Specifications of T B M used in Outlet Tunnel

GENERAL ARRANGEMENT	.....	D15062
BORE DIAMETER - (New Cutters)	.....	18' -6"
ADVANCE RATE - Maximum	.....	26.1 ft./hr. (.90 in./rev.)
MINING RATE		
@ 26.1 ft.hr.	.....	450 cu.yds./hr.
THRUST		
Maximum - per Cutter	.....	40,000 lbs.
TOTAL - operating @ 2700 psi	.....	1,433,500 lbs. (716 tons)
TOTAL - operating @ 3500 psi	.....	1,858,250 lbs. (930 tons)

POWER		
Cutterhead - @ 5.87 RPM	.....	1200 HP
@ 2.93 RPM	.....	600 HP
Hydraulic Pump - Propel		
Low Pressure	.....	50 HP
Hydraulic Pump - Gripper		
Low Pressure	.....	50 HP
Lube Oil Pump	.....	3 HP
Air Compressor - Clutch	.....	1 HP
TRANSFORMER	.....	1500 KVA
(mounted on trailing equipment)		nitrogen filled
ELECTRICAL POWER	.....	480 - 3 phase - 60 hz
Control	.....	120v - 60 hz
Lighting	.....	120v - 60 hz

ROBBINS EQUIPMENT CO. : Dan E. Nowak, V.-P., Kent, Washington, U.S.A.
TEL:206-395-0365

