AAA-First Term Activety Report
Supplemental Volume

Investigating the Single Tunnel Proposal in a Japanese Mountainous Site

Civil Engineering Work Package JPY2009
Report of Findings
March 12, 2010

Advanced Accelerator Association
Promoting Science & Technology

Technology Study Group
Facilities Working Group

Contents

1. Introduction

It was proposed in SB2009 to change from a 2 tunnel to a single tunnel plan by GDE to reduce the total project cost, which was one of the most important points of the re-baselining for the RDR design work.

Two proposals of RF source have been presented to realize a single tunnel scheme. One is "Klystron Cluster System" (KCS), which moves every RF source related components from the underground tunnel to the above ground buildings. This would require that the surface topography be rather flat, but by making maximum above ground use, it also allows the cost reductions. However, with this single tunnel scheme insuring personnel safety in the event of an accident or fire presents should be seriously considered.

Another one is the Asian (Japanese) proposal, "Distributed RF System" (DRFS), which does not greatly increase the above ground facilities, and instead every accelerator components such as cryomodules and RF sources are put into a single tunnel. Instead of powering with large-scale klystrons, downsized modules are distributed throughout. Here we propose to make a single accelerator tunnel with a parallel sub-tunnel, in which cooling water piping is installed. The sub-tunnel can also be used for the emergency escape, underground water drainage, maintenance work and etc. This has many merits, among which are greatly reduced requirements on the surface environment and lessened difficulties in assuring personnel safety in an emergency. Because the Japan sample site is assumed to be in a rolling mountainous region with already existing surface land uses, the DRFS would be superior to KCS in having a smaller impact on the surface environment. As for the safety concerns in the single tunnel case, since the assumption for Japan is that the site location would have either a hilly or mountainous topography, the first question to be considered is whether or not a "real" single tunnel would even be possible or not.

1.1 Investigation Goals

1.1.1 To confirm that Japan could be a feasible site for the ILC, conduct a concrete study of the construction plan with the aim of showing Japan's attractiveness.

1.1.2 This plan should be based upon the particular situation and conditions actually existing in Japan while taking into account the activities of the GDE.

1.2 Special Features of any Japan Site

The sample site for Japan is chosen to be located in a region of granitic rock. The surface topography would be hilly to mountainous and inhabited. In places several hundred meters of mountain would have to be gone through. Although the surface is covered primarily with naturally existing mountain forests, we must also assume there would be preexisting extensive land use for farm or pasture, as well as human habitation, and there should the impact on the surface environment must be taken into careful consideration. Accordingly, it would be desirable to avoid large-scale surface development, and to keep the surface facilities as compact and concentrated as possible.

At places where the elevation is the lowest, where rivers and valleys cut across the tunnel, it would be necessary to be able to cover the tunnel running below ground surface with at least a 2D (twice the tunnel diameter) thickness of overburden. By taking advantage of surface undulations and putting the drainage water outflow in places below the tunnel elevation it should be possible to use natural gravity flow to remove the water inflow. This possibility would greatly reduce the running costs of operating the accelerator and risks when the electricity blackout happens. The sample site has been specified to be in a favorable granite formation region, but since it would likely be impossible to have the entire 31.5 km extent in such ideal conditions, we must also assume that there would be places with poor rock conditions. Therefore efforts to reduce the geologic risk by preliminary research of geology and a pilot tunnel excavation would be very important.

1.3 Assumptions and Preconditions for the Study

1.3.1 There would be two parallel tunnels, the Main Linac Tunnel (MLT) and a sub-tunnel, with the accelerator (cryomodules and RF source) installed in the MLT, and the sub-tunnel capable of holding for large diameter cooling water pipe plant, escape route, and providing for equipment installation, maintenance and water drainage.
→ As a result, there would only have to be 3 above ground cooling tower stations.
→ Further, the design would be 'free' of the influence of the Japanese complex surface topography (hills, inhabited mountain sides, etc.).

1.3.2 By proceeding with the sub-tunnel construction ahead of the MLT, it would also function as a pilot tunnel and a water drainage tunnel for the MLT excavation.
→ As a result, the risk in handling underground water and for the main tunnel excavation would be greatly reduced.

1.3.3 The tunnel elevation should be as high as possible, so long as the minimum required earth cover could be assured.
→ As a result, when it came time to operate the accelerator, the Japan site would be superior in that water inflow could be discharged by gravity alone.
→ The depth of the collision experimental hall cavern should be about 100m. (This would be an allowable depth condition for cavern stability on the Japan site.)

1.3.4 All the infrastructure plant equipment for helium liquefaction, commercial power high voltage distribution, cooling water, etc. would be installed underground, either by widening the sub-tunnel or by excavation of side caverns.

1.3.5 Consistent with the construction timetable, a minimum number of access tunnels for the purpose of dividing up the construction areas should be set. Above ground facilities (cooling towers) should be at least in 3 locations. Needles to say, the number of the above ground facility can be increased if allowed by a good condition of the topography. In such case, we can reduce the diameter of the cooling water piping. →See (1.3.1).

1.3.6 We assume a water inflow volume of 0.9 m^3 / min / km (totaling in all 28 tons/min), based on the many experiences of underground construction, with natural draining discharge. →See (1.3.3)

1.3.7 As working assumptions for the present studies, we set that the goal should be 2 years for survey and geological studies, 8 years for the civil engineering construction, 4 years for equipment installation. Since some of this can be done in parallel, the total construction period should come in under 10 years. Of course, we still need further studies to fit the schedule to the proposed GDE plan.
The above conditions and requirements will be taken into account in the investigations as to whether or not the Japanese edition single tunnel proposal is realizable.

2. Civil Engineering Work Package Investigation Goals

The civil engineering work package group divided up their considerations of the overall ILC facilities into 5 areas: [overall facilities layout], [sub-tunnels and access tunnels], [main linac tunnel], [groundwater and water inflow handling], [cavern for collision experimental hall].

The members of each sub-group are listed in parenthesis below with the name of the leader underlined. K. Fukuda (Shimizu Corporation) took overall coordination

2.1 Overall Facilities Layout

S. Shikama (Kumagai Gumi), I. Sekine (Toda Corporation), K. Fukuda (Shimizu Corporation)

Our work centered about the 2 principal tunnels, the main linac tunnel and sub-tunnel; we looked at the underground facilities including the cavern for collision experimental hall, connection routes between tunnels, low voltage power supplies and cryogenic equipment.

2.2 Sub-tunnel and Access Tunnels

H. Sasao (Tekken Corporation), S. Ebisu (Okumura Corporation), M. Kuji (Maeda Corporation)

The sub-tunnel's place in the construction means that it functions as a pilot tunnel since exploration borings can be made from it during the construction phase of the project. After the initial excavation, the pipes for cooling water and internal drainage will be put into the sub-tunnel. Further it will provide an emergency escape route as well as a maintenance corridor. The access tunnels will be used to bring the TBMs in and out, removing the excavation spoils, drainage and ventilation. Further, after the civil engineering construction is over, the access tunnels can be used to bring in various equipment for the accelerator and experiments. We looked into the specifications, structure and construction methods for these multi-purpose, multi-functional tunnels.

2.3 Main Linac Tunnel

K. Ryoke (TAISEI Corporation), Y. Kawabata (Tobishima Corporation)

We investigated the specifications and structure for the main linac tunnel as well as the construction methods for it and the associated connecting routes, and spaces for the low voltage power supplies and cryogenic equipment.

2.4 Groundwater and Water Inflow Handling

K. Akiyoshi (Obayashi Corporation), K. Ishiyama (Nishimatsu Construction Co.), T. Haruki (Takenaka Civil Engineering & ConstructionCo.)

We investigated the basic concept behind the drainage system after the construction is complete, taking into account the need for radiation safety control. We did a design for the underground facilities and pumps etc. as well as a conceptual design of the procedure for making drainage tunnel. At the same time, we clarified the structure of the waterproofing and drainage systems: main linac tunnel (MLT) drainage work, sub-tunnel drainage work, drainage connection between the sump pit inside the MLT and the drainage tank in the sub-tunnel, as well as the emergency escape routes.

2.5 Collision Experimental Hall Cavern

T. Akojima (Kajima Corporation), K. Kawakami (Penta-Ocean Construction Co.), T. Nishimura (Hazama Corporation)

We investigated the structure and construction methods for the main collision experimental hall cavern and its access tunnel. This time we treated the collision experimental hall and related areas as well as the main linac tunnel and sub-tunnel to be as independent as possible, with as little mutual interference as possible in our thinking about the work and so we arranged separate access to each work site.

3. Overall Facilities Layout

3.1 Facilities to be Investigated

For this report, we concentrated our underground facilities efforts on the main linac tunnel (MLT) and the sub-tunnel, but we also looked at the collision experimental hall, interconnecting routes between tunnels, the low voltage power supply and cryogenics equipment spaces. Because we have not yet received definitive requirements, we did not consider the damping ring, beam delivery system, above ground research facilities or access to or emergency escape from the underground facilities. Our objective was to verify the technical feasibility of the proposed layout from the civil engineering planning point of view. Once we had determined that our objectives could be achieved for these facilities we undertook to design their layout.

3.2 Facilities Layout Plan

3.2.1 Planning the MLT elevation and the distance between it and the sub-tunnel

Following three important elements went into our considerations for MLT elevation, which determines the rest of the design:

3.2.1.1 Securing an earth cover of at least 100m at the location of cavern containing the collision experimental hall.

3.2.1.2 Securing an earth cover of at least twice the tunnel diameter (2D) in order to provide safety during tunnel excavation.

3.2.1.3 Securing an incline such as to permit natural gravity drainage discharge into nearby streams or rivers.

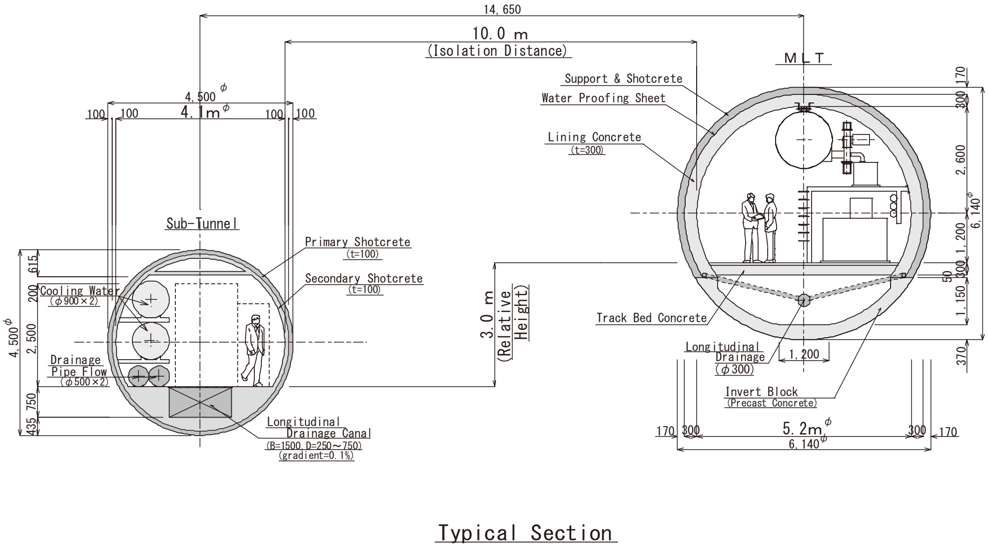


Figure 3-1: Tunnel Spacing

As for the conditions setting the distance separating the sub-tunnel from the MLT:

3.2.1.4 Since the sub-tunnel construction proceeds the other tunneling, its location should facilitate drainage of the main tunnel.

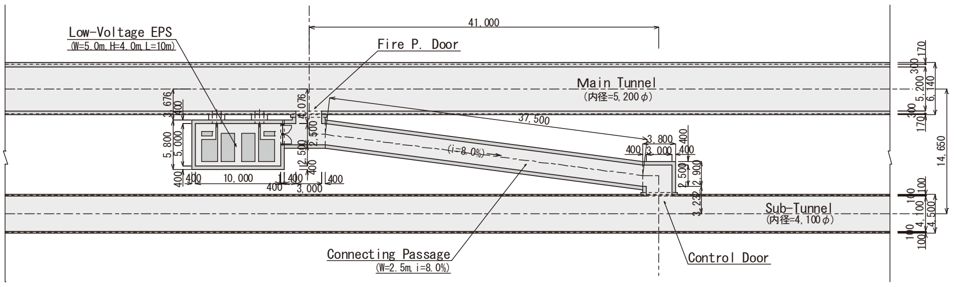
3.2.1.5 In order to secure the safety of both tunnels, the associated sub-tunnel should be separated by a distance of at least 2D from the MLT.

3.2.1.6 Its location with respect to the MLT should be such that water can flow naturally to drain the MLT.

Therefore, taking the above conditions into account, we have decided to fix the horizontal spacing between both tunnels at 10.0m between inside walls, and a vertical spacing of 3.0m. Figure 3-1 shows the spacing relationship between the tunnels.

In our planning, both the MLT and sub-tunnel would be built their entire length in parallel, however, because of their complex cross sections, the central region containing the DR, BDS etc. would be excavated with NATM instead of a TBM. Including the experimental cavern and the drainage tunnels, there would be a total of 11 shafts, 6 inclined and 5 vertical shafts for access during the construction. As shown in Figure 3-5, each zone would be excavated by a TBM or NATM. The overall length would be 30.9 km; the central region 5.9 km as well as the both end of the linac tunnels (RTML) would be excavated by NATM. In the detailed design stage it will be necessary to find optimal layouts taking into account the access tunnels needed for the excavation and construction and how they could be utilized in an appropriate manner to fill the requirements of the research operation. We leave that for future work. We also looked into raising the MLT elevation as high as consistent with the needed earth cover over the experimental cavern, perhaps even exposing some places above ground. However, we have concluded it would be best to have the entire linac underground because of concerns about radiation safety and unresolved difficulties in avoiding the effects of thermal expansion and contraction of the reinforced concrete structure on the accelerator alignment. We leave the consideration of a thermally insulating structure for the future. Further, because there are so many connecting tunnels between the MLT and sub-tunnel, having them as close together as possible would reduce overall expense. However, our conclusion for now is that just how close can they be will require further analysis.

3.2.2. Connecting tunnels and low voltage power supply spaces



Connected Passage Between M.T. & S.T.

Figure 3-2: Connecting tunnel and low voltage power supply room plan view

Every 500 m there would be a tunnel connecting the MLT and sub-tunnel, with spaces for low voltage power supplies on the side of the MLT next to where the connecting tunnels come in. In order to shut out radiation in the sub-tunnel, the connecting tunnel would approach the MLT at an inclined angle. Since we would like to be able to use a forklift or other small vehicles in the connecting tunnels to bring equipment in and out, we have set the free clearance to be 2.5 m and the slope at 8.5%. Since we expect it would be difficult to create such a profile with a TBM, after the tunnels have been excavated NATM would be used to make the necessary side chambers.

Figure 3-2 shows the connecting tunnel and low voltage power supply room plan view, Figure 3-3 shows the sub-tunnel and connecting tunnel cross section and Figure 3-4 shows the cross section of the MLT, connecting tunnel and low voltage power supply side chamber.

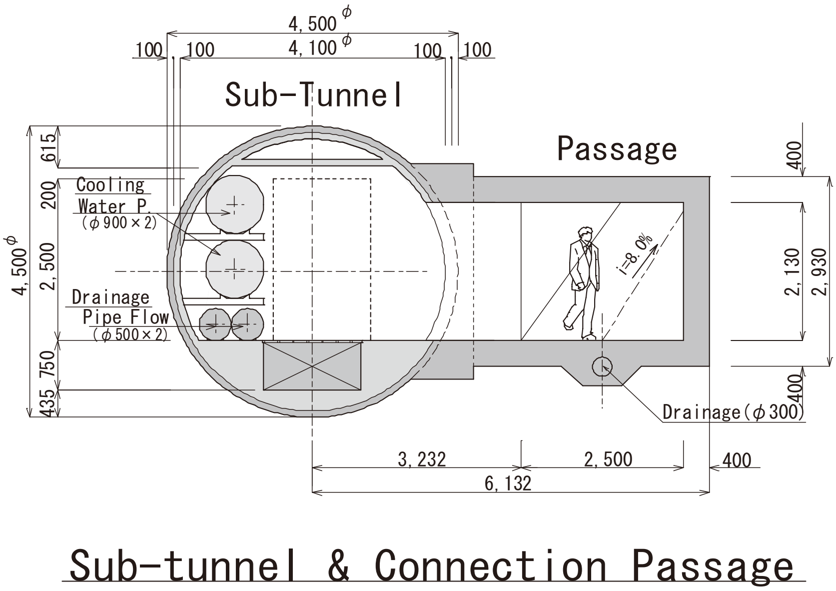


Figure 3-3: Sub-tunnel and connecting tunnel cross-section

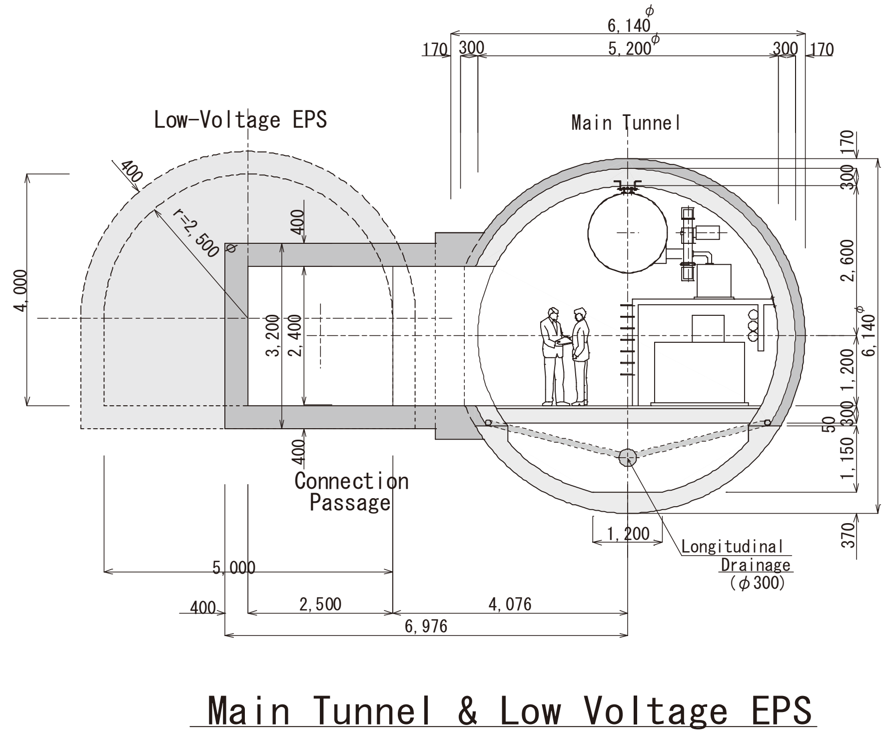


Figure 3-4: Cross section of the MLT, connecting tunnel and low voltage power supply side cavern

To complete our task for this phase, Figure 3-5 shows the overall facilities layout during the construction phase, and Figure 3-6 gives the vertical cross sectional view for after completion. Please note that for this time we only carried out the layout planning for the principal facilities. We defer for the future consideration of the many other facilities that will be required for running and maintaining the complete system. In the future the detailed layout for each of those facilities as well as optimizing the overall system tying everything together will be required, of course.

