Appendix 13
Sample of Sand Flushing Operation

1. General Layout of Hydroelectric Power Facilities with Run-of-River-Type

The hydroelectric power facilities with run-of-river-type are generally composed of a weir, an intake, a de-silting basin, a waterway, a head tank/ regulating pond, penstock lines, a power station, a tailrace, etc. and their general layout is illustrated below.

As to the sand flushing operation, it is a major point to be suggested that the de-silting basin be facilitated so as to trap and settle foreign particles contained in water in the upstream of the headrace canal or the headrace tunnel and be designed to have sufficient transportation forces to flush out sediments.

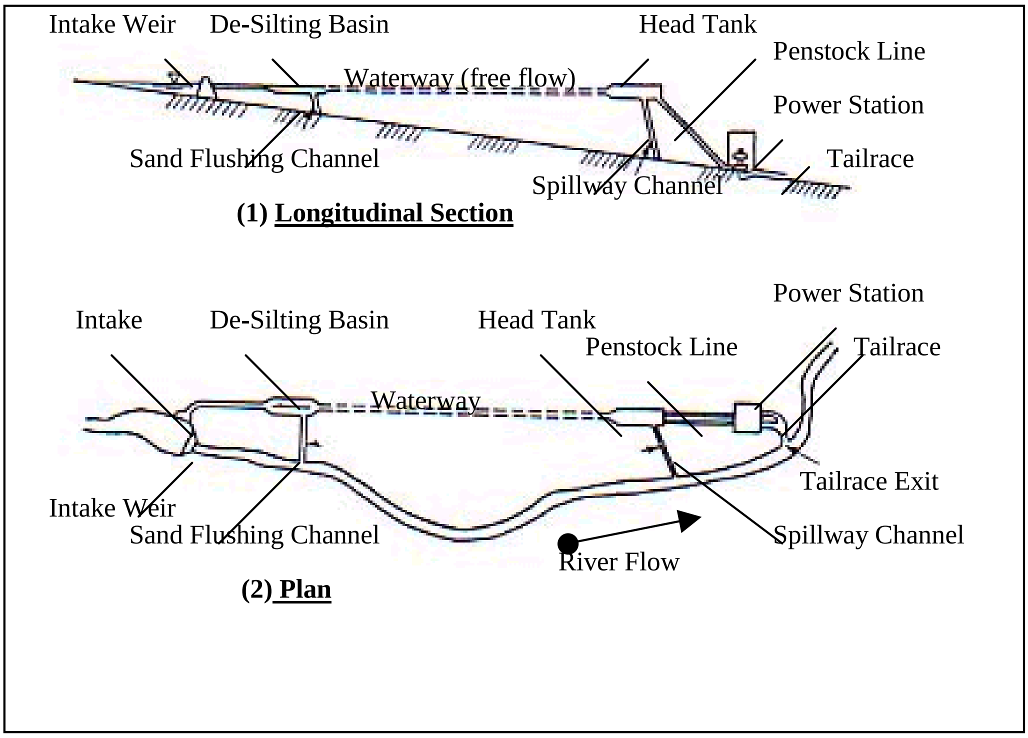


Figure 1 Hydroelectric Power Facilities with Run-of-River-Type

2. Example of Hydroelectric Power Facilities with Run-of-River-Type

The layout of major hydraulic facilities for the Project for Rural Electrification in Aceh, Indonesia is shown in Figures 2 - 5. In reference to those figures and the above mentioned suggestion, it could be said that the hydraulic design for the Project for Rural Electrification in Aceh meets the suggestion and follows the conventional hydraulic design such as illustrated in Figure 1.

3. Comparison of Hydraulic Design between Project for Rural Electrification in Aceh and Zi Chaung Power Station

The layout of major hydraulic facilities for Zi Chaung Power Station is shown in Figures 6 ~ 12. In comparison of the hydraulic design between Project for Rural Electrification in Aceh and Zi Chaung Power Station, remarkable differences and comments are summarized below.

No.	Structure	Aceh	Zi Chaung	Remarks
1	Sand flushing gate in intake	Nil.	Upstream of screen	The sand flushing gate of Zi Chaung is provided upstream of the intake gate, however it is in sub-critical flow. Consequently, the efficiency of transportation force to flush out cobble, gravel, sand, etc. will be so low (See Fig.9).
2	Location of de-silting basin	Upstream of headrace canal	Downstream of headrace canal	As to Zi Chaung, such a location of de-silting basin as designed downstream of the headrace canal, i.e. upstream of the regulating pond causes sediments in the headrace canal and further erosion of the canal (See Fig. 6).
3	Transportation force to flush out sediment	Provided by a super-critical flow through the gradient of the canal, 1/50.	Provided by a steep headrace canal just upstream of the de-silting basin.	Transportation force to flush out sediment is given by use of a super-critical force (See Fig. 4 for Aceh and Fig.12 & Photo for Zi Chaung).

