2-2-2-3 Design of Reservoir Facilities

2-2-2-3-1 Dam

1) Investigation of embankment materials

(1) Quarry site (riprap material) investigation

Date :6th of September, 2013

Location :Muhulire, outcrops beside the road, about 4 km to the dam site

Quality :Quartzose sandstone which is hard and used for bedding rocks of houses and rocks for masonry, hides inner cracks caused by alternation, but is massive enough for ripraps' use

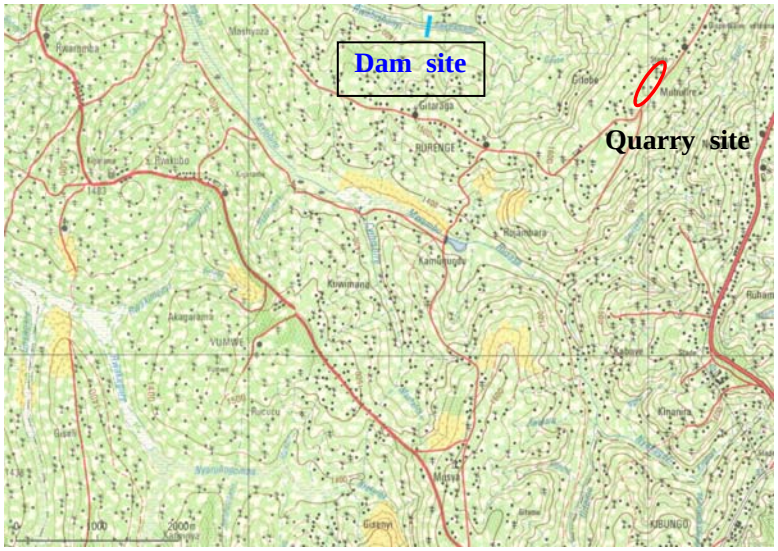


Figure 2.2.2.17 Location of Quarry Site

Photo 2.2.2.1 Outcrops and Ripraps Produced

(2) Sand and gravel（filter material, aggregate for concrete）

Date :6th of September, 2013

Location :Rwinkwuvu sand pit, about 30 km to the dam site

Quality :Deposits on an old river terrace which is composed of alternative layers of fine to coarse gravel and fine to medium sand; the former consists of hard and angular gravels measuring 5mm to 20mm in grain size and originating from quartzite, sandstone and shale. After being mixed, the material is classified into sand-and-gravel, suitable for the filter material of fill type dams and might available to the aggregate of concrete.

Photo 2.2.2.2 Profile of the Alternative Layers, Conditions after Mixed

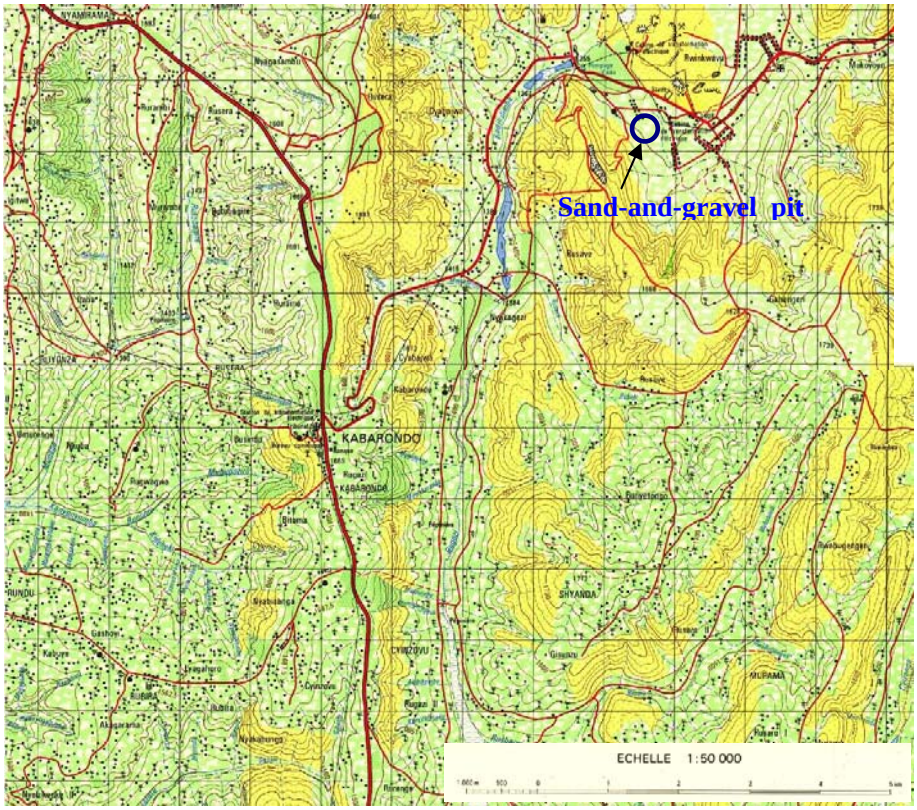


Figure 2.2.2.18 Location of Sand-and-gravel Pit

(3) Sand (fine aggregate of concrete, etc.)

Date :9th of September, 2013

Location :Rukira sand pit, about 43 km to the dam site

Quality :The layer consisting of medium sand, uniform in grain size, lies at the bottom of small valley, which is the deposit of highly weathered sandstone with characteristic features of thermal metamorphism. It would not be able to be evaluated 'high quality' but be able to be used as the fine aggregate for concrete due to lack of silt and organic materials. At the time of implementation, it would be desirable to arrange the gradational conditions of coarse aggregate; and before implementation, it is necessary to confirm if harmful substance is contained or not as the thermal metamorphism is often caused by hydrogen sulfide vapor rising along cracks.

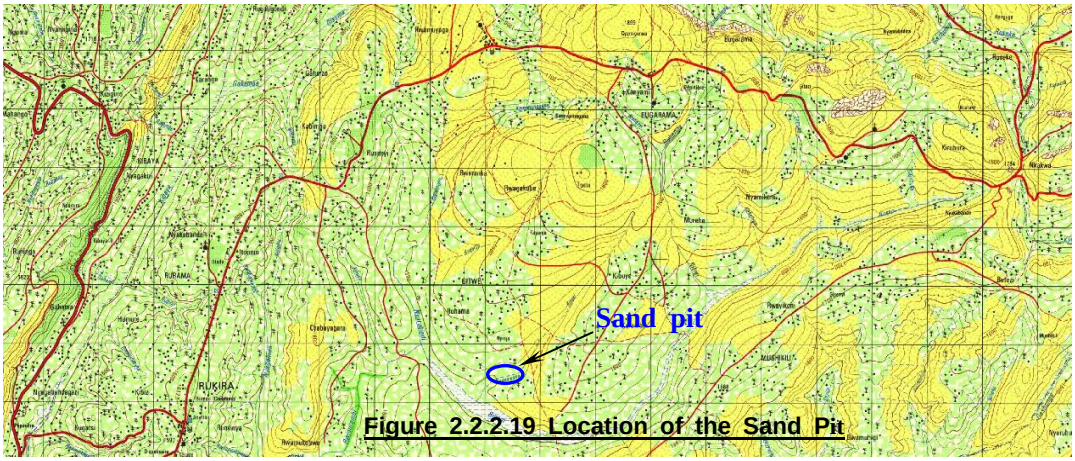


Figure 2.2.2.19 Location of the Sand Pit

Photo 2.2.2.3 Profile of the Layer and the Material

(4) Earth material

[Foot slope beyond the river bed, upstream right-bank side]

The walls of test pits, TP-1 and TP-2, are composed of reddish brown lateritic sandy clay and uniform to the depth of 4m with half-consolidated thin layers appearing sometimes though. The upper portion of the pits is hard and becomes solid blocks after excavation by manpower due to the low moisture content condition; but changes its impression to be cohesive clayey soil after water being added and several palm grips being repeated.

It would be the point how to crush the solid blocks of soil and how to make it uniform in moisture content condition from the view point of implementation of the embankment by using this material. In TP-2, the ground water table appeared at the depth of 4m, where the excavated soil has almost the condition of optimum moisture content.

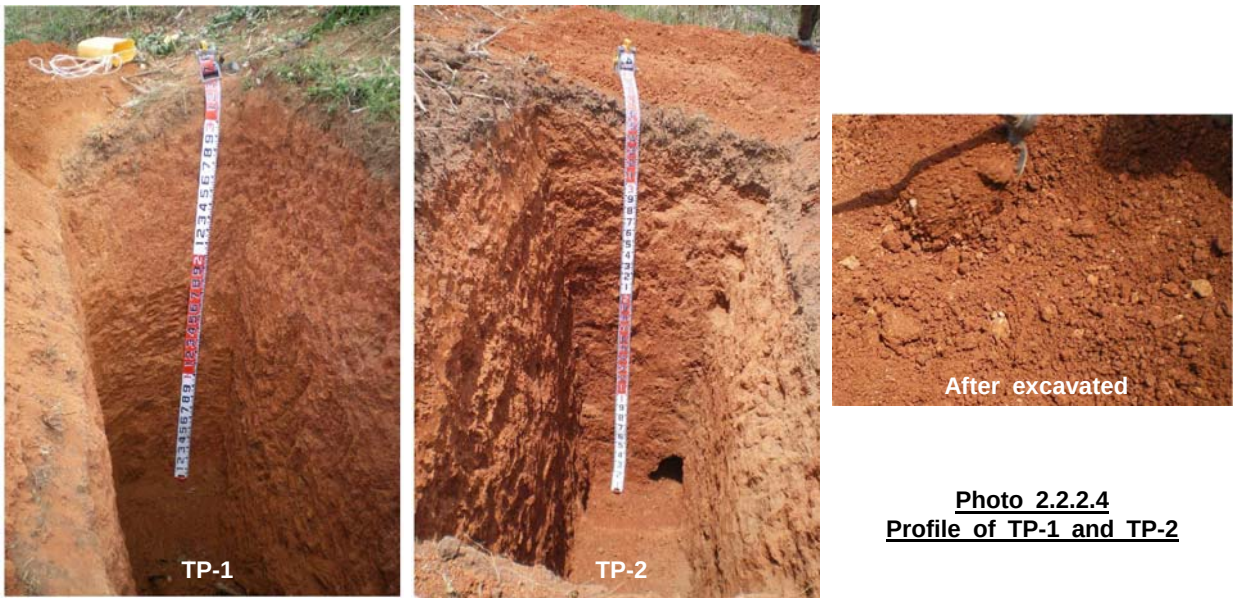


Photo 2.2.2.4
Profile of TP-1 and TP-2

[Foot slope beyond the river bed, upstream left-bank side]

The walls of test pits, TP-3 and TP-4, are composed of yellowish brown sandy clay originating from shale. These layers are assumed to be terrace or talus deposits as a layer containing flat-and-round shale gravels appeared at the depth of 2m in TP-3 and semi-angular gravels of quartzose sandstone appeared here and there in TP-4. The excavation by manpower was a painstaking work because of the upper being dry, hard and half-consolidated and the lower consisting of layers with residual rock structures, though completely weathered, and rocks/gravels appearing occasionally. The excavated soils seemed to be highly cohesive so that these soils are available as the embankment materials.

It would be the point how to crush the solid blocks of soil and how to make it uniform in the moisture content condition from the view point of implementation of the embankment by using these materials. In TP-4, the ground water table appeared at the depth of 4m, where the excavated soil has almost the condition of optimum moisture content.

Photo 2.2.2.5 Profile of TP-3 and TP-4

[Test pit logs and locations]

Test Pit No.1

Depth (m)	Color	Classification etc.	Moisture content	Cohesion
	Black	Top soil	Dry	
0.5				
1.0				
1.5		Lateritic soil		
	Redish brown	Sandy clay	12%±	High
2.0	Hard clods, able to be crushed by repeated clasping			
2.5	Excavation			
3.0				
3.5				
4.0				

Test Pit No.3

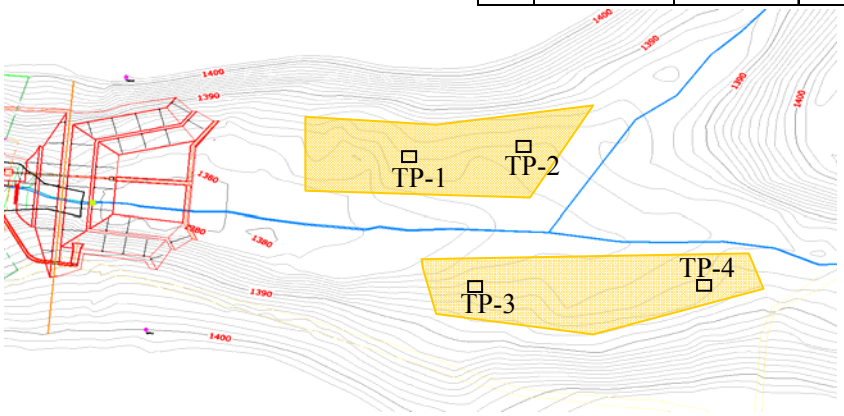
Depth (m)	Color	Classification etc.	Moisture content	Cohesion
	Greyish brown	Top soil	Dry	
0.5				
1.0				
1.5	yellowish brown	harf coagulated clay		
			10%±	High
2.0				
2.5	Brown	harf coagulated clay		
			10%±	High
3.0	Excavation	Lateritic soil With planular and round gravels		
3.5	Dark brown	Sandy clay	15%±	High
4.0				

Test Pit No.2

Depth (m)	Color	Classification etc.	Moisture content	Cohesion
	Black	Top soil	Dry	
0.5				
1.0				
1.5		Lateritic soil		
	Redish brown	Sandy clay	Wopt－1%～2%	High
2.0	Hard clods, able to be crushed by repeated clasping			
2.5				
3.0	Excavation			
3.5				
4.0				

Test Pit No.4

Depth (m)	Color	Classification etc.	Moisture content	Cohesion
	Dark brown	Top soil	Dry	
0.5				
1.0	Yellowish brown	Sandy clay	Wopt－5%	High
	Hard clods, able to be crused by repeated clasping			
1.5				
2.0				
2.5				
3.0	Brown with yellowish spots			
3.0		Sandy clay	Wopt±	High
	Excavation	containing quartish sandstones with rounded edges		
3.0				
4.0				



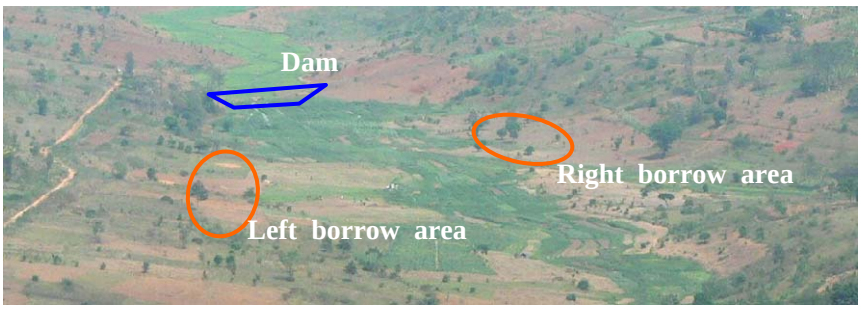


Figure 2.2.2.20 Test-pit Logs and Locations

2) Result of laboratory soil tests

Physical soil tests of six samples were carried out in 2009 and physical and mechanical soil tests of 4 samples (standard compaction test to 4 samples and direct shear test to two samples) were carried out in this preparatory survey. Followings are the achievement of these.

Table 2.2.2.33 Summary of Physical Soil Test

Sample Name	F.M.C. (%)	Specific Gravity	Atterberg Limits			Particle Size Distribution			
			LL(%)	PL(%)	PI(%)	Clay	Silt	Sand	Gravel
Sand & gravel						1.2		34.1	64.7
Sand						5.9		94.1	—
TP−1	13.3	2.21	43.9	22.7	21.2	81.0	3.8	8.8	6.4
TP−2	11.2	2.16	39.7	21.2	18.5	75.2	2.9	10.9	11.0
TP−3	12.2	2.22	38.4	24.3	14.1	66.0	3.7	13.0	17.3
TP−4	11.0	2.13	31.1	21.9	9.2	74.5	3.4	15.7	6.4
Test results in 2009									
A(0.2～1.5m)	9.6	2.65	40.9	19.2	21.7	32.0	46.0	20.0	2.0
A(1.5～3.5m)	10.4	2.66	58.6	28.7	29.9	18.0	68.4	12.6	1.0
A(3.5～5.0m)	11.6	2.70	55.6	27.9	27.7	28.0	56.2	13.8	2.0
B(0.2～1.0m)	7.6	2.65	57.9	27.5	30.4	23.5	64.9	6.1	5.5
B(1.0～3.5m)	9.6	2.63	44.7	22.8	21.9	16.5	30.9	20.6	32.0
B(3.5～5.0m)	6.8	2.70	38.4	17.6	20.8	18.4	52.0	16.6	13.0

Table 2.2.2.34 Summary of Mechanical Soil

Sample Name	Standard Compaction		Permeability Test			Direct Shear Test				Consolidation Test					
			Specimen Condition		Result	Specimen Condition		Result		Specimen Condition		% of Settlement			
	O_{pt}.M.C.(%)	ρ_dMax(t/m^3)	ρ_d(t/m^3)	M.C.(%)	k (m/sec)	ρ_d(t/m^3)	M.C.(%)	C(KN/m^2)	ϕ(°)	ρ_d(t/m^3)	M.C.(%)	50^{kPs}	100^{kPs}	200^{kPs}	400^{kPs}
Sand & gravel	8.3	2.00	2.00	8.3	3.92E−05										
TP−1	19.4	1.68	1.68^{D-100}	19.4	2.59E−08	1.69^{D-100}	20.0	43.19	25.49	1.69^{D-100}	20.0	1.78	2.72	4.00	4.73
			1.60^{D-95}	19.4	6.32E−08	1.61^{D-95}	20.0	40.05	24.36	1.61^{D-95}	20.0	1.33	2.69	4.28	6.29
			1.43^{D-85}	19.4	2.11E−07										
TP−2	18.1	1.71													
TP−3	14.8	1.78	1.77^{D-100}	14.8	1.04E−07										
			1.60^{D-95}	14.8	5.69E−08	1.63^{D-91}	22.0	33.82	27.12	1.63^{D-91}	22.0	1.00	1.55	3.02	4.70
			1.52^{D-85}	14.8	2.36E−07	1.55^{D-87}	22.0	32.48	26.18	1.55^{D-87}	22.0	1.88	3.61	4.49	6.68
TP−4	14.3	1.81													

3) Dam Type

The homogeneous type shall be adopted as the most adequate type for dam body based on the following reasons.

- Fill-type dam should be adopted as the dam body constructed on the soft ground composed of earthen foundation from the view point of stability and economy.
- The foundation treatment for reducing the seepage quantity shall be done by the blanket method because the usual grouting method injecting cement milk into rock cracks can not be applied to earthen foundations, where the wide bottom of the homogeneous dam body can contribute to increase the seepage length and decrease the length of the horizontal blanket.
- Earth materials good and much enough in quality and quantity can be obtained from the borrow area close to the dam site.
- The dam height is less than 15m, which assures the stability of the embankment constructed adequately and requests the simple structural composition, i.e. the homogeneous type rather than the zoned type, from the view point of workability.

In case of the homogeneous type dam, specifications of the dam body are defined as follows.

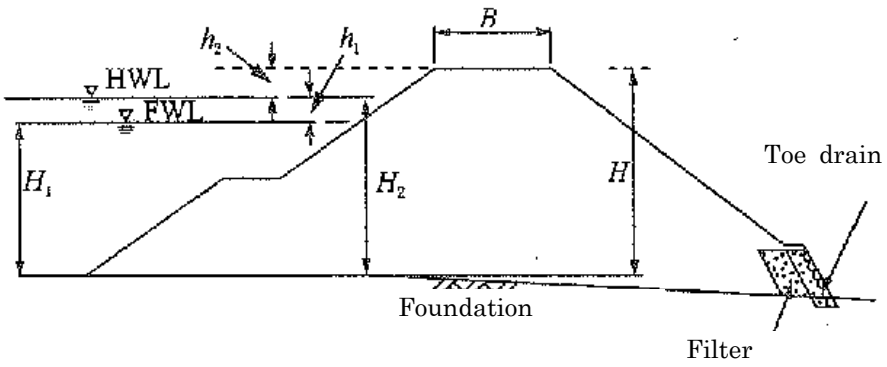


Figure 2.2.2.21 Illustrated Specifications of Homogeneous Dams

H :Dam height
B :Dam crest width
HWL :High water level (the maximum water level at the time of the design flood overflowing the spillway weir)
FWL :Full water level (the maximum water level at the time of daily storage behavior)
H1 :Water depth at the time of FWL
H2 :Water depth at the time of HWL
h1 :Overflow depth at the time of the design flood overflowing the spillway weir
h2 :Freeboard of the dam crest to HWL

4) Dam axis

The following two cases of dam axis location, the downstream axis and the upstream axis, would come to the surface as candidates in this dam site. Here, the downstream axis is adopted based on the following comparison results, of which advantage is the capability of storing the more water in the reservoir by the less embankment volume.

Table 2.2.2.35 Comparison on the Dam Axis Location

Item	Upstream dam axis	Downstream dam axis
Catchment area	8.68 km^2	8.8 km^2
Reservoir capacity	400,000m^3	600,000m^3
Dam crest elevation	EL.1390m (to do the comparison under the same condition)	
Dam crest length	225m	145m
Embankment volume	37,000m^3	30,000m^3
Dam height	10.0m	11.5m

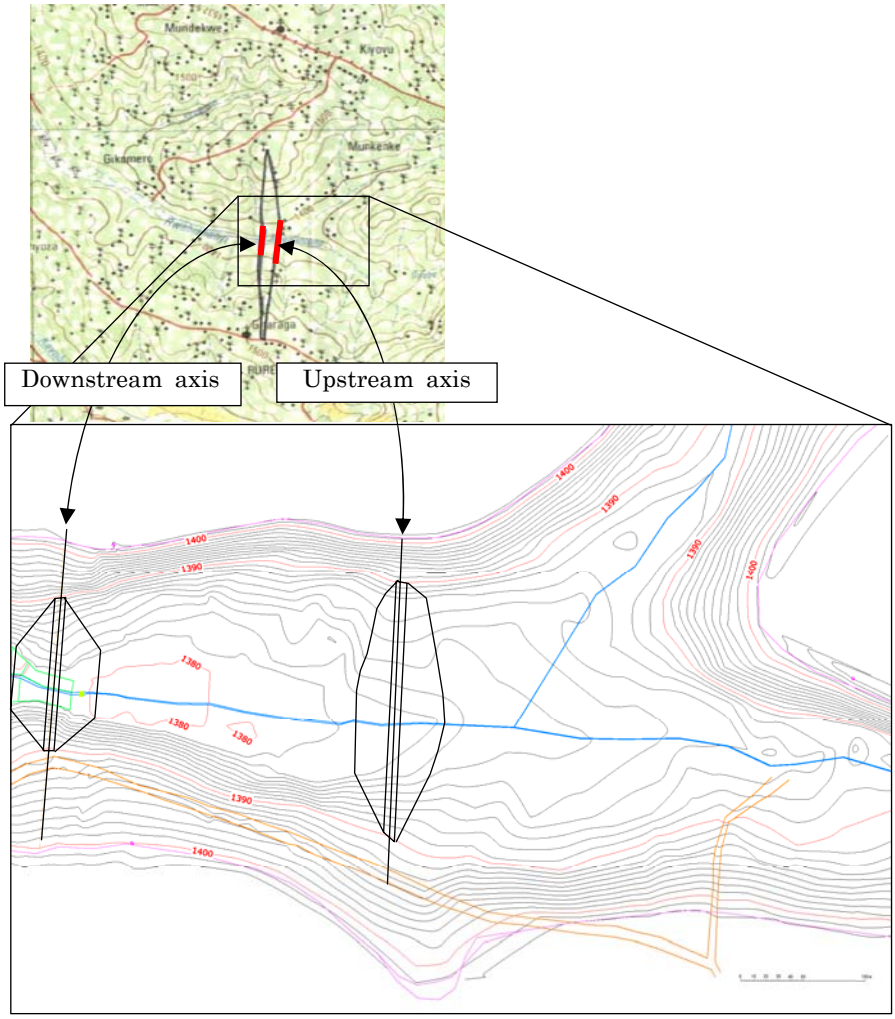
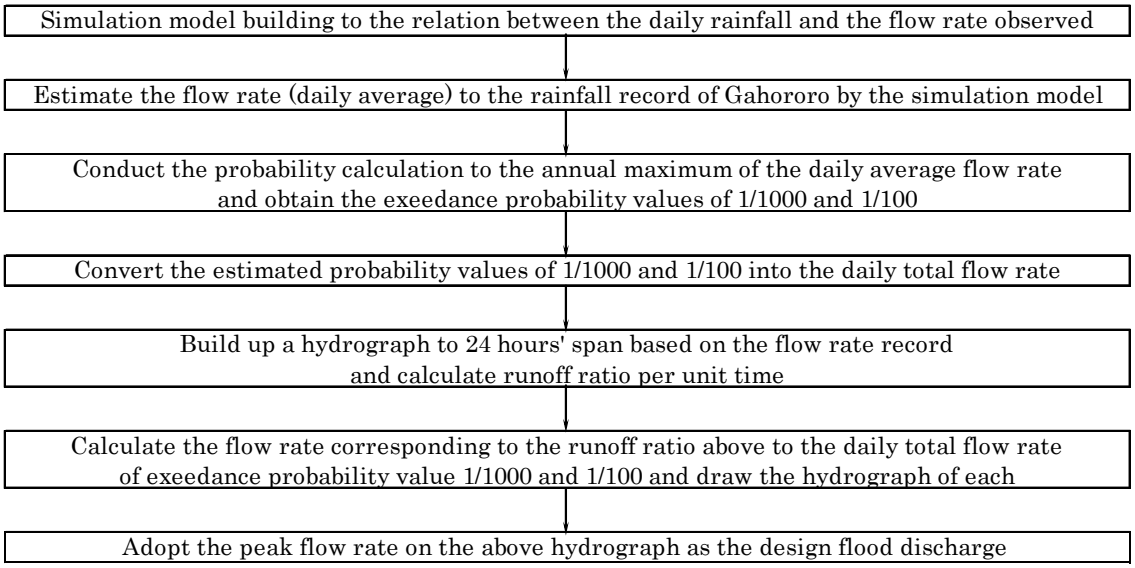


Figure 2.2.2.22 Location Map of Dam Axes

5) Design flood discharge

(1) Methodology

In the Ngoma22 site, the one and a half year record of precipitation and river flow rate observed by a JICA Expert, the former agricultural advisor of MINAGRI, is available for studying the flood discharge at the dam site. And there is Gahororo meteorological weather station near by which provides the daily rainfall record ranging from 1960 to 1993. Based on these records, the design flood discharge shall be studied and estimated through following steps.



(2) Simulation model by Tank Model Method

The simulation model was built up by Tank Model method through trial and error process with intentions of giving the first priority to accord the peaks of the flow rate each other. The obtained factors of the model are shown on Fig 2.2.2.23 and the relationship between the simulated flow rate conditions and the observed ones are shown on Fig 2.2.2.24.

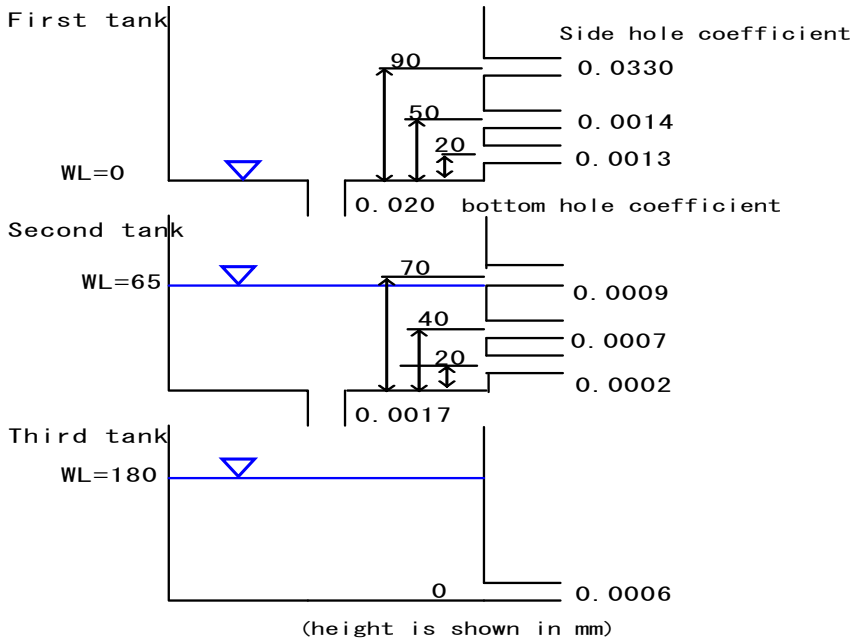
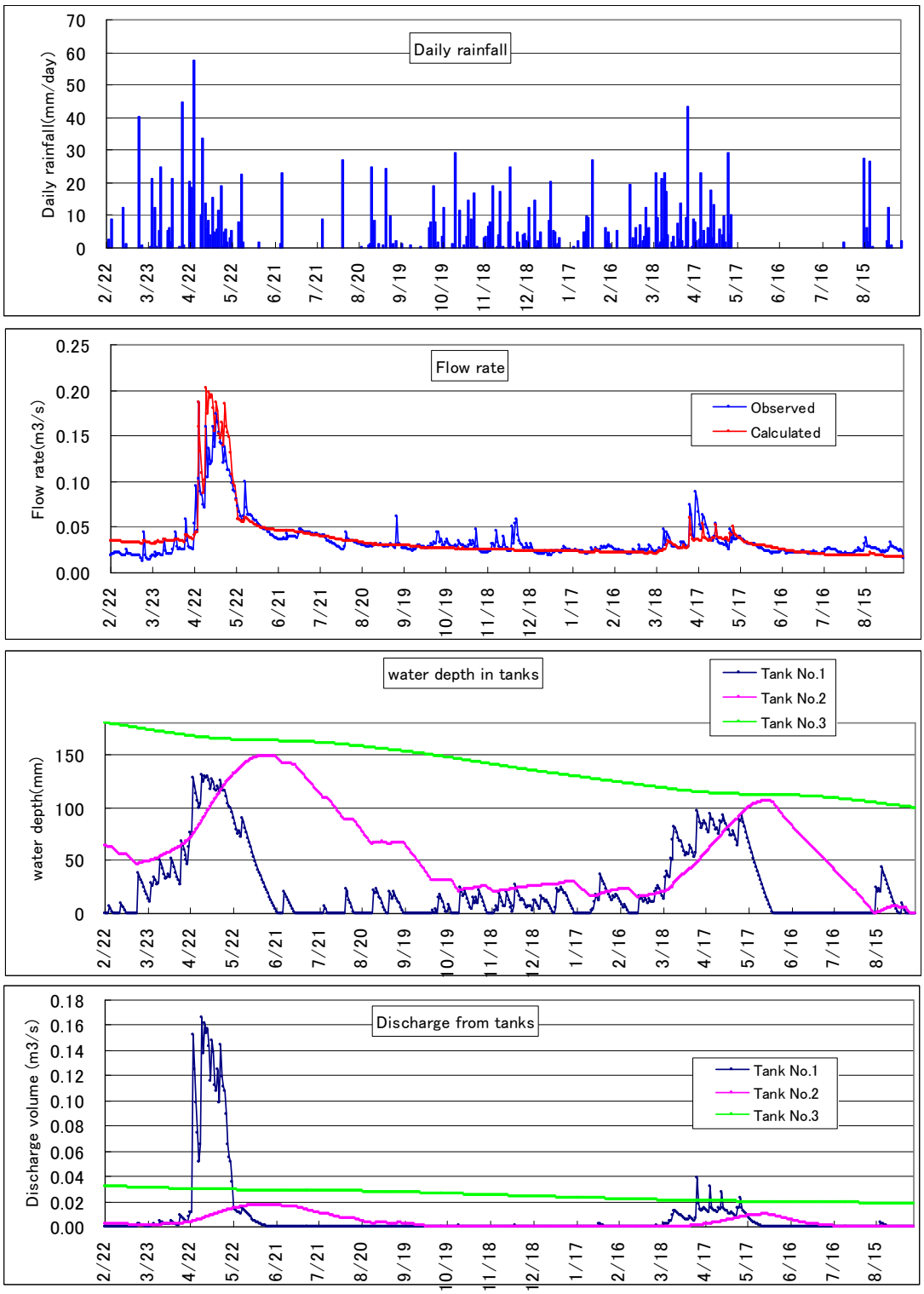


Figure 2.2.2.23 Simulated Discharge Model by Tank Model Method



Result of simulation analysis

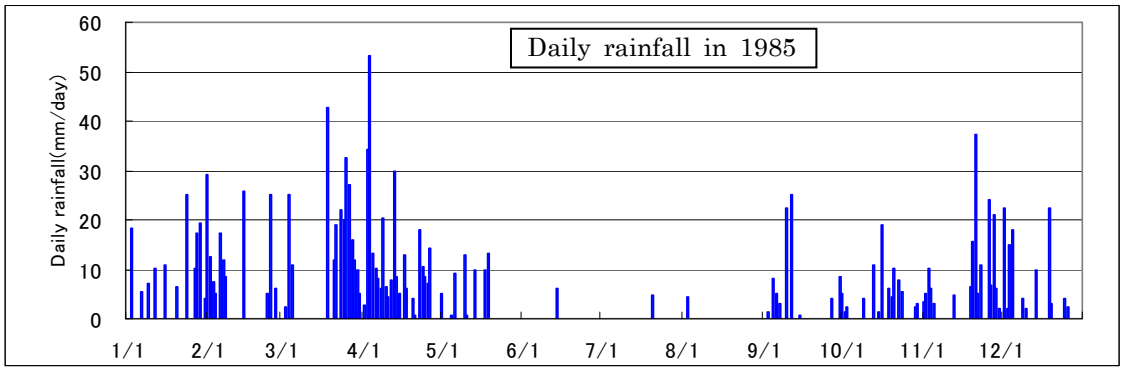
period	22/2/2012～10/9/2013		
Correlation coefficient	0.921	Runoff ratio(%)	
Cumulative flow rate calculated	1,760 ×1000m3	calculated	12.8%
Cumulative flow rate observed	1,720 ×1000m3	Observed	12.5%
Cumulative rainfall observed	1,564 mm		

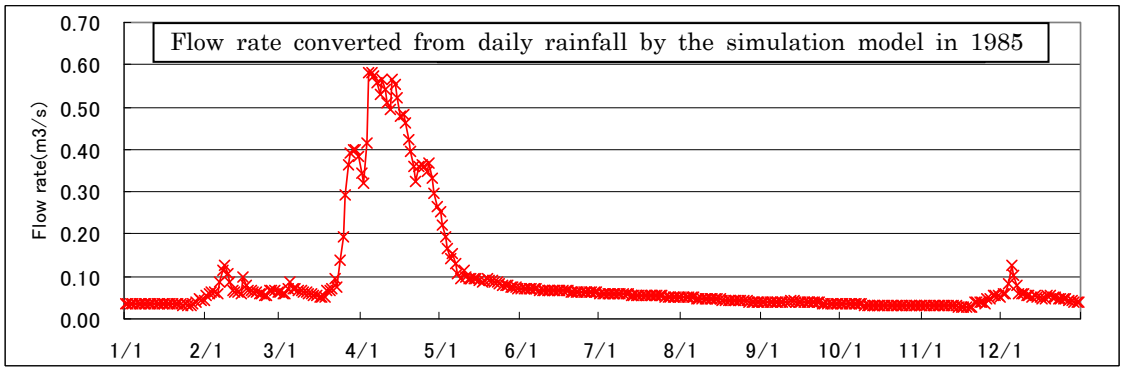
Figure 2.2.2.24 Observed Flow Rate and the Simulated Flow Rate

(3) Simulated flow rate based on the Gahororo daily rainfall

The annual maximum of the daily average flow rate calculated by applying the simulated runoff model by Tank Model method to the Gahororo daily rainfall are as shown below. Among these, the flow rate of 1985 is the maximum of which flow rate conditions are shown on Fig 2.2.2.25.

Year	Annual maximum of the daily average flow rate (m^3/sec)	Ranking	Year	Annual maximum of the daily average flow rate (m^3/sec)	Ranking
1960	0.510	4	1977	0.408	8
1961	0.298	13	1978	0.276	15
1962	0.279	14	1979	0.532	2
1963	0.447	7	1980	0.156	27
1964	0.175	23	1981	0.358	10
1965	0.504	5	1982	0.234	17
1966	0.392	9	1983	0.193	21
1967	0.041	34	1984	0.272	16
1968	0.494	6	1985	0.583	1
1969	0.160	26	1986	0.312	12
1970	0.150	28	1987	0.199	20
1971	0.105	30	1988	0.530	3
1972	0.066	31	1989	0.218	18
1973	0.177	22	1990	0.353	11
1974	0.174	25	1991	0.201	19
1975	0.052	33	1992	0.054	32
1976	0.150	28	1993	0.175	23





Year and calculation period	1985, 1/1-12/31
Cumulative flow rate, calculated	2,935 ×1000m3
Annual rainfall	1,349 mm
Annual runoff ratio	24.7%

Figure 2.2.2.25 Simulated Flow Rate (Maximum : 1985)

(4) Flow rate by exceedance probability calculation

The flow rate with 1/1,000 probability shall be applied to the design of spillway channels and the one with 1/100 probability is to be applied to the stilling basin as same as other recent dams in Rwanda.

The flow rates with 1/1,000 probability and 1/100 probability are obtained as follows by applying the exceedance probability calculation method shown by Ph.D. Iwai to the annual maximum values in the previous section.

Calculated results:

- 1/1,000 daily average flow rate :1.124m^3/sec (Total flow rate=1.124×86,400=97,114m^3/day)
- 1/100 daily average flow rate :0.803m^3/sec (Total flow rate=0.803×86,400=69,379m^3/day)
- 1/10 daily average flow rate :0.490m^3/sec (Total flow rate=0.490×86,400=42,336m^3/day)

Table 2.2.2.36(1) Exceedance Probability Calculation by Iwai Method

xl Max	xs Min	xg $\log_{10}xg = \Sigma \log_{10}xi$	$xl \cdot xs - xg^2$	$2xg-(xl+xs)$	bs $xl \cdot xs - xg^2 / 2xg-(xl+xs)$	b Average bs
0.583	0.041	0.2222	−0.03	−0.18	0.14	0.1
0.532	0.052	0.2222	−0.02	−0.14	0.16	0.1
0.530	0.054	0.2222	−0.02	−0.14	0.15	0.1
0.510	0.066	0.2222	−0.02	−0.13	0.12	0.1
0.504	0.105	0.2222	0.00	−0.16	−0.02	0.1
0.494	0.150	0.2222	0.02	−0.20	−0.12	0.1
0.447	0.150	0.2222	0.02	−0.15	−0.12	0.0
0.408	0.156	0.2222	0.01	−0.12	−0.12	0.0
0.392	0.160	0.2222	0.01	−0.11	−0.12	0.0
0.358	0.174	0.2222	0.01	−0.09	−0.15	0.0

Occurrence year T	ξ	1/a・ξ	Yaverage +1/a・ξ	x+b	Probability value to the occurrence x
2	0.0000	0.0000	(0.4068)	0.4	0.244
5	0.5951	0.1393	(0.2675)	0.5	0.392
10	0.9062	0.2121	(0.1946)	0.6	0.490
20	1.1630	0.2722	(0.1345)	0.7	0.585
30	1.2967	0.3035	(0.1032)	0.8	0.640
50	1.4520	0.3399	(0.0669)	0.9	0.709
100	1.6450	0.3851	(0.0217)	1.0	0.803
200	1.8215	0.4264	0.0196	1.0	0.898
500	2.0350	0.4764	0.0696	1.2	1.025
1000	2.1850	0.5115	0.1047	1.3	1.124

Table 2.2.2.36(2) Exceedance Probability Calculation by Iwai Method

Number of sample N= 34		②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
	Total	0.00		-22.214		-13.830	6.530	3.3	1	
	Mean	0.00		-0.653		-0.407	0.192	0.1	0	

※ In case of occurrence year being less than 2.0, expressed as 1.

①		②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪				
Ranking n	YEAR	xi	Fn(%)	$log_{10}xi$	xi+b	Y= log(xi+b)	Y^2	x^2	x^3	ξ	$period_1$	$period_2$	$ξ_1$	$ξ_2$	e year
1	1985	0.583	97.14	-0.23433	0.731	-0.13583	0.01845	0.3	0	1.1574	19	20	1.1455	1.1630	19.7
2	1979	0.532	94.29	-0.27409	0.680	-0.16722	0.02796	0.3	0	1.0233	13	14	1.0084	1.0361	13.5
3	1988	0.530	91.43	-0.27572	0.678	-0.16850	0.02839	0.3	0	1.0179	13	14	1.0084	1.0361	13.3
4	1960	0.510	88.57	-0.29243	0.658	-0.18149	0.03294	0.3	0	0.9624	11	12	0.9442	0.9780	11.5
5	1965	0.504	85.71	-0.29757	0.652	-0.18547	0.03440	0.3	0	0.9454	11	12	0.9442	0.9780	11.0
6	1968	0.494	82.86	-0.30627	0.642	-0.19218	0.03693	0.2	0	0.9167	10	11	0.9062	0.9442	10.3
7	1963	0.447	80.00	-0.34969	0.595	-0.22517	0.05070	0.2	0	0.7758	7	8	0.7547	0.8134	7.4
8	1977	0.408	77.14	-0.38934	0.556	-0.25459	0.06482	0.2	0	0.6501	5	6	0.5951	0.6858	5.6
9	1966	0.392	74.29	-0.40671	0.540	-0.26726	0.07143	0.2	0	0.5960	5	6	0.5951	0.6858	5.0
10	1981	0.358	71.43	-0.44612	0.506	-0.29548	0.08731	0.1	0	0.4754	3	4	0.3045	0.4769	4.0
11	1990	0.353	68.57	-0.45223	0.501	-0.29979	0.08987	0.1	0	0.4570	3	4	0.3045	0.4769	3.9
12	1986	0.312	65.71	-0.50585	0.460	-0.33684	0.11346	0.1	0	0.2987	2	3	0.0000	0.3045	3.0
13	1961	0.298	62.86	-0.52578	0.446	-0.35025	0.12267	0.1	0	0.2414	2	3	0.0000	0.3045	2.8
14	1962	0.279	60.00	-0.55440	0.427	-0.36914	0.13626	0.1	0	0.1608	2	3	0.0000	0.3045	2.5
15	1978	0.276	57.14	-0.55909	0.424	-0.37220	0.13853	0.1	0	0.1477	2	3	0.0000	0.3045	2.5
16	1984	0.272	54.29	-0.56543	0.420	-0.37631	0.14161	0.1	0	0.1301	2	3	0.0000	0.3045	2.4
17	1982	0.234	51.43	-0.63078	0.382	-0.41745	0.17426	0.1	0	-0.0456	1	2	0.0000	0.0000	1.0
18	1989	0.218	48.57	-0.66154	0.366	-0.43601	0.19011	0.0	0	-0.1249	1	2	0.0000	0.0000	1.0
19	1991	0.201	45.71	-0.69680	0.349	-0.45664	0.20852	0.0	0	-0.2131	1	2	0.0000	0.0000	1.0
20	1987	0.199	42.86	-0.70115	0.347	-0.45913	0.21080	0.0	0	-0.2237	1	2	0.0000	0.0000	1.0
21	1983	0.193	40.00	-0.71444	0.341	-0.46670	0.21781	0.0	0	-0.2560	1	2	0.0000	0.0000	1.0
22	1973	0.177	37.14	-0.75203	0.325	-0.48754	0.23770	0.0	0	-0.3451	1	2	0.0000	0.0000	1.0
23	1964	0.175	34.29	-0.75696	0.323	-0.49022	0.24032	0.0	0	-0.3565	1	2	0.0000	0.0000	1.0
23	1993	0.175	34.28	-0.75696	0.323	-0.49022	0.24032	0.0	0	-0.3565	1	2	0.0000	0.0000	1.0
25	1974	0.174	28.57	-0.75945	0.322	-0.49157	0.24164	0.0	0	-0.3623	1	2	0.0000	0.0000	1.0
26	1969	0.160	25.71	-0.79588	0.308	-0.51085	0.26096	0.0	0	-0.4446	1	2	0.0000	0.0000	1.0
27	1980	0.156	22.86	-0.80688	0.304	-0.51651	0.26679	0.0	0	-0.4688	1	2	0.0000	0.0000	1.0
28	1970	0.150	20.00	-0.82391	0.298	-0.52516	0.27579	0.0	0	-0.5058	1	2	0.0000	0.0000	1.0
28	1976	0.150	20.00	-0.82391	0.298	-0.52516	0.27579	0.0	0	-0.5058	1	2	0.0000	0.0000	1.0
30	1971	0.105	14.29	-0.97881	0.253	-0.59614	0.35539	0.0	0	-0.8090	1	2	0.0000	0.0000	1.0
31	1972	0.066	11.43	-1.18046	0.214	-0.66872	0.44718	0.0	0	-1.1190	1	2	0.0000	0.0000	1.0
32	1992	0.054	8.57	-1.26761	0.202	-0.69373	0.48126	0.0	0	-1.2259	1	2	0.0000	0.0000	1.0
33	1975	0.052	5.71	-1.28400	0.200	-0.69804	0.48726	0.0	0	-1.2443	1	2	0.0000	0.0000	1.0
34	1967	0.041	2.86	-1.38722	0.189	-0.72255	0.52209	0.0	0	-1.3490	1	2	0.0000	0.0000	1.0

(5) Estimation of design flood runoff

a) Analysis of actual hydrographs observed

Followings are the representative and actual relationships between flow rate and time, i.e. hydrographs, regarding observed runoffs to daily rainfalls of different amount, pattern and period.

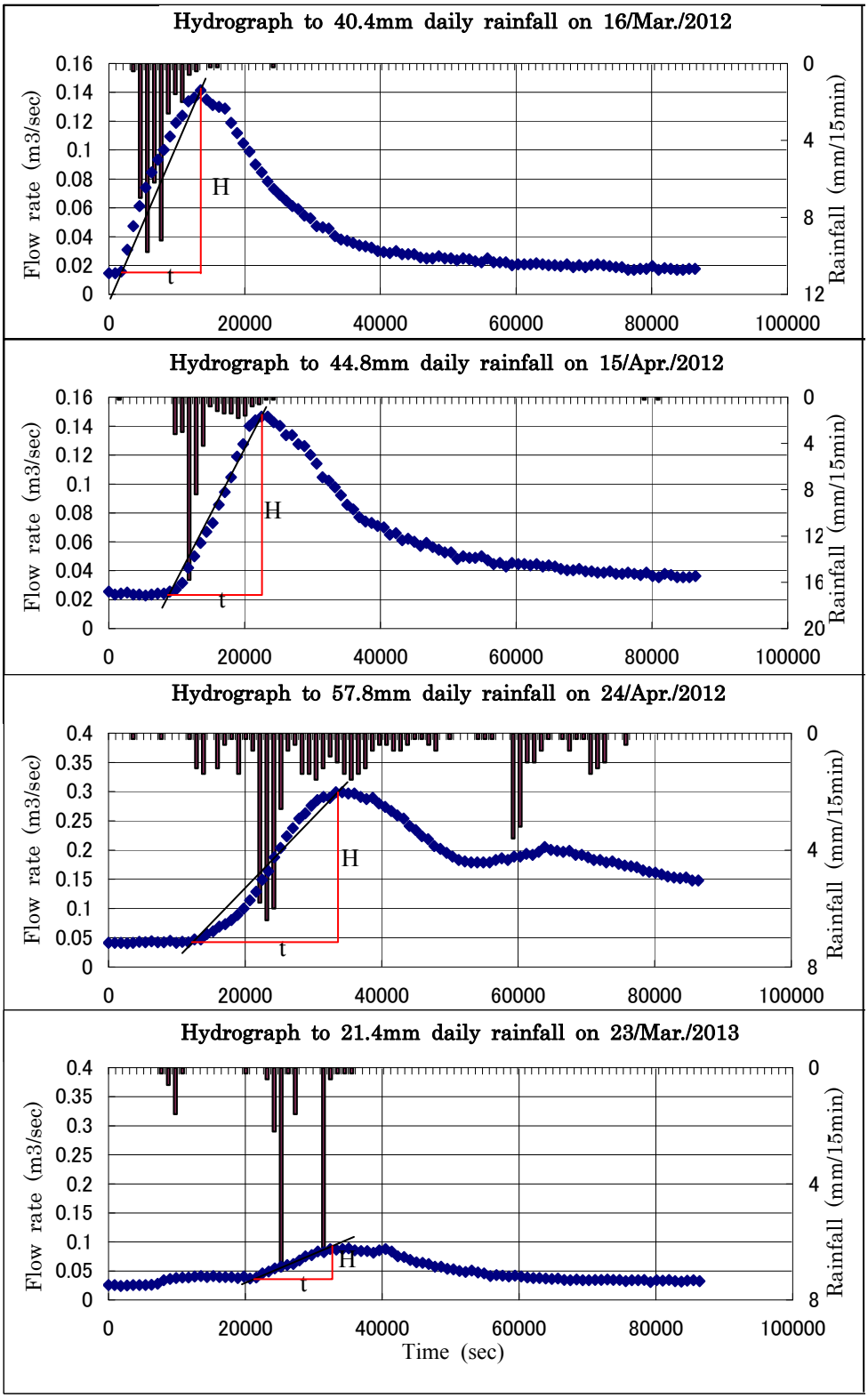


Figure 2.2.2.26 Actual Hydrographs Observed

b) Runoff model

Followings are the profiles of each runoff shown on Fig 2.2.2.26.

Table 2.2.2.37 Characteristics of the Period of Flood Concentration

Occurrence date and Daily rainfall	(1) Period of flood concentration (hour)	(2) Increased flow rate (m3/sec)	Increasing gradient (2)／(1)	Characteristics
16/3/2012, 40.4mm	t=3.24	H=0.127	0.039	The runoff finished in about 24hours.
15/4/2012, 44.8mm	t=3.94	H=0.124	0.031	The base flow kept increased conditions after the flood.
24/4/2012, 57.6mm	t=6.10	H=0.258	0.042	The base flow kept highly increased conditions after the flood.
23/3/2013, 21.4mm	t=3.22	H=0.054	0.017	The flow rate increased but the runoff ratio was very low, i.e. a large part of rainfall was absorbed into ground.

Through the analysis above, following points are clarified.

- The longer the duration time of rainfall becomes, the longer the period of flood concentration becomes. The increasing gradient of runoff, however, is almost constant regardless of the difference in rainfall amount, pattern and period.
- Though the decreasing gradient is also almost constant, the amount of base flow and its discharging time will be increased and kept longer respectively if the duration of rainfall becomes longer which occurs in the latter half of rainy season.