VI Fukuoka Municipal Subway

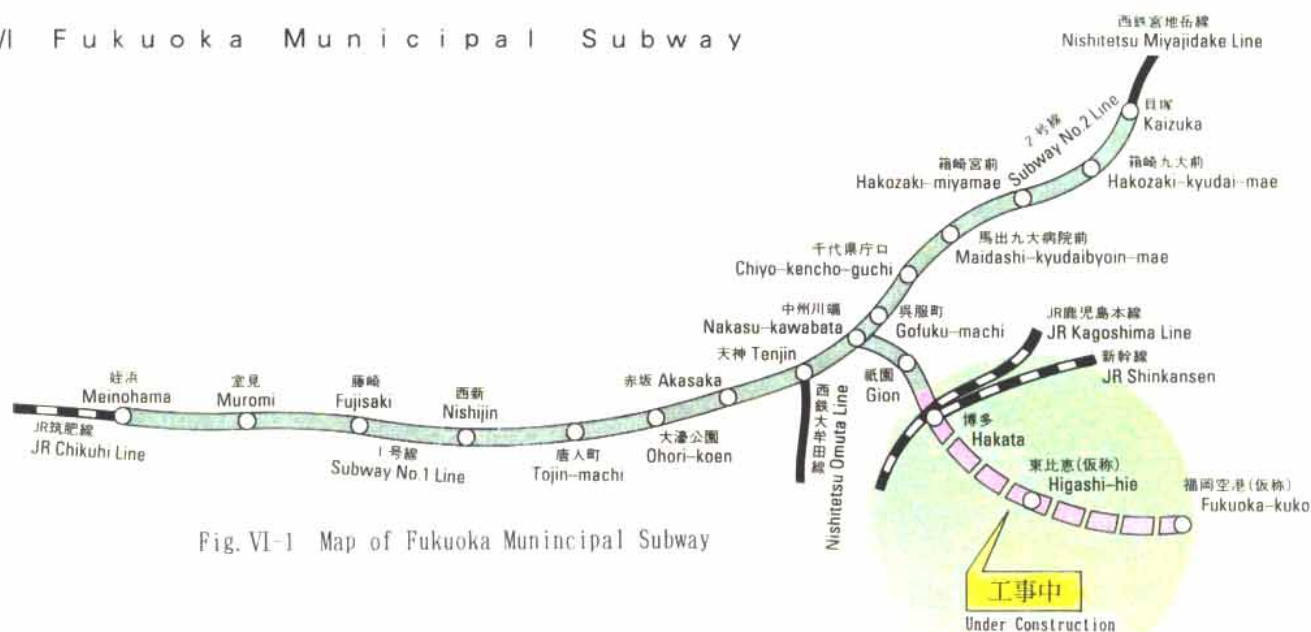


Fig. VI-1 Map of Fukuoka Municipal Subway

Table. VI-1 Outline of Fukuoka Municipal Subway

Item	Subway No. 1 Line	Subway No. 2 Line	Hakata-Fukuoka Airport Route
From-to	Meinohama ~ Hakata	Nakasu-kawabata ~ Kaizuka	From 2 Hakataeki Higasi, Hakata-ku, Fukuoka-city To Oaza shimousui, Hakata-ku, Fukuoka-city
Construction Length	11.8km	5.2km	3.1km
Operation Length	9.8km	4.7km	3.3km
Construction Period	1974~1986		1987~1992
Year Operation Began	Jul. 1981~Nov. 1986		Spring 1993
No. of Stations	11	7	2 Higasi-hie Fukuoka-kuko
Avg. Distance Between Stations	0.98km	0.78km	1.65km
Construction Costs	354,200million yen (20,800million yen/km)		51,700million yen(16,700million yen/km)
No. of Train Cars	108 cars (18 trains)		12 cars (2 trains)



Fig. VI-2 Plan of Hakata-Fukuoka Airport Route

In order to solve the commuting problems and to provide an easy and convenient route to the airport, Fukuoka city has developed a plan to extend the existing Subway No. 1 Line 3.1km from Meinohama Station in the downtown area to Hakata near the airport. This extension will provide a reliable and fast mode of transportation.

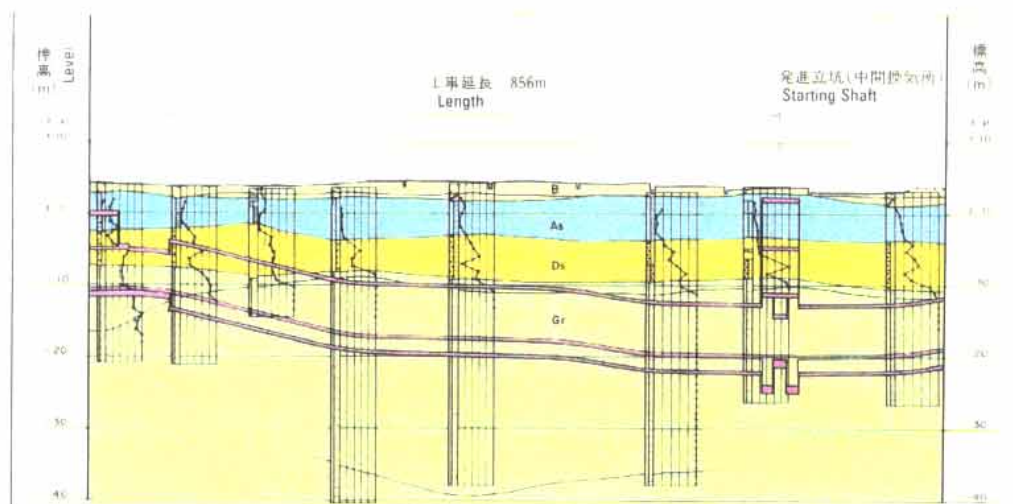
In recent years, the population and density of the Urban area southeast of Fukuoka City on Kyushu island in Japan has been increasing rapidly. At the present, only conventional methods of transportation, such as busses and cars, are being used, resulting in crowded commuting conditions to the downtown area. Also, the Fukuoka Airport, one of the major departure/arrival points for asia, is located in the southeast area. The number of passagers using Fukuoka. Airport has been increasing yearly, increasing the congestion in the area.

2. Outline of Tunnel

An underground tunnel between Higashi-hie and Enokida intermediate Ventilation Shaft, which is a part of Hakata-Fukuoka Airport Route, is shown below.



Fig. VI-3 Plan of Tunnel



Legend

Epoch	Geology	Symbol	Soil	Notes
Quaternary	Fill Material	B	Sand w/gravel	Earthwork includes site development and reclamation.
	Alluvial Sand	As	Sand w/gravel	Coarse sand (includes 10~30% of 2-10mm dia gravel). Permeability is high.
	Diluvial Sand	Ds	Sandy soil	Mainly relatively coarse crystal particles. The layers varies in thickness and denseness. Includes 10~30% of 2-10mm dia gravel and 10% fine particles.
Cretaceous	Granite	Gr	Biotite Muscovite Granite	Unweathered layer is very hard, however, layer to be tunneled is weathered granite (Massado).