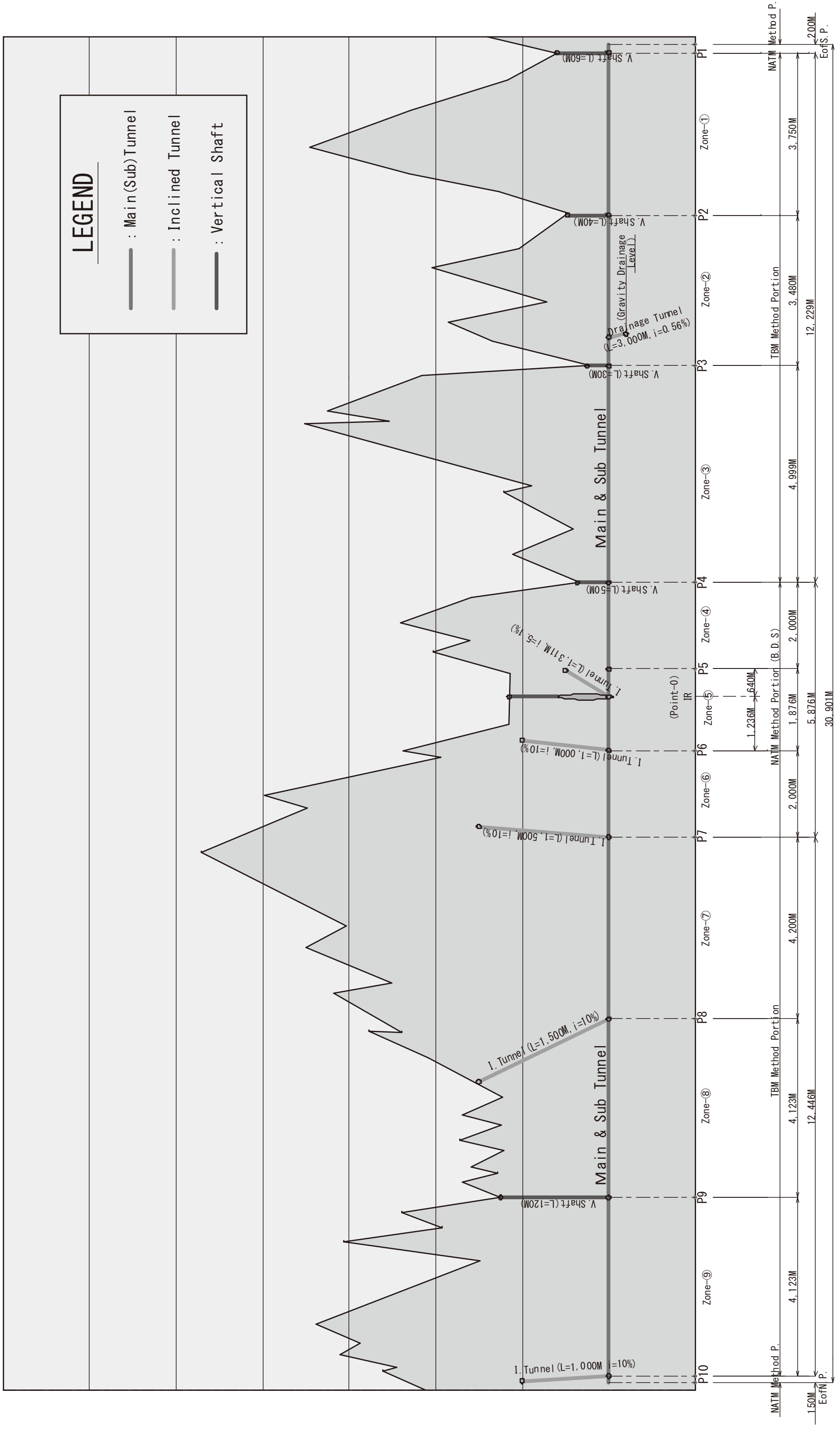


Figure 3-5: Overall facilities layout during the construction phase

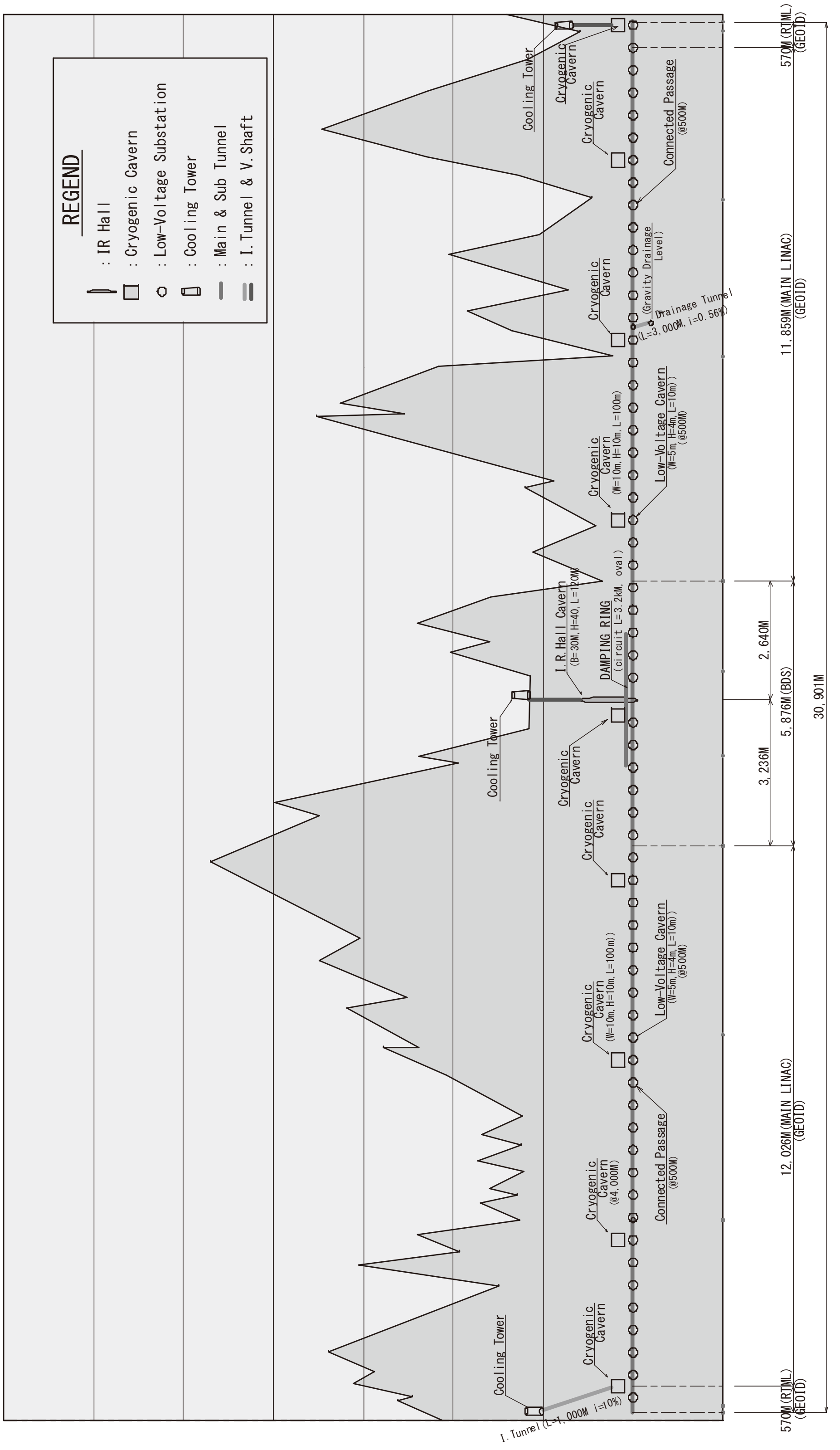


Figure 3-6: Vertical cross sectional view of the entire project after completion

4. Sub-tunnel and Access Tunnels

4.1 Baseline Concept for Design and Construction Plans

During the initial excavation and construction phase the sub-tunnel will also function as a pilot tunnel facilitating the needed geologic survey before the main tunnel work. Further, after the machine goes into operation, it will provide a place for the cooling water distribution system, drainage system for water inflow, as well as an emergency escape route and a maintenance access route. The access tunnels will be used during the construction phase for assembly and disassembly of the TBMs, mucking, drainage and ventilation. After the completion of the civil engineering they will also be used for bringing in accelerator components as well as experiment equipment.

4.1.1 TBM Specification

Because of their proven record in use excavating evacuation tunnels and pilot tunnels, for high-speed highway and the like, we will use TBMs that excavate a 4.5mϕ (completed inner diameter 4.1m ϕ) bore. Doing that should be cost effective because their proven record shows we may expect to make reliable progress in the excavation, and also there would no necessity of any new machine design or prototyping.

4.1.2 Tunnel lining

The tunnels shall be lined with two layers of shotcrete. Shotcrete compares very favorably with precast concrete liners both in cost and speed of installation.

4.1.3 Construction sections and access tunnel locations

The overall tunnel shall be partitioned to make construction sections of about 4 km stretch each. An access tunnel shall be made at the end of each section (either an inclined slope tunnel or a vertical shaft); this area would be excavated by NATM. In total there would be 9 construction sections, 5 inclined tunnels and 4 vertical shafts.

4.1.4 TBM assembly

The TBMs and associated conveyances would be assembled at the bottom of their access tunnels and commence excavation from there.

4.2 Points to be Taken into Consideration in Determining the Sub-tunnel Cross-section

The sub-tunnel cross-section should be set so as to make possible the extremely high-speed excavation that the TBM can do. Taking into account the equipment that has to be installed later, the sub-tunnel excavation diameter as well as the connection to the MLT, access tunnels and other caverns, we can determine the following specifications:

- During construction

- Space for installing a continuous conveyor belt for high-performance mucking.
- Space for installing a drill for investigation bores in front of the main drill.
- Space as necessary for temporary equipment and drainage facilities.

- In operation

- cooling water piping (ϕ900), drainage pipes and ditches, ventilation ducts
- pedestrian path, maintenance and transportation carriage lane

- Other common requirements

Dimensions and spacing as specified by the rules and regulations of the applicable fire and other regulatory bodies.

4.3 Proposed Sub-tunnel Cross Section (operational stage)

Figure 4-1 shows a sub-tunnel cross-section with suggested installed locations of its contents in the completed operational status. The inner walls would be covered with shotcrete only, no concrete linings would be installed to save the cost. The pipes for the cooling water and water drainage are supposed to be on the opposite side from the connecting tunnel to the main tunnel.

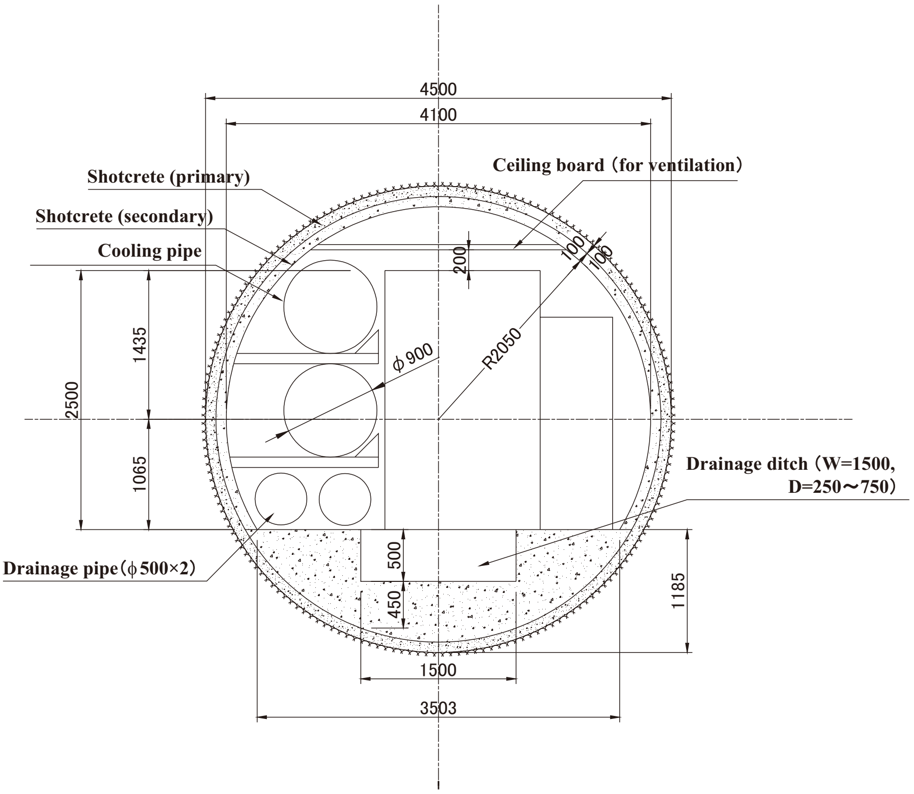


Figure 4-1: Proposed sub-tunnel cross-section

4.4 Access Tunnels (vertical shafts) Cross Section (proposal)

Figure 4-2 gives a cross sectional view of the proposed access tunnels and vertical shafts. We estimate that at least these dimensions would be needed after taking into account the largest dimension of the TBM components after diss-assembly for insertion.

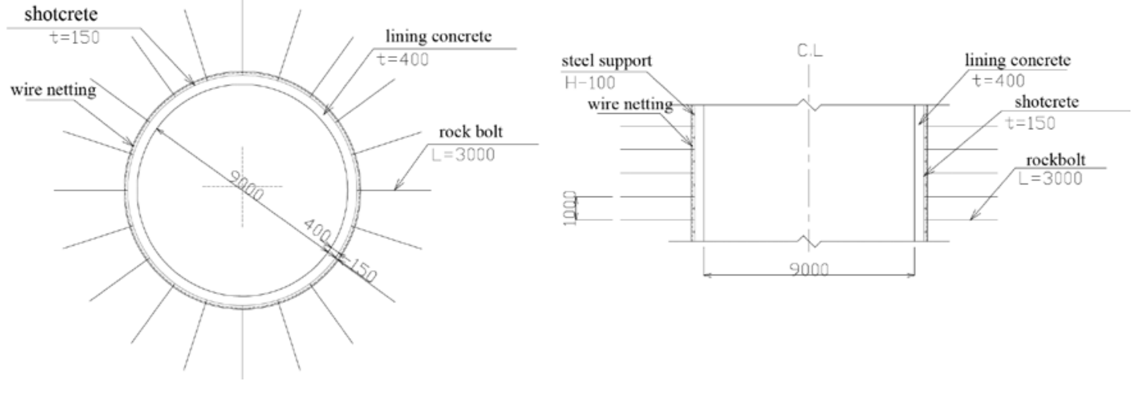


Figure 4-2: Proposed access tunnel cross sections

4.5 Underground Assembly Area for the TBM Machine

Figure 4-3 is a conceptual drawing of the way the TBM components could be brought through the (inclined) access tunnel and then reassembled. When the TBM parts are brought in on a trailer through the inclined access tunnel, a large tunnel cross section would be required for the TBM reassembly at the end of the access tunnel. An overhead crane would be used to lift the TBM parts back into place for assembly.

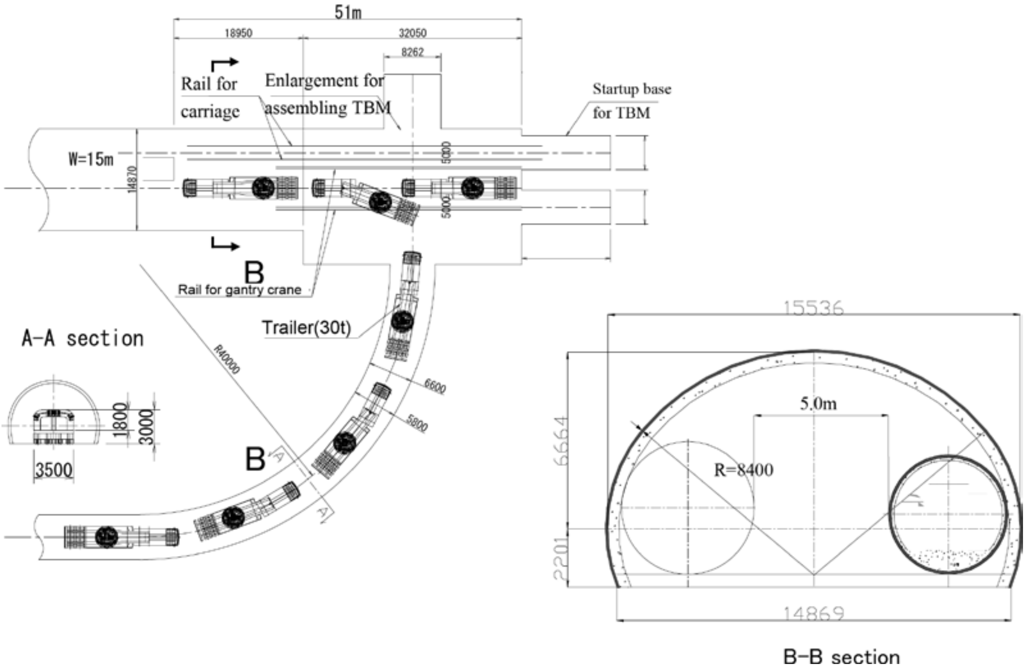


Figure 4-3: TBM insertion and assembly concept.

