Annex F

Study on Water Resources Facilities

Annex F STUDY ON WATER RESOURCES FACILITIES

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Annex F STUDY ON WATER RESOURCES FACILITIES

F1 Introduction

In the Master Plan Study carried out in 2001 as the Phase 1 of the Study, the Development Scenario B was selected as the most optimum development scenario to meet the water demand of Metro Manila up to the target year 2025. Out of the components included in the Development Scenario B, the Project formulated in the Feasibility Study comprises Kaliwa Low Dam and Agos Dam as the water resources facilities as well as the two (2) lanes of Kaliwa-Taytay Waterways to convey water of the Agos River Basin to Metro Manila.

The Study contemplates to develop the proposed development plan (Development Scenario B) in accordance with the following staged development plan as discussed in Chapter VI of Volume IV:

Proposed Staged Development Plan of the Project (Development Scenario B)

Staged Development	Water Resources Facilities In the Agos River Basin	Kaliwa-Taytay Waterway
i) Stage 1	Kaliwa Low Dam	1st Waterway
ii) Stage 2		
• Stage 2 -1	Agos Dam (w/Agos Power Station)	-
• Stage 2 -2	-	2nd Waterway

Out of main structures involved in the Project, the development scales and features of Agos Dam and other main components are optimized as described in Chapter VI of Volume IV. These are tabulated in the table below:

Optimum Development Scale/Feature of the Project

	Item	Optimum Development Scale/ Feature
i)	Development Scale of Agos Dam	FSL at EL. 159m
ii)	Dam Axis of Agos Dam	Upstream dam axis
iii)	Dam Type of Agos Dam	Concrete Face Rockfill Dam (CFRD)
iv)	Operation mode of Agos Power Plants	Semi-base load operation with an installed capacity of 51.5 MW
v)	Diameter (D) of Upper Tunnels (Tunnel No.1) of Kaliwa-Taytay Waterway	D=3.5m
vi)	Installation of Lagundi Powerhouse	Installation of Valve House No.1 instead of Lagundi powerhouse

This Annex F explains the results of the comparison study on water resources facilities of the Project that are planned to be provided in the Agos River Basin.

F2 Water Resources Facilities in Stage 1 Development

F2.1 General

In the Stage 1 Development of the Project, the Kaliwa Low Dam is to be constructed as the water resources facilities in the Agos River Basin.

This Chapter F2 describes the Kaliwa Low Dam and the intake structure for the Kaliwa-Taytay Waterway.

F2.2 Kaliwa Low Dam

F2.2.1 Functions of Kaliwa Low Dam

The Kaliwa Low Dam is proposed to be constructed in the 1st Stage Development in order to convey water from the Kaliwa River Basin to Metro Manila through 1st Kaliwa-Taytay Waterway whose intake structures are located on the right bank of the Kaliwa River.

In the context of the Development Scenario B, the Kaliwa Low Dam is planned to be of a temporary structure, since it is planned to function only for three (3) years and eventually to be inundated by the reservoir of Agos Dam in case the proposed Project development plan is realized in accordance with the construction schedule shown in Figure J5.1 of Annex J. The Kaliwa Low Dam needs to be removed before the start of water impounding of Agos Dam so as to avoid accumulation of sediments on its immediate upstream reach of the Kaliwa River. Accordingly, the Kaliwa Low Dam is planned to be constructed using mainly earth/rock materials to be produced from excavation works for intake structure and waterway tunnel from the economical aspect.

In addition to the temporary structure type, the present Study contemplates the alternative structure type of Kaliwa Low Dam with more durability. These two structural types of Kaliwa Low Dam are shown in Figure F2.1.

F2.2.2 Temporary Structure Type of Kaliwa Low Dam

Figure F2.2 illustrates a general layout plan of the temporary structure type of the Kaliwa Low Dam.

The crest level of the Kaliwa Low Dam is set at EL. 129m, which is 4m lower than an minimum operation level (MOL) of Agos Dam. At the riverbed of the Kaliwa Low Dam site, hard rock appears at about 5m below from ground surface. The dam height of the Kaliwa Low Dam is 36m. A sand flush gate is planned to be provided in concrete wall on the right bank in order to flush out sands depositing in front of the Kaliwa Low Dam during its operation.

No spillway gates are planned to be provided on its crest so that the flood water will be discharged downstream overflowing its crest. A 5-year probable flood of 1,670 m^3/sec is adopted as the design flood therefor. For the design flood, an overflow depth on dam crest is estimated at about 3.6m for the crest length of 110m.

After the completion of the Stage 1 Development, the Kaliwa River water is taken by an intake structure of 1st Kaliwa-Taytay waterway for the purpose of water supply to Metro Manila, which is to be provided on the right bank of the Kaliwa Low Dam site.

The Kaliwa Low Dam is designed to have upstream and downstream slopes of 1:2.4 and 1:1.5, respectively. Its crest width is 8m. The dam body is planned to be built mainly with random fill materials to be obtained through excavation works for the Kaliwa Low Dam, intake structure and upper headrace tunnel (Tunnel No.1) for 1st Kaliwa Taytay Waterway. The 4m thick crest portion up to EL.125m is planned to be built with crib blocks so as to allow the flood flow to overtop from the crest. Besides, the downstream embankment surface will be protected with cribs filled with rocks. The upstream zone of Kaliwa Low Dam will be embanked with earth materials, forming the impervious zone.

F2.2.3 Durable Structure Type of Kaliwa Low Dam

It is conceived that Kaliwa Low Dam would be utilized over a longer period if the Kaliwa Low Dam is built to function as a water transfer intake for the Laiban Dam. As described in Volume II and Volume III, this represents the case of the Development Scenario G, one of the 8 development scenarios examined in the Master Plan Study stage (2001), in which the water resources facilities are going to be constructed in the order of Kaliwa Low Dam, Laiban Dam, and Agos Dam. In such a case, Kaliwa Low Dam needs to be constructed to have more durability.

The durable structure type for Kaliwa Low Dam is shown in Figure F2.1. In case of the alternative design, the upstream embankment surface is protected with cribs filled with rocks and further the whole embankment surfaces are covered with concrete slab so as to extend a life of the Kaliwa Low Dam. With the design, Kaliwa Low Dam will be durable over at least 10 years.

The following table compares the construction costs of the temporary structure type and durable structure type for Kaliwa Low Dam:

Cost Comparison of Construction Costs of Alternative Designs for Kaliwa Low Dam

Structural Type of Kaliwa Low Dam	Construction Cost (Million US$)
- Temporary Structure Type	7.26
- Durable Structure Type	7.40

The present feasibility-grade design adopts the temporary structure type taking into account the easiness in removing the Kaliwa Low Dam, although there is no large difference between the construction costs of the two structural types as shown in the above table.

F2.3 Intake Structure for Kaliwa-Taytay Waterway

An intake structure is planned to be constructed for each of the two (2) lanes of Kaliwa-Taytay Waterway to convey the daily maximum discharge of 3,640 MLD at the full development stage of the Project. These two (2) intake structures are laid out on the right bank of the Kaliwa Low Dam site as shown in Figure F2.2. The intake structures for 1st and 2nd lane of the Kaliwa-Taytay Waterways are situated just upstream and downstream of the Kaliwa Low Dam axis, respectively.

The proposed intake structure is of sloped and multi-stages intake type with intake gate shaft. The sill level of the lowest inlet portion is set at EL. 120m. The 1st lane of Kaliwa-Taytay Waterway to be provided in the Stage 1 Development will take the Kaliwa River water to be diverted by Kaliwa Low Dam, while both Waterways will convey water to be regulated by Agos Dam to Metro Manila after their completion in the Stage 2-2 Development of the Project. Although there is some time lag in the scheduled completion times of Kaliwa Low Dam and 2nd Lane Kaliwa-Taytay Waterway, main part of the intake structure for the 2nd Kaliwa-Taytay Waterway will also have to be constructed in the Stage 1 Development, as well as that for the 1st lane of Kaliwa-Taytay Waterway.