Fig. VI-4 Soil Profile

Table. VI-2 Outline of Tunnel

Construction Explanation

Project Name	Fukuoka Municipal Subway No.1 Line Enokida Intermediate Ventilation Shaft and Running Tunnel Construction		
Client	Fukuoka Municipal Transportation Bureau		
Location	1. Higashi Hie Hakata-ku, Fukuoka-city 2. Enokida, Hakata-ku, Fukuoka-city		
Construction Period	Sep. 13 1987 ~ Oct. 1 1991		
Type of Shield	Slurry Pressurized Shield Machine		
Outer Diameter of Shield	Φ10.2m	Finished Inside Diameter Φ8.9m	
Length	856m	Shield Portion	830.9m
		Shaft Portion	25.1m

3. TBM

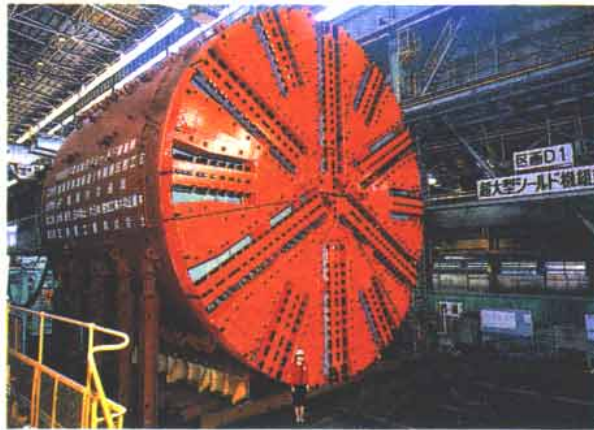


Photo. VI-1 TBM used in Tunnel between Higashi-hie and Enokida Intermediate Venturation Shaft

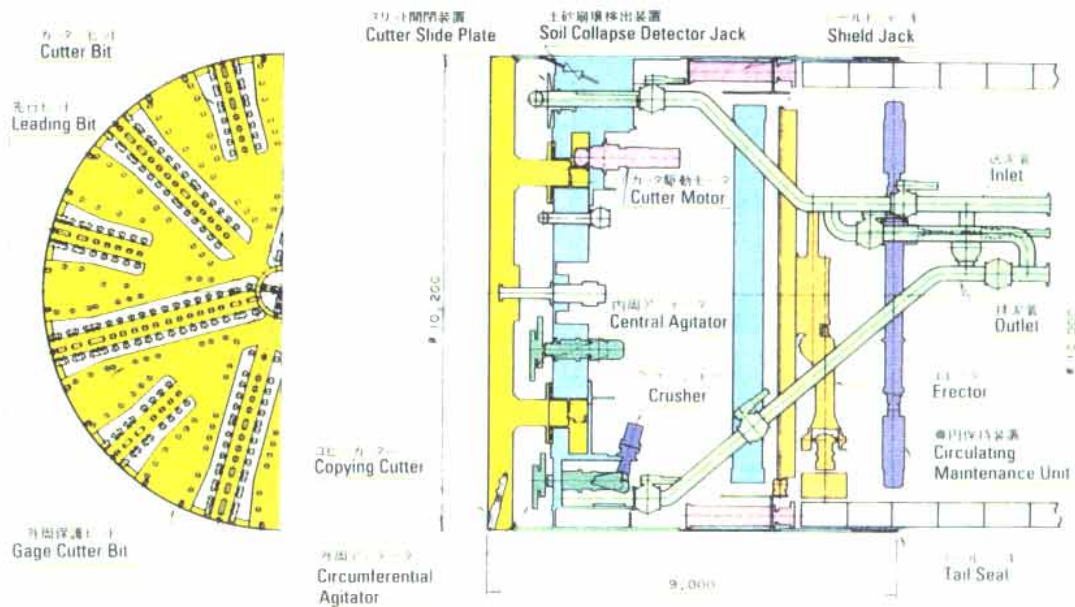


Fig. VI-5 TBM used in Tunnel between Higashi-hie and Enokida Intermediate Venturation Shaft

