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APPENDIX A.2.2-1 Hydraulics of Open Transitions (1), (2) and (3)

OPEN TRANSITION (1) : (Open Canal (B=14m) → Open Canal (B=12m))

Distance (km)	Length of Open Trans. (m)	Bottom Elevation (EL. m)	Water Level (EL. m)	Water Depth (m)	Velocity (m/sec)	Velocity Head (m)	Head Loss (m)	Specific Energy (EL. m)	Possible Bottom Elv. (EL. m)	Remarks
86.500		10.14	13.64	3.50	0.716	hv1=0.03		13.67		
	15.00						0.00			
86.515		10.14*	13.45	3.31	0.854	hv2=0.04		13.67	10.36	

Head Loss (Transition Head Loss) = fc x (hv2 – hv1) = 0.1 x (0.04 – 0.03) = 0.00

Note : The bottom elevation at downstream end is decided to be same as the bottom elevation at upstream end in order to prevent sand deposit on the canal bottom.

OPEN TRANSITION (2) : (Open Canal (B=12m) → 4-Cell Box (3.7m x 3.7m x 4))

Distance (km)	Length of Open Trans. (m)	Bottom Elevation (EL. m)	Water Level (EL. m)	Water Depth (m)	Velocity (m/sec)	Velocity Head (m)	Head Loss (m)	Specific Energy (EL. m)	Possible Bottom Elv. (EL. m)	Remarks
94.270		9.52	12.83	3.31	0.854	hv1=0.04		12.87		
	30.00						0.01			
94.300		9.45	12.80	3.35	1.062	hv2=0.06		12.86	9.45	

Head Loss (Transition Head Loss) = fc x (hv2 – hv1) = 0.5 x (0.06 – 0.04) = 0.01

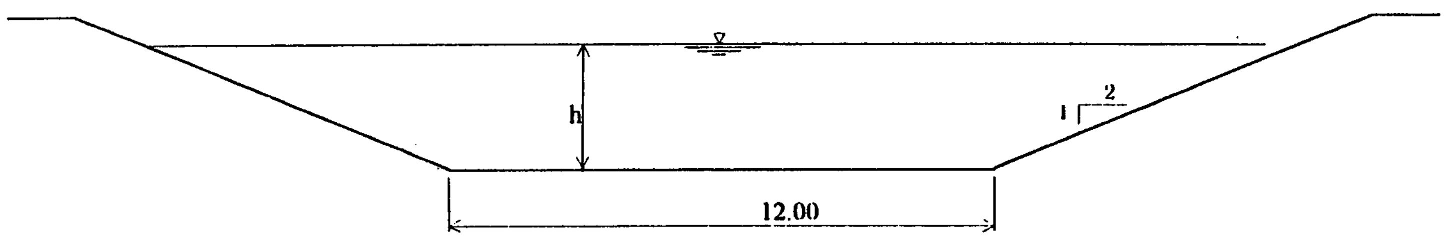
OPEN TRANSITION (3) : (4-Cell Box (3.7m x 3.7m x 4) → Open Canal (B=12m))

Distance (km)	Length of Open Trans. (m)	Bottom Elevation (EL. m)	Water Level (EL. m)	Water Depth (m)	Velocity (m/sec)	Velocity Head (m)	Head Loss (m)	Specific Energy (EL. m)	Possible Bottom Elv. (EL. m)	Remarks
101.800		7.95	11.30	3.35	1.062	hv1=0.06		11.36		
	30.00						0.02			
101.830		7.95*	11.26	3.31	0.854	hv2=0.04		11.34	7.99	

Head Loss (Transition Head Loss) = fe x (hv1 – hv2) = 1.0 x (0.06 – 0.04) = 0.02

Note : The bottom elevation at downstream end is decided to be same as the bottom elevation at upstream end in order to prevent sand deposit on the canal bottom.