The intake structure is designed to have three inlet portions along the sloped intake surface, whose intake sill levels differ one another. During the operation of the Kaliwa Low Dam to be constructed in the Stage 1 Development, the Kaliwa River water will be fed by the lowest inlet connected to the waterway tunnel of 3.5m diameter. On the other hand, the upper two inlets will also be used to feed the Agos Reservoir water after the completion of Agos Dam. Screens are planned to be provided in front of these three (3) inlet portions of the sloped intake to prevent floating matters such as trees from going inside the downstream waterway tunnel (Tunnel No.1 of the Kaliwa-Taytay Waterway). Thus, the Agos Reservoir is connected with intake gate shaft of 14m diameter by the three conduits to allow intake of the Agos Reservoir water at the three different stages of EL. 120m, 134m and 147m. This will enable the feeding of water at selected depths (usually taken at shallow depths) where better quality of water would be available.

F3 Water Resources Facilities in Stage 2 Development

F3.1 General

The feasibility-grade design for the Agos Dam and its appurtenant structures were carried out applying the design criteria and standards in Japan and those accepted internationally.

As stated in the foregoing Chapter F1, the optimum development scale of the Agos Dam is found to be FSL 159m, which is associated with the Agos power station with an installed capacity of 51.5 MW. This Chapter F3 presents the results of comparative study on Agos Dam and its appurtenant structures as well as the feasibility-grade design thereof.

F3.2 River Diversion Facilities

F3.2.1 Functions of River Diversion Facilities

The Agos River flow needs to be diverted to make the construction area of the Agos main dam and its appurtenant structures dry during their construction. The hydrological analysis reveals that a larger magnitude of flood occurs on the Agos mainstream and Kanan River not only in the wet season, but also in the dry season to lesser extent. Accordingly, it is prerequisite to adopt the river diversion method combined by diversion tunnels and cofferdams for the purpose of construction of the Agos Dam.

Concrete face rockfill dam (CFRD) is selected as the most suitable dam type for the Agos Dam as discussed in Chapter F1. It is accepted that the CFRD has a high resistibility against overtopping flow from its dam crest during the construction. From the point of view, it is determined that a 20-year probable flood of 4,360 m^3/sec at the Agos Dam site is adopted as the design flood for the river diversion works.

F3.2.2 River Diversion Alternatives

Since the Study contemplates to use one diversion tunnel for the river outlet facilities that are to be provided as the permanent structure, at least two diversion tunnels need to be constructed. With the plan, one tunnel can continue to divert the river flow in the dry season, while the river outlet facilities are installed in the other diversion tunnel. Concerning the alignment of these two diversion tunnels, it is preferable to provide one diversion tunnel to be used for the river outlet on the left bank, since the plunge pool of spillway can be used as an energy dissipater for the river outlet. While, the other diversion tunnel has to be aligned on the right bank, since the left bank is congested with such structures as spillway, Agos power waterway and the one diversion tunnel. The other aspects to be taken into account in determining the alignments of diversion tunnels and cofferdams are the following topographic and geological conditions specific to the Agos Dam site:

a) The river deposits at the Agos Dam site are as deep as 35 to 40m. The present feasibility-grade design contemplates to remove the river deposits so that the plinth of CFRD is founded on the fresh rock below the river deposits. Consequently, there is a possibility that the seepage of river water stored by the upstream cofferdam will reach the deeply excavated portion to provide the plinth during construction of the Agos Dam, hampering the smooth construction thereof.

b) The distance from the Agos dam axis to the confluence of the Kanan and Kaliwa Rivers is very short at about 550m. Hence, the upstream cofferdam will have to be constructed adjacent to the Ago Dam in case the upstream cofferdam is aligned on the Agos mainstream. This may cause the seepage problem in the foundation of the Agos Dam during its construction.

To cope with the seepage problem in the main dam foundation during the construction, the following two river diversion methods are worked out for the comparison:

i) River Diversion Method-A: In the method-A, an upstream cofferdam is planned to be constructed on each of the Kanan and Kaliwa Rivers to secure a sufficient seepage length between the upstream cofferdam and the main dam foundation. The two ponds created by the two cofferdams, one on each of the Kanan and Kaliwa Rivers, are linked by 372m long connecting tunnel of 6m diameter which is not to be concrete-lined. To minimize seepage water from ponds of the upstream cofferdams, which may reach a construction area in the foundation of the Agos main dam through river deposits, a slurry wall is planned to be provided along the upstream toe of the upstream cofferdam. Thus, the safer side design is adopted in the Method-A. Besides, the cofferdam crests can be utilized as the temporary access roads to the upstream quarry site during the construction of the Agos Dam.

ii) River Diversion Method-B: In the method-B, an upstream cofferdam is planned to be constructed on the Agos mainstream. The right diversion tunnel length in this method-B becomes shorter than the Method-A mentioned above. In consideration of the very short distance between the upstream cofferdam and foundation of the Agos main dam, a slurry wall in river deposits will have to be constructed at the upstream toe of the upstream cofferdam as shown in Figure F3.1.

The pond areas on the Kanan and Kaliwa Rivers that are to be created by the upstream cofferdam on the Agos mainstream, the main tributaries of the Agos River, are planned to be linked by the connection channel as shown in Figure F3.2. The connecting channel will be constructed by excavating lowermost part of the quarry site area intervening between the two tributaries. Since it is needed to continuously access to the quarry site during the embankment works for the Agos Dam to carry the quarry rock materials to the Agos Dam site, a temporary bridge with high piers across the connecting channel or Kaliwa River is planned to be built taking into account the hydrological condition that a large-scale flood sometime occurs on the Kanan River even in the dry period.

The typical cross sections of these two (2) river diversion alternatives are compared in Figure F3.1. Figure F3.2 shows the general layout plan of the Method-B, while that of the Method-A is illustrated in Figures F3.3.

F3.2.3 Comparison of Alternative River Diversion Method

To find out the optimum combination of diameter of diversion tunnels and height of upstream cofferdam(s), the upstream maximum water level required to discharge the design flood of 4,360 m^3/sec is calculated by diameter of diversion tunnels for each of the two (2) cases. There is a general tendency that it is cost-effective to divert the design flood with diversion tunnels of smaller diameter by heightening the upstream cofferdam(s). Judging from the construction time schedule of the Project, on the other hand, the embankment volume of upstream cofferdam has to be limited to that in the maximum, which can be embanked during one dry season. In the present feasibility-grade design, the maximum embankment volume of upstream cofferdam(s) is conservatively estimated at about 1.2 million m^3. As a result, the economic diameter of the diversion tunnels is determined to be 10m, in case the upstream cofferdam crest level is set at EL. 81m.

To select the most appropriate diversion method, the aforesaid two (2) river diversion methods, Method-A and Method-B, are compared from the aspects of cost and safety in the construction as described below.

i) The construction costs of the river diversion works for each of the Method-A and Method-B are preliminarily estimated. With regard to the diversion tunnel and cofferdam embankment, the work quantities in the Method-B are derived to be smaller than those in the Method-A, since only one cofferdam is to be built on the Agos mainstream more adjacent to the Agos Dam in case of the Method-B. On the other hand, the Method-B requires construction of the connecting channel and a temporary bridge to cross over the connecting channel or the Kaliwa River as mentioned above. Consequently, the construction costs of the Method-A and method-B are both approximated at 71.0 million US$, showing that there is no large difference between the construction costs of the two alternative river diversion methods.

ii) It is essential to ensure the seepage water to be shut off during the construction of the Agos dam foundation in order to complete the Agos Dam in accordance with the proposed schedule. The Method-A is much safer than the Method-B in view of seepage water reaching the construction area of the Agos main dam foundation taking into account a very short distance between the cofferdam and main dam in the Method-B.