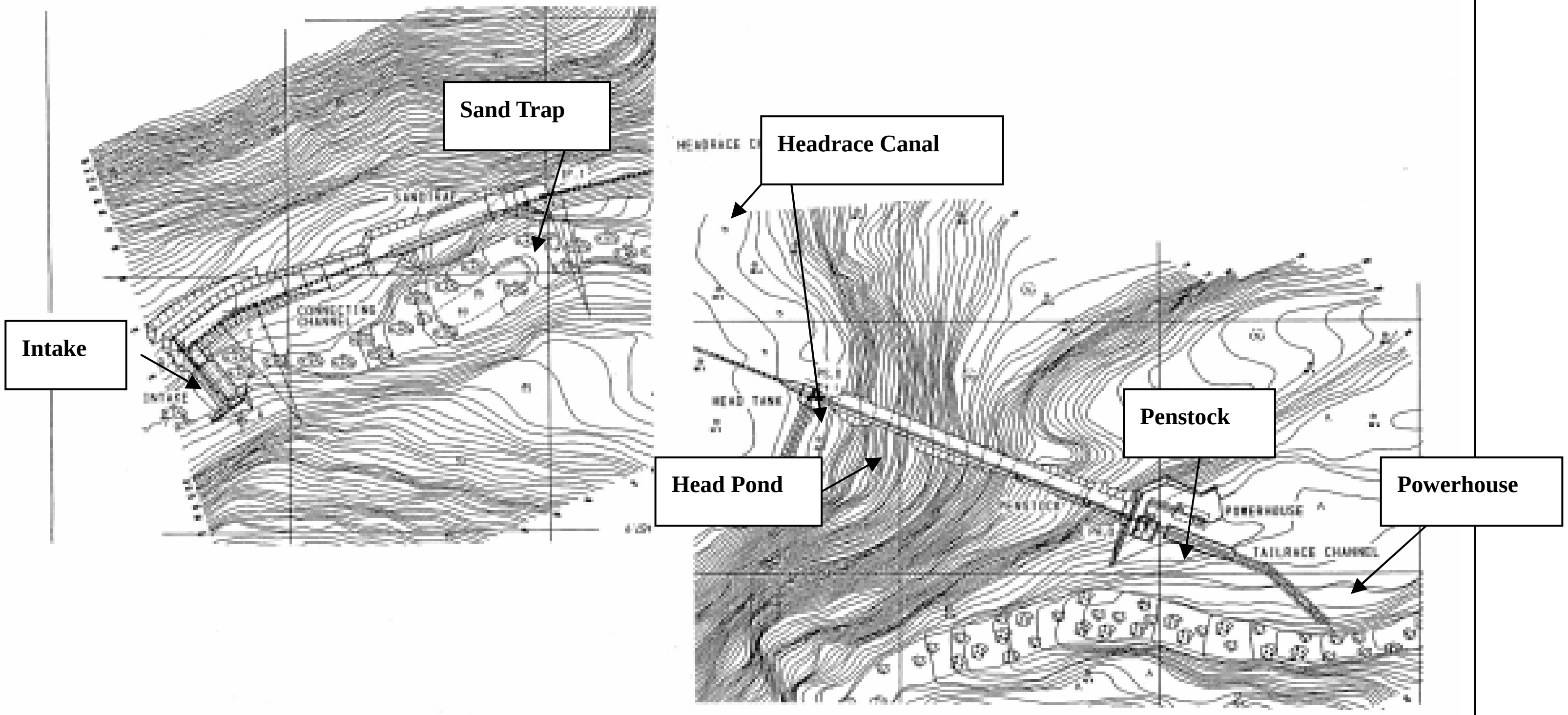


Figure 2 Schematic Layout for the Project for Rural Electrification in Aceh

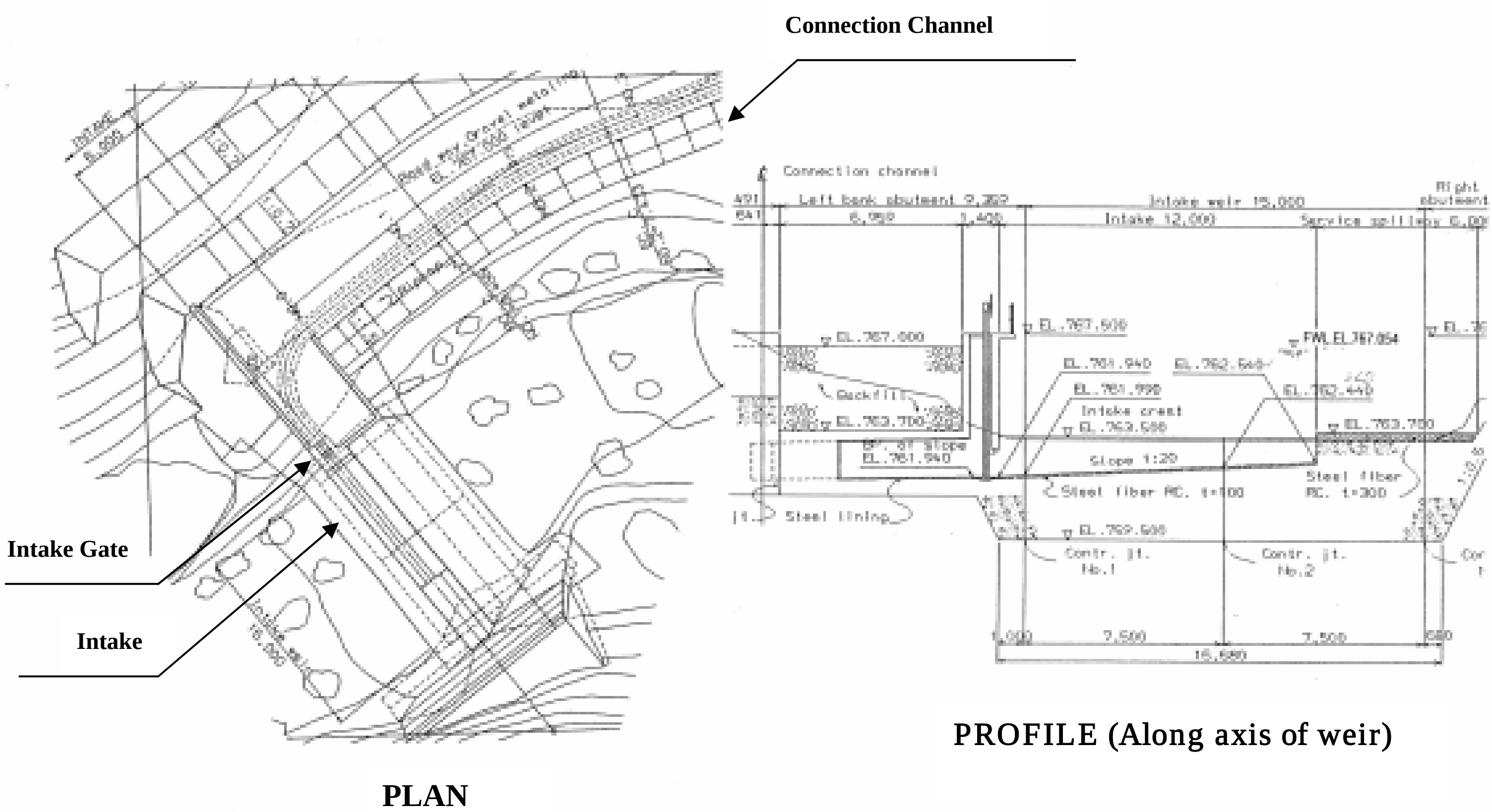


Figure 3 Intake for the Project