The hydrograph of the runoff on 16th March 2012 is adopted as the runoff model based on the following perception.

- Although the runoff corresponding to the daily rainfall with probability of 1/1000 and 1/100 brings about the base flow increase for long duration as analyzed above, taking account of safer side for design, it assumes that the peak flood finishes in 24 hours

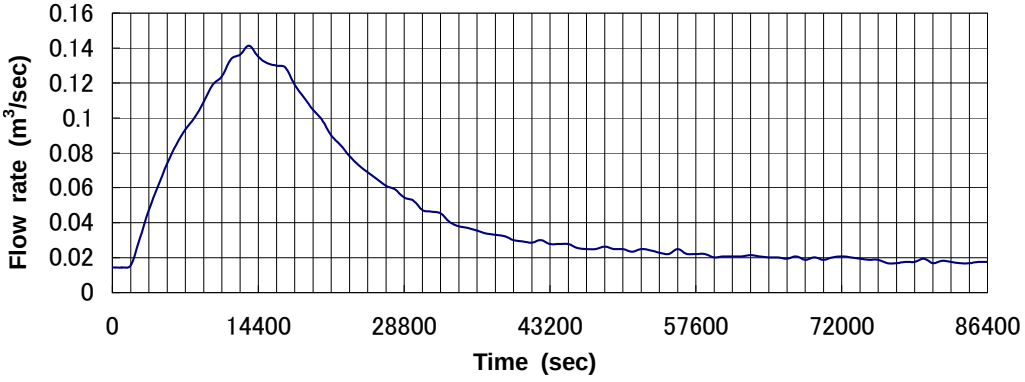


Figure 2.2.2.27 Runoff Model

c) Distribution of the probability daily flow rate

The distribution of the probability daily flow rate shall be done as follows.

- To read out the flow rate (m^3/sec) at 30 minute interval from Fig 2.2.2.27
- To calculate the runoff quantity for 30 minute
- To calculate the ratio (%) of this runoff quantity to the total daily flow rate

- To distribute the probability daily flow rate according to this calculated ratio

Table 2.2.2.38 shows the distribution process and the result is shown as Fig 2.2.2.28.

Table 2.2.2.38 Distribution of Probability Daily Flow Rate following the Runoff Model

Time (hour)	Flow rate (m3/sec)	30min. inflow (m3)	ratio to the total (%)	1/1,000 daily flow rae		1/100 daily flow rae		1/10 daily flow rae		1/2 daily flow rae	
				30min. inflow (m3)	average rate (m3/sec)	30min. inflow (m3)	average rate (m3/sec)	30min. inflow (m3)	average rate (m3/sec)	30min. inflow (m3)	average rate (m3/sec)
0.5	0.01479	26.6211	0.657698057	638.7168909	0.3548427	456.3043348	0.2535024	278.443049	0.1546906	138.655904	0.0770311
1.0	0.047058	84.7035	2.092675635	2032.281016	1.129045	1451.877429	0.8065986	885.955157	0.4921973	441.177877	0.2450988
1.5	0.073948	133.1055	3.288490284	3193.584454	1.7742136	2281.521674	1.267512	1392.21525	0.7734529	693.279522	0.3851553
2.0	0.092771	166.9869	4.125560538	4006.496861	2.2258316	2862.272646	1.5901515	1746.59731	0.9703318	869.750673	0.4831948
2.5	0.108905	196.0281	4.843049327	4703.278924	2.6129327	3360.059193	1.8666996	2050.35336	1.1390852	1021.01166	0.5672287
3.0	0.123694	222.6492	5.500747384	5341.995815	2.9677755	3816.363528	2.120202	2328.79641	1.2937758	1159.66756	0.6442598
3.5	0.135795	244.4301	6.038863976	5864.582362	3.2581013	4189.703438	2.327613	2556.61345	1.4203408	1273.1133	0.7072852
4.0	0.141173	254.1105	6.278026906	6096.843049	3.387135	4355.632287	2.4197957	2657.86547	1.4765919	1323.53363	0.7352965
4.5	0.13445	242.01	5.979073244	5806.51719	3.2258429	4148.221226	2.3045673	2531.30045	1.406278	1260.50822	0.7002823
5.0	0.121005	217.809	5.381165919	5225.865471	2.9032586	3733.399103	2.0741106	2278.1704	1.2656502	1134.4574	0.6302541
5.5	0.104871	188.7678	4.66367713	4529.083408	2.5161574	3235.612556	1.7975625	1974.41435	1.0968969	983.196413	0.5462202
6.0	0.090082	162.1467	4.005979073	3890.366517	2.1613147	2779.308221	1.5440601	1695.9713	0.9422063	844.540508	0.4691892
6.5	0.079326	142.7859	3.527653214	3425.845142	1.9032473	2447.450523	1.3596947	1493.46726	0.829704	743.699851	0.4131666
7.0	0.06857	123.4251	3.049327354	2961.323767	1.6451799	2115.592825	1.1753293	1290.96323	0.7172018	642.859193	0.357144
7.5	0.061847	111.3246	2.750373692	2670.997907	1.4838877	1908.181764	1.060101	1164.39821	0.6468879	579.833782	0.3221299
8.0	0.05378	96.804	2.391629297	2322.606876	1.2903372	1659.28849	0.9218269	1012.52018	0.5625112	504.203288	0.2801129
8.5	0.048402	87.1236	2.152466368	2090.346188	1.1613034	1493.359641	0.8296442	911.268161	0.5062601	453.78296	0.2521016
9.0	0.044369	79.8633	1.97309417	1916.150673	1.0645282	1368.913004	0.7605072	835.329148	0.4640717	415.967713	0.2310932
9.5	0.038991	70.1829	1.733931241	1683.889985	0.9354944	1202.984155	0.6683245	734.07713	0.4078206	365.547384	0.2030819
10.0	0.036302	65.3427	1.614349776	1567.759641	0.8709776	1120.019731	0.6222332	683.451121	0.3796951	340.33722	0.1890762
10.5	0.033613	60.5025	1.494768311	1451.629297	0.8064607	1037.055306	0.5761418	632.825112	0.3515695	315.127055	0.1750706
11.0	0.030924	55.6623	1.375186846	1335.498954	0.7419439	954.0908819	0.5300505	582.199103	0.3234439	289.916891	0.1610649
11.5	0.029579	53.2422	1.315396114	1277.433782	0.7096854	912.6086697	0.5070048	556.886099	0.3093812	277.311809	0.1540621
12.0	0.028235	50.8221	1.255605381	1219.36861	0.677427	871.1264574	0.4839591	531.573094	0.2953184	264.706726	0.1470593
12.5	0.02689	48.402	1.195814649	1161.303438	0.6451686	829.6442451	0.4609135	506.26009	0.2812556	252.101644	0.1400565
13.0	0.026218	47.19195	1.165919283	1132.270852	0.6290394	808.903139	0.4493906	493.603587	0.2742242	245.799103	0.1365551
13.5	0.025546	45.9819	1.136023916	1103.238266	0.6129101	788.1620329	0.4378678	480.947085	0.2671928	239.496562	0.1330536
14.0	0.024201	43.5618	1.076233184	1045.173094	0.5806517	746.6798206	0.4148221	455.634081	0.25313	226.89148	0.1260508
14.5	0.023529	42.35175	1.046337818	1016.140508	0.5645225	725.9387145	0.4032993	442.977578	0.2460987	220.588939	0.1225494
15.0	0.022857	41.1417	1.016442451	987.1079223	0.5483933	705.1976084	0.3917764	430.321076	0.2390673	214.286398	0.119048
15.5	0.022857	41.1417	1.016442451	987.1079223	0.5483933	705.1976084	0.3917764	430.321076	0.2390673	214.286398	0.119048
16.0	0.022184	39.93165	0.986547085	958.0753363	0.5322641	684.4565022	0.3802536	417.664574	0.2320359	207.983857	0.1155466
16.5	0.021512	38.7216	0.956651719	929.0427504	0.5161349	663.7153961	0.3687308	405.008072	0.2250045	201.681315	0.1120452
17.0	0.02084	37.51155	0.926756353	900.0101644	0.5000056	642.97429	0.3572079	392.35157	0.2179731	195.378774	0.1085438
17.5	0.020168	36.3015	0.896860987	870.9775785	0.4838764	622.2331839	0.3456851	379.695067	0.2109417	189.076233	0.1050424
18.0	0.020168	36.3015	0.896860987	870.9775785	0.4838764	622.2331839	0.3456851	379.695067	0.2109417	189.076233	0.1050424
18.5	0.019495	35.09145	0.86696562	841.9449925	0.4677472	601.4920777	0.3341623	367.038565	0.2039103	182.773692	0.1015409
19.0	0.019495	35.09145	0.86696562	841.9449925	0.4677472	601.4920777	0.3341623	367.038565	0.2039103	182.773692	0.1015409
19.5	0.019495	35.09145	0.86696562	841.9449925	0.4677472	601.4920777	0.3341623	367.038565	0.2039103	182.773692	0.1015409
20.0	0.019495	35.09145	0.86696562	841.9449925	0.4677472	601.4920777	0.3341623	367.038565	0.2039103	182.773692	0.1015409
20.5	0.019495	35.09145	0.86696562	841.9449925	0.4677472	601.4920777	0.3341623	367.038565	0.2039103	182.773692	0.1015409
21.0	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
21.5	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
22.0	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
22.5	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
23.0	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
23.5	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
24.0	0.018823	33.8814	0.837070254	812.9124066	0.451618	580.7509716	0.3226394	354.382063	0.1968789	176.471151	0.0980395
Total		4047.617	100	97114		69379		42336		21082	

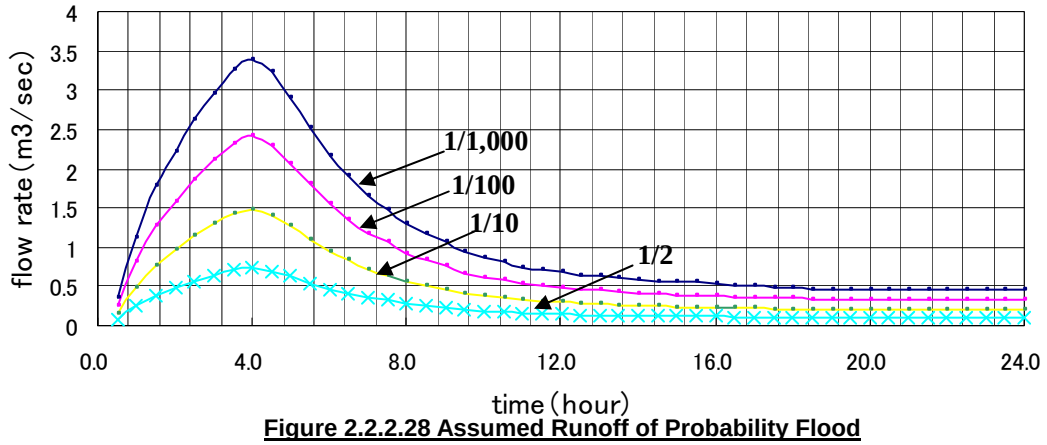


Figure 2.2.2.28 Assumed Runoff of Probability Flood

(6) Estimation of design flood discharge

In Ngoma22 the reservoir surface area at its full water level is small compared with the catchment area and the period of flood concentration is short. Therefore, the storage function of the reservoir is not taken into account in the estimation of design flood discharge. In other words, the effect of the stored water being discharged through the spillway during the flood flowing into the reservoir is not taken into account, and the runoff peak is assumed to reach the spillway at once under the full water level condition of the reservoir. Following values are adopted as the design flood discharge by reading out the peak value of the runoff curve of each probability flood as shown on Fig 2.2.2.28.

- Design flood discharge with 1/1000 probability applied to the spillway channel :Q=3.4 m^3/sec
- Design flood discharge with 1/100 probability applied to the spillway channel :Q=2.45m^3/sec
- Design flood discharge with 1/10 probability applied to the downstream river :Q=1.5m^3/sec

6) Sedimentation into the reservoir

Followings are the hydro-geological and environmental characteristics related to sedimentation phenomenon in the catchment area of Ngoma22 reservoir.

- The ground surface is covered with a thick sandy clay layer measuring up to almost 10m or so in the catchment area of Ngoma22 reservoir. This sandy clay is mainly composed of fine particles, i.e. silt and clay, counting almost 80% in dry weight. Nevertheless this layer is highly pervious under in-situ conditions so that a large portion of rainfall is absorbed into ground.
- The hydro-geological condition mentioned above makes the runoff ratio low, gully erosion not to appear on the slope surface, and outcrops not to appear at the bottom of valleys on the hill slopes.
- The hill slopes including farmlands are covered with green vegetation in rainy seasons.
- The river water does not become muddy but opaque and light yellowish brown under heavy rainfall.

It is adequate to consider the erosive action of rainfall water to be low so that the smallest value of sedimentation shall be adopted among the ones which are estimated by using the formulas suggested as follows.

Sediment :Qsd=D・A・Y

D :Sediment yield (Specific sediment rate, specific degradation) in m^3/km^2 per year

A :Catchment area : A=8.8 km^2

Y :Durable years of the reservoir, 50 years is applied generally in Rwanda.

- Gresillons (France) :$D = 700(P/500)^{-0.22} \cdot A^{-0.1}$ (P:Anual rainfall)
  $= 700 \cdot (1112/500)^{-0.22} \cdot 8.8^{-0.1}$
  $= 472.3 m^3/km^2/year$
- Gottshalk (USA) :$D = 260 \cdot A^{-0.1}$
  $= 260 \times 8.8^{-0.1}$
  $= 209.2 m^3/km^2/year$
- Puech (West Africa) :$50 < D < 200$ $m^3/km^2/year$
  $D = 70 m^3/km^2/year$

Based on these sediment yield values, sedimentation volumes are estimated as follows.

Equation/Method	Evaluated value	Adopted value
Gresillons	208,000 m^3	30,000 m^3
Gottshalk	92,000 m^3	
Puech	30,000 m^3	

30,000m^3 is adopted as the design sedimentation and the design sedimentation level becomes EL. 1382.0 meter according to the water level and storage volume relation indicated on Fig 2.2.2.11 in the previous section.

7) Freeboard of the dam crest

The freeboard of the dam crest is decided by the following formula.

- h2=0.05・H2+1.0 (in case of "R" being less or equal than 1.0m (R≦1.0m))
- h2=0.05・H2+R (in case of "R" being larger than 1.0m (R＞1.0m))

"R" is the wave height that includes the height of wave swash on the slope, and estimated by the following diagram usually. Rwanda is situated in the equatorial calm zone so that the average wind velocity does not exceed 10m/sec as shown below as the observation record in Kigali. Therefore "R" is considered to be less than 1.0m to 900m of the opposite shore distance and the freeboard is estimated to be 1.1m as follow.

- h2 =0.05・H2+1.0

  =0.005×{EL.1392.3m H.W.L.－(EL.1380m Foundation－1.5m Excavation)}+1.0m

  =1.07m

  ≒1.1m

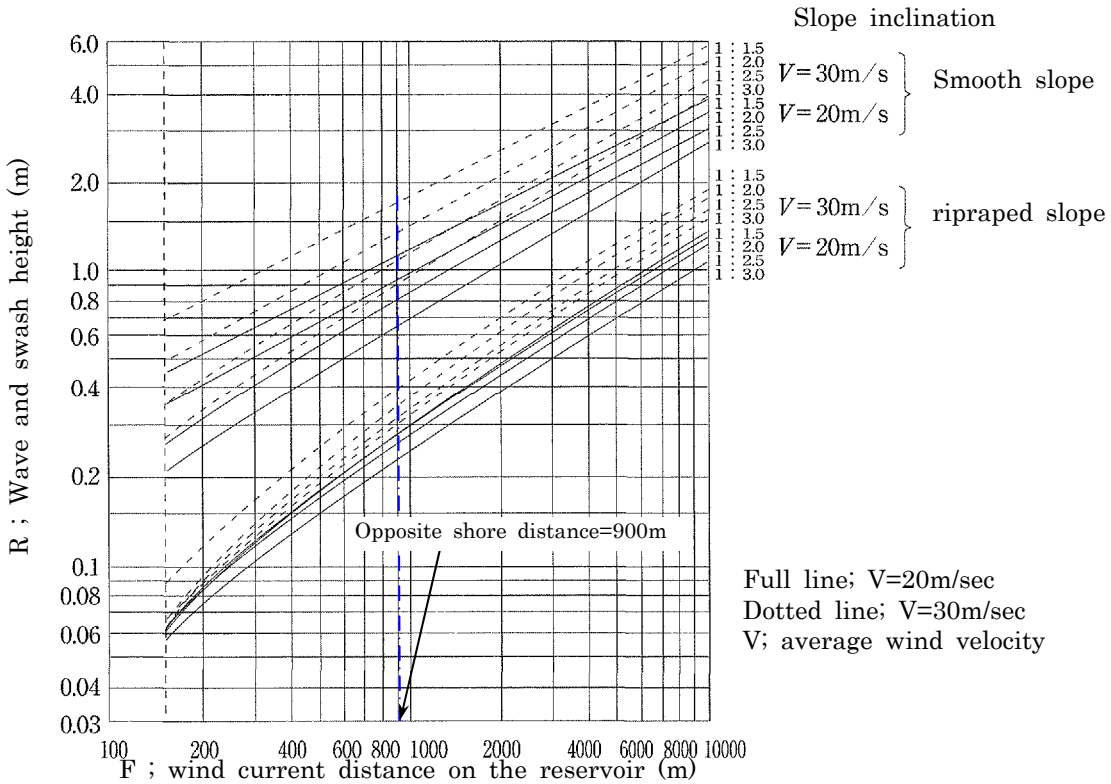


Figure 2.2.2.29 Swash Height of Waves on the Slope

Frequency of wind velocity and direction in Kigali(%) (Data number: 8,056)

	DIRECTION								
	NE	E	SE	S	SW	W	NW	N	TOT-V
SPEED(m/s)									
1-2	5.6	5.2	4.8	9.2	2.2	2.7	4.9	6.9	41.6
3-5	4.3	4.3	2.8	4.6	.7	.5	1.1	4.0	22.2
6-7	.3	.4	.1	.1	.0	.1	.1	.3	1.3
8-10	.1	.0	.0	.0	.0	.0	.0	.0	.2
> 10	.0	.0	.0	.0	.0	.0	.0	.0	.0

8) Design of Foundation Treatment against Seepage

(1) Foundation treatment method

The foundation of the dam body is composed of the upper pervious ~ semi-pervious earthen layer, and the lower semi-pervious weathered rock layer. In the dam construction, foundation treatment works are usually provided to reduce the leakage through foundation, in other words to secure the storage function of the reservoir.

As the treatment method, the grouting method and the blanket method are common. The former is the technological method where cracks in a rock formation are choked by cement milk injected through the wall of drilled hole and the consequent imperviousness of the foundation can reduce the leakage quantity. The latter is composed of earthen works of the horizontal blanket, which is connected to the impervious embankment, increase the seepage path length and decrease the hydraulic gradient and leakage quantity consequently.

In the case of Ngoma22, the grouting method can not be applied because of the foundation being composed of earthen to highly weathered rock formation and having no cracks/room for cement milk to be injected. The blanket method is the only applicable method for the foundation treatment of the dam of Ngoma22.

(2) Basic equations

$$q_f = \frac{k \cdot h \cdot d}{x_r + x_d} \qquad x_r = \frac{e^{2ax} - 1}{a\,(e^{2ax} + 1)} \qquad a = \sqrt{\frac{k_1}{t \cdot k \cdot d}}$$

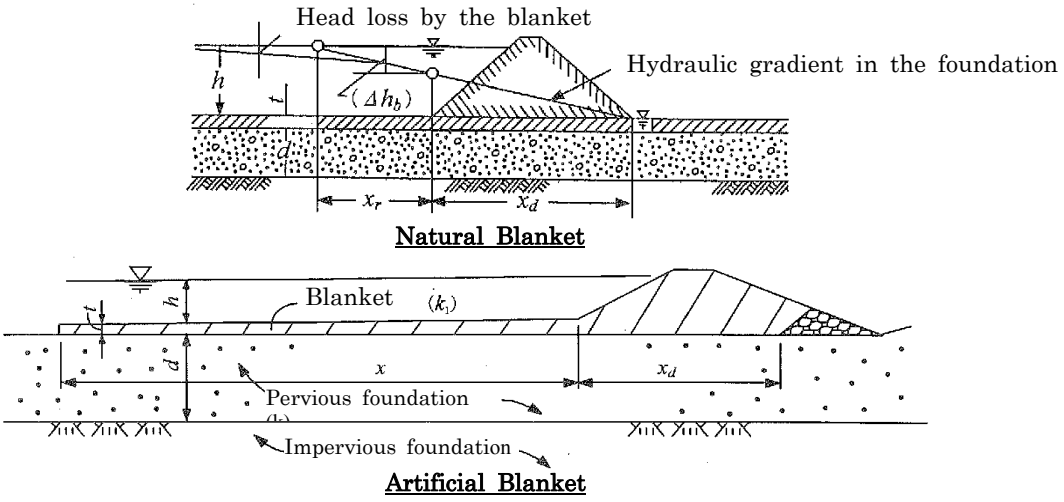


Figure 2.2.2.30 Component for Studying the Blanket Structure

Here,

qf :Seepage quantity through the foundation layer (m^3/sec)

h :Differential between the reservoir water level and the downstream water level (m)

xr :Effective seepage length (m)

xd :Bottom length of the dam body (m)

x :Required length of the blanket (m)

k :Permeability coefficient of the foundation layer (m/sec)

k_1 :Permeability coefficient of the blanket and the dam body (m/sec)

t :Thickness of the blanket (m)

d :Thickness of the foundation layer (m)

(3) Permeability coefficient of the foundation

Table 2.2.2.39 and Fig 2.2.2.31 are the results of in-situ permeability tests by pit method carried out in 2012 and 2013 and the borehole permeability tests done by this preparatory survey. On Fig 2.2.2.31 the boundary in permeability coefficient shall be drawn at the depth of 10m. The upper layer's permeability coefficient is estimated to be $k=4.2\times10^{-3}$cm adopting the additional value of average and standard deviation from the view point of margin. The lower layer is considered to be impervious with the permeability coefficient of less than $K=1.0\times10^{-4}$cm/sec in comparison with the upper layer so that the lower layer is not counted as the foundation through which seepage arises. The thickness of the foundation layer becomes 8.5m when considering the excavation depth of 1.5m (Refer to Appendix 6.14).

Table 2.2.2.39 Summary of In-situ Permeability Test Results

Pit/ Bore hole	Hole No.	test depth (m)	Permeability coefficient (cm/sec)	mean value (cm/sec)	ground condition
TP-1	N0.1	1.7	3.60E-03	9.87E-04	earth
	No.2	1.7	3.30E-02		earth
	No.3	3.4	2.30E-04		earth
	No.4	3.4	3.20E-03		earth
	No.5	5.1	8.50E-04		earth
	No.6	5.1	1.00E-03		earth
TP-2	No.1	1.0	2.20E-03		earth
	No.2	1.0	4.30E-03		earth
TP-3	N0.1	1.7	1.20E-02		earth
	No.2	1.7	1.00E-02		earth
	No.3	3.4	1.40E-03		earth～highly weathered
	No.4	3.4	1.30E-03		
	No.5	4.2	1.10E-04		highly weathered
	No.6	4.2	1.00E-04		highly weathered
TP-4	N0.1	1.7	2.15E-04		earth
	No.2	1.7	2.17E-04		earth
	No.3	3.4	2.42E-03		earth
	No.4	3.4	2.42E-03		earth
	No.5	3.7	3.91E-03		highly weathered
	No.6	3.7	4.32E-03		highly weathered
TP-5	N0.1	1.7	8.05E-04		earth
	No.2	1.7	2.22E-03		earth
	No.3	3.4	1.30E-04		earth, water
	No.4	3.4	1.32E-04		earth, water
TP-6	N0.1	1.7	2.11E-03		earth
	No.2	1.7	1.64E-03		earth
	No.3	3.4	7.27E-04		earth
	No.4	3.4	7.14E-04		earth
	No.5	4.3	1.03E-03		highly weathered
	No.6	4.3	1.03E-03		highly weathered
TP-7	N0.1	1.7	7.14E-04		earth
	No.2	1.7	9.66E-04		earth
	No.3	3.4	3.28E-04		earth
	No.4	3.4	3.18E-04		earth
	No.5	4.2	1.40E-04		earth
	No.6	4.2	1.39E-04		earth
BH-4	0～5m	2.5	1.70E-04	7.5m以深 9.40E-05	earth
	5～10m	7.5	2.40E-04		earth
	10～15m	12.5	5.90E-04		highly weathered
BH-5	0～5m	2.5	9.90E-04		earth
	5～10m	7.5	1.40E-05		earth
	10～15m	12.5	5.30E-05		highly weathered
BH-6	0～5m	2.5	1.50E-04		earth
	5～10m	7.5	1.80E-04		earth
	10～15m	12.5	3.70E-05		weathered rock

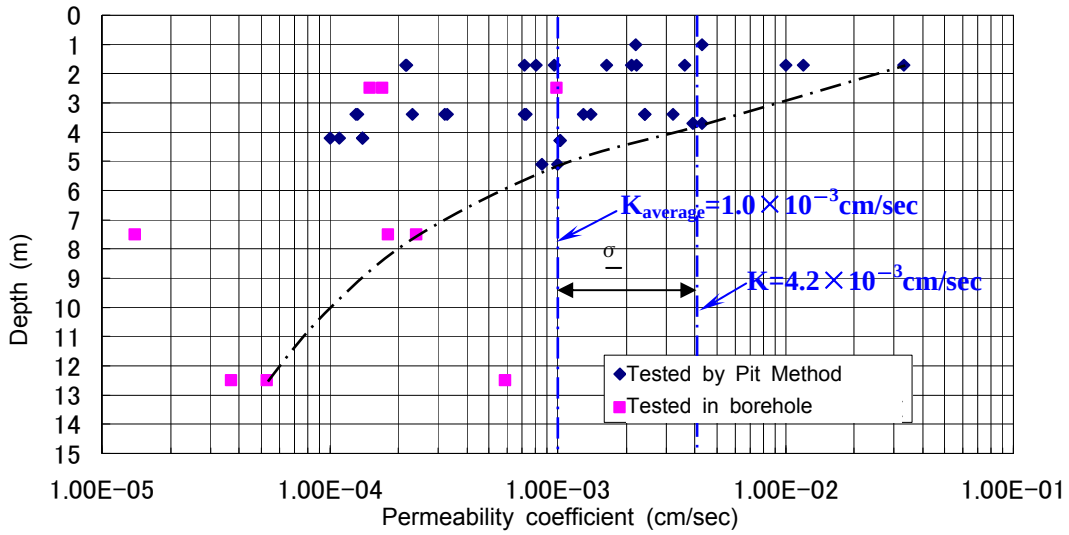
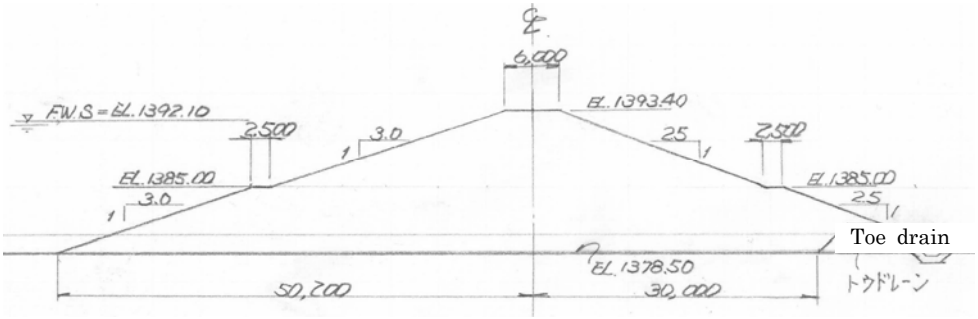


Figure 2.2.2.31 Results of In-situ Permeability Tests

(4) Assumed cross-section of dam body

The cross-section of the homogeneous type dam is assumed for the study.



(5) Trial calculation and adoption of blanket length "x"

To the cases of the blanket thickness: 1.0m, 1.5m, 2.0m, 2.5m, the seepage quantity "qf" is calculated to the given value of "x" by the former basic equations. The calculated result is shown in Table 2.2.2.40 and summarized on Fig 2.2.2.32.

Here, the allowable leakage quantity is set to be 0.05% of the total reservoir capacity per day. Then the allowable quantity is calculated at 480m^3/day (= 960,000m^3×0.05/100)

Through checking the calculation result, it is clarified that 1.5m of the blanket thickness and 30m of the blanket length can satisfy the allowable limit.

The leakage quantity per meter to these dimensions is as follows.

qf=3.98×$10^{-5}$$m^3$/sec=3.98×$10^{-5}$ m^3/sec×86,400sec/day=3.44m^3/day

When the leakage quantity all through the longitudinal dam crest length is counted, the total leakage quantity per day is estimated to be 325.9m^3/day, which is less than the allowable one.

Q =3.44m^3/(day・m)×22m+(1/2)×(167.5m－22m)×3.44m^3/(day・m)

=325.9m^3/day<485m^3/day

Table 2.2.2.40 Trial Calculation of Blanket Length and Thickness

t(m)	k	d(m)	k1	a	x(m)	e2ax	xr(m)	qf(m3/sec)
1	0.000042	8.5	0.0000001	0.016737	0	1	0	6.069E-05
1	0.000042	8.5	0.0000001	0.016737	10	1.397564	9.907664	5.00313E-05
1	0.000042	8.5	0.0000001	0.016737	20	1.953186	19.28506	4.53059E-05
1	0.000042	8.5	0.0000001	0.016737	30	2.729703	27.70967	4.17623E-05
1	0.000042	8.5	0.0000001	0.016737	40	3.814936	34.93109	3.91382E-05
1	0.000042	8.5	0.0000001	0.016737	50	5.331618	40.87611	3.72133E-05
1	0.000042	8.5	0.0000001	0.016737	60	7.45128	45.60973	3.58109E-05
1	0.000042	8.5	0.0000001	0.016737	70	10.41364	49.27964	3.47943E-05
1	0.000042	8.5	0.0000001	0.016737	80	14.55374	52.06650	3.40601E-05
1	0.000042	8.5	0.0000001	0.016737	90	20.33978	54.14966	3.35312E-05
1	0.000042	8.5	0.0000001	0.016737	100	28.42615	55.68850	3.31509E-05
1	0.000042	8.5	0.0000001	0.016737	110	39.72738	56.81536	3.28779E-05
1	0.000042	8.5	0.0000001	0.016737	120	55.52157	57.63526	3.2682E-05
1.5	0.000042	8.5	0.0000001	0.013665	0	1	0	6.069E-05
1.5	0.000042	8.5	0.0000001	0.013665	10	1.314303	9.938214	4.80296E-05
1.5	0.000042	8.5	0.0000001	0.013665	20	1.727393	19.51647	4.34069E-05
1.5	0.000042	8.5	0.0000001	0.013665	30	2.270318	28.42512	3.98404E-05
1.5	0.000042	8.5	0.0000001	0.013665	40	2.983887	36.44095	3.70978E-05
1.5	0.000042	8.5	0.0000001	0.013665	50	3.921732	43.44123	3.4994E-05
1.5	0.000042	8.5	0.0000001	0.013665	60	5.154345	49.39699	3.33833E-05
1.5	0.000042	8.5	0.0000001	0.013665	70	6.774373	54.35246	3.2152E-05
1.5	0.000042	8.5	0.0000001	0.013665	80	8.90358	58.3998	3.12117E-05
1.5	0.000042	8.5	0.0000001	0.013665	90	11.702	61.65561	3.04944E-05
1.5	0.000042	8.5	0.0000001	0.013665	100	15.37998	64.24283	2.99474E-05
1.5	0.000042	8.5	0.0000001	0.013665	110	20.21396	66.27884	2.95306E-05
1.5	0.000042	8.5	0.0000001	0.013665	120	26.56728	67.86883	2.92131E-05
2.0	0.000042	8.5	0.0000001	0.011835	0	1	0	6.069E-05
2.0	0.000042	8.5	0.0000001	0.011835	10	1.267049	9.953575	4.60371E-05
2.0	0.000042	8.5	0.0000001	0.011835	20	1.605413	19.6347	4.15638E-05
2.0	0.000042	8.5	0.0000001	0.011835	30	2.034137	28.79997	3.80625E-05
2.0	0.000042	8.5	0.0000001	0.011835	40	2.577351	37.25769	3.53171E-05
2.0	0.000042	8.5	0.0000001	0.011835	50	3.26563	44.88021	3.31614E-05
2.0	0.000042	8.5	0.0000001	0.011835	60	4.137713	51.60508	3.14669E-05
2.0	0.000042	8.5	0.0000001	0.011835	70	5.242685	57.42731	3.01337E-05
2.0	0.000042	8.5	0.0000001	0.011835	80	6.642738	62.38641	2.90842E-05
2.0	0.000042	8.5	0.0000001	0.011835	90	8.416675	66.55195	2.82576E-05
2.0	0.000042	8.5	0.0000001	0.011835	100	10.66434	70.01017	2.76061E-05
2.0	0.000042	8.5	0.0000001	0.011835	110	13.51224	72.85338	2.70926E-05
2.0	0.000042	8.5	0.0000001	0.011835	120	17.12067	75.17232	2.66877E-05
2.5	0.000042	8.5	0.0000001	0.010585	0	1	0	6.069E-05
2.5	0.000042	8.5	0.0000001	0.010585	10	1.23578	9.962818	4.40482E-05
2.5	0.000042	8.5	0.0000001	0.010585	20	1.527153	19.70647	3.97437E-05
2.5	0.000042	8.5	0.0000001	0.010585	30	1.887225	29.03068	3.63448E-05
2.5	0.000042	8.5	0.0000001	0.010585	40	2.332195	37.76952	3.36479E-05
2.5	0.000042	8.5	0.0000001	0.010585	50	2.88208	45.80129	3.14997E-05
2.5	0.000042	8.5	0.0000001	0.010585	60	3.561617	53.05172	2.97832E-05
2.5	0.000042	8.5	0.0000001	0.010585	70	4.401376	59.49142	2.84082E-05
2.5	0.000042	8.5	0.0000001	0.010585	80	5.439133	65.12907	2.73047E-05
2.5	0.000042	8.5	0.0000001	0.010585	90	6.721572	70.00253	2.64176E-05
2.5	0.000042	8.5	0.0000001	0.010585	100	8.306385	74.16955	2.57035E-05
2.5	0.000042	8.5	0.0000001	0.010585	110	10.26487	77.69932	2.51282E-05
2.5	0.000042	8.5	0.0000001	0.010585	120	12.68512	80.66565	2.46643E-05

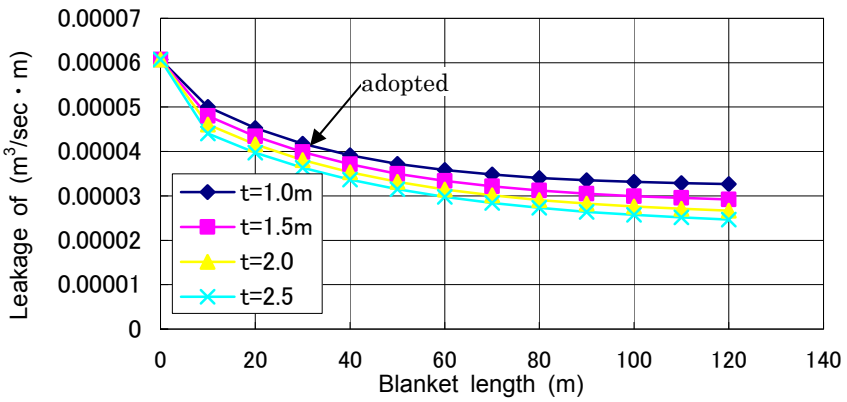


Figure 2.2.2.32 Blanket Length and Leakage Quantity

(6) Seepage analysis by finite element method

Here, the seepage analysis by finite element method shall be conducted to confirm the seepage suppressive effect of the foundation treatment by the combination of homogeneous dam body and horizontal blanket and the safety of the foundation against seepage failure.

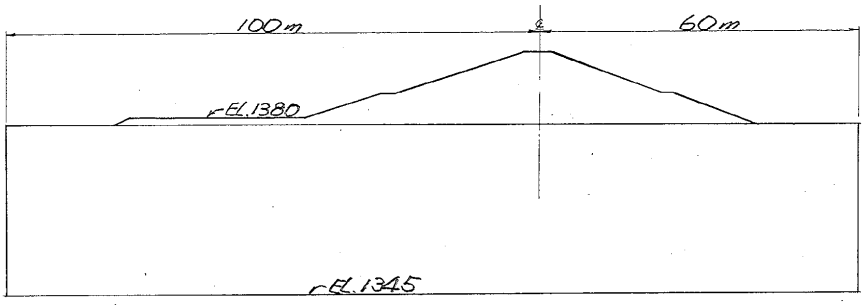
a) Coverage of the analysis

The analysis targets the total mass of dam body and foundation. The analysis coverage of the foundation is decided empirically as follows.

Upstream :100m from the dam axis (upstream end of the horizontal blanket + dam height)

Downstream :60m from the dam axis (slope toe of the embankment + dam height)

Depth :To the elevation line of EL. 1345.0 (from the river bed elevation to the depth about twice of dam height)



b) Permeability coefficient

Permeability coefficient k=1×10^{-5}cm/sec, which corresponds to the quality control criteria to the embankment work, is applied to the dam body and the horizontal blanket. k=5×10^{-3}cm/sec is applied to the drain and the toe drain judging empirically from the material's gradational conditions. As for the foundation, it is divided into two layers by the boundary at 7m in depth (EL. 1373.0m) based on the geological conditions and the result of borehole permeability tests. The permeability coefficients are estimated as follows based on Fig 2.2.2.33.

The upper layer ; k= 4.2×10^{-3}cm/sec, The lower layer ; k= 3.7×10^{-4}cm/sec

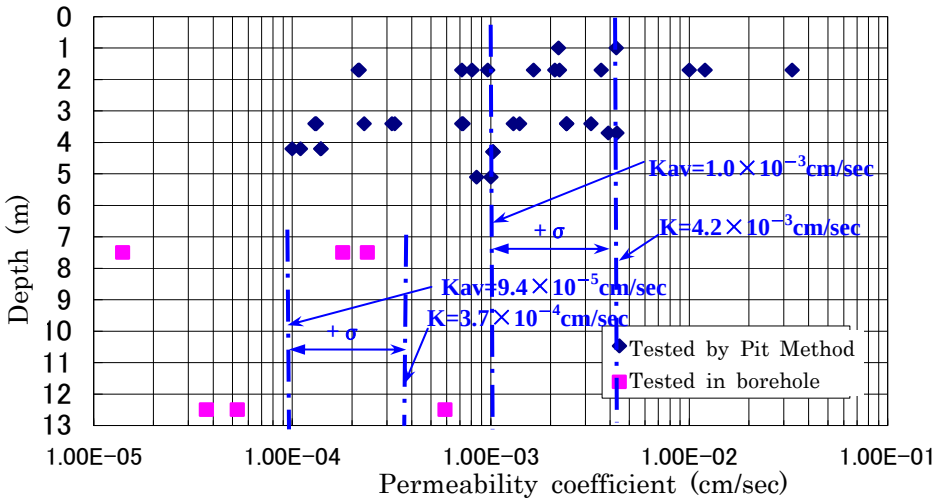


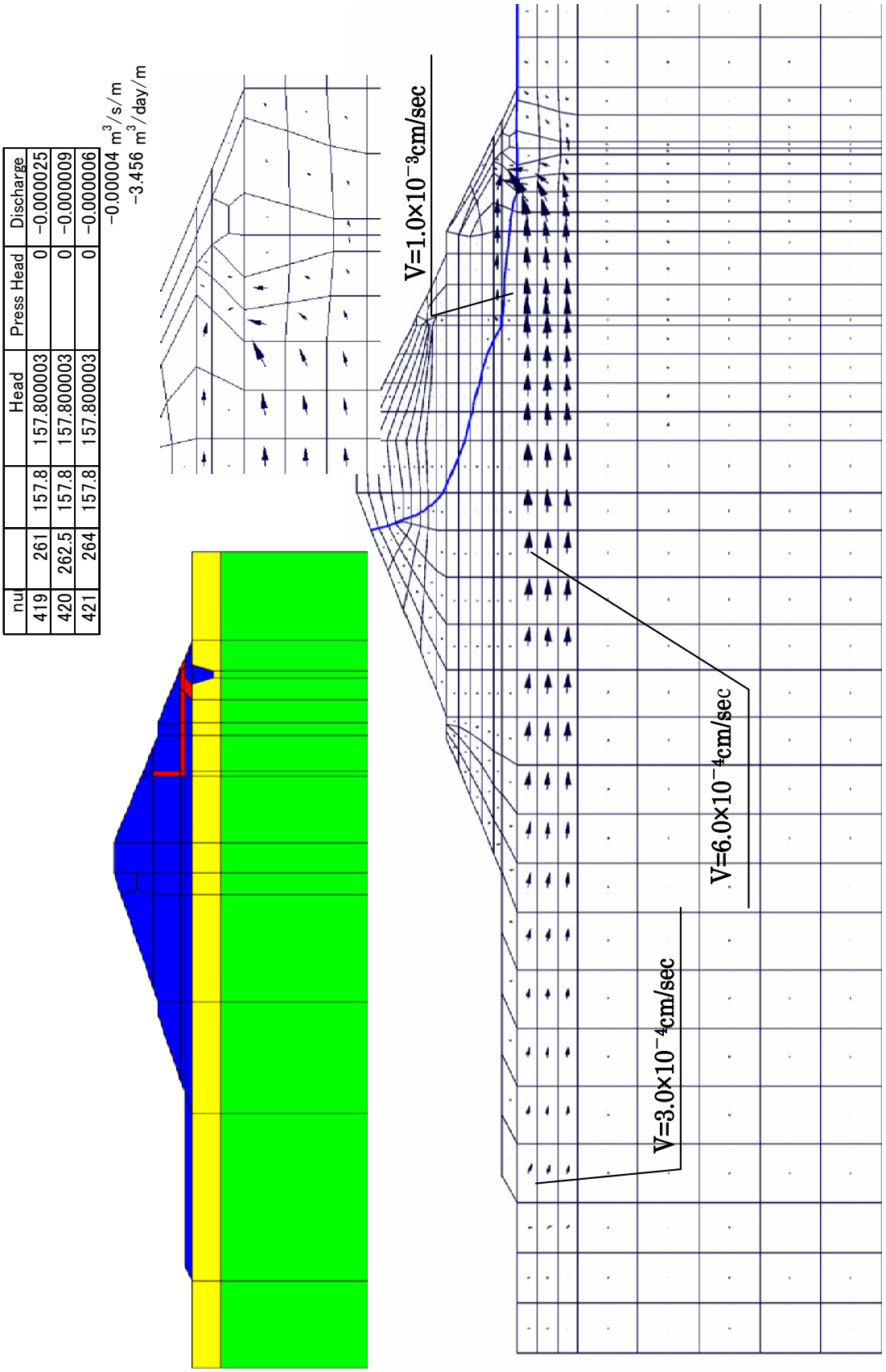
Figure 2.2.2.33 Estimation of k for Finite Element Analysis

c) Analysis result

Fig 2.2.2.34 of the illustration of analysis model, where the seepage flow is caught by the drains colored in red, shows the zones in permeability coefficient and the velocity vector distribution obtained by the analysis. The seepage flow through the dam body and the foundation is concentrated in the upper foundation layer and is gathered effectively into the toe drain by the aid of impervious trench and the embankment at the slope toe. 1.0×10^{-3}cm/sec is the maximum seepage flow velocity at the toe drain bottom. To this, the hydraulic gradient is: $i=v/k=(1.0\times10^{-3}\text{cm/sec})/(4.2\times10^{-3}\text{cm/sec})=0.24$. The value of 0.24 is estimated to have a large margin to the critical hydraulic gradient that is defined as the ratio of "underwater unit weight of soil" and "unit weight of water" so that there is no possibility of the piping phenomenon arising at the seeping out point.

The leakage quantity is estimated by summing up the seeping out quantity of each element. A vast majority of the amount is concentrated on two elements with three nodes, No.419, No.420 and No.421, and counted to be 0.00004m^3/sec/m (=3.46m^3/day/m), which is equivalent to 3.44m^3/day/m calculated by the equations.

Though total amount of leakage shall be a little bit larger than this amount, it would be able to say that the foundation treatment by the combination of homogeneous dam body and horizontal blanket functions enough to reduce the leakage and that the adequacy of design details is confirmed.



nu			Head	Press Head	Discharge
419	261	157.8	157.800003	0	−0.000025
420	262.5	157.8	157.800003	0	−0.000009
421	264	157.8	157.800003	0	−0.000006

Figure 2.2.2.34 Seepage Analysis Result（Analysis Model and Velocity Vector Distribution）

9) Typical Cross-Section of the Dam Body and the Slope Blanket

(1) Typical cross-section of the dam body

a) Crest width

The width of the dam crest is provided with 6m as the safety treatment considering the additional dam height being not so high and the water surface coming up near the dam crest.

b) Slope inclination

The upstream slope and the downstream slope is provide with the inclination of 1:3.0 and 1:2.5 respectively considering the stability of the dam body and the bottom width of the embankment being effective to reduce the seepage quantity.

c) Berm

A berm of 2.5m wide is provided at EL.1385.0m on the upstream slope and the downstream slope of the dam body considering its contribution to the embankment stability and maintenance works.

d) Drain

A vertical drain, which has 1.0m of width and continuously longitudinal, is provided in the downstream embankment to catch the seepage flow toward downstream and prevent it from appearing on the downstream slope.

The seepage water caught by the vertical drain is led by the horizontal drain to the toe drain and discharges outside. The horizontal drain is placed on the bed of impervious embankment to make the seepage path length in the foundation as long as possible.

e) Toe drain and catch-weir embankment

Toe drain is provided as a pan of drainage to which the seepage through embankment and foundation flows into. Behind the toe drain, a catch-weir embankment with a impervious trench is provided to catch the seepage flow as much as possible.

f) Slope protection

The upstream slope is protected by riprap works against the erosive action of waves. The protection range by riprap works is from EL. 1388.50m (Low Water Level – 0.50m) to EL. 1392.30m (High Water Level).

The downstream slope and the slope toe are protected by grass planting against the erosive action of rain water.

g) Dam crest protection

The dam crest is protected by the compacted soil-cement mixture, 4m wide and 0.4m deep, against the erosive action of rain water, ant activities digging holes into embankment and the wheel load of vehicles for maintenance works. Here, this soil-cement improving method is introduced considering the protection work to be impervious and not to increase the dam height.

A row of curbstones composed of cubic rocks with the size 40cm x 40cm x 60cm approximately laid at 1.0m interval are provided to the dam crest edge upstream and downstream respectively to prevent cars from dropping from the crest.

(2) Typical cross-section of the slope blanket

a) Coverage area by the slope blanket

The hill slopes extending at the both sides beyond the horizontal blanket, of which length is decided to be 30m in the previous section, must be covered by the slope blanket to prevent the reservoir water from seeping into the foundation from both sides of the horizontal blanket.

b) Back pressure and the shape of the cross-section

The ground water in hills flows down toward the slope toe or the water table in the valley river before the reservoir being filled with water, and after water being stored in the reservoir the ground water flows down toward the water surface in the reservoir. Therefore, the ground water table goes up remarkably after the water is stored in the reservoir.

The slope blanket restrains reservoir water from seeping into the hillside ground and also restrains ground water from seeping out from the hillside to the reservoir side. Therefore, at the stage of the reservoir water level being lowered, the slope blanket receives on its contact surface the water pressure caused by the ground water table contained in hills. The slope blanket must be designed to be safe against this back pressure something like lifting up or pushing foreword the embankment from its contact surface.

The slope blanket is designed to resist this back pressure by its own embankment weight, so that the cross-section is shaped with following dimensions that secure the embankment to have the zone thickness more than 50% of the water depth at the corresponding position.

Excavation of the ground;

- Cutting slope in the area of higher than EL.1381.50 :Inclination=1:2.4
- Berm at EL.1381.50 :Width=3.5m
- Cutting slope in the area of lower than EL.1381.50 :Inclination=1:4.0

Embankment shape of the dam;

- Crest width :W=4.0m
- Embankment slope in the parts of higher than EL.1385.00 :Inclination=1:3.0
- Berm at EL.1385.00 :Width=2.5m
- Embankment slope in the parts of lower than EL.1385.00 :Inclination=1:5.0

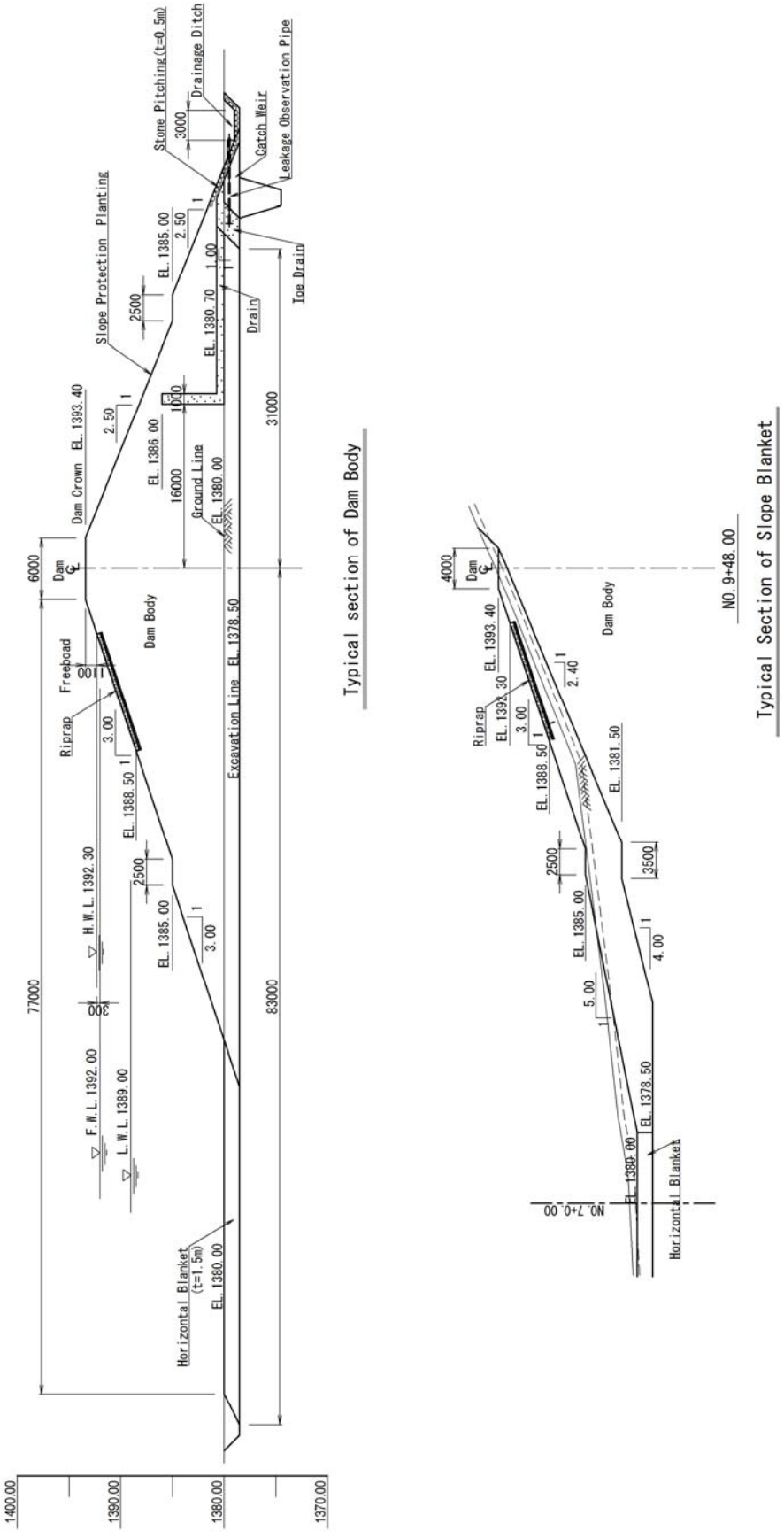


Figure 2.2.2.35 Typical Cross-section of the Dam Body and the Slope Blanket

10) Stability Analysis of the Dam Body

(1) Standard to be followed

The stability analysis of the dam body is to be conducted following the standard "Design of Storage Reservoir", which is the design standard of low dams edited by Ministry of Agriculture, Forestry and Fisheries of Japan.