APPENDIX A.2.3-1 Detailed Hydraulic Properties of Open Canal



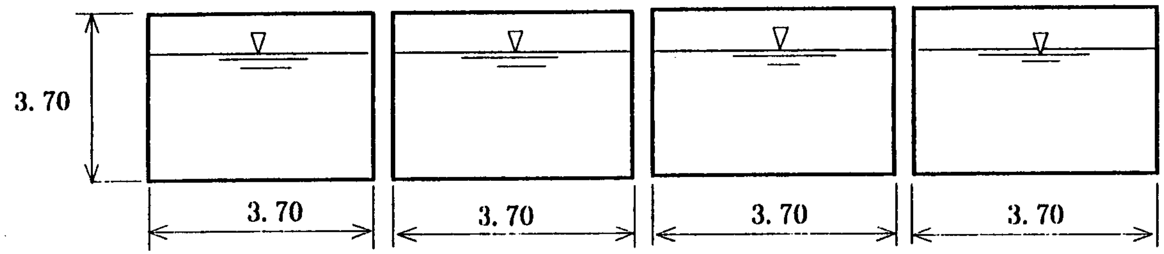
	Symbol	unit	Stage I Min. Discharge	Stage I Ave. Discharge	Stage I Max. Discharge	Stage II Min. Discharge	Stage II Ave.. Discharge	Stage II Max. Discharge
Design Discharge	Q	m^3/s	8.09	16.98	32.48	13.93	28.05	52.66
Hydraulic Gradient	I		0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Roughness Coefficient	1/n		55	55	55	55	55	55
Assumed Water Depth	h'	m	1.17	1.79	2.55	1.60	2.36	3.31
Flow Area	A	m^2	16.78	27.83	43.61	24.32	39.51	61.63
Wetted Perimeter	P	m	17.23	19.99	23.40	19.16	22.56	26.80
Hydraulic Radius	R	m	0.974	1.392	1.864	1.269	1.751	2.300
	$R^{2/3}$		0.983	1.247	1.515	1.172	1.453	1.742
Velocity	V	m/s	0.483	0.613	0.745	0.577	0.715	0.857
Estimated Discharge	Q'	m^3/s	8.10	17.06	32.49	14.03	28.25	52.82
Friction Velocity	U_*	cm/s	2.76	3.30	3.82	3.15	3.71	4.25
Critical Tractive Particle Size	d_{max}	mm	1.0	1.4	1.8	1.3	1.7	2.3
Design Water Depth	h	m	1.17	1.79	2.55	1.60	2.36	3.31

Manning' Formula $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^*/1.2)^2 \times 10/55.0$

APPENDIX A.2.3-2 Detailed Hydraulic Properties of 4-Cell Box Culvert



	Symbol	unit	Stage I			Stage II		
			Min. Discharge	Ave. Discharge	Max. Discharge	Min. Discharge	Ave. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	8.09	16.98	32.48	13.93	28.05	52.66
Hydraulic Gradient	I		0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
Roughness Coefficient	1/n		67	67	67	67	67	67
Assumed Water Depth	h'	m	0.82	1.38	2.29	1.19	1.98	3.35
Flow Area	A	m^2	12.14	20.42	33.89	17.61	29.37	49.58
Wetted Perimeter	P	m	21.36	25.84	33.12	24.32	30.67	41.60
Hydraulic Radius	R	m	0.568	0.790	1.023	0.724	0.958	1.192
	$R^{2/3}$		0.686	0.855	1.015	0.806	0.972	1.124
Velocity	V	m/s	0.650	0.810	0.962	0.764	0.921	1.065
Estimated Discharge	Q'	m^3/s	7.89	16.54	32.60	13.45	27.05	52.80
Friction Velocity	U_*	cm/s	3.34	3.93	4.48	3.77	4.33	4.83
Critical Tractive Particl	d_{max}	mm	1.4	2.0	2.5	1.8	2.4	2.9
Design Water Depth	h	m	0.82	1.38	2.29	1.19	1.98	3.35

Manning' Formula $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^*/1.2)^2 \times 10/55.0$

APPENDIX A.2.3-3 Hydraulic Design of Delivery Pressured Pipeline

(1) Calculation of Head Loss

Calculations of hydraulic head losses for each pump unit operation between beginning point of pipeline KM 108.985 and end point of pipeline KM 118.360 are tabulated in the following tables;

Table 1; Q = 10.827 m^3/s, 3 pumps operation

Table 2; Q = 7.977 m^3/s, 2 pumps operation

Table 3; Q = 4.300 m^3/s, 1 pump operation

Table 1 Q=10.827 m^3/s, 3 pumps operation

Calculation of Head Loss

Case : Stage I max, Q = 10.827 m^3/s (3 Pump) × 3 lane

Route Name : North Sinai
Q = 10.827 (m3/s) D = 2400 (mm) V = 2.3933 (m/s) hv = 0.292237 (m) C = 130 I = 0.15117 (%) Enl = 107.937 (m)