4.6 Basic Parameters for the Schedule Planning

The project planning (monthly progress) for the sub-tunnel and access tunnels and associated construction was based on the following points:

4.6.1 Preparatory construction

We assigned a uniform 3-month period for preparing the site for each of the access tunnel entrances.

4.6.2 Access tunnel excavation

We assign a rate of 10 meters/month for vertical shafts and 80 meters/month for the inclined tunnels. Further, we uniformly assigned a period of 3 months for excavation and preparation of the TBM assembly cave and then one month for assembling each TBM.

4.6.3 Tunneling

For the sub-tunnel, because of the uncertainty in geologic formation and conditions, we estimate the time needed for geologic survey and additional construction very conservatively at a progress target of 250 meter/month. For the MLT, because the unknown geologic risk would be less, we assume that even with additional ad hoc work a progress rate of 350 meters/month would be possible. The sub-tunnel excavation should begin at a time such that it would be finished 4 months after the MLT. We assume a rate of 80 meters/month for the NATM excavated portions of the MLT. When both can start from the same access tunnel, we assume that the MLT tunneling would begin 2 months after the sub-tunnel.

The MLT concrete liner application rate we assume to be 150 meter/month, we assume that this could be done in parallel in two places except for the Central Region where we assume only one. We assume a rate of 1,000 meters/month for the sub-tunnel shotcrete.

4.6.4 Equipment installation

We assume it will take about 0.5 months for each low voltage power supply room, we estimate that 2.7 low voltage supply rooms will be needed every 1,000 meters. Since we can use precast concrete for the MLT floor, an installation rate of 1,000 meter/month should be possible.

4.6.5 Other construction

Cryogenic equipment rooms we estimate to take 3 months each, but because the locations, shape and quantities are unknown at this time, we exclude them from the project timeline. Whether or not the work for the escape tunnels (MLT and sub-tunnel connectors, 500 meters each) could be done in parallel with the sub-tunnel shotcrete application and the low voltage power supply room space excavation needs further study.

Whether or not the preparation of the sub-tunnel bottom drainage ditches for constant water inflows could be done in parallel with the sub-tunnel shotcrete and the low voltage power supply space excavation needs further study.

4.7 Considerations for the Sub-tunnel Construction

4.7.1 Excavation rate

For the sub-tunnel we assume an average progress rate of 250 meters/month, taking into consideration that we could run into huge volumes of water inflow and other undesirable geology. This is a well-established rate with tunneling granites formations in Japan. In order to be able to predict accurately the non-ideal geology and maintain the planned excavation rate we will use the following technologies.

4.7.1.1 Drilling Survey (DRISS)

Applying Drill-Logging to capture the variations in energy required we could profile the changing rock quality and prepare any necessary measures.

4.7.1.2 Construction informed by the TBM data

Going forward, excavation rate estimations will be improved as we will be able to use data collected from the machine: TBM cutter torque the forward thrust force, as well as the construction conditions encountered.

4.7.2 Geologic survey for shortening the MLT construction period

The sub-tunnel DRISS, machine data and excavation data, can give geologic survey data to apply to the MLT work, which follows behind. By having that sub-tunnel data available for feedback, the MLT excavation rate should be able to be sped up to 350 meters/month.

Further, since the sub-tunnel excavation level is below that of the MLT, it will function as a drainage tunnel for the MLT. Because of that, we expect to run into considerably less water inflow when excavating the MLT, which should also contribute to its high-speed excavation.

4.7.3 Miscellaneous

We need to look into the project steps for the low voltage supply caverns etc., in some cases it may be possible to excavate them from the sub-tunnel side and thus shorten the overall project time to completion.

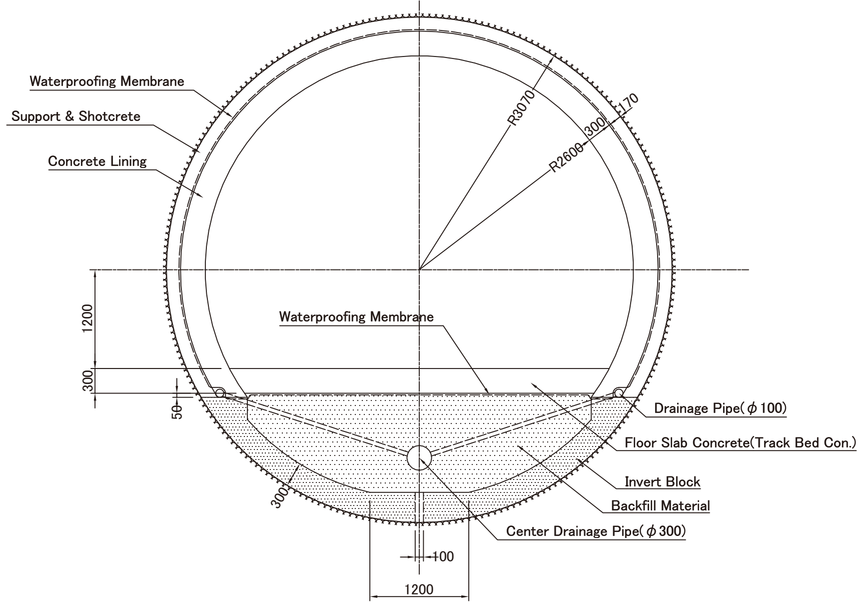
5. Main Linac Tunnel

5.1 Basic Design Concept

5.1.1 Finished inside diameter

Beginning with the dimensions required for the facilities needed inside the tunnel as well as the space needed for operations, the actual target finished inner bore diameter is determined by the construction gauge. For the purpose of this study, we fix our considerations using as a given:
Finished inside diameter: ϕ 5.2 m

TBM



NATM

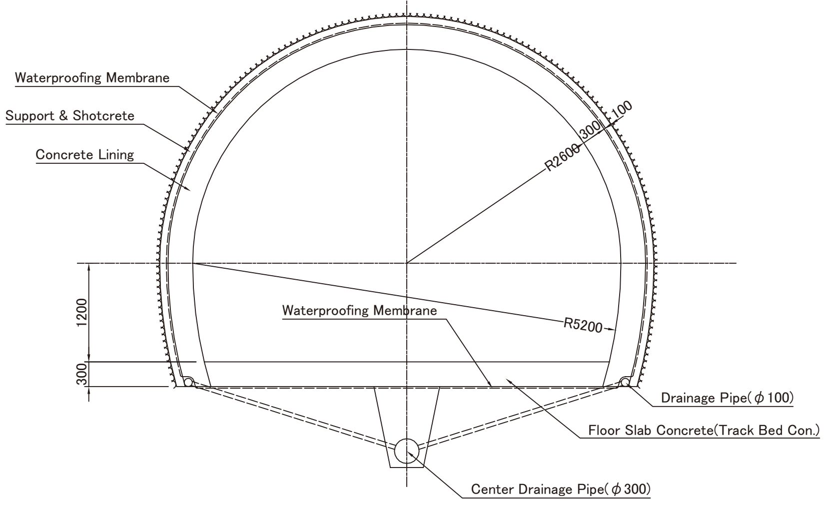


Figure 5-1: Typical MLT cross sectional drawing

5.1.2 Tunnel shape

5.1.2.1 MLT (electron side) + MLT (positron side) approximately 12 km each

We assume a uniform cross section for these two regions. Assuming that a relatively good geologic formation location can be chosen for the project, and further that the preceding sub-tunnel work has refined the geologic survey information and that we may expect that water drainage can be handled effectively; then it should be appropriate to use a TBM for excavation, especially as that would shorten the construction time. Therefore the tunnel cross section should be circular.

5.1.2.2 Central Region

According to the RDR drawings, the circular cross section diameter of ϕ 4.5m should transition to widths of 6.2m ～ 7.4m ～ 8.5m. If we suppose that we must provide a cross section in line with those drawings then it would be very difficult to use a TBM for the excavation. Therefore because of its flexibility, we will use NATM for the transition zones. Typically NATM constructed tunnels are horseshoe shape or U shaped cross-section.

5.1.3 All radiation safety control regions

The entire length of the MTL would be a radiation safety control zone. In particular, radiation shielding etc. would apply to the groundwater existing surrounding the tunnel. We assume a 30cm thick concrete lining and floor slab concrete as a countermeasure. Since we don't want any water to seep or leak into the tunnel, the entire tunnel including the floor slab should using waterproofing membrane with a non-textile sheet proof water.

5.1.4 Water draingge design

The water seepage prevention strategy is the same, adoption of a complete waterproofing. However, the tunnels themselves, in common with all mountain tunnels, are drainage tunnels, but the structure is such that there will not be water pressure on the outside walls of the tunnels due to water flowing around them. Groundwater surrounding the tunnel will be drained and led by transverse drainpipes to a central drainage pipe. (See section 6. for details about the underground water treatment methods.)

5.1.5 MLT cross sectional diagram

Figure 5-1 shows a proposed standard cross section for the MLT based on the above considerations.

5.2 Basic Plan of the Construction

5.2.1 Division into work sections, access tunnels, TBM assembly and disassembly locations and method

The access tunnels, which divide the work sections and the TBM assembly and disassembly locations and method shall be as described in the sub-tunnel section. With the exception of the muck transport conveyor belt and a few other exceptions, the access tunnels and their temporary equipment shall be shared with the sub-tunnel.

5.2.2 TBM Type

The TBM type shall be chosen depending on the geologic conditions and the required tunnel support system as well as the tunnel lining method. When we can expect to run into very good tunneling conditions in the mountain, we will choose the open type TBM because of its high speed and cost effectiveness. In that case, for tunnel support we may choose to use in combination or singularly whatever is appropriate: shotcrete (either fiber reinforced mortar or concrete etc), rock bolts, or steel arch supports. Depending on the conditions, open unlined tunneling may be possible. In that case the excavation bore would be of minimal diameter.

For the cases where we may expect to encounter extended regions of bad geological conditions, we will choose a tunnel liner support system (in simplified segments) that allows the least slow down in excavation rate. Therefore, when the conditions were good, the open type TBM would show its excellence in high speed excavation, but in regions of bad conditions where a tunnel liner could be used, it would be better to choose the "improved open" type TBM which combines the above-mentioned both functions (based on the main beam TBM, behind the cutter head there is a short shielded area with auxiliary propel cylinder, in shield mode, after the tunnel liner is assembled under the shield the whole TBM can be thrust ahead by pushing on the liner, but when the liner is not needed, the TBM can be propelled in the usual open TBM way by pushing on the main gripper).

5.2.3 TBM excavation bore diameter

For the open TBM case:	approximately ϕ6.14m
For the improved open TBM case:	approximately ϕ6.60m

5.2.4 Assumed excavation rate

We assume a monthly progress rate of 350m (Rock class assumed mostly C_H, C_M with some C_L, D). With the premise that the sub-tunnel work has gone ahead (in each construction section, the planned completion goal for the MLT to be 4 months behind that of the sub-tunnel, with at all times a minimum of 500 m to about 2 km separation between the respective boring face). We base this estimation on the usefulness of the sub-tunnel for producing a geologic survey, and as well as a place to divert the drainage water to maintain dry working conditions in the main tunnel.

5.2.5 Drainage during the excavation

Since the vertical alignment of the MLT will follow the geoids it is predictable that there will be difficulties in handling water inflow during excavation. We will execute drainage boring in places where large quantities of water inflow may be expected in order to lower water pressure and reduce the amount of water inflow. Groundwater removed through boreholes (clean water) and water inflow will be separately treated.

5.2.6 Invert liner for the entire length of the TBM

In order to maintain the high speed of TBM excavation and to take care of water inflow, we will install an invert liner because of the way it allows us to build rapidly the concrete lining and floor. (Track construction, water inflow handling, drainage pit and drainage lines.)

5.2.7 Construction of lining and floor slab concrete

Because of the dimension of the MLT cross-section it would be too difficult to do the excavation and concrete lining work at the same time. Therefore after the excavation is complete, construction of lining and floor slab concrete will be done.

5.2.8 Construction of connecting tunnels, low voltage power supply and cryogenic equipment rooms

Because the MLT itself is on the project critical path, we will try to plan on doing the construction on the above items from the sub-tunnel side, therefore work on them could commence as soon as the sub-tunnel excavation is complete. We will also look into the possibilities of parallel work from the MLT side as soon as its excavation is complete.

5.3 Proposal to Shorten the Construction Schedule

Because the MLT itself creates the critical path for the project, we next look into possible ways of shortening its required construction time.

5.3.1 Floor slab concrete construction work for TBM section

Using an invert bridge, we could simultaneously have the TBM proceed with its forward excavation while floor slab concrete was placed. Or, by making some modifications to the invert liner we might be able to shorten the mold formation/installation and the concrete pouring cycle.

5.3.2 Lining of the TBM construction zone

It might be possible to adopt a one pass lining operation by using pre-cast segments, in which case it could be done at the same time as the excavation proceeds. This would be done when shortening the schedule has the highest priority.
→ Problems: increased cost, joint structure of segments, difficult watertight seal (lifetime endurance and quality assurance)

5.3.3 Central Region (excavation, lining)

By making the cross-section of this zone all uniformly the maximum required size it could be excavated by TBM that would shorten the excavation step. Or, even if we use NATM, if we again excavate to the maximum size everywhere the excavation and lining steps could be done at the same time.
→ Problem: increased cost

6. Water Inflow Handling

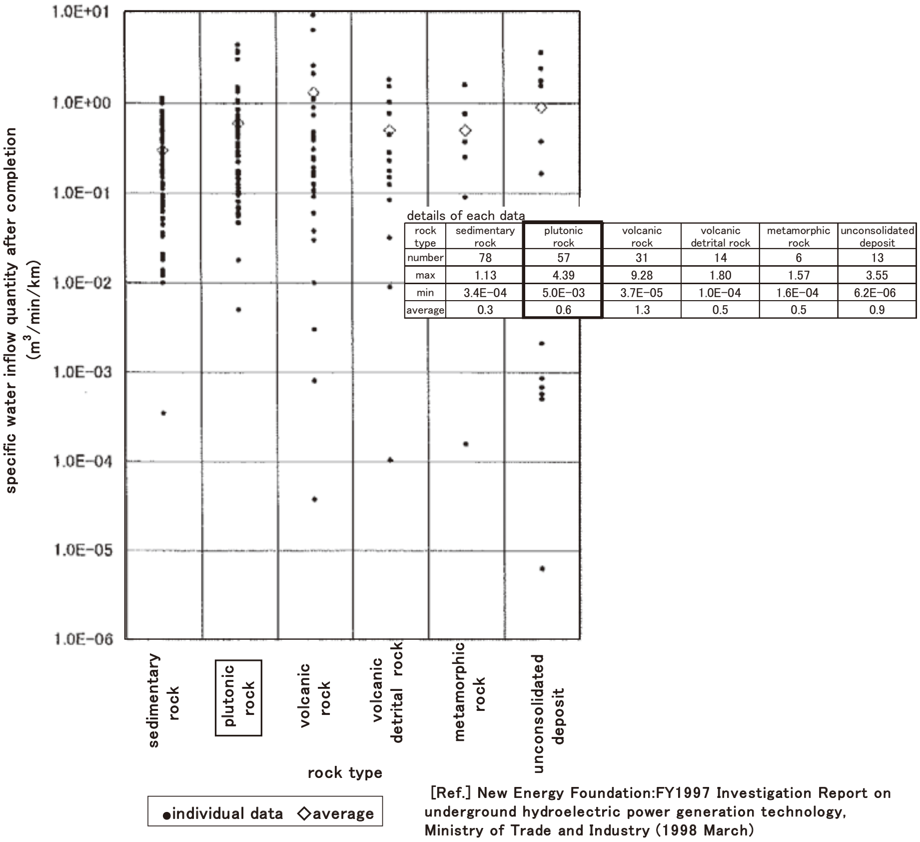
6.1 Fundamental Concepts Behind the Drainage Plan for After Construction Completion

6.1.1 Estimation of the steady water inflow quantity

The quantity of water inflow that will create a steady flow into the tunnel after completion depends on the particular site characteristics such as the geology, overburden, topography etc. Therefore it is very difficult to say anything definitive about the water quantity for the project at this time. However, we can make some hypothetical assumptions based on the newest comparative specific water inflow quantity data from a 1997 report from the Japan Agency for Natural Resources and Energy (see Figure 6-1)

Specific water inflow quantity = 0.6m^3/min/km
(Assumed geology = plutonic rock)
Safety factor = 1.5
Tunnel length = 31 km
Therefore: The total steady water inflow quantity would be
0.6 m^3/min/km×1.5×31km = 27.9 m^3/min

Accordingly, we posit for the purposes of the drainage water treatment design that after the tunnels are completed, the main linac tunnel (MLT) and the sub-tunnel would each have to deal with one half of that value, 13.95 m^3/min.



details of each data

rock type	sedimentary rock	plutonic rock	volcanic rock	volcanic detrital rock	metamorphic rock	unconsolidated deposit
number	78	57	31	14	6	13
max	1.13	4.39	9.28	1.80	1.57	3.55
min	3.4E−04	5.0E−03	3.7E−05	1.0E−04	1.6E−04	6.2E−06
average	0.3	0.6	1.3	0.5	0.5	0.9

[Ref.] New Energy Foundation:FY1997 Investigation Report on underground hydroelectric power generation technology, Ministry of Trade and Industry (1998 March)

Figure 6-1: Specific water inflow quantity inflows for existing tunnels by rock type

6.1.2 Baseline concept

6.1.2.1 Natural discharge

While the Central Region will be laser straight, the design for the vertical alignment for the two linacs of the MLT will follow the local earth geoids. The single tunnel design proposal for location on a plain requires a constantly pumped drainage system to evacuate underground water coming into the completed tunnel. In contrast, in the Japan single tunnel proposal forced drain pumping would not be needed as natural discharge by gravity type could be used by taking into advantage the surrounding mountains and valleys to provide an outlet at a lower gravity potential. The water could be collected through the connecting passages from the sub-tunnel into drainage tunnels for discharge.