(2) Methodology of stability analysis

a) Earthquake-resisting design by static seismic force

Lake Kivu in the northern part of Rwanda is situated on African Great Rift Valley and earthquakes occur occasionally in Rwanda so that the earthquake-resisting design shall be applied to the dam body, where the stability of dam body is evaluated to a body force assumed by a seismic acceleration acting horizontally on the dam body, the method of which is so-called "static seismic intensity method".

b) Stability analysis by the sliding-circle sliced block method

In this method, a sliding surface is set as a circular arc in through the dam body, the soil block on the assumed sliding surface is sliced into reed-shape. The slide-resisting force and slide-activating force is evaluated at the bottom of each slice, and then slide-resisting forces and slide-activating forces are summed up respectively. The safety factor is defined as the proportion of the total slide-resisting forces against the total slide-activating forces by the following formula.

$$F_s = \frac{\Sigma\{c' \times l + (N - U - N_e) \times \tan\phi'}{\Sigma(T + T_e)}$$

Here,

Fs :Safety factor

c' :Cohesion of the material at the slice bottom on the sliding surface

ϕ ' :Internal friction angle of the material at the slice bottom on the sliding surface

l :Length of the sliding surface at the slice bottom l=b/cos α

b :Width of the slice

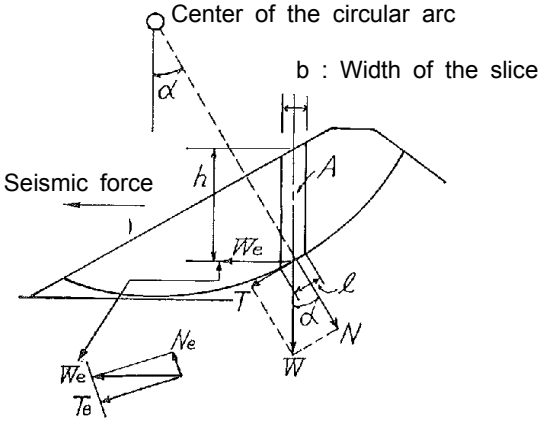
N :Vertical force component of the total load acting on the slice bottom

T :Tangential force component of the total load acting on the slice bottom

Ne :Vertical force component of the seismic load acting on the slice bottom

Te :Tangential force component of the seismic load acting on the slice bottom

U :Pore pressure acting on the slice bottom



c) Design seismic intensity

"Seismic Hazard Map of the World" estimates the western part of Rwanda, Lake Kivu side, to be "Moderate Hazard" and the eastern part to be "Low Hazard". The Ngoma22 site is located in the latter area where the maximum acceleration with 475 years exceedance probability is estimated to be 0.8m/sec^2. This value is converted into static seismic intensity "k" as follows.

k=0.8 m/sec^2/9.8 m/sec^2

=0.08

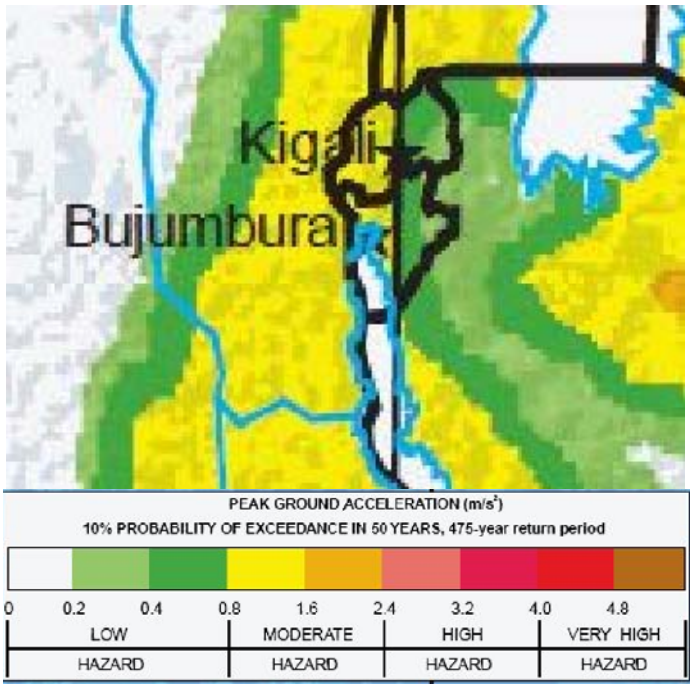


Figure 2.2.2.36 Earthquake in Rwanda
(Seismic Hazard Map of the World, by Andrew Alden)

d) Conditions for analysis

Conditions such as the situation of the dam body and the reservoir, requested safety factor, design seismic intensity 'k', etc. are as follows in accordance with the standard "Design of Storage Reservoir".

Reservoir situation		k	Stress condition	Side	Safety factor
Just after completion	—	50%	Total stress	Up/Downstream	1.20≦
F.W.L.	EL.1392.0	100%	Effective stress	Up/Downstream	1.20≦
L.W.L.	EL.1389.0	100%	Effective stress	Upstream	1.20≦
Rapid draw down	EL.1392.0→ EL.1389.0	50%	Effective stress	Upstream	1.20≦

e) Design values

(a) Quality control criteria

Quality control criteria shall be set to conduct the quality control of the embankment works and secure the quality of the embankment that satisfies the design conditions. Physical properties of the embankment materials shall be decided in accordance with the quality control criteria.

[Impervious embankment]

To the impervious embankments consisting of the dam body, the horizontal blanket and the slope blanket, the "D value" control method is applied based on the dependency of mechanical properties on the relative density (compaction degree of the embankment; "D value"). "D value" is defined by the following formula.

$$D\ value = \frac{Dry\ \ density\ \ of\ \ the\ embankment}{Maximum\ dry\ density\ in\ the\ laboratory\ compaction\ test} \times 100(\%)$$

The impervious materials in the dam site area used for the embankment materials are pervious in the layer and untouched conditions in spite of the materials being composed of mainly clay and silt gradationally. Moreover, the excavated materials tend to be solid lumps due to the low moisture content and solidity of the layer itself. Therefore, it is important to crush the lumps of soil and break

the structural fabric of soil particles in the layer to make the embankment impervious. Considering this point, high level compaction is to be requested and in this line the vibratory tamping roller shall be adopted as a compaction machine and D value of 97% shall be applied as the compaction criteria.

Permeability coefficient should be a factor for embankment quality control so that the field permeability test is planned to implement. The criteria value is set to be 1.0 X 10-5 cm/sec taking account of some empirical elements in terms of embankment permeability such as 1) as anisotropic aspect, in terms of permeability in vertical and in horizontal direction, caused by horizontal spreading and compaction of embankment works being carries out layer by layer, 2) the difference of permeability direction between the results of field test and laboratory 3) it is empirically said that the value of permeability obtained by the field test is larger than that of laboratory test result, the difference is one order of magnitude.

[Drain and Toe Drain]

Sand-and-gravel obtained from the Rwinkwuvu sand pit 30 km away from the dam site shall be used as the embankment materials for drain and toe drain. The quality control of these zones shall be done in terms of the compaction degree, D value, and the field permeability test. The criteria shall be set as follows.

- D value :High level compaction is not required so that D value of 95% shall be adopted as the common value.
- Permeability coefficient:

  The value of $k \geqq 1.0 \times 10^{-3}$cm/sec shall be adopted considering the zone's function to catch the seepage flow, lead and discharge it out of the embankment.

(b) Physical properties

[Impervious embankment]

- Unit weight:

  Dry density :Based on the compaction test results, the average dry density corresponding to D-97% is adopted.

  $\rho d=(1.68+1.71+1.78+1.81)\times 0.97\div 4=1.69$ tf/m^3

  Wet density :Moisture content shall be adjusted at around the optimum moisture content Wopt so that the materials' moisture content is assumed to be at Wopt.

  $\rho t=\rho d\times(1+w/100)=1.69\times\{1+(19.4/100+18.1/100+14.8/100+14.3/100)/4\}=1.97$tf/m^3

- Saturated unit weight:

  Specific gravity of soil particles shall be estimated based on the test result of the previous study in 2009.

  $Gs=(2.65+2.66+2.70+2.65+2.63+2.70)/6=2.67$

  Void ratio "e" shall be calculated as the value corresponding to the dry density D 97%.

  $e=Gs/\rho d-1=2.67\div 1.69-1=0.58$

  Saturated unit weight is calculated as follows.

  $\rho sat=(Gs+e)\div(1+e)=(2.67+0.58)/(1+0.58)=2.06$ tf/m^3

- Shear strength;

Shear strength of the materials is evaluated based on the direct shear tests carried out in this preparatory survey. Reduction of the shear strength factors obtained in the test shall not be considered because of the specimens consisting of clay and silt only and the shear strength factors being not influenced by granular particles on the shearing surface.

Shear strength (τ) is expressed in the equation: $\tau = \sigma \tan \phi + c$ by the shear strength factors, i.e. cohesion: c and internal friction angle: ϕ , here σ : vertical stress. The figure below is the test result expressed by the equation above. This shows the tendency of the shear strength being proportional to the density condition. The design shear strength is evaluated as follows focusing on the lowest shear strength considering the safety side and the requisite minimum numbers of testing though it might be able to adopt higher values in accordance with the quality control criteria.

- Cohesion :C=32 KN/m^2
- Internal friction angle : ϕ =26°

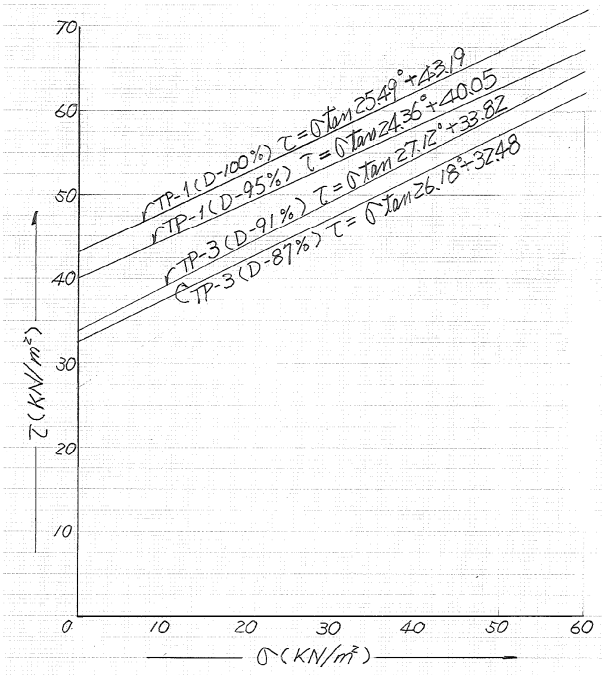


Figure 2.2.2.37 Summary of the Direct Shear Tests

[Drain and Toe Drain]

- Unit weight:

  Dry density :D 95% dry density is adopted in accordance with the compaction criteria; the value is calculated based on the maximum dry density of the compaction curve.

  $\rho d=2.00\times0.95=1.90 tf/m^3$

  Wet density :Moisture content shall be adjusted at around the optimum moisture content Wopt so that the materials' moisture content is assumed to be at Wopt.

  $\rho t=\rho d\times(1+w/100)=1.90\times(1+8.3/100)=2.06$ tf/m^3

- Saturated unit weight;

  The drain zone and the toe drain zone shall not be fully saturated so that the saturated unit weight is treated to be equivalent to the wet density.

  $\rho sat=2.06$ tf/m^3

  Shear strength :Internal friction angle 35° is adopted as the commonly evaluated value to sand. Cohesion is not counted.

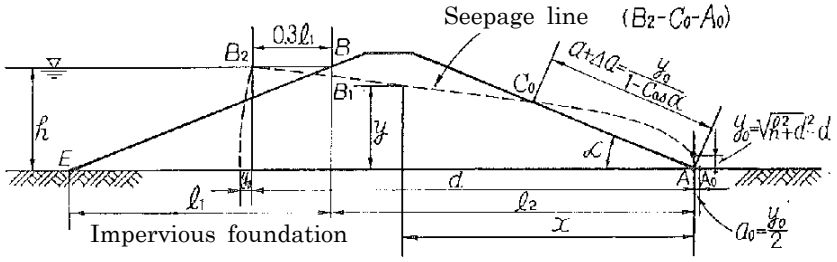
  ϕ =35°

f) Seepage line in the dam body

The seepage line in the homogeneous fill type dam is estimated by the method suggested by A. Casagrande. In embankment banked layer by layer through spreading and compaction process, there is a differential in permeability between the horizontal direction and the vertical direction. It is said empirically that the ratio of the horizontal permeability coefficient (kh) of the vertical permeability

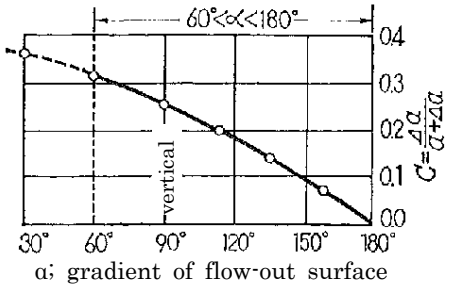
coefficient (kv) is 5.0 (kh/kv =5) in case of the compaction being done by tamping rollers. Before applying the method, the cross-section of dam body must be transformed from such anisotropic conditions into isotropic conditions. This transformation can be done through multiplying the horizontal length and distance of dam body by 1/√5. A. Casagrande showed the way of setting the seepage line by a fundamental parabola and the way to modify this parabola in terms of the flowing-in portion and the flowing-out portion. The fundamental parabola is given by the formula based on the illustration indicated below.

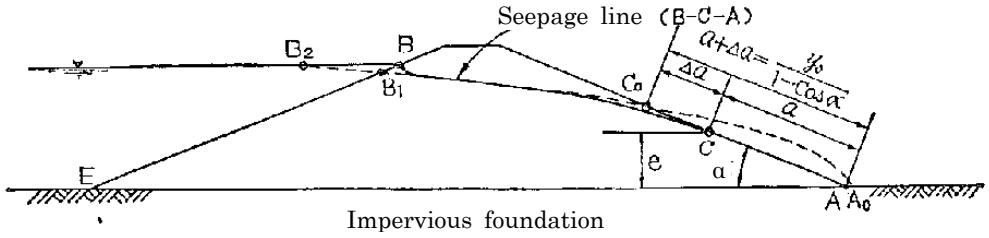
$$y = \sqrt{2y_0 x + y_0^2} \qquad y_0 = \sqrt{h^2 + d^2} - d$$



Modifications of the flowing-in portion and the flowing-out portion are done as follows by the equation and illustrations.

$$a + \Delta a = \frac{y_0}{1 - \cos\alpha}$$





The F.W.L. (WL.=EL.1392.0) and L.W.L.(WL.=EL.1389.0) is shown in Fig 2.2.2.38.

g) Results of the stability analysis

The results of the stability analysis are shown on Fig 2.2.2.39 to Fig 2.2.2.44. Here, the safety of dam body against sliding failure at the event of earthquake is confirmed with the minimum safety factor being 1.865 to the downstream side just after completion of dam construction.

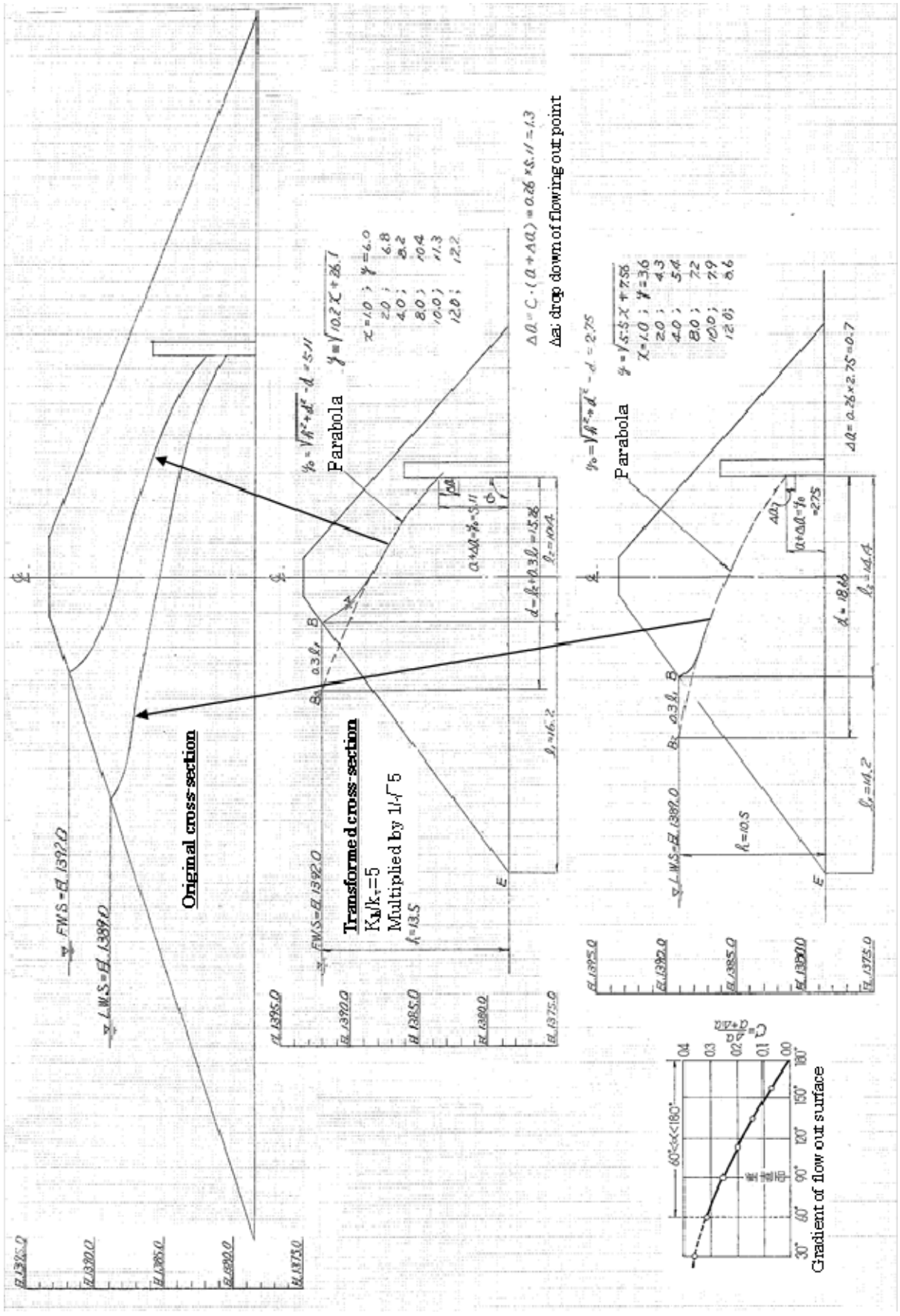


Figure 2.2.2.38 Setting of Seepage Line in the Dam Body

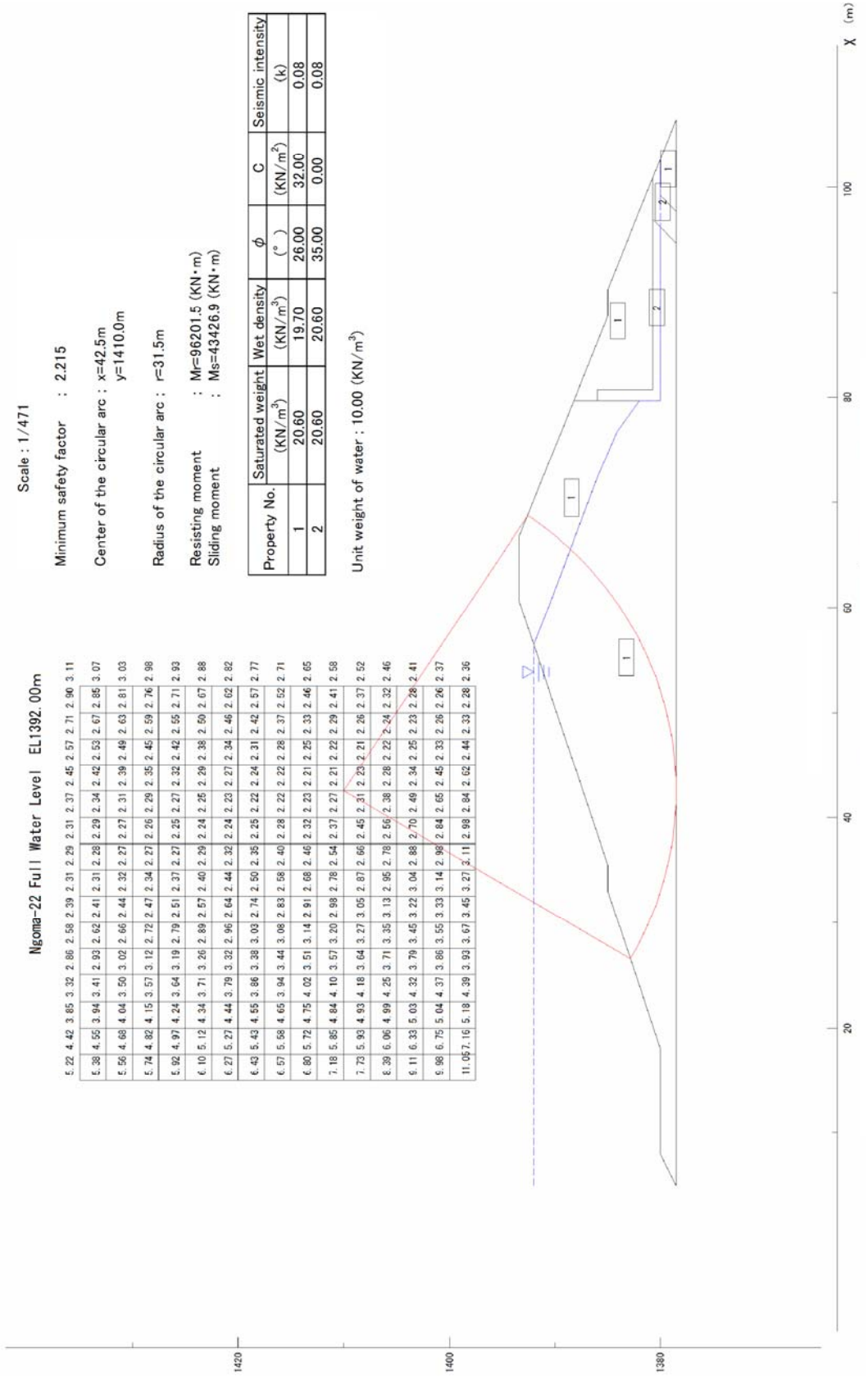
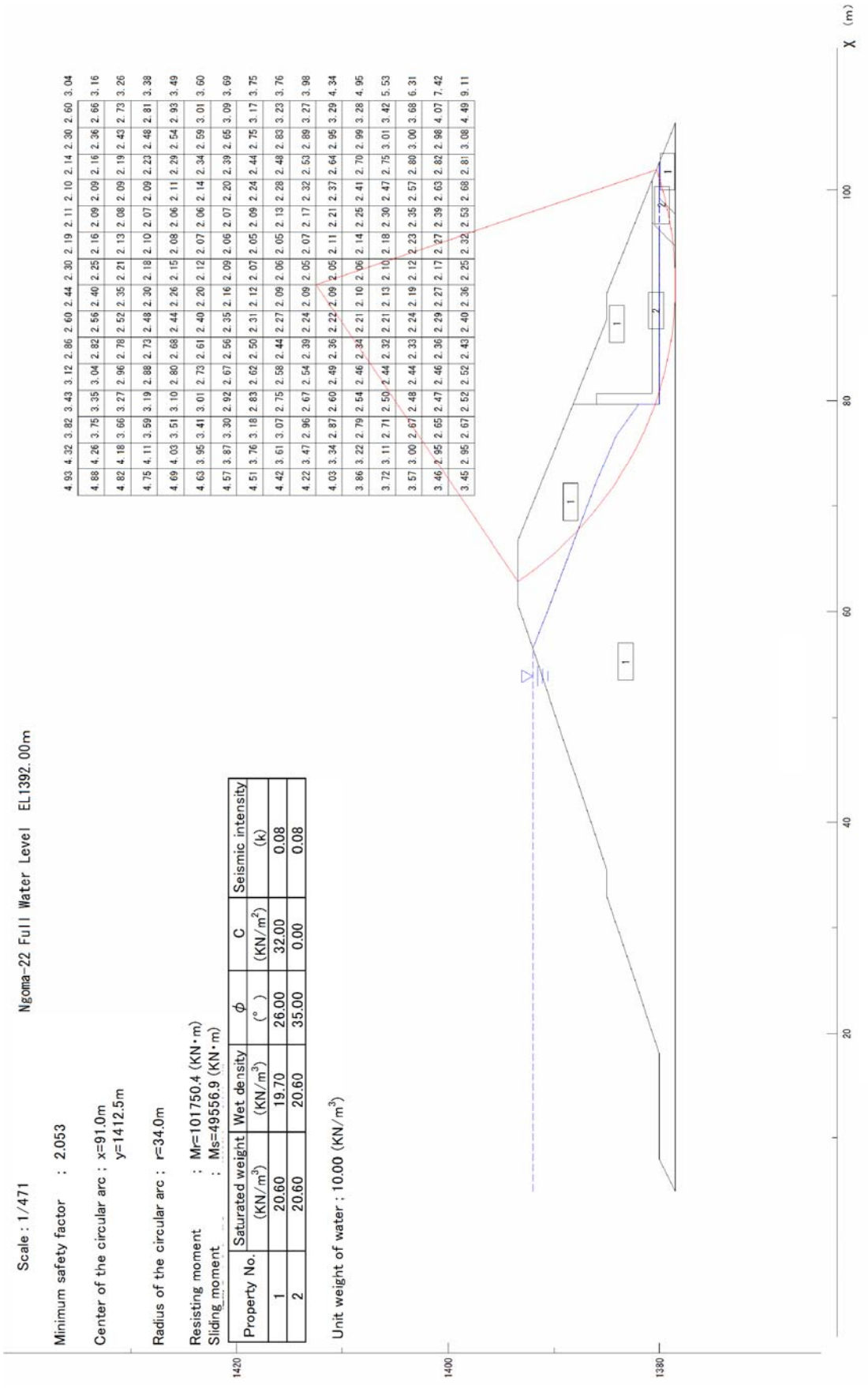


Figure 2.2.2.39 Safety Factor Distribution (F.W.L / Upstream)



Property No.	Saturated weight (KN/m³)	Wet density (KN/m³)	φ (°)	C (KN/m²)	Seismic intensity (k)
1	20.60	19.70	26.00	32.00	0.08
2	20.60	20.60	35.00	0.00	0.08

Figure 2.2.2.40 Safety Factor Distribution (F.W.L / Downstream)

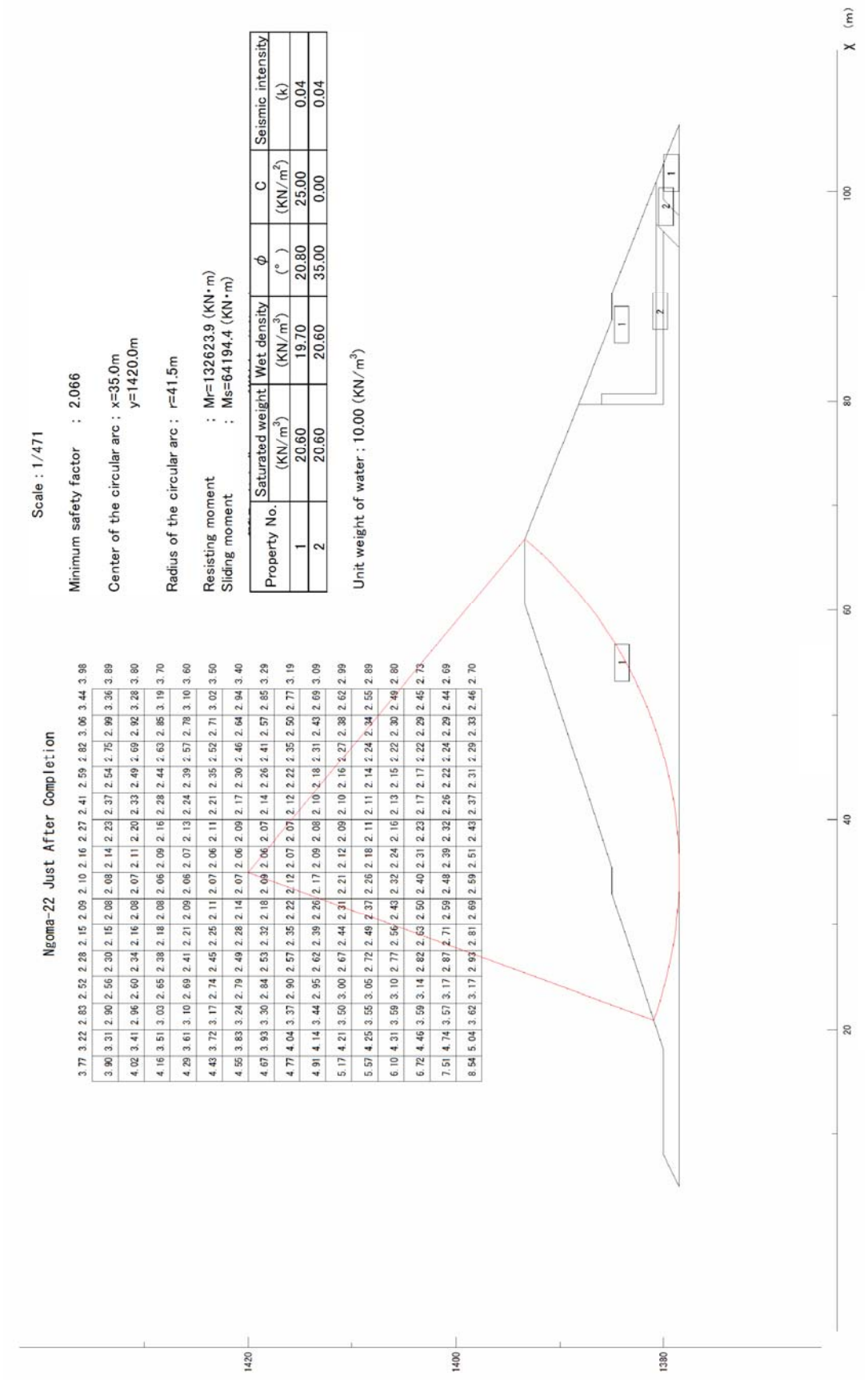


Figure 2.2.2.41 Safety Factor Distribution (Just after completion / Upstream)

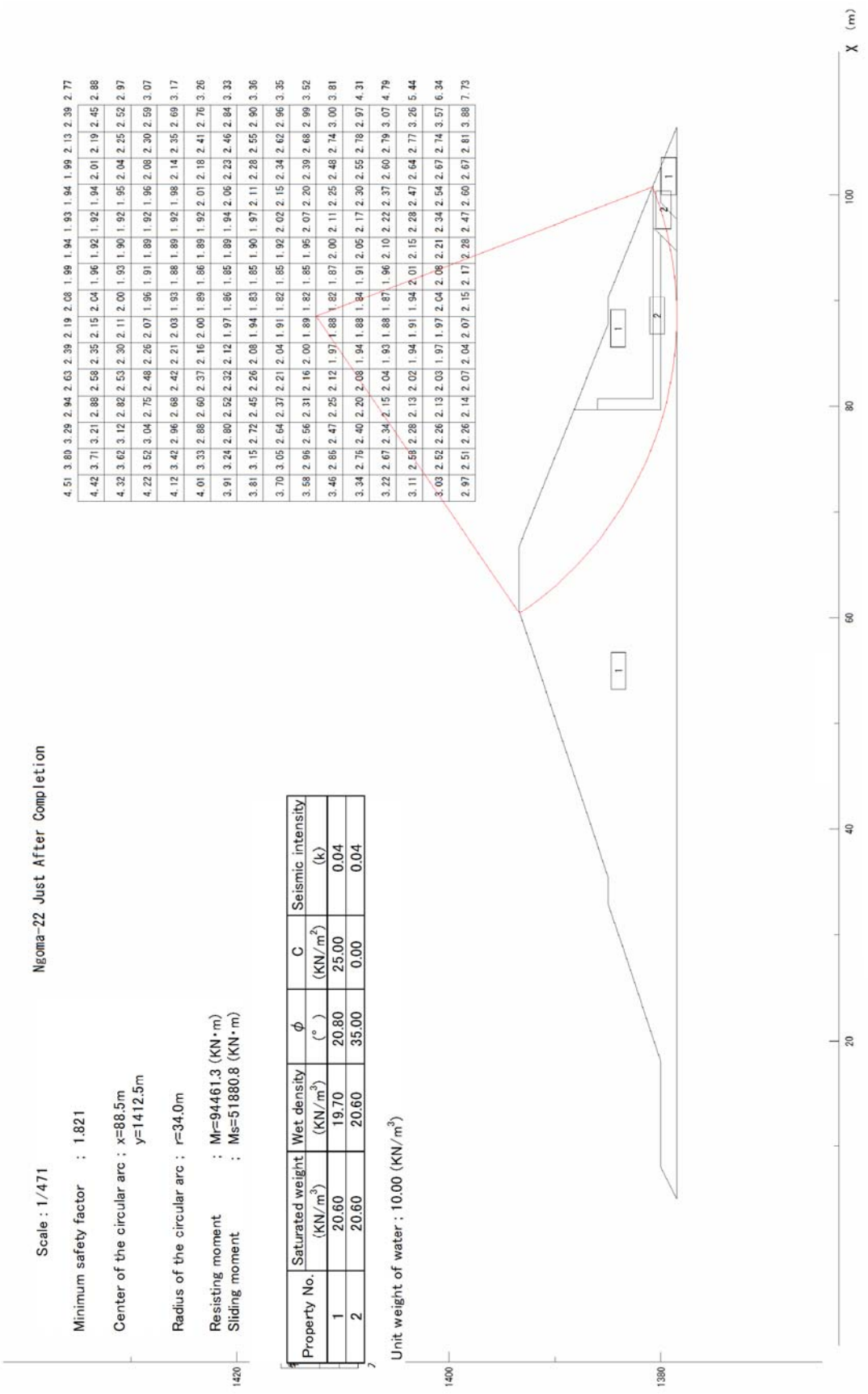
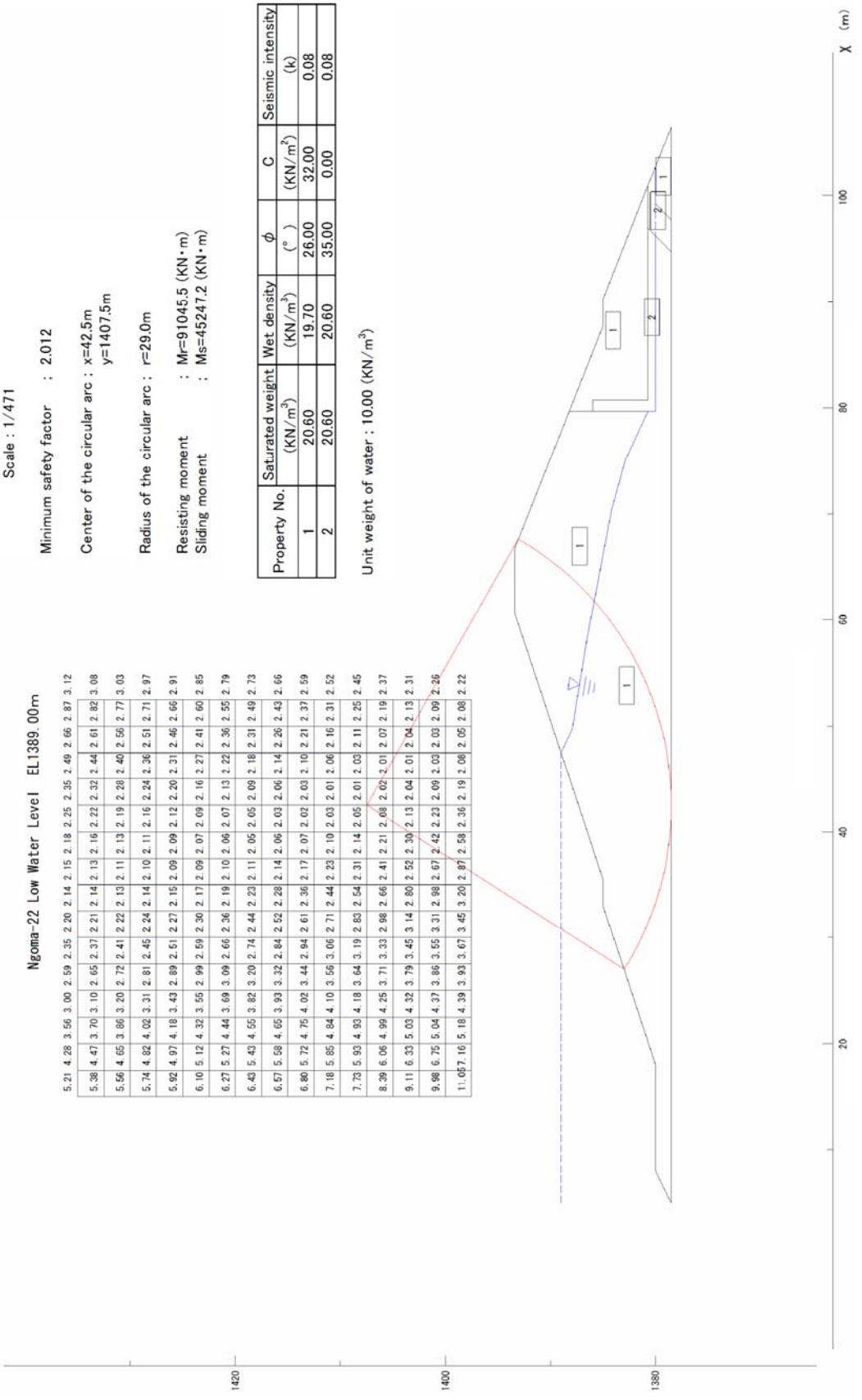


Figure 2.2.2.42 Safety Factor Distribution (Just after completion / Downstream)



Property No.	Saturated weight (KN/m³)	Wet density (KN/m³)	φ (°)	C (KN/m²)	Seismic intensity (k)
1	20.60	19.70	26.00	32.00	0.08
2	20.60	20.60	35.00	0.00	0.08

Figure 2.2.2.43 Safety Factor Distribution (L.W.L / Upstream)

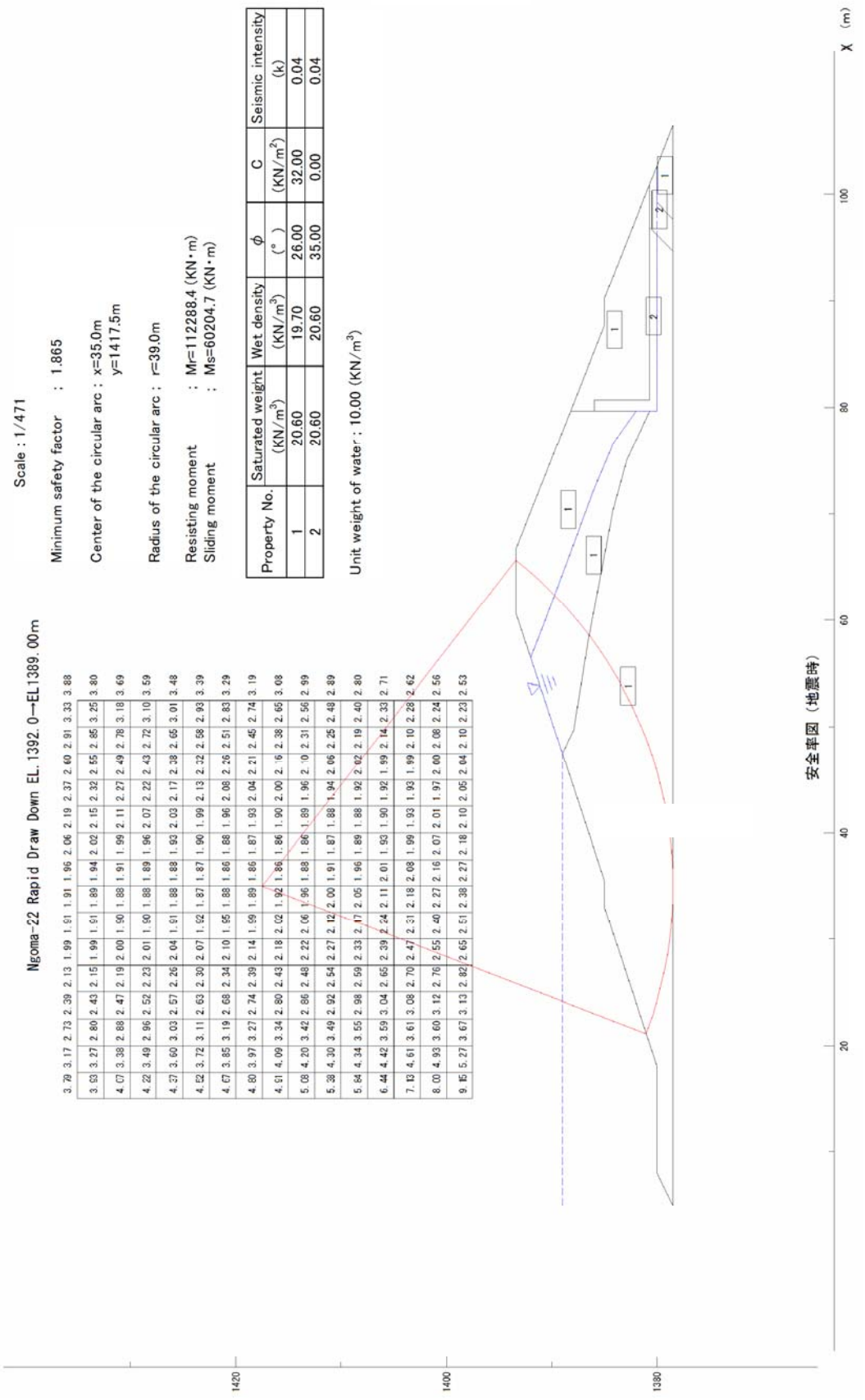
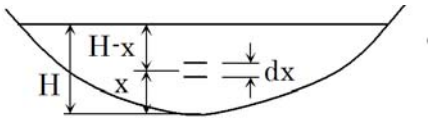


Figure 2.2.2.44 Safety Factor Distribution (Rapid draw Down / Upstream)

11) Additional Embankment for Settlement

The embankment materials consist of cohesive soils so that the consolidation shall not finish completely within the period of construction but some portions are postponed after the end of the construction term. The additional embankment is provided to avoid the shortage of freeboard of the dam crest due to this postponed settlement. The adequate height of additional embankment can be evaluated based on the relation curve between the load and the settlement ratio obtained from the consolidation test result as follows.



An element with the thickness of "dx" at the position "x" m above the embankment bottom, is assumed here H: dam height and γ : unit weight of embankment, the load "L" acting on the element "dx" is expressed as "L=(H－x)・γ".

A settlement ratio "y" is introduced and expressed as the function of load "L". Then, the settlement of "dx" is expressed as "y・dx" and the settlement at the dam crest can be calculated by integrating "y・dx" from the bottom (x=0) to the dam crest (x=H). The relation between "L" and "y" is expressed by a linear approximate equation "y=aL". The settlement of dam crest is shown as follows;

$$\int_0^H y\,dx = \int_0^H aL\,dx = a\int_0^H (\gamma H - \gamma x)\,dx = a\left[\gamma Hx - \gamma\frac{x^2}{2}\right]_0^H = \frac{a\gamma H^2}{2}$$

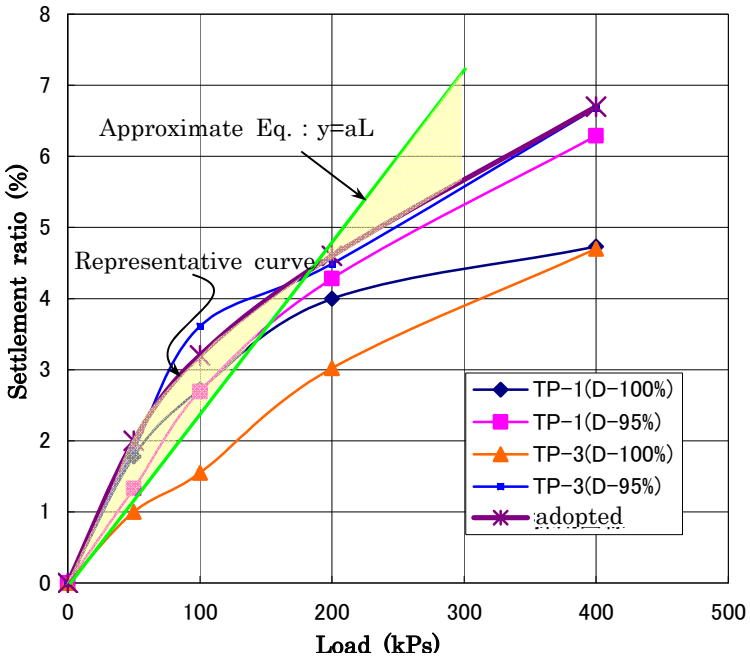


Figure 2.2.2.45 Load - Settlement Ratio Curve

Here, y=aL, a=7.2%/(300kPs), γ=1.97tf/m^3, and H=14.9m

Then, the settlement of dam crest =1/2×(0.072/30.0tf/m^2)×(1.97tf/m^3)×(14.9m)^2

=0.52m

The consolidation settlement occurs even during the construction period. It is said empirically that the percentage of the postponed settlement to the total settlement is about 35% or so. In this Project, however, the embankment works shall be conducted in a concentrated manner in dry season, so that the postponed percentage of settlement is assumed to be 80% and the additional height of embankment is designed to be 40 cm.

The additional height 40 cm is applied to the central section longitudinally and is gradually decreased toward the abutment.

12) Design of Drain

Materials the drain zone are requested to satisfy the following gradational conditions from the view point of piping phenomena at the time of the seepage flowing into the drain from the impervious embankment, and the drainage capacity for water caught by the drain to be led and discharged outside.

(1) $\frac{F_{15}}{B_{85}} < 5$, $\frac{F_{15}}{B_{15}} > 5$

Here,

F_{15} :Grain size of the drain corresponding to passing percent 15%

B_{85} :Grain size of passing percent 85% regarding the zone through which seepage flows into the drain

B_{15} :Grain size of passing percent 15% regarding the zone through which seepage flows into the drain

(2) Drain materials are to be non-cohesive and the content percentage of fine particles less than 0.075mm in grain size is to be less than 5% fundamentally. The particle size distribution curves of both the drain material and the zone material in front of the drain are to be parallel.

Though sand-and-gravel materials gathered from Rwinkwuvu are considered to be suitable for drain material, the compatibility of conditions above will be confirmed as follows.

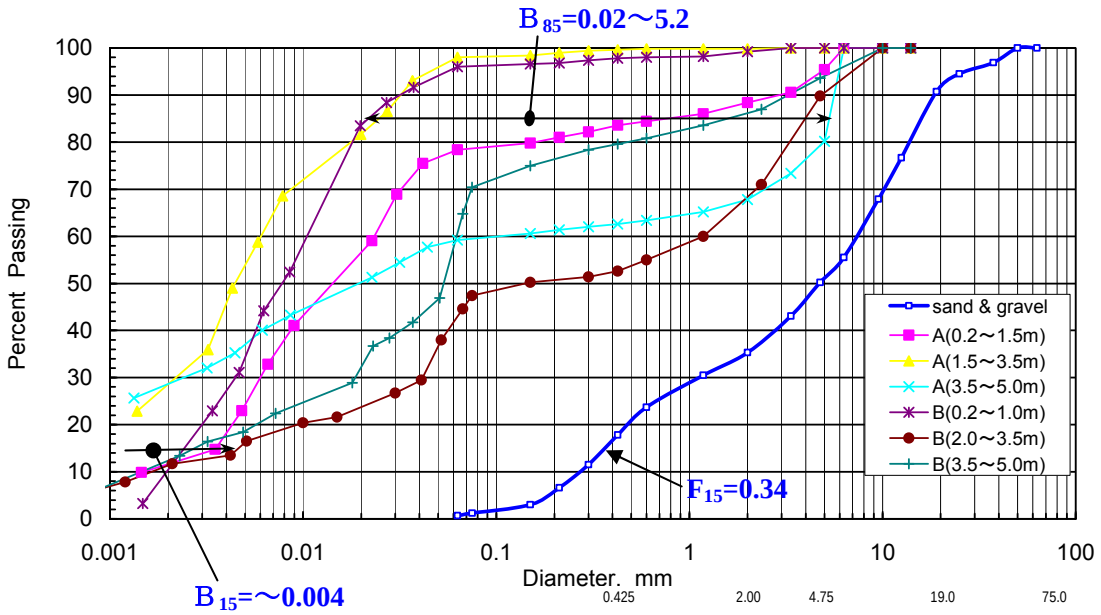


Figure 2.2.2.46 The Gradation Balance between Sand-and-Gravel and Impervious Filling Materials

$$\frac{F_{15}}{B_{85}} = 0.34/(0.02 \sim 5.2) = 17 \sim 0.065 < 5$$

Although two samples, which are A (1.5 - 3.5m) and B (0.2 - 1.0m), don't satisfy the standard due to the overmuch content of clay, the other samples satisfy the standard. As a whole, it is judged that this sand-and-gravel material can be used for the drain as the impervious materials is expected to be homogenized through excavation works in borrow areas and the high cohesiveness of clay is supposed to resist against the wash-away action of seepage flow.

$$\frac{F_{15}}{B_{15}} = 0.34/(\sim 0.004) = 85 \sim > 5$$

Based on examination above, the standard condition is satisfied.