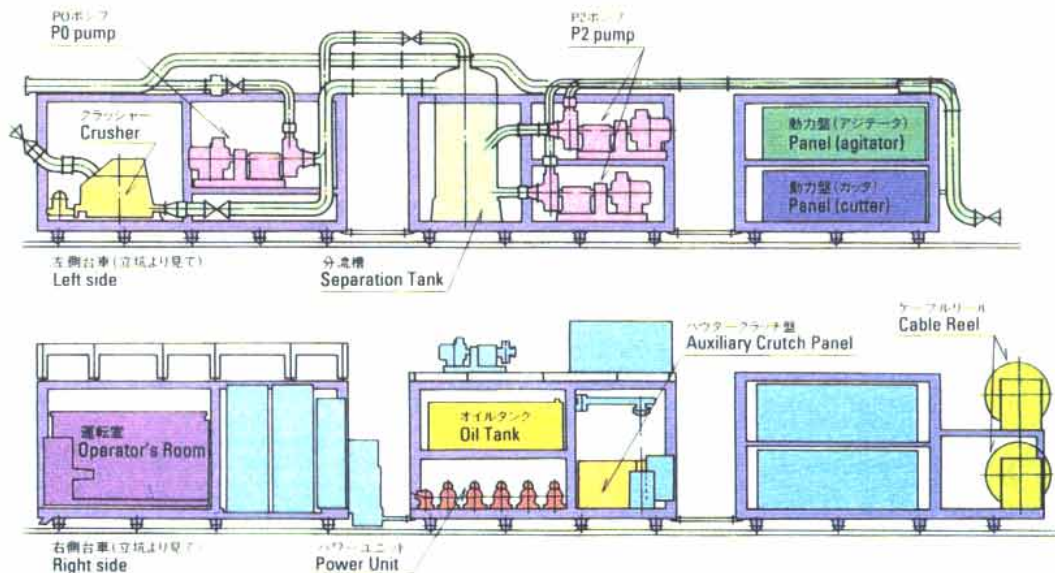


Fig. VI-6 TBM used in Tunnel between Higashi-hie and Enokida Intermediate Venturation Shaft

Table. VI-3 Specifications of TBM used in Tunnel between Higashi-hie and Enokida
Intermeadiate Venturation Shaft

Shield Specification				Erector specification			
Outer Diameter		φ 10,200mm		Rotation Speed		0.6rpm	
Length		9,000mm		Rotation Hydraulic Motor		1.192tf·m×175kgf/cm ² 2	
Excavation Speed		max. 4.1cm/min		Extension Jack		17tf ×11tf×1200s ×140kgf/cm ² 2	
Full Propulsion Force		9,900tf		Slide Jack		7tf ×4.8tf ×300s×140kgf/cm ² 1	
Force par Unit Face		121 tf/m ²		Support Jack		7tf ×150s×140kgf/cm ² 2	
Shield Jack		300tf ×1200s ×300kgf/cm ² 33		Grip Jack		2.7tf×1.4tf ×90s ×140kgf/cm ² 1	
Hydraulic Unit	Pump	69 l/min. ×300kgf/cm ² 2		Hydraulic Unit	Pump	143 l/min. ×175kgf/cm ² 1 29.1 l/min. ×140kgf/cm ² 1	
	Motor	37kw×4P×440v×60Hz2			Motor	45kw×4P×440v×60Hz1 7.5kw ×4P×440v×60Hz1	

Cutter Specification			Agitator Specification		
Cutter Torque	1362~1634tf·m		Number	Central 1	Circumferential 4
Cutter Rotation	0.48rpm		RPM	57rpm	
Ignition Motor	45kw×4p×440v×60Hz	15	Agitator Torque	0.75tf·m/0.5tf·m	
Copying Cutter	20tf×150s×210kgf/cm ²	2	Motor	Central	45kw ×4P×440v×60Hz 1
Cutter Slit Plate	13.2tf ×860s×140kgf/cm ²	4		Circumferential	30kw ×4P×440v×60Hz 4