6.1.2.2 Radiation safety management

There would be a possibility that any underground water that seeped into the MLT during machine operation could become radioactive. In such a case it would be necessary to install a large capacity reservoir tank underground so that the water could be monitored and cleared before discharge. Rather than risk this, we plan a complete waterproofing of the entire circumference of the MLT with a waterproofing membrane with permeable felt so as to avoid water inflow getting into the tunnel in the first place.

6.1.2.3 Underground hydrostatic pressure

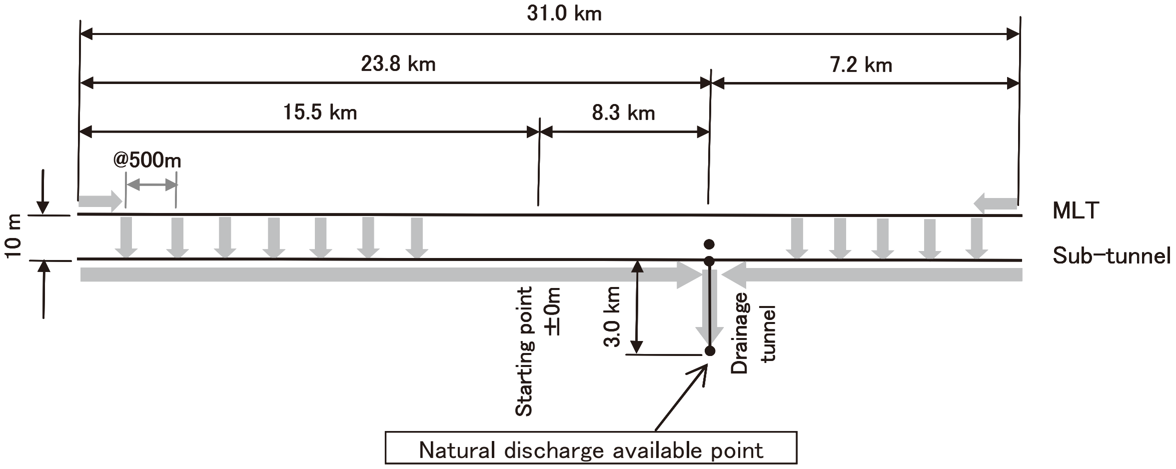
In order to prevent the build up of water pressing on the MLT when it becomes operational, we will install drainage pipes on the outside of the waterproofing membrane.

6.1.2.4 Maintenance considerations

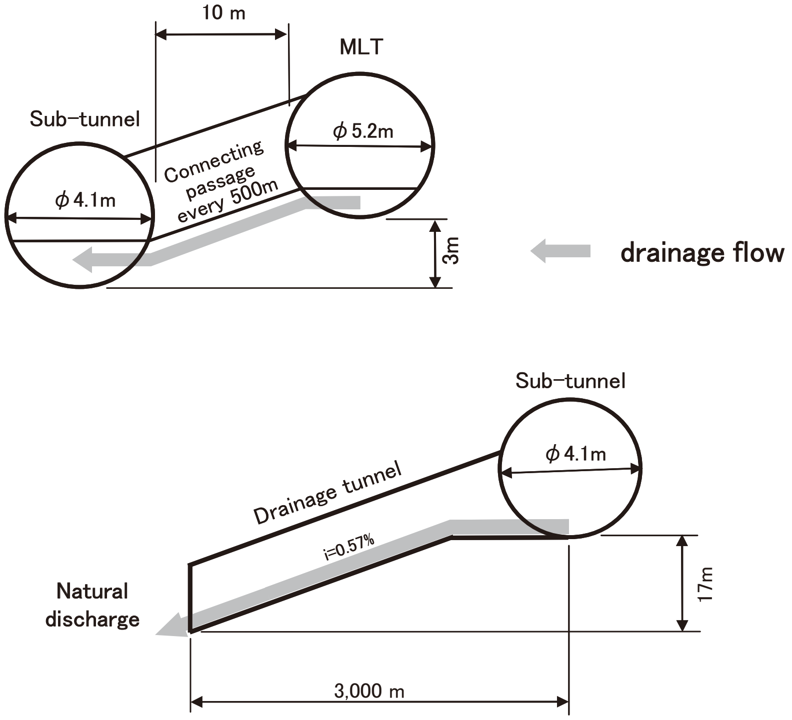
No drainage related powered equipment that would required maintenance shall be installed inside the MLT where radiation safety control would prevent human entry. Further, in order to provide for improved maintainability, the pumps installed in the sub-tunnel shall be off-the-shelf pumps of as small a capacity as possible, and as few of them as possible.

6.1.2.5 Drainage system goal

In order that accidents or unforeseen trouble related to the tunnel drainage need not cause interruption of the accelerator operation, we will assure the drainage capability by the use of the drainage filter material to bypass the underground water, as well as always provisioning spare pumps.



(A) Plan view



(B) Transverse view

Figure 6-2: Underground facilities layout.

6.2 Drainage System Fundamental Design Philosophy

6.2.1 Fundamental concepts behind the drainage plan for after construction completion

6.2.1.1 Dividing up the MLT into zones

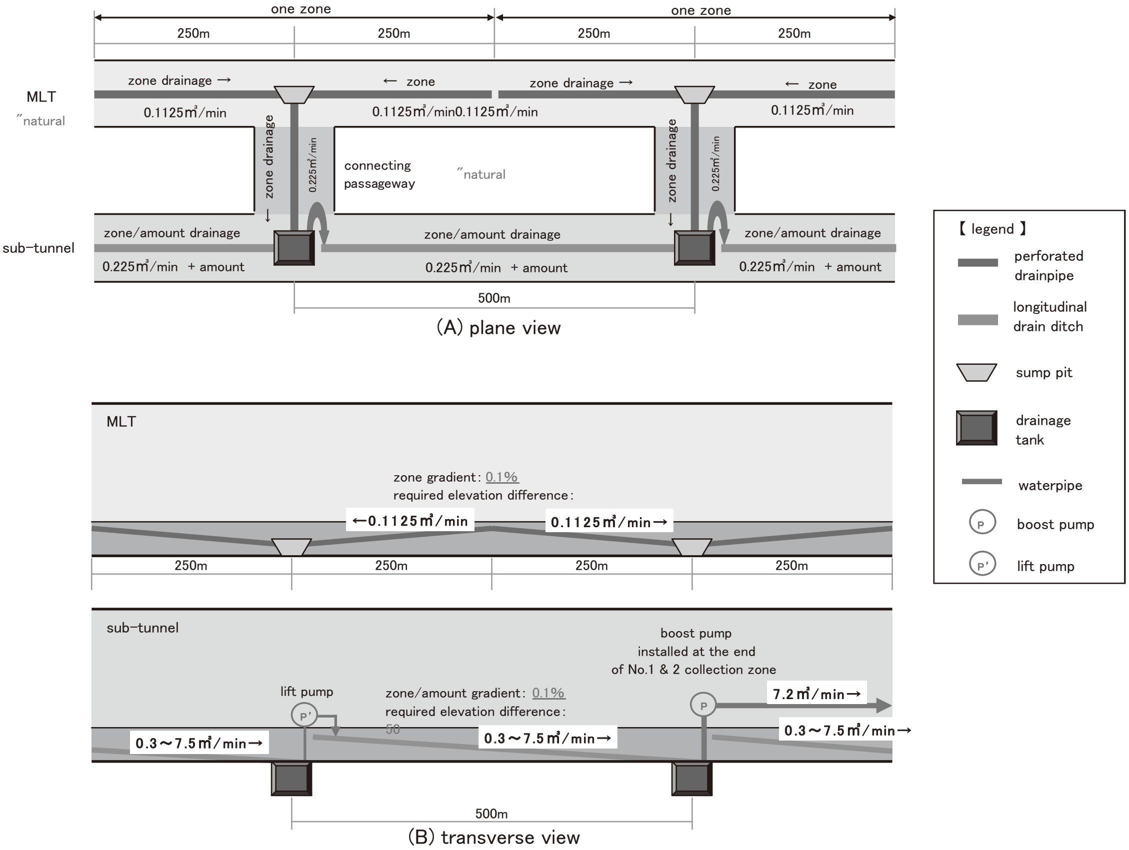
If we divide up the 31 km length of the MLT by connecting passages every 500 m, the 13.95m^3/min total flow would be reduced to 0.225 m^3/min in each of the 62 zones. Each connecting passage tunnel would drain the water collected over 250 m of the MLT on either side of it. This would minimize the elevation differences needed in the MLT for drainage purposes. (Figure 6-3.) We take the gradient necessary for drainage to be 0.1% (Lower limit from the Japanese agricultural underdrain pipe recommended gradient of 1/100 ~ 1/1000 [1)])

6.2.1.2 Drainage inside the sub-tunnel

The water collected from each MLT zone would flow through the connecting passage into the sub-tunnel where it would join the drain water for that part of the sub-tunnel, this combined water would then be drained into the next sub-tunnel zone. (See Figure 6-3.)

6.2.1.3 Organization of the drainage zones

Based on the above design, the 27.9m^3/min volume of water collected to and flowing through the 31 km total length of the sub-tunnel would be led by gravity feed to drainage tunnels for eventual above ground discharge. Figure 6-4 shows an example of how the drainage tunnels for our hypothetical site could be divided into 4 blocks, 2 requiring pumps for lifting the drainage water and 2 where free flowing discharge would be possible. On average we'd expect a drainage volume of about 6~7m^3/min.



(A) plane view

(B) transverse view

Figure 6-3: 500 m block drainage conceptual drawing

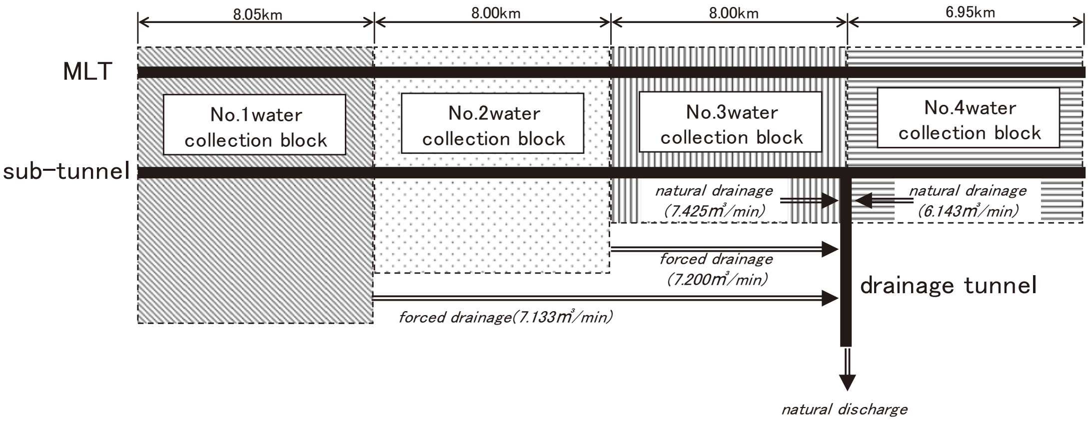


Figure 6-4: Overall drainage system conceptual drawing.

6.2.2 Design of drainage equipment and facilities

6.2.2.1 Central drain-pipe at the bottom of the MLT

Taking it as a requirement that each 250m block has to handle 0.1125m^3/min, we will use the Manning formula to calculate the numbers for free flowing pipes. We assume the ϕ300mm-perforated pipe typically used for the central drainage pipe in automotive and railroad tunnels.

Gradient $I = 0.1\%$,
Gauckler–Manning roughness coefficient $n = 0.010$ (smooth inner wall pipe)
Pipe diameter $d = 0.3\text{m}$,
Water surface included angle from the center $\theta = 4\pi/3$ (=240°)
Cross sectional area of the flowing water $A=d^2\times(\theta\text{-sin }\theta)/8= 0.057\text{m}^2$
Wetted perimeter length $P = 1/2\times d\times\theta = 0.628\text{m}$,
Hydraulic radius $R = A/P = 0.091\text{m}$

Therefore: Flow rate $V = 1/n\times R^{2/3}\times I^{1/2} = 0.64\text{m/s} > 0.585\text{m/s}$
(Which is the smallest permissible flow rate for culvert drain pipes2) ⇒ OK!
Therefore: Volume $Q=A\times V=0.037\text{m}^3/\text{s} =2.22\text{m}^3/\text{min} >> 0.1125\text{m}^3/\text{min}$ ⇒ OK!

6.2.2.2 Central drainage pipe in the connecting passages

Every 500m there is a connecting passage that should have a drainage capacity of 0.225m^3 / min. Again using the same ϕ300mm perforated pipe as above, we calculate the Manning formula:

Gradient $I \fallingdotseq 10\%$,
Gauckler–Manning roughness coefficient $n = 0.010$ (smooth inner wall pipe)
Pipe diameter $d = 0.3\text{m}$,
Water surface included angle from the center $\theta = 4\pi/3$ (=240°)
Cross sectional area of the flowing water $A = d^2\times(\theta\text{-sin }\theta)/8 = 0.057\text{m}^2$
Wetted perimeter length $P = 1/2\times d\times\theta = 0.628\text{m}$,
Hydraulic radius $R = A/P = 0.091\text{m}$

Therefore: Flow rate $V = 1/n\times R^{2/3}\times I^{1/2} = 6.40\text{m/s} > 0.585\text{m/s}$
(Which is the smallest permissible flow rate for culvert drain pipes2.) ⇒ OK!
Therefore: Volume $Q = A\times V = 0.365\text{m}^3/\text{s} = 21.9\text{m}^3/\text{min} >> 0.225\text{m}^3/\text{min}$ ⇒ OK!

6.2.2.3 Drainage transiting a sub-tunnel

For this scenario the maximum amount of water transiting a 500m block (the No. 3 collection block in the figure), would be estimated at 7.425 m^3 / min. We would be able to make rectangular drainage trough 1.5 m wide by 0.25 ～ 0.75 m in height in the floor under the track of the TBM making the 4.1 m finished inner diameter tunnel.
The Manning formula for this would be:

Gradient $I \fallingdotseq 0.1\%$, Gauckler – Manning roughness coefficient $n = 0.013$
(Concrete with mortar finish)
Width $b = 1.5\text{m}$, Effective height $h = 0.20\text{m}$ (Water depth 80% of the 0.25m trough)
Flowing water area $A = b \times h = 0.3\text{m}^2$
Wetted perimeter length $P = b + 2 \times h = 1.9\text{m}$,
Hydraulic radius $R = A/P = 0.158\text{m}$

Therefore: Flow rate $V = 1/n\times R^{2/3}\times I^{1/2} = 0.71\text{m/s} > 0.45\text{m/s}$
(Which is the smallest permissible flow rate for open channel drains2.) ⇒ OK!
Therefore: Volume $Q = A \times V = 0.213\text{m}^3/\text{s} = 12.8\text{m}^3/\text{min} > 7.425\text{m}^3/\text{min}$ ⇒ OK!

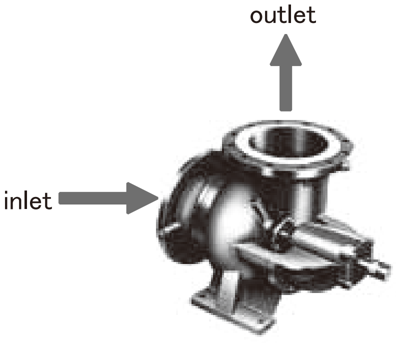
6.2.2.4 Sub-tunnel drainage tanks

For the 6.75m^3 / min maximum water collection in any one 500 m sub-tunnel block (No.2 and No. 3 in our example scenario), we would put in a tank 2m × 1.5m × 3m (W × H × D) making a volume of 9 m^3, or more than a minute's worth of storage capacity.

6.2.3 Pump design

6.2.3.1 Lift pumps

Each 500m sub-tunnel block has a drain water tank; a pump will be needed in the tank to lift that water on to the next block. For specifications, the necessary head would be about 4 m, and with a pumping volume of 0.3 ～ 6.75m^3 / min. Pumps commonly used in agricultural irrigation applications could fill that. There exist off-the-shelf commercial spiral type semi-axial flow pumps (see Photograph 6-1 and Figure 6-5.) On average they would have a power consumption of 3.7 kW each, and in total 59 would be required.