Moreover, the request for "parallel" is highly satisfied in the particle size distribution curves between the sand-and-gravel and the impervious materials and the standard of "the content percentage of fine particles ranging less than 0.075mm in grain size is to be less than 5%" is also satisfied. Permeability coefficient of the sand-and-gravel estimated by the Hazen formula is as follows and pervious enough for the requested discharge function.

$$k = C_1 D_{10}^2 = 100 \times 0.028^2 = 0.078 cm/\sec$$

Based on the examinations above, the sand-and-gravel is judged to be suitable for the drain material.

13) Monitoring Facilities of the Dam Body

According to recommendation of International Commission on Large Dam which is the Commission categorizing a dam having 15m height is the large dam, the lathe Ngoma22 dam plans to install some monitoring facilities of the dam body because the Ngoma22 dam has 14.9 m height and applies the blanket method applied as the foundation treatment where the seepage through foundation is allowed to some extent.

Following equipment are to be installed in accordance with the large homogeneous fill-type dam being requested to be provided with deformation monitoring equipments, leakage monitoring equipments and seepage line monitoring equipments.

- Deformation monitoring equipments

Deformation of the dam body surface shall be monitored by checking the deformation at measuring points against the fixed points placed on the both abutment ground. In this regard, one fixed observation point is placed on each abutment ground, and seven deformation observation points are placed on the dam crest and on the berms upstream and downstream.

- Leakage monitoring equipments

Perforated PVC pipes shall be laid in the toe drain to catch the seepage water gathered by the toe drain and discharge it through PVC pipe connected to the perforated ones outside the dam body. At the discharge mouth of the PVC pipes, leakage quantity is measured by hand. Two systems composed of perforated pipes and non-perforated ones are installed to the left-bank-side river bed and the right-bank-side river bed respectively to grasp the aerial difference in leakage.

- Installation of pore water pressure gauges

Pore water pressure gauges shall be installed instead of monitoring boreholes of seepage lines. In case of homogeneous fill-type dams which a large amount of residual pore pressure relatively keeps

existing, water tables in monitoring boreholes are sometimes not clear whether they reflect the pore water corresponding to the residual pore water pressure or they reflect the water levels of seepage flow. Pore water pressure gauges can catch the turning point from the descending tendency of residual pore pressure due to dissipation of the ascending tendency caused by seepage flow so that it is possible to clarify the pore pressure to be the residual one or to be the one brought from seepage flow.

Moreover, in case of the pore pressure being measured in a saturated zone, it is possible to conduct an analysis of seepage flow conditions by drawing a flow-net diagram which is obtained by grasping the total head distribution. Total head is calculated as the sum of the pore pressure and the gauge elevation.

From the view point mentioned above, seven (7) gauges in the dam body and fifteen (15) gauges on the foundation surface are installed.

In addition, the pore water pressure gauges are electric type and the measurement shall be done by the electric transducer at the observation pit on the downstream berm in which the tail ends of lead cables are gathered.

2-2-2-3-2 Design of Spillway

1) Decision of alignment

The alignment of the spillway is designed taking account of some conditions such as topographical and geological conditions and relation with other facilities. At 1,390m elevation, topographical steepness and gentleness are inversed, and slope is gentle at the high elevation and it is steep at low elevation on the left bank, while the condition at right bank shows opposite trend. In terms of geological condition, abutment part of both banks within 0.75 m depth is judged as relatively good and there is no big difference between the right and left banks.

Concerning relation with other facilities, the spillway can compete with the intake works from the reservoir to dam body. If intake pipe and the spillway will be parallel and the intake will be set at upstream of toe of the spillway, they will not be crossed, which leads to easy construction and maintenance.

Since a pump station is to be set at the left bank, it is recommended to construct the spillway at the right bank to avoid the competition with the piping of the pump station and also to minimize extension and bend of spillway. Moreover, it is needed to pay attention to connection with slope blanket at the side canal of spillway. Under the condition that foundations are different, different settlement can be caused at the side canal. Therefore, parallel alignment with contour and blanket axis of ground on the right bank is applied for the design. Based on the conditions mentioned above, following alignment is proposed.

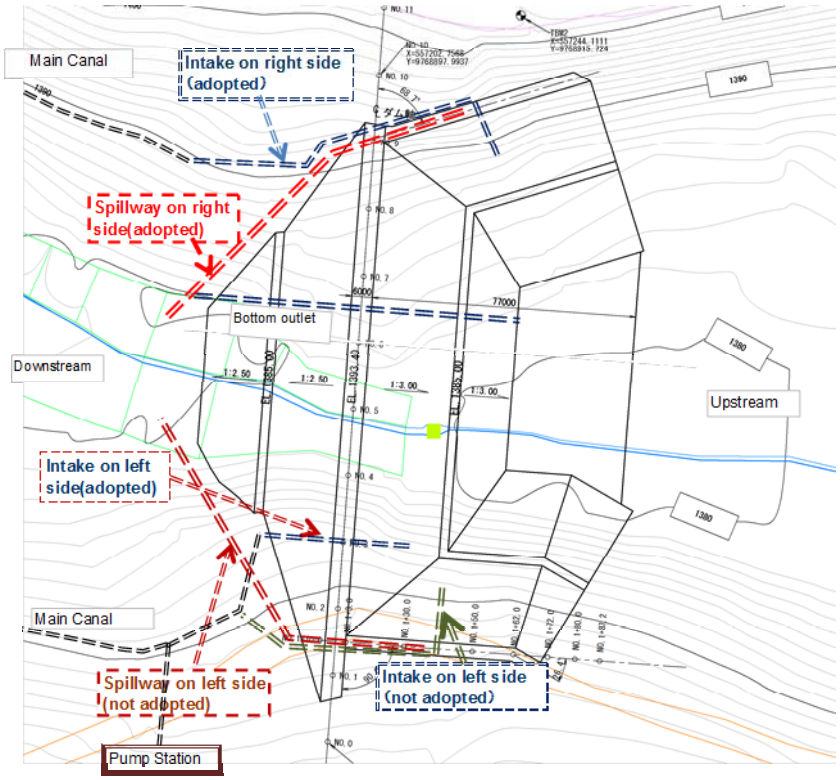


Figure 2.2.2.47 Case Study of Alignment of the Spillway

2) Decision of Spillway Type

In terms of topographic matter, it is proposed to select a type of spillway which forms side canal with nearly 90 degree between flow direction of inflow part and the spillway alignment, if contours of both banks are parallel with a river route such as the valley shape.

The basic structure of spillway is open canal type with rectangle shape. It is designed to cross with the dam axis at the link part. It is needed to set a box culvert type bridge at the dam crest, which makes it possible for persons concerned to walk the spillway. Especially, the surface, which tangents with dam embankment at the upstream of dam axis, will have 1:0.3 slopes so that the rolled compaction banking can be easily applied on the surface of the structure. Just before banking, contact clay will be applied for impervious effects. The chute and energy dissipator, which will connect with existing river also, will have rectangle shape. It is needed to propose a layout taking consideration into that intake will connect with the energy dissipator.

3) Hydraulic Design

(1) Name of part

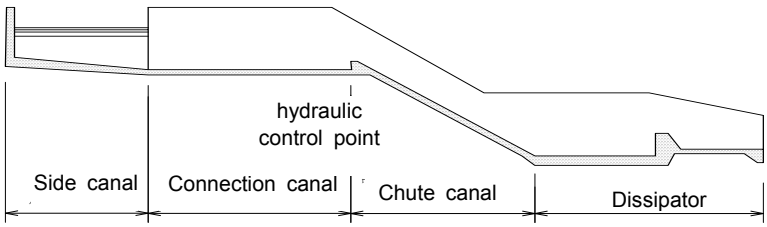


Figure 2.2.2.48 Longitudinal Section

(2) Design of side intake canal

a) Design of overflow head

Overflow head is a factor for dam height decision. It is, therefore, needed to determine the design considering construction conditions of the spillway mentioned above and dam size. Economical overflow head of the side canal spillway can be calculated by using the formula as shown below:

$$H_d = \frac{1}{1.63} \times Q_d^{1/2} \times HF^{-1/4} \times CLF^{-1/8} - 0.05$$

Hd : Design overflow head (m)
Qd : Design flood discharge = 3.4 (m^3/s)
HF : Dam height＝14.9 (m)
CLF : Dam length (banking) = 200.0 (m)

$$H_d = \frac{1}{1.63} \times 3.4^{1/2} \times 14.9^{-1/4} \times 200^{-1/8} - 0.05$$

＝0.247 (m)

Based on the calculation result mentioned above, the overflow head of the side canal spillway is designed as 0.3m.

b) Design of overflow weir

Design full water level (=crest elevation): EL. 1392.00 (m)
Design flood water level: EL. 1392.30 (m)
Approaching canal elevation: EL. 1391.50 (m)
Design overflow head: Hd = 0.30 (m)
Height of overflow weir: W=0.50 (m)

Discharge formula is as shown below:

$$Q=C \cdot L \cdot H^{3/2}$$

$$Cd=2.20-0.0416(Hd/W)^{0.99}$$

$$C = 1.60 \times \frac{1 + 2a\ (H/Hd)}{1 + a\ (H/Hd)}$$

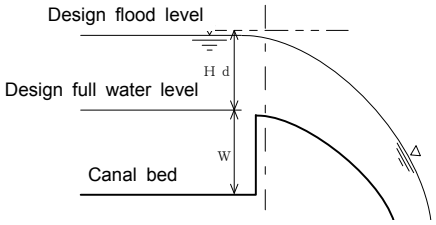


Figure 2.2.2.49 Cross Section of Overall Weir

Q : Discharge (m^3/s)
L : Width of overflow weir (m)
H : Any overflow head (m)
Hd : Design overflow head (m)
W : Weir height of overflow (m)
a : Constant
C : Coefficient of discharge
Cd : Coefficient of discharge when H = Hd

$Cd= 2.20-0.0416\times(0.30/0.50)^{0.99} = 2.1749$

$A = (1.60-Cd)/ (Cd-3.20) = 0.561$

$$C = 1.60 \times \frac{1 + 2 \times 0.561 \times 1}{1 + 0.561 \times 1} = 2.175$$

$$L = \frac{Q}{C \cdot H^{3/2}} = \frac{3.4}{2.175 \times 0.30^{3/2}} = 9.514$$

Considering the calculation result above and safety, length of overflow weir is designed as 10.000 (m). The Harold standard overflow crest is applied and proposed slope of the bottom part of the overflow weir cross section is 1:0.7, which is proper for nappe.

c) Determination of side canal cross section

Cross section of side canal and slope of overflow weir is designed as trapezoidal and 1:0.7 respectively. The proposed cross section will be applied for all the side canals. Width of canal bottom is 1.5m, and longitudinal slope of the side canal will be level in consideration of efficient construction.

(3) Hydraulic design of transition canal

The side canal at the end point is connected to rectangle shape transition canal with contraction of side wall at weir side. The length of transition canal part is designed as 20.000 (m) considering topographic situations, geological conditions and relation with other facilities, and it will be connected with the chute. Overflow weir will be set as a hydraulic control point to stabilize flow conditions of side canal.

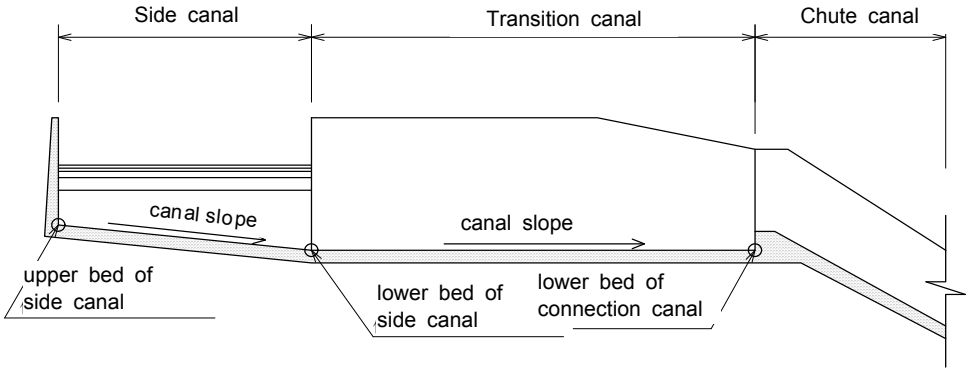


Figure 2.2.2.50 Cross Section of Transition Canal

a) Cross section of transition canal

Width of bottom of canal is designed as 1.500 (m) as well as that of the side canal end.

Longitudinal slope of the transition canal should be designed taking account of prevention of shock wave, surface vibration and control of Froude number of the side canal. Therefore, the slope of transition canal shall have sufficient gentle slope and it can be calculated by using following formula.

$$s = \frac{g \cdot n^2 \cdot Fr^2 \cdot (1 + 2d/B)^{4/3}}{d^{1/3}}$$

s	: Longitudinal slope of transition canal	
g	: Acceleration of gravity	9.8 (m/s^2)
n	: Coefficient of roughness	n = 0.015
Fr	: Froude number	Fr = 0.369
d	: Depth of side canal at the end point	d =1.397 (m)
B	: Width of bottom of side canal	B = 1.500 (m)

$$s = \frac{9.8 \times 0.015^2 \times 0.369^2 \cdot (1 + 2 \times 1.397/1.50)^{4/3}}{1.397^{1/3}} = 1/916$$

Based on the calculation result, longitudinal gradient of transition canal is designed as level.

b) Freeboard of transition canal

Freeboard is calculated based on following formula:

$$Fb = 0.07d + hv + 0.10$$

Fb : Freeboard of transition canal (m)
d : Depth of design flood discharge (m)
Hv : Velocity head for design flood discharge (m)

Based on the calculation, freeboard of access canal, vertical height and design crest elevation are as shown below:

Table 2.2.2.41 Calculation Result of Transition Canal Height

Distance (m)	Water depth (m)	Freeboard (m)	Necessary height (m)	Design height (m)	Bed elevation (EL.m)	Crest of wall (EL.m)
0.00	1.006	0.420	1.426	1.50	1390.50	1392.00
6.00	1.267	0.311	1.578	2.90	1390.50	1393.40
12.00	1.283	0.309	1.593	2.90	1390.50	1393.40
18.00	1.298	0.308	1.606	2.90	1390.50	1393.40
20.00	1.303	0.307	1.611	2.90	1390.50	1393.40

(4) Hydraulic design of chute canal

a) Cross section of chute canal part

In consideration of topographic, geological and construction condition of energy dissipator, the slope of chute part is set at 1:5.00. The chute canal has rectangle shape and its width of bottom is 1.50m as well as that of the transition canal for efficient connection with energy dissipator downstream.

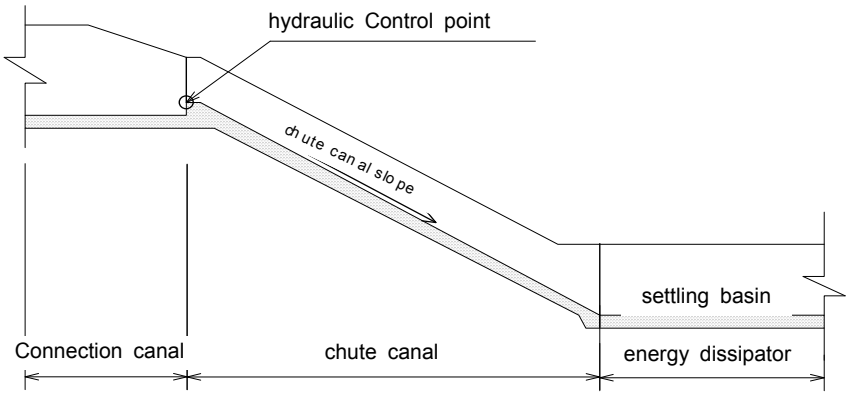


Figure 2.2.2.51 Cross Section of Chute

b) Freeboard of chute canal

Freeboard of the chute canal is calculated based on the following formula:

$$Fb = 0.6 + 0.037V \cdot d^{1/3}$$

Fb : Freeboard (m)
V : Velocity (m/s)
d : Depth (m)

In addition, height of canal is calculated based on the following formula:

$$H = (d + Fb) \times \frac{1}{\cos \theta}$$

θ : Degree slope at the bottom of canal

The calculation results are as shown below:

Table 2.2.2.42 Calculation Results of Freeboard and Height of Shute

Distance (m)	Water depth (m)	Freeboard (m)	Wall height (m)	Vertical height (m)	Design height (m)
9.00	0.328	0.776	1.104	1.126	1.30
18.00	0.278	0.797	1.075	1.096	1.10
27.00	0.259	0.807	1.065	1.086	1.10
36.00	0.249	0.812	1.061	1.082	1.10
45.00	0.245	0.814	1.059	1.080	1.10
54.00	0.242	0.816	1.058	1.079	1.10
60.00	0.241	0.816	1.058	1.079	1.10

(5) Hydraulic design of energy dissipater

a) Type of chute

The purpose of chute construction is to prevent from destruction and erosion of dam body, spillway structure and other structures caused by high discharge velocity. The chute should have functions to soften high energy by flood by changing fast supercritical flow in the shute canal to subcritical flow.

There are many cases of design for hydraulic jump style of chute as fill dam spillway construction. The chute type is determined depending on relation between hydraulic jump curve and water level-discharge curve in the downstream of dam. In terms of economical matter, forced hydraulic jump type, which has short chute length, is applied.

b) Stilling basin inflow

Depth, discharge velocity, Froude number and hydraulic jump depth of flood, which dash to apron bed of the stilling basin,

$$Fr = \frac{V_1}{(g \cdot d_1)^{1/2}} \qquad d_2 = \frac{1}{2} \times d_1 \times (\sqrt{1 + 8Fr^2} - 1)$$

Fr : Froude number
V_1 , d_1 : Inflow acceleration velocity (m/s), inflow depth (m)
d_2 : Depth of hydraulic jump (m)
g : Gravity acceleration velocity 9.8 (m/s^2)

Table 2.2.2.43 Specifications of Stilling Basin Inflow

Category of flood discharge	Elevation of apron bed (EL.m)	Depth of inflow d_1(m)	Velocity of inflow V_1(m/s)	Froude number Fr	Depth of hydraulic jump d_2(m)
Design flood discharge Qd Qd= 3.4 m^3/s	1378.7	0.241	9.395	6.110	1.968
Chute design flood discharge Qe=2.45 m^3/s	1378.7	0.193	8.446	6.135	1.584

c) Length of stilling basin

Length of stilling basin is calculated based on the formula as shown below:

$$L = a \cdot d_2$$

L : Length of stilling basin (m)
a : Enforced hydraulic jump type a=3.0
d_2 : Depth of hydraulic jump (m)

$$\therefore L = 3.0 \times 1.584 = 4.752 \text{ (m)}$$

Based on the result mentioned above, the length is designed 5.00 (m) as safer side.

d) Height of stilling basin

If hydraulic jump does not exceed crest of side wall under the condition of 1/1,000 year probability, there is not big problem in terms of safety. Given that discharge of design spillway flood (Qd) is 3.4 (m^3/s) and hydraulic jump depth of discharge is 1.968m, height of stilling basin is designed at 2.00m.

e) Height of sub-dam

Height of sub-dam is calculated based on following formula.

$$\frac{W}{d_1} = \frac{(1+2Fr^2)\sqrt{1+8Fr^2}-1-5Fr^2}{1+4Fr^{1/2}-\sqrt{1+8Fr^2}} - \left(\frac{\sqrt{g}}{2}Fr\right)^{2/3}$$

W :Height of sub-dam
Fr :Froude number before hydraulic jump Fr =6.135
d_1 :Depth before hydraulic jump =0.193 (m)
W = 0.666 m

In consideration of that it is not very big issue if conjugate depth in the downstream is low in case of enforced hydraulic jump type, height of sub-dam is designed 0.6 m. Crest elevation (EL. 1378.7 + 0.600 = EL. 1379.3m) will be same as that of existing canal lot. Transition canal to the downstream is set at inversed slope of 1:5.0.

(6) Share of energy dissipater for spillway chute of low water level outlet works

Low water level outlet works functioning through bottom outlet will be used for outflow of river environmental maintenance water for the downstream, irrigation water for paddy field, and regulation of reservoir water level. Since there are paddy plots just downstream of the proposed dam axis and a part of them will be expropriated for the dam construction, it is necessary to minimize the area of land to be expropriated for the dam construction. It is, therefore, proposed not to set chute of outlet works

and to discharge water to the chute through the pipe. In that case, there is a possibility the water discharged will crash the vertical wall of spillway at opposite side and also spray can be caused, since it can be air outlet. Therefore, it is proposed to cover the canal of spillway by cover to reduce the water energy in the canal.

2-2-2-3-3 Design of Intake and Outlet Works

Purpose of the proposed reservoir construction is to irrigate paddy fields and hillside farm land. The proposed intake works consist of outlet works at low water level and intakes on the right and left banks. They are designed in accordance with necessity. The outlet works at low water level is designed taking account of temporary drainage and functions for safety management.

1) Basic conditions

(1) River water discharge (current and planned discharge for paddy field irrigation)

- River maintenance discharge : $0.004m^3/s$
- Maximum discharge : $0.020m^3/s$

When the volume intake discharge for paddy field is more than that of river maintenance discharge, which is calculated at $0.004m^3/s$, it is not necessary to discharge river maintenance water additionally.

(2) Hillside irrigation discharge

- Maximum intake for left bank hillside irrigation : $0.080\ m^3/s$ ($=0.0008m^3/s/ha \times 100ha$)
- Maximum intake for right bank hillside irrigation : $0.132\ m^3/s$ ($=0.0008m^3/s/ha \times 165ha$)

(3) Conditions of reservoir

Table 2.2.2.44 Basic Conditions for Reservoir Design

Water storage volume		
Effective capacity	450,000	m^3
Total capacity	960,000	m^3
Design low water discharge	510,000	m^3
Design sedimentation volume (for	30,000	m^3
Design elevation		
Crest elevation	EL.1393.40	m
Freeboard	1.10	m
Design flood elevation	EL.1392.30	m
Normal full water level	EL.1392.00	m
Low water level	EL.1389.00	m
Available water depth	3.00	m
Design sedimentation level	EL.1382.00	m

(4) Conditions of air and water temperature

Existing paddy field is located at just downstream of the proposed dam axis and its irrigation water resource is river at present. The source of river is spring water from the foot of upstream mountain and the water reaches to the whole paddy field by forming natural flow. Given that the river bottom width in the upstream of the proposed dam axis is small, so that water temperature from the upstream to the paddy field downstream will not be influenced very much by air temperature. Mean air temperature in the area is more that 20 degree through the year, therefore, it can be considered that river water flowing into the site can not damage the paddy because the water temperature can not be very low.

Table 2.2.2.45 Lowest, Suitable and Highest Temperature for Paddy Growing (Japonica Rice)

Item	Lowest temperature ℃	Optimum temperature ℃	Highest temperature ℃
Germination	10 - 13	30 - 34	40 - 44
Growth of seedling	―	32	―
Extension of height	15 - 16	30 - 32	40
Increase of tillering	14	28 - 34	40
Total weight	13 - 14	30 - 34	40
Differentiation of young panicle	15		
Heading	17 - 20		
Flowing	15 - 19	28 - 40	50 - 60

(5) Intake for paddy field

Irrigation water for the paddy field downstream will be taken from low water level outlet facility by using the bottom outlet. Bearing capacity of the soil on the site is categorized into weak soil foundation, since N-value is less than 20.

If an intake tower is constructed, foundation treatment works such as pile foundation are needed to be constructed, since weigh of the tower is so heavy for its height, namely, 12m reading from surface of planned horizontal blanket (EL.1380.0m) to full water level (EL.1392.0m) and the weight of maintenance bridge due to the length of 36m. It is, however, not recommended to construct such structure taking account of impact on the bottom outlet or the dam body.

It is possible to construct a slope intake on the slope of the dam body, however, it is not recommended to operate the gate because the length of spindle of the gate is long, which is 38m. Therefore, it is judged that expanding the bottom outlet to intake water from the reservoir directly is quite difficult.

In case of intake from the low water outlet facility, the height of design sedimentation level (EL.1382.0m), which is equivalent to 2.5m, is considered to be structural limit. Water temperature at design sedimentation level is generally low, however, it ranges from 20℃ to 23℃ constantly through the year and it is considered that the water temperature of the dam lake is almost same as that of underground spring. In other words, temperature of reservoir water to be irrigated will range almost same as the current irrigation water temperature. Therefore, management of irrigation water temperature for paddy cultivation will be done as well as it has been done so far.

Intake at low water level can be influenced by mud water inflow. Since the particles are heavy and it takes time for precipitation, bottom water is relatively muddier that surface water. However, the water will be used for paddy field, which will not result in a big issue. Therefore, low water level outlet works will be used for the paddy irrigation.

(6) Hillside irrigation

Pipelines and horses will be installed for hillside irrigation so that muddy water is not suitable. Therefore, intake from surface water within 3m depth is proposed. It is common to set the intake works at just upstream of the dam. It is, however, needed to consider the dam body design since slope blankets are set on right and left banks. It is possible to construct the intake at upstream by avoiding slope blanket, however, it is needed to set more than 50 m distance from the dam axis. Considering scale of structure, construction cost, maintenance and so on, it is better to construct the intake near the dam axis as much as possible. Moreover, soil surface does not have sufficient bearing capacity so that it is judged that foundation on well compacted dam body is safer. It is recommended to set intake works on both right and left banks in terms of maintenance and safety since the hillside farmlands are extended on the both banks.

Based on the examination mentioned above and the left bank intake will divert water to the pump

station, the intake should be set on the dam body, which makes it possible to minimize the length of pipeline and construction works. The spillway is designed on the right bank, therefore, the right bank intake will be set on the upstream of spillway to avoid crossing and it will divert water to the downstream on the mountainous side of the spillway.

2) Design of low water level outflow works

(1) Pipe type and diameter for river water outlet

It is proposed to use steel pipe which has toughness and ductility for river maintenance outlet and paddy field irrigation in consideration of water storage pressure and influence of settlement and deformation. The design velocity is set at 0.7 - 1.6m/sec and ϕ 150mm of pipe is applied.

(2) Temporary drainage during dam construction

Flood discharge during the construction work is estimated 1.5m^3/sec at 1/10 probability. There are two methods of the type for temporary drainage as follows:

Case-A :Multiple-stage diversion method

Drain water is discharged at the place where dam body banking works is not under operation, while the construction works of remaining parts can continuously be implemented.

Case-B :Complete closure method

Pipe drain is buried and then and dam body banking can be carried out continuously.

They mentioned two methods, however, are not suitable on the side by the reason mentioned below.

In case of A, it is possible to minimize the construction period since dam body, blanket, excavation and banking can be started from the beginning of overall construction period. On the other hand, regarding case B, construction period will be longer than 1, since it is needed to construct pipe drain. If construction work will be done during rainy season, moisture control is necessary. On the other hand, in case that construction works will be suspended during rainy season, excavation of soil surface is required. Therefore, both methods are not recommendable.

Large scale structure for temporary drainage should be determined carefully taking account of appropriation for other purpose expected in future and safety for soil foundation. Multiple-stage diversion method is more proper than complete closure and the method is possible to minimize construction scale by temporary storing of drained water at the reservoir.

Therefore, multiple-stage diversion is proposed as drain water treatment method during the dam construction period.

If temporary drain around current river is set for dam construction works for dry season (January and February) and rainy season (March to May), specifications are presented as follows based on the hydraulic calculation.

Table 2.2.2.46 Hydraulic Calculation for Temporary Drainage

Item	Calculated result	Remarks
Discharge (m^3/s)	1.500	flood discharge at 10 years probability
Bed Slope (1/I)	1,000	
Roughness Coefficient.	0.018	
Item	Calculated result	Remarks
Side Slope	1.000	
Bottom Width (m)	2.000	

Item	Calculated result	Remarks
Area of Cross (m^2)	1.530	
Wetted Perimeter (m)	3.670	
Hydraulic Radius (m)	0.417	
Velocity (m/s)	0.980	
Depth of Flow (m)	0.591	
Froude Number	0.45	

(3) Drain water treatment after dam construction

After the dam body construction, water will be stored at the reservoir and discharged from the spillway when water level becomes higher than intake or full water level. Virgin water storage will be experienced through controlling of water level and monitoring conditions of the reservoir for safety confirmation. It is needed to construct a structure equipped with sufficient outlet capacity to control water level of the reservoir.

In such case, the structure should have more outlet capacity than that of intake, however, large scale discharge exceeding intake volume is not recommendable in consideration of conditions of irrigation canal in the downstream. For the purpose of the dam safety, an outlet structure which can reduce water level to middle level within 100 days is examined as discussing below.

a) Design conditions

- Normal full water level : EL.1392.0m
- Planned sedimentation level : EL.1382.0m
- Middle water level : EL.1387.0m
- Downstream water level : EL.1379.67m
- Extension of pipeline canal : 92.717m

b) Outlet time and pipe diameter

When reservoir water level is low, outlet time (T) is calculated based on the formula below. It is needed to calculate pipe diameter to satisfy (T).

$$T = \Sigma \triangle T = \Sigma \frac{\triangle V}{K\sqrt{2g\left(H - \frac{\triangle h}{2}\right)}}$$

$\triangle T$: Time for reduction of reservoir water level from H to $\triangle h$

H : Difference between reservoir water surface and outlet of intake pipe

$\triangle V$: Storage capacity between H and $\triangle h$

K : Coefficient

$$K = \frac{1}{\sqrt{\Sigma\left(fi / ai^2\right)}}$$

Fi : Loss coefficient

Ai : Cross section area of pipe

Table 2.2.2.47 Examination of Outlet Time

	WL (EL.m)	⊿V (m^3)	H-⊿h/2 (m)	K x⊿T	KT
Normal full water level	1,392	167,304	11.83	10,987	10,987
	1,391	147,538	10.83	10,127	21,114
	1,390	130,712	9.83	9,417	30,531
	1,389	114,037	8.83	8,668	39,199
	1,388	97,144	7.83	7,842	47,041
Middle water level	1,387	81,993	6.83	7,087	54,127

When ⊿h is 1.0m and outflow water level is 1379.67m, KT=54,127, T=864,000 seconds (for 10 days). Therefore, K=KT/T=0.06265.

Diameter of pipe (D) is calculated based on inflow loss, friction loss and outflow loss. When D =0.4468m, the value can be same as K value mentioned above. Therefore, D is determined 0.50m (ϕ 500mm) considering safety. In that case, K=0.08295, T=54,127/0.08295=652,525 seconds, namely, 7 days, 13 hours and 15 minutes.

3) Design of intake works of right and left banks

(1) Design intake

The pump station will be set on left bank which has gentle slop on the hillside and irrigation water for beneficiary area will be diverted to the right bank after intake at left bank. Therefore, intake discharges at right and the left banks are as shown below:

Table 2.2.2.48 Intake from Right and Left Bank Intake Works

Unit: m^3/s

	Left bank gravity irrigation area	Left bank pumping irrigation area	Right bank gravity irrigation area	Right bank pumping irrigation area	Total
Intake from left bank	0.048	0.032		0.048	0.128
Intake from right bank			0.084		0.084

(2) Hydraulic calculation

Hydraulic calculation of intake pipe from inside of reservoir to the junction point in the downstream of dam axis is done. Head loss is determined based on screen loss, inflow loss, friction loss, outflow loss and other conditions.

a) Screen Loss: hr

In case of surface water intake, screen to catch leaves and dust is set in general. However, it is considered not to be necessary to set screen for the proposed dam construction, since the intake structure is to be set at lower place than effective water depth of the dam and the dam water will be taken at the position considered the seal height in order to prevent aeration, which leads to low possibility of suspended solid inflow. However, screen loss is examined taking account of head loss occurs. Screen loss is calculated based on Kirschmer formula.

$$hr = \beta \sin\theta \left(\frac{t}{b}\right)^{4/3} \cdot hv$$

β : bar shape coefficient degree: 2.43

θ : Degree 90°

t : Thickness of bar 0.005m、b: chink of bar 0.05m

hv : Velocity head=$V_2/2g$

V : = $0.35464C \cdot D^{0.63} \cdot I^{0.54}$

I : = $10.666C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85}$

C : Velocity coefficient

D : Pipe diameter (m)

I : Dynamic water slope

b) Inflow loss: he

$he = 1.0 \times hv$

c) Friction head loss: hf

$hf = 10.666C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85} \cdot L$ (extension, m)

d) Inflow loss head: ho

$ho = 1.0 \times hv$

e) Other head loss

As other head loss, it is set of 20% of friction head loss.

Hydraulic calculation results are summarized in following table. Head loss is set at less than 0.3m, moreover, ϕ 450mm and ϕ 400mm of steel pipes are applied for left bank and right bank, respectively to minimize the construction cost.

Table 2.2.2.49 Hydraulic Calculation Result of Intake Works

		left bank intake		right bank intake	
Pipe diameter	(m)	0.40	0.45	0.35	0.40
Deign discharge	(m^3/s)	0.128	0.128	0.084	0.084
Extension	(m)	72.0	72.0	100.0	100.0
Velocity coefficient		100	100	100	100
Mean velocity	(m/s)	1.025	0.810	0.879	0.673
Velocity head	(m)	0.054	0.033	0.039	0.023
Screen loss	(m)	0.006	0.004	0.004	0.003
Inflow loss	(m)	0.054	0.033	0.039	0.023
friction loss	(m)	0.296	0.167	0.362	0.189
Outflow loss	(m)	0.054	0.033	0.039	0.023
Other loss	(m)	0.059	0.033	0.072	0.038
Total head loss	(m)	0.469	0.271	0.517	0.275

2-2-2-4 Pump Station

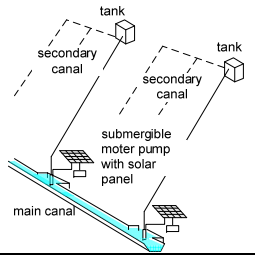
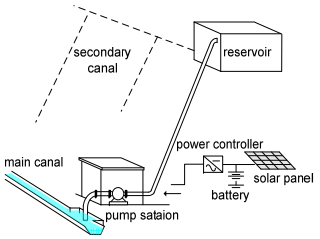
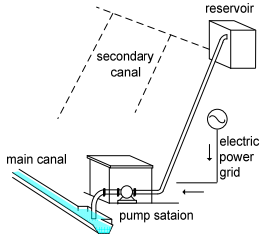
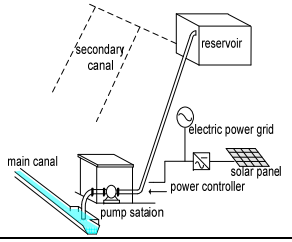
2-2-2-4-1 Type of Pump Facilities

Although power transmission has not equipped yet at the planned construction site of pump station, power source of three-phase alternating current (AC) can be extended from the point of 6 km away from the site. On the other hand, Rwandan government regards solar power generation as important energy source on social capital development policy and some sales agencies providing solar power generation system equipment are operating in Kigali. Using diesel generator for the power source of electric pump is out of touch with reality because of high cost of fuel and transportation.

From points of mentioned above, commercial power or solar power generation will be examined for the power source of prime mover of pump. Therefore, comparative study about the method of water distribution is conducted, one method is installing solar power generation system integrated lifting pumps, which is submergible motor pump, along the irrigation canals in command area, the other is installing facilities at dam site to distribute irrigation water to whole command area from the point which consist of pumps and solar power generation system or receiving equipment from commercial power.

As the result of comparative study shown in next table, installing a pump station at the dam site using solar power generation mainly and commercial power subsidiary is selected plan.

Table 2.2.2.50 Pump Facilities Arrangement and Power Source

Plan	Plan A Pumps with solar panel along the canal	Plan B Pump station at dam site (solar power only)	Plan C Pump station at dam site (power grid only)	Plan D Pump station at dam site (solar power an power grid)
Schematic diagram				
Outline of facility	- Solar power system integrated pumps are installed along the main canal. - Command are is divided into blocks by each pump, where irrigation water is distributed from tanks.	- Pump station is installed at the dam site, which can pump up irrigation water to whole command area. - Power source of pumps is solar power generated electricity. - Irrigation water is stored once in reservoir tank at upper place and distributed to command area.	- Pump station is installed at the dam site, which can pump up irrigation water to whole command area. - Electric grid extended is used for power source. - Irrigation water is stored once in reservoir tank at upper place and distributed to command area.	- Pump station is installed at the dam site, which can pump up irrigation water to whole command area. - Generated electricity by solar is used mainly, grid power is used subsidiary. - Irrigation water is stored once in reservoir tank at upper place and distributed to command area.
Advantages	- Installation is easy since absorption pipes or buildings are not necessary. - Water management or facility control by farmers' organization on each irrigation block is realized.	- Operation and maintenance is easy at one place. - Electric charge which will be paid by farmers is low - Farmers' economic obligation is quite low since electric charge is not required.	- Operation and maintenance is easy at one place. - Stable operation of pumps and supply of irrigation water according to demand are possible.	- Operation and maintenance is easy at one place. -Stable operation of pumps irrespective of insolation is possible.
Disadvantages	- Since exchange by each part is difficult, whole facility should be replaced. - Products which can provide required discharge and lift head as well as guaranteed manufacture's aftercare.	- Since discharge depends on insolation, shortage of water might happen by weather. - Failure of equipment or mistake of operation will affect whole command area.	- Electric charge, which is farmers' obligation, may affect their living expenses. - Failure of equipment or mistake of operation will affect whole command area.	- Failure of equipment or mistake of operation will affect whole command area.
Comprehensive evaluation	Though initial cost is cheapest, manufacturers of equipment are limited. Since the failure of equipment may cause long malfunction of irrigation system. Confidence for effecting permanent project benefit is low.	Monthly farmers' economical obligation is small. While unexpected lack of water caused by weather might happen and it may affect crop yield.	Initial cost is relatively low and also maintenance of facilities is easy. However farmers' economical obligation such as electric charge may affect farmer's living until their income will increase as a result of the project.	Only a little economical burden by farmers allows stable supply of irrigation water. For this reason, project benefit will appear quickly and sustainable development is possible. ◎

2-2-2-4-2 Determination of Pump Specifications

1) Design conditions

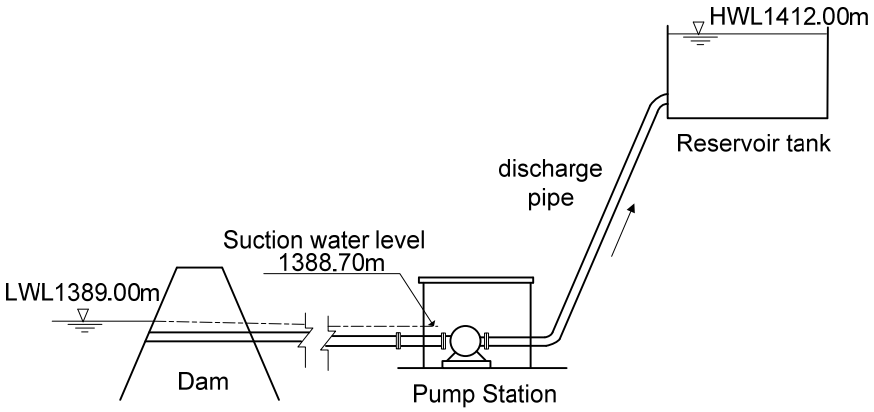


Figure 2.2.2.52 Design Conditions of Pump Station

- Design discharge : 0.080m^3/s
  (Left hill main canal 0.032m^3/s + Right hill main canal 0.048m^3/s)
- Discharge water level : EL. 1412.00m
- Suction water level : EL. 1388.70m
- Actual head : 23.30m
- Length of discharge pipe : 130m
- Type of discharge pipe : PVC (polyvinyl chloride)

2) Discharge pipe

Assumed that the average velocity of pumping as 0.9 - 1.6m/s (in case pipe diameter of 200 - 400mm), pipe diameter to meet this condition is obtained by following formula.

$$D = 1000\left(\frac{4Q}{\pi V}\right)^{1/2}$$

where, D : Diameter (mm)
Q : Discharge (m^3/s)
V : Velocity (m/s)

Provided that the velocity is nearly 1.3m/s as intermediate value of mentioned above,

D=1,000 × (4×0.08/π/1.3) 1/2＝280mm≒D=300mm

3) Calculation of total head of pump

Total head is obtained by adding pipe losses to actual head using following formula. As the result of computation, design total head is calculated at H=24m.

Calculation of total head

$H = Ha + H_l = (DWL\text{-}LWL) + h_f + f_n \cdot V^2/2g$

where,
H : Total head (m)
Ha : Actual head (m)
H_l : Total head loss (m)
DWL : Discharge water level (m)

LWL : Suction water level (m)
h_f : Friction loss of pipe (m)

$h_f = 10.666 \cdot \{Q^{1.85} / (C^{1.85} \cdot D^{4.87})\} \cdot L$; Hazen Williams formula

Q : Discharge (m^3/s)
C : Velocity coefficient; 150 (Average value of PVC pipe)
D : Diameter (m)
L : Length of pipeline (m)
f_n : Coefficient of various head loss
V : Velocity (m/s)
g : Gravity acceleration (m/s^2) = 9.8 (m/s^2)

Table 2.2.2.51 Results of Pipe Losses Calculation

Items		Value	Remarks
Discharge	(m^3/s)	0.08	
Diameter	(mm)	300	
Length of pipe	(m)	130	
Velocity	(m/s)	1.13	
Velocity head	(m)	0.065	
Friction loss	(m)	0.43	C=150
Bend, knee loss	(m)	0.010	f=0.05,3points
outflow loss	(m)	0.065	f=1.0
Other losses	(m)	0.10	
Total loss	(m)	0.605	
Actual head	(m)	23.30	
Calculated total head	(m)	23.91	
Design total head	(m)	24.00	

4) Discharge capacity and number of pumps

Since the main power source of pumps is solar generation, discharge capacity and number of sets of pump units are determined taking account of following points.

- Required volume of irrigation water should be pumped by using solar generated electricity on almost all days through a year.
- When maximum irrigation water volume planned is required, both solar generated power as main power source and commercial electricity as subsidiary are used.
- During cloudy days or when solar power generation system will come to stop by breakdown and/or for maintenance, necessary irrigation water will be pumped by using commercial electricity.

In addition, daily water requirement on irrigation planning are obtained by another examination as follows.

- Annual average irrigation water requirement on average weather conditions : $600m^3$/day
- Annual maximum irrigation water requirement on average weather conditions : $2,200m^3$/day
- Annual average irrigation water requirement on dry year weather conditions : $800m^3$/day
- Annual maximum irrigation water requirement on dry year weather conditions : $3,000m^3$/day
  (=Design daily maximum water requirement)

Suppose that a pump with discharge capacity of 0.080m^3/s (=0.080×3,600＝288m^3/hour) according to the condition 3) mentioned above, operation hours of pump for daily maximum irrigation water designed is,

3,000 / 288＝10.4 hours

This means only daytime operation can supply water even when maximum water is required.

Now suppose that two horizontal centrifugal pumps with discharge capacity Q=140m^3/hour/set (Total head H=24m) whose discharge is almost same as that of described above and which can be procured from local store.

Following graph shows power energy generated by required capacity of solar panel (=14,280 Wp) and hourly discharge when operating the supposed pump by solar power generation. Daily total irradiation amounts to 5.1kWh/m^2 and total discharge is estimated as 532m^3 referring to local agency's estimation.

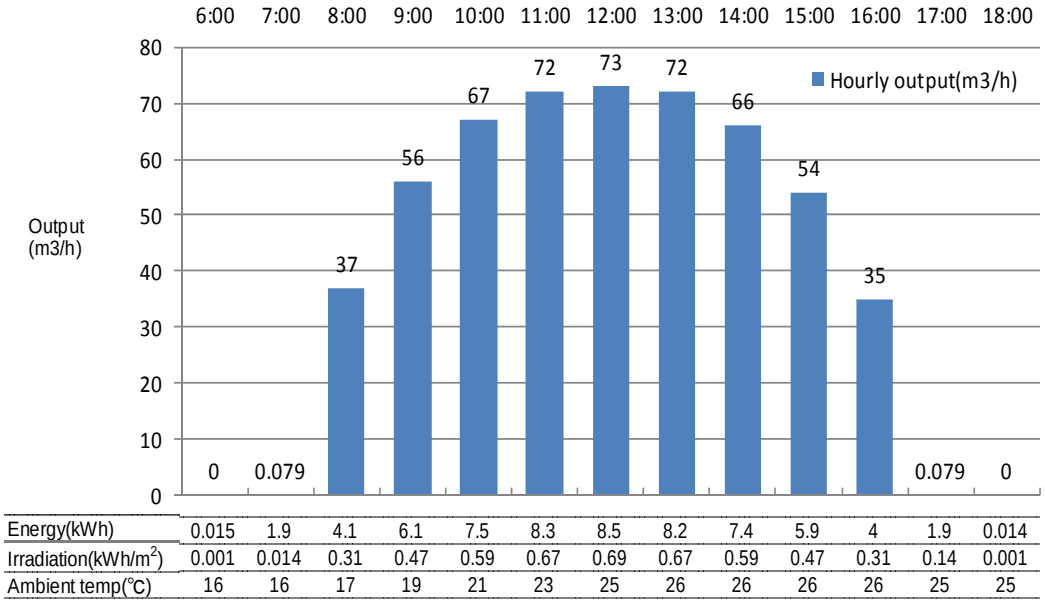


Figure 2.2.2.53 Daily Average Pump Discharge by Solar Generation

From this estimation, number of pumps required whose maximum discharge capacity is 500 m^3/day for different conditions including the case that its discharge capacity may decline to 50 - 60% because of weather fluctuation or generation efficiency is obtained as following table.

Table 2.2.2.52 Number of Pumps Required (sets)

Discharge capacity \ Required capacity		Average year		Dry year (1974)		
		Average	Maximum	Average	Maximum	Remarks
		600	2,200	800	3,000	
500	m^3/day	1.2	4.4	1.6	6.0	Maximum
300	m^3/day	2.0	7.3	2.7	10.0	60%
250	m^3/day	2.4	8.8	3.2	12.0	50%

The table below shows discharges by three pumps using solar power generation as well as irrigation water requirement in average year and dry year. Concerning average water requirement, assumed three pumps by solar power can provide necessary water almost through the year. While in the case of maximum water is required, pumps should be operated not only using solar generation but also using

commercial electricity because facilities by solar power only might become uneconomical.

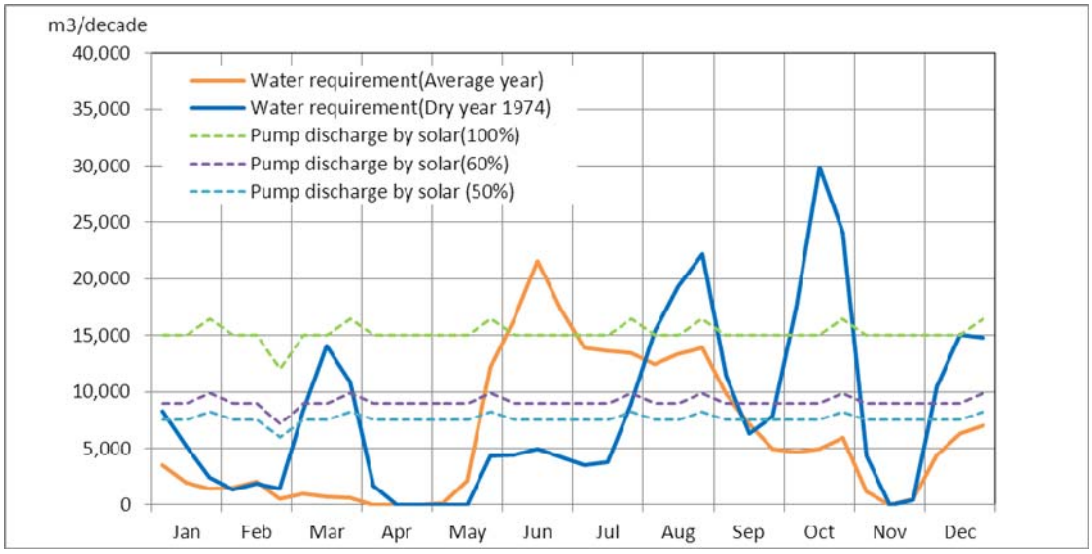


Figure 2.2.2.54 Pump Discharge and Irrigation Water Requirement per Decade

Therefore, facilities are composed of three pumps to be operated by solar power generation and two pumps connected to grid power, so that five pumps in total are to be installed with same specifications.

Table 2.2.2.53 Specification of Recommended Pump

Items	Specification	Remarks
Pump type	horizontal centrifugal pump	with closed coupled motor
Number	5sets	3 sets by solar power generation for regular operation
		2 sets by commercial power for emergency operation
Total head	24.0m	
Discharge	140m^3/h/set	declared power 11kw
Solar modules	43kw	14.28Wp×3

Yet since number of pumps might be reduced by installing control panel which can exchange power sources of solar generation and commercial power mutually, specifications of pumps and their number as well as solar system shall be examined on detail design stage in the respects of initial cost and running cost of them.

2-2-2-4-3 Pump Station Building and Supplemental Facilities

1) Structure of building

Pump station building is constructed for the purpose to protect the equipment and O&M works from winds and rains, and the structure shall be of percolation-proof from rain water. The structure type of pump station building shall be of reinforced concrete which is superior in the characteristics of fire-proofing, durability and anti-wind, though concrete blocks shall be used for the wall body on ground because of economical reason. The type of foundation is adopted spread foundation since the weight of building is not so heavy, and overhead crane is not necessary because each pump's weight may be about 100kg.

2) Pump room layout

The plan of pump room shall be decided mainly by the alignment of pumps and receiving panels in order to be made daily operation, inspection and maintenance easily and safely. Since operator's twenty-four hours staying in the room is not supposed, particular office space and daily life equipment

shall not be provided.

3) Space for solar modules

The size of solar panel is $2m^2$ (1m x 2m) generally and 151 panels which is equivalent to $300m^2$ are designed in this Project.

The location of installing the panels is near the pump station and gathering one place is better for operation and maintenance. Though it is possible to install the panels on the ground directory, they shall be installed on the top of regulating tank which will be constructed to store irrigation water with its size is 3m high and surface area of $600m^2$ so as not to be stolen or broken. Moreover the fence will be installed around the tank for safety. Installing the panels on the top pf the tank is reasonable from the view point of decreasing land expropriation and compensation.

2-2-2-5 Plan of Irrigation Canal

2-2-2-5-1 Canal Types

Canal types are selected taking account of economy, water management system and O&M conditions since they play an important role for function of canal system and may influence construction cost largely.

1) Secondary canal

Secondary canals which are diverted from main canal and convey irrigation water to each farm plots shall be pipeline because they are arranged along the slope of a hillside and required to supply pressured water through hydrant.