From the above comparison, it is determined that the present feasibility-grade design adopts the Method-A as the river diversion method for construction of the Agos Dam. It is recommended that more detailed comparison study be carried out in the next detailed design stage after clarification of engineering and physical properties of the river deposit materials at the Agos Dam site.

The principal features of the river diversion works are itemized below:

Principal Features of River Diversion Works

1) Upstream cofferdam		
- No.1 cofferdam on the Kanan River	・Crest elevation	: EL. 81m
	・Height	: 35m
	・Embankment volume	: $0.64\text{x}10^6$ m^3
- No.2 cofferdam on the Kaliwa River	・Crest elevation	: EL. 81m
	・Height	: 36m
	・Embankment volume	: $0.57\text{x}10^6$ m^3
- Downstream cofferdams	・Crest elevation	: EL.57.0
	・Height	: 16m
2) Diversion Tunnels		
- No.1 Diversion Tunnel on the Left Bank	・Diameter	: 10m
	・Length	: 772m
- No.2 Diversion Tunnel on the Right Bank	・Diameter	: 10m
	・Length	: 1,589m
3)Connecting Tunnel between the Kanan and Kaliwa Rivers		
	・Diameter	: 6.0m
	・Length	: 372m

Figure F3.4 shows the inflow and outflow hydrographs of 20-year probable flood on the condition that the above river diversion facilities be provided.

F3.3 Main Dam

F3.3.1 Surcharge Water Level of Agos Reservoir

As described in the succeeding Section F3.4, the combined type of gated and non-gated weir portions is adopted as the spillway type.

To avoid occurrence of adverse effect on the downstream reach of Agos Dam due to improper operation of the spillway gates, the Study contemplates to set the reservoir surcharge water level for a 5-year probable flood. The usual floods of a 5-year probable flood and less than that are to be discharged downstream from the non-gated weir portion without opening the spillway gates. As a result of the hydraulic analysis, the surcharge water level is derived to be EL.160.8m as shown in Figure F3.5.

F3.3.2 Freeboard

The Agos Dam type is selected to be a concrete face rockfill dam (CFRD) with a FSL of 159m. The design flood for the Agos Dam is adopted to be 1.2 times the 200-year probable flood at the Agos Dam site in accordance with the design criteria for fill type dam in Japan. The design flood for Agos Dam is derived to be 9,620 m^3/sec through the hydrological analysis. Besides, the Agos Dam is designed to secure the safety against the probable maximum flood (PMF) thereat. The PMF is estimated at 17,100 m^3/sec.

A freeboard for Agos Dam is calculated for the following four (4) cases:

Case-(i) Freeboard (H_{f1}) required on the condition of the reservoir water level being FSL

$$H_{f1}=h_{w1}+h_e+h_a+h_i$$

Case-(ii) Freeboard (H_{f2}) for surcharge water level
$H_{f2}=h_{w1}+h_e/2+h_a+h_i$
Case-(iii) Freeboard (H_{f3}) for design flood water level (for Q=9,620 m^3/sec)
$H_{f3}=h_{w1}+h_a+h_i$
Case-(iv) Freeboard (H_{f4}) for flood water level of PMF (Q=17,100 m^3/sec)
$H_{f4}=h_{w2}+h_i$

Where, H_{fi}: Freeboard (m)
h_w: Rise of reservoir water level generated by wind (m)
(h_w is derived at 2.2m for sloped surface ($=h_{w1}$) and 0.6m for vertical slope (h_{w2}) adopting the design wind velocity of 30 m/sec)
h_e: Rise of reservoir water level generated by earthquake (m)
(*he* is derived at 1.4 m adopting an earthquake coefficient of 0.15).
h_a : Allowance in case of spillway gate being installed (m) (*ha*=0.5m)
h_i : Allowance in case of fill type dam (m) (*hi*=1.0m)

The required dam crest elevation is estimated for each of the four (4) different conditions mentioned above:

Case	Reservoir Water Level	Freeboard	Required Crest Level
Case-(i)	EL. 159m (=FSL)	$H_{f1}=h_{w1}+h_e+h_a+h_i$=5.1 (m)	EL. 164.1m
Case-(ii)	EL.160.8 m (=SWL)	$H_{f2}=h_{w1}+h_e/2+h_a+h_i$ =4.4 (m)	EL. 165.2m
Case-(iii)	EL. 161.5m (FWL for Design Flood)	$H_{f3}=h_{w1}+h_a+h_i$ =3.7 (m)	EL. 165.2m
Case-(iv)	EL. 163.2m (FWL for PMF)	$H_{f4}=h_{w2}+h_i$ =1.1(m)	EL. 164.3m

From the above examinations of freeboard, it is determined that the crest elevation of the Agos Dam is set at EL. 165.2m. Figure F3.5 shows the inflow and outflow hydrographs of the design flood and PMF for the Agos Dam.

F3.3.3 Dam Foundation Excavation

The typical cross section of Agos Dam whose dam type is selected to be CFRD is shown in Figure F3.6. The upstream surface of the dam body is composed of face concrete whose toe forms plinth. To ensure the dam stability against earthquake and considering the dam height of about 125m above ground surface in the river channel, the dam foundation of upstream side including the plinth is designed to be placed on fresh rock by means of excavating river deposits of 40m deep in the maximum. On the typical cross section, consequently, about one third of the total base width including the plinth is founded on fresh rock in order to ensure the dam safety.

The maximum dam height above bottom of the plinth is about 165m and the total crest length is 780m.

F3.3.4 Dam Embankment

The Agos Dam designed to be of CFRD is composed of the following embankment zones in the order from upstream zone to downstream one, except for the concrete face forming the most upstream zone of CFRD:

- Zone 1A: Impervious earthfill on plinth
- Zone 1B: Random fill on plinth
- Zone 2A: Fine filter
- Zone 2B: Coarse filter
- Zone 3A: Selected small rock
- Zone 3B: Rockfill, quarried rock
- Zone 3C: Rockfill, random rock and gravel to be obtained from excavation of dam, spillway and other structures
- Zone 3D: Selected large rock for riprap

Out of the above embankment materials for Agos Dam, the rockfill materials occupy a larger part of the total embankment volume. The rockfill materials to be used for above embankment of CFRD are planned to be obtained from the following sources:

- Quarry site located immediately upstream of the confluence of the Kanan and Kaliwa Rivers, which is intervened by the both rivers,
- River deposit of the Agos River where gravel materials are to be obtained from excavation of river deposit for construction of the main dam foundation,
- Structure sites at the Agos Dam site such as the main dam, spillway, diversion tunnels and power facilities site where rock materials are to be obtained from excavation works for construction thereof,

The rockfill materials obtained from the above sources are sound greywacke, basalt and pyroclastic rock, which are hard and stable with an unconfined compressive strength of 50-60 Mpa (510-610 kgf/cm^2). Accordingly, these rock materials are judged to have sufficient qualities required for the rockfill materials.

F3.3.5 Dam Slopes

The embankment slopes of CFRD which can ensure the dam stability are dependent mainly on quality of rockfill materials and magnitude of earthquake at the dam site. In the detailed design on the MWSP III, on the other hand, the Laiban Dam on the Kaliwa River was designed to be of CFRD. The detail design on Laiban Dam adopted the upstream and downstream slopes to be 1:1.5. This suggests that the similar slopes should also be adopted for the Agos Dam, since the Laiban Dam is situated adjacent to the active fault and in the strong seismic zone as well as the Agos Dam and the rockfill materials to be used for these two (2) CFRDs are very similar to each other.