Photograph 6-1: Spiral type semi-axial flow pump

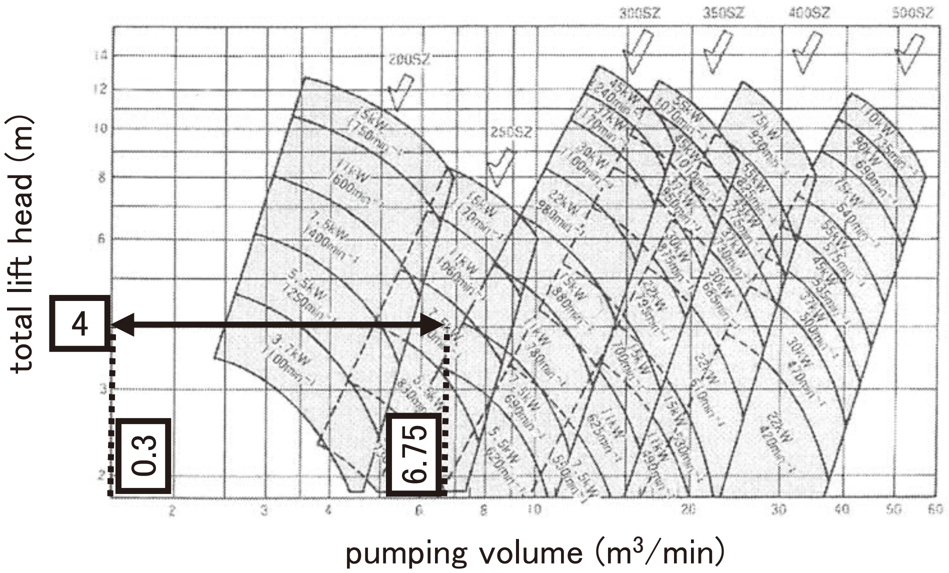
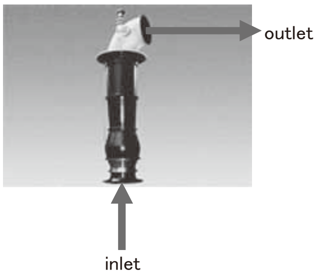


Figure 6-5 Pump characteristics, operating regions (belt driven, 50 Hz)

6.2.3.2 Boost pumps

There would be ϕ500m water pipes installed in two places in the sub-tunnel, two pumps would be needed to get the water to the drain tunnel. For these pumps a 15 ～ 30 m lift head (including pressure losses), and a maximum discharge rate of 7.2m^3 / min (= 0.12 m^3 / sec) would be needed. As this spec at 37kW and 30kW is unfortunately mid-way between the ‘horizontal centrifugal pump’ and the commonly used industrial low head / high capacity 'vertical shaft type semi-axial flow pump' (See Photograph 6-2 and Figure 6-6.) custom order would be necessary.



Photograph 6-2: Vertical shaft type semi-axial flow pump

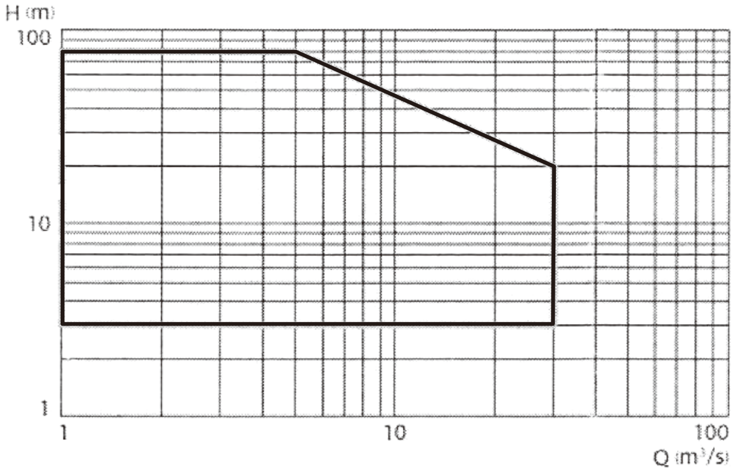


Figure 6-6. Vertical shaft type semi-axial flow pump operational region

6.2.3.3 Power consumption

We can estimate the maximum power consumption for the drainage pumps as follows:

Sump pumps (Average power 3.7 kW, n = 59 units)
Boost pumps (One each of 37kW and 30kW)
Therefore Total power consumption = (3.7 kW × 59) + (37kW + 30kW) = 285.3 kW
Pump utilization rate = 0.8 (realized experience)
Therefore Maximum power consumption = 285.3 kW × 0.8 = 228.24 kWh

6.3 Drainage Work for the Main Linac Tunnel

6.3.1 Design of waterproofing and drainage construction

A representative design for the waterproofing and drainage construction for the TBM and NATM constructed tunnels is given in Figure 6-7. Particular features to be noted are:

The entire length of the tunnel to be surrounded by a waterproofing membrane. Underground water getting to the tunnel arch would flow around the bonded non-woven fabric and impermeable sheet where it be collected into $\phi100$ perforated pipes running along the tunnel exterior. $\phi150$ perforated pipes every 50m would connect the external drainpipe the central drain pipe, a $\phi300$ perforated pipe.

In order that the waterproofing sheet under the floor concrete not be damaged by the backfill under the invert, a protective layer of sand (t = 100) will be put down first. A non-woven fabric sheet between them will keep the backfill separated from the sand. The ϕ300 perforated central drain pipe will be covered with a filtering material to keep the pipe from plugging.

By faithfully implementing the above waterproofing and drainage construction, we should be able to avoid any radio activation of the underground water, and with the passive gravity drain it should be a maintenance free facility.

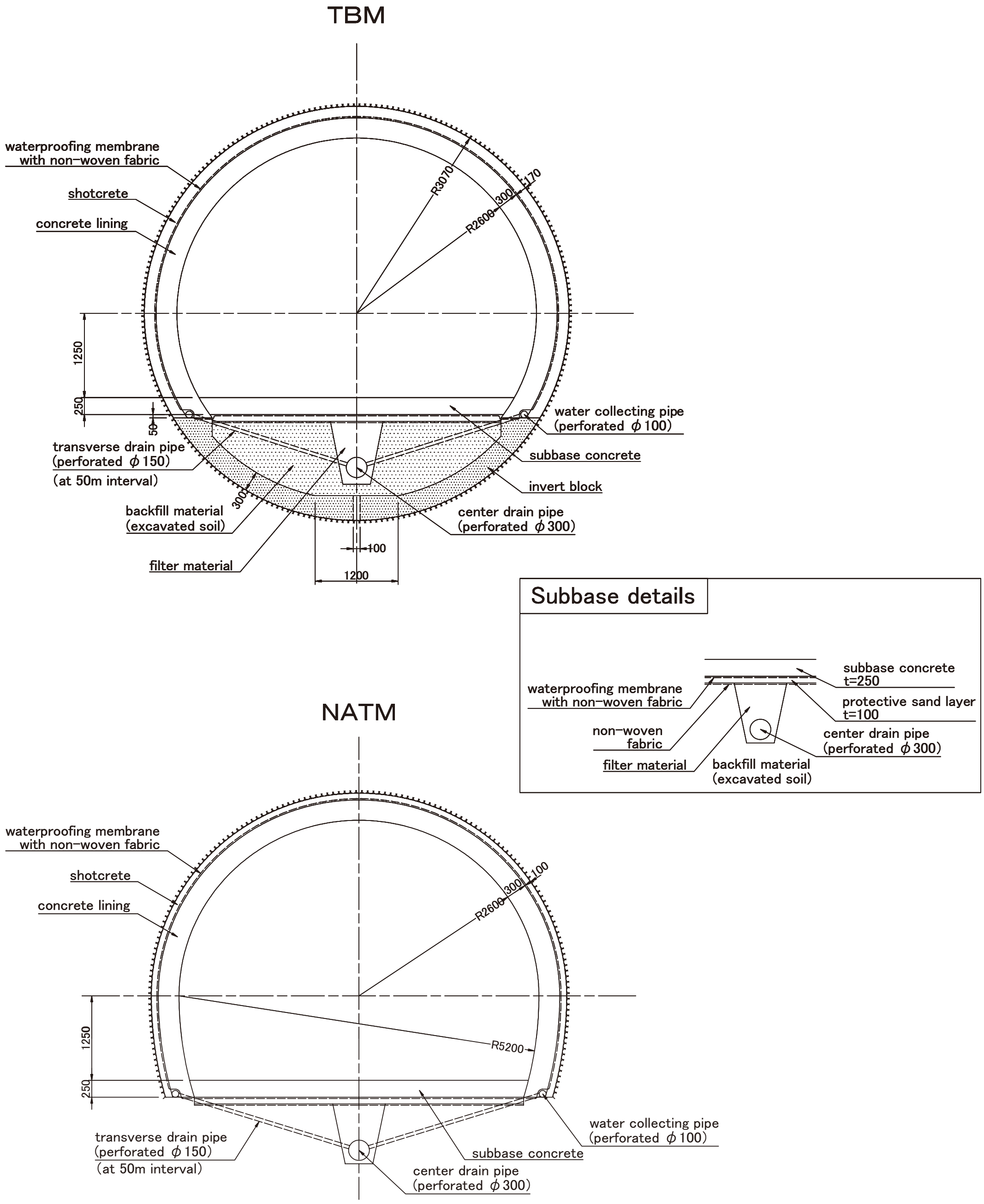


Figure 6-7 Standard constructions for the MLT waterproofing and water drainage

6.4 Drainage Work for the Sub-Tunnel

6.4.1 Drainage plan

The drainage plan for the circular TBM dug tunnel is shown in Figure 6-8. Features to note are the following:

Because of the cost, the entire length of the tunnel would NOT be lined with a waterproof sheet. Instead an appropriate case-by-case strategy would be chosen for only those locations where there is a water problem.

For example: If the water is coming from a linear crack between rock layers, drain holes could be opened into the rock, and along the tunnel inside wall a drain trough eventually connecting with a cross trough to the central drain ditch 1.5m × 0.25m ~ 0.75m (W × H), slope 0.1%, draining the length of the tunnel.

If the water was coming from an entire area, a waterproof panel could be installed there to constrain the water on its outside and deliver it to the tunnel floor, from there in the same way as above, cross troughs would connect to the central drain channel.

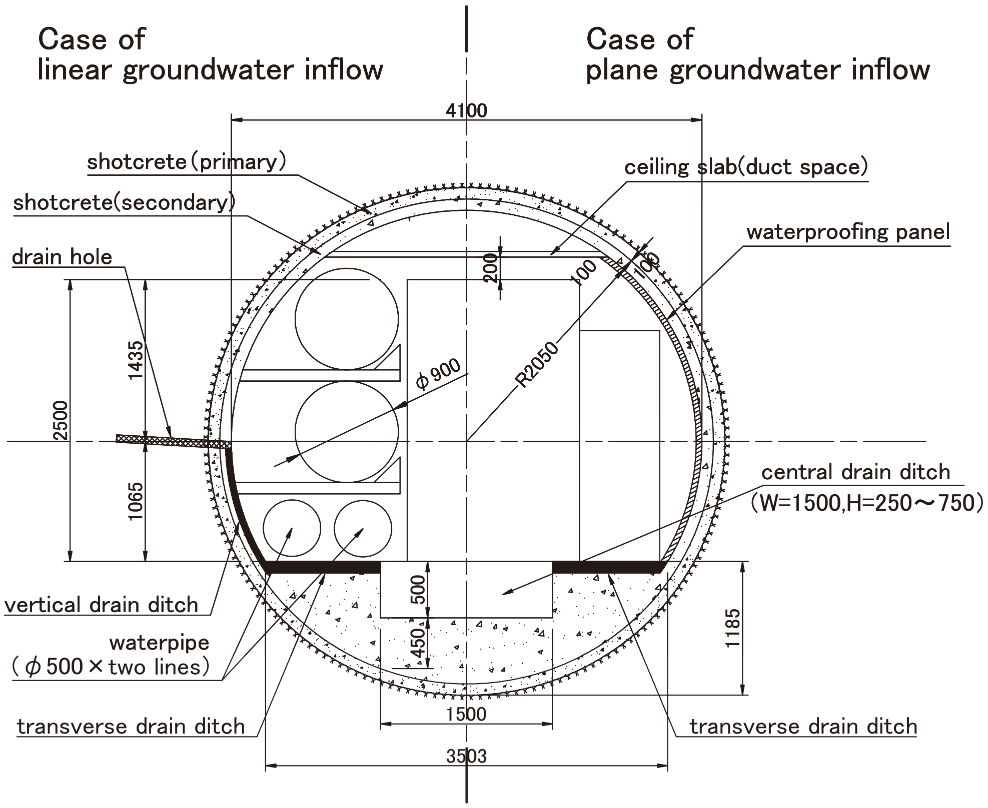


Figure 6-8: Standard sub-tunnel water drainage plan

6.4.2 Flooding risk

In the unlikely event of a complete power failure, all the pumps in the sub-tunnel would stop. Any water inflow that overflowed the longitudinal drainage channel would then only flood the tunnel slightly before flowing naturally out of the drainage tunnels. There would be no possibility of flooding the MLT or even flooding the sub-tunnel seriously.

6.5 Drainage Work Construction for the Connecting Passageways

6.5.1 Design of waterproofing and drainage construction

Figure 6-9 shows a typical waterproofing and drainage plan for the connecting passageways. These tunnels also provide the drainage path between the drainage pits in the MLT and the drainage tanks in the sub-tunnel. Features to note are the following:

To make sure that water inflow cannot get into the MLT from the arch of the connecting passageway, the arch should be lined with a waterproof sheet and non-woven fabric layer.

A ϕ300 perforated drainage pipe would be installed in the bottom of the passageway which would connect the MLT drainage pit to sub-tunnel drainage tank.

By taking the above waterproofing and drainage construction steps reliably, we can avoid getting the underground water exposed to radiation, and the natural drainage plan should provide a maintenance free system.

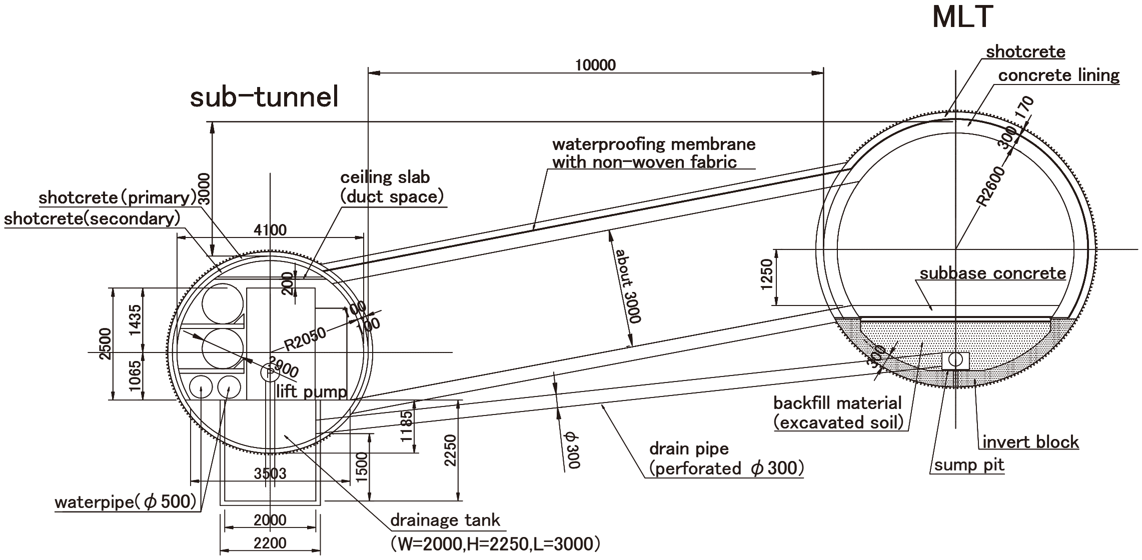


Figure 6-9: Standard plan for waterproofing and draining of the connecting passageways

6.6 Drainage Tunnel

6.6.1 Cross sectional design

We consider the specification for drainage tunnels to connect the sub-tunnel to locations where natural flowing discharge would be possible. We assume a capacity requirement of 27.9 m^3 / min.

6.6.1.1 Internal cross section shape

For our hypothetical site we assume a drainage tunnel could be 3,000m long and with an elevation change of 20m - 3m = 17m and thus a slope of 0.57%. A circular cross section is optimal both for its hydraulics and from the rock-mining point of view, and it could be excavated with a TBM. Because of their established record in Japan, we choose a small bore TBM (excavated diameter 3.5m or less) 3) the finished inside diameter to be 2.5m.

6.6.1.2 Tunnel support shoring and lining

Again from our experience with small bore TBMs for using in drainage tunnels, a shotcrete layer (t = 100) should be adequate for support, and for lining a typical concrete liner (t = 300) makes sense.

6.6.1.3 Drainage capacity check

Running the numbers for the 2.5m id. drainage tunnel through the Manning formula gives:

Slope I = 0.57%, Gauckler–Manning roughness coefficient n = 0.017
(Artificial concrete channel)
Pipe diameter d = 2.5m
Water surface included angle from the center $\theta = 4\pi/3$ (=240°)
Cross sectional area of the flowing water $A=d^2\times(\theta\text{-sin }\theta)/8= 3.95\text{m}^2$
Wetted perimeter length $P = 1/2\times d\times\theta = 5.236\text{m}$,
Hydraulic radius R = A/P = 0.754m
Therefore: Flow rate $V =1/n\times R^{2/3}\times I^{1/2} = 3.68\text{m/s} > 0.585\text{m/s}$
(Which is the smallest permissible flow rate for drain tunnels[2]) ⇒ OK!
Therefore: Volume $Q=A\times V= 14.5\text{m}^3/\text{s} = 872\text{m}^3/\text{min} >> 27.9\ \text{m}^3/\text{min}$ ⇒ OK!