2) Main canal

Main canal consists of lower canal which conveys irrigation water by natural gravity using lifted head at the reservoir and upper canal which conveys pumped up water. Those structural types are considered as open channel and pipeline receptivity.

General characteristics of both types and composite type are enumerated the table below. Moreover following points should be considered on this Project besides own merits and demerits of their types.

- Open channel type takes long time to reach steady state of flow since the pressure traveling velocity is slow and affects water management operability. Due to this feature, open channel type should be avoided for long length section.
- Pipeline is hard to repair once some problem occurs. Whereas open channel type shall be expected to be maintained properly by WOU judging from other past case in Rwanda even though daily maintenance works such as removal of sediment are required.
- In case of long length canal, constructing regulating tank on the way can make the cross section of canal smaller and reduce the water traveling time.

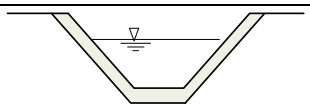
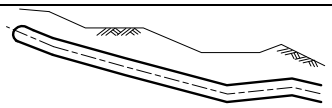
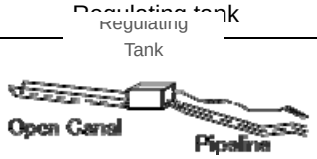
From the point of view described above, open channel type is adopted basically for economical reason. While constructing regulating tank shall be adopted for lower main canal and pipeline type which can be laid regardless of topographical conditions shall be selected for downstream from the tank because the discharge is little and the difference of construction cost with open channel type may be also small.

Table 2.2.2.54 Length and Type of Main Canal

Location	Length	Canal type	Remarks
Right side lower	10.2km	Open channel＋Pipeline	with Regulating tank
Right side upper	6.0km	Open channel	

Left side lower	7.5km	Open channel＋Pipeline	with Regulating tank
Left side upper	4.6km	Open channel	

Table 2.2.2.55 Comparison Table for Canal Types

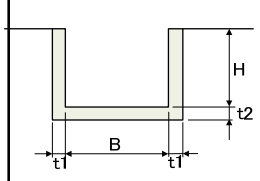
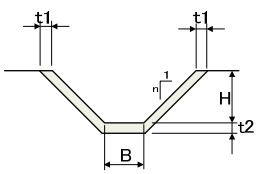
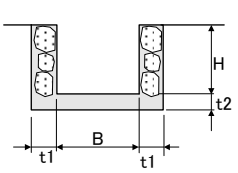
Type	A: Open Canal	B: Pipeline	C: Open Canal + Pipeline with Regulating tank
Sketch			
Advantage	- Construction cost is cheaper than pipeline. - Maintenance works to be done by the users can be managed easier than pipeline, because the material such as sand, stone, cement etc. can be got in local market. - It is affordable for the beneficiaries to purchase such material for maintenance works. - Water flow can be seen by the users, so that they can check the condition of the canal anytime and feel effectiveness of the Project.	- The route of pipeline can be planned freely relatively without taking account of topographic condition. - Irrigation water can be utilized effectively because the system can minimize water loss. - Easy operational system of water management can be realized by establishing the demand-oriented water control equipped with pressure regulating facilities constructed on the part of pipeline system. - The land on the line of pipe can be effectively used after laying the pipe underground.	- Time of water arrival will be reduced by regulating tank in middle stream. - Diameter of pipeline is smaller than Type B in downstream, so that it is easier to repair works for the beneficiaries. - The extent for land expropriation can be smaller than Type A. - Cross section of open canal will be smaller than Type A.
Disadvantage	- There is possibility to clean up inside the canal frequently because of much sedimentation run off from hillside. - It will be take a long time of water arrival to the end from the beginning of the canal, so that the water management is more difficult for the users than pipeline system. - The extent for land expropriation can be larger than pipeline system.	- Although it is not necessary for daily maintenance works, repair works such as water leakage, pipe bursting etc. may be difficult for the users. - Construction cost is higher than open canal type. - In order to prevent choking pipe with leaves, an equipment such as bar screen at the inlet of pipeline is necessary.	- There is possibility to clean up inside the canal frequently because of much sedimentation run off from hillside in open canal .(*1) - In order to prevent choking pipe with leaves and rubbish, an additional equipment such as bar screen at the inlet of pipeline is necessary.

2-2-2-5-2 Structure of Open Channel

Economical comparison of structural type for open channel is conducted concerning reinforced concrete type with rectangular shape, concrete lining type with trapezoid shape and masonry type with rectangular shape as follows. The height of side is determined in consideration of necessary freeboard. The side wall gradient for concrete lining type is same as cutting gradient for terracing works generally.

As the result of estimation of construction cost per meter, concrete lining type is found to cheapest among three types. Concrete lining type shall be selected as open channel main for canal since this is superior to easiness of construction as well.

Table 2.2.2.56 Economical Comparison of Open Channel

Type			Reinforced concrete (Rectangular shape)		Concrete lining (Trapezoid shape)		Masonry (Rectangular shape)	
Cross Section								
Design Dischrge(m^3/sec)			0.048		0.048		0.048	
Slope of canal bed			1/1000(0.001)		1/1000(0.001)		1/1000(0.001)	
Coefficient of roughness			0.015		0.015		0.024	
Dimensions								
B	m		0.40		0.30		0.50	
H	m		0.40		0.40		0.40	
t1	m		0.10		0.07		0.15	
t2	m		0.10		0.07		0.10	
n			0		3		0	
Construciton Cost		Unit Price	Quantity	Price	Quantity	Price	Quantity	Price
Excavation	m^3/m	4,500	0.58	2,625	0.28	1,262	0.68	3,075
Backfilling	m^3/m	5,500	0.28	1,558	0.00	0	0.28	1,558
Concrete	m^3/m	300,000	0.14	42,000	0.09	26,040	0.08	24,000
Masonry	m^3/m	75,000					0.12	9,000
Total				46,183		27,302		28,633
ratio				1.69		1.00		1.05

2-2-2-5-3 Canal Alignment Selection

Canal alignment along the ground contour line is selected so that water can flow by gravity to the command area. Investigations around both sides of Ngoma22 valley and downstream area of river show some afforestation area on the route of canal. One of the areas which is located at right side hill of about 6km apart from dam site is found to be possible to arrange a canal along the road which is constructed at lower area of the hill. On the other hand, the afforestation areas of right side hill located 10km from dam site and left side hill located 8km from dam shall be the terminal point of main canals of both banks since these have some difficulties for construction and cannot be considered as effective beneficial area due to extending canal for topographically reverse direction.

Photo 2.2.2.6 Present State of Right Side Hill

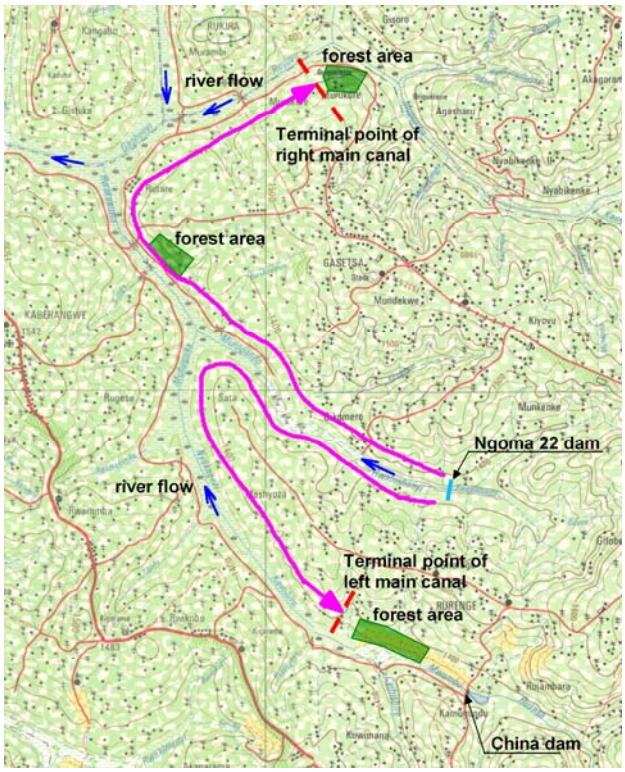


Figure 2.2.2.55 Main Canal Alignment Selection Diagram

2-2-2-5-4 Longitudinal Plan

If the longitudinal slope of canal is set to be large, it would be the cause of deterioration of flow or scour of canal section owing to excessive increase of flow velocity while it can make the cross section of canal smaller. Setting the longitudinal slope as small as possible is required in the extent of allowable lowest velocity since large head between reservoir water level and the end of beneficiary area are not secured on this Project are topographically. Furthermore, cross section is almost minimum size necessary for construction and maintenance and construction cost is not so high even if setting the longitudinal slope more gentle due to small discharge as 0.05m^3/s.

The design velocity of canal secures more than 0.45m/s in order to avoid sedimentation of floating sand particles and allowable maximum velocity is decided as 1.5m/s for using thin concrete.

As the result of calculation, longitudinal slope of 1/1,000 (=0.1%) shall be adopted taking above mentioned conditions into account.

Table 2.2.2.57 Results of Uniform Flow Calculation for Main Canal (Open Channel)

		Right lower	Right upper	Left lower	Left upper
Roughness coefficient n=		0.015	0.015	0.015	0.015
Canal bed slope I=		0.001	0.001	0.001	0.001
Side slope(right)1:m1		0.333	0.333	0.333	0.333
(left) 1:m2		0.333	0.333	0.333	0.333
Canal bed width B=	(m)	0.300	0.300	0.300	0.300
Water depth h=	(m)	0.355	0.250	0.251	0.194
Cross section area A=	(m^2)	0.148	0.096	0.096	0.071
Wetted perimeter P=	(m)	1.048	0.827	0.829	0.708
Hydraulic mean depth R=	(m)	0.142	0.116	0.116	0.100
Velocity V=	(m/s)	0.573	0.501	0.502	0.453
Discharge Q=	(m^3/s)	0.085	0.048	0.048	0.032
Froude number Fr=		0.307	0.320	0.320	0.329
Freeboad	(m)	0.126	0.119	0.119	0.115
Necessary height	(m)	0.481	0.369	0.370	0.309
Section size（width×height；m）		0.3×0.5	0.3×0.4	0.3×0.40	0.3×0.3

2-2-2-5-5 Discharge Tank

At the start point of main canal, discharge tank shall be constructed which dissipate outlet flow from reservoir or reservoir tank and connect the flow to main canal with regulating.

The structure of the discharge tank should be reinforced concrete securing a required space for dissipation and stilling. The discharge to main canal shall be regulated by valve opening with controlling overflowing water depth at the rectangular weir.

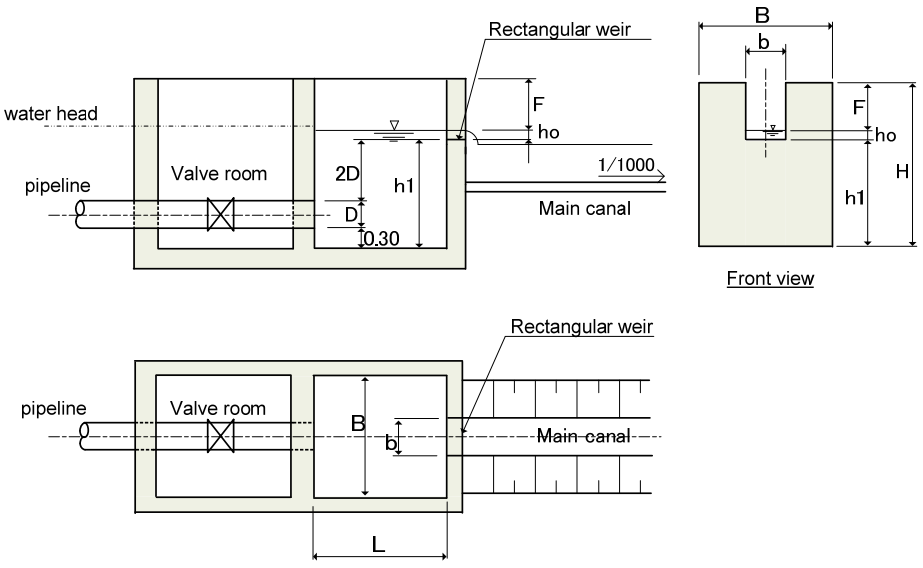


Figure 2.2.2.56 Discharge Tank Structural Diagram

<Discharge formula of rectangular weir>

$$Q=C\cdot b\cdot h^{3/2}$$

$$C = 1.705 + \frac{0.00295}{h} + 0.237\frac{h}{H} - 0.420\sqrt{\frac{(B-H)h}{D\cdot H}} + 0.034\sqrt{\frac{B}{H}}$$

Table 2.2.2.58 Study Table of Discharge Tank Size

		No.1 right/upper	No.2 right/lower	No.3 left/lower	Remarks
D	(m)	0.45	0.40	0.30	
B	(m)	1.50	1.50	1.50	
b	(m)	0.40	0.50	0.40	
h1	(m)	1.65	1.50	1.20	=D3+0.3
ho	(m)	0.168	0.211	0.169	
F	(m)	0.182	0.289	0.331	
H	(m)	2.00	2.00	1.70	=h1+ho+F
L	(m)	1.50	1.50	1.50	≧2D×1.5
C		1.7422	1.7353	1.7362	discharge coefficient
Q	(m^3/s)	0.048	0.084	0.048	main canal discharge
water head (EL.m)		1409.30	1388.70	1388.70	
crest elevation (EL.m)		1409.13	1388.49	1388.53	

2-2-2-5-6 Regulating Reservoir Plan

Three regulating reservoirs shall be constructed in the command area, one is a temporary storage facility located at the beginning of the main canal on left hillside in order to distribute water to the pump irrigated area, the others are regulating facilities located in the middle of main canal to control water distribution. The former is named No.1 reservoir tank, the latter is No.2 regulating tank at right side hill and No.3 regulating tank at left side hill.

Capacities of each tank are as follows.

1) No.1 regulating tank

The pumps are running to be run mainly by using generated electricity of solar energy. The pump discharge in the early morning when most farmers start farming will not reach maximum level since the output power is too low to make the motor run fast enough. Therefore, provided that required water for about 4 hours' irrigation, which is average irrigation hour annually, shall be stored beforehand, the necessary volume is,

V=0.0008m^3/sec/ha (=maximum unit water requirement)×100ha (pump irrigated area)×4 (hour)×3,600＝1,152m^3

Besides the total discharge of three pumps whose average discharge per day through the year supposed about 500m^3 in consideration of generated power by solar is estimated 1,500m^3 per day. Consequently, the capacity of No.1 tank shall be 1,500m^3 that is enough to utilize generated power effectively and does not influence farming.

Irrigation water requirement for farm land in the dry year of occurrence provability 1/5 is estimated 2,990 m^3 per day in peak month. From the simulation on daily water balance in the reservoir tank of 1,500m^3, it is proved that the tank will become full by water which will be pumped by maximum 5 pumps operated by solar power as well as grid power.

Table 2.2.2.59 Fluctuation of Pump Discharge and Reservoir Volume

Time	Pump discharge			Irrigation water outflow		Volume	Remarks
	Solar 3 sets (m3/h)	Grid 2 sets (m3/h)	accumulation (1) (m3)	per hour (m3/h)	accumulation (2) (m3)	(3)-(2)+(1) (m3)	
						1,500	Initial volume(3)
6:00	0		0	-288	-288	1,212	
7:00	0.237		0	-288	-576	924	
8:00	111		111	-288	-864	747	
9:00	168		279	-288	-1,152	627	
10:00	201		480	-288	-1,440	540	
11:00	216		696	-288	-1,728	468	
12:00	219		915	-288	-2,016	399	
13:00	216		1,131	-288	-2,304	327	
14:00	198	280	1,609	-288	-2,592	517	Using grid
15:00	162	280	2,051	-288	-2,880	671	
16:00	105	280	2,436	-110	-2,990	946	
17:00	0.237	280	2,716	0	-2,990	1,226	
18:00	0	274	2,990	0	-2,990	1,500	

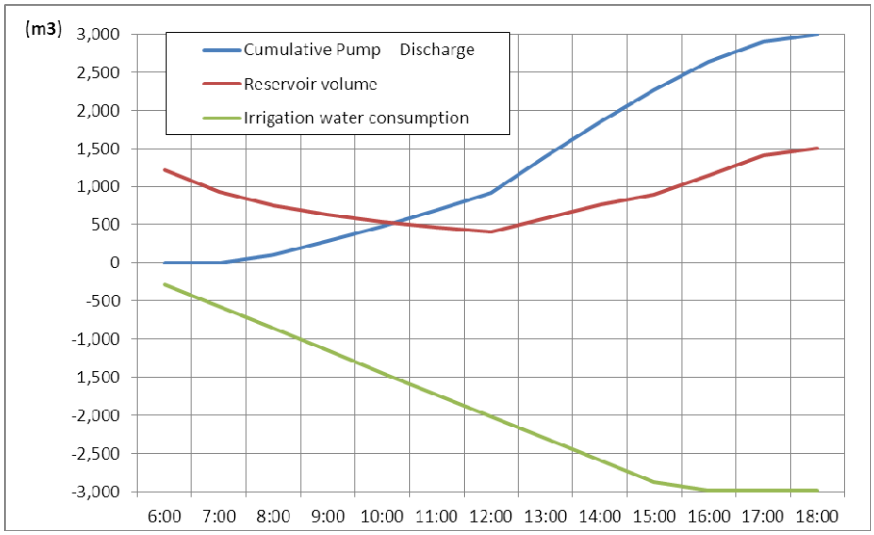


Figure 2.2.2.57 Simulation on Change of Reservoir Volume

2) No.2 and No.3 regulating tank

No.2 and No.3 regulating tank are facilities of controlling water distribution to the downstream of lower main canal, or pipeline area without time difference.

If irrigation water necessary for the pipeline area and the period equivalent to the water traveling time from water source point to regulating tank, or upstream canal length is stored beforehand, farmers can start irrigation almost simultaneously with upstream area.

Table 2.2.2.60 Capacity of No.2 & No.3 Regulating Tank

	Length of upstream canal (m)	Design velocity of upstream canal (m/s)	Traveling hours of upstream canal (hr)	Design discharge of downstream canal (m^3/s)	Required capacity of eservoir (m^3)	Design reservoir size
No.2 tank (right side)	5,210	0.57	2.5	0.036	324.0	10.0m×22.0m×1.5m (=330m^3)
No.3 tank (leftt side)	4,300	0.50	2.4	0.012	103.7	10.0m×10.0m×1.05m (=105m^3)

2-2-2-6 Plot Construction Plan for Existing Paddy Field

1) Irrigation development and plot construction in the project

(1) Standing position and importance of plot construction in irrigation development

- Based on the bio-physical conditions and other relevant data, Rwanda Irrigation Master Plan has

determined the potential irrigable area so far, a summary of which has been given in the table below. The assessment of Rwanda's irrigation potential indicates that the country has a national irrigation potential of nearly 589,711 ha, taking into consideration the following domains. As indicated in the table below, irrigation development potential of marshland runs up to about half of the national total, which is 219,793 ha occupying 47% of total irrigation development potential. It can be said that marshland and/or existing paddy filed are given a key role in the irrigation development of the country.

Table 2.2.2.61 Summary of Potential Irrigable Area

Irrigation Domain	Potential Area (ha)	%
Runoff for small reservoir	125,627	27
Runoff for dams	27,907	6
Direct river and flood water	79,847	17
Lake water resources	100,107	22
Groundwater resources	36,432	8
Marshland	**219,793**	**47**
Total	464,086	100

- On the other hand, current situation of underdeveloped and /or deficiency of irrigation facilities in marshland are cited as a constraint factor in improvement of rice production which is a main product in the marshland. As a participant country of CARD (Coalition for Africa Rice Development) program, Rwanda has formulated NRDS (National Rice Development Strategy) so far. It can be evaluated that necessity and/or demand of marshland development and plot-construction of existing paddy fields are quite high.

(2) Present situation of marshland (exiting paddy field) in the project site

- Because of the condition of Project site, where spreads out 35 ha of existing paddy fields downstream of the dam axis, the Project proposes to carry out hillside irrigation comprehensively and effectively through improvement of irrigation facilities put in existing paddy field so as to create water resource for hillside irrigation.
- The OD (Outline Design) team observed some disadvantages which obstruct a proper sharing of irrigation water among the rice growers on the existing paddy field:

  i) Small ditch in the plot and plot-to-plot irrigation system disturb a smooth flow of irrigation water from plot to plot. The water level in the small ditch of the plot becomes lower than the elevation of plot surface with the passage of time due to scraping away of the bottom in the ditch which is caused by energy of irrigation water flow, so that the irrigation water cannot go into from plot to next plot continuously.

  ii) There is much water leakage from levee.

  iii) The plots are not leveled, which causes unbalanced feeding of irrigation water in a plot bringing the farmers to loss of harvest.

  iv) Current irrigation system (plot-to-plot system) makes the farmers difficult to manage irrigation and drainage properly because almost of all the plots are not connected to irrigation and drainage canal directory and separately. In principle, irrigation and drainage of each plot should be independent for proper water management. Even the size of plots is small for a better water management, which must be at least 30m x 100m per plot.

  v) Such situation on the paddy plots mentioned above can be commonly seen everywhere

(3) Necessity of implementation of plot construction

- Technical countermeasure which the Project proposes can be a model in LWH project in the future at the place where has similar topographic condition to Ngoma22 Project site.
- The leveling accuracy of paddy plot is a very important factor in the improvement of labor productivity by realization of efficient and labor-saving water management. The leveling works executed so far, however, have relied on only manpower so that the plots are not seen as level in many project sites. It has become a case of bad construction cases.
- According to the situation mentioned so far, it can be considered that there is significance to implement plot construction in Ngoma22 Project by introduction of Japanese technology using advanced equipment like laser-leveler which are able to make the paddy plots level with accuracy.

2) Outlive design of plot construction

Taking account of current situation of existing paddy field and circumstances of marshland development as a part irrigation developed, the Project plans to implement this component as follows through discussion made by both parties of Rwanda side and Japan side.

- Japan side takes construction of main irrigation canal and drainage canal over the whole line of 3.9 km, O&M road construction along the canals, and re-plotting (leveling) at model area of 2 ha,
- Rwanda side is responsible for executing re-plotting (leveling) for remaining area of 33 ha, and
- Heavy equipment such as tractor, laser-leveler and so on for leveling will be provided to Rwanda side after completion of the construction works.

(1) Construction of main irrigation and drainage canal, division box, and O&M road

Alignment of these facilities basically follows the current lines so as not to disturb present paddy plots taking account of water management the farmers have practiced so far. This is also considered to avoid poor drainage of the plots where are newly embanked along the current irrigation canal and drainage due to collection of underground water coming down through hillside upland spreading both banks of targeted paddy fields.

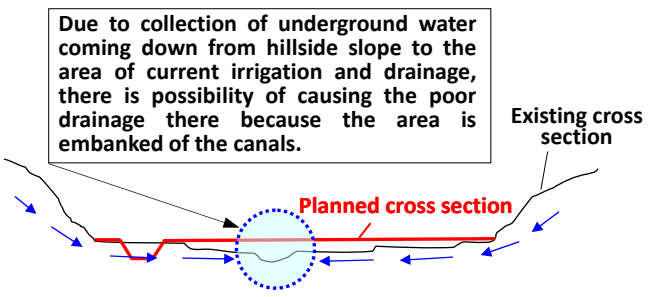


Figure 2.2.2.58 Canal Alignment shifting to Skirt of Hillside

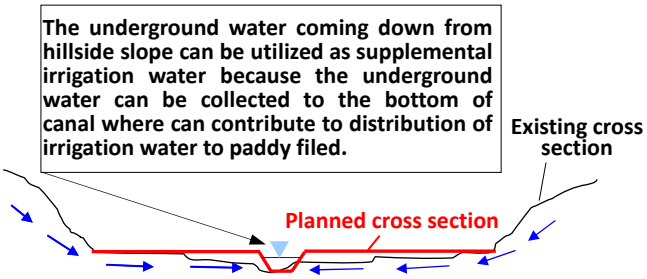


Figure 2.2.2.59 Canal Alignment following Current Location (Proposed)

Along the main canal of around 3.9 km, 12 division boxes are to be constructed with around 300 m interval to deliver the irrigation water to paddy plots spreading both sides of the main canal by raising water level in the canal. At present, there is no O&M road, even footpath on the targeted paddy field so that maintenance works for the facilities to be carried out by the farmers has not been very active. After completion of all construction works planned, the road will be used for maintenance activities

for project sustainability.

(2) Plot construction (enlargement, leveling, and levee construction)

As mentioned already, plot re-construction including enlargement and leveling of paddy plots, levee rehabilitation /newly construction is to be implemented by Japan side at model area of 2 ha as a part of technical transfer. Reaming area for re-plotting will be executed by Rwanda side. Construction machine s like tractor, laser-leveler will be provided to C/P agency after completion of construction works.

The size of a plot is planned as around 30m x 100m - 150m and each plot will be equipped with inlet and outlet and then they are directory connected to the sub-irrigation canal and the main drainage respectively for independent water management on plot base. One irrigation management block composed of 10 paddy plots. The figures shown below indicate typical plan and cross section of plot construction respectively.

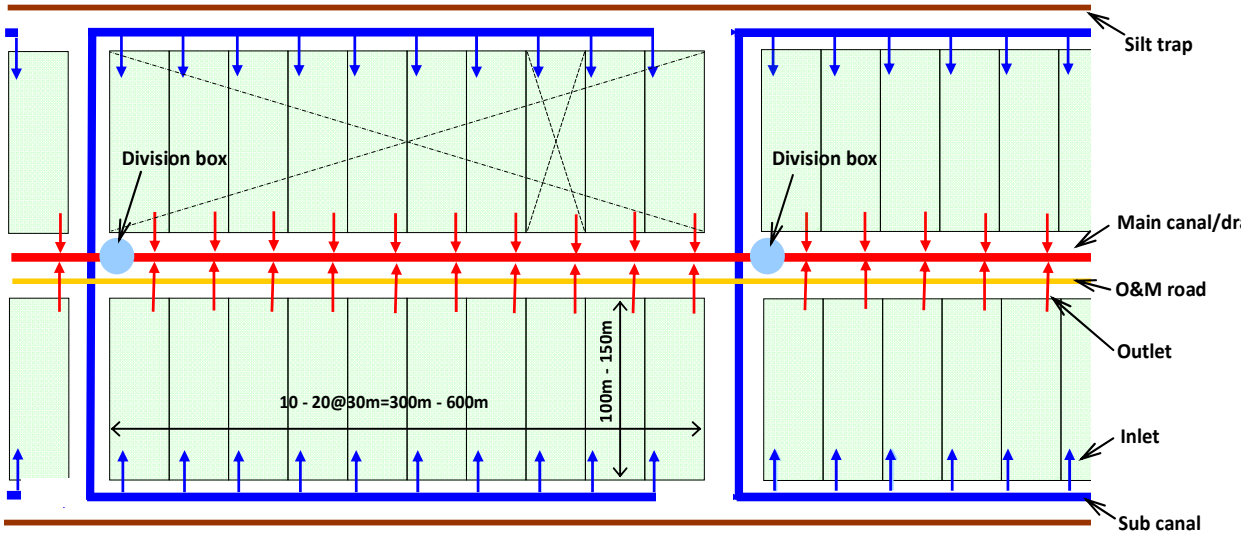


Figure 2.2.2.60 Typical Plan of Plot Construction of Existing Paddy Field

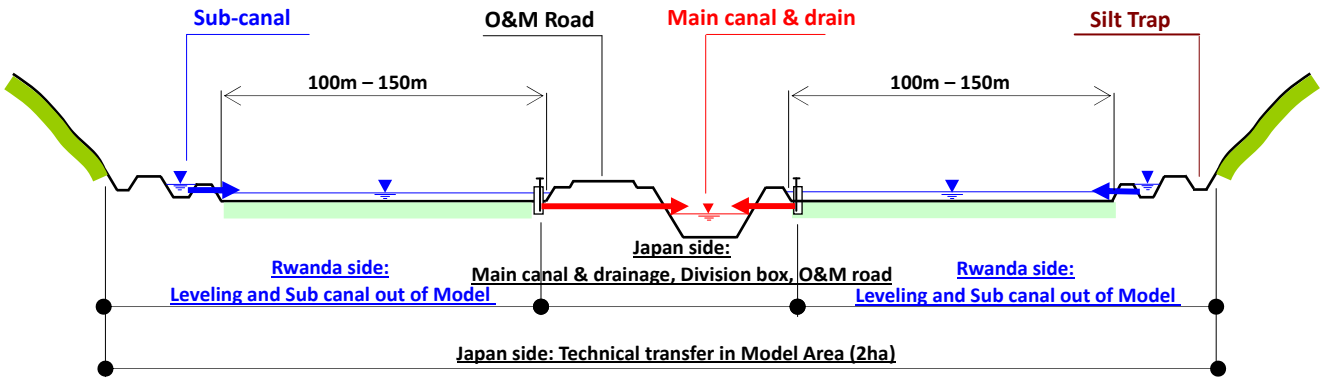
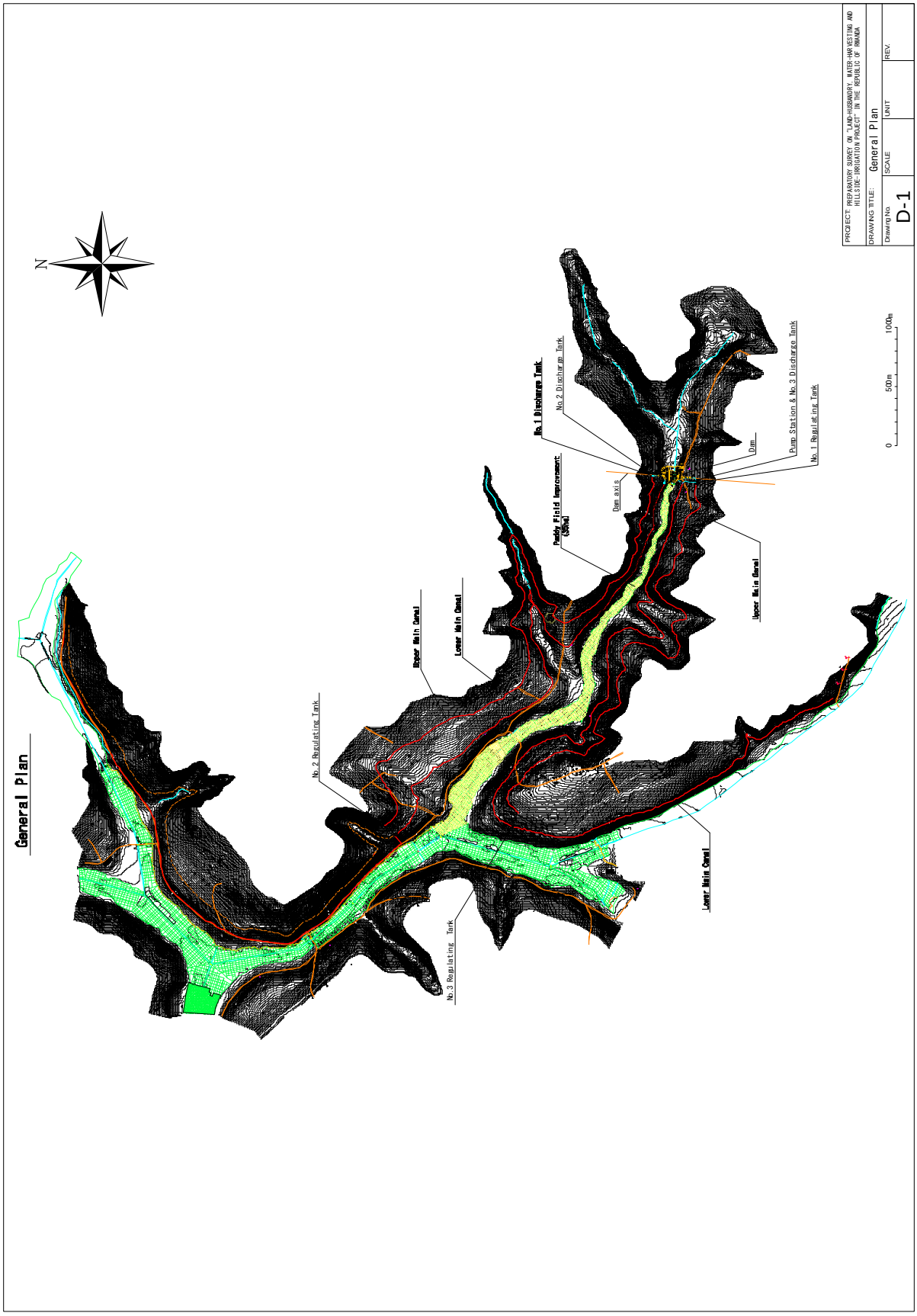


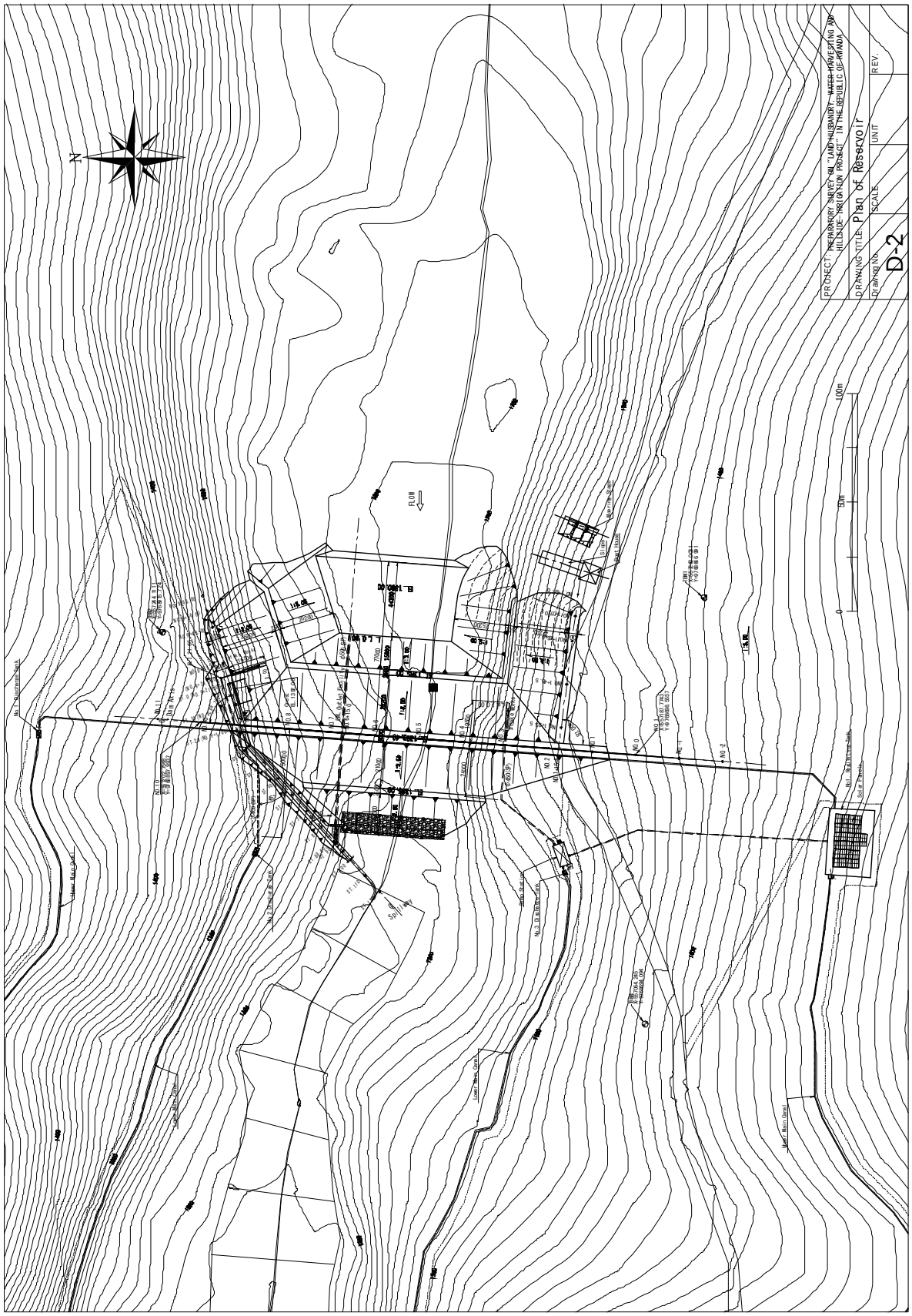
Figure 2.2.2.61 Typical Cross Section of Plot Construction and Role Sharing between Rwanda and Japan Side

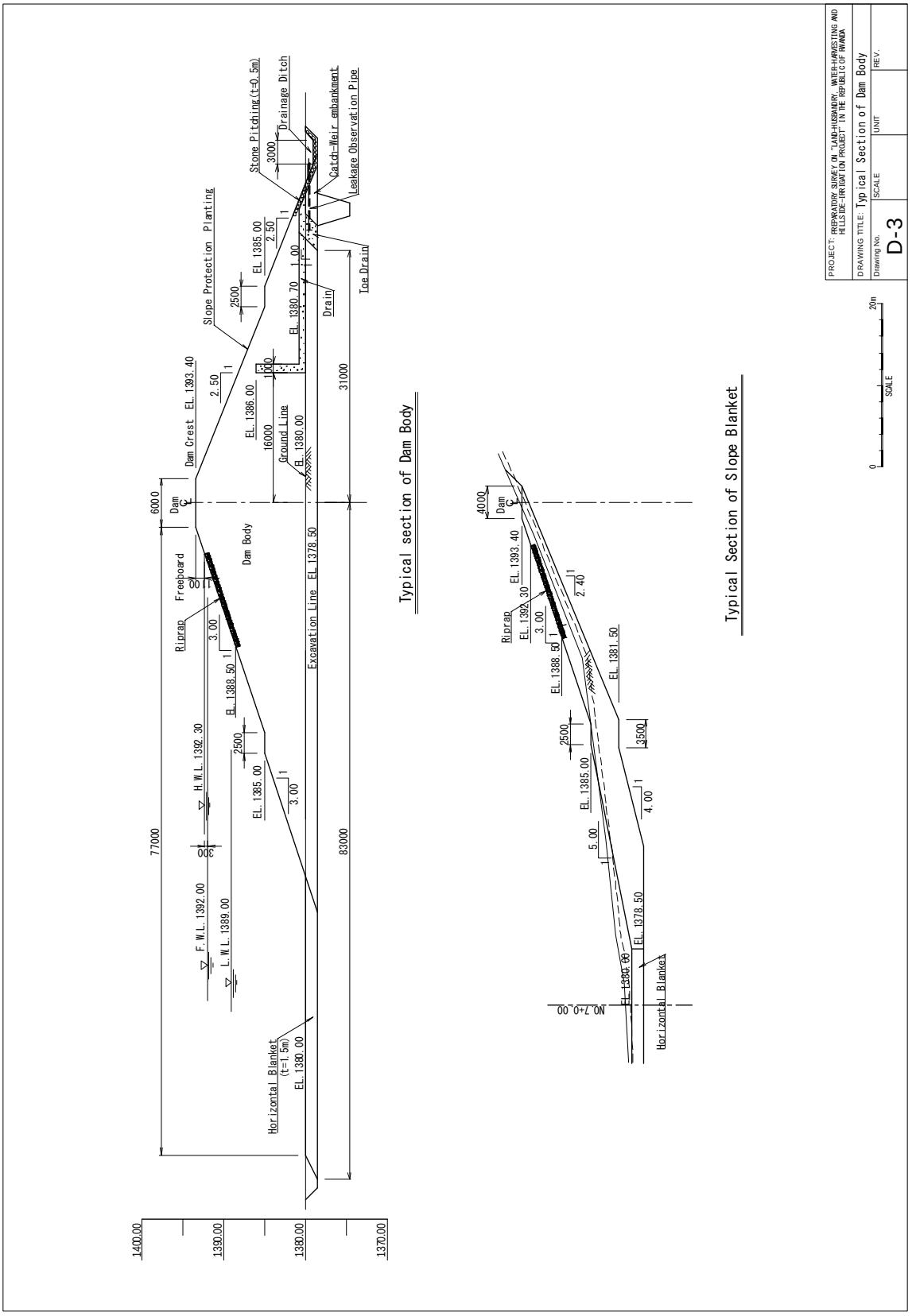
2-2-3 Outline Design Drawing

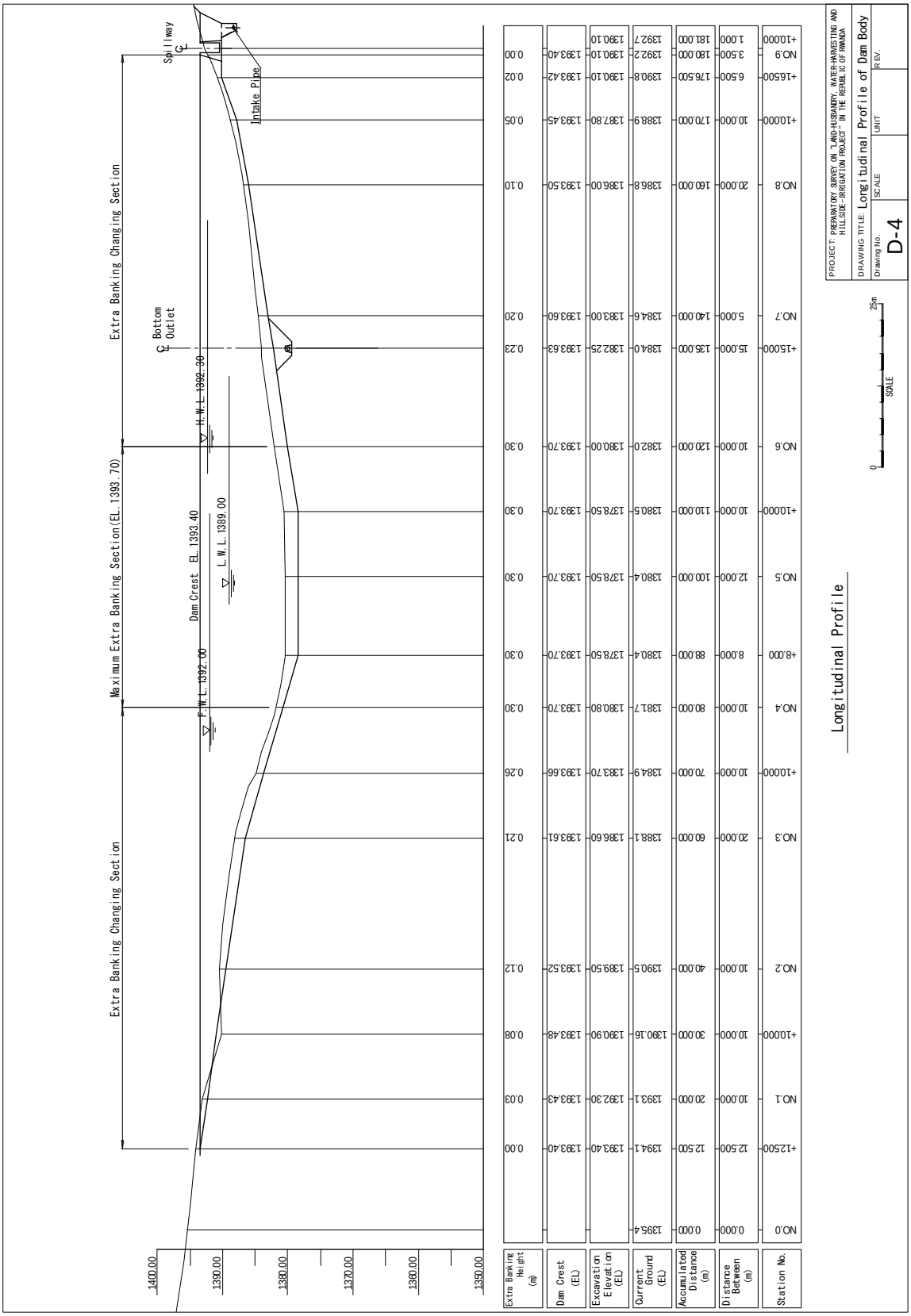
Drawings List

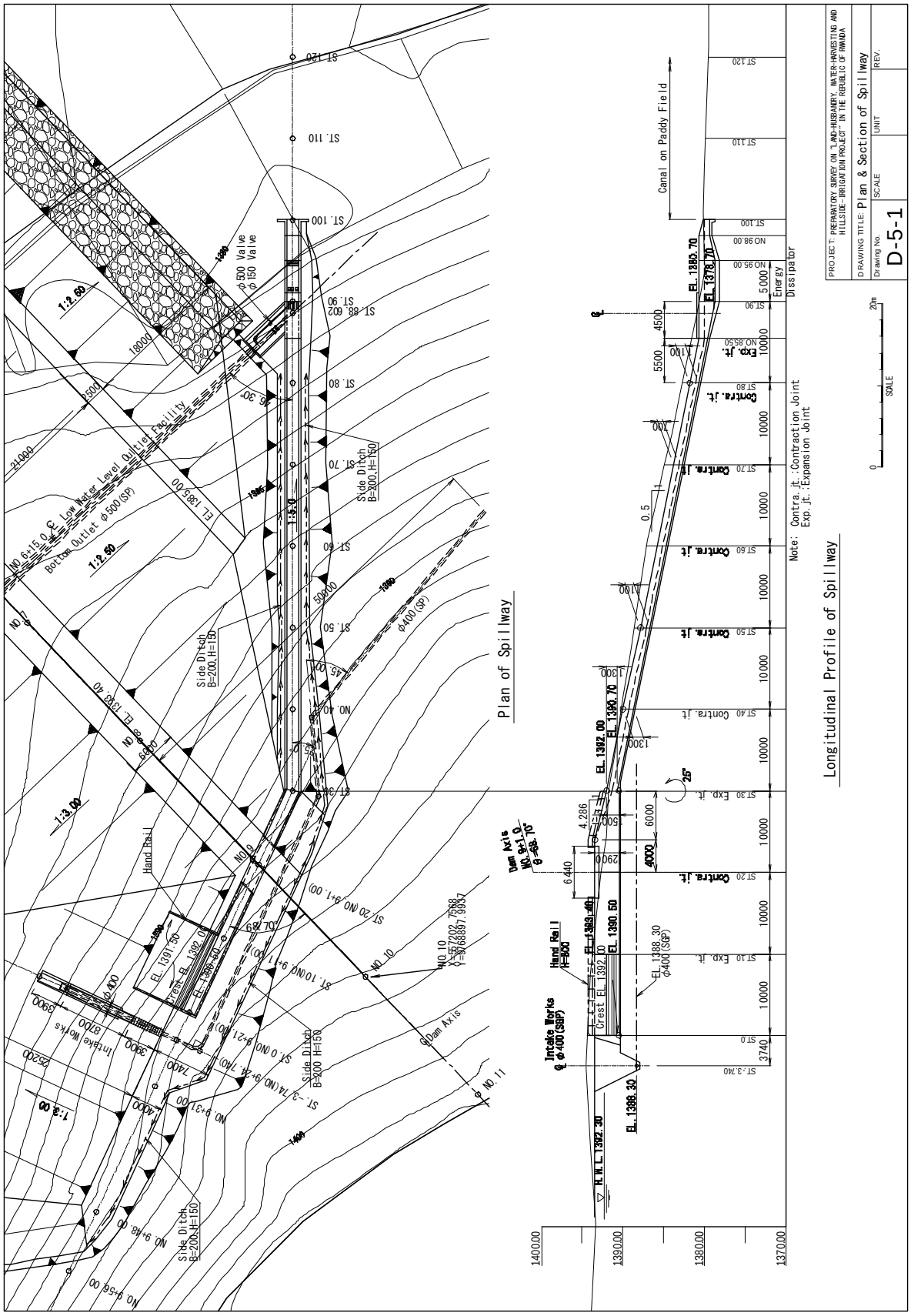
Drw.No.	Drawing Name	Pcs.
Reservoir		
D-1	General Plan	1
D-2	Plan of Reservoir	1
D-3	Typical Section of Dam body	1
D-4	Longitudinal Profile of Dam Body	1
D-5	Plan and Section of Spillway	3
D-6	Section of Low Water Level Outlet Facility	3
D-7	Plan and Profile of Intake Works on Right Bank	1
D-8	Plan and Profile of Intake Works on Left Bank	1
Canal Facilities		
C-1	Plan of Irrigation Canals	3
C-2	Typical Section of Main Canal	1
C-3	Section of Pump Station and No.3 Discharge Tank	1
C-4	Section of Discharge Tank	1
C-5	Section of Regulating Tank	2
C-6	Single Line Diagram	1
Paddy Field Improvement		
L-1	Plan of Plot Construction	1
L-2	Cross Section of Paddy Plot	3
Total		25

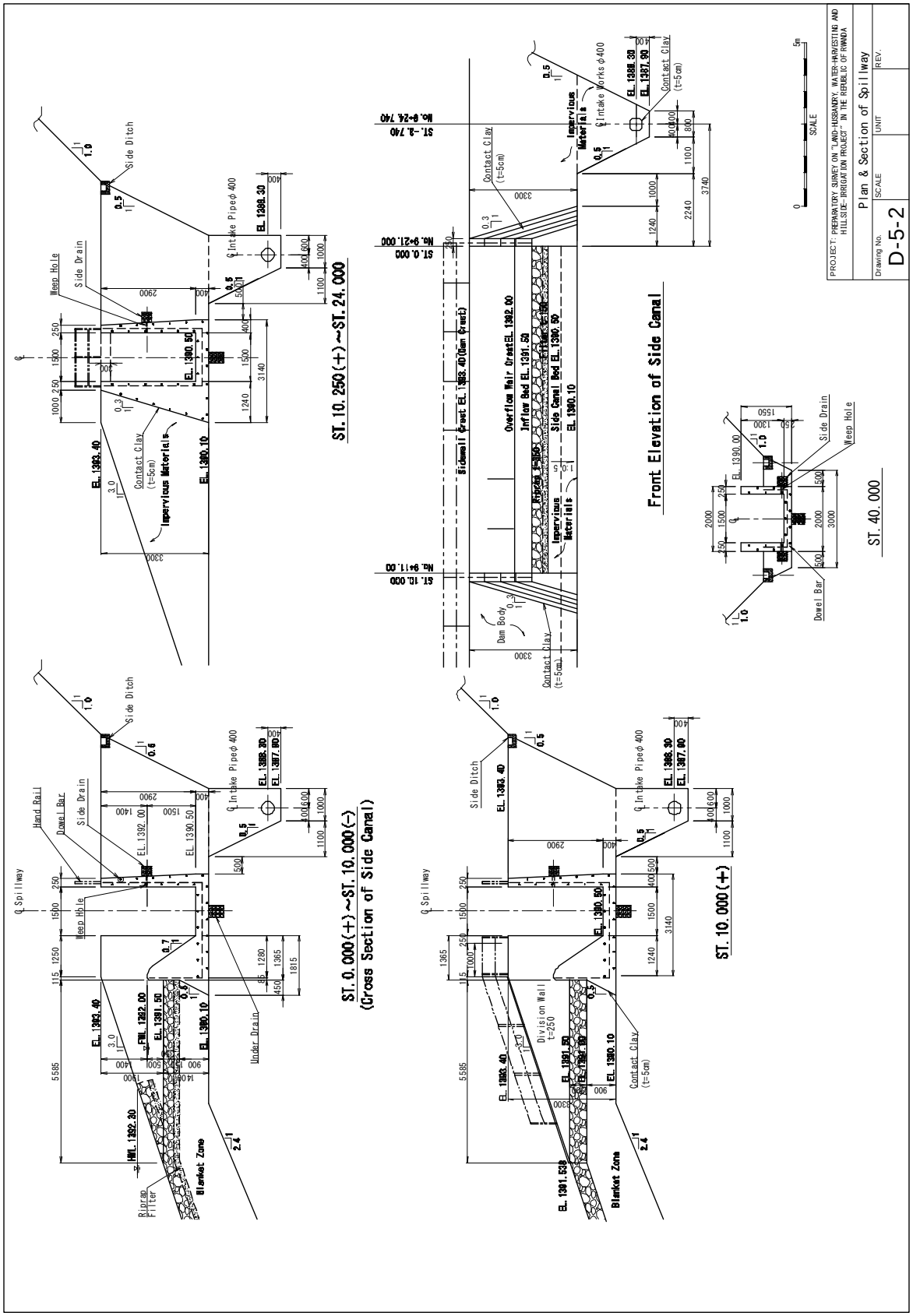

PROJECT PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: General Plan
Drawing No. D-1
SCALE
UNIT
REV.
N
General Plan
No.1 Discharge Tank
No.2 Discharge Tank
Dam
Pump Station & No.3 Discharge Tank
No.1 Regulating Tank
Dam axis
Paddy Field Improvement (50ha)
Upper Main Canal
Lower Main Canal
Upper Main Canal
Lower Main Canal
No.2 Regulating Tank
No.3 Regulating Tank
0
500m
1000m