Mesure Point	Real Pipe Length(m)	Compound Angle(D.M.S)	Entrance (m)	Friction (m)	Bend (m)	Valve (m)	Flowmeter (m)	Branch (m)	Transition (m)	Energy (m)	Dynamic Head(m)
108km 985	0.000	0 0 0	0.000 (0.0)	0.000	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	107.937	107.645
109km157.62	172.823	34 48 45	0.000 (0.0)	0.261	0.029 (0.100)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	107.647	107.355
IP.16Survey	118.028	0 43 14	0.000 (0.0)	0.178	0.001 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	107.468	107.176
110km 0	760.003	0 41 15	0.000 (0.0)	1.149	0.001 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	106.318	106.026
110km 300	300.167	22 32 52	0.000 (0.0)	0.454	0.021 (0.073)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.843	105.551
110km315.69	15.690	22 28 45	0.000 (0.0)	0.024	0.021 (0.072)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.798	105.506
110km381.69	66.000	11 29 47	0.000 (0.0)	0.100	0.009 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.689	105.397
110km 410	30.100	11 29 47	0.000 (0.0)	0.046	0.009 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.634	105.342
110km553.65	143.650	10 54 58	0.000 (0.0)	0.217	0.008 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.409	105.117
IP.17	179.910	21 49 57	0.000 (0.0)	0.272	0.020 (0.069)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	105.117	104.825
110km964.31	179.910	10 54 59	0.000 (0.0)	0.272	0.008 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	104.837	104.545
111km746.14	781.831	26 25 11	0.000 (0.0)	1.182	0.028 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	103.627	103.335
111km992.58	246.445	26 25 35	0.000 (0.0)	0.373	0.028 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	103.226	102.934
112km 115.8	123.245	0 5 57	0.000 (0.0)	0.186	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	103.040	102.748
112km 500	392.825	1 23 9	0.000 (0.0)	0.594	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	102.445	102.153
112km 800	300.001	1 39 56	0.000 (0.0)	0.454	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.990	101.698
113km 200	400.195	2 35 47	0.000 (0.0)	0.605	0.002 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.383	101.091
IP.19	177.598	12 20 38	0.000 (0.0)	0.268	0.010 (0.033)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.105	100.813
113km 500	117.254	2 42 14	0.000 (0.0)	0.177	0.002 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.926	100.634
113km 750	250.002	0 29 56	0.000 (0.0)	0.378	0.000 (0.001)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.548	100.256
IP.20	212.362	9 44 56	0.000 (0.0)	0.321	0.007 (0.025)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.220	99.928
114km 691	733.126	23 57 17	0.000 (0.0)	1.108	0.024 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	99.088	98.796
114km 700	9.853	23 59 45	0.000 (0.0)	0.015	0.024 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	99.049	98.757
114km740.1	40.100	7 37 10	0.000 (0.0)	0.061	0.006 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.982	98.690
114km 770	30.170	7 44 22	0.000 (0.0)	0.046	0.006 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.930	98.638
115km 200	430.107	1 32 47	0.000 (0.0)	0.650	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.279	97.987
115km382.14	182.142	9 59 59	0.000 (0.0)	0.275	0.008 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.996	97.704
115km558.46	164.972	9 59 59	0.000 (0.0)	0.249	0.008 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.739	97.447
115km 800	241.543	0 0 0	0.000 (0.0)	0.365	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.374	97.082
116km 400	600.006	0 0 0	0.000 (0.0)	0.907	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.467	96.175
117km 50	650.007	2 1 37	0.000 (0.0)	0.983	0.002 (0.005)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.482	95.190
117km 300	250.200	1 43 3	0.000 (0.0)	0.378	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.103	94.811
118km 0	700.035	1 15 42	0.000 (0.0)	1.058	0.001 (0.003)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.044	93.752
IP.22	306.097	30 4 22	0.000 (0.0)	0.463	0.025 (0.085)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.556	93.264
118km 360	47.350	0 0 0	0.292 (1.0)	0.072	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.192	92.900
			0.292	14.141	0.312	0.000	0.000	0.000	0.000		14.745 (m) Total Head Loss

Table 2 Q=7.977 m³/s, 2 pumps operation

Calculation of Head Loss

Case : Stage *I* , Q = 7.977 m^3/s *(2 Pump)* ×3 *lane*

Route Name : North Sinai
Q = 7.977 (m3/s) D = 2400 (mm) V = 1.7633 (m/s) hv = 0.158635 (m) C = 130 I = 0.08591 (%) EnI = 101.322 (m)