✓
MITSUI ENGINEERING & : 6-4, Tsukiji, 5-chome, Chuo-ku, Tokyo, 104, Japan. ✓
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VII Underground River beneath Loop Road No. 7

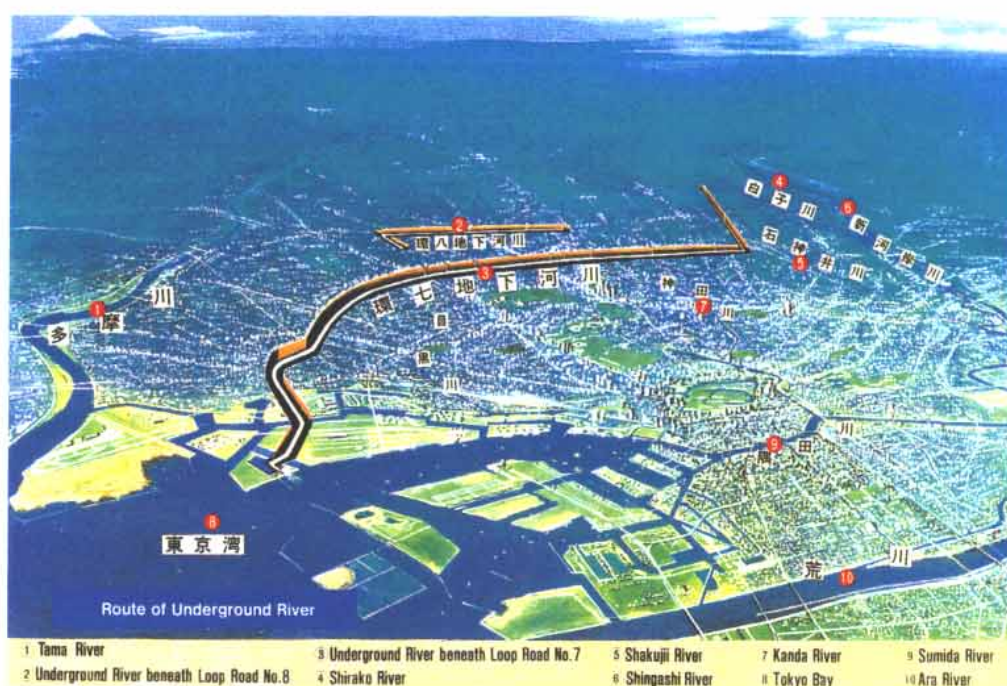


Fig. VII-1 Route of Underground River



Fig. VII-2 Underground River System

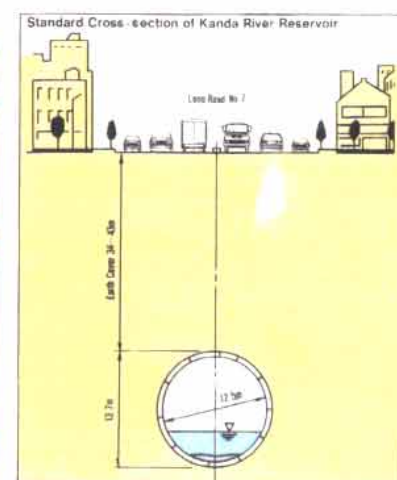


Fig. VII-3 Standard Cross Section of Underground River beneath Loop Road No. 7

Tokyo, Japan, is a growing and ever changing city. At one time, small streams and medium-size rivers flowed quietly and copiously through uptown Tokyo. With the advent of urban area developments, houses and buildings encroached on the river boundaries, making the rivers narrower and narrower. Now, when the city is hit by a heavy downpour, the area around the low flat land, which was once a buffer zone, is flooded. In Tokyo, although the rearrangement of flood control facilities to cope with rainfall of 50mm/hour is under ways, to further improve safety from floods in the 21st century, a plan to handle 75mm/hour of rainfall has been developed.