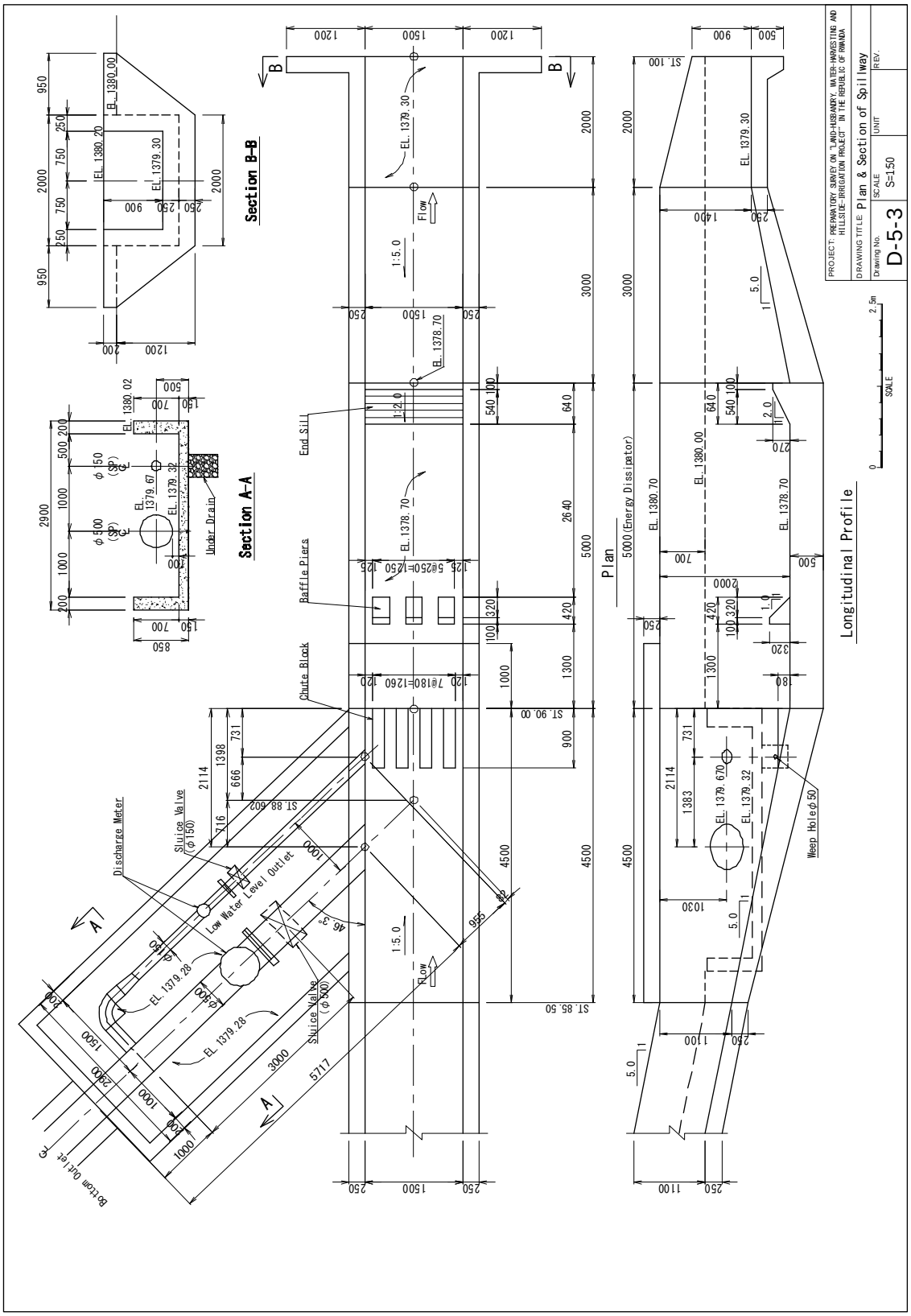

N
FLOW
PROJECT: PREPARATORY SURVEY ON "LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan of Reservoir
Drawing No. D-2
SCALE
UNIT
REV.
100m
50m
0

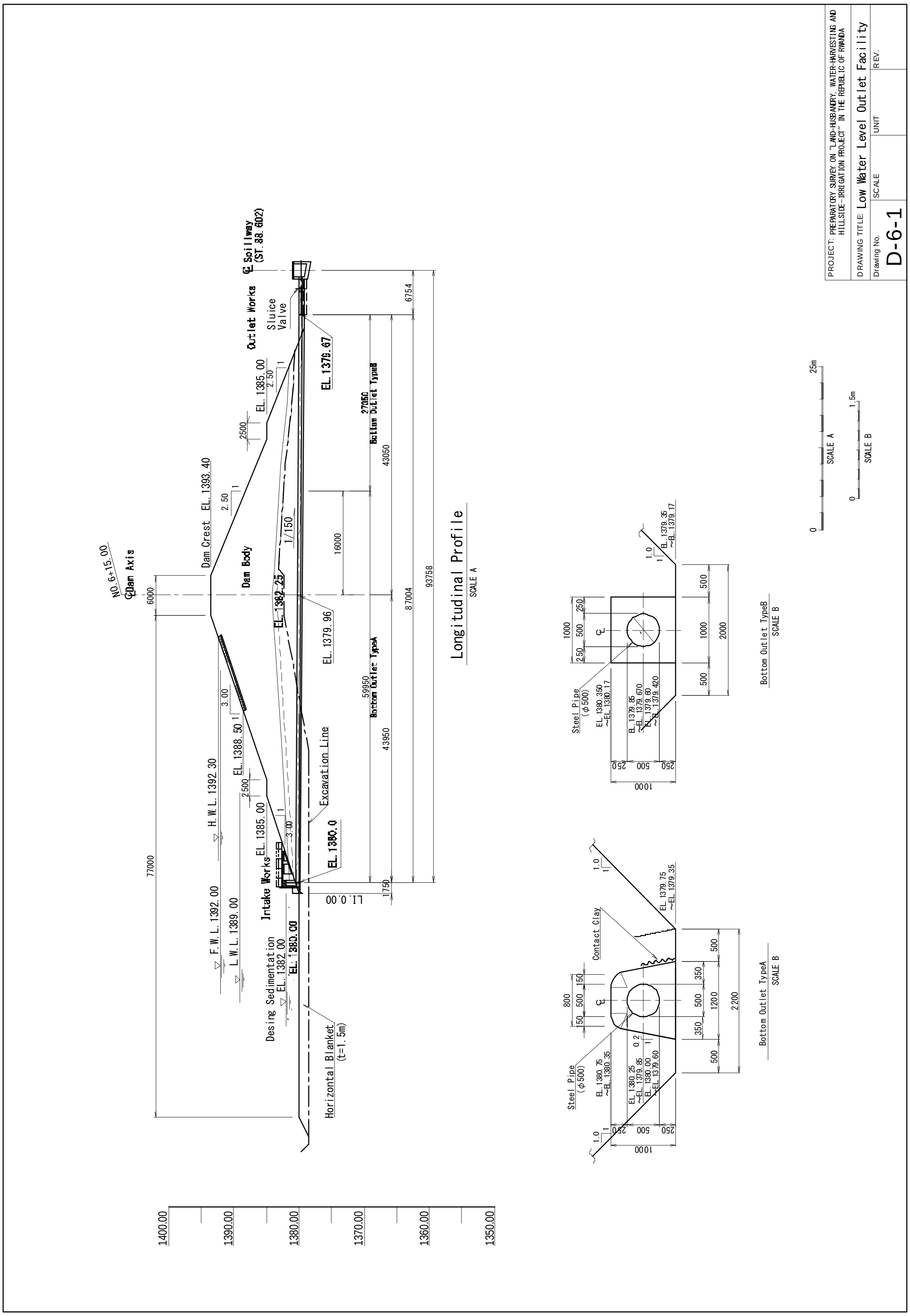

Typical section of Dam Body
Typical Section of Slope Blanket
Dam Crest EL.1393.40
Slope Protection Planting
Stone Pitching(t=0.5m)
Drainage Ditch
Catch-Weir embankment
Leakage Observation Pipe
Toe Drain
Drain
Freeboard
Riprap
Dam Body
Excavation Line EL.1378.50
Ground Line
H.W.L.1392.30
F.W.L.1392.00
L.W.L.1389.00
Horizontal Blanket (t=1.5m)
EL.1380.00
EL.1386.00
EL.1385.00
EL.1380.70
EL.1388.50
EL.1381.50
EL.1378.50
2.50
3.00
2.40
4.00
1.00
16000
31000
83000
77000
6000
4000
2500
3500
3000
5.00
NO.7+0.00
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Typical Section of Dam Body
Drawing No. D-3
SCALE
UNIT
REV.
0
20m
SCALE

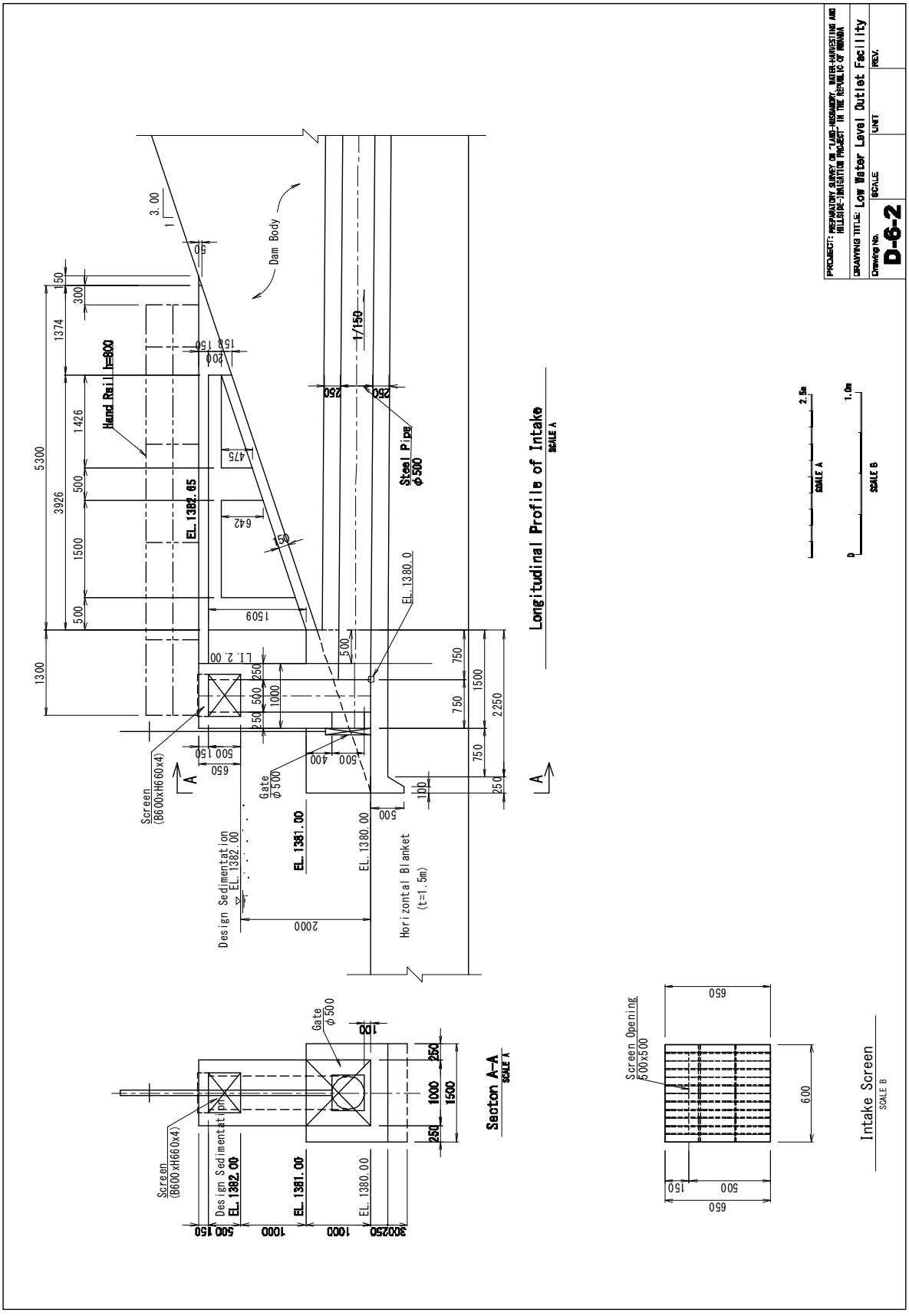

Spillway
Intake Pipe
Bottom Outlet
Extra Banking Changing Section
Maximum Extra Banking Section(EL. 1393.70)
Extra Banking Changing Section
H.W.L. 1392.30
L.W.L. 1389.00
F.W.L. 1392.00
Dam Crest EL. 1393.40
1400.00
1390.00
1380.00
1370.00
1360.00
1350.00
Station No.
Distance Between (m)
Accumulated Distance (m)
Current Ground (EL)
Excavation Elevation (EL)
Dam Crest (EL)
Extra Banking Height (m)
NO.0 0.000 0.000 1395.4
+12500 12.500 12.500 1394.1 1393.40 1393.40 0.00
NO.1 10.000 20.000 1393.1 1392.30 1393.43 0.03
+10000 10.000 30.000 1390.16 1390.90 1393.48 0.08
NO.2 10.000 40.000 1390.5 1389.50 1393.52 0.12
NO.3 20.000 60.000 1388.1 1386.60 1393.61 0.21
+10000 10.000 70.000 1384.9 1383.70 1393.66 0.26
NO.4 10.000 80.000 1381.7 1380.80 1393.70 0.30
+8.000 8.000 88.000 1380.4 1378.50 1393.70 0.30
NO.5 12.000 100.000 1380.4 1378.50 1393.70 0.30
+10000 10.000 110.000 1380.5 1378.50 1393.70 0.30
NO.6 10.000 120.000 1382.0 1380.00 1393.70 0.30
+15000 15.000 135.000 1384.0 1382.25 1393.63 0.23
NO.7 5.000 140.000 1384.6 1383.00 1393.60 0.20
NO.8 20.000 160.000 1386.8 1386.00 1393.50 0.10
+10000 10.000 170.000 1388.9 1387.80 1393.45 0.05
+16500 6.500 176.500 1390.8 1390.10 1393.42 0.02
NO.9 3.500 180.000 1392.2 1390.10 1393.40 0.00
+10000 1.000 181.000 1392.7 1390.10
PROJECT: PREPARATORY SURVEY ON "LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Longitudinal Profile of Dam Body
Drawing No. D-4
SC-ALE
UNIT
REV.
Longitudinal Profile
0
25m
SCALE

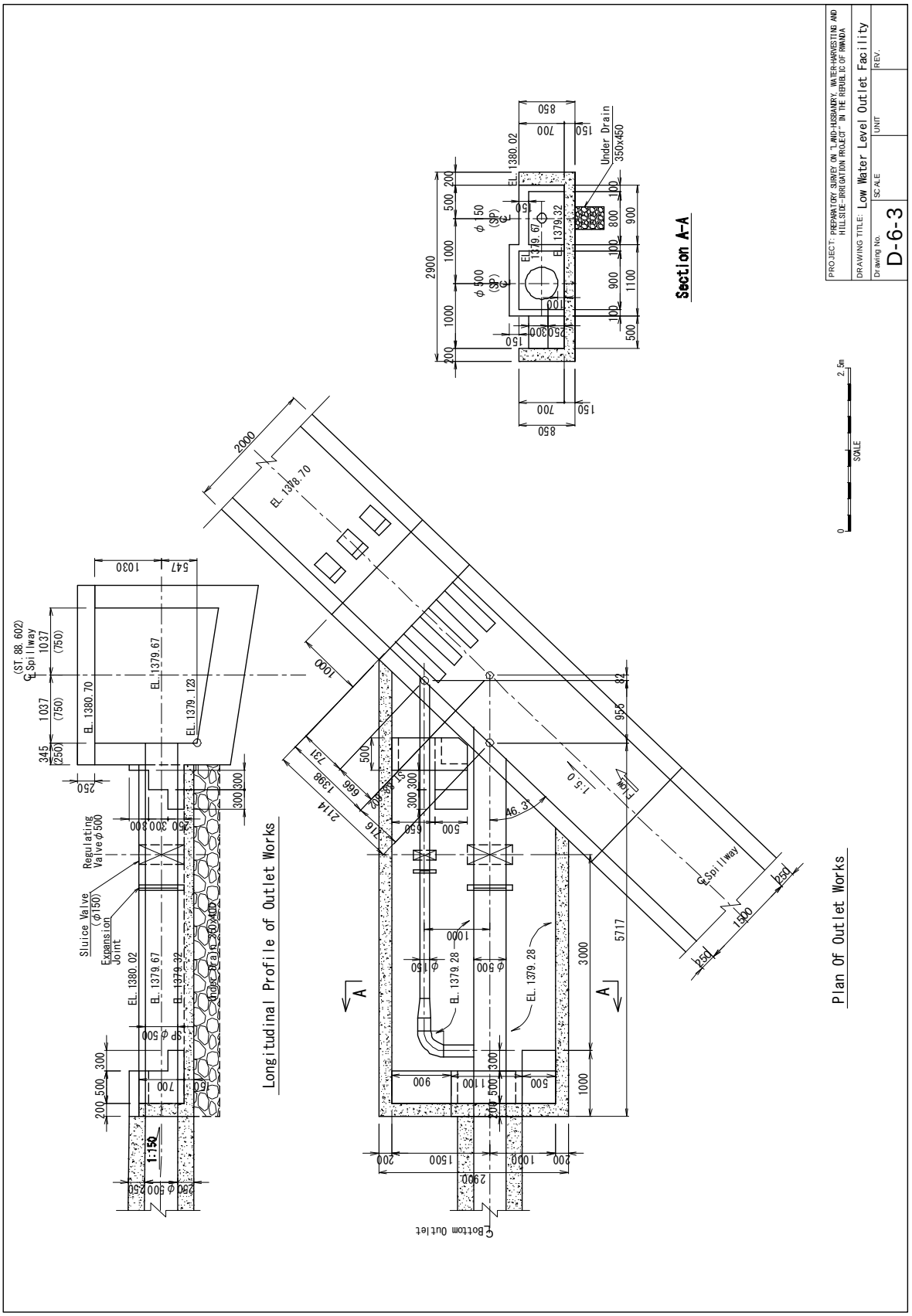

Plan of Spillway
Longitudinal Profile of Spillway
PROJECT: PREPARATORY SERVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan & Section of Spillway
Drawing No. D-5-1
SCALE
UNIT
REV.
Intake Works
Hand Rail
Side Ditch
Bottom Outlet φ500(SP)
Low Water Level Outlet Facility
Canal on Paddy Field
Energy Dissipator
Contra. jt.
Exp. jt.
Note: Contra. jt. :Contraction Joint
Exp. jt. :Expansion Joint
Dam Axis
SCALE

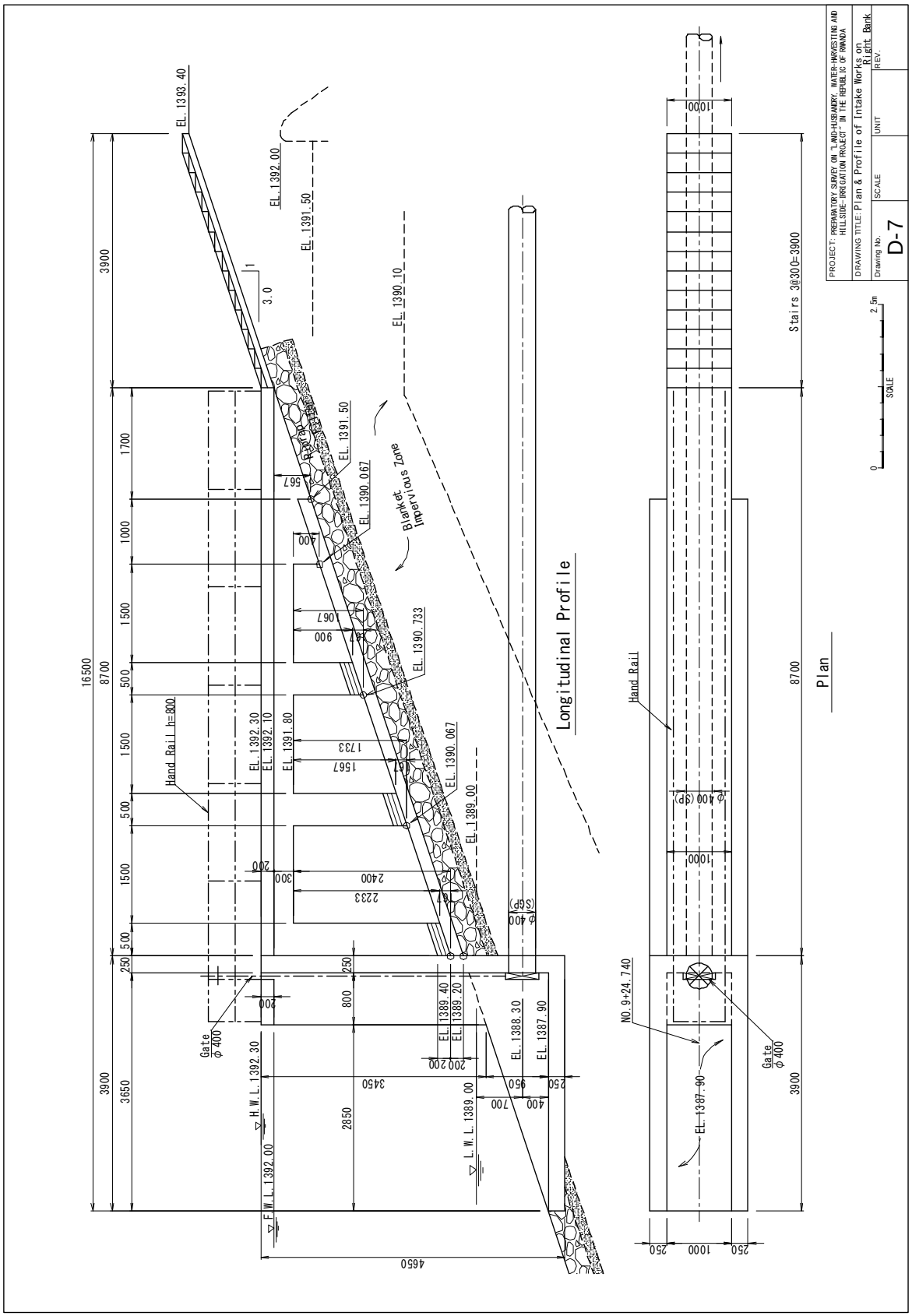

PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
Plan & Section of Spillway
Drawing No. D-5-2
SCALE
UNIT
REV.
SCALE
0
5m
Front Elevation of Side Canal
ST. 10, 250 (+) ~ ST. 24, 000
ST. 0, 000 (+) ~ ST. 10, 000 (-)
(Cross Section of Side Canal)
ST. 10, 000 (+)
ST. 40, 000
Side Ditch
Intake Pipe φ 400
Weep Hole
Side Drain
Contact Clay
(t=5cm)
Impervious Materials
Overflow Weir Crest EL. 1392.00
Inflow Bed EL. 1391.50
Side Canal Bed EL. 1390.90
Sidewall Crest EL. 1393.40 (Dam Crest)
Dam Body
Hand Rail
Dowel Bar
Spillway
Division Wall t=250
Under Drain
Riprap
Filter
Blanket Zone

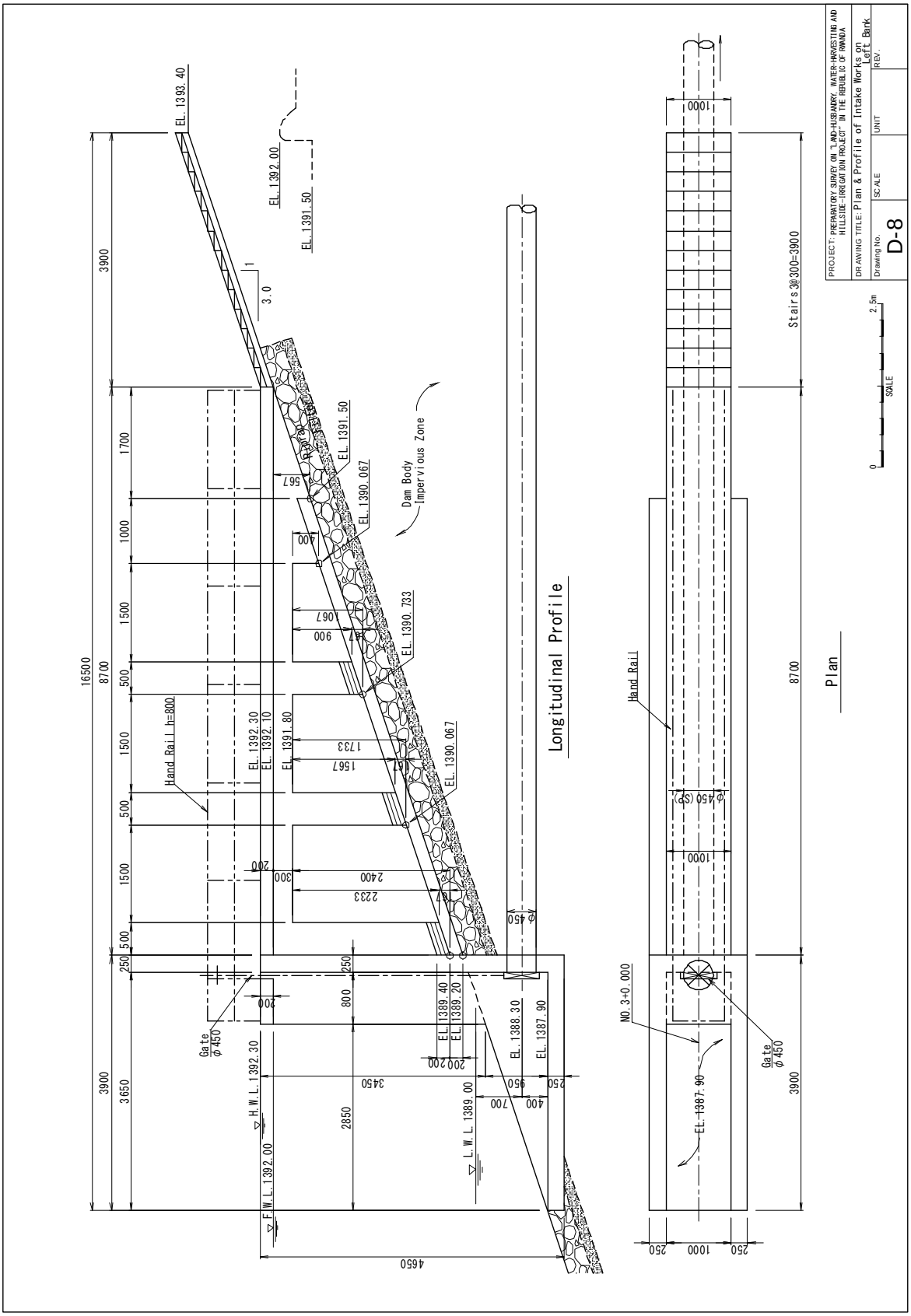

PROJECT PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE Plan & Section of Spillway
Drawing No. D-5-3
SCALE S=1:50
UNIT
REV.
Section B-B
Section A-A
Plan
Longitudinal Profile
Flow
End Sill
Baffle Piers
Chute Block
Discharge Meter
Sluice Valve (φ150)
Low Water Level Outlet
Sluice Valve (φ300)
Bottom Outlet
Under Drain
Weep Hole φ50
5000 (Energy Dissipator)
SCALE

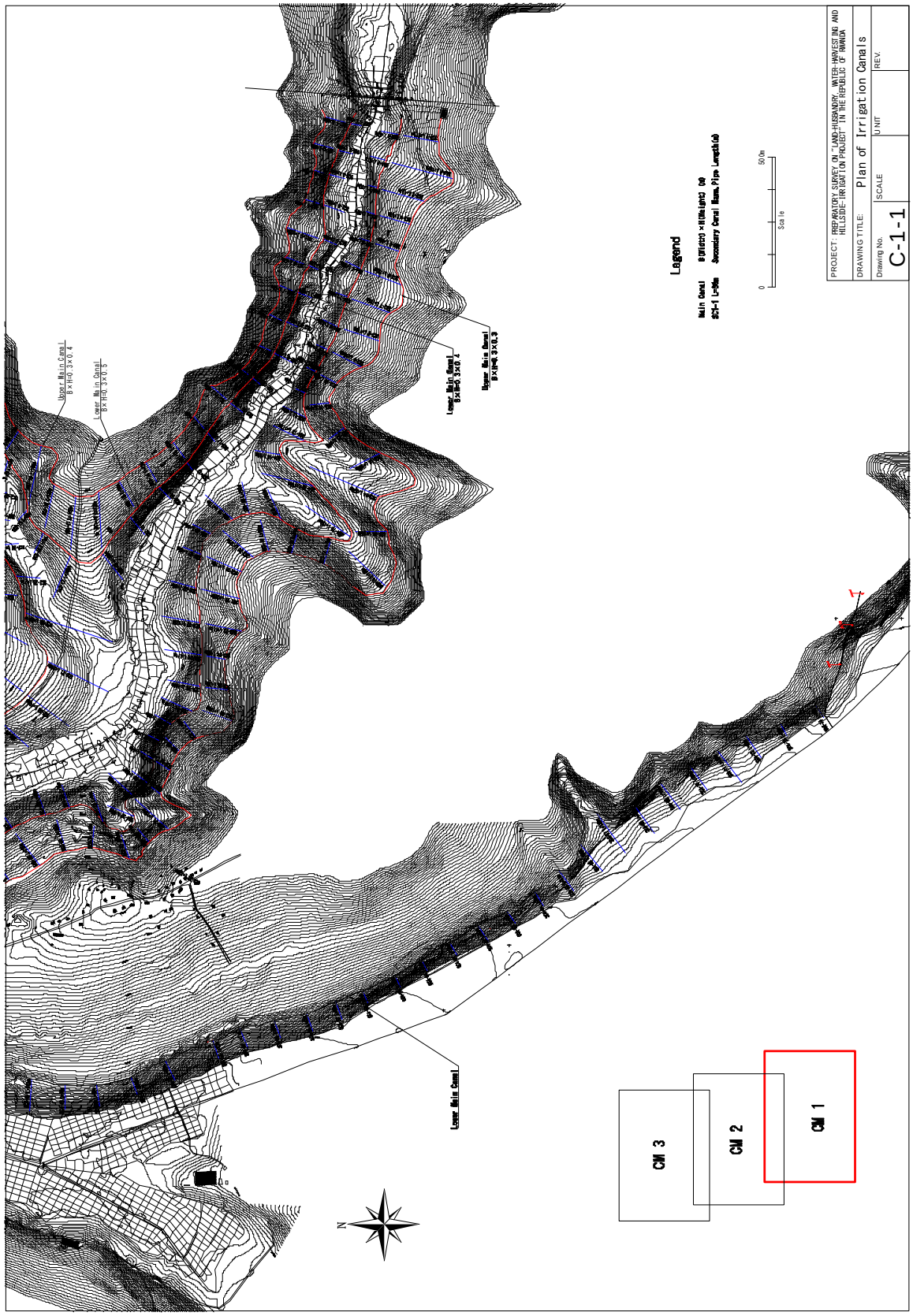

PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Low Water Level Outlet Facility
Drawing No. D-6-1
SCALE
UNIT
REV.
Longitudinal Profile
SCALE A
Bottom Outlet TypeA
SCALE B
Bottom Outlet TypeB
SCALE B
Dam Crest EL. 1393.40
Dam Axis
Dam Body
H.W.L. 1392.30
F.W.L. 1392.00
L.W.L. 1389.00
Intake Works
Outlet Works
Sluice Valve
Spillway (ST.88.602)
Excavation Line
Horizontal Blanket (t=1.5m)
Desing Sedimentation EL. 1382.00
Steel Pipe (φ500)
Contact Clay
SCALE A
SCALE B

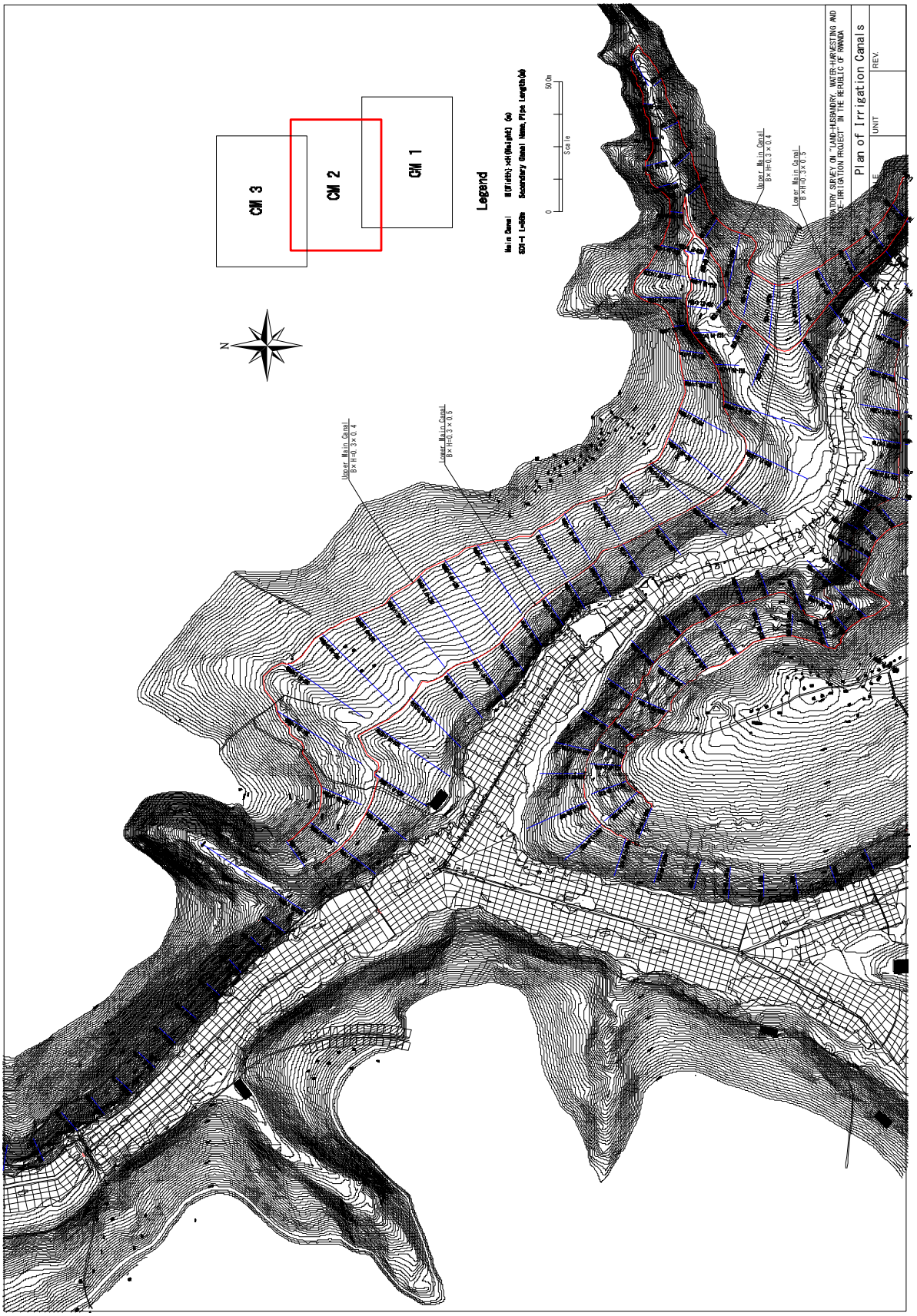

PROJECT: PREPARATORY SURVEY ON CLIMATE-RESILIENT WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Low Water Level Outlet Facility
Drawing No. D-6-2
SCALE
UNIT
REV.
Longitudinal Profile of Intake
SCALE A
Section A-A
SCALE A
Intake Screen
SCALE B
Dam Body
Hand Rail h=600
Steel Pipe φ500
Screen (B600xH660x4)
Gate φ500
Design Sedimentation
Horizontal Blanket (t=1.5m)
EL. 1382.65
EL. 1382.00
EL. 1381.00
EL. 1380.00
EL. 1380.0
Screen Opening 500x500

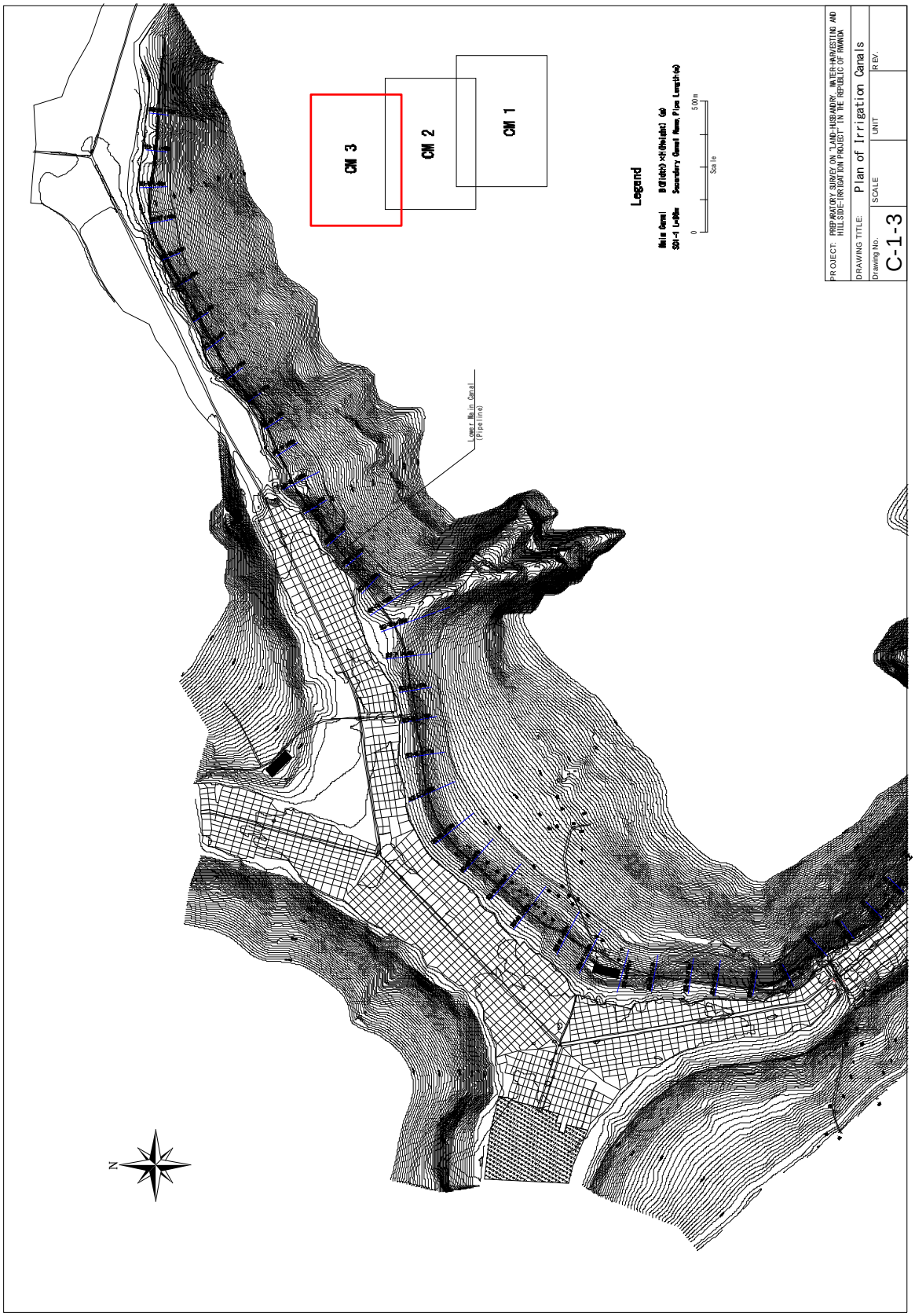

PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Low Water Level Outlet Facility
Drawing No. D-6-3
SCALE
UNIT
REV.
Section A-A
Under Drain 350x450
Longitudinal Profile of Outlet Works
Plan Of Outlet Works
Regulating Valve φ500
Sluice Valve (φ150)
Expansion Joint
Under Drain 350x400
Bottom Outlet
EL. 1380.70
EL. 1379.67
EL. 1379.123
EL. 1380.02
EL. 1379.32
EL. 1379.28
EL. 1378.70
(ST. 88.602) ℄ Spillway
℄ Spillway
1:150
SCALE
0
2.5m

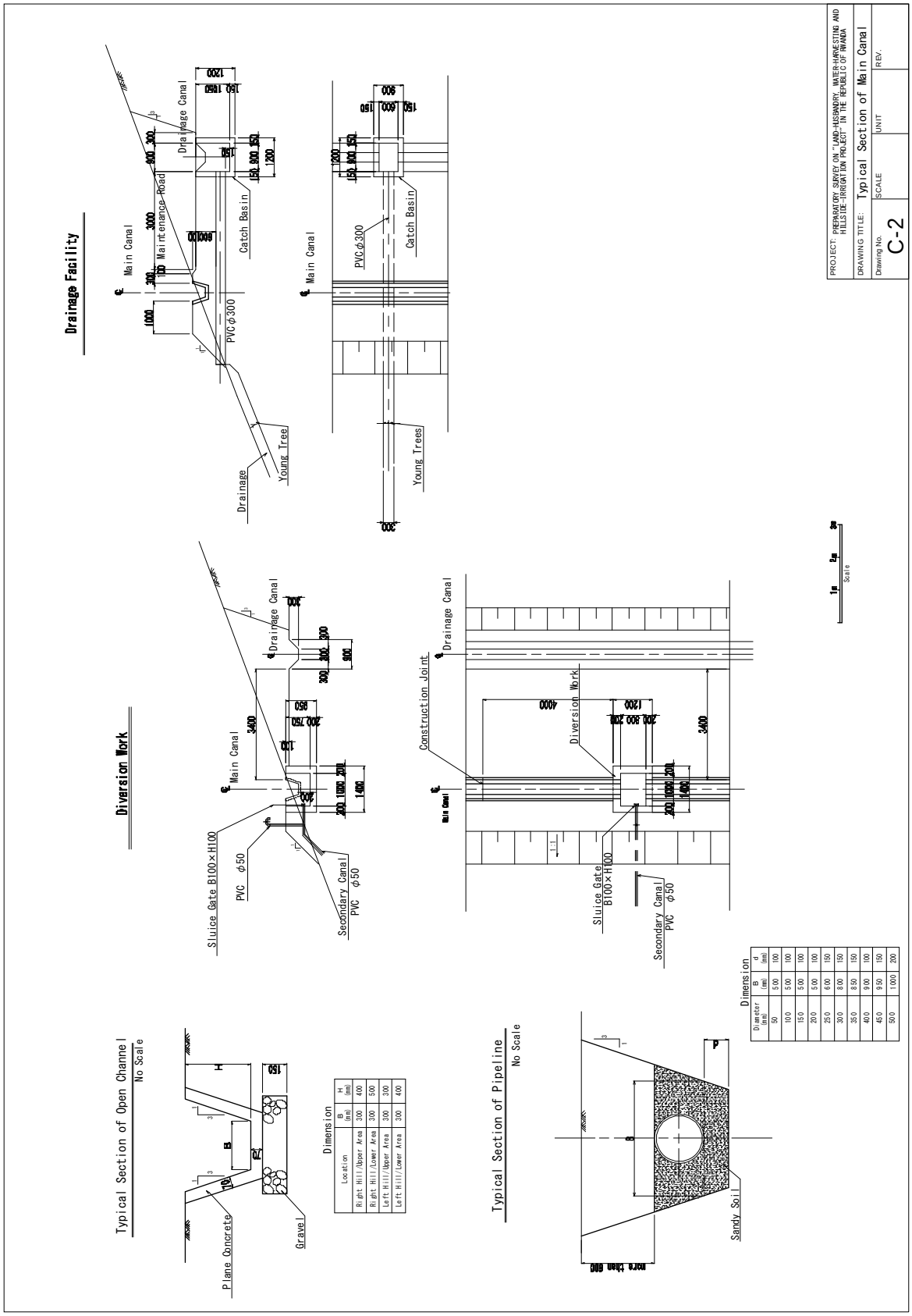

PROJECT: PREPARATORY SURVEY ON "LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan & Profile of Intake Works on Right Bank
Drawing No. D-7
SCALE
UNIT
REV.
Longitudinal Profile
Plan
Blanket Impervious Zone
Hand Rail h=800
Hand Rail
Gate φ400
Stairs 38@300=3900
EL. 1393.40
EL. 1392.00
EL. 1391.50
EL. 1390.10
EL. 1390.067
EL. 1390.733
EL. 1389.00
EL. 1392.30
EL. 1392.10
EL. 1391.80
EL. 1389.40
EL. 1389.20
EL. 1388.30
EL. 1387.90
H.W.L. 1392.30
L.W.L. 1389.00
F.W.L. 1392.00
NO.9+24.740
3.0
1
SCALE
0
2.5m


PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan & Profile of Intake Works on Left Bank
Drawing No. D-8
SCALE
UNIT
REV.
SCALE 0 2.5m
Longitudinal Profile
Plan
Dam Body Impervious Zone
Hand Rail h=800
Hand Rail
Gate φ450
Stairs 30@300=3900
EL. 1393.40
EL. 1392.00
EL. 1391.50
EL. 1390.067
EL. 1390.733
EL. 1392.30
EL. 1392.10
EL. 1391.80
EL. 1389.40
EL. 1389.20
EL. 1388.30
EL. 1387.90
H.W.L. 1392.30
L.W.L. 1389.00
F.W.L. 1392.00
NO.3+0.000
16500
8700
3900
3650
4650
3450
2850
2400
2233
1733
1567
1067
900
800
700
567
400
300
250
200
1000


Legend
Main Canal
SCH-1 L=4km
Secondary Canal Name, Pipe Length(m)
0
50m
Scale
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan of Irrigation Canals
Drawing No. C-1-1
SCALE
UNIT
REV.
Upper Main Canal
Lower Main Canal
CM 1
CM 2
CM 3
N

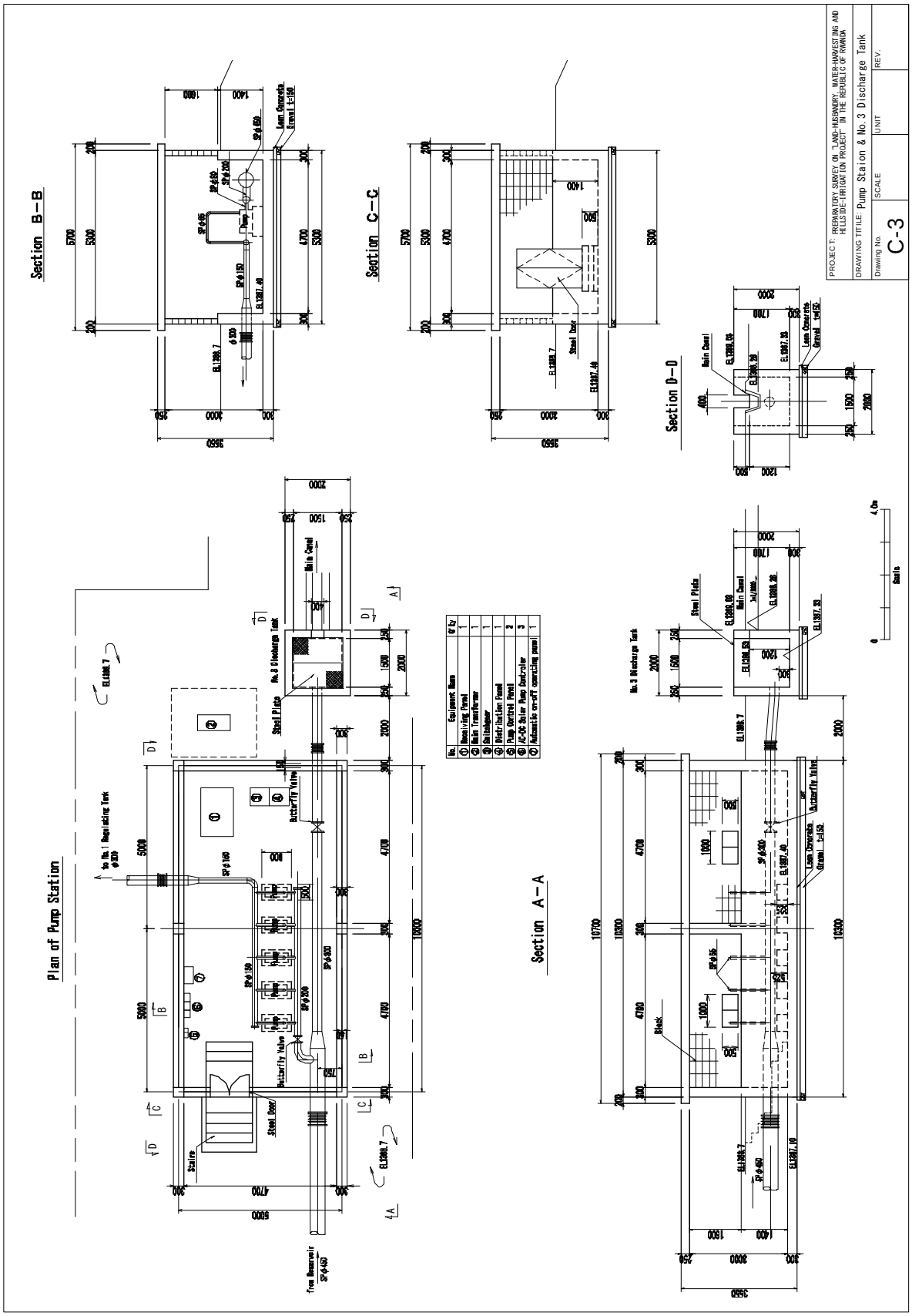

CM 3
CM 2
CM 1
Legend
Upper Main Canal
B×H=0.3×0.4
Lower Main Canal
B×H=0.3×0.5
Plan of Irrigation Canals
UNIT
REV.