Mesure Point	Real Pipe Length(m)	Compound Angle(D.M.S)	Entrance (m)	Friction (m)	Bend (m)	Valve (m)	Flowmeter (m)	Branch (m)	Transition (m)	Energy (m)	Dynamic Head(m)
108km 985	0.000	0 0 0	0.000 (0.0)	0.000	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.322	101.163
109km157.62	172.823	34 48 45	0.000 (0.0)	0.148	0.016 (0.100)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.158	100.999
IP.16Survey	118.028	0 43 14	0.000 (0.0)	0.101	0.000 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	101.057	100.898
110km 0	760.003	0 41 15	0.000 (0.0)	0.653	0.000 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.404	100.245
110km 300	300.167	22 32 52	0.000 (0.0)	0.258	0.012 (0.073)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.134	99.975
110km315.69	15.690	22 28 45	0.000 (0.0)	0.013	0.011 (0.072)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.110	99.951
110km381.69	66.000	11 29 47	0.000 (0.0)	0.057	0.005 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.048	99.889
110km 410	30.100	11 29 47	0.000 (0.0)	0.026	0.005 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	100.017	99.858
110km553.65	143.650	10 54 58	0.000 (0.0)	0.123	0.005 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	99.889	99.730
IP.17	179.910	21 49 57	0.000 (0.0)	0.155	0.011 (0.069)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	99.723	99.564
110km964.31	179.910	10 54 59	0.000 (0.0)	0.155	0.005 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	99.563	99.404
111km746.14	781.831	26 25 11	0.000 (0.0)	0.672	0.015 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.876	98.717
111km992.58	246.445	26 25 35	0.000 (0.0)	0.212	0.015 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.649	98.490
112km 115.8	123.245	0 5 57	0.000 (0.0)	0.106	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.543	98.384
112km 500	392.825	1 23 9	0.000 (0.0)	0.337	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	98.205	98.046
112km 800	300.001	1 39 56	0.000 (0.0)	0.258	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.946	97.787
113km 200	400.195	2 35 47	0.000 (0.0)	0.344	0.001 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.601	97.442
IP.19	177.598	12 20 38	0.000 (0.0)	0.153	0.005 (0.033)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.443	97.284
113km 500	117.254	2 42 14	0.000 (0.0)	0.101	0.001 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.341	97.182
113km 750	250.002	0 29 56	0.000 (0.0)	0.215	0.000 (0.001)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	97.126	96.967
IP.20	212.362	9 44 56	0.000 (0.0)	0.182	0.004 (0.025)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.940	96.781
114km 691	733.126	23 57 17	0.000 (0.0)	0.630	0.013 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.297	96.138
114km 700	9.853	23 59 45	0.000 (0.0)	0.008	0.013 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.276	96.117
114km740.1	40.100	7 37 10	0.000 (0.0)	0.034	0.003 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.239	96.080
114km 770	30.170	7 44 22	0.000 (0.0)	0.026	0.003 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	96.210	96.051
115km 200	430.107	1 32 47	0.000 (0.0)	0.369	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.840	95.681
115km382.14	182.142	9 59 59	0.000 (0.0)	0.156	0.004 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.680	95.521
115km558.46	164.972	9 59 59	0.000 (0.0)	0.142	0.004 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.534	95.375
115km 800	241.543	0 0 0	0.000 (0.0)	0.207	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.327	95.168
116km 400	600.006	0 0 0	0.000 (0.0)	0.515	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.812	94.653
117km 50	650.007	2 1 37	0.000 (0.0)	0.558	0.001 (0.005)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.253	94.094
117km 300	250.200	1 43 3	0.000 (0.0)	0.215	0.001 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.037	93.878
118km 0	700.035	1 15 42	0.000 (0.0)	0.601	0.001 (0.003)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.435	93.276
IP.22	306.097	30 4 22	0.000 (0.0)	0.263	0.013 (0.085)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.159	93.000
118km 360	47.350	0 0 0	0.159 (1.0)	0.041	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.959	92.800
			0.159	8.034	0.170	0.000	0.000	0.000	0.000		8.363 (m) Total Head Loss

Table 3 Q=4.300 m³/s, 1 pump operation

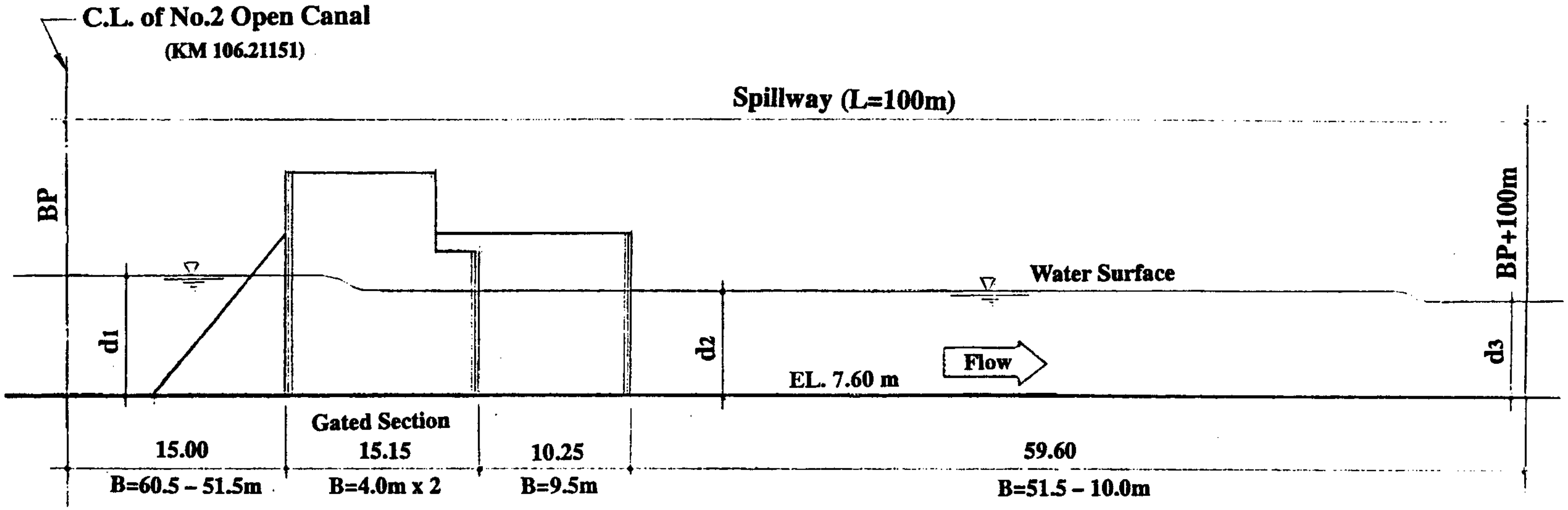
Calculation of Head Loss

Case : Stage *I min* , Q = 4.300 *m³/s (1 Pump)* ×3 *lane*

Route Name : North Sinai
Q = 4.300 (m3/s) D = 2400 (mm) V = 0.9505 (m/s) hv = 0.046095 (m) C = 130 I = 0.02739 (%) Enl = 95.196 (m)