for Rural Electrification in Aceh

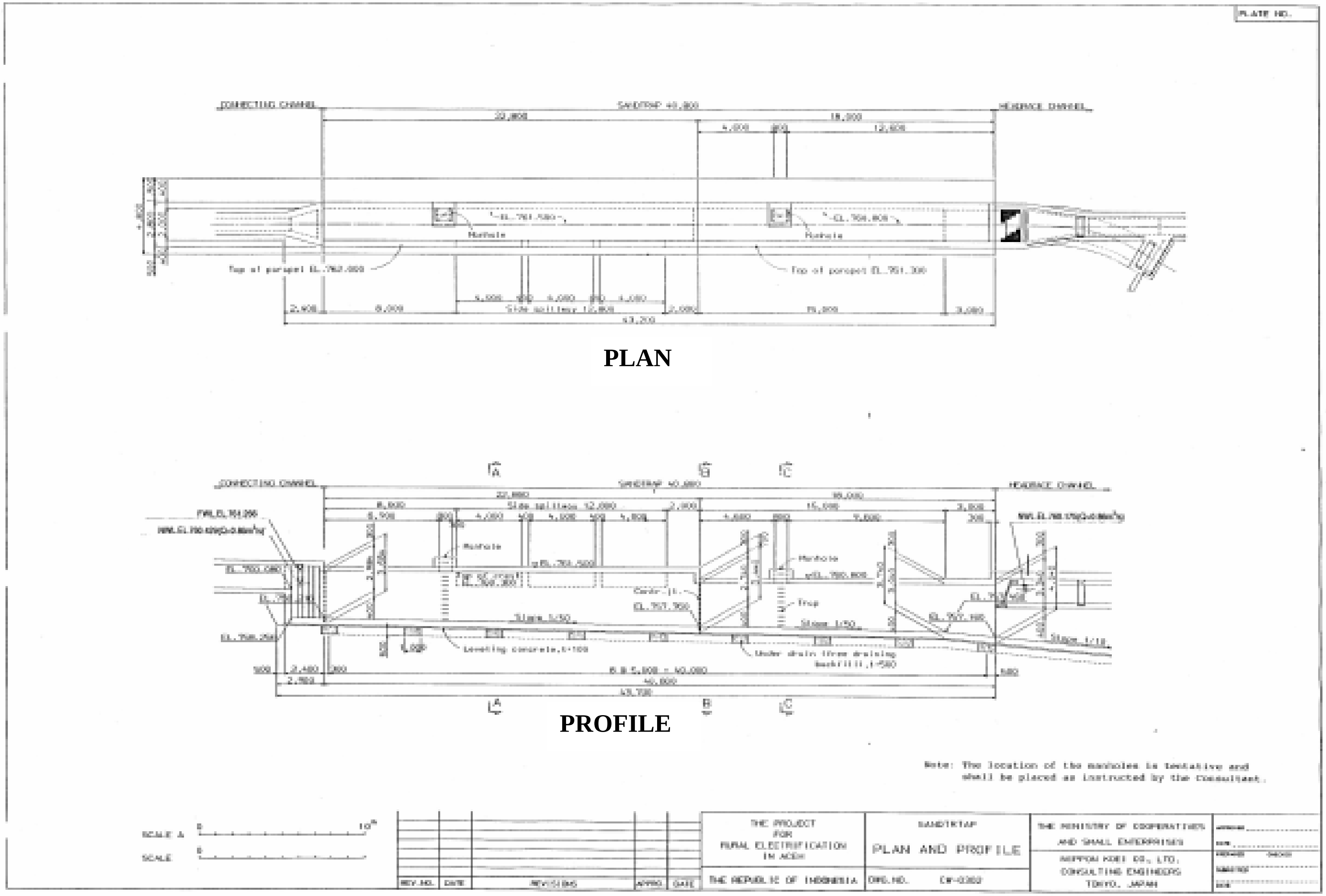


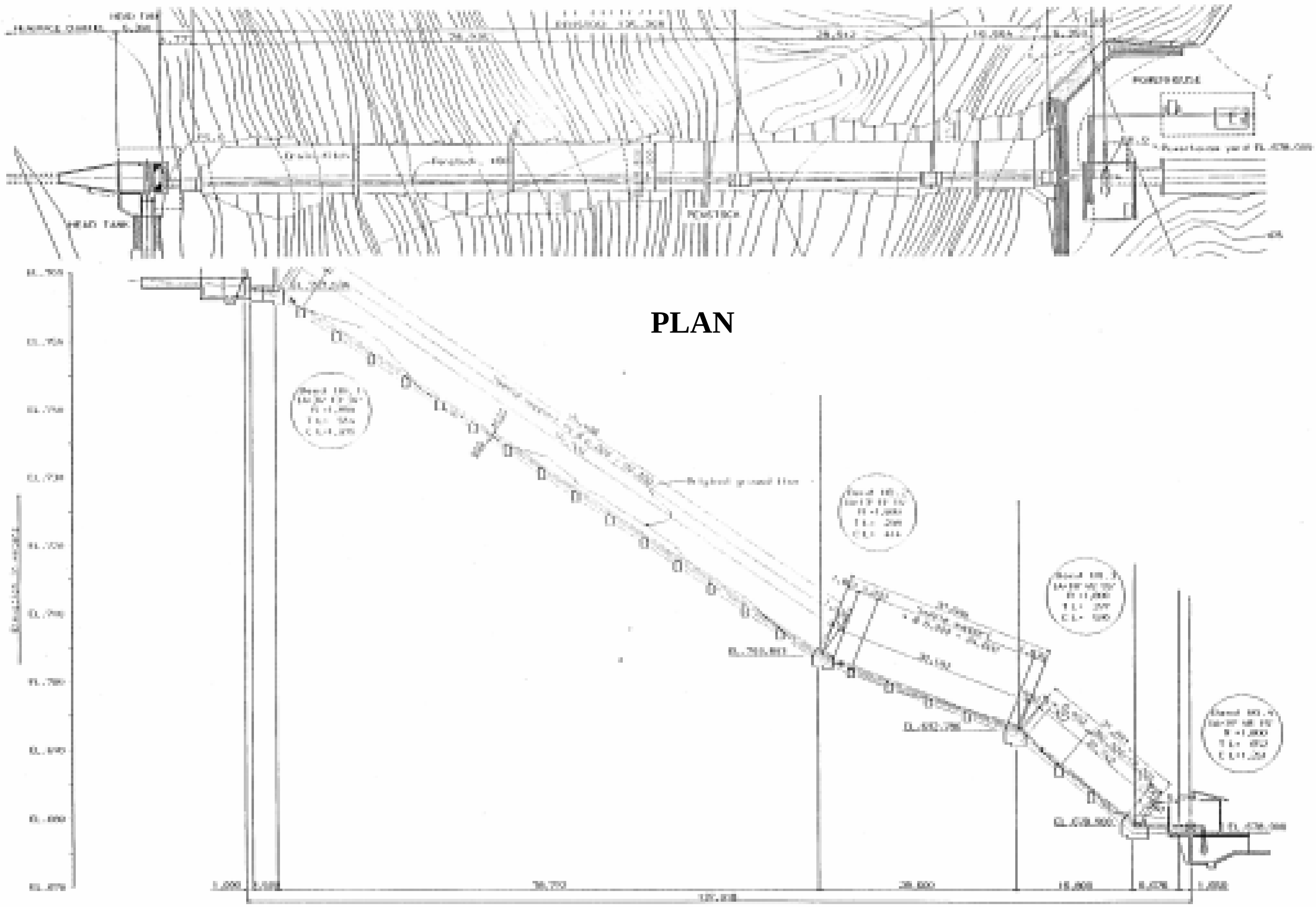
Figure 4 De-Silting Basin for the Project for Rural Electrification in Aceh