The center point of the measures is an underground river which will be located under Loop Road No. 7, one of Tokyo's major arteries. The underground river will be connected with 10 tributaries inducing sewer mains. During a rainfall, the overflow from the tributaries will flow into the underground river and run to the mouth at Tokyo Bay where the water will be pumped up into the bay. The total length of the whole plan will be over 30 km. The first step in constructing this plan is the construction of the Kanda River Reservoir.

2. Scope of Project

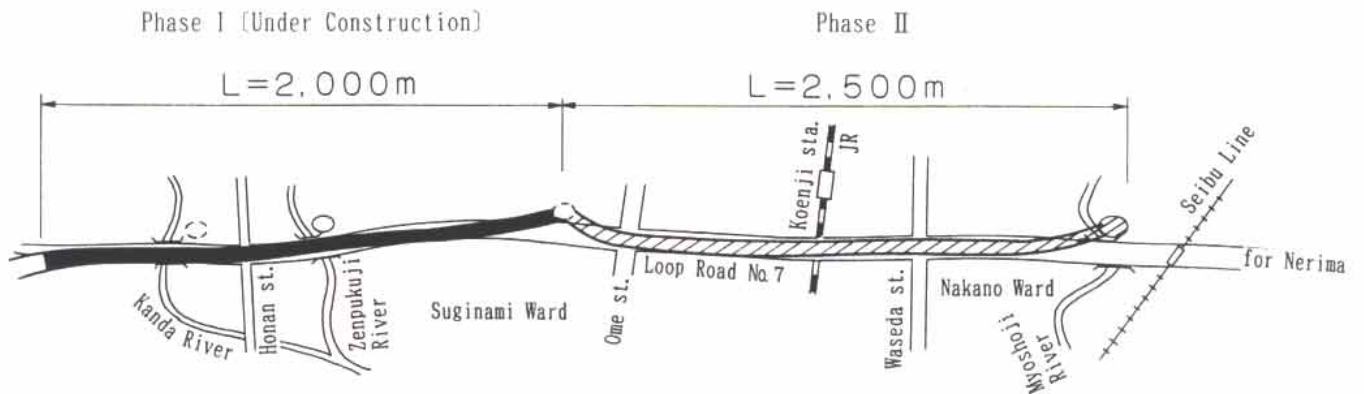


Fig. VII-4 Plan of Underground River beneath Loop Road No. 7

Table. VII-1 Outline of Tunnel (Phase I)

Client	Tokyo Construction Bureau
Location	2. Umesato, Suginami-ku, Tokyo-metropolis 1. Waizumi, Suginami-ku, Tokyo-metropolis (Under the beneath Loop Road No. 7)
Length	2km
Cover	34~43m
Radius of Curve	300mR: 1No. , 600mR, 800mR: 2No.
縦断線形勾配	1:1500 (down)
地下水圧	Max: 4.1kgf/cm ² (center of shield)
設計泥水圧	6.0kgf/cm ² (center of shield)

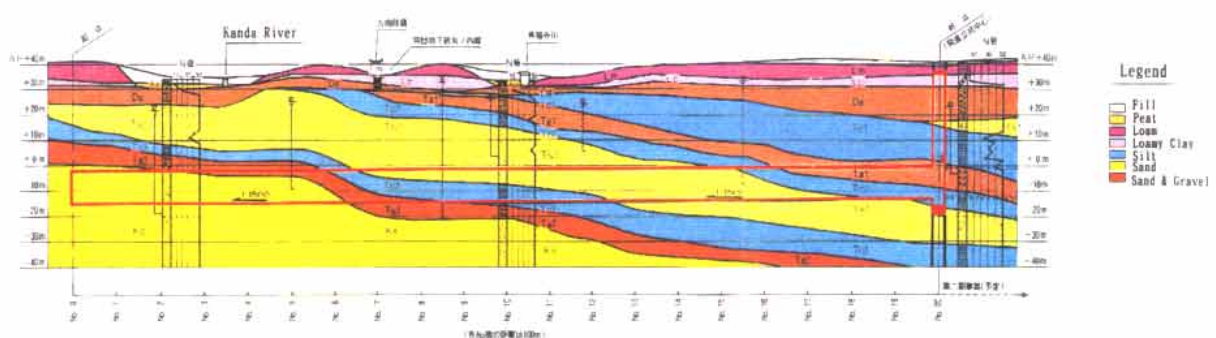


Fig. VII-5 Soil Profile of Underground River beneath Loop Road No. 7
(Phase I)