Table F3.1 shows upstream and downstream slopes of CFRD designed worldwide. As shown in the Table, the upstream and downstream slopes of 1:1.5 are in a safer range for CFRDs constructed with rock materials other than gravel. According to ICILD Bulletin, “Rockfill Dams with Concrete Facing”, beside, downstream slope of 1:1.4 is suggested for the high seismic area.

Taking into account the design example of CFRD in the Laiban Dam as well as the worldwide dam engineering mentioned above, the upstream and downstream slopes for the Agos Dam are determined to be 1:1.5. It is recommenced that the dynamic analysis of the Agos Dam be carried out in the next detailed design stage to further verify the dam safety against earthquake.

F3.3.6 Concrete Face Slab, Plinth and Joints

The concrete face slab is designed to be of reinforced concrete with larger thickness downward. The sloped concrete face slab functions as impervious zone in the upstream embankment surface. Thickness of the concrete face slab is estimated using the formula: T=0.3 + 0.003 x h, where, T is thickness in meter, and h is vertical height in meter below dam crest. Consequently, the thickness of the concrete face slab varies from 30cm at the top to 80cm at the bottom linked to its plinth.

The concrete face slab and plinth are planned to be placed at 15m interval using a slip form on the fine filter zone (Zone 2A). The water stops made of copper and stainless will be provided along joints between the two concrete face blocks. It is essential to embank the impervious material (Zone 1A) on concrete face slab in the high static water pressure zone and plinth, which is to act as a joint or crack healer.

The plinth is to be placed at a toe of the upstream sloped concrete face slab. Taking the static water pressure into consideration, the width and thickness of the plinth are determined to be 8.0m and 1.0m, respectively.

F3.3.7 Parapet Wall

A 6m high vertical parapet wall will be provided at the upstream dam crest portion to reduce the total dam embankment volume. Besides, it is expected to be useful to protect people and cars on the dam crest from splash of the reservoir water, when a large-scale flood takes place. Its top elevation is set at EL. 166.0 m, which is 0.8 m higher than the main dam crest level. The parapet wall will be placed on the top of the sloped face slab concrete.

F3.3.8 Main Features of Agos Dam

The main features of Agos dam are as follows:

- Dam crest elevation : EL. 165.2m
- Parapet top elevation : EL. 166.0m
- Lowest elevation of dam foundation and plinth : EL. 0m
- Maximum dam height : 165.2m
- Dam slopes : 1:1.5 for upstream slope
  : 1:1.5 for downstream slope
- Dam crest length : 780 m
- Maximum length of plinth : 8 m
- Dam volume : 13.4×10^6 m^3

The general layout plan of the Agos Dam is shown in Figure F3.3.

F3.4 Spillway

F3.4.1 Conditions and Principles for Spillway Design

The spillway has to safely discharge downstream the design flood and probable maximum flood (PMF). The design flood is adopted to be 1.2 times 200-year probable flood at the Agos Dam site. The design flood and PMF are estimated at 9,620 m^3/sec and 17,100 m^3/sec, respectively, through the hydrological analysis. Because of such large scales of those floods, spillway gates need to be provided to safely spill out them. Besides, the non-gated overflow sections are provided to pass the usual floods equal to and less than a 5-year flood without opening spillway gates in order to avoid occurrence of sudden flooding in the downstream reach due to the mal-operation of spillway gates as mentioned in the foregoing Subsection F3.3.1. Thus, the combined type of gated and non-gated overflow sections is selected as the spillway type.

From the topographic and geologic conditions at the Agos Dam site as well as the immediate downstream meandering of the Agos River to the right, it is preferable to align the spillway on the left bank.

The proposed spillway is composed of the following four sections in the order from upstream to downstream:

- Forebay including non-gated overflow weir portions,
- Gated overflow weir section,
- Chuteway, and
- Energy dissipater

F3.4.2 Length of Non-Gated Overflow Weir Portion

To determine the adequate combination of number of spillway gates and length of non-gated overflow weir section, the economic comparison is made for the following two (2) cases:

Case-A: Four (4) spillway gates, each having a clear span of 14m, and a 200m long non-overflow section on both sides of forebay are provided.

Case-B: The same number of spillway gates with the same dimensions as those in Case-A and a 200m long non-gated overflow section only on mountain side of forebay are provided.

The alignment and section of spillway overflow crest portion in Case-A and Case-B are shown in Figure F3.7. The required freeboard is estimated for each of Case-A and Case-B to determine their dam crest elevations. In succession, the total costs of spillway and main dam are calculated for each case. The results are shown in the following table:

Item	Case-A	Case-B
1. Length of Overflow Section		
• Number of Spillway Gates	4	4
(14m width per 1 gate)		
• Length of non-gated overflow weir in forebay		
- Mountain side	200m	200m
- River side	200m	-
Total	400m	200m
2. Required Freeboard		
• Flood water level of reservoir		
- 5-year probable flood	160.75	161.71
- Design flood (1.2 x 200-year)	161.49	162.43
- PMF	163.20	165.11
3. Dam Crest Elevation	165.2	166.2
4. Construction Costs of Dam/Spillway		
- Dam	95 mill. US$	100 mill. US$
- Spillway	108 mill. US$	119 mill. US$
Total	203 mill. US$	219 mill. US$

From the above economic comparison, the Case-A is selected as the optimum dimensions for the spillway.

F3.4.3 Overflow Weir Sections

As mentioned above, the spillway overflow sections consist of 4 gated portions, each having 14m in width, and a 200m long non-gated overflow section on each side of forebay in front of the gated portion. The crest elevation of gated overflow weir is set at EL. 151.5m, while that of non-gated overflow weir is at EL. 159m that is equal to FSL.

Each spillway gate has a dimension of 14m in width and 11m in height. With the dimension, the usual floods up to 5-year probable flood can be regulated without opening any spillway gates.

In the vent of the design flood of 9,620 m^3/sec and PMF of 17,100m^3/sec, the reservoir water level rises to EL. 161.5m and EL. 163.2m, respectively.

F3.4.4 Chuteway

After passing the gated overflow section, the excessive flood is to be conveyed by the spillway chuteway whose width is gradually reduced downstream from 120m to 90m. The chuteway has a slope of 1:4.3 downward with exception of the upper section. The chuteway wall heights in the respective sections are determined so that the water levels of the design flood and PMF do not exceed the wall top elevations. Aerators are to be provided in slab concrete of the chuteway in order to avoid occurrence of cavitation which may lead to its erosion.

F3.4.5 Energy Dissipater

The energy dissipater is required to be provided at the downstream end so as to return the flood water to the Agos River after dissipating its high energy accelerated when it goes down the chuteway. From the economic viewpoint, a 100-year probable flood is adopted as the design flood for the energy dissipater.

As the energy dissipater in the spillway, the following two (2) alternative types are conceivable:

- Type-1: Plunge pool
- Type-2: Stilling basin

The above two (2) alternatives for energy dissipater are illustrated in Figure F3.8. In case of the stilling basin, the hydraulic analysis reveals that a 140m long channel is required dissipate the flow energy. Because of the geologic condition thereat, a considerable quantity of concrete needs to be placed to construct the stilling basin.

The following table compares the construction costs of the Type-1 and Type-2:

Comparison of Construction Costs of Alternatives for Spillway Energy Dissipater

Item	Type-1: Plunge Pool	Type-2: Stilling Basin
• Quantity of major work item for energy dissipater - Concrete - Excavation	 21,600 m^3 1.62 10^6 m^3	 143,100 m^3 9.96 m^3
• Construction Cost of Energy Dissipater	14.4 million US$	76.0 million US$

As shown in the above table, Type-1 is much economical than Type-2. Therefore, it is determined to adopt the plunge pool as the spillway energy dissipater.