Sediment in De-Silting Basin

De-Silting Basin after Sand Flushing

Super-Critical Flow for Sand Flushing

Photo 1 De-Silting Basin for the Project for Rural Electrification in Aceh



PLAN

PROFILE

Figure 5 Penstock for the Project for Rural Electrification in Aceh

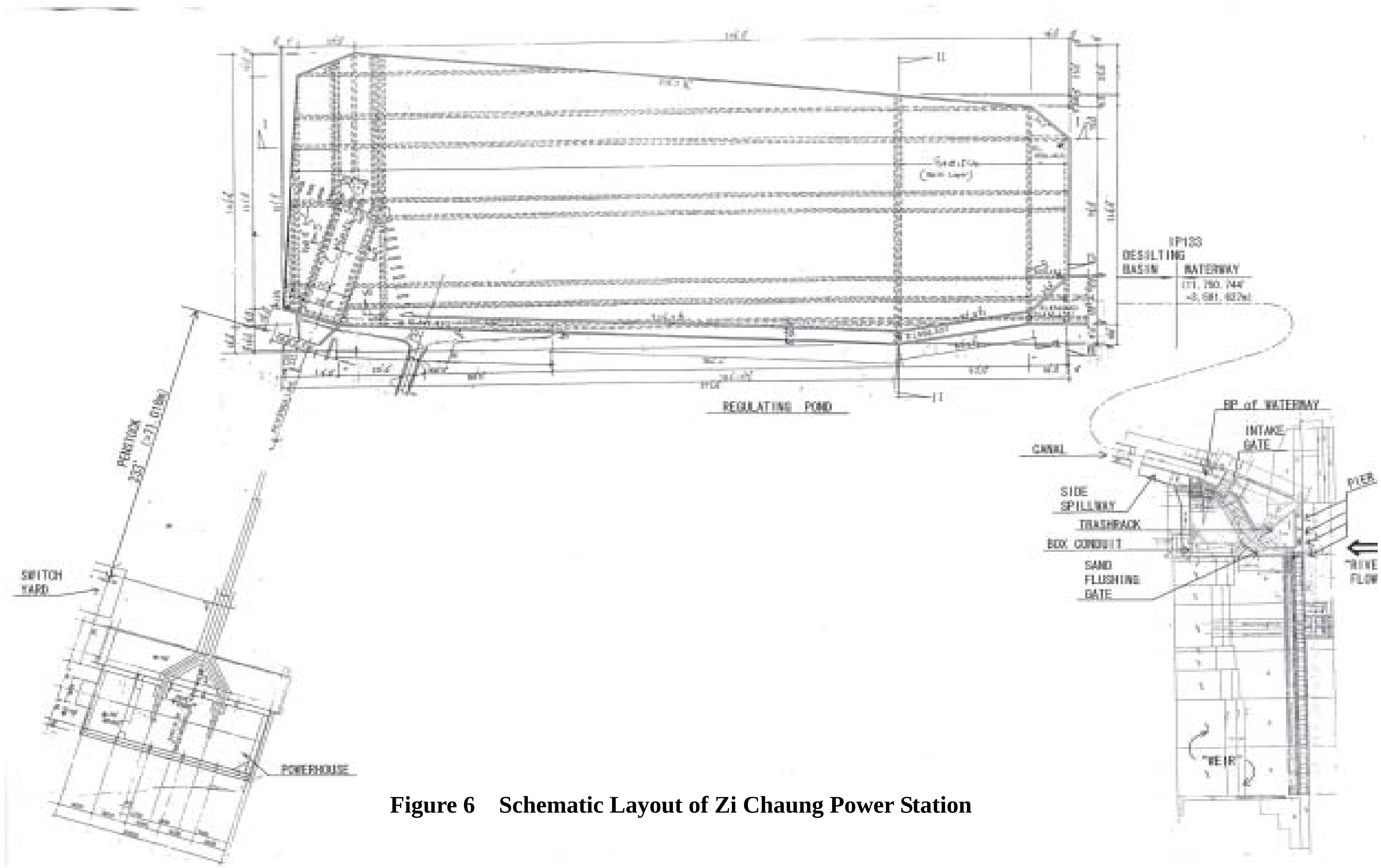


Figure 6 Schematic Layout of Zi Chaung Power Station

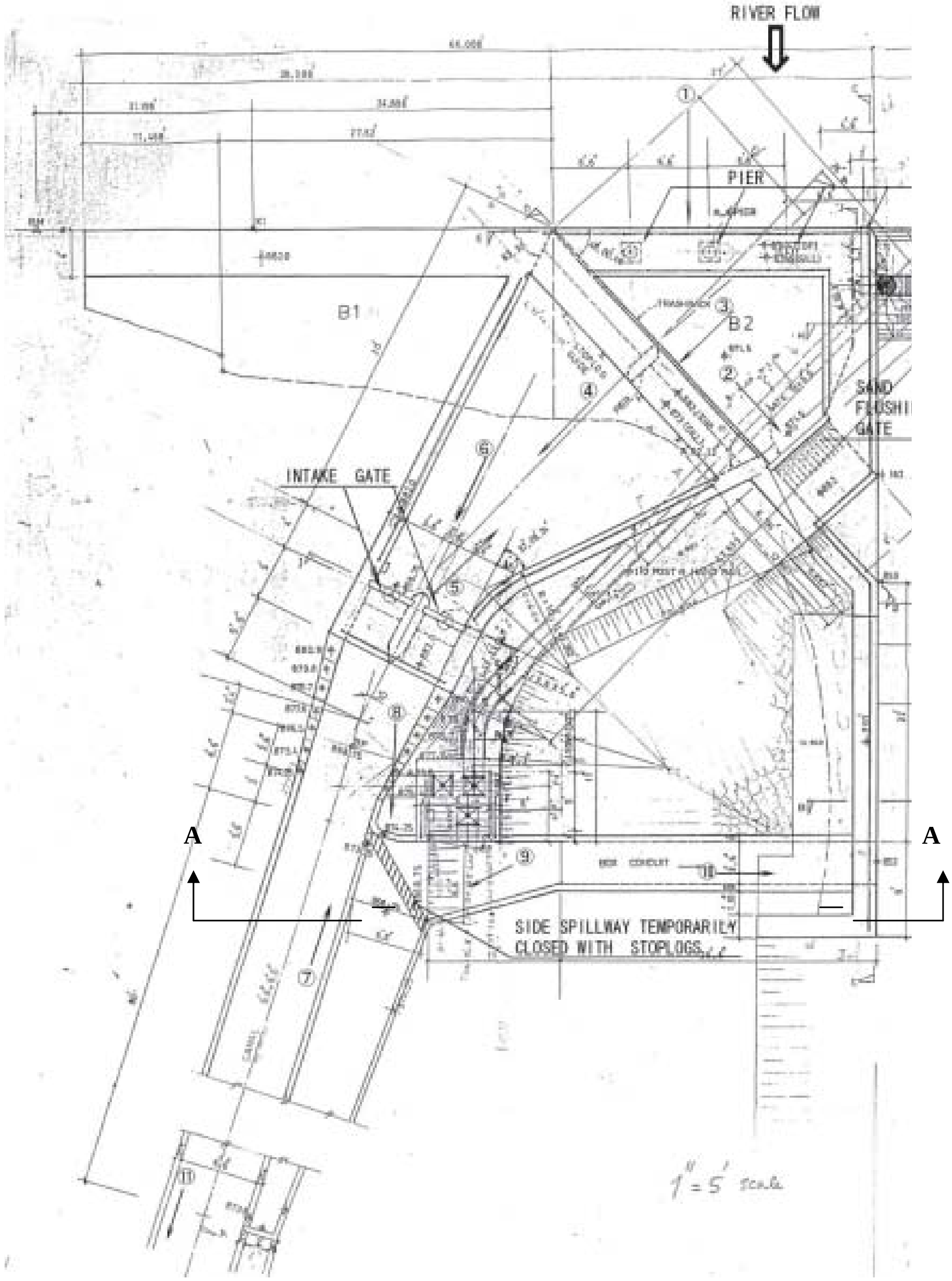