Mesure Point	Real Pipe Length(m)	Compound Angle(D.M.S)	Entrance (m)	Friction (m)	Bend (m)	Valve (m)	Flowmeter (m)	Branch (m)	Transition (m)	Energy (m)	Dynamic Head(m)
108km 985	0.000	0 0 0	0.000 (0.0)	0.000	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.196	95.150
109km157.62	172.823	34 48 45	0.000 (0.0)	0.047	0.005 (0.100)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.144	95.098
IP.16Survey	118.028	0 43 14	0.000 (0.0)	0.032	0.000 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	95.112	95.066
110km 0	760.003	0 41 15	0.000 (0.0)	0.208	0.000 (0.002)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.904	94.858
110km 300	300.167	22 32 52	0.000 (0.0)	0.082	0.003 (0.073)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.819	94.773
110km315.69	15.690	22 28 45	0.000 (0.0)	0.004	0.003 (0.072)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.812	94.766
110km381.69	66.000	11 29 47	0.000 (0.0)	0.018	0.001 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.793	94.747
110km 410	30.100	11 29 47	0.000 (0.0)	0.008	0.001 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.784	94.738
110km553.65	143.650	10 54 58	0.000 (0.0)	0.039	0.001 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.744	94.698
IP.17	179.910	21 49 57	0.000 (0.0)	0.049	0.003 (0.069)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.692	94.646
110km964.31	179.910	10 54 59	0.000 (0.0)	0.049	0.001 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.642	94.596
111km746.14	781.831	26 25 11	0.000 (0.0)	0.214	0.004 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.424	94.378
111km992.58	246.445	26 25 35	0.000 (0.0)	0.067	0.004 (0.094)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.353	94.307
112km 115.8	123.245	0 5 57	0.000 (0.0)	0.034	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.319	94.273
112km 500	392.825	1 23 9	0.000 (0.0)	0.108	0.000 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.211	94.165
112km 800	300.001	1 39 56	0.000 (0.0)	0.082	0.000 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.129	94.083
113km 200	400.195	2 35 47	0.000 (0.0)	0.110	0.000 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	94.019	93.973
IP.19	177.598	12 20 38	0.000 (0.0)	0.049	0.002 (0.033)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.968	93.922
113km 500	117.254	2 42 14	0.000 (0.0)	0.032	0.000 (0.007)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.936	93.890
113km 750	250.002	0 29 56	0.000 (0.0)	0.068	0.000 (0.001)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.868	93.822
IP.20	212.362	9 44 56	0.000 (0.0)	0.058	0.001 (0.025)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.809	93.763
114km 691	733.126	23 57 17	0.000 (0.0)	0.201	0.004 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.604	93.558
114km 700	9.853	23 59 45	0.000 (0.0)	0.003	0.004 (0.081)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.597	93.551
114km740.1	40.100	7 37 10	0.000 (0.0)	0.011	0.001 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.585	93.539
114km 770	30.170	7 44 22	0.000 (0.0)	0.008	0.001 (0.020)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.576	93.530
115km 200	430.107	1 32 47	0.000 (0.0)	0.118	0.000 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.458	93.412
115km382.14	182.142	9 59 59	0.000 (0.0)	0.050	0.001 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.407	93.361
115km558.46	164.972	9 59 59	0.000 (0.0)	0.045	0.001 (0.026)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.361	93.315
115km 800	241.543	0 0 0	0.000 (0.0)	0.066	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.295	93.249
116km 400	600.006	0 0 0	0.000 (0.0)	0.164	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	93.131	93.085
117km 50	650.007	2 1 37	0.000 (0.0)	0.178	0.000 (0.005)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.953	92.907
117km 300	250.200	1 43 3	0.000 (0.0)	0.069	0.000 (0.004)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.884	92.838
118km 0	700.035	1 15 42	0.000 (0.0)	0.192	0.000 (0.003)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.692	92.646
IP.22	306.097	30 4 22	0.000 (0.0)	0.084	0.004 (0.085)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.604	92.558
118km 360	47.350	0 0 0	0.046 (1.0)	0.013	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	92.545	92.499
			0.046	2.560	0.045	0.000	0.000	0.000	0.000		2.651 (m) Total Head Loss

APPENDIX A.2.4-1 Hydraulics of Gated Sections



PROFILE OF SPILLWAY

Hydraulic Calculation of Gated Sections (4.0m wide x 2)

Q (m^3/sec)	d_3 (m)	V_3 (m/sec)	hv_3 (m)	d_2 (m)	V_1 (m/sec)	hv_1 (m)	d_1 (m)
51.0	2.61	1.95	0.20	2.91	2.19	0.24	3.27
51.5	2.62	1.97	0.20	2.92	2.20	0.25	3.30
◎ *52.0*	*2.63*	*1.98*	*0.20*	*2.93*	*2.22*	*0.25*	*3.31*
52.66	2.65	1.99	0.20	2.95	2.23	0.25	3.33