As a result of the hydraulic analysis, the water jet of 100-year probable flood jumped from the flip bucket whose floor elevation is set at EL. 153m reaches 80m downstream. Besides, the required depth of the plunge pool is derived at 20m. Based on the results of the hydraulic analysis, the length and bed level of the plunge pool are determined to be 90m and El. 20m, respectively.

The plan, profile and sections of the proposed spillway are shown in Figures F3.3 and F3.9.

F3.5 River Outlet

The river outlet works are planned to be provided for the following purposes:

- To release water to the downstream reach of Agos Dam that is required for irrigation and other purposes in case the Agos power plants stop the power generation,
- To lower the reservoir water level in case the emergency takes place,

The river outlet is planned to be provided in the diversion tunnel on the left bank. Since the intake level of the river outlet needs to be set above the reservoir sediment level, the river outlet intake consisting of morning glory type is planned to be newly constructed on the upper position of centerline of the left bank's diversion tunnel. The river outlet intake is connected with the left bank's diversion tunnel through the vertical shaft of 8.0m diameter and then the reservoir water is planned to flow down through a steel pipe from 70 m long plug concrete below the Agos

Dam to the valve chamber to be provided just downstream of the plug concrete. Finally, the reservoir water will go into the plunge pool through the left diversion tunnel which is aligned to pass below the spillway flip bucket.

F4 Agos Hydropower Facilities

F4.1 Basic Policy of Hydropower Development

The Study contemplates to develop hydropower to effectively harness the head to be created by the Agos Dam as well as the water in excess of that to be conveyed to Metro Manila out of the water to be regulated by the Agos Dam. The Agos powerhouse is planned to be provided at a toe of the Agos Dam. As discussed in Annex H, the installed capacity of the Agos power station is optimized at 51.5 MW.

As discussed in Chapter VI of Volume IV, the mean daily water demand of Metro Manila in the year 2025 is projected to be 6,980MLD in 2025, of which 3,000MLD is planned to be supplied from the Agos River Basin. Thus, it takes about 8 years for the water demand of Metro Manila to reach 3,000 MLD after the start of water supply from the Agos Dam/Reservoir in 2017. During the immature period of water demand in Metro Manila, the water to be exploited by the Agos Dam that exceed the water demand of Metro Manila will be able to be effectively utilized for the hydropower generation.

F4.2 Economic Comparison of Alternative Waterway Plans

The Agos hydropower facilities comprise power intake, headrace tunnel, penstock line, and powerhouse. For the power waterway, the following two (2) alternative waterway plans are worked out for the comparison:

i) Route-1: Left-bank power waterway
ii) Route-2: Right-bank power waterway

These two waterway routes for the Agos power station are shown in Figures F4.1 and F4.2 and compared below:

- In case the power waterway is aligned on the left bank, the Agos powerhouse needs to be provided in the space between the downstream toe of the Agos Dam and the spillway plunge pool. However, there is a possibility that the powerhouse is hit by the water jet when a large-scale flood is discharged from the spillway. Therefore, the Agos powerhouse needs to be aligned at the location where it is not hit by the water jet from the spillway plunge pool.
- Figures F4.1 and F4.2 show the waterway alignments on the left and right banks, respectively. The total length of the power waterway in the right bank waterway plan is 1,106m, while that in the left bank waterway plan is 755m. Thus, the total length of the left bank waterway is 351m shorter than that of the right bank waterway.
- In case of the left bank waterway, it is envisaged that it is not necessarily economical to provide a surge tank on the waterway route because of its rather short length. While, the right bank waterway requires construction of a surge tank.

The surge tank in the Route-2 is designed to be of the restricted orifice type, which is generally accepted to be the most economical. The major dimensions of the surge tank are derived through the hydraulic analysis adopting the flow velocity of 3.5 m/sec in headrace tunnel and 5m/sec in penstock as shown below:

Main dimensions of Surge Tank in Route-2

- Orifice diameter	2.3m
- Diameter of main shaft	6.5m
- Up-surge level	EL.171.4m
- Down-surge level	EL.123.7m

Based on the major structures' dimensions including those of surge tank mentioned above, the waterway construction costs in the Route-1 and Route-2 are estimated as follows:

Features and Construction Costs of Waterway Alternatives for Agos Power Station

Item	Route-1 (Left Bank)	Route-2 (Right Bank)
- Maximum Plant Discharge	55.4 m^3/sec	55.4 m^3/sec
- Headrace tunnel	535m long x 5.9m in diameter	777m long x 4.5m in diameter
- Surge tank	-None	Main shaft: 53 m high x 6.5m in diameter with upper/lower chambers
- Penstock line	212m long x 5.4m in diameter	321m long x 3.8m in diameter
- Construction cost	78.7 million US$	81.7 million US$

The above cost comparison clarifies that the Route-1 is more economical than the Route-1. Therefore, it is determined to align the power waterway on the left bank.

F4.3 Principal Features of Agos Hydropower Facilities

(1) Power Intake

In front of inlet structure of the power intake, trashracks are provided to prevent trash from intruding into the waterway. Besides, the dimension of inlet structure is designed so that flow velocity at the trashracks is 0.5 m/sec so as to trap trash.

The sill level of the inlet culvert is set at EL.120 to keep the pressure flow condition even when the reservoir water level is at the minimum operation level (MOL) of EL.133m.

(2) Headrace Tunnel and Penstock Tunnel

The total length of the Agos power waterway from the inlet structure to the center of turbine accommodated in the powerhouse is about 755m, out of which the upper 535m tunnel section is designed to be of headrace tunnel without steel lining on account of the lower water pressures. The intake gate shaft is planned to be constructed about 148m downstream of the inlet structure. While, the lower tunnel section of about 212m to the turbine is designed as penstock tunnel due to the high water pressures.

In case of the Agos power waterway on which a surge tank is not provided, the hydro-mechanical equipment such as turbine and generators require excessively large dimensions in case high velocities in the waterway are adopted, eventually resulting in large size of the Agos powerhouse. Based on the results of the comparative study taking into account the economical size of powerhouse which is to be constructed in a limited space at the downstream toe of the Agos Dam on the left bank, the velocities in headrace tunnel and penstock are adopted to be 2.0 and 2.4 m/sec, respectively. Consequently, the diameters of headrace tunnel and penstock are determined to be 5.9m and 5.4m, respectively.

(4) Agos Powerhouse

The Agos powerhouse is designed to be located about 250m downstream of the Agos Dam axis on the right bank, since there is not enough space to construct it keeping the necessary distance from the spillway plunge pool on the right bank as mentioned above.

Two types of powerhouses, namely outdoor type and underground type, are conceivable as the type for the Agos powerhouse. From the topographical and geological conditions, however, the outdoor type is obviously much more economical than the underground type. Therefore, the outdoor type is selected as the type for the Agos powerhouse.

The ground elevation in the powerhouse yard is determined to be EL. 55m, which is 1m higher than the flood water level of the Agos River corresponding to 1.2 times 200-year probable flood. The dimensions and elevations of the powerhouse are determined to accommodate two units of the generating equipment, each having an installed capacity of 25.75MW. The turbine center is set at EL. 33.4m and the floor level of generator room at EL. 39.5m. The approximate dimension of the powerhouse is 48.3m in length, 34.4m in width and 47.4m in height.

Plan and sections of the Agos powerhouse are shown in Figure F4.3.