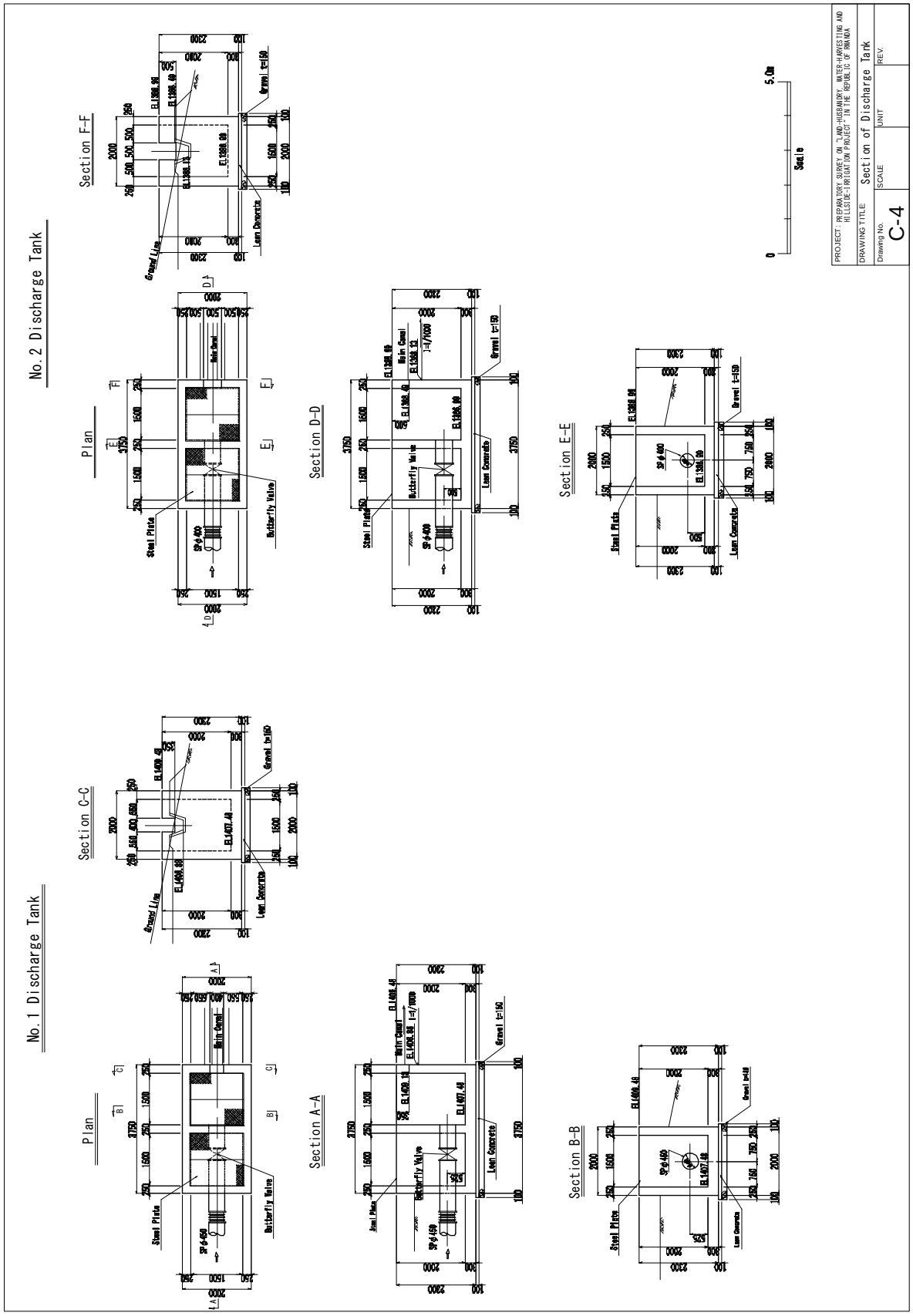

CM 3
CM 2
CM 1
Legend
Scale
N
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan of Irrigation Canals
SCALE
UNIT
REV.
Drawing No.
C-1-3

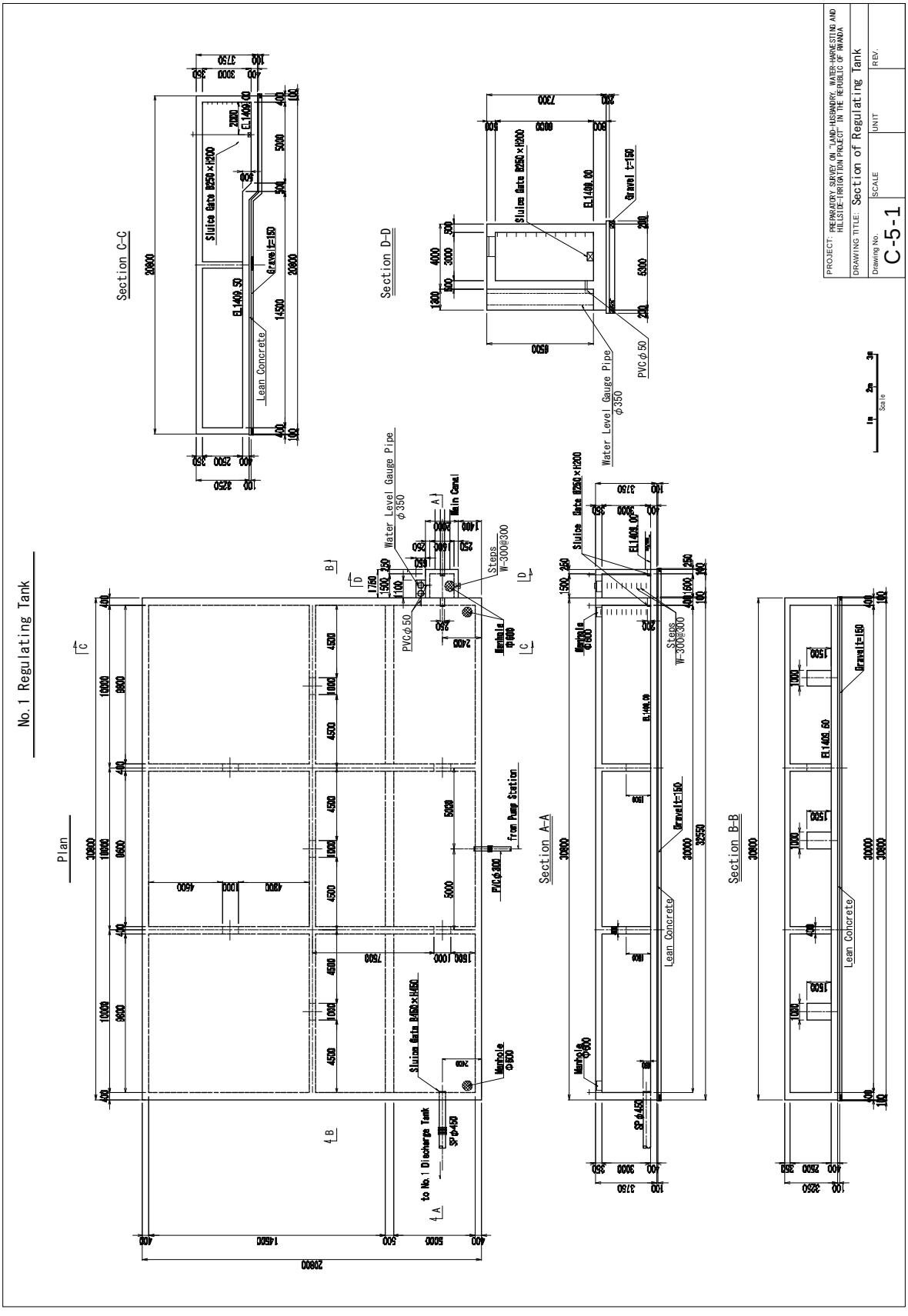


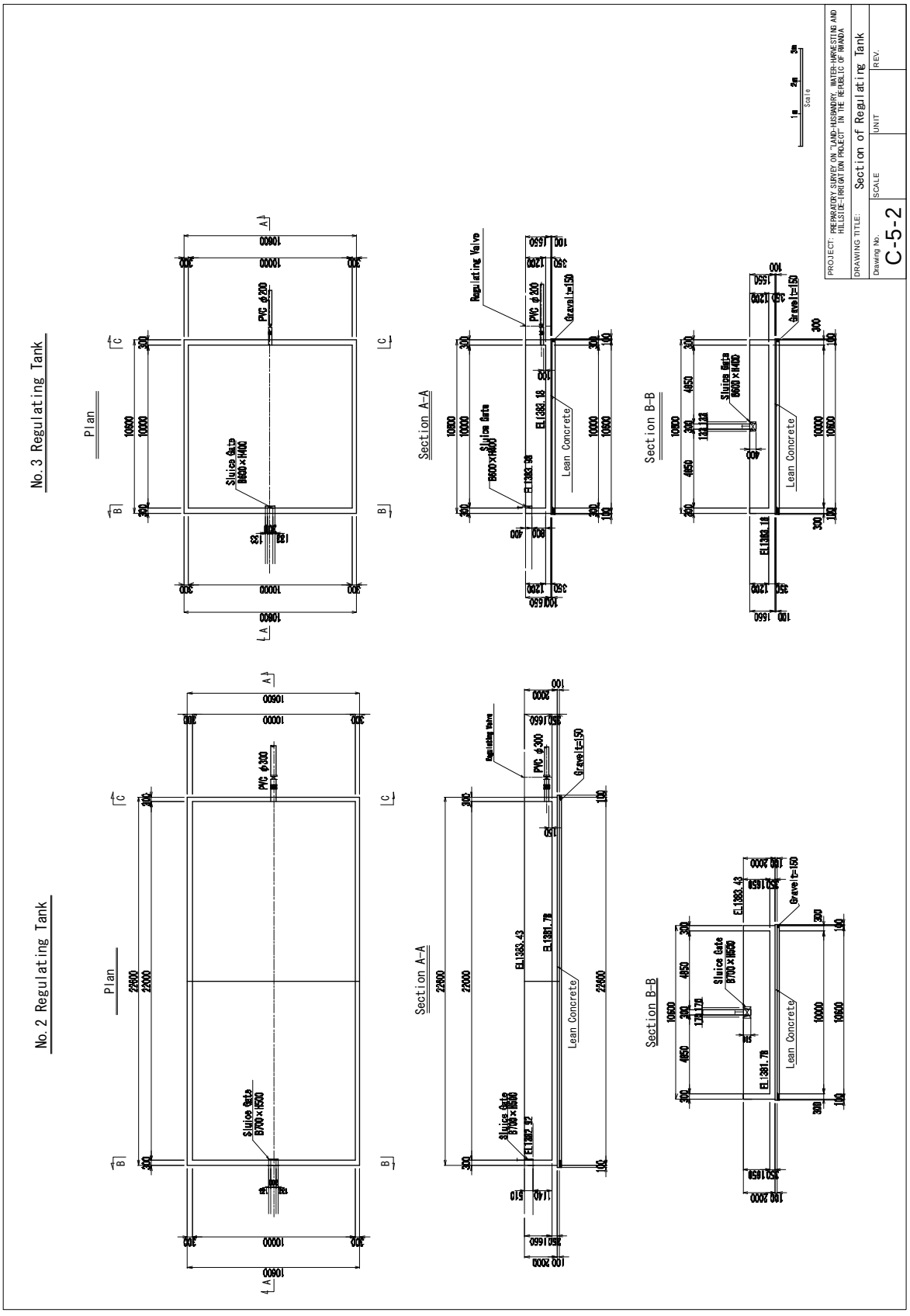
Location	B (mm)	H (mm)
Right Hill/Upper Area	300	400
Right Hill/Lower Area	300	500
Left Hill/Upper Area	300	300
Left Hill/Lower Area	300	400

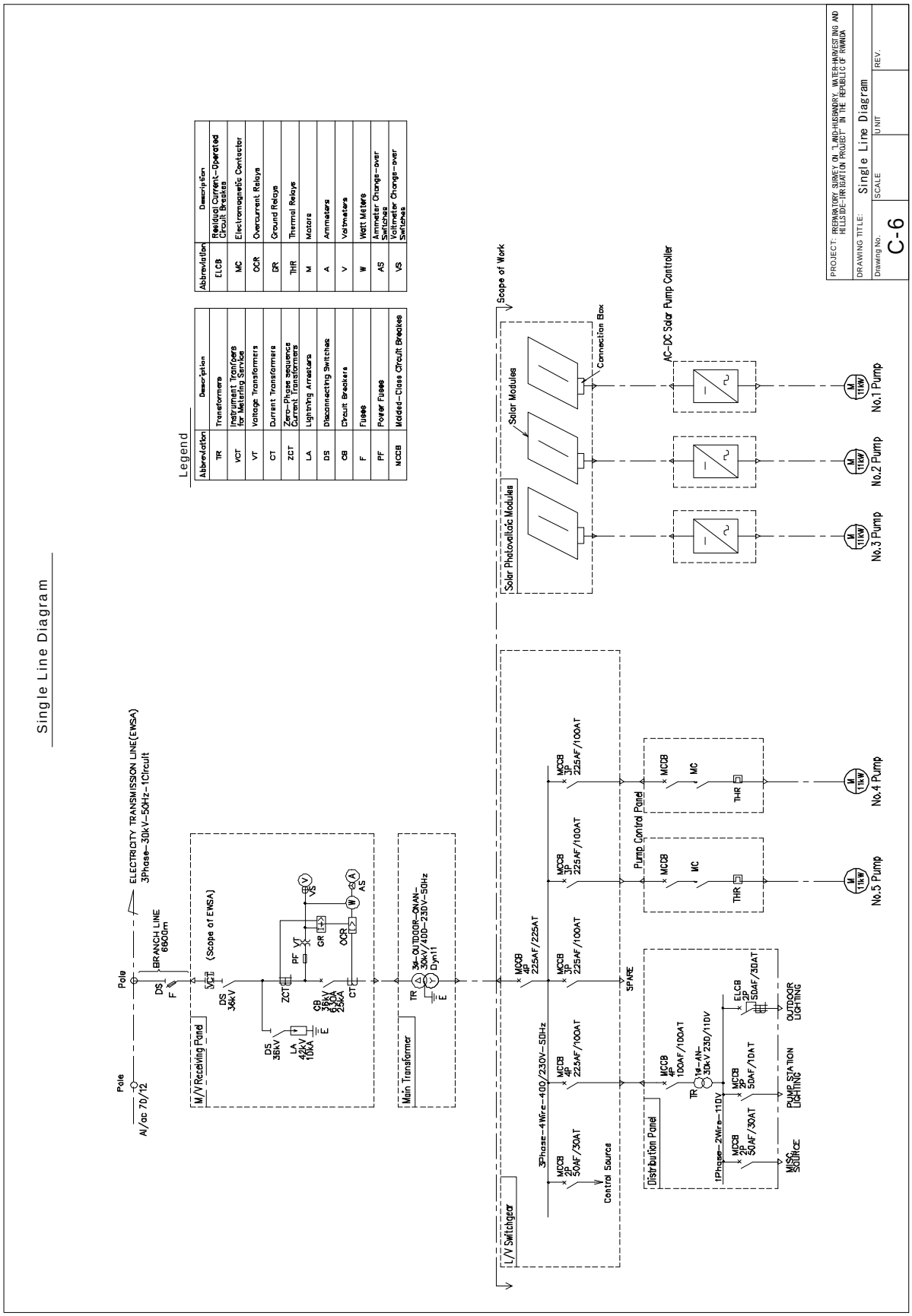
Diameter (mm)	B (mm)	H (mm)
50	5.00	100
10.0	5.00	100
15.0	5.00	100
20.0	5.00	100
25.0	6.00	150
30.0	8.00	150
35.0	8.50	150
40.0	9.00	100
45.0	9.50	150
50.0	10.00	200

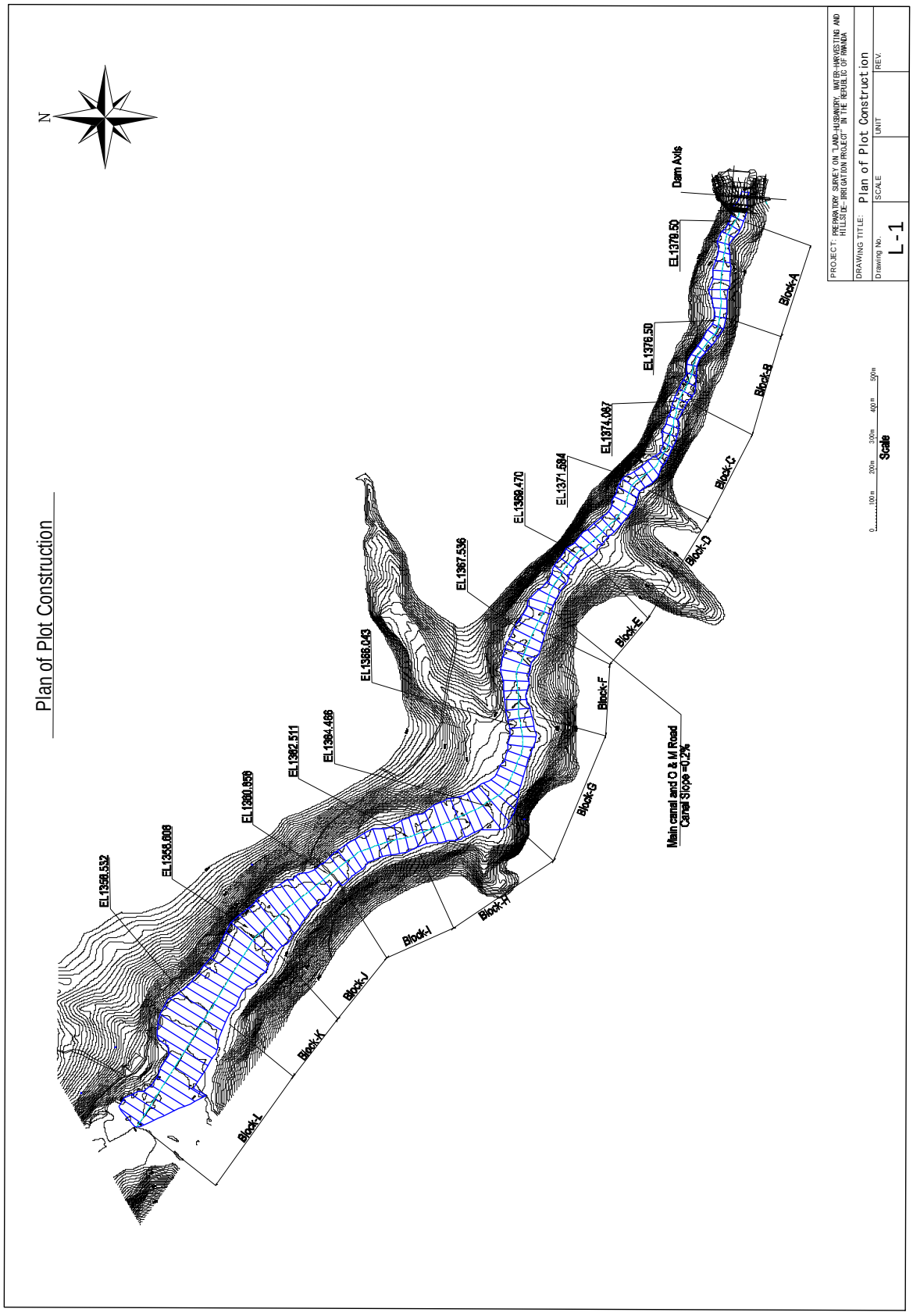

Section B-B
Section C-C
Section D-D
Section A-A
Plan of Pump Station
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Pump Staion & No.3 Discharge Tank
Drawing No. C-3
SCALE
UNIT
REV.
No. Equipment Name Q'ty
① Receiving Panel 1
② Main Transformer 1
③ Distributor 1
④ Distribution Panel 1
⑤ Pump Control Panel 2
⑥ AC-DC Solar Pump Controller 3
⑦ Automatic on-off connecting panel 1
Main Canal
Steel Plate
Steel Door
Stairs
Butterfly Valve
Block
Basis
No.3 Discharge Tank
No.1 Receiving Tank
From Reservoir


No. 2 Discharge Tank
Section F-F
Plan
Section D-D
Section E-E
No. 1 Discharge Tank
Section C-C
Plan
Section A-A
Section B-B
Steel Plate
Butterfly Valve
Main Canal
Gravel t=150
Lean Concrete
Gravel Line
Scale
0
5.0m
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Section of Discharge Tank
Drawing No. C-4
SCALE
UNIT
REV.


No. 1 Regulating Tank
Plan
Section C-C
Section D-D
Section A-A
Section B-B
Water Level Gauge Pipe φ350
Steps W-300@300
Manhole Φ600
Sluice Gate B250×H200
Gravel t=150
Lean Concrete
PVC φ50
PVC φ300
SP φ450
from Pump Station
to No. 1 Discharge Tank
Main Canal
Sluice Gate B450×H450
EL.1409.50
EL.1408.00
EL.1406.60
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Section of Regulating Tank
Drawing No. C-5-1
SCALE
UNIT
REV.

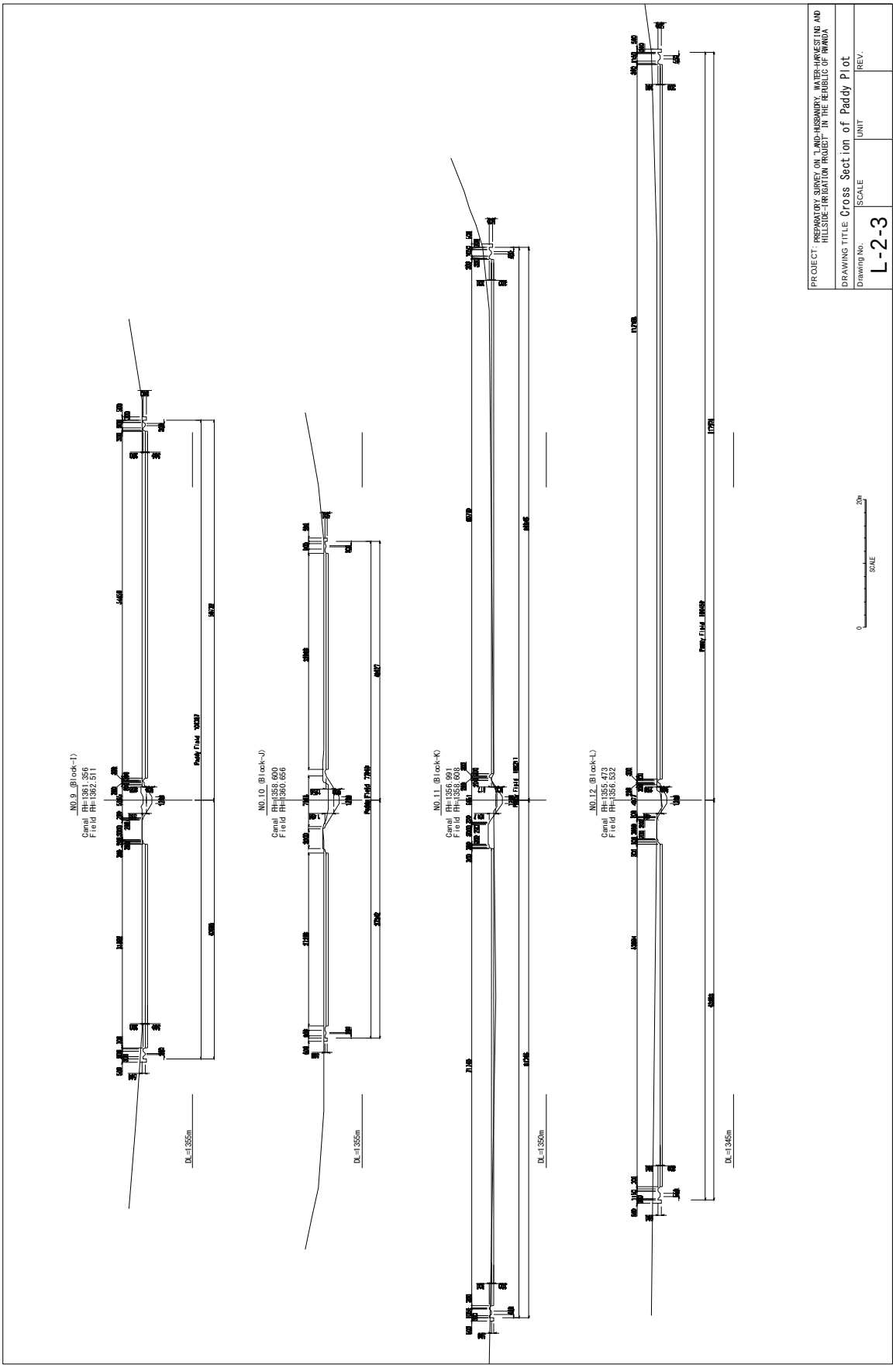

No.3 Regulating Tank
Plan
Section A-A
Section B-B
No.2 Regulating Tank
Plan
Section A-A
Section B-B
Lean Concrete
Gravel t=150
Regulating Valve
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Section of Regulating Tank
Drawing No. C-5-2
SCALE
UNIT
REV.


Single Line Diagram
Legend
Abbreviation | Description
TR | Transformers
VCT | Instrument Tranfoers for Metering Service
VT | Voltage Transformers
CT | Current Transformers
ZCT | Zero-Phase sequence Current Transformers
LA | Lightning Arresters
DS | Disconnecting Switches
CB | Circuit Breakers
F | Fuses
PF | Power Fuses
MCCB | Molded-Class Circuit Breakes
Abbreviation | Description
ELCB | Residual Current-Operated Circuit Breakes
MC | Electromagnetic Contactor
OCR | Overcurrent Relays
GR | Ground Relays
THR | Thermal Relays
M | Motors
A | Ammeters
V | Voltmeters
W | Watt Meters
AS | Ammeter Change-over Switches
VS | Voltmeter Change-over Switches
ELECTRICITY TRANSMISSION LINE(EWSA)
3Phase-30kV-50Hz-1Circuit
Pole
A/ac 70/12
BRANCH LINE
6600m
DS
F
M/V Receiving Panel
(Scope of EWSA)
DS
36kV
VCT
ZCT
PF
GR
OCR
CT
VS
AS
DS
36kV
LA
42kV
10kA
E
CB
36kV
630A
25kA
E
Main Transformer
TR
3ϕ-OUTDOOR-ONAN-
30kV/400-230V-50Hz
Dyn11
E
L/V Switchgear
3Phase-4Wire-400/230V-50Hz
MCCB
4P
225AF/225AT
MCCB
4P
225AF/100AT
MCCB
3P
225AF/100AT
SPARE
Control Source
MCCB
2P
50AF/30AT
Distribution Panel
MCCB
4P
100AF/100AT
TR
1ϕ-4W-
3kV 230/110V
1Phase-2Wire-110V
MCCB
2P
50AF/30AT
MCCB
2P
50AF/10AT
ELCB
2P
50AF/30AT
MISC.
SOURCE
PUMP STATION
LIGHTING
OUTDOOR
LIGHTING
Pump Control Panel
MCCB
MC
THR
MCCB
MC
THR
Scope of Work
Solar Photovoltaic Modules
Solar Modules
Connection Box
AC-DC Solar Pump Controller
No.1 Pump
No.2 Pump
No.3 Pump
No.4 Pump
No.5 Pump
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Single Line Diagram
Drawing No. C-6
SCALE
UNIT
REV.


Plan of Plot Construction
N
Dam Axis
EL.1378.50
EL.1376.50
EL.1374.087
EL.1371.584
EL.1369.470
EL.1367.536
EL.1366.043
EL.1364.466
EL.1362.511
EL.1360.559
EL.1358.606
EL.1358.532
Block-A
Block-B
Block-C
Block-D
Block-E
Block-F
Block-G
Block-H
Block-I
Block-J
Block-K
Block-L
Main canal and C & M Road
Canal Slope =0.2%
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Plan of Plot Construction
Drawing No. L-1
SCALE
UNIT
REV.
Scale
0 100m 200m 300m 400m 500m


PROJECT: PREPARATORY SURVEY ON "LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Cross Section of Paddy Plot
SCALE
UNIT
REV.
Drawing No. L-2-1
NO.1 (Block-A)
Canal FH=1378.088
Field FH=1379.500
NO.2 (Block-B)
Canal FH=1375.396
Field FH=1376.500
NO.3 (Block-C)
Canal FH=1372.693
Field FH=1374.087
NO.4 (Block-D)
Canal FH=1370.464
Field FH=1371.584
DL=1370m
0
20m
SCALE


NO.5 (Block-E)
Canal FH=1368.294
Filed FH=1369.470
NO.6 (Block-F)
Canal FH=1366.437
Field FH=1367.536
NO.7 (Block-G)
Canal FH=1364.768
Field FH=1366.043
NO.8 (Block-H)
Canal FH=1363.306
Field FH=1364.466
DL=1360m
DL=1360m
DL=1360m
DL=1355m
PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Cross Section of Paddy Plot
Drawing No. L-2-2
SCALE
UNIT
REV.
0
20m
SCALE


PROJECT: PREPARATORY SURVEY ON "LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT" IN THE REPUBLIC OF RWANDA
DRAWING TITLE: Cross Section of Paddy Plot
Drawing No.: L-2-3
SCALE
UNIT
REV.
NO.9 (Block-I)
Canal FH=1361.356
Field FH=1362.511
NO.10 (Block-J)
Canal FH=1358.600
Field FH=1360.656
NO.11 (Block-K)
Canal FH=1356.991
Field FH=1358.609
NO.12 (Block-L)
Canal FH=1355.472
Field FH=1356.532
DL=1355m
DL=1355m
DL=1350m
DL=1345m
0
20m
SCALE

2-2-4 Implementation Plan

2-2-4-1 Implementation Policy

1) General

The Project activity will proceed to implementation stage after exchange of the Exchange of Note (E/N) on approval of Japan Government to outline design. Contract form of Project implementation is a lump-sum contract system. The Project components are construction of dam, pump, main canal (open, pipeline), secondary canal, on-farm irrigation facilities, and plot construction of existing paddy field at Ngoma22 site crossing two sectors of Remera and Rurenge in Ngoma District.

2) Availability of Local Contractor

Rwanda has been a member of East African Community (EAC) since 2007. From that time, logistics and human interaction have become active. Particularly, various material and technology for construction have brought from Kenya and then the local contractors have improved construction experiences and capability and then they have piled up performance of civil construction works. Based on the background mentioned above, therefore, the Project plans to utilize effectively the local contractors stationing in Kigali. Some of them have already has experiences to construct irrigation facilities as the Project plans.

3) Implementation Agency of Rwanda side

Implementation agency of Rwanda side of the Project is MINAGRI, which has responsibility for promotion and implementation of LWH project.

2-2-4-2 Implementation Condition

1) Matters to be considered on construction

The type of dam is planned as the homogeneous embankment dam of 14.9 m height. Borrow-pit and dump-pit of soil will be placed in submerged area created by dam construction. Banking material will be embanked while controlling the soil moisture by spraying. Regarding heavy equipments for banking work of dam body, bulldozer of 21 ton class and vibratory roller of 10 ton class will be used for spreading and tamping to make the finished thickness 20 cm.

Both the solar power and the commercial power will be used for operation of pumping system. The commercial power (three faces) is planned to extend from 6.6 km away from the construction site. Taking account of delay of extension work of commercial power and also power cut, the power generator will be installed as backstop.

The main canals, which consist of open canal running in upstream of benefit area and pipeline system laying underground in downstream range of Project area, are aligned along the contour line of hillside ground. Construction of main canal is to be started from open canal covering lower elevation area (gravity irrigation area) of either bank on upstream benefited area. After then, the construction work will go to higher elevation area (pump irrigation area) of both bank on upstream area to be benefited. The pipeline parts will be dealt after completion of open canal construction.

The secondary canals of 27 km, which are PVC pipes, are to be laid at 100 m intervals along the main canal. On-farm irrigation system after abstraction of irrigation water from hydrant set along the secondary canals will be carried out by using hose and watering can in order to practice water-saving irrigation. The construction of secondary canal is to be executed by only manpower because it is difficult for heavy equipment to enter the construction place.

As of plot construction (re-plotting) of existing paddy field, rehabilitation work of irrigation and

drainage canal and O&M road construction will be borne by Japan side, while leveling work of paddy plots is to be shared by both side of Japan (2 ha) and Rwanda (30 ha) after implementation of technical transfer by using equipments like tractor, laser leveler, etc. to be provided with Rwanda side after completion of all the construction work.

2) Matters to be considered on procurement

Because the residents living around the construction area will be forced to break farming during construction period, the Project plans to employ them as worker. While skilled labor will be hired from Ngoma and/or Kirehe District, engineers is to be recruited from Kigali due to difficulty to procure them in Ngoma area.

2-2-4-3 Scope of Works

Construction works are shared by Japan and Rwanda as the table below.

Table 2.2.4.1 Construction, Procurement and Installation Plan

Facilities	Japan side	Rwanda side
Whole	- Gravel pavement of approach road (L=2.2km) - Construction road	- Land acquisition - Removal of obstacles in the site and leveling - Preparing temporary yard
Dam	- Dam, Intake, Spill way	
Pump station	- Pump station, Regulating tank (No.1), Conduit pipe - Pump equipment, Electric equipment, Solar panel - Extension of grid line (Outsourcing to EWSA) - Safety fence of Regulating tank (No.1) with solar panel	
Main canal, 2ndary canal, On farm facilities	- Main canal (open canal, pipe line), Regulating tank (No.2, No.3), 2ndary canal, Hydrant	- Terracing - Safety fence of regulating tank (No.2, No.3) and Discharge tank (No.1, No.2 and No.3)
Plot construction of existing paddy filled	- Irrigation and drainage canal, O&M road, diversion box - Land leveling of paddy plots as technical transfer (2 ha)	- Land leveling of paddy plots (28 ha)

2-2-4-4 Consultant Supervision

1) Primary tasks and matters to be considered

In performing the supervision works under the Project, the following shall be paid with due attention.

(1) Primary tasks

- To fully grasp the contents and processes of outline design and detailed design
- To understand the framework and arrangements of the grant aid program by GOJ
- To grasp the contents of E/N and G/A signed by and between GOJ and GOS
- To cooperate with MINAGRI for smooth implementation of the Project
- To reconfirm the items agreed in the Outline Design stage to be covered by Government of Rwanda.

(2) Matters to be considered in construction supervision

a) Construction schedule

- Confirmation shall be made on the procedures for custom clearance and tax exemption required for importing of equipment/materials under the Project and due consultation shall be made with MINGRI.
- Banking work of dam main body shall be mainly carried out in dry season from June to September. Particularly, in April earth works are not executed due to heavy rain.

b) Quality control

- Banking work of dam needs rolled compaction with moisture content control by spraying.
- Quality of concrete is to be secured with paying due attention on temperature and working conditions
- In test running of new pumps, it is necessary to confirm the capacities obtained as designed

c) Safety control

- During the construction work period, attention shall be paid carefully so as not to cause any traffic as well as electric shock accidents
- Communication network for emergency case shall be made up

d) Documentation/records

- Such documents, drawings and records as shop drawing, construction drawing, as-built drawing, inspection records, meeting minutes and progress reports shall be properly managed and kept in order.

2) Organization for construction/procurement supervision and tasks

Consultant services for construction supervision of the subject project include the following.

- Consultation meeting among parties concerned before commencement of works
- Approval on the shop drawings and construction drawings
- Supervision on schedule/quality/safety controls of construction works
- Inspection of articles before shipping, checking on quality of work, various tests, quality inspection and inspection for work completion
- Required report preparation during the construction period
- Issuance of certificate for construction work completion and for payment

For the organizational arrangement of the construction supervision, a resident supervisor shall be assigned for overall arrangement of construction works at the Project site through the entire construction period, and for the occasions of commencement and completion of construction works, the advisory supervising engineer will participate and support the resident supervisor. While for the excavation and banking of dam body, and installation of embedded measuring instruments in the dam body, dam civil engineer shall be dispatched for the specific purpose of supervision work. Even the time of installation work for pump and solar system, machine and electricity engineer will be assigned to manage and control quality and safety of the works. In addition, a local civil engineer shall be assigned as an assistant to the resident engineer.

As for the supervision work for which provision of equipment/materials, the tasks of consulting service are as follows.

- Consultant services for procurement supervision shall include checking and inspection of goods/materials to be procured from Japan at the specified period and task items as indicated below through due reference to the specifications and contract documents to be made. In each stage of the subject procurement, it is necessary for the consultant to have a constant and close communication with the Rwandese authorities concerned.

Table 2.2.4.2 Occasions and task Items for Inspection/Checking Work

Occasions	Task items
Interim	Prior to manufacturing, to check whether specifications and drawing are consistent with the contract and contract drawing or not.
Factory	After manufacturing, factory inspection documents shall be checked. For major items, participate in capacity testing.
Before shipment	Before the goods/materials be shipped, the appearance, quantities and the results of capacity tests be confirmed and only those items granted with approval shall be embarked.
During installation	Tasks include 1) confirmation on work schedule for installation and adjustment, 2) confirmation on inspection made before and after installation and guidance on O&M, 3) confirmation on guidance made on test run/initial operation/, 4) confirmation on guidance for O&M and 5) Inspection and turn over of equipment/materials.

- Concerning the goods and materials procured in Rwanda, related documents shall be checked based on the specifications, contract and contract drawings.
- The contractor will manage procurement and construction of all the work items with having the supervision by consultant.

2-2-4-5 Quality Control Plan

Items for quality control of dam body banking, earth work, concrete construction and so on to be covered by quality control plan under the construction supervision f are as following. Moisuture test of dam banking shall be done every construction day. A compression test for concrete shall be done with the sample once a day for each class of strength. A water pressure test is to be done for a certain distance of pipe length so as to confirm the leakage.

Table 2.2.4.3 Quality Control Plan (Construction)

Work item	Control item	Methods	Frequency
Banking	Completed works	Slope gradient, Measuring banking elevation	Every main parts
	Material	Grading distribution	3 samples / time / 15,000m^3
		Moisture ratio	Every construction day
	Degree of compaction	Field density test, Tamping test	3 holes / time / 2,500m^3
	Permeability	Field permeability test	3 holes/ time / 2,500m^3
Leveling work	Soil condition	Visual inspection, Measuring	Every main parts
	Bearing capacity	Plate bearing test	Every main parts
	Width/ height	Measuring	Every main parts
Concrete	Aggregate	Grain size analysis	1 time
	Cement	Physical/chemical	1 time/month
	Concrete	Slump	1 time/placing day/class
		Compression test (7days, 28days)	1 time/placing day/class

Work item	Control item	Methods	Frequency
Reinforcing	Strength	Tensile strength	Every supplier
	Arrangement position	Inspection	Every parts
Frame work, supporting work	Arrangement place	Fixing place/ method	Every main part
	Strength	Design, calculation report	If necessary
Completed works of structure	Completed size	Measuring	Evert main parts
Pump	Installation accuracy	Measuring of installation position	All equipment
Electrical equipment	function	Load operation test	All equipment at test run
Pipe material, Plumbing	Strength, Size	Factory inspection report	Every approval time
	Appearance, Size	Visual, size measuring	Every delivery time
	Torque	Torque wrench	Every construction place
	Junction	Feeler gauge	Every construction place
	Welding	Color check	Every construction place
	Water leakage	Visual test	All place

2-2-4-6 Procurement Plan

1) Equipment and materials for construction works

It is available to procure material and equipment such as banking material, aggregate, cement, reinforcement bar, pipe, and so on in local market. Regarding pump equipment, pump made in Italy, pump control panel made in Germany, solar panel made in China can be easily procured in local market because they are required as small-scale. On the other hand, valve, ultrasonic current meter and low voltage control panel are to be procured in Japan due to product guarantee and request rained by MINAGRI.

Table 2.2.4.4 Procurement Plan of Main Material

Material	Source			Remarks
	Local	Japan	3rd country	
Banking material	●			
Fine aggregate, coarse aggregate	●			
Portland cement	●			
Reinforcement bar	●			
Timber	●			
Plywood	●			
Scaffolding material	●			
Frame work material	●			
Pipe	●			
Pump, Motor, Solar panel, Pump control panel	●			
Boat, Gridiron		●		No possible at local
Valve		●		Ditto
Electric equipment (Low voltage panel)		●		Ditto
Hose, Watering can	●			

2) Construction machineries

Such commonly used construction machineries as backhoe, bulldozer and crane are owned by local contractors and ready to be availed on rental basis. It is, however, difficult to procure tractor and

laser-leveler for plot construction works so that they will be procured in Japan or the third country.

Table 2.2.4.5 Procurement Plan of Construction Equipment

Equipment	Source			Remarks
	Local	Japan	3rd country	
Backhoe	●			Class: 0.28m^3, 0.8m^3, 1.4m^3
Bulldozer	●			Class: 15t, 21t
Dump track	●			Class: 4t, 10t
Truck crane	●			Class: 4.9t, 20t, 25t
Vibratory roller	●			Class: 0.8-1.1t, 3-4t
Tamping roller	●			Class: 10t
Rough terrain crane	●			Class: 25t
Power Generator	●			Class: 125kVA, 200kVA
Sprinkler truck	●			Class: 10m^3

3) Equipment to be procured

Equipment to be procured is listed as the table below, and they will be provided to Rwanda side after completion of the construction works.

Table 2.2.4.6 Procurement of Equipment to be provided

Equipment	Source			Remarks
	Local	Japan	3rd country	
Tractor	●			
Laser leveler		●		
Trenching machine		●		
Boat		●		
Gridiron		●		
Personal computer	●			
Printer	●			
Watering can	●			
Hose (including hose head)	●			

4) Transportation plan

Equipment and material to be procured such as valve, control panel of power, laser-leveler and so on in Japan will be transported by using container of 20 feet.

2-2-4-7 Training Plan for Initial Operation and Maintenance

2-2-4-7-1 Pump Facilities

- Installation: The contractor shall undertake all works under the supervision by the consultant.
- Installation and inspection before operation: Inspection and records shall be made whether or not the equipment and materials are installed accurately in accordance with the specification. For the operation, mechanical works and electrical works shall be made in an integrated manner since a unified and systematic function is necessary for one pump system. During this occasion, the contractor will undertake the guidance and training for O&M staff of Rwanda side concerning the operation and O&M of subject facilities.
- Trial Operation: In order to unify the pump station facilities in one system, trial operation shall be continued for the duration sufficient for due confirmation. In the operation, mainly the confirmation shall be made by five senses where no records shall be required.

- Initial operation: This shall be undertaken after the trial operation. Confirmation and inspection shall be made on whether or not the pump facilities fully function without defects. The operation shall cover several hours of duration until temperatures of each part of electric motor be stabilized as specified. During the period, the contractor shall keep the records of confirmation and inspection regularly. Moreover, the contractor shall provide for the O&M staff of Rwanda side guidance during the trial operation on operation method as well as confirmation/handling of protective devices.

- Operation guidance: This shall apply the actual operation mode. First the contractor shall operate the system and then substituted by the O&M staff of Rwanda side. In the guidance, operation shall be trained in a practical manner on maintenance and inspection prior to the operation, measurements during operation and continued confirmation works, and due explanation is required so that the O&M staff be fully aware of the necessity and importance of the said works.

For the above-mentioned stages of training, staff in charge of O&M of Rwanda side shall participate. Taking into account the expertise both of mechanical and electrical aspects, the training shall be undertaken separately and/or combined together depending on the adequateness. The number of participants for the training shall be several for each stage and finally subject to the intention by the contractor. Rwanda side is requested to submit through the consultant to the contractor the request paper indicating the number of participants and their name list to discuss the matter to reach an agreement.

2-2-4-7-2 Other Irrigation Facilities

Some operation and maintenance facilities such as intake gates, diversion gates, and regulating valves shall be installed in this Project. All of these facilities are operated by manual and Japanese technicians of contractor shall guide the operational manner when delivering the facilities to Rwanda side. However, technical guidance about operational method of gates and valves along with irrigation plan should be implemented according to the soft component plan.

2-2-4-8 Soft Component Plan

1) Necessity for the soft component

In order to sustain irrigation agriculture at the Project site, it is proposed to integrate 1) WUO establishment and strengthening including aquaculture training, 2) O&M of irrigation facilities, water management and farming technology, and 3) test filling of the dam into the soft component of the Project. Fig. 2.2.4.1 shows a positive cycle aiming at income improvement through proper WUO management and irrigation farming.

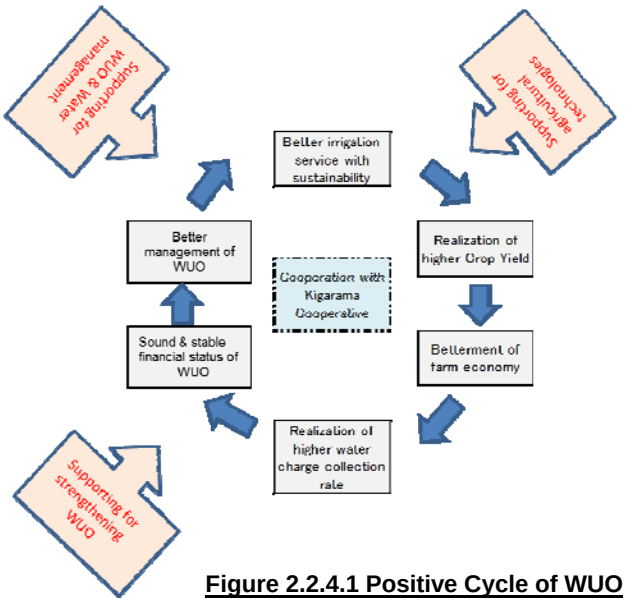


Figure 2.2.4.1 Positive Cycle of WUO

The issue of 1) indicated above is how to secure necessary amount of revenue for O&M through water charge collection. The revenue of WUO is only from water charge being collected from members but WUO has not been organized yet at the Project site. Therefore, it is necessary to organize a WUO newly under the support of WUOs Supporting Unit of MINAGRI immediately and then human

resources for the soft component will be inputted to strengthen WUO and O&M on the above mentioned 2). As to 2), training on improved farming technologies for upland crops and paddy will lead to sustainable management of irrigation facilities through stable crop production, which is expected to result in 100% of water charge collection.

2) Problems to be solved

(1) Problems on WUO management

Followings could be indicated on this matter;

- WUO has not been organized yet at the Project site,
- Necessity for systematic management of basic data of the WUO,
- Securing water charge collection from paddy and upland farmers and its management,
- Transparent financial affairs,
- Preparation of the own by-law agreed among the members,
- Cooperativeness between paddy farmers and upland farmers,
- Ownership of the irrigation facilities as their property, and
- Close linkage between WUO and Cooperative in water use and management.

(2) Problems on O&M of the facilities

Followings could be indicated on this matter;

- Lack of experience and techniques concerning O&M of irrigation facilities,
- Necessity of establishment of the even water distribution system,
- Lack of on-time water management technology based on planned cropping calendar and equitable water distribution,
- Lack of operational technology of operators,
- Lack of repairing technology of canal and others,
- Necessity for systematic recording regarding operation, power consumption and so on,
- Necessity for regular maintenance of facilities by members, and
- Necessity for strengthening technologies for MINAGRI staff on filling the reservoir at the constructed dam.

(3) Problems on faming technologies

Following matters could be indicated;

- Low yields due to extensive farming technologies on paddy and upland crops,
- Difficulty in irrigation on steep hillside,
- Water leaking caused from lack of leveling and ridge-coating,
- Difficulty in expansion of farmlands and small farm size,
- Lack of agronomist for agricultural extension services,
- Low land use ratio, and
- Lack of warehouse, thresher, and drying yard at Kigarama Rice Farmers Cooperative

3) Soft component plan

It is judged that input concerning the soft component in the Project is necessary in order to solve the various problems mentioned above and to use irrigation facilities to be constructed effectively under the well-organized WUO. Following components could be proposed for the soft component;

(1) Supporting for WUO Establishment and strengthening including aquaculture training,

(2) Supporting for O&M of the facilities, water management and farming technologies, and

(3) Supporting for the test filling of the reservoir.

4) Contents of the soft component plan

(1) Supporting for WUO establishment and strengthen aquaculture training

a) Fostering leadership

WUO will be managed well in irrigation services and O&M under the excellent leader, which will lead WUO to sustainable management and stable crop production to improve farm economy.

b) Compilation and management of basic data of members

Basic data on WUO such as cadastral maps, acreage by land use, number of beneficial farmers, projected irrigable area and actual irrigated area, cultivated area by crop and its production, marketed volume etc. will be compiled and managed with provided computers to be provided by the Project. Analysis time-series on trend of WUO management will become easier for the better management.

c) Training on WUO management

Coordination between cooperative, WUO and DISC (District Irrigation Steering Committee), and decision process will be built. WUOs' board members and representatives of farmers will acquire the methods of grasping farmers' demand, problem solution, effective water charge collection, preparation of budget document, auditing, value chain analysis, preparation of action plan and business plan etc. for the better and sustainable management of WUO.

d) Concept of PIM (Participatory Irrigation Management)

Ownership of irrigation facilities as the community's property will be fostered based on PIM (Participatory Irrigation Management) concept.

e) Preparation of by-law

Internal regulations of the WUO in response to the site condition will be prepared based on agreement among members, especially focusing on participation of hillside farmers, water charge to be imposed upon upland farmers and rice farmers, equitable water distribution, prohibition of stealing water, water charge collection system, members' duties and penalties, and procedure of decision-making etc.

f) Training on needs assessment of farmers

WUOs' board members and agronomists will acquire techniques for needs assessment of the WUO members by means of some methods, e.g. Project Cycle Management, Participatory Rural Appraisal and Rapid Rural Appraisal so on, which will lead to higher crop yields and higher water charge collection.

g) Training on value addition

WUO members and representative of farmers will understand importance of quality of crops and processing in order to add value to the original products of crops for more advantageous marketing, and farmers' income will be increased.

h) Acquisition of the methods for build-up of water charge collection system and its management and recording

Along with construction of irrigation facilities, water charge collection system and its status by irrigation block and individual members will become possible by using provided computers, and the results will be fed back to water distribution system by analyzing them.

i) Preparation of annual action plan and business plan

Annual action plan linked with cropping plan of the WUO covering irrigation schedule, meeting, training, mutual work for O&M, business plan will be prepared and make use it for the better management.

j) Acquisition of the methods for assembly, monthly meeting and minutes preparation

WUO members and board members will understand and acquire the methods for preparation of agenda for the assembly and monthly meeting for smooth and democratic proceeding.

k) Training on the management of ledger, checks, receipts

WUO board members, accountants and persons in charge of auditing will acquire how to manage documents on accounting management to realize transparent and sound financial affairs of the WUO.

l) Preparation of monthly report of accounting

Members’ reliability of WUO management will become higher by securing transparency of financial affairs such as documents of production, marketed amount, amount of distributed agricultural materials, unit prices, revenue from water charge and expenses etc. prepared by trained board members, accountants and auditors.

m) Training for accountants and auditors to secure transparency of financialaAffairs:

Accountants and auditors, DISC members will acquire the points for auditing accounting of the WUO.

n) Recording method of crop prices and fertilizers etc.