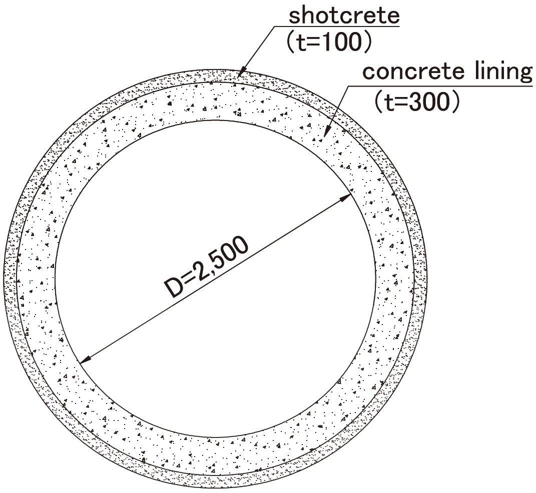


Figure 6-10: Drainage tunnel cross section

6.6.2 Construction schedule

Taking into account our experience with small-bore TBM drainage tunnel work [3], our estimated schedule would be as seen in Figure 6-11. In all, the construction would occupy 38 months (excluding any time for TBM design or fabrication).

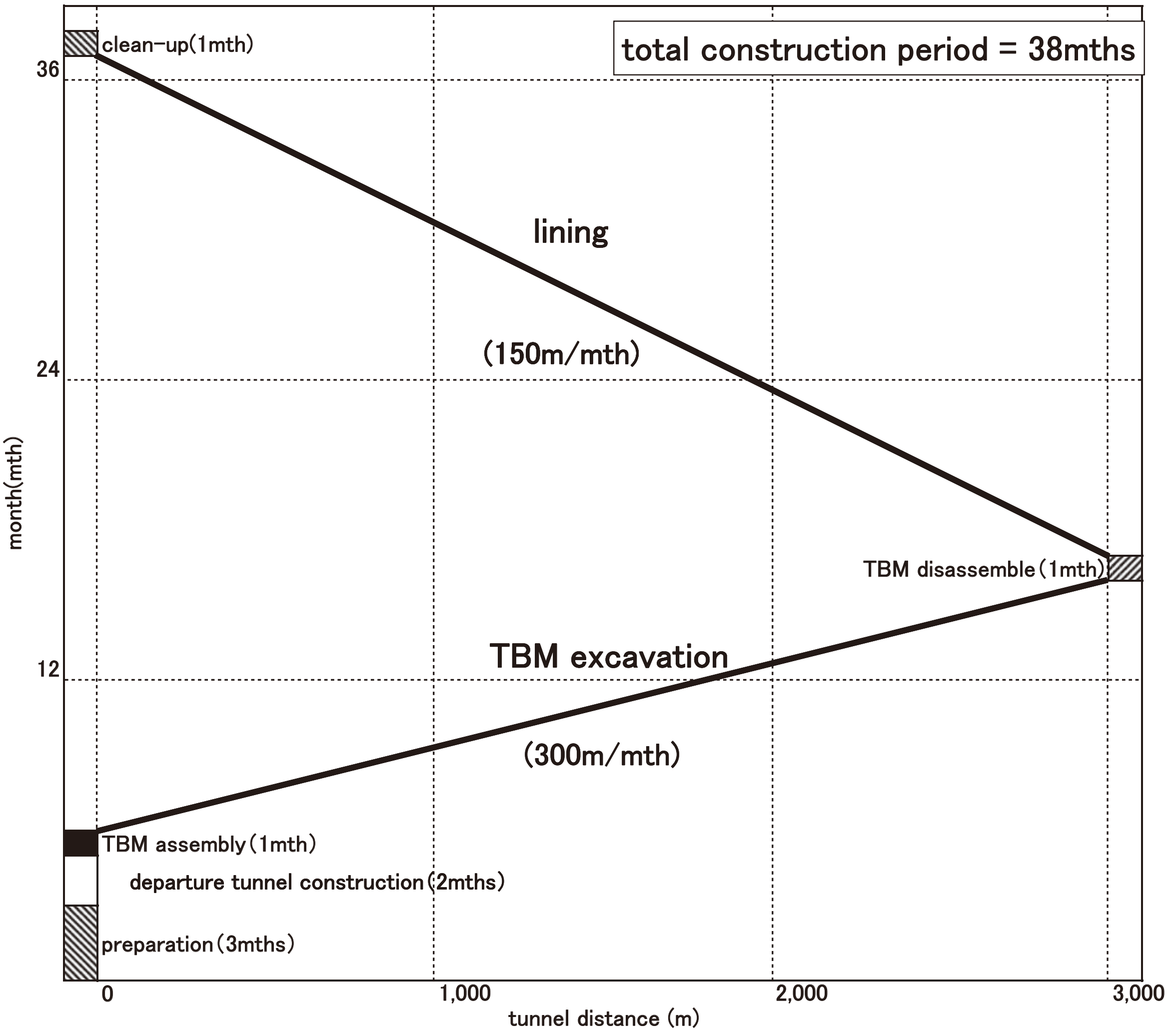


Figure 6-11: Drainage tunnel construction schedule outline

[References]

1. The Agricultural Upland Development Association, “Design and Construction of Underdrainage”, p.62 (March 1982)
2. Agricultural Engineering Society, “Design Standard for Land Improvement Project, Technical Specifications for Designing of Water Channel Works”, pp. 152-153 (March 2001)
3. Japan Tunneling Association, “TBM Handbook”, pp.78-103 (February 2000)

7. Cavern for Collision Experimental Hall

7.1 Requirements for the collision experimental hall

Because the collision experimental hall is in a very large cavern, careful consideration of the geologic structure is very important in the site determination. However, because its spot in the center of the accelerator tunnel is fixed, in the event that the ground pressure conditions, directionality of the bedrock fractures etc. cannot be freely chosen, it may be necessary to go ahead with the cavern excavation in an adverse location. At the very minimum there should be a ground cover of 2D or more.

Also, there should be adequate level space available above for a yard area should the access to the collision experimental hall be by a vertical shaft.

7.1.1 Collision experimental hall

Bedrock under consideration:	B ~ CH class Granite (Japan Society of Engineering Geology classification)
Earth cover:	on the order of 100m
Cavern dimensions:	30m wide, 40m high and 120m long
Shape:	Bread loaf (Arch and vertical walls)

Lining shall be done after the excavation is complete.

7.1.2 Vertical access shafts

Finished inside diameter and locations:	ϕ16m, one at each end of the cavern

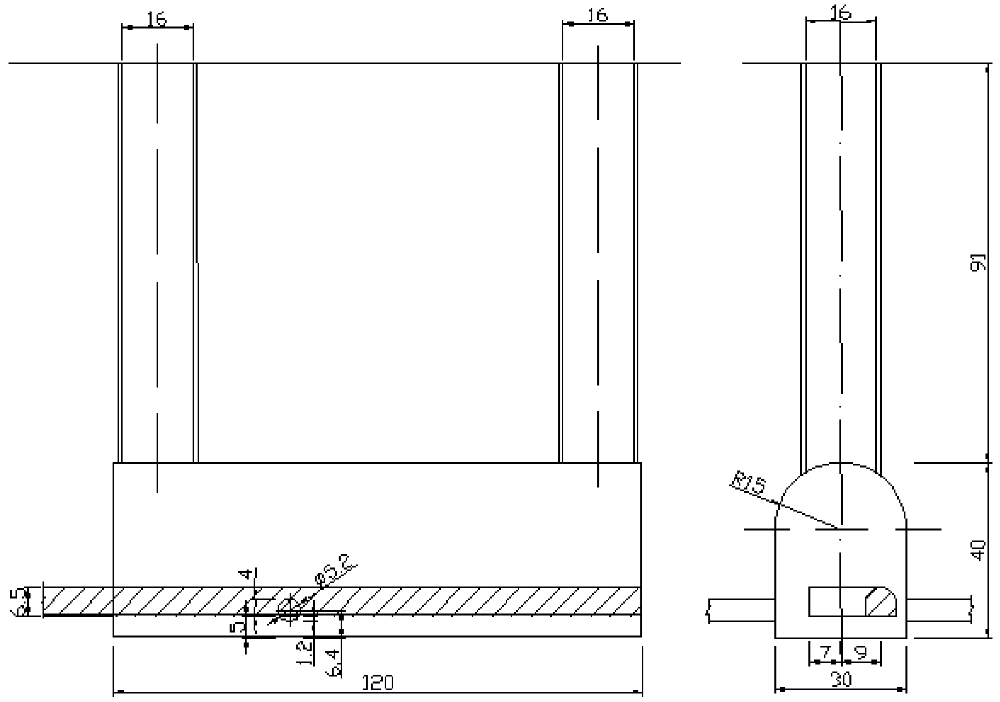


Figure 7-1: Sketch of the collision experimental hall and vertical access shafts

7.2 Inclined Access Tunnel Considerations

7.2.1 Study premise conditions

The location for the tunnel construction should take into account providing access from the existing roads and space for establishing a temporary working yard area.

The new road between the level straight entrance of the tunnel and the existing road should have a minimum turning radius of R150m. In order that semi-trailers could bring in loads to the experimental hall, the access tunnel itself should have a minimum turning radius of R30m. As for the vertical profile of the tunnel, taking into account the climbing ability of semi-trailers and the like transporting loads, a slope of 5.12% for the straight sections, and zero slope for the R30m turns and the final entrance to the collision experimental hall.

Tunnel dimensions would be about 10.20m wide, 7.20m high and 1,311m long. The final 120m would extend inside the collision experimental hall.

7.2.2 Access tunnel specifications

Inside area: 61.97m^2
Shape: Horseshoe
(Note that the portion inside the collision experimental hall would not be lined.)
Bedrock under consideration: B ~ D class Granite
Earth cover: 5 ~ 150m
Support patterns: DⅢa(50m)、DⅠ(50m)、CⅡ(100m)、CⅠ(300m)、B(811m)

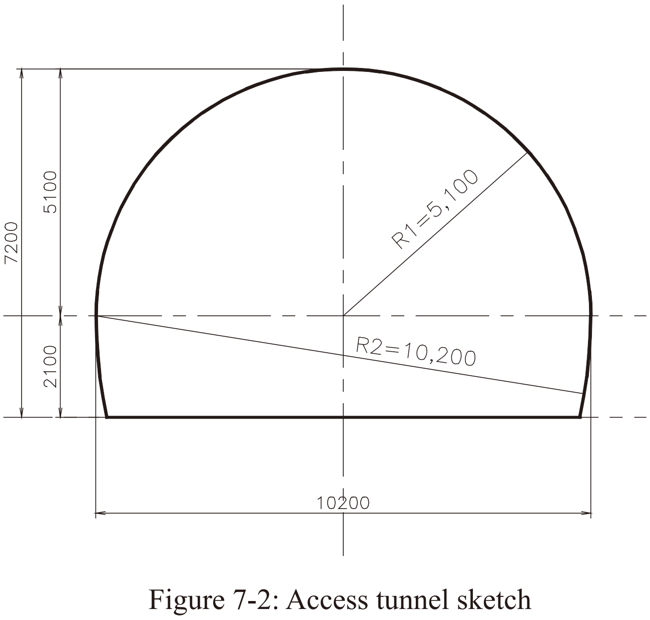
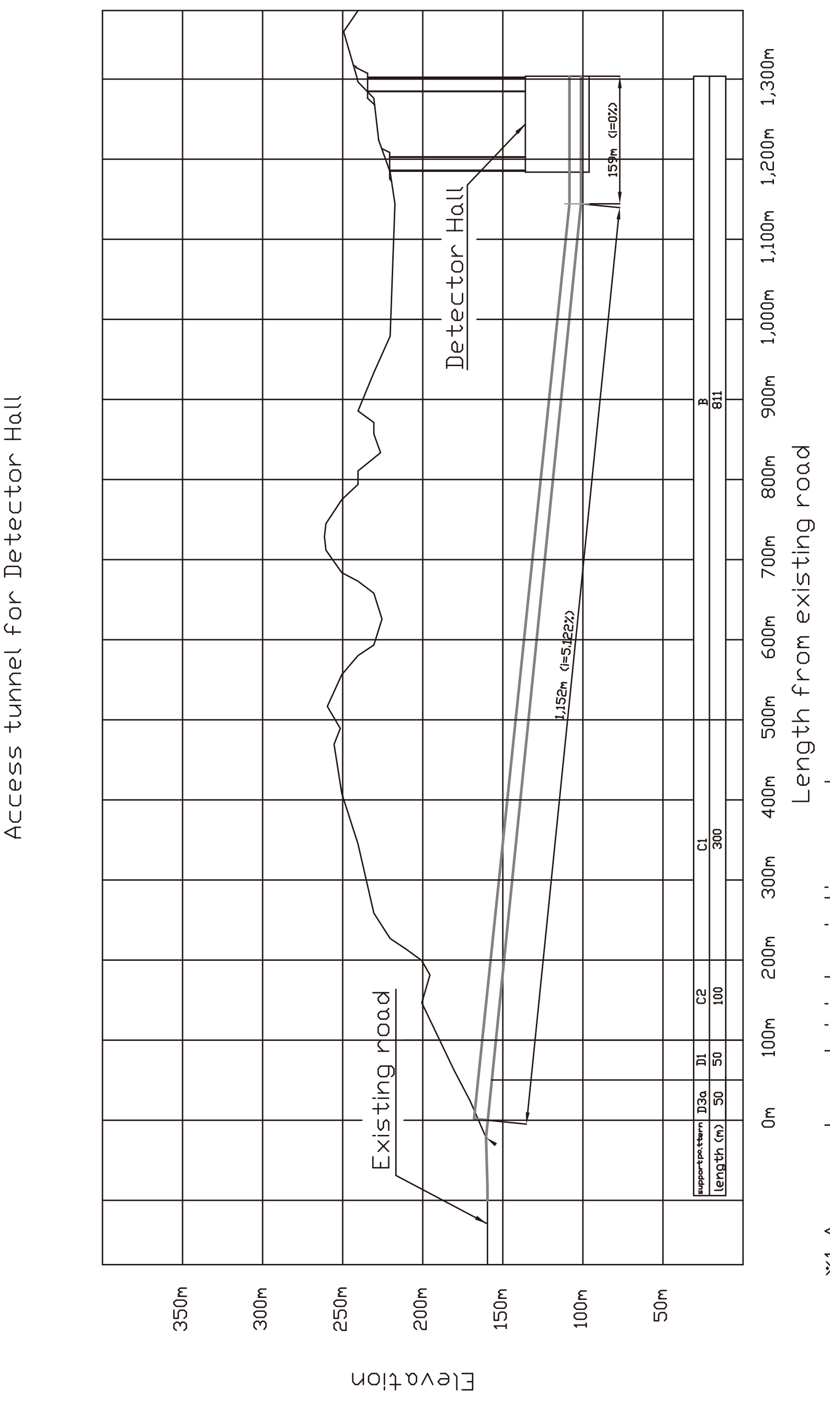


Figure 7-2: Access tunnel sketch



※1 Access tunnel joint existing road

※2 Total tength of access tunnel is 1311m included straight section 1152m, curve section 39m and length of Detector Hall 120m

※3 Vertical profile of access tunnel is a slope of 5.12% for the straight section ,and zero slope for R30m turns and Detector Hall

Figure 7-3: Access tunnel(s) elevation view

7.2.3 Access tunnel project scheduling

Figure 7-4 shows the overall access tunnel project schedule.

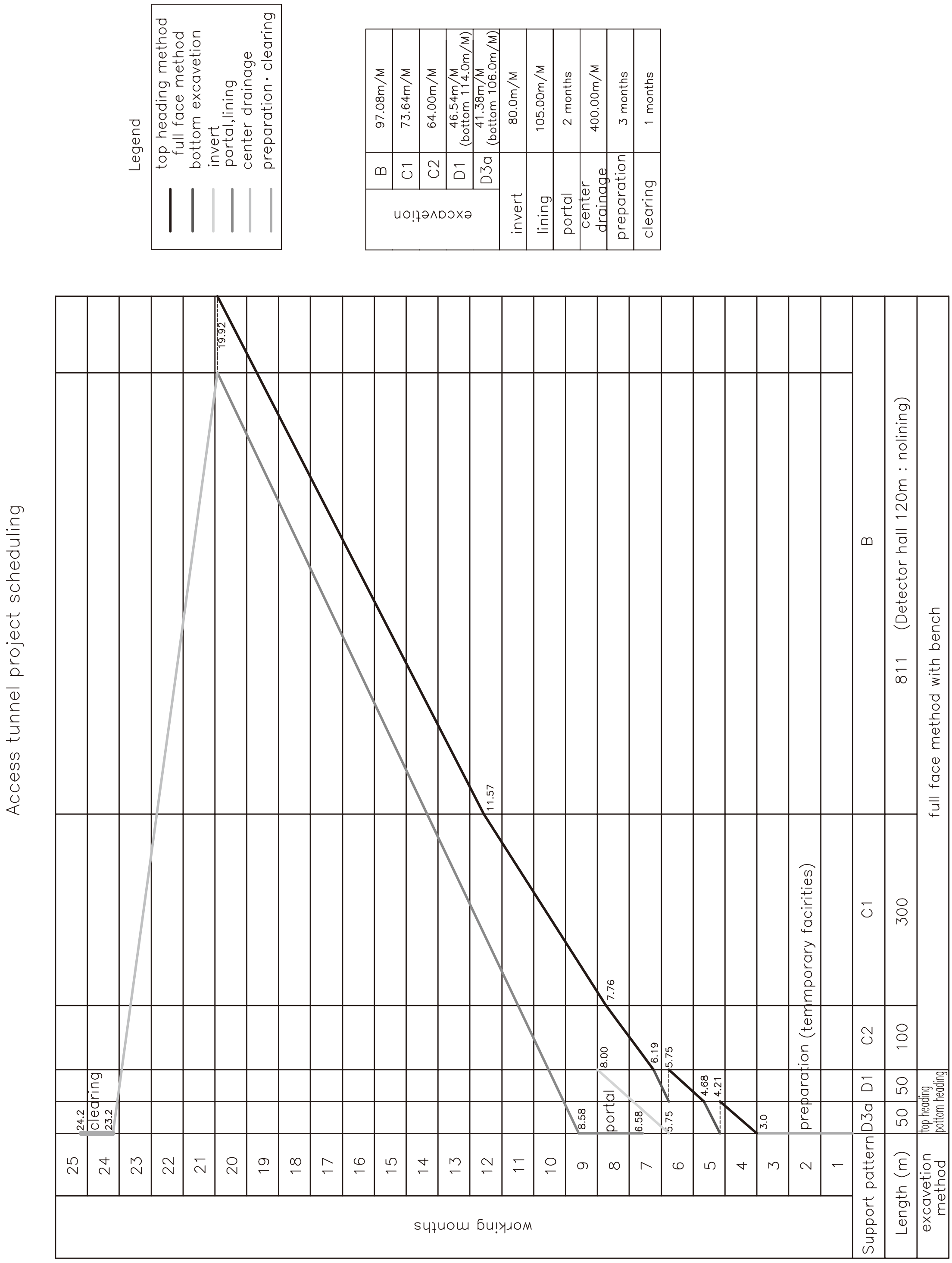


Figure 7-4: Access tunnel project schedule

7.3 Collision Experimental Hall and Vertical Access Shaft Considerations

7.3.1 Collision experimental hall specifications

Cavern dimensions: 30m wide, 40m high and 120m long
Shape: ‘bread loaf’ (Arch 15m radius, 25m vertical walls)
The chamber lining by a separate process after excavation, details not considered in this study.
Vertical shaft finished inner diameter and numbers:
ϕ16m, 2 shafts, one at each end of the cavern
Bedrock under consideration: B ~ CH class Granite
Earth cover: about 100m