Tables

Table F3.1 Embankment Slopes Adopted for Concrete Face Rockfill Dam

Embankment Material: Rock (Limestone)

Name of Dam	Country	Dam Height (m)	Year Completed	Upstream Slope	Downstream Slope
Dix River	Calif. USA	84	1925	1 - 1.2	1.4
El Tejo	Spain	40	1974	1.3	1.4
Neveti	Venezuela	115	1981	1.4	1.5
Alfilorios	Spain	75	1983	1.4	1.4
Khao Laem	Thailand	130	1984	1.4	1.4
Alsasua	Spain	50	1985	1.5	1.4
Bolboci	Romania	56	1985	1.3	1.3
Xibeokou	China	95	1989	1.4	1.4
Shushuqiao	China	78	1990	1.4	1.7
U.Siah Bishe	Iran	100	1994	1.5	1.6
L. Siah Bishe	Iran	130	1994	1.5	1.6
Messochoba	Greece	135	1994	1.4	1.4
Baiyun	China	120	1996	1.4	1.4
Tianshengqiao I	China	178	1998	1.4	1.4
Hon Gjiadu	China	182	U/D	1.4	1.4
Pankou	China	123	U/D	1.4	1.5
Poneasca	Romania	52	U/D	1.3	1.4
Nam Ngum 3	Lao	220	2001	1.4	1.4
Shui Bu Ya	China	232	U/D	1.4	1.4
Gordes	Turkey	95	2001	1.4	1.5
Xiaoxikou	China	68	U/C	1.4	1.3
Antamina	Peru	115	U/D	1.3	1.3

Embankment Material: Gravel

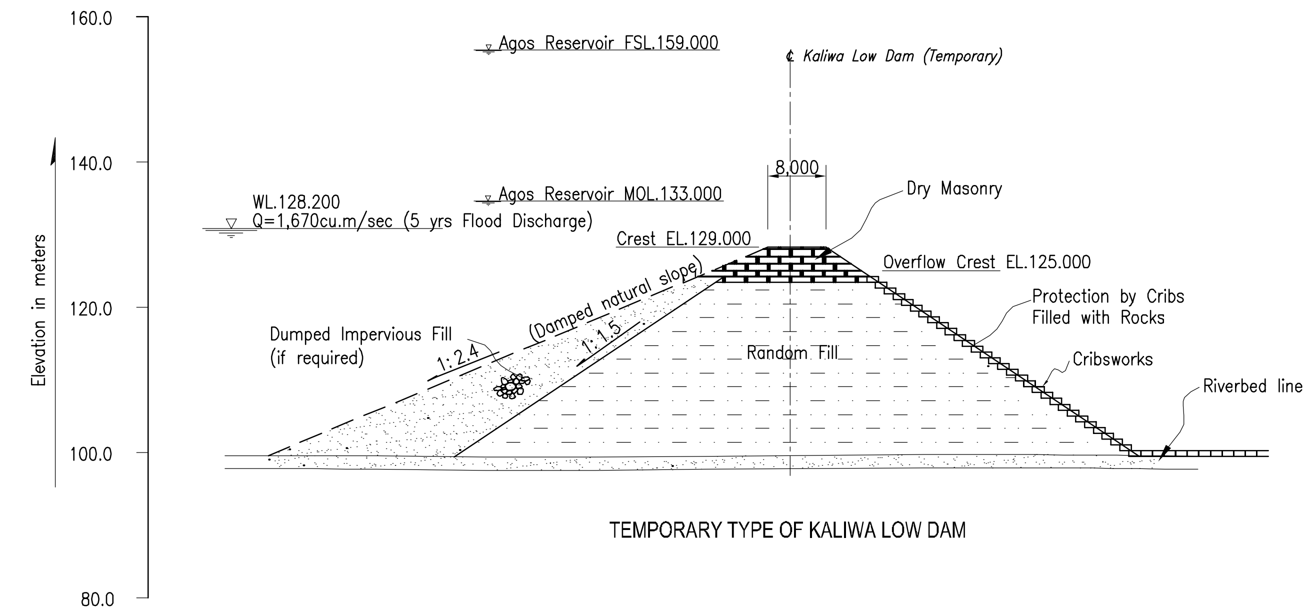
Name of Dam	Country	Dam Height (m)	Year Completed	Upstream Slope	Downstream Slope
Kekeya	China	42	1986	1.5	1.5
Xiaogan Gou	China	55	1990	1.55	1.6
Upper Guangzhou	China	68	1992	1.4	1.4
Aguamilpa	Mexico	187	1993	1.5	1.4
Yacambu	Venezuela	162	1996	1.5	1.6
Wuluwati	China	135	U/C	1.6	1.6
M'dez	Morocco	97	P	1.8	1.6
Los Molles	Argentina	46	P	1.5	1.5
La Parota	Mexico	162	P	1.5	1.4
El Cajon	Mexico	189	P	1.5	1.4
Quimbo	Colombia	150	P	1.5	1.6
Corrales	Chile	70	2000	1.5	1.6
Puclaro	Chile	100	2000	1.5	1.6
La Regadera II	Colombia	90	2002	1.5	1.6
Daqiao	China	68	U/C	1.5	1.7
Sogamoso	Colombia	190	2004	1.4	1.4
Gudongkou	China	120	U/C	1.4	1.5
Heiquan	China	124	U/C	1.55	1.4
West Seti	Nepal	220	P	1.5	1.6

Embankment Material: Rock

Name of Dam	Country	Dam Height (m)	Year Completed	Upstream Slope	Downstream Slope
Salazar	Portugal	70	1949	1.25	1.4
Kangaroo	Creak/Australia	50	1968	1.3	1.4
Oasa	Romania	91	1971	1.3	1.6
MangroveCr.	Australia	80	1981	1.5	1.6
Wuluwadi	China	138	1998	1.6	1.6
Taia	Romania	64	U/D	1.65	1.55
Bajiaotan	China	70	P	1.4	1.4
Dim	Turkey	135	2001	1.4	1.5
Morena	Calif. USA	54	1895	0.5 - 0.9	1.3
Strawberry	Calif. USA	50	1916	1.1 - 1.2	1.3
Salt Springs	Calif. USA	100	1931	1.1 - 1,4	1.4
Cogswell	Calif. USA	85	1934	1.35	1.6
L. Bear No.2	Calif. USA	50	1952	1.0	1.4
Paradela	Portugal	112	1955	1.3	1.3
Courtright	Calif. USA	98	1958	1.3	1.3
Wishon	Calif. USA	82	1958	1.0 - 1.3	1.4
Vilar	Portugal	55	1965	1.1 - 1.3	1.3
Fades	France	70	1967	1.3	1.3
Kootenay	Canal / Canada	37	1975	2.0	1.3
Rouchain	France	60	1976	1.4	1.4
Fantanele	Romania	92	1978	1.3	1.3
Outarde no.2	Canada	55	1978	1.4	1.4
Bejar	Spain	71	1984	1.3	1.3
Spicer	Meadows/Calif. USA	82	1988	1.5	1.5
Balsam	Meadows/Calif. USA	40	1988	1.4	1.4
Xingo	Brazil	150	1994	1.4	1.3
Wananxi	China	94	1995	1.4	1.4
Haichaoba	China	57	1996	1.4	1.4
Douyan	China	58	1996	1.4	1.6
Lianhua	China	72	1997	1.4	1.4
Runcv	Romania	90	1999	1.4	1.4
Caruachi	Venezuela	80	1999	1.3	1.3
Acena	Spain	65	U/D	1.3	1.3
Merowe	Sudan	83	P	1.3	1.4
Yang Yang	S. Korea	93	2000	1.4	1.4
Mukorsi	Zimbabwe	89	2002	1.3	1.3
Itatebi	Brazil	100	2003	1.3	1.3
Qiezishan	China	107	U/C	1.4	1.4
Gongbaixia	China	130	U/D	1.4	1.4

(Source : International Water Power and Dam Construction, Year Book 1999)