WUO board members and member farmers will have a sense of management to sell products more advantageously.

o) Study tour to the preceding projects

p) Aquaculture training

Aquaculture of Tilapia at the proposed dam is planned as well as those in Chinese dam, Kiliba dam and Kanyonyomba dam. Cooperative will be in charge of management according to the by-law. The training on aquaculture will be conducted by the local resources.

(2) Supporting for O&M of the facilities, water management and farming technologies

The following training session are planned;

a) Preparation of inventory of the irrigation facilities

Various information on irrigation facilities such as number, capacity, constructed and repaired year, degree of superannuation, construction and repairing costs will be managed on computers to be provided by the Project for the better management.

b) Understanding of legislations and regulations on WUO and cooperative

Not only WUO board members but also representatives of farmers will understand legislations and regulations on WUO and cooperative for the better management.

c) Preparation of cropping calendar

Cropping calendar for on-time/on-demand water distribution will be prepared.

d) Acquisition of recording method of pump operation

Prescribed format for recording operation will be prepared and water manager and his staff will acquire its method to manage them on provided computers in order to make use it for the better water management and O&M of facilities.

e) Training for water manager and other members

Water manager and his/her staff will acquire technologies to handle facilities to distribute water on time and on demand by block according to water availability. In addition, they will be able to record data on water level and volume etc.

f) Preparation of plan for annual O&M

The annual O&M Plan will be prepared to maintain irrigation facilities such as canals, pumps, gates etc. taking into consideration the prepared irrigation schedule linked with cropping calendar and O&M from upstream to tail-end canals will be done as well. Regular maintenance of canal will be done by member themselves, namely, *Umganda* according to the traditional custom in the area.

g) Training on broad-based water management

Suitable water management based on land use, crops and cropping period will be done on farm level and crop yield will be increased.

h) Acquisition of monitoring and feedback methods of the annual O&M activities

The annual O&M mentioned above in 5) will be monitored and its result will be reflected for the O&M plan based on the discussion in WUO for better O&M and sustainable use of the facilities.

i) Training on personal computers for water managements

Water requirement according to the cropping calendar and pump operation will be done using provided computers and make use its results for on-time and on-demand irrigation.

j) Equitable water distribution

Internal rules for equitable water distribution will be prepared in the discussion of members, and equitable water distribution on farm level will be realized by improvement of excessive irrigation and prioritized intake of water at upstream. As the result, the ratio of water charge collection will be increased, and financial status of the WUO will become sounder.

k) Handling and O&M of pumps

Installed pumps will be operated and maintained properly based on the provided O&M manual of pumps when installment.

l) Training on canal repairing technology:

Member of the WUO will acquire necessary masonry technology to repair canals by themselves to save the cost for maintaining canals.

m) Paddy field consolidation technologies

According to the model of land consolidation technology done for about two hectare by the Project, the remaining 33 ha will be suitably consolidated and leveled for effective paddy farming.

n) Study tour to preceding project

The trainings mentioned above will be carried out for representatives of Kigarama Rice Farmers Cooperative, agronomists of District and Sector Offices, and conducted before finishing filling the storage in order to transfer facilities smoothly to users/WUO.

o) Training on farming technologies,

Training on improved farming technologies will be conducted to extend technologies though some representatives of Kigarama Cooperative were trained under the technical cooperation of JICA (PiCROPP). The practical training on land leveling and ridge-coating to prevent water leak shall be provided along with land consolidation model in about two hectare.

In addition, improved farming technologies for upland crops shall be also provided for horticultural crops such as vegetables, fruit trees and coffee etc. Since Ngoma22 site has not enough room to expand farmland, increase of yield will be better choice. Beneficiaries in the site manage small farm size in general and input of fertilizers is not adequate due to high prices. Therefore, cost reduction and environment using organic fertilizers shall be taken into consideration when planning the trainings. Through the following trainings, farmer's mentality consisting on the traditional farming method will be changed;

- Deed selection using salty water,
- Planting interval and density,
- Water depth suitable for each growing stage of paddy,
- Technology to prevent water leak from ridge and land leveling,
- Suitable input of fertilizers and agro-chemicals,
- Suitable irrigation, frequency of irrigation and its intervals,
- Water-saving irrigation mainly for upland crops,
- Crop rotation,
- Mulching,
- Preparation of organic fertilizers using Indigenous Micro Organism (IMO),
- Preparation of organic pesticides to control disease and pest using materials available at the site,
- Preparation of rice husk charcoal to improve water holding capacity of the soil, and
- Post-harvest technologies (threshing, drying and storage)

(3) Supporting for the test filling of the reservoir:

During water storing period at the dam of about one year, the test filling the reservoir shall be carried out. The test is important to confirm and secure safety of the dam, therefore a dam engineer will be input to carry out training for the concerning staff in MINAGRI and WUO members. Before starting irrigation services, safety of the dam bank, basement, and discharge structure will be confirmed practically by storing and releasing water by changing water level.

5) Necessary resources for the soft component of the Project

(1) Necessary sub-sectors

In the soft component of the Project, the resources on 1) WUO establishment and strengthening

including aquaculture, 2) O&M of facilities, water management, and improved farming technologies on upland crops and paddy, and 3) test filling of the reservoir will be required. Japanese resources shall be planned as shown below, and in addition, one (1) local staff for interpretation and two (2) drivers shall be input;

Table 2.2.4.7 Necessary Resources

Field	Japanese	Rwandan	Target
1. WUO Strengthening	1 person x 3 months	1 person x 3 months	WUO representatives Cooperative representatives
Inland fisheries (Aquaculture)		1 person x 2months	Agronomists of District, Sector Offices Representatives of farmers Representatives of DISC
2. O&M of facilities and water management	1 person x 3 months	1 person x 3 months	WUO representatives Cooperative representatives
Improved farming technologies	- Horticulture agronomist: 1 person x 3 months - Paddy agronomist: 1 person x 3 months	- Horticulture: 1 person x 3 months - Paddy: 1 person x 6 months	Agronomists of District, Sector Offices Representatives of farmers Representatives of DISC
3. Test filling	Dam engineer: 1 person x 1 month	Dam engineer: 1 person x 1 month	MINAGRI staff WUO representatives Cooperative representatives Representatives of DISC

(2) Procurement of Implementation Resources

Only Kinyarwanda language is available when communicating villagers at the site. Therefore, training materials in English are necessary to translate into Kinyarwanda by local staff.

As mentioned in the table above, experts covering 1) WUO establishment and strengthening and 2) aquaculture, 3) O&M of facilities and water management, 4) Improved farming technologies on upland crops and paddy, and 5) Test for filling the reservoir will be assigned. Japanese experts will manage for 1, 3, 4, and 5) out of them, while local resources will cover 2) mentioned above.

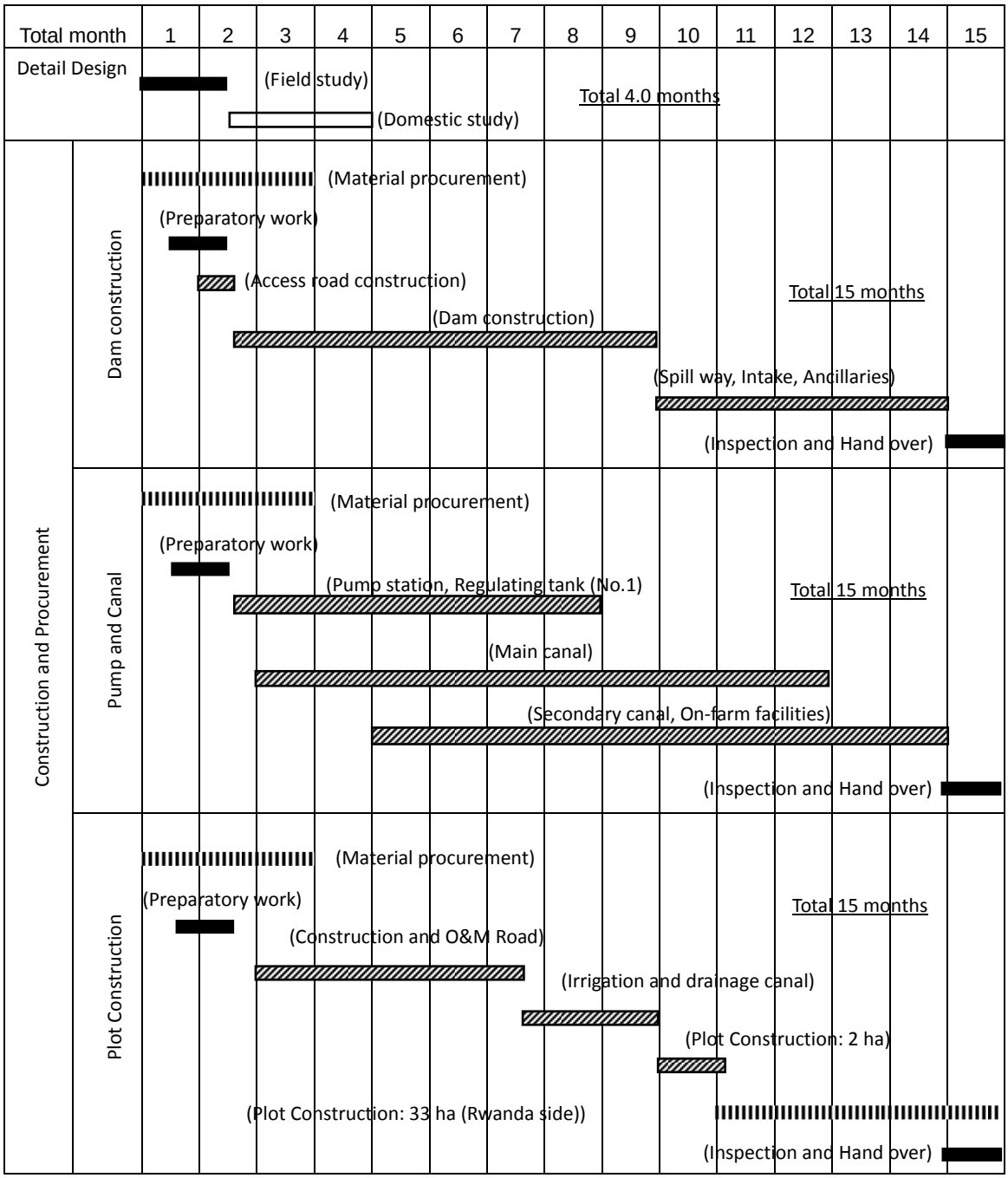
There are local consulting companies (service providers) on the soft component sub-sector in Rwanda, but, Japanese experts and local resources of concerning agencies will be procured for the implementation of the soft component of the Project taking into consideration quality of trainings and saving times.

2-2-4-9 Implementation Schedule

Since dam banking is a part of component of the Project, construction works of irritation facilities shall be carries out efficiently in dry season. While embankment works are executed, the other components such as pump, canal and plot construction for existing paddy field will be implemented overall implementation schedule is planned as the table shown below.

- Detail design : 4.0 months
- Bidding and Contract : 3.0 months
- Construction : 15.0 months (from contract to completion on construction)

Table 2.2.4.8 Implementation Schedule



2-3 Obligations of Recipient Country

2-3-1 Major Undertakings to be implemented by GoR

During the period of construction works and also of actual implementation of irrigation agriculture performed by the beneficiaries, GoR executes some activities so as to make the Project progress smoothly and sustainable. The major undertakings to be covered by GoR are summarized as follows. The detailed undertakings and necessary budget are shown in the following table.

1) Implementation of compensation and expropriation for affected people on the Project site
2) Implementation of tree cutting and transplanting in the Project area
3) Implementation of EIA and acquisition of approval by RDB
4) Provision of alternative land or compensation for land owners during construction period
5) Formulation of environmental check list and environmental monitoring sheet
6) Application and acquisition of the water right to RNRA
7) Distribution of power line to the Project site
8) Assignment of counterparts personnel to the Project and expenses
9) Implementation of operation and maintenance on irrigation facilities after completion of construction period
10) Implementation of environmental monitoring after completion of construction period
11) Implementation of Land Husbandry design and construction
(except design in the command area, which is to be done by Japan side)
12) Implementation of support for establishment of WUO
13) Construction of fences around the regulating tanks (No.2 and No.3) and the discharge tanks (No.1, No.2 and No.3)
14) Plot construction of downstream paddy field
15) Commission for Banking Arrangement (B/A) and Authorization to Pay (A/P)

Table 2.3.1.1 Summary of Major Undertakings to be implemented by GoR

Items	Implementation Procedures	Implementation Schedule	Responsible Organization	Expenses needed (Rwf)	Budget Preparation
1) Implementation of compensation and expropriation for affected people on the project site	1)Final asset survey 2)Compensation for the affected persons 3)Training of local level officers for grievance settlement	1)After official decision of the project 2)Within 4 months after the final census survey 3)Before compensation	MINAGRI /District	1)1,210,700 2)24,213,500 3)941,600	MINAGRI
2) Implementation of tree cutting and transplanting in the project area	1)Final asset survey 2)Compensation for the affected persons who planted trees 3)Clearance of trees will be done by the contractor	1)After official decision of the project 2)Within 4 months after the final census survey 3)After payment of compensation	MINAGRI /District	1)610,600 2)12,212,400 3)Included in the construction cost	1)MINAGRI 2)MINAGRI 3).Contractor
3) Implementation of EIA and acquisition of approval by RDB	Submission of EIA report	at the end of Dec. 2013 (ALREADY DONE)	MINAGRI	None	-
4) Provision of alternative land or compensation for land owners during construction period	No temporary land loss	None	None	None	-
5) Formulation of environmental check list and environmental monitoring sheet	1)Formulation of environmental check list 2)Monitoring sheet is prepared in the EIA report and RAP in collaboration with MINAGRI	After EIA report submission Monitoring sheet is included in EIA report and RAP	MINAGRI and JICA study team	None	-
6) Application and acquisition of the water right to RNRA	Application and acquisition of the water right to RNRA	After approval of EIA report by RDB	MINAGRI	35,000 as application fee to RNRA	MINAGRI
7) Distribution of power line to the project site	1)Power sources of pump are solar and commercial power. 2)Extension of commercial power line about 6 km away from the dam construction site is born by Japan side. 3)Extension work is to be carried out by EWSA.	1)Extension works to be done by EWSA should be complete until the commencement of construction period.	MINAGRI EWSA	(around 94 million Rwf)	(Japan side)
8) Assignment of counterparts personnel to the project and expenses	MINAGRI allocates the counterparts for implementation of the soft-component of the project	14 months	MINAGRI RAB NAEB	2,992,000	MINAGRI
9) Implementation of operation and maintenance on irrigation facilities after completion of construction	1)WUO will get Certificate of Legal Personality (Registration Certificate) to be issued by Ministry of	During the period of operation and maintenance	MINAGRI WUO	O&M cost will be born by WUO	MINAGRI WUO

Items	Implementation Procedures	Implementation Schedule	Responsible Organization	Expenses needed (Rwf)	Budget Preparation
period	Local Government 2)MINERERA will give the water permit to MINAGRI(WUO) and, irrigation facilities will be transferred to WUO from GoR				
10) Implementation of environmental monitoring after completion of construction period	1)Monitoring of project affected persons due to land expropriation 2)Monitoring of number of malaria patients 3)Monitoring of chemical and fertilizer use condition	For two years after project completion	1)District/ MINAGRI 2)Ministry of Health/Sector/Cell 3)Sector	1)2,772,000 2)Regular budget 3)Regular budget	1)MINAGRI 2)Ministry of Health 3)District/ Sector
11) Implementation of Land Husbandry design and construction (except design in the command area, which is to be done by Japan side)	MINAGRI will start preparation works of terracing construction when the decision of project implementation is made between GoJ and GoR.	9 months	MINAGRI	311,000,000	MINAGRI
12) Implementation of support for establishment of WUO	1)WUO will get Certificate of Legal Personality (Registration Certificate) to be issued by Ministry of Lcal Government 2)MINERERA will give the water permit to MINAGRI(WUO) 3)and, irrigation facilities will be transferred to WO from GoR	4 months	WUO Supporting Unit	790,000	MINAGRI
13) Construction of fences around the regulating tanks (No.2 and No.3) and the discharge tanks (No.1, No.2 and No.3)	MINAGRI will construct fences around the concrete structure: the regulating tanks (No.2 and No.3) and the discharge tanks (No.1, No.2 and No.3)	By commencement of operation and maintenance of irrigation facilities constructed	MINAGRI	5,000,000	MINAGRI
14) Plot construction of downstream paddy field	Demo plot construction will be covered by Japanese side and remaining part will be covered by Rwandan side.	During irrigation facility construction	MINAGRI	27,000,000	MINAGRI
15) Commission for Banking Arrangement (B/A) and Authorization to Pay (A/P)	Rwanda will open an account under the name of the Government of the recipient country in a bank in Japan. Rwanda should bear an advising commission of an Authorization to Pay and payment commissions paid to the Bank.	After 1 month of EN, GA exchanged	MINAGRI MINECOFIN	4,700,000	MINAGRI MINECOFIN
Expense needed (Rwf)				**393,477,800**	

2-3-2 Obligation of GoR on the Soft Component of the Project

1) Deployment of counterparts

For the purpose of project sustainability through proper management of irrigation facilities after the construction, it is planned to organize the soft component for capacity development of WUO and official personnel concerned.

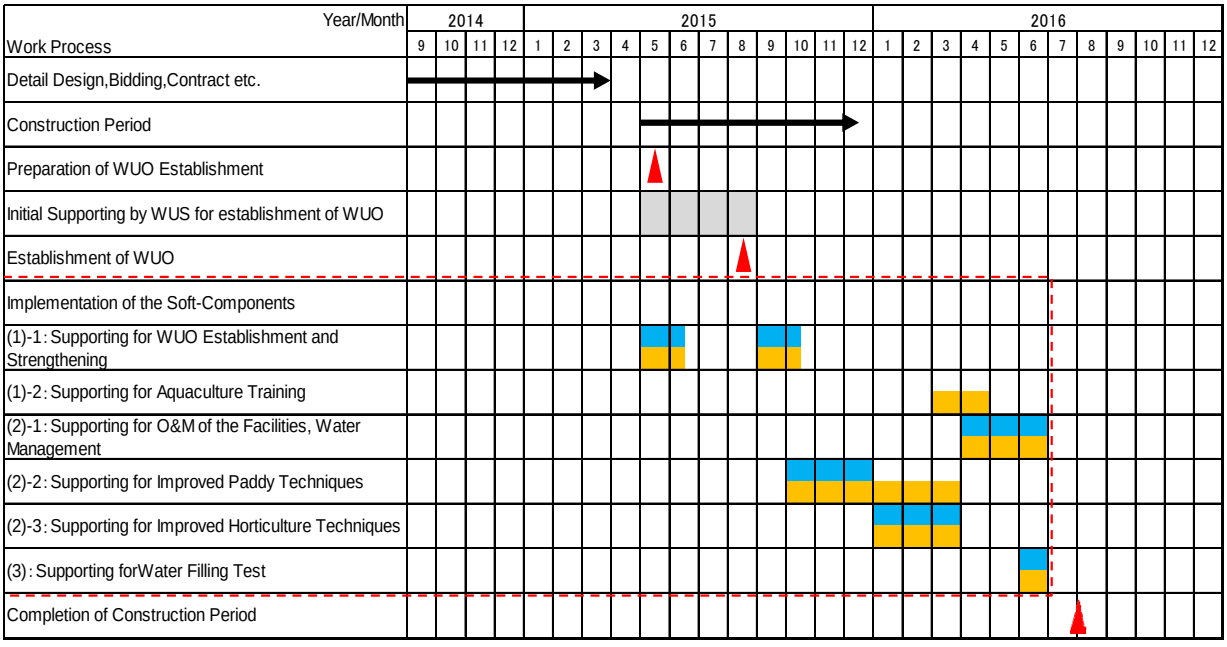
The soft component will cover three (3) fields, namely, 1) Supporting for WUO establishment and strengthening including aquaculture training, 2) Supporting for O&M of facilities, water management and improved farming techniques on horticultural crops and paddy, 3) Supporting for test filling of the reservoir.

Based on the proposed soft component plan mentioned above, the Rwandan counterparts will be assigned to participate a series of training sessions on each component. They are expected to manage workshop/training together with the experts, who are trainers to be procured by the Project, and also learn knowledge and skills of specific filed of the soft component.

2) Schedule

It will take one (1) year for the dam construction and one (1) year for storing water, two (2) years in total, therefore, irrigation services will be available from the third year. If the construction work will be started in May 2015, irrigation water will be distributed actually from August or September 2017. In parallel with those construction works, preparation activities for establishment of WUO will be commenced in May 2015, and then WUO is expected to be officially established around by August 2015. During the soft component implementation, WUOs Supporting Unit, of MINAGRI and the counterparts will be assigned as illustrated in the following table:

Table 2.3.2.1 Schedule of the Soft Component and the Counterpart Personals



Note:WSU;Water Users Organization Supporting Unit (MINAGRI),Blue; Japanese expert, Yellow; Local resources

3) Cost estimation to be burdened by the Rwandan side

Prior to the soft component implementation, workshops will be organized to explain about the Project to the beneficiaries. Specifically, a kickoff workshop and a wrap-up workshop will be held before the proposed training sessions and after completion of all the training sessions, respectively. The official personnel are expected to support for the training sessions, which will be organized by private sector trainers (Japanese and local resources), and one officer will be assigned to each training item. The cost of venue is expected to be burdened by the Rwandan side. In addition, the daily allowance and lodging expense for the assigned counterparts for the soft component is also burdened by the Rwandan side. The cost estimate of counterparts is as shown below;

Table 2.3.2.2 Cost Estimation to be burdened by the Rwandan Side for Soft-Component Operation

Item	Frequency, CP & MM	Estimated Costs
Workshops	Twice	Venue：30,000Rwf／day x 2＝60,000Rwf Allowance for participants：2,000Rwf／capita x 61persons／time x 2=244,000Rwf Allowance & lodging for CP：32,000Rwf／day／person x 7 x 2=448,000Rwf Total：688,000 Rwf （participants: beneficiaries：5persons／village x 9 villages=45、District：2persons, sector:3persons x 2=6、cell：2 persons x 4=8, Total ：61persons）
Counterpart: WUO establishment / strengthening, And aquaculture training	1 person x 3months 1 person x 2 months	Allowance & lodging：32,000Rwf/day x 4days/month x 3 =384,000 Rwf Allowance & Lodging：32,000Rwf/day x 4days/month x 2 = 256,000 Rwf
Counterpart: O&M of facilities, water management, And Farming technologies	1 person x 3months Paddy: 1person x 6months Horticulture: 1person x 3months	Allowance & lodging：32,000Rwf/day x 4days/month x 3 =384,000 Rwf Paddy: Allowance & lodging：32,000Rwf/day x 4days/month x 6 = 768,000 Rwf Horticulture: Allowance & lodging：32,000Rwf/day x 4days/month x 3 = 384,000 Rwf
Counterpart: Test filling of the reservoir	1person x 1 month	Allowance & lodging：32,000Rwf/day x 4days/month x 1 =128,000 Rwf
Grand Total		**2,992,000 Rwf**

Note: Allowance & lodging is estimated based on 4 days per month in each sub-sector

2-3-3 Establishment of WUO and Cost

1) Procedure for WUO establishment

A new WUO shall be established prior to operation of the irrigation facilities. The WUO needs to get the certificate of legal personality (Registration Certificate) from the Ministry of Justice, water permit from MINERERA, and IMTA (Irrigation management Transfer) from the government. The flow of procedure is illustrated as follows:

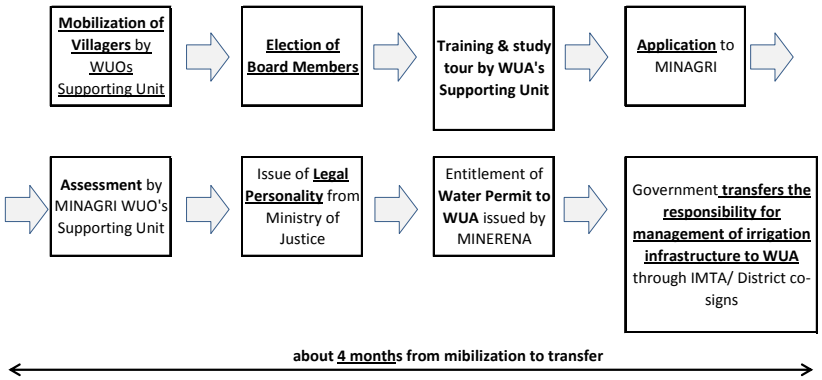


Figure 2.3.3.1 Flow Chart of WUO Establishment

For establishment of WUO, the WUOs Supporting Unit of Irrigation and Mechanization Task Force under the MINAGRI is responsible for mobilization and trainings covering financial management and O&M of irrigation infrastructure. Unit price of water charge for irrigation agriculture to be covered by the beneficiaries has been under the discussion between MINIRENA and MINAGRI at present and it is needed to pay attention to the progress.

2) Schedule

Temporarily, it is planned to establish the new WUO in August 2015 as mentioned above.

3) Responsible organization

The WUOs Supporting Unit of MINAGRI is responsible for establishment of WUO. The WUO will be given approval of registration and water permit from RGB (Rwanda Government Board) under the support of WUOs Supporting Unit. Training for intended WUOs' board members and general members shall be conducted prior to WUO establishment. Mobilization of members, training sessions on accounting and infrastructure management training and study tour will be organized.

There is no WUO on the site at present. After the completion of the irrigation facilities, the WUO will be established newly and it will be composed of members of hillside farmers and the Kigarama Rice Farmers Cooperative.

4) Costs and budget allocation

In preparation for the WUO establishment at the site, costs for training by the WUOs Supporting Unit of MINAGRI including study tour are estimated as below, which will be burdened by GoR.

Table 2.3.3.1 Costs for Establishment of WUO

Item	Number (person／time)	Frequency (time)	Unit Price (Rwf／capita ／time)	Amount (Rwf)
Training 1：O&M of Irrigation Infrastructure				
Allowance of participants	55	1	2,000	110,000
Cost for venue	1	1	30,000	30,000
Training 2：WUO management				
Allowance of participants	55	1	2,000	110,000
Cost for venue	1	1	30,000	30,000
Training 3：Study tour	55	1	2,000	110,000
Rental fee of buses	4	1	100,000	400,000
Total				790,000

O&M cost, pump operation cost and repairing cost shall be shouldered by the WUO members. O&M cost of the proposed facilities can be estimated based on that of the preceding WUO, namely, APIISAMAK WUO at Kanyonyomba dam. 40% of the collected water charge is allocated to O&M, 30% to WUO management, 20% to saving for depreciation, and 10% to Irrigation Trust Fund. The Trust Fund is spent for development of marshlands by the government. It is considered that the new WUO will manage the budget as well as APIISAMAK WUO. Pump operation cost (electricity cost) for hillside irrigation is estimated at Rwf 725,418 per year. The detail estimation is indicated in the section of 2-5-2.

2-4 Project Operation Plan

2-4-1 Structural Plan for O&M

As a prerequisite, it is necessary that the newly establishing WUO has to selected necessary staff for O&M of facilities such as board members, accountant, facility operators etc., at the beginning time of construction works of irrigation facilities since WUO is responsible for managing irrigation scheme at the Ngoma22 site under IMTA (Irrigation Management Transfer Agreement) with the government. Therefore, WUOs Supporting Unit of MINAGRI is required to instruct hillside benefited farmers and Kigarama Rice Farmers' Cooperative who will be members of the new WUO according to the flow chart shown in the pervious section. Then the soft component of the Project will be conducted for WUO management, O&M and water management etc. with dispatch of Japanese experts on the required sub-sectors to build up member's capacity. By doing so, capacity of board members and ordinary members will be formulated properly in order to operate and maintain the constructed facilities after the completion of the work and full storage of water at the dam. Basic organization of a WUO is as shown below.

WUOs Supporting Unit of MINAGRI is required to visit the site once every three months to inspect and monitor WUO status (especially financial status and its recording) such as water management, facility management etc. and if found problems, they are requested to advice WUO to improve the issues.

In addition, DISC (District Irrigation Steering Committee) is also required to visit the site to visit WUO once every three months to inspect and monitor WUOs status from viewpoint of management, O&M and water management, and to inform the results to MINAGRI.

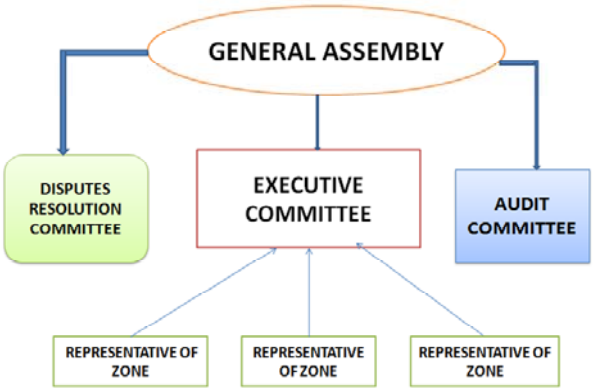


Figure 2.4.1.1 Basic WUO Organizational Structure

2-4-2 Method for O&M

The constructed irrigation facilities shall be operated and maintained by the WUO members and hired employees. Practical management of WUO will be done by the Executive Committee members, accountants, auditors, the committee members for conflict solution, and representatives of each zone. In the soft component plan, personal computers will be planned to introduce for effective management of basic data, inventory of facilities, and various records such as financial data, cropping calendar, water level, water volume at the dam, pump operation, business plan, documents on assembly and monthly meeting, shifting from hand writing records. Training on handling personal computers to input and manage various data shall be provided in the soft component.

In addition to the initial guidance on how to handle and maintain pumps, gates, division works and

solar penal etc. to be conducted by makers and contractors, practical trainings on O&M of those facilities shall be provided for board members and ordinary members in the soft component too.

The cost for O&M and management shall be relied on collected water charge, which is required to attain 100% through on-time and on-demand water distribution, equitable water distribution to meet farmer's demand along with introduction of improved farming technologies in hillside and paddy filed (refer to Fig. 2.2.4.1 indicated in the previous section). It is estimated that about 40% of the revenue (water charge) is spent for O&M according to the preceding WUOs. Soundness of financial status of WUO shall be inspected and monitored by DISC (District Irrigation Steering Committee) and will be reported to members regularly in order to secure transparency.

2-4-3 Staff Fostering Plan on O&M

Hillside farmers will join into the new WUO in addition to the existing Kigarama Rice Farmers Cooperative. They have no experience of O&M of irrigation facility to date, therefore, necessary O&M staff such as gate-keepers, pump operators, staff in charge of solar panel etc. will be fostered through the projected soft component of the Project, as well as practical training on masonry to repair canals. For horticultural farmers, they will be trained practically on how to use irrigation hose with water-saving technology to maintain irrigation hose in group basis by themselves.

In addition to engineering matters, institutional training shall be provided for WUO staff focusing on securing transparency of financial affairs and sound management of WUO. Educational training for WUO staff using computers shall be conducted on WUO management, financial management, basic data preparation and preparation of various types of documents.

2-5 Project Cost Estimation

2-5-1 Initial Cost Estimation

The total cost to be incurred by the subject project implementation is about *** Million Yen (Japanese side *** Million Yen and Rwanda side 58 Million Yen), with detailed items as born by both Japan and Rwanda side based on the demarcated obligation as discussed above. The estimation was done applying the estimation conditions as indicated below. The amount estimated, however, dose not indicate the ceiling limit in the E/N to be signed.

1) Cost to be born by Japanese side

Table 2.5.1.1 The Project Cost under Grant Aid

Total Cost estimated Approx. *** Million Yen

Cost Items		Contents	Amount (Million Yen)
Civil Works	Direct Construction Cost	Dam	***
		Pump station	***
		Main canal (Open channel)	***
		Main canal (Pipeline)	***
		Drainage facility	***
		Secondary canal, On-farm facilities	***
		Land consolidation of paddy field	***
		Direct temporary works, Transportation and Pump installation	***
	Indirect Construction Cost		***
	Overhead Cost		***
	Sub-Total		***
Procurement Cost of Equipment			***

Cost Items	Contents	Amount (Million Yen)
Design, Supervision, Soft Component		***

2) Cost to be born by GOR: Rwf 393.48 Million (Approx. 58 Million Yen)

(1)	Implementation of compensation and expropriation for affected people on the project site	Rwf	26.37	Million	(3.9 Million Yen)
(2)	Implementation of tree cutting and transplanting in the project area	Rwf	12.82	Million	(0.4Million Yen)
(3)	Implementation of EIA and acquisition of approval by RDB	Rwf	-		-
(4)	Provision of alternative land or compensation for land owners during construction period	Rwf	-		-
(5)	Formulation of environmental check list and environmental monitoring sheet	Rwf	-		-
(6)	Application and acquisition of the water right to RNRA	Rwf	0.04	Million	-
(7)	Distribution of power line to the project site	Rwf	-		-
(8)	Assignment of counterparts personnel to the project and expenses	Rwf	2.99	Million	(0.4Million Yen)
(9)	Implementation of operation and maintenance on irrigation facilities after completion of construction period	Rwf	-		-
(10)	Implementation of environmental monitoring after completion of construction period	Rwf	2.77	Million	(0.4 Million Yen)
(11)	Implementation of Land Husbandry design and construction (except design in the command area, which is to be done by Japan side)	Rwf	311.00	Million	(46.0 Million Yen)
(12)	Implementation of support for establishment of WUO	Rwf	0.79	Million	(0.1 Million Yen)
(13)	Construction of fences around the structures like the discharge tank the regulating tank	Rwf	5.00	Million	(0.7 Million Yen)
(14)	Plot construction of downstream paddy field	Rwf	27.00	Million	(4.0 Million Yen)
(15)	Commission for Banking Arrangement (B/A) and Authorization to Pay (A/P)	Rwf	4.70	Million	(0.7 Million Yen)

Note: (8) means that C/Ps are expected to operate trainings of the soft component. (11) excepts designing of terracing inside command area.

3) Estimation condition

(1) Estimation made at : November 2013

(2) Exchange rate : 1USD = 99.27Yen = 670.7Rwf (1Rwf = 0.148Yen)

(3) Construction and Procurement period: As shown in the implementation schedule of section 2-2-4-9.

(4) Others : Cost estimation was made in accordance with the guidelines adopted for the grant aid and project by GOJ

2-5-2 Operation and Maintenance Cost

1) Annual pump operation cost

Pump operation cost is estimated as follows. Though electric motor pumps shall be adopted in this Project, electric charges may not be required normally because the motor works using the generated electricity by solar power generation system. However, it might be better to ensure necessary water by operating pumps using commercial electricity on cloudy days or during the period when irrigation water requirement exceeds pump discharge capacity by solar generation from the viewpoints of

reducing initial cost and dispersion of risk.

The estimate below is the result of calculation for necessary operation hours utilizing commercial electricity and its charge that can be obtained from the difference between the amount of irrigation water requirement on the condition of average climate and the reduced pump discharge capacity taking account of instability of generated power by solar. Pump operation cost is estimated at 725,418 Rwf.

Table 2.5.2.1 Pump Operation Hours using Commercial Electricity and its Cost

Month	Decade	Days	Irrigation Water Requirement		Pump Discharge by Solar		Balance		Operation hours of Grid		Electric Charge	
			Right Hill (m3)	Left Hill (m3)	Right:2sets (m3)	Left:1set (m3)	Right Hill (m3)	Left Hill (m3)	Right Hill (hour)	Left Hill (hour)	Right Hill (RWF)	Left Hill (RWF)
Jan	1st.	10	2,127	1,418	4,880	2,440	2,753	1,022				
	2nd.	10	1,209	806	4,880	2,440	3,671	1,634				
	3rd.	11	860	573	5,368	2,684	4,508	2,111				
Feb	1st.	10	929	619	5,300	2,650	4,371	2,031				
	2nd.	10	1,262	841	5,300	2,650	4,038	1,809				
	3rd.	8	299	199	4,240	2,120	3,941	1,921				
Mar	1st.	10	618	412	5,280	2,640	4,662	2,228				
	2nd.	10	418	279	5,280	2,640	4,862	2,361				
	3rd.	11	383	255	5,808	2,904	5,425	2,649				
Apr	1st.	10	0	0	5,320	2,660	5,320	2,660				
	2nd.	10	0	0	5,320	2,660	5,320	2,660				
	3rd.	10	4	2	5,320	2,660	5,316	2,658				
May	1st.	10	103	68	5,320	2,660	5,217	2,592				
	2nd.	10	1,316	877	5,320	2,660	4,004	1,783				
	3rd.	11	7,324	4,883	5,852	2,926	-1,472	-1,957	10.5	14.0	18,040	23,982
Jun	1st.	10	9,836	6,558	5,760	2,880	-4,076	-3,678	29.1	26.3	49,965	45,077
	2nd.	10	12,942	8,628	5,760	2,880	-7,182	-5,748	51.3	41.1	88,036	70,458
	3rd.	10	10,382	6,921	5,760	2,880	-4,622	-4,041	33.0	28.9	56,653	49,536
Jul	1st.	10	8,326	5,551	6,130	3,065	-2,196	-2,486	15.7	17.8	26,917	30,467
	2nd.	10	8,165	5,443	6,130	3,065	-2,035	-2,378	14.5	17.0	24,944	29,152
	3rd.	11	8,038	5,359	6,743	3,372	-1,295	-1,987	9.3	14.2	15,876	24,359
Aug	1st.	10	7,477	4,985	5,950	2,975	-1,527	-2,010	10.9	14.4	18,717	24,633
	2nd.	10	8,033	5,356	5,950	2,975	-2,083	-2,381	14.9	17.0	25,535	29,179
	3rd.	11	8,333	5,556	6,545	3,273	-1,788	-2,283	12.8	16.3	21,922	27,985
Sep	1st.	10	5,904	3,936	5,600	2,800	-304	-1,136	2.2	8.1	3,725	13,924
	2nd.	10	4,266	2,844	5,600	2,800	1,334	-44		0.3		541
	3rd.	10	2,948	1,965	5,600	2,800	2,652	835				
Oct	1st.	10	2,821	1,881	5,030	2,515	2,209	634				
	2nd.	10	3,000	2,000	5,030	2,515	2,030	515				
	3rd.	11	3,581	2,387	5,533	2,767	1,952	379				
Nov	1st.	10	692	461	4,620	2,310	3,928	1,849				
	2nd.	10	0	0	4,620	2,310	4,620	2,310				
	3rd.	10	329	219	4,620	2,310	4,291	2,091				
Dec	1st.	10	2,663	1,775	4,650	2,325	1,987	550				
	2nd.	10	3,812	2,542	4,650	2,325	838	-217		1.5		2,656
	3rd.	11	4,221	2,814	5,115	2,558	894	-256		1.8		3,140
Sub-total			132,619	88,413	194,184	97,092			204.2	218.6	350,331	375,087
Grand-total		365	221,032		291,276				422.7		725,418	

2) Operation and maintenance cost

Operation and maintenance of irrigation facilities which will be constructed in the Project shall be conducted by WUO to be established in the future. The necessary cost for operation and maintenance will be provided by water fee collected from users. According to the survey for existing WUO formed though RSSP, it is often the case that 40% of total collected amount will be used for maintenance, 30% for management and 20% for reserve as depreciation expenses.

Based on the survey results above, water fee to be collected from the WUO members is estimated as follows:

- For hillside: Rwf 225/are × 100 are × 265 ha = Rwf 5,962,500/year

- For paddy field: Rwf 200/are × 2 times/year × 100 are × 35 ha = Rwf 1,400,000/year

Total amount Rwf 7,362,500/year (≒7,362,000)

Annual operation and maintenance cost including electric charge estimated above is assumed as follows, given that the maintenance cost accounts for 40 % of total collected water fee in other WUOs.

Table 2.5.2.2 Annual O&M Cost Estimation

Items	Amount (Rwf/year)	Remarks
Electric Charge（for pump operation）	725,418	
Maintenance Cost（without electric charge）	2,944,800	40% of Rwf 7,362,000 estimated above
Total	3,670,218	

CHAPTER 3 PROJECT EVALUATION

3-1 Preconditions for Project Implementation

1) Land Expropriation and Construction Permission

The project components consist of two parts, namely, irrigation for hillside horticulture farming and for paddy farming. For the former, the project will newly construct origination facilities such as dam, pumping station irrigation canals, regulating tank / discharge tank. For the latter, land consolidation of existing paddy field of about 35ha together with rehabilitation of irrigation and drainage canal and newly construction of operation and maintenance road which will be built to penetrate the project area from the dam to downstream.

Ownership of the land in the project site is divided into two categories. Marshland belongs to GOR and hillside area is private land. Although it is not necessary of land expropriation for marshland, compensation should be done for the owners of private land before commencement of construction works. As per construction permission, there is no hindrance if the expropriation (compensation) for private lands will be successfully completed by the time specifically.

2) Acquisition of the certificate of EIA

In any development business, the project implementers area required to submit EIA report to RDB. MINAGRI, therefore, has submitted the EIA report responding to the TOR indicated by RDB through consigning a consultant registered with REMA in December 2013. After reviewing, the EIA report was approved and the certificate was issued by RDB in February 2014. There is no hindrance to implement the project from the environmental point of view.

In addition, the environmental checklist and monitoring plan to be carried out during the construction period have also been created so that the monitoring activity will be done by MINAGRI based on the plan and the checklist.

3) Costumes Procedure and Tax Exemption

Since this is a Japan Grant Aid project, tariff, domestic tax and other surcharges is exempted.

4) Undertakings to be done by GOR

Undertakings which should be implemented are expropriation of the private lands, opening the banking account, tax exemption, supporting WUO establishment and so on. These are to be executed under the responsibility of MINAGRI and Ngoma District. In implementation of the soft component activities, MINAGRI and Ngoma District have to encourage the persons concerned such as counterparts, board members of WUO, Sector and Cell officers and so on to participate in a series of trainings to manage them.

3-2 Undertakings to be done by GOR

In order to express and sustain the project effects, GOR is expected to undertake the following items.

1) Establishment and Strengthening of WUO

WUO is to be the main entity to make irrigation agriculture sustainable and secure in the project. As one of major activities of WUO, the organization has to secure the revenue required for implementation of proper operation and maintenance of irrigation facilities. The water tariff is the fund for it so that the members of WUO will deliver a certain amount from the irrigation agriculture income.

Although WUO manages maintenance and/or repair works of the irrigation facilities by using the water tariff paid by the members, it has not established yet on the project site. The project, therefore, prioritizes to form WUO as important and top priority activity in the soft components. In order to smoothly establish WUO and educate its members, it is indispensable for the WUO members to be supported by WUO Supporting Unit of MINAGRI.

2) Technical Support for Operation and Management of Irrigation Facilities

After completion of construction works of irrigation facilities, the responsibility for O&M of them is to be transferred from GOR to WUO, while the ownership of the facilities still belongs to GOR. This is the first effort to practice irrigation agriculture by using facilities for the beneficiaries who are the members of WUO. The beneficiaries, therefore, have to learn how the facilities are operated and maintained.

For that, the project is to carry out the soft component activity to strengthen the capacity of farmers for operation and maintenance of the irrigation facilities, which contain water management training and cultivation technique training. In order for smooth implementation of training and/or workshop, MINAGRI and Ngoma District have the responsibility for assignment of counterparts and spending the expense necessary.

3) Measures for Environmental and Social Consideration

Irrigation facilities are to be newly constructed by the project except canal and drainage rehabilitation of land consolidation in existing paddy field. Therefore, appropriate consideration and measures to the environment and local communities are essential through expropriation of private lands and compensation for the peoples who will be affected by the project implementation.

Also, the environmental negative impact that may occur temporarily during construction stage is required to be monitored based on the monitoring plans formulated in advance and by using the environmental check list.

3-3 Important Assumption

Important assumptions to express and sustain the project effects are itemized as follows.

- Policy of agriculture and irrigation development are not changed extremely,
- Market price of agricultural products and farming materials are not changed drastically,
- Roles and responsibilities for operation and maintenance between MINAGRI and WUO are not changed,
- Personnel necessary for the operation and maintenance of irrigation facilities, consumables, spare parts, and funds are stable supplied for proper operation and maintenance, and
- Severe natural disaster is not caused.

3-4 Project Evaluation

3-4-1 Relevance

Because of the reasons pointed out shown below, it is judged that the project is valid to implement as a Japan Grant Aid project

1) Urgency of the Project

The agriculture sector of Rwanda is an important industry accounting for about 40% of GDP component ratio, which provides 90% of employment opportunity. Rice cultivation is practiced mainly in the low wetland (marshland) and there have been horticulture crops in the slope of 5 - 55 degrees, which accounts for 80% of the country land. In the hillside area, soil erosion during the rainy season, low maintenance ratio of development of irrigation facilities, soil degradation and so on have become a constraint of crop productivity improvement. Despite agriculture sector is positioned as the key industry in the country, it have been facing with low productivity and small-scale farming size scale, which have been closely linked with the issues of nationwide such as poverty of the people, food shortage and so on.

Under such circumstances, the project is responsible for promotion of irrigation development of 10,000 ha by reservoir construction of about 100 sites based on the policy to LWH project so that urgency to implement the project is higher in the policy.

According to the feasibility study report formulated in 2012, average monthly expenditure per house hold in the project site is estimated at Rwf 13,775, which is equivalent to only a half of the living standard of the national average of Rwf 27,500/HH/month. In addition to this, the wages of casual labor in the area is around Rwf 800/capita/day - Rwf 1,000/capita/day only. It is a level of less than 2 USD/capita/day, which is referred to as the poverty line.

Farm sizes per household of hillside farm land and existing paddy plots in the project area are 34 are/HH and 11.7 are/HH respectively, which is much smaller than that of the average farming scale of the national level of 0.76 ha/HH. In addition, irrigation facilities contributing to improvement of agricultural productivity have been undeveloped so far so that WUO has also not established on the project site.

As described above, there is no room for expansion of farmland and being a small-scale farming on the project site so that it is a good idea for promoting crop production increase through improvement of the yield per unit area, but the cultivation state is extensive and the irrigation facilities are not developed. Furthermore, the living standard of the targeted beneficiaries in the project area is lower than that of the national level. In order to improve the livelihood of the beneficiaries and make the consumer stable, the urgency of the implementation of the project is high.

Table 3.4.1.1 Comparison of Farm Economic Size

Item	National Ave.	Project Site Ave.	Poverty Line
Farm Economic size per HH (are/HH)	76	Hillside: 34、Paddy: 11.7	Rwf 118,000 /Adult/Year (Poverty profile, JICA 2012)
Farm Ave. Expense per HH (Rwf/HH/Month)	27,500*	13,775*	
Wages per day (Rwf/labor/day)		800 - 1,000	

Source: *= Data Collection Survey on Irrigation Development in Ngoma District of Eastern Province in Rwanda (July 2012)

2) Consistence with the Rwanda Development Plan

GOR has positioned agriculture and irrigation development as an important policy as an engine for economic development and poverty reduction. Furthermore, in order to realize the sustainable production system, National Agriculture Policy and Strategic Plan for Agricultural Transformation II (SPAT-II) have been developed in 2004 and 2009 respectively, and then as sub-program of those policies Rural Sector Support Program (RSSP) and Land Husbandry, Water Harvesting and Hillside Irrigation Project (LWH) have been planned. At present, SPAT-III is drafted to implement comprehensive reformation the agricultural production system.

Based on the LWH policy, this project aims to improve the livelihood of farmers through increase of crop production by development of a reservoir and irrigation facilities at Ngoma22 site in Ngoma

District so that it can be said that the consistency is high as a project that will contribute to the goal of national development plan.

3-4-2 Effectiveness

Expected effects of the implementation of soft components as well as the construction of irrigation facilities in the project are as follows.

1) Quantitative Effect

- As irrigated area expansion effect, irrigated area of hillside farm land is expanded to 265ha from 26 ha of current,
- As total cropping acreage effect, irrigated area of hillside farm land is expanded to 610ha from 99 ha of current,
- As crop yield per unit area increased effect, the yield per unit area of planned crops is increased as shown in the table below,
- As irrigation time savings, irrigation time for paddy cultivation is saved to 50 man-day from 100 man-day of current, and

Table 3.4.2.1 Project Quantitative Effect (Increase of Crop Unit Production and Shipping Rate)

Index	Reference Value (2013)		Target Value (2019) (After 3 years of construction completion)	
Effect of Crop Unit Production Increase (kg/ha)	Paddy :	4,000	Paddy :	6,000
	Maize :	2,000	Maize :	5,000
	Beans :	1,000	Beans :	2,000
	Cabbage :	8,000	Cabbage :	12,000
	Carrot :	10,000	Carrot :	25,000
	Tomato :	10,000	Tomato :	20,000
	Eggplant	3,500	Eggplant	7,400
	Tree tomato	2,500	Tree tomato	3,500
	Coffee :	3,500	Coffee :	5,500

2) Qualitative Effect

- With introduction of terminal irrigation method that incorporates the hose irrigation and development of key irrigation facilities including reservoir, farming conversion can be performed as individual farmer level by growing more profitable crops than that of traditional crops such as maize, beans and so on,
- Through organizing WUO composed of different community peoples and managing the irrigation facilities as common property of WUO members, the project contributes to stabilization of residents living and to the stabilization of the consumer. In addition, cooperativeness between paddy farmers and hillside farmers is increased, and
- Through practicing soft component activities, the ownership which considers the irrigation facilities as a common property of the community is built up, which leads the farmers to high transparency of financial management of WUO. In addition, farming management sense of the farmers is fostered through appropriate water management realizing appropriate amount and on-time water distribution and equitable water sharing, which takes the farmers to increase of high management sense of farming.