Figure 7 Plan of Intake for Zi Chaung Power Station

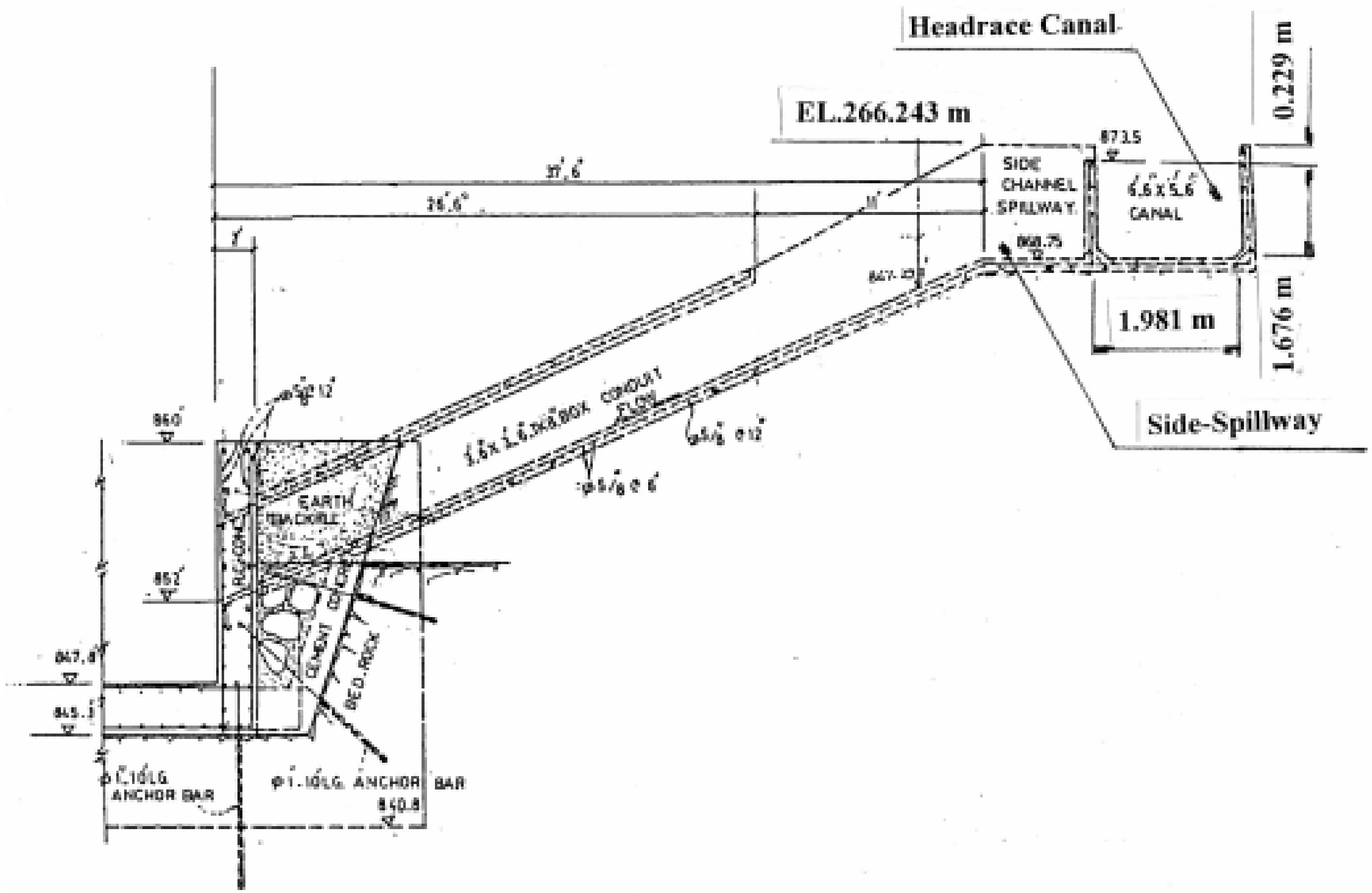


Figure 8 Section A ~ A of Intake for Zi Chaung Power Station

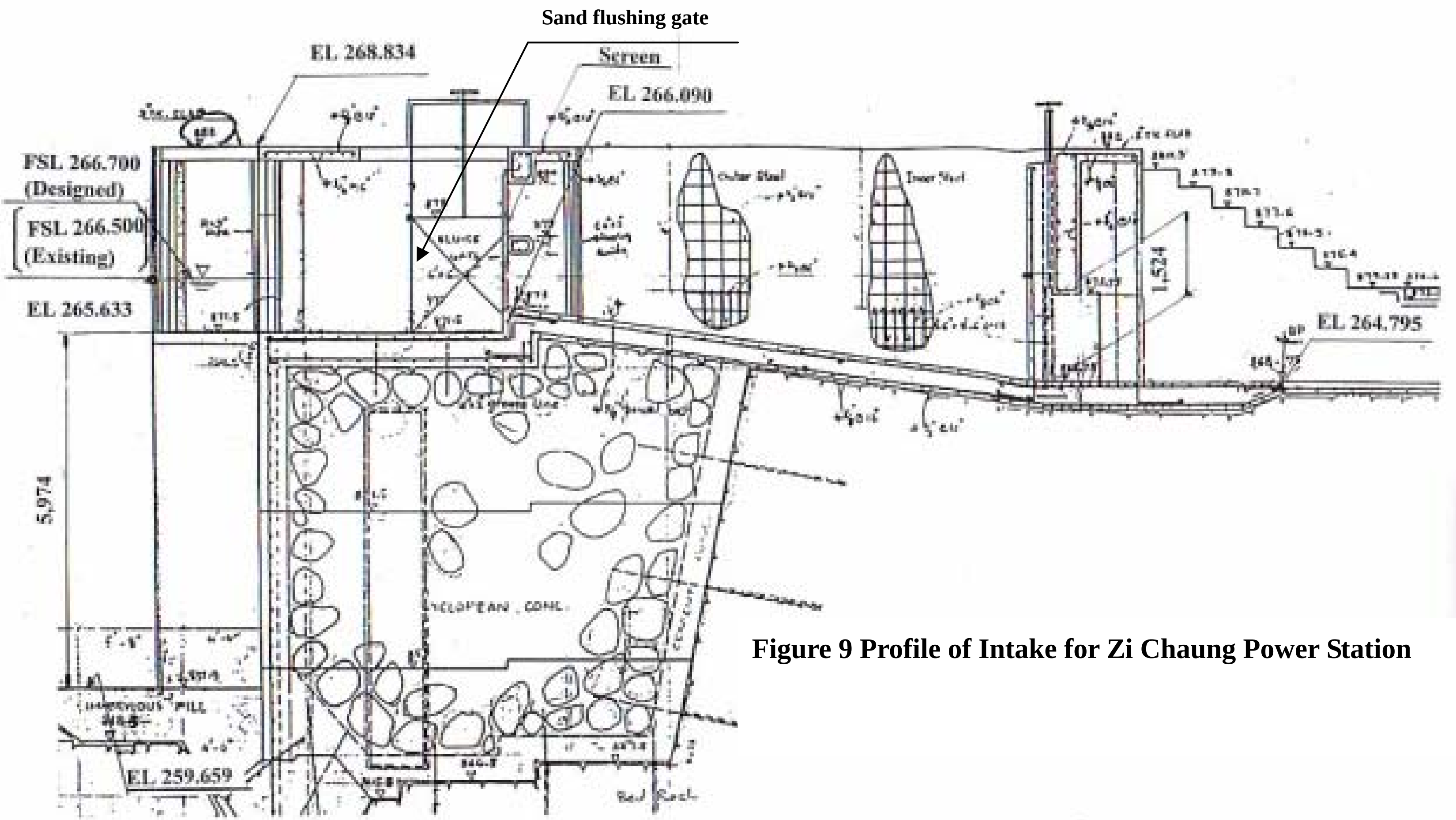


Figure 9 Profile of Intake for Zi Chaung Power Station

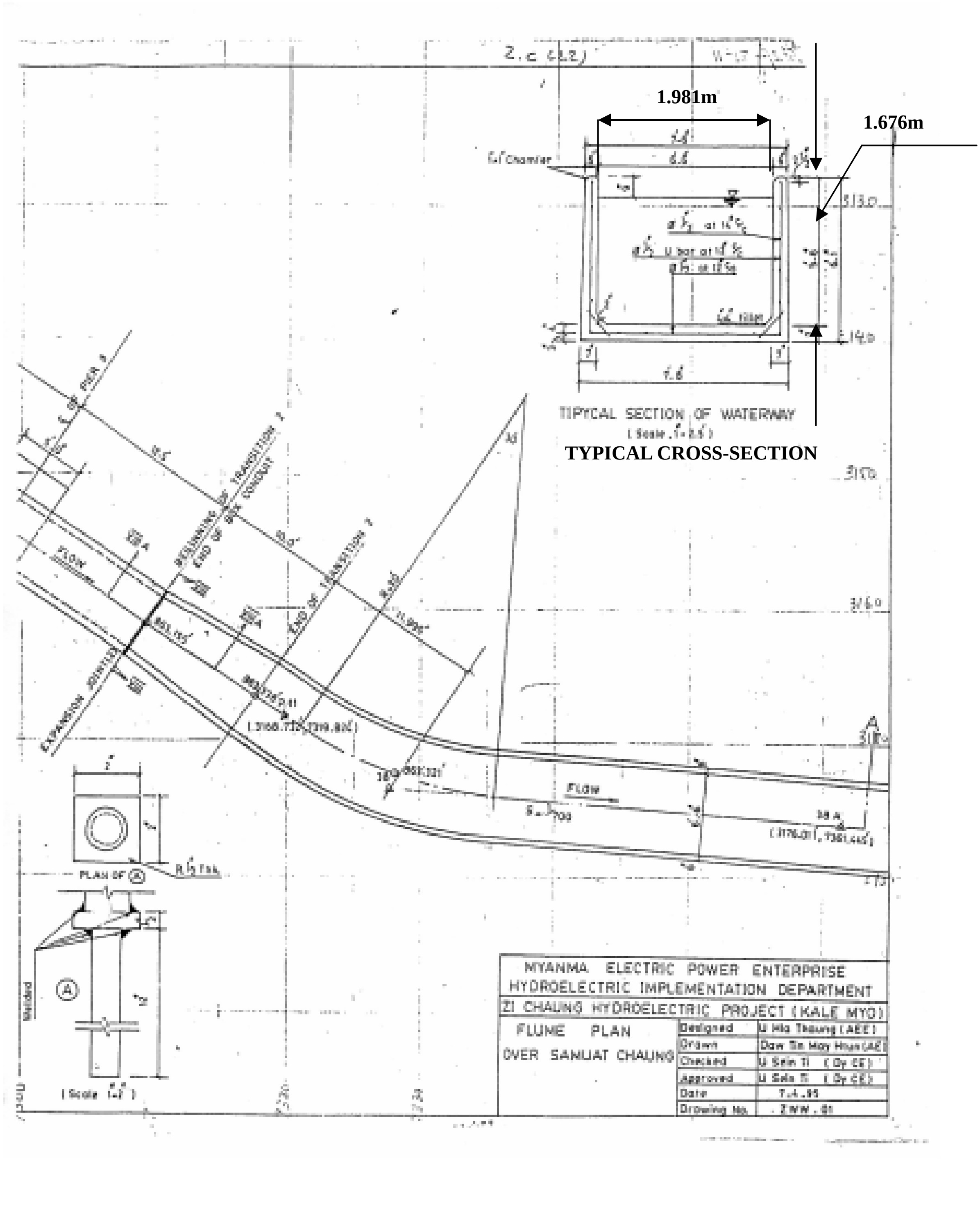


Figure 10 Typical Cross-Section of Headrace Canal for Zi Chaung Power Station

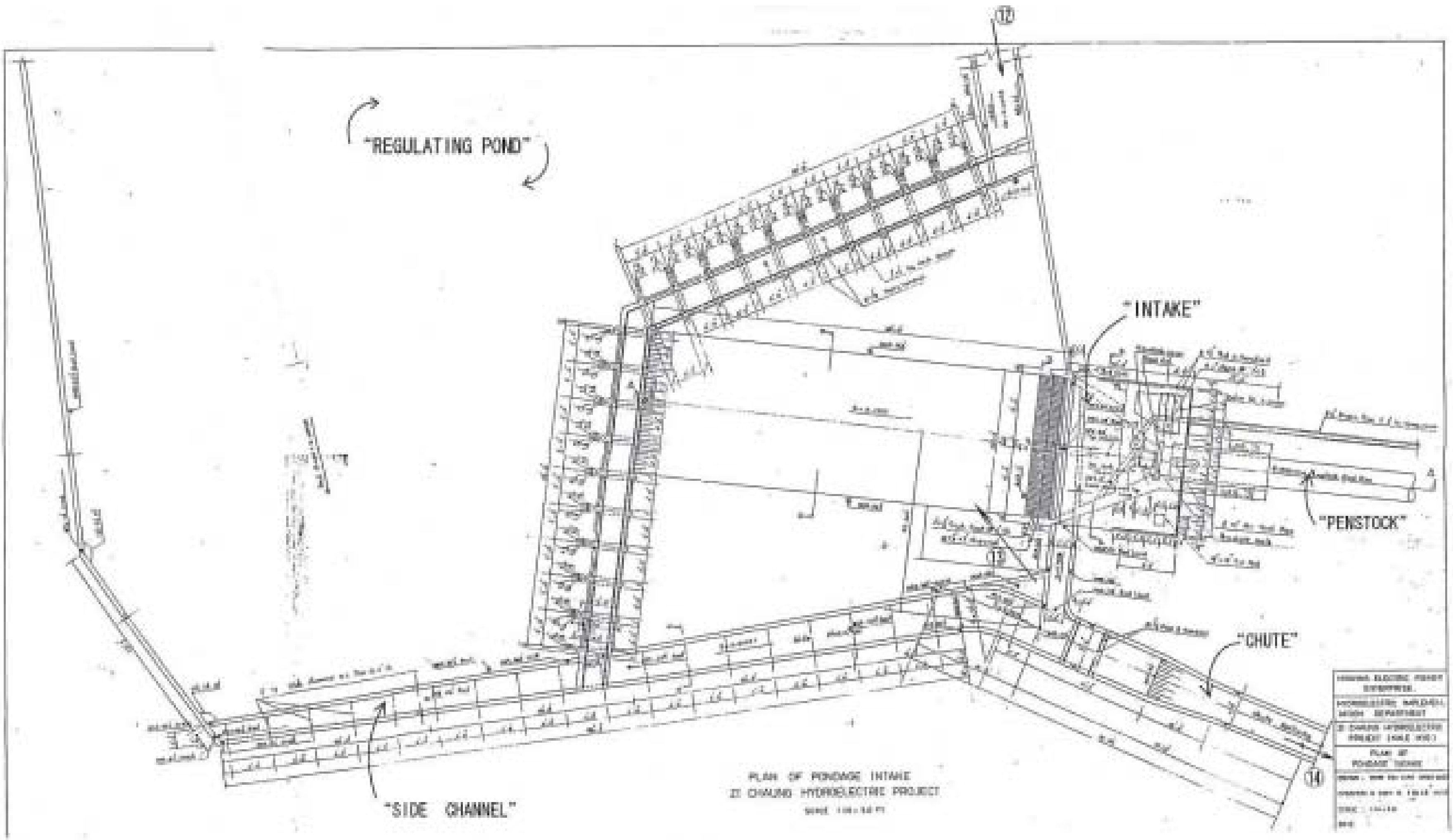