Figures



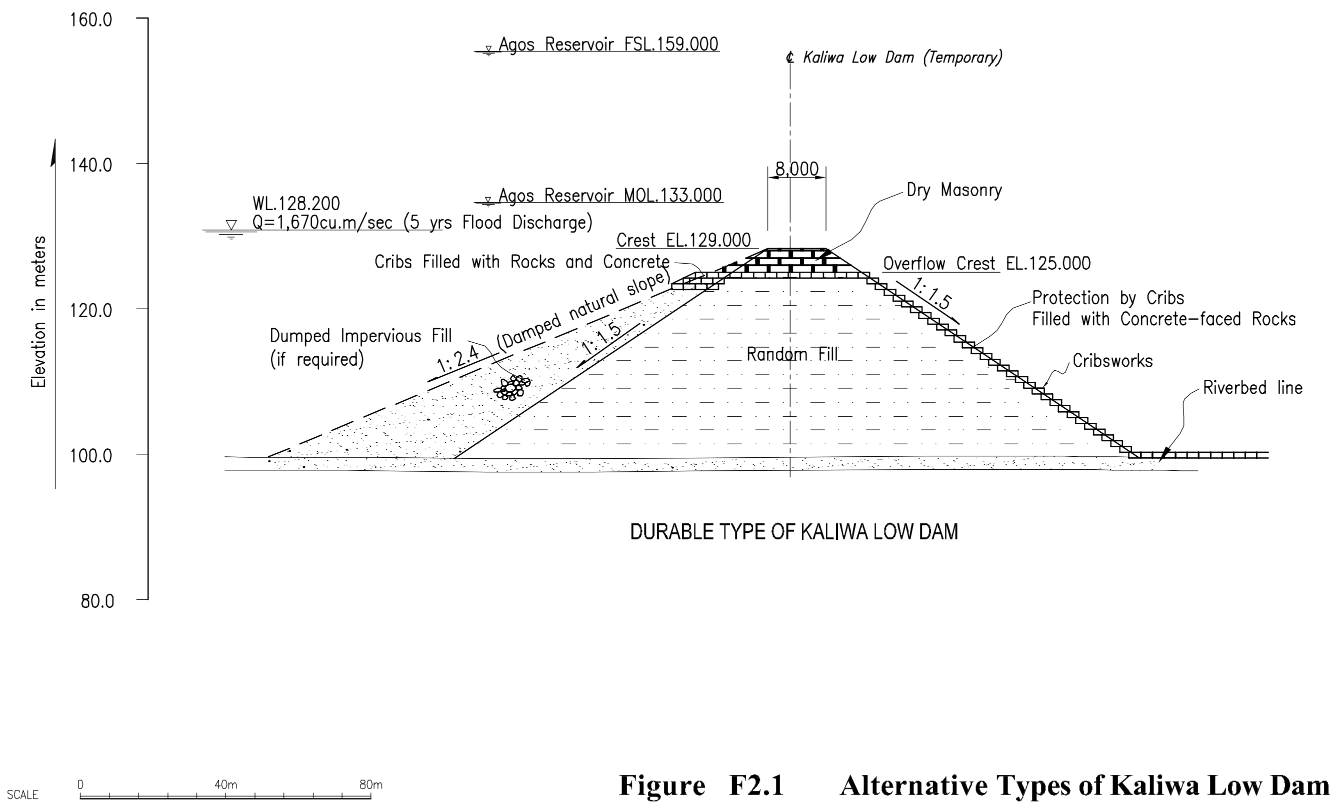


Figure F2.1 Alternative Types of Kaliwa Low Dam

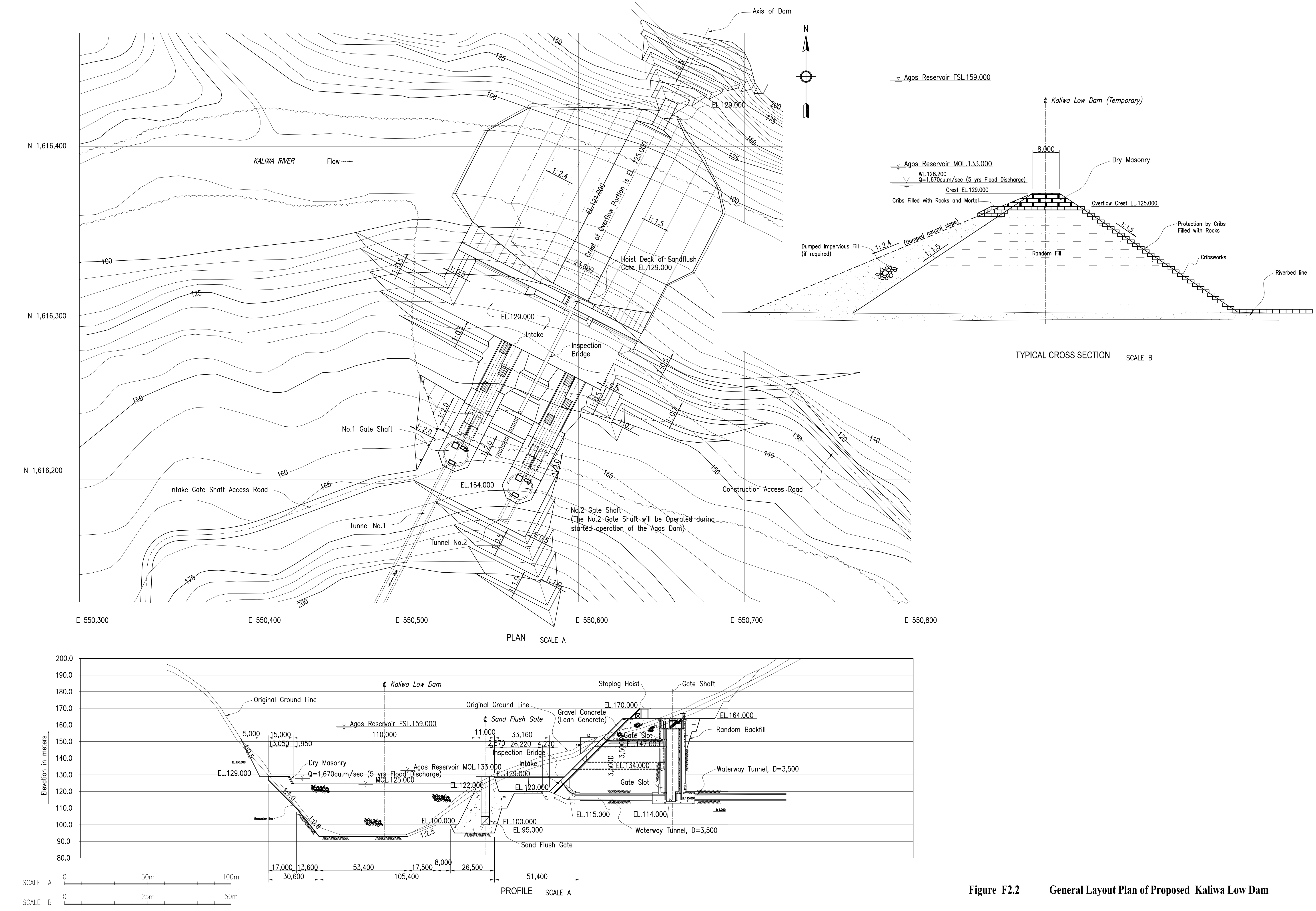


Figure F2.2 General Layout Plan of Proposed Kaliwa Low Dam

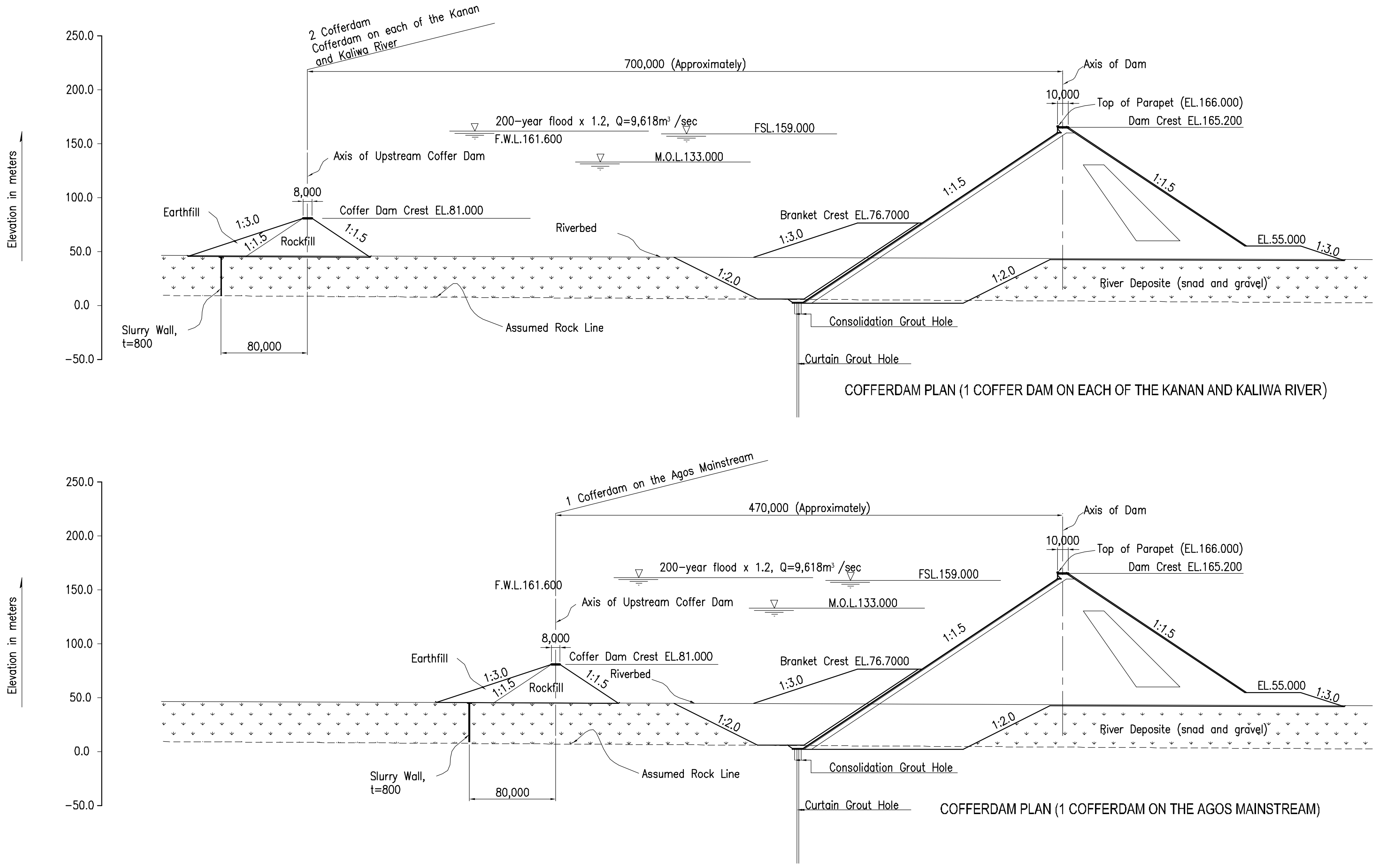