$d_2 = d_3 + 1.5 \times hv_3$, $V_1 = Q / (d_2 \times 4.0 \text{ m} \times 2)$, $d_1 = d_2 + 1.5 \times hv_1$

APPENDIX A.2.4-2 Hydraulic Computation of Flow in Discharge Canal

Q=52.66m³/sec

BED SLOPE : LEVEL (EL.7.60m), N=0.015

SECTION	DISTANCE	DELTAL	EL	WL	D	B	A	V	HV	HF	H1	H2
1 (BP+1,100m)	0.000	0.000	7.600	9.014	1.414	10.000	14.140	3.724	0.708			
2	12.000	12.000	7.600	9.186	1.586	10.000	15.859	3.321	0.563	0.028	0.173	0.172
3	24.000	12.000	7.600	9.252	1.652	10.000	16.523	3.187	0.518	0.022	0.066	0.066
4	36.000	12.000	7.600	9.303	1.703	10.000	17.031	3.092	0.488	0.020	0.050	0.051
5	48.000	12.000	7.600	9.342	1.742	10.000	17.421	3.023	0.466	0.018	0.040	0.039
6	60.000	12.000	7.600	9.377	1.777	10.000	17.773	2.963	0.448	0.017	0.035	0.035
7	72.000	12.000	7.600	9.409	1.809	10.000	18.085	2.912	0.433	0.016	0.031	0.031
8	84.000	12.000	7.600	9.436	1.836	10.000	18.359	2.868	0.420	0.015	0.028	0.027
9	96.000	12.000	7.600	9.463	1.863	10.000	18.632	2.826	0.408	0.015	0.027	0.027
10	108.000	12.000	7.600	9.487	1.887	10.000	18.866	2.791	0.397	0.014	0.024	0.023
11	120.000	12.000	7.600	9.510	1.910	10.000	19.101	2.757	0.388	0.014	0.023	0.023
12	132.000	12.000	7.600	9.532	1.932	10.000	19.316	2.726	0.379	0.013	0.022	0.021
13	144.000	12.000	7.600	9.551	1.951	10.000	19.511	2.699	0.372	0.013	0.020	0.020
14	156.000	12.000	7.600	9.571	1.971	10.000	19.706	2.672	0.364	0.012	0.020	0.020
15	168.000	12.000	7.600	9.590	1.990	10.000	19.902	2.646	0.357	0.012	0.019	0.020
16	180.000	12.000	7.600	9.610	2.010	10.000	20.097	2.620	0.350	0.012	0.019	0.020
17	192.000	12.000	7.600	9.627	2.027	10.000	20.273	2.598	0.344	0.011	0.017	0.018
18	204.000	12.000	7.600	9.643	2.043	10.000	20.429	2.578	0.339	0.011	0.016	0.016
19	216.000	12.000	7.600	9.659	2.059	10.000	20.585	2.558	0.334	0.011	0.016	0.016
20	228.000	12.000	7.600	9.674	2.074	10.000	20.741	2.539	0.329	0.011	0.016	0.016
21	240.000	12.000	7.600	9.690	2.090	10.000	20.898	2.520	0.324	0.010	0.015	0.016
22	252.000	12.000	7.600	9.705	2.105	10.000	21.054	2.501	0.319	0.010	0.015	0.016
23	264.000	12.000	7.600	9.719	2.119	10.000	21.191	2.485	0.315	0.010	0.014	0.014
24	276.000	12.000	7.600	9.733	2.133	10.000	21.327	2.469	0.311	0.010	0.014	0.014
25	288.000	12.000	7.600	9.746	2.146	10.000	21.464	2.453	0.307	0.010	0.013	0.014
26	300.000	12.000	7.600	9.758	2.158	10.000	21.581	2.440	0.304	0.009	0.013	0.012
27	312.000	12.000	7.600	9.770	2.170	10.000	21.698	2.427	0.301	0.009	0.012	0.012
28	324.000	12.000	7.600	9.782	2.182	10.000	21.815	2.414	0.297	0.009	0.012	0.012

EL : BTTOM ELEVATION (EL. m)
WL : WATER LEVEL (m)
D : WATER DEPTH (m)
B : BOTTOM WIDTH (m)
P : WETTED PERIMETER (m)
A : AREA OF FLOW (m²)
V : VELOCITY (m/sec)
HF : FRICTION LOSS (m)
HV : VELOCITY HEAD (m)