7.3.2 Tunnel support structures

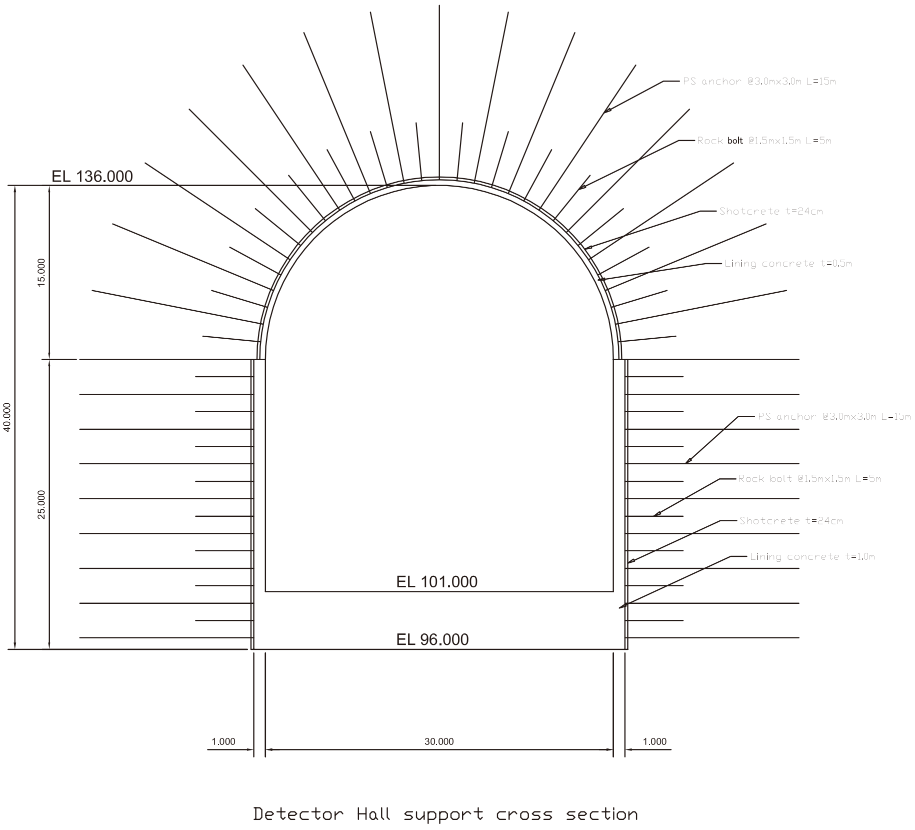


Figure 7-5 : Collision Experimental Hall support cross section

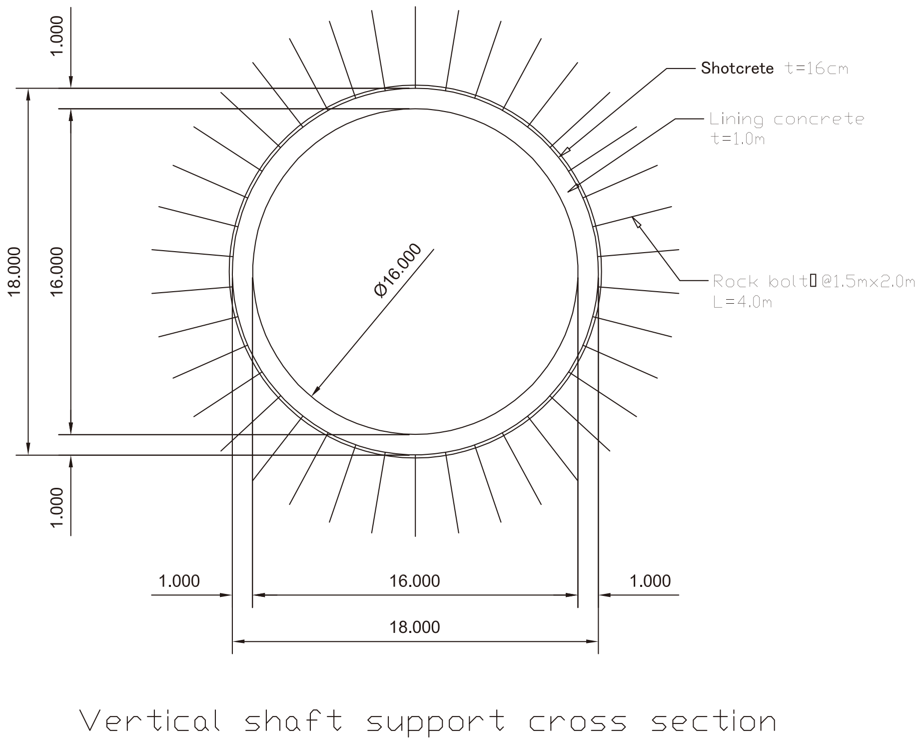


Figure 7-6 : Vertical shaft support cross section

7.3.3 Construction methods and order of operations

We will use both the vertical shafts and the inclined slope tunnels to access the collision experimental hall work area. The shafts would be used during cavern excavation for inserting and removing materials and equipment, after excavation for bringing in experiment equipment and as an assembly operations area. The inclined slope access tunnel would be used initially to remove the spoils from the cavern and vertical shaft excavations, and for bringing material and equipment to the work site. After project completion it would provide the road for transporting in material and equipment. The tunnel slope would be 5.12% from the above considerations. The construction order would be first the inclined access tunnel excavation, then a service tunnel across the bottom of the cavern, vertical shafts and finally the rest of the collision experimental cavern excavation.

7.3.3.1 The construction of the inclined tunnel would begin with an excavation as far where the tunnel would enter into the cavern, and then a service tunnel the length of the cavern. The spoils from the vertical shaft excavations would be taken out via the inclined tunnel.

7.3.3.2 The excavation of the vertical shafts would be done by first down boring, punching through a ϕ270mm pilot hole to the service tunnel, after which a ϕ2000mm bit would be fitted for raise boring and reaming up. Further excavation to the full diameter would be by drill and blast from above, with the spoils falling down to the service tunnel through the ϕ2000mm hole. After the shaft was expanded to full diameter, slip forms would be used to make a secondary tunnel lining of concrete, from the bottom up.

7.3.3.3 The excavation of the cavern arch would be done by enlarging an arch created from an upper service tunnel. Materials and equipment would be lowered from the surface by a gantry crane. Excavation spoils would be passed down a chute to be taken care of below.

7.3.3.4 The main volume of the cavern would be excavated by sequential bench blasting (3m benches). In the same way as for the arch, excavation spoils would be passed down chutes to the lower service tunnel and then taken out of the tunnel via the inclined access tunnel.

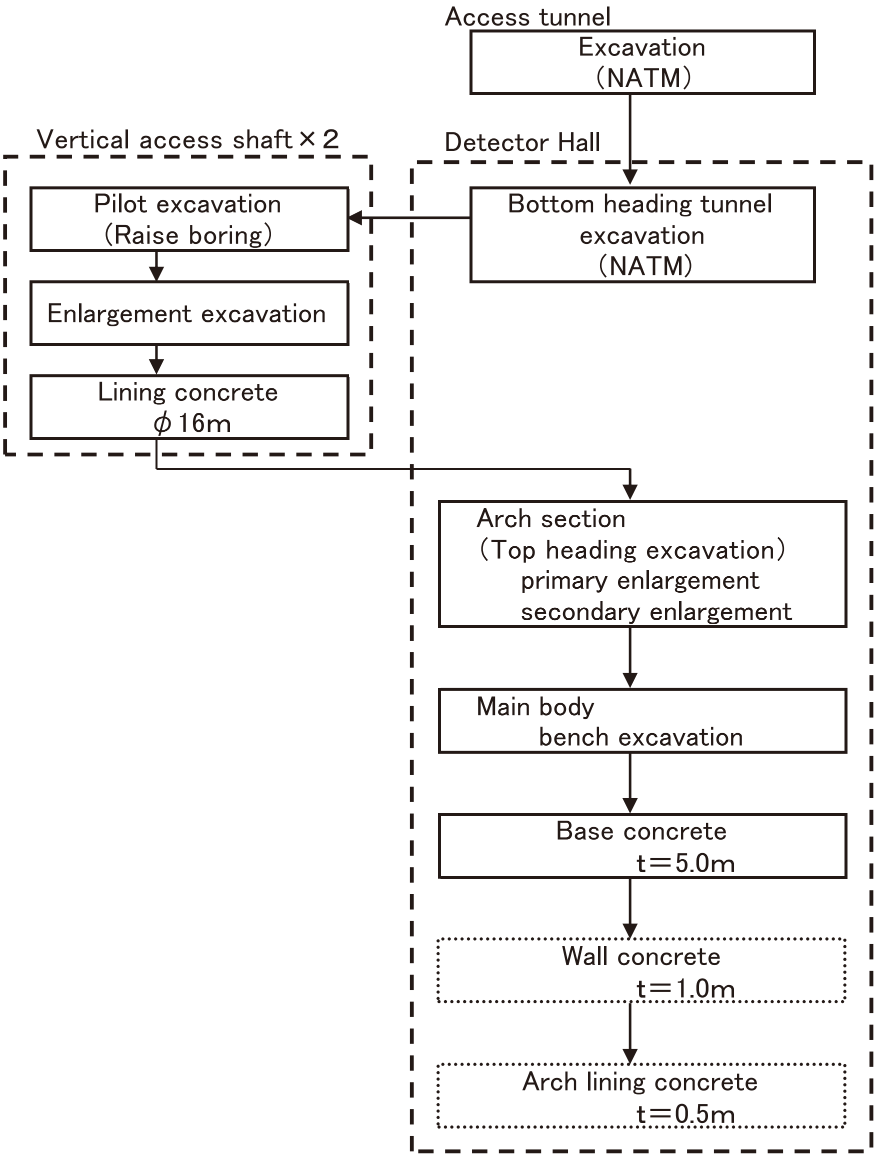


Figure 7-7 Collision Experimental Hall construction flow chart

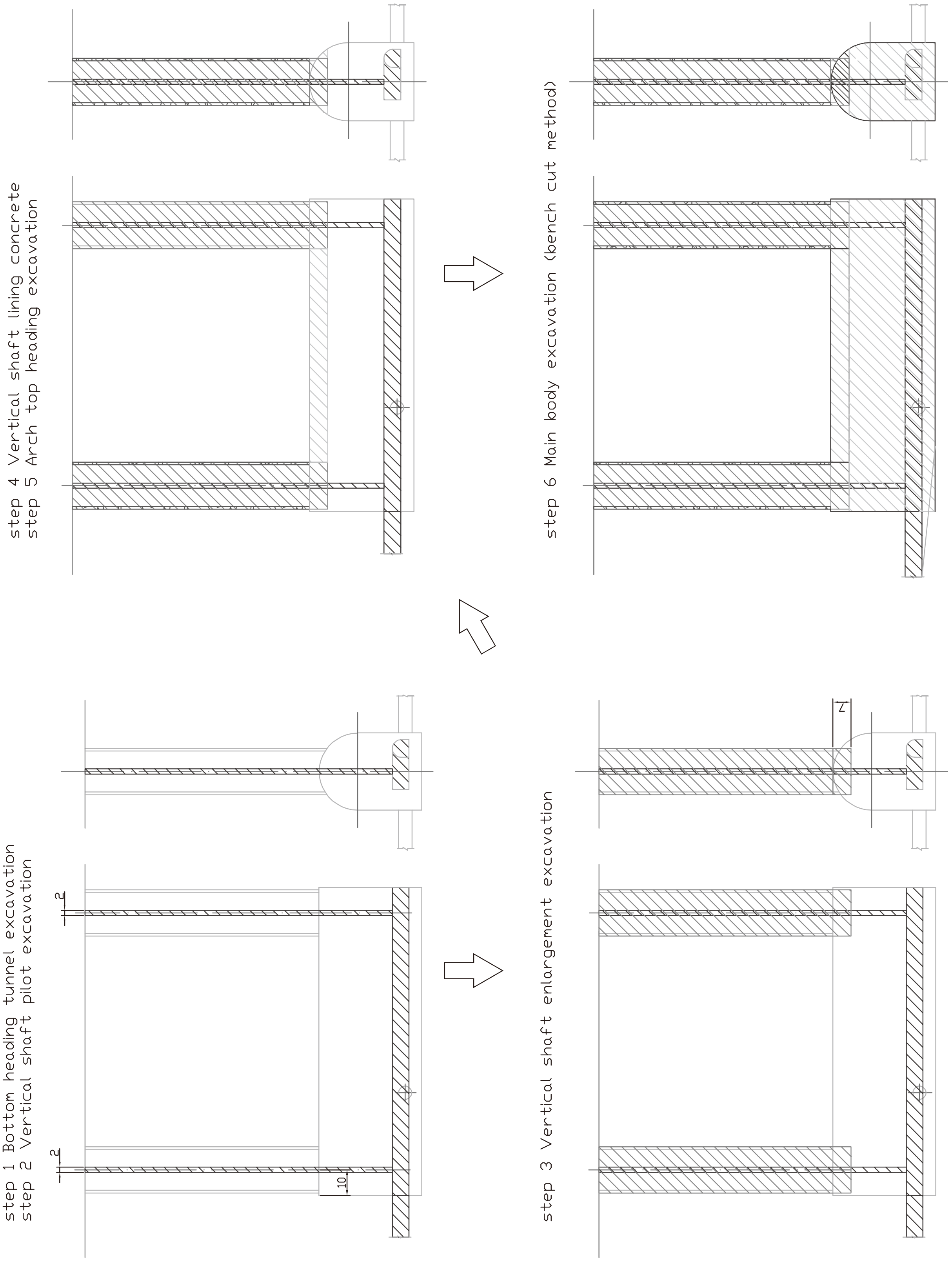


Figure 7-8: Construction order diagram

7.3.4 Construction schedule of the cavern and vertical shafts

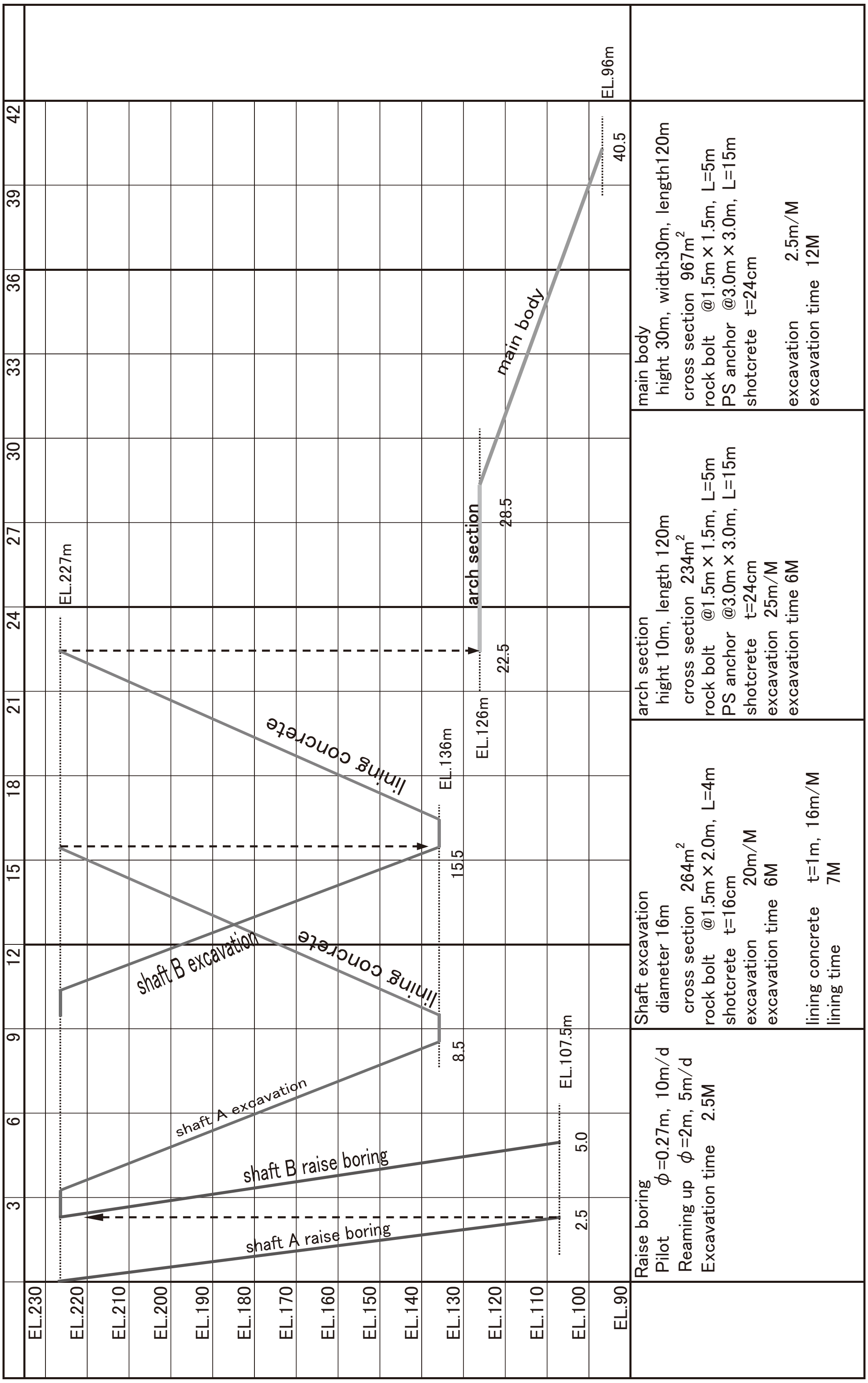


Figure 7-9: Construction schedule

8. Overall Construction Schedule

In this section we will make some assumptions about possible access methods during construction and construction blocks to investigate the overall scheduling for the project based on the considerations of "Section 3. Overall Facilities Layout" and with the facilities layout for the sample site as shown in Figure 3-5. We have idealized the situation by taking the main linac tunnel and sub-tunnel to be isolated from the collision experimental hall cavern in that work for all three could proceed simultaneously with non-interfering access. Obviously this is not realistic and scheduling for the work around the connection of the main linac tunnel and the collision experimental hall and the nearby tunneling would have to be studied in great detail to minimize the mutual interference.