Figure 11 Plan of Regulating Basin for Zi Chaung Power Station

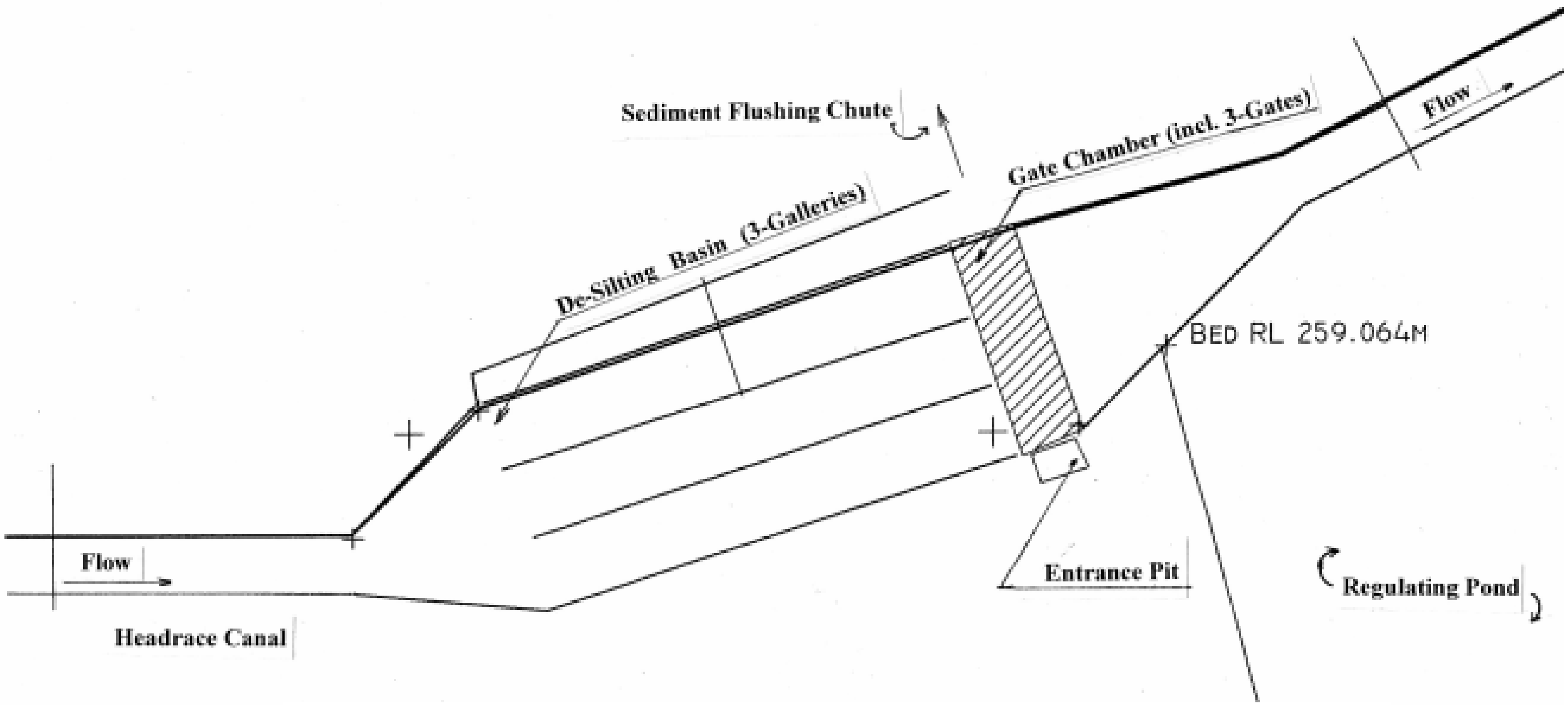


Figure 12 Schematic Plan of De-Silting Basin for Zi Chaung Power Station

De-Silting Basin & Regulating Pond

De-Silting Basin & Headrace Canal

De-Silting Basin

Photo 2 De-Silting Basin for Zi Chaung Power Station

Appendix 14
Monitoring Data for Civil Works Structures of Zi Chaung Power Station