29	336.000	12.000	7.600	9.793	2.193	10.000	21.933	2.401	0.294	0.009	0.012	0.012
30	348.000	12.000	7.600	9.805	2.205	10.000	22.050	2.388	0.291	0.009	0.012	0.012
31	360.000	12.000	7.600	9.817	2.217	10.000	22.167	2.376	0.288	0.009	0.012	0.012
32	372.000	12.000	7.600	9.828	2.228	10.000	22.284	2.363	0.285	0.009	0.012	0.012
33	384.000	12.000	7.600	9.840	2.240	10.000	22.401	2.351	0.282	0.008	0.011	0.012
34	396.000	12.000	7.600	9.852	2.252	10.000	22.519	2.339	0.279	0.008	0.011	0.012
35	408.000	12.000	7.600	9.864	2.264	10.000	22.636	2.326	0.276	0.008	0.011	0.012
36	420.000	12.000	7.600	9.875	2.275	10.000	22.753	2.314	0.273	0.008	0.011	0.012
37	432.000	12.000	7.600	9.885	2.285	10.000	22.850	2.305	0.271	0.008	0.010	0.010
38	444.000	12.000	7.600	9.895	2.295	10.000	22.948	2.295	0.269	0.008	0.010	0.010
39	456.000	12.000	7.600	9.905	2.305	10.000	23.046	2.285	0.266	0.008	0.010	0.010
40	468.000	12.000	7.600	9.914	2.314	10.000	23.143	2.275	0.264	0.008	0.010	0.010
41	480.000	12.000	7.600	9.924	2.324	10.000	23.241	2.266	0.262	0.008	0.010	0.010
42	492.000	12.000	7.600	9.934	2.334	10.000	23.339	2.256	0.260	0.007	0.010	0.010
43	504.000	12.000	7.600	9.944	2.344	10.000	23.436	2.247	0.258	0.007	0.010	0.010
44	516.000	12.000	7.600	9.953	2.353	10.000	23.534	2.238	0.255	0.007	0.009	0.010
45	528.000	12.000	7.600	9.963	2.363	10.000	23.632	2.228	0.253	0.007	0.009	0.010
46	540.000	12.000	7.600	9.971	2.371	10.000	23.710	2.221	0.252	0.007	0.009	0.008
47	552.000	12.000	7.600	9.979	2.379	10.000	23.788	2.214	0.250	0.007	0.009	0.008
48	564.000	12.000	7.600	9.987	2.387	10.000	23.866	2.206	0.248	0.007	0.009	0.008
49	576.000	12.000	7.600	9.994	2.394	10.000	23.944	2.199	0.247	0.007	0.009	0.008
50	588.000	12.000	7.600	10.002	2.402	10.000	24.022	2.192	0.245	0.007	0.008	0.008
51	600.000	12.000	7.600	10.010	2.410	10.000	24.100	2.185	0.244	0.007	0.008	0.008
52	612.000	12.000	7.600	10.018	2.418	10.000	24.178	2.178	0.242	0.007	0.008	0.008
53	624.000	12.000	7.600	10.026	2.426	10.000	24.257	2.171	0.240	0.007	0.008	0.008
54	636.000	12.000	7.600	10.034	2.433	10.000	24.335	2.164	0.239	0.007	0.008	0.008
55	648.000	12.000	7.600	10.041	2.441	10.000	24.413	2.157	0.237	0.007	0.008	0.008
56	660.000	12.000	7.600	10.049	2.449	10.000	24.491	2.150	0.236	0.006	0.008	0.008
57	672.000	12.000	7.600	10.057	2.457	10.000	24.569	2.143	0.234	0.006	0.008	0.008
58	684.000	12.000	7.600	10.065	2.465	10.000	24.647	2.137	0.233	0.006	0.008	0.008
59	696.000	12.000	7.600	10.073	2.473	10.000	24.725	2.130	0.231	0.006	0.008	0.008
60	708.000	12.000	7.600	10.080	2.480	10.000	24.803	2.123	0.230	0.006	0.008	0.008
61	720.000	12.000	7.600	10.088	2.488	10.000	24.881	2.116	0.229	0.006	0.008	0.008

62	732.000	12.000	7.600	10.096	2.496	10.000	24.960	2.110	0.227	0.006	0.008	0.008
63	744.000	12.000	7.600	10.104	2.504	10.000	25.038	2.103	0.226	0.006	0.007	0.008
64	756.000	12.000	7.600	10.112	2.512	10.000	25.116	2.097	0.224	0.006	0.007	0.008
65	768.000	12.000	7.600	10.119	2.519	10.000	25.194	2.090	0.223	0.006	0.007	0.008
66	780.000	12.000	7.600	10.127	2.527	10.000	25.272	2.084	0.222	0.006	0.007	0.008
67	792.000	12.000	7.600	10.135	2.535	10.000	25.350	2.077	0.220	0.006	0.007	0.008
68	804.000	12.000	7.600	10.143	2.543	10.000	25.428	2.071	0.219	0.006	0.007	0.008
69	816.000	12.000	7.600	10.151	2.551	10.000	25.506	2.065	0.217	0.006	0.007	0.008
70	828.000	12.000	7.600	10.159	2.558	10.000	25.584	2.058	0.216	0.006	0.007	0.008
71	840.000	12.000	7.600	10.166	2.566	10.000	25.663	2.052	0.215	0.006	0.007	0.008
72	852.000	12.000	7.600	10.174	2.574	10.000	25.741	2.046	0.214	0.006	0.007	0.008
73	864.000	12.000	7.600	10.182	2.582	10.000	25.819	2.040	0.212	0.006	0.007	0.008
74	876.000	12.000	7.600	10.188	2.588	10.000	25.877	2.035	0.211	0.006	0.006	0.006
75	888.000	12.000	7.600	10.194	2.594	10.000	25.936	2.030	0.210	0.005	0.006	0.006
76	900.000	12.000	7.600	10.200	2.599	10.000	25.995	2.026	0.209	0.005	0.006	0.006
77	912.000	12.000	7.600	10.205	2.605	10.000	26.053	2.021	0.208	0.005	0.006	0.006
78	924.000	12.000	7.600	10.211	2.611	10.000	26.112	2.017	0.208	0.005	0.006	0.006
79	936.000	12.000	7.600	10.217	2.617	10.000	26.170	2.012	0.207	0.005	0.006	0.006
80	948.000	12.000	7.600	10.223	2.623	10.000	26.229	2.008	0.206	0.005	0.006	0.006
81	960.000	12.000	7.600	10.229	2.629	10.000	26.287	2.003	0.205	0.005	0.006	0.006
82	972.000	12.000	7.600	10.235	2.635	10.000	26.346	1.999	0.204	0.005	0.006	0.006
83	984.000	12.000	7.600	10.241	2.640	10.000	26.405	1.994	0.203	0.005	0.006	0.006
84	996.000	12.000	7.600	10.246	2.646	10.000	26.463	1.990	0.202	0.005	0.006	0.006
85 (BP+100m)	1000.000	4.000	7.600	10.248	2.648	10.000	26.483	1.988	0.202	0.002	0.002	0.002