As for the geological conditions, since this is for the sample site we can assume the entire tunneling project to be in granite bedrock; we did not consider faulting or the distribution of other adverse geology, or the effect of area with small overburden.

Further, for our sketch of the overall project scheduling, the following listed items were not considered at this time.

(1) Investigation of ground conditions, investigation of topography and geology, research of geology and location conditions
(2) Overall design, detailed design
(3) Excavation, construction planning
(4) Environmental assessment
(5) Land acquisition, compensation stakeholders investigation
(6) Permit application, approval and recognition

We also assumed that the construction of other facilities installation would begin after the completion of the underground construction work. However, our schedule planning does assume that the access methods during construction, and the way the blocks are divided up would be such that each construction block could be completed independently. This means building the access tunnels with structures such that they can be used for facilities installation. Beginning with the blocks where the construction finishes first, one after another the work for facilities installation could begin. This would shorten the total construction time to completion, or make it easier to spread out the concentrated work for facilities installation.

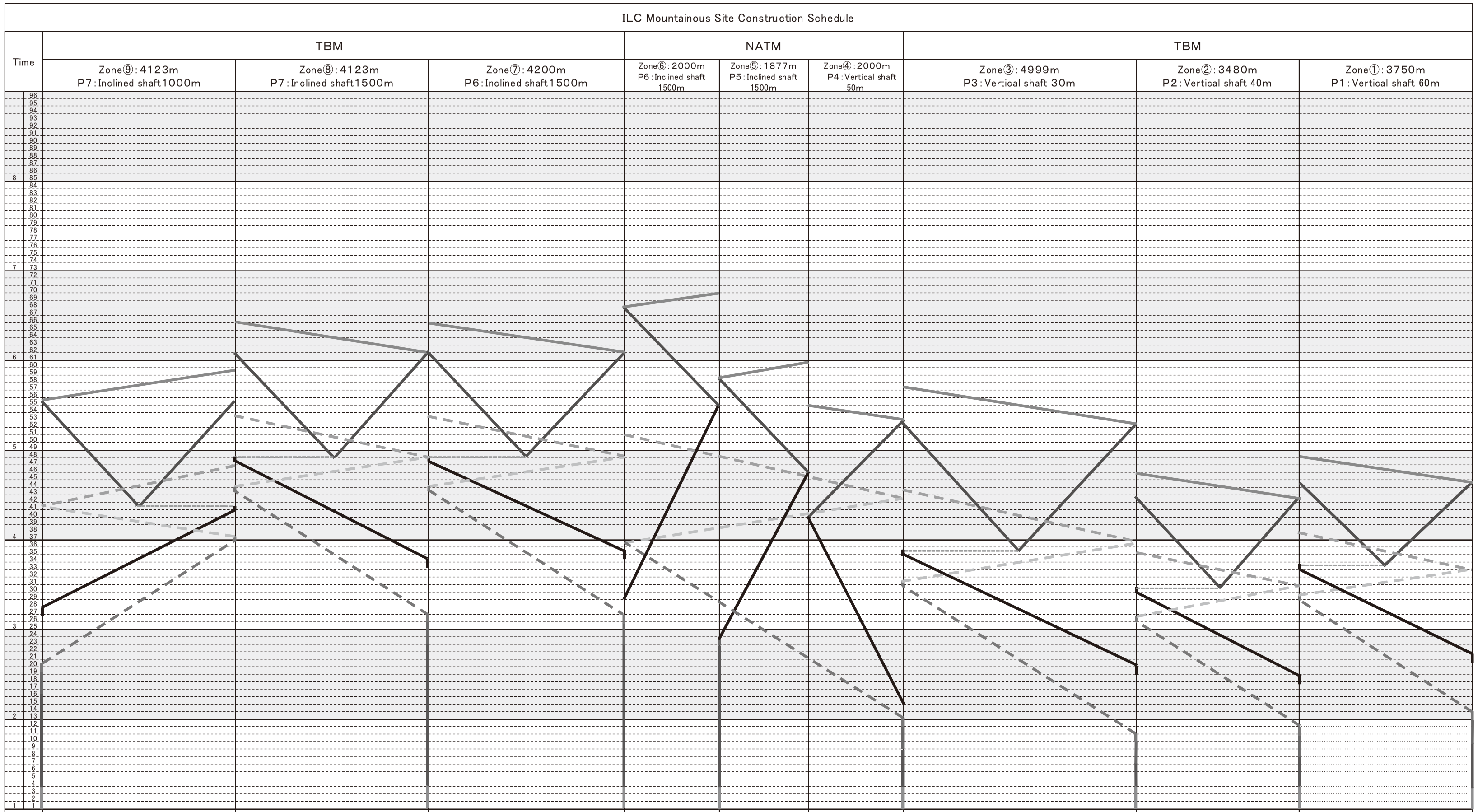
8.1 Overall Schedule for the Main Linac Tunnel, Sub-tunnel and Associated Caverns

Based on the ground conditions, access and construction zones as shown in Figure 3-5 for the sample site main linac tunnel, sub-tunnel and associated caverns, we made estimates for the access tunnel locations and numbers and scale. We suppose Zones (1)~(3) to be to going through a small overburden region and access would be by vertical shaft. Zones (4)~(6) are in the central region, it is planned that the excavation would be by NATM and access would be by inclined shaft such that each zone would be 2 km or less in length. Because Zones (8) and (9) of the sample site are under a surface topography where access is constrained, we assume locations for inclined shaft access tunnels at each end even though the zones become rather long and would be the project critical path.

Based on the scheduling rationales, Figure 8-1 shows our estimations for the outline scheduling of each zone.

From the start of preparatory construction the overall project would take approximately 5 years and 9 months. However, as the construction time of zone (2) is estimated to be shortest approximately 3 years and 9 months in this assumed conditions, parallel construction and facilities installation work would be possible for about 2 years.

Note that the overall project schedule given in Figure 8-1 does not include the construction of the drainage tunnel. However, since that work is estimated to only require 38 months (see Figure 6-11) we can ignore it for our purpose of finding the critical path for the entire project schedule.



	Zone⑨: 4123m P7: Inclined shaft1000m	Zone⑧: 4123m P7: Inclined shaft1500m	Zone⑦: 4200m P6: Inclined shaft1500m	Zone⑥: 2000m P6: Inclined shaft 1500m	Zone⑤: 1877m P5: Inclined shaft 1500m	Zone④: 2000m P4: Vertical shaft 50m	Zone③: 4999m P3: Vertical shaft 30m	Zone②: 3480m P2: Vertical shaft 40m	Zone①: 3750m P1: Vertical shaft 60m
Condition	Inclined shaft:1000m TBM:4123m EL-200 Total: 58 months	Inclined shaft:1500m TBM:4123m EL-250 Total: 65 months	Inclined shaft:1500m TBM:4200m EL-250 Total: 65 months	Inclined shaft:1500m NATM:2000m EL-250 Total: 69 months	Inclined shaft:1000m NATM:1877m EL-200 Total: 59.5 months	Vertical shaft:50m NATM:2000m EL-150 Total: 54 months	Vertical shaft:30m TBM:4999mm EL-130 Total: 56.5 months	Vertical shaft:40m TBM:3480m EL-140 Total: 45 months	Vertical shaft:60m TBM:3750m EL-160 Total: 47 months
Schedule Calculation	Preparation work: 3mos. Inclined shaft: 12.5mos. Assembly Tunnel: 3mos. TBM Assembly: 1mo. TBM Sub T :16.5mos.,Main T: 12mos. TBM Dismantlement: 0.5mo. Main T Con. Lining/2parts: 14mos. Sub T Shotcrete: 4mos. LVPS Spaces: 5.5mos. Floor Slab Con. :4mos.	Preparation work: 3mos. Inclined shaft: 19mos. Assembly Tunnel: 3mos. TBM Assembly: 1mo. TBM Sub T: 16.5mos.,Main T: 12mos. TBM Dismantlement: 0.5mo. Main T Con. Lining/2parts: 14mos. Sub T Shotcrete: 4mos. LVPS Spaces: 5.5mos. Floor Slab Con.: 4mos.	Preparation work: 3mos. Inclined shaft: 19mos. Assembly Tunnel: 3mos. TBM Assembly: 1mo. TBM Sub T: 16.5mos.,Main T: 12mos. TBM Dismantlement: 0.5mo. Main T Con. Lining/2parts: 14mos. Sub T Shotcrete: 4mos. LVPS Spaces: 5.5mos. Floor Slab Con.: 4mos.	Preparation work: 3mos. Inclined shaft: 19mos. Enlargement: 1mo. NATM Main T: 26mos. MainT Con. Lining: 13mos. Floor Slab Con.: 2mos.	Preparation work :3mos. Inclined shaft: 19mos. Enlargement: 1mo. NATM Main T: 22mos. MainT Con. Lining: 12.5mos. Floor Slab Con.: 2mos.	Preparation work: 3mos. Vertical sahft 5mos. Assembly. T: 3mos. TBM Assembly: 1mo.. TBM Sub T: 23.5mos. NATM Main T: 25mos. MainT Con.Lining:13mos. Sub T Shotcrete: 6mos. LVPS Spaces: 8.5mos. Floor Slab Con:. 2mos.	Preparation work: 3mos. Vertical shaft: 3mos. Assembly Tunnel: 3mos. TBM Assembly: 1mo. TBM Sub T: 20mos.,Main T: 14mos. TBM Dismantlement: 0.5mo. Main T Concrete Lining/2parts: 17mos. Sub T Shotcrete: 5mos. LVPS Spaces: 7mos. Floor Slab Concrete: 5mos.	Preparation work: 3mos. Vertical shaft: 4mos. Assembly Tunnel: 3mos. TBM Assembly: 1mos. TBM Sub T: 14mos.,Main T: 10mos. TBM Dismantlement: 0.5mos. Main T Con. Lining/2parts: 12mos. Sub T Shotcrete: 3.5mos. LVPS Spaces: 4.5mos. Floor Slab Con.: 3.5mos.	Preparation work: 3mos. Vertical shaft: 6mos. Assembly Tunnel: 3mos. TBM Assembly: 1mo. TBM Sub T: 15mos.,Main T: 11mos. TBM Dismantlement: 0.5mo. Main T Con. Lining/2parts: 11mos. Sub T Shotcrete: 3.5mos. LVPS Spaces: 4.5mos. Floor Slab Con.: 3.5mos.
Unit Process	Preparation work: 3mos. Inclined shaft: 80m/mth(include Pavement) Vertical shaft: 10m/mth(include Lining) Assembly Tunnel 3mos. NATM: 80m／mth NATM Isolation Distance: M-S 2mos.	TBM Sub T: 250m/mth TBM Main T: 350m/mth TBM Isolation Distance: M-S 4mos. TBM Assembly: 1mo. Dismantlement: 0.5mo. Main T Con. Lining: 150m/mth	Sub T Shotcrete: 1000m/mth Floor Slab Con. (Precast): 1000m/mth	LVPS Spaces: 0.5mos./part, 2.7part/1000m					

Figure 8-1. Project schedule for the main linac tunnel, sub-tunnel and associated facilities

8.2 Overall Schedule for the Collision Experimental Hall Including Access Tunnel and Vertical Shafts

The excavation of the collision experimental hall cavern should take about 64.5 months (5.4 years) as is shown in Figure 8-2.

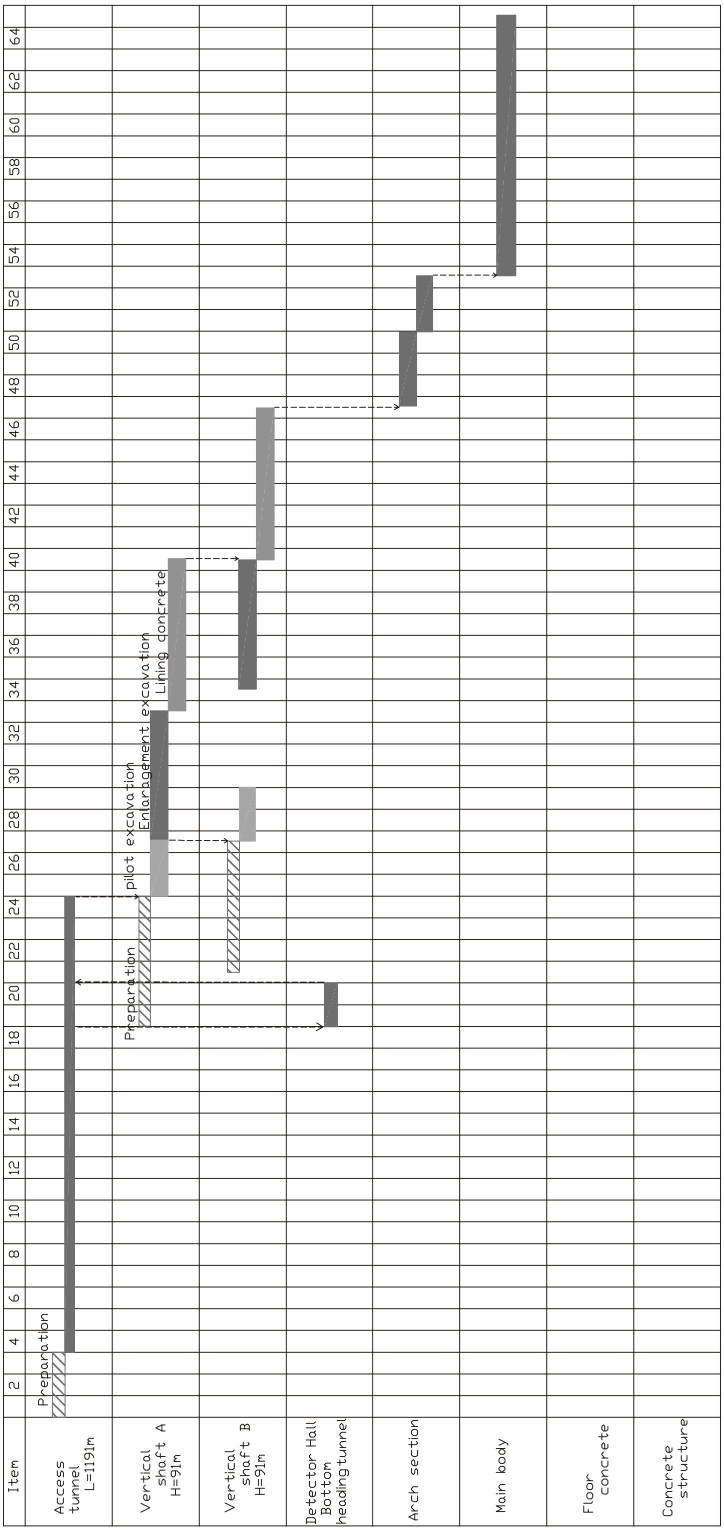


Figure 8-2: Project schedule for the detector hall

9. Conclusions

9.1 From the results of our investigations, we can conclude that the original philosophy – the tunnel should be located as shallowly as possible, the construction period should be short and underground water inflow should be handled via natural outflow – is consistent and feasible.

9.2 As for the schedule, it should be possible to complete the excavation and basic civil engineering construction in 6 years max, and 4 years if we are lucky. This is based on dividing the main tunneling work zones into 7 plus the collision experimental hall, where the maximum tunnel length would be less than 5 km. 2 years would be required for preliminary surveys and studies etc. and a further one-year of preparation before the real construction could begin. Therefore, even with that margin the total project should be able to be completed inside of 10 years.

9.3 Underground water inflow would be handled only by extremely small pumps, after which the water would flow out naturally under gravity. As compared with alternatives where all of the underground water has to be pumped up to the surface elevation from below, this provides a major plus to the Japan version single tunnel plan.

9.4 At this time we have investigate a large number of problems and potential problems, in this process we have assured ourselves that all problems are solvable and no insurmountable difficulties are likely to arise.

9.5 So far no actual site location has been fixed. Therefore this study could only consider the "sample site". However, once actual potential sites have been proposed more detailed surveys and studies will be undertaken, the result will be an even more definite and further rationalized plan.

9.6 Based on all the above work, our final conclusion is that the Japan version single tunnel proposal is completely realistic and realizable.

Editor's Note:

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