1. Monitoring Data of Discharge Measurement

Table 1 Summary of Discharge Measurement

No.	Location	Discharge (m^3/s)	Leakage (m^3/s)	Percentage (%)
1	Downstream face of 2nd concrete cover about 100 m downstream of intake	1.74	-	
2	Upstream face of the concrete cover about 200 m downstream of intake	1.74	-	
3	Upstream of de-silting basin	1.35	-	
4	Just upstream of inlet of head pond	1.21	-	69.5
	(Available discharge of power generation)			
5	Water leakage to upstream of de-silting basin	-	0.39	22.4
6	Total of water leakage:	-	0.53	30.5
	(Water leakage to just upstream of inlet of head pond)			

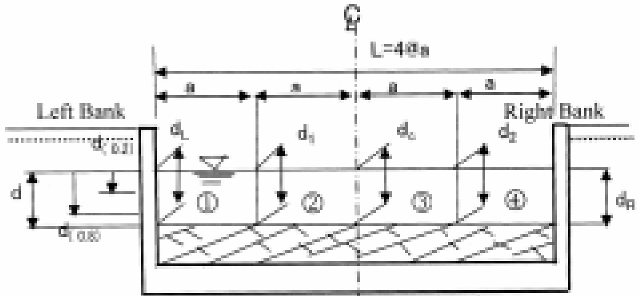
Table 2 Calculation of Discharge

No.	Location	Velocity (m/sec)			Passage Area (m^2)			Discharge (m^2)
		①+②	③+④	Ave.	①+②	③+④	Total	(m^3/s)
1	Downstream face of 2nd concrete cover about 100 m downstream of intake	1.35	1.34	1.35	0.635	0.657	1.29	1.74
2	Upstream face of concrete cover 200 m downstream of intake	1.32	1.40	1.36	0.646	0.633	1.28	1.74
3	Upstream of de-silting basin	0.884	0.774	0.829	0.820	0.805	1.63	1.35
4	Just upstream of inlet of head pond	0.399	0.429	0.414	1.46	1.45	2.91	1.21

Table 3 Data of Discharge Measurement at Downstream Face of 2nd Cover

DATE: May 24, 2003

LOCATION: Downstream face of the 2nd cover



Cross-Section of Canal

1. MEASURED DATA:

(1-1) Length of Canal:

L= 197.0 cm

a= 49.25 cm

(1-2) Water Depth at Two (2) Locations:

d_L= 64.5 cm

d_R= 66.7 cm

d_{AVE} = (64.5+66.7)/2= 65.6 (cm)

(1-3) Water Depth of Velocity Measurement:

$d_{AVE(0.2)}$= 65.6 x 0.2= 13.1 cm

$d_{AVE(0.8)}$= 65.6 cm x 0.8= 52.5 cm

(1-4) Sound and duration at $d_{1(0.2)}$

No.	Sound**	Duration
1	9	21.20
2	9	21.25
3	9	20.97
Average	9	21.14

(1-5) Sound and duration at $d_{1(0.8)}$

No.	Sound**	Duration
1	7	22.34
2	8	22.79
3	8	24.42
Average	7.67	23.18

(1-6) Sound and duration at $d_{2(0.2)}$

No.	Sound**	Duration
1	10	23.13
2	9	21.77
3	9	21.47
Average	9.33	22.12

(1-7) Sound and duration at $d_{2(0.8)}$

No.	Sound**	Duration
1	8	25.00
2	7	21.14
3	7	21.74
Average	7.33	22.63

2. CALCULATION:

(2-1) Velocity

Location	Average		N= S / T	V = 0.716N - 0.001	V_{mean}
	Sound: S (nos.)	Duration: T (sec)	(nos./sec)	(m/sec)	(m/sec)
$d_{1(0.2)}$	9	21.14	2.13	1.52	1.35
$d_{1(0.8)}$	7.67	23.18	1.65	1.18	
$d_{2(0.2)}$	9.33	22.12	2.11	1.51	1.34
$d_{2(0.8)}$	7.33	22.63	1.62	1.16	

Note: **: 1 Sound: per 5 rotations

(2-2) Flow Passage Area:

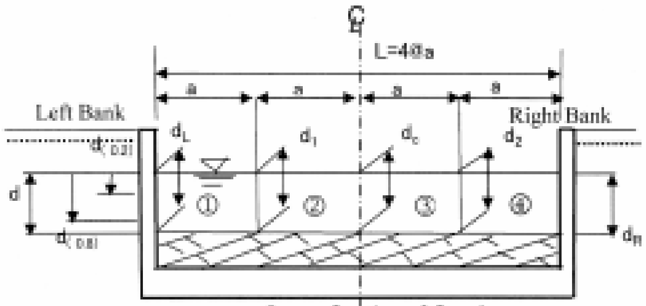
Passage Block	2a (m)	d_L (m)	d_R (m)	Area (m^2)
①+②	0.985	0.645		0.635
③+④	0.985		0.667	0.657

(2-3) Discharge

Passage Block	$V_{(mean)}$ (m/sec)	Area (m^2)	Discharge (m^3/s)
①+②	1.35	0.635	0.857
③+④	1.34	0.657	0.880
Total		Q (m^3/s) =	1.74

Table 4 Data of Discharge Measurement at 200 m Down Stream of Intake

DATE: May 28, 2003
LOCATION: 300 m downstream of the intake



Cross-Section of Canal

1. MEASURED DATA:

(1-1) Length of Canal
L= 200.0 cm
a= 50.0 cm

(1-2) Water Depth at Five (5) Locations:
d_L= 65.9 cm
d_c= 63.3 cm
d_R= 63.2 cm
d_{AVE} = (65.9+63.3+63.2)/3= 64.1 (cm)

(1-3) Water Depth of Velocity Measurement:
$d_{AVE(0.2)}$= 64.1 x 0.2= 12.8 cm
$d_{AVE(0.8)}$= 64.1 cm x 0.8= 51.3 cm

(1-4) Sound and duration at $d_{1(0.2)}$

No.	Sound**	Duration
1	18	45.00
2	20	45.00
3	20	45.25
4	20	45.28
Average	19.5	45.13

(1-5) Sound and duration at $d_{1(0.8)}$

No.	Sound**	Duration
1	14	45.69
2	14	47.49
3	14	44.60
4	14	45.32
Average	14	45.78

(1-6) Sound and duration at $d_{2(0.2)}$

No.	Sound**	Duration
1	20	42.90
2	20	45.13
3	20	43.00
4	20	43.90
Average	20	43.73

(1-7) Sound and duration at $d_{2(0.8)}$

No.	Sound**	Duration
1	14	43.53
2	14	42.75
3	14	43.03
4	14	44.30
Average	14	43.40

2. CALCULATION:

(2-1) Velocity

Location	Average		N= S / T	V = 0.716N − 0.001	V_{mean}
	Sound: S (nos.)	Duration: T (sec)	(nos./sec)	(m/sec)	(m/sec)
$d_{1(0.2)}$	19.5	45.13	2.16	1.55	1.32
$d_{1(0.8)}$	14	45.78	1.53	1.09	
$d_{2(0.2)}$	20	43.73	2.29	1.64	1.40
$d_{2(0.8)}$	14	43.4	1.61	1.15	

Note: **: 1 Sound: per 5 rotations

(2-2) Flow Passage Area:

Passage Block	2a (m)	d_L (m)	d_c (m)	d_R (m)	d_{mean} (m)	Area (m^2)
①+②	1	0.659	0.633		0.646	0.646
③+④	1		0.633	0.632	0.633	0.633

(2-3) Discharge

Passage Block	$V_{(mean)}$ (m/sec)	Area (m^2)	Discharge (m^3/s)
①+②	1.32	0.646	0.853
③+④	1.40	0.633	0.886
Total		Q (m^3/s) =	1.74