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Figure F3.1 Plans for River Diversion Works of Agos Dam

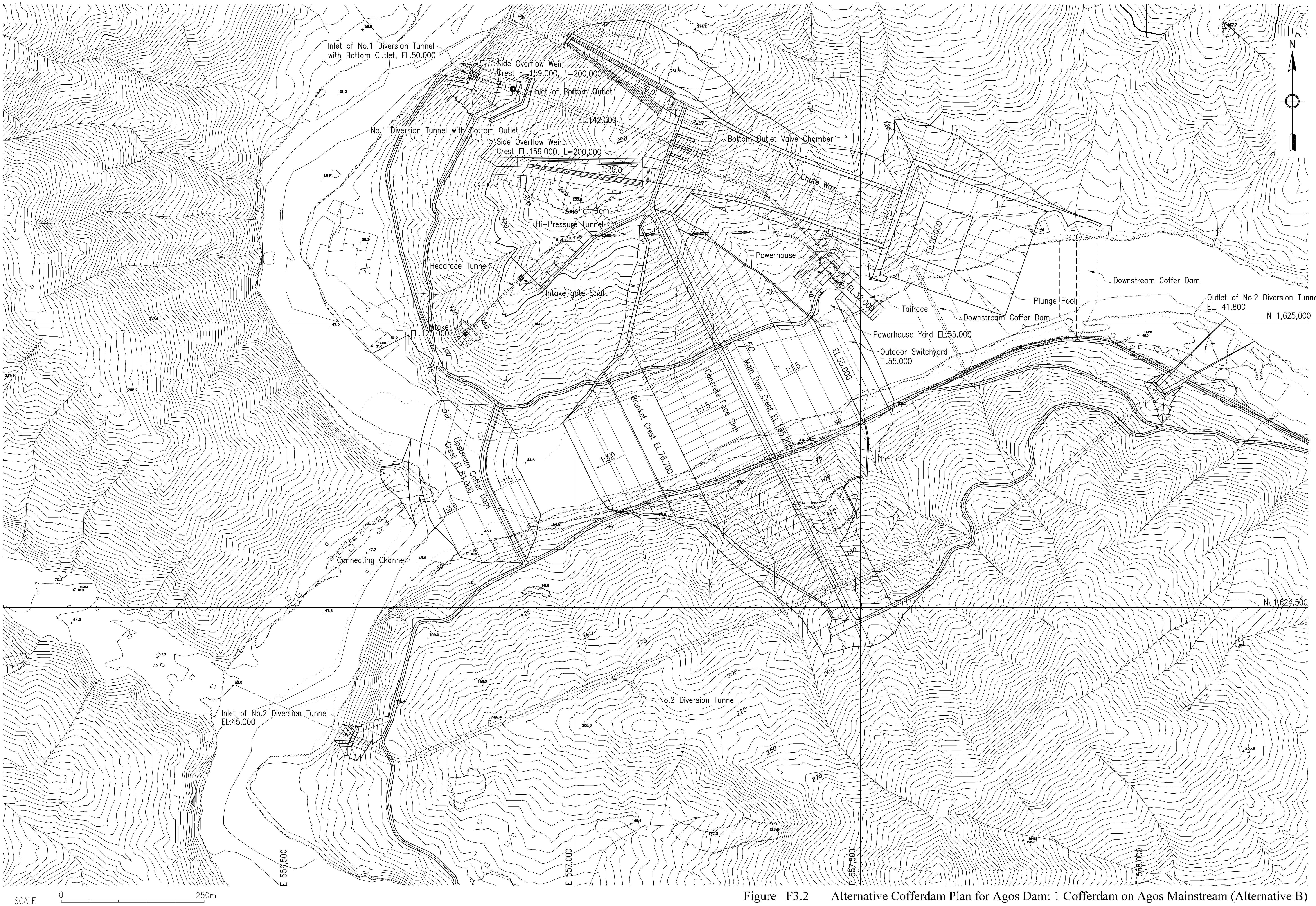

Figure F3.2 Alternative Cofferdam Plan for Agos Dam: 1 Cofferdam on Agos Mainstream (Alternative B)