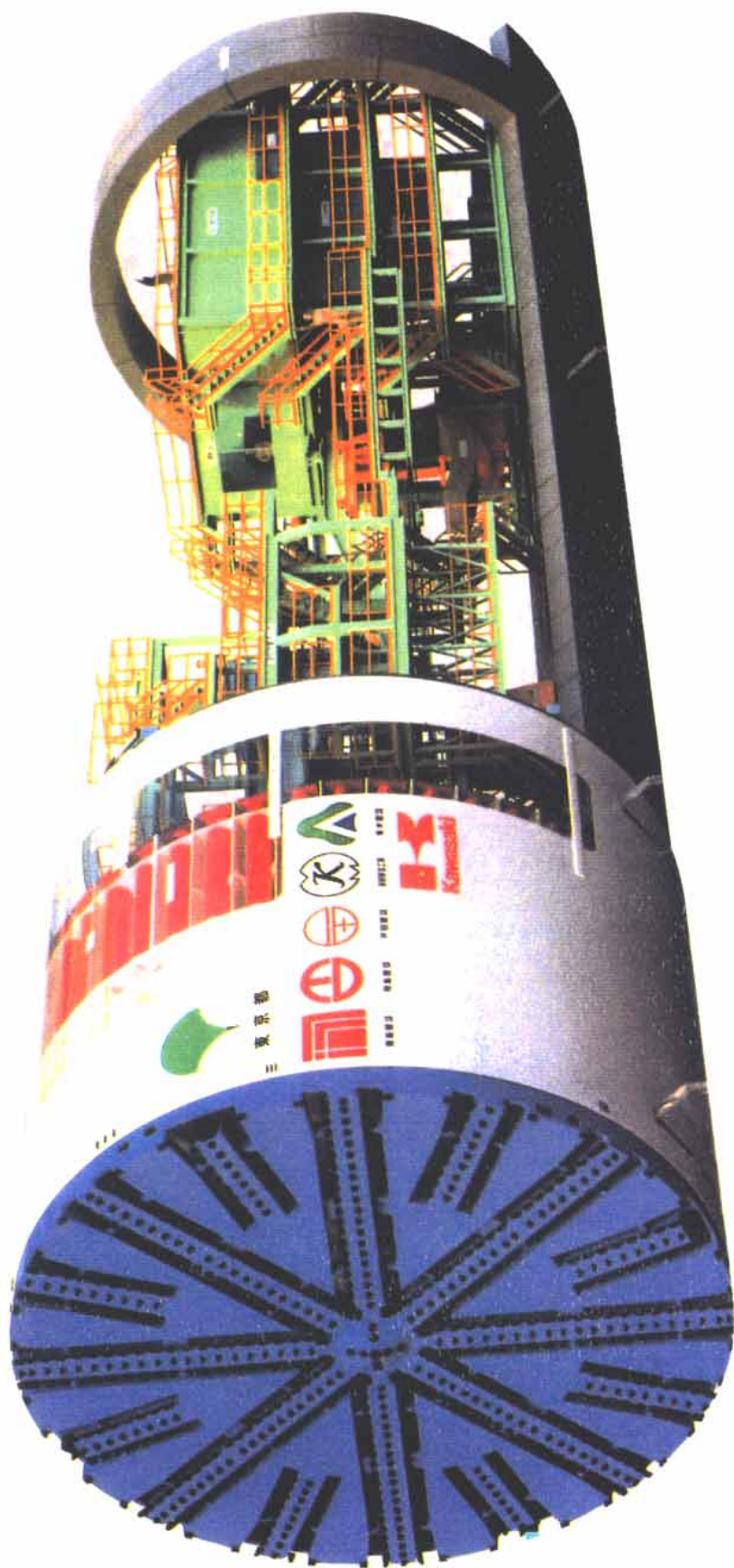


Photo. VII-1 TBM Used in underground River beneath Loop Road No. 7

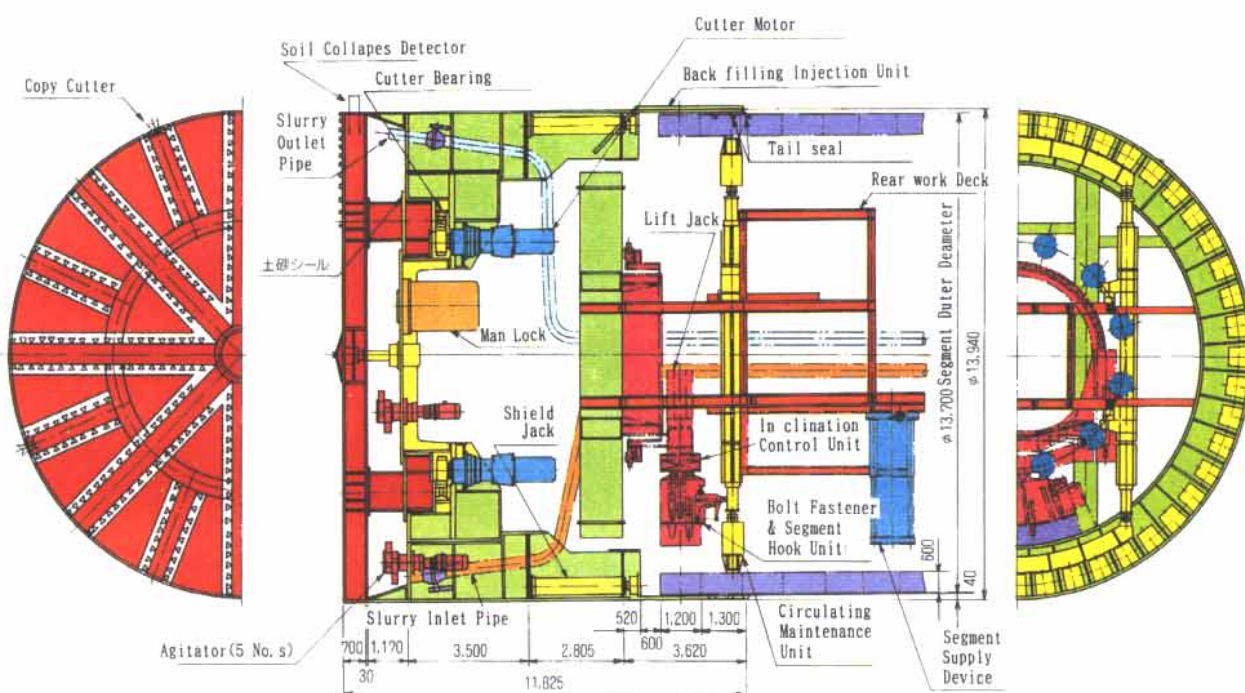


Fig. VII-6 TBM of Underground River beneath Loop Road No. 7

Table. VII-2 Specification of Underground River beneath Loop Road No. 7

Outer Diameter of Shield	13.940mm
Length	11.825mm
Cutter Motor's Power	1.080kw
Rotational speed	0.3856r. p.m. 0.1928r. p.m.
Thrust Force of shield Jacks	19.200ton (400t ×1900s ×48本)

The Kanda River Reservoir, planned to extend over 4,500m, will have an inside diameter of 12.5m, and a reservoir volume of 540,000m³. Phase I, a 2,000m section has already been started. A slurry type shield machine was chosen, in consideration of the fact that Phase I will pass through the Tokyo formation (consisting of sand layers, silt layers, and sand gravel layers) accompanied with high ground water pressure, to ensure a high degree of safety and to reduce the impact on the surroundings. Since 60cm thick reinforced concrete segments will be used for the lining, the outside diameter of the tunnel will be 13.7m.

✓
KAWASAKI HEAVY INDUSTRIES, LTD.:W.T.C.Bldg., 4-1, Hamamatsu-cho, 2-chome.Minato
-ku, Tokyo.105 Tel:03-3435-2111 Telefax:03-3436-3037