Table 5 Data of Discharge Measurement at Upstream of De-silting Basins

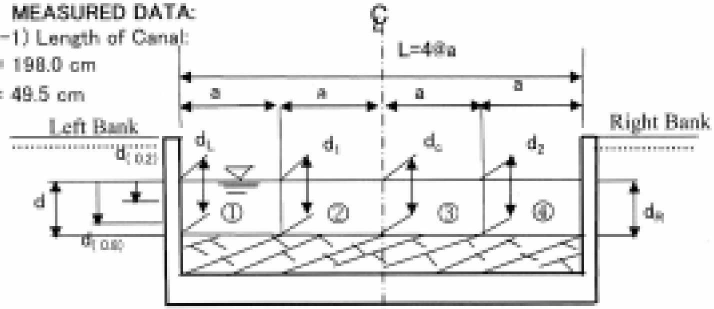
DATE: May 28, 2003
LOCATION: Just upstream of the inlet of de-silting basin

1. MEASURED DATA:

(1-1) Length of Canal:

L= 198.0 cm

a= 49.5 cm



Cross-Section of Canal

(1-2) Water Depth at Five (5) Locations:

d_L= 81.0 cm

d_1= 83.5 cm

d_c= 83.5 cm

d_2= 81.0 cm

d_R= 80.0 cm

(1-3) Water Depth of Velocity Measurement:

$d_{1(0.2)}$= (81.0+83.5+83.5)/3 x 0.2= 82.7 x 0.2 = 16.5 cm

$d_{1(0.8)}$= 82.7 cm x 0.8= 66.2 cm

$d_{2(0.2)}$= (83.5+81.0+80.0)/3 x 0.2= 81.5 x 0.2 cm= 16.3 cm

$d_{2(0.8)}$= 81.5 cm x 0.8= 65.2 cm

2. CALCULATION:

(2-1) Velocity

No.	Location	1st Measurement		2nd Measurement		Average		N= S / T	Velocity = 0.716N−0.001	V_{mean}
		Sound**: S (nos.)	Duration: T (sec)	Sound**: S (nos.)	Duration: T (sec)	Sound S (nos.)	Duration: T (sec)	(nos./sec)	(m/sec)	(m/sec)
1	$d_{1(0.2)}$	11	42.00	10	40.80	10.5	41.40	1.27	0.909	
2	$d_{1(0.8)}$	10	42.00	10	41.53	10.0	41.77	1.20	0.859	0.884
3	$d_{2(0.2)}$	10	43.50	10	46.47	10.0	44.99	1.11	0.795	
4	$d_{2(0.8)}$	10	49.00	10	46.37	10.0	47.69	1.05	0.752	0.774

Note: **: 1 Sound: per 5 rotations

(2-2) Flow Passage Area:

Bkock No.	a (m)	d_L (m)	d_1 (m)	d_c (m)	d_2 (m)	d_R (m)	d_{mean} (m)	Area (m^2)
①	0.495	0.81	0.835				0.823	0.407
②	0.495		0.835	0.835			0.835	0.413
③	0.495			0.835	0.81		0.823	0.407
④	0.495				0.81	0.8	0.805	0.398

(2-3) Discharge

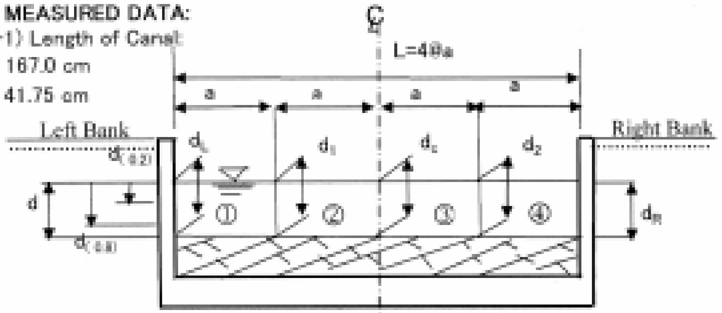
Passage Block	$V_{(mean)}$ (m/sec)	Area (m^2)	Discharge (m^3/s)
①+②	0.884	0.820	0.725
③+④	0.774	0.805	0.623
Total		Q (m^3/s) =	1.35

Table 6 Data of Discharge Measurement at Just Upstream Inlet of Head Pond

DATE: May 29, 2003
LOCATION: Just upstream of the inlet of head pond

1. MEASURED DATA:

(1-1) Length of Canal:
L= 167.0 cm
a= 41.75 cm



Cross-Section of Canal

(1-2) Water Depth at Five (5) Locations:
d_L= 175 cm
d_1= 175 cm
d_c= 174 cm
d_2= 174 cm
d_R= 172 cm

(1-3) Water Depth of Velocity Measurement:
$d_{1(0.2)}$= 175 cm x 0.2= 35.0 cm
$d_{1(0.8)}$= 175 cm x 0.8= 140.0 cm
$d_{2(0.2)}$= 174 cm x 0.2= 34.8 cm
$d_{2(0.8)}$= 174 cm x 0.8= 139.2 cm

2. CALCULATION:

(2-1) Velocity

No.	Location	1st Measurement		2nd Measurement		Average		N= S / T	Velocity	V_{mean}
		Sound** S (nos.)	Duration: T (sec)	Sound**: S (nos.)	Duration: T (sec)	Sound S (nos.)	Duration: T (sec)	(nos./sec)	= 0.716N−0.001 (m/sec)	(m/sec)
1	$d_{1(0.2)}$	14	22.38	14	23.33	14	22.86	0.612	0.438	
2	$d_{1(0.8)}$	13	25.59	13	26.27	13	25.93	0.501	0.359	0.399
3	$d_{2(0.2)}$	13	21.50	13	21.23	13	21.37	0.608	0.435	
4	$d_{2(0.8)}$	14	24.05	14	23.37	14	23.71	0.590	0.422	0.429

Note: **: 1 Sound: per 1 rotation

(2-2) Flow Passage Area:

Bkock No.	a (m)	d_L (m)	d_1 (m)	d_c (m)	d_2 (m)	d_R (m)	d_{mean} (m)	Area (m^2)
①	0.4175	1.75	1.75				1.75	0.731
②	0.4175		1.75	1.74			1.75	0.731
③	0.4175			1.74	1.74		1.74	0.726
④	0.4175				1.74	1.72	1.73	0.722

(2-3) Discharge

Passage Block	$V_{(mean)}$ (m/sec)	Area (m^2)	Discharge (m^3/s)
①+②	0.399	1.46	0.583
③+④	0.429	1.46	0.626
Total		Q (m^3/s) =	1.21

2. Monitoring Data of Sand Flushing

Table 7 Result of Sieve Analysis for 'Sample-Silt' and 'Sample-Sand'

No.	Name of Sample	Sieve Analysis (%)				
		Clay	Silt	Sand	Gravel	Total
1	Sample-Silt	20	54	26	0	100
2	Sample-Sand	8	18	73	1	100

Table 8 Result of Sieve Analysis for 'Sample-Gravel'

Sieve Size (mm)	Retaining (g)	Retaining (%)	Accumulation of Retaining (%)	Accumulation of Passing (%)
15.0	21.95	1.098	1.098	98.90
10.0	114.80	5.745	6.843	93.16
5.0	398.05	19.919	26.762	73.24
2.5	589.79	29.513	56.275	43.72
1.2	511.57	25.599	81.874	18.13
0.6	235.90	11.805	93.679	6.32
0.3	82.07	4.107	97.786	2.21
0.15	17.20	0.860	98.646	1.35
less than 0.15	27.06	1.354		
Total	1998.39			

Table 9 Percentage of Flushed Sand or Gravel in Total Flushed Material

No.	Name of Sample	Weight of Flushed Gravel or Sand (g)	Total Weight of Flushed Material (g)	Percentage of Gravel or Sand (%)
1	Sample-Gravel	398.6	25530 *1	1.6
2	Sample-Sand	1072.8	25530 *1	4.2
Note: *1: Volume of basin: V= π x42.5^2/4X18 cm^3 = 25530 cm^3				