APPENDIX A.2.4-3 Hydraulic Computation of Flow in Chute

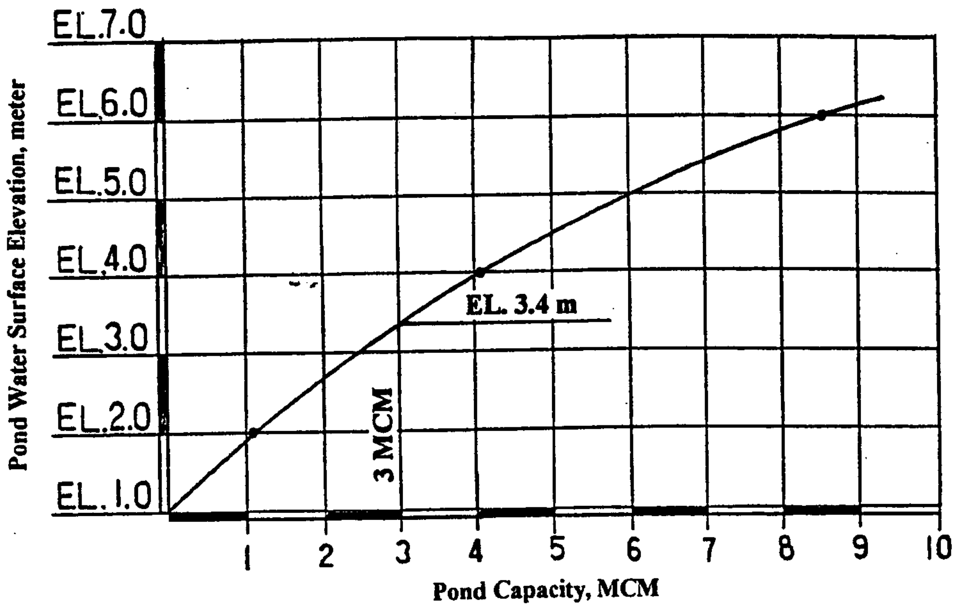
Q=52.66m³/sec BED SLOPE = 1 : 3, N=0.015

	DISTANCE	DELTAL	EL	D	B	P	A	R	V	HF	HV	H1	H2
(CONTROL POINT)	0.000		7.600	1.414	10.000	12.827	14.135	1.102	3.725		0.708		
	3.162	3.218	7.087	0.894	10.000	11.788	8.940	0.758	5.890	0.018	1.770	1.080	1.079
	6.000	2.991	6.141	0.705	10.000	11.410	7.050	0.618	7.470	0.049	2.847	1.126	1.125
	9.000	3.162	5.141	0.607	10.000	11.213	6.066	0.541	8.682	0.096	3.845	1.095	1.093
	12.000	3.162	4.141	0.545	10.000	11.091	5.453	0.492	9.658	0.144	4.759	1.058	1.058
	15.000	3.162	3.141	0.502	10.000	11.005	5.024	0.457	10.482	0.195	5.606	1.042	1.041
	18.000	3.162	2.141	0.471	10.000	10.941	4.707	0.430	11.189	0.247	6.387	1.029	1.030
	21.000	3.162	1.141	0.446	10.000	10.892	4.460	0.409	11.807	0.299	7.112	1.024	1.023
	22.923	2.027	0.500	0.433	10.000	10.866	4.330	0.399	12.161	0.219	7.545	0.652	0.653
(END OF CHUTE)	24.423	1.581	0.000	0.424	10.000	10.848	4.241	0.391	12.418	0.186	7.868	0.509	0.509
	25.923	1.581	-0.500	0.416	10.000	10.832	4.160	0.384	12.660	0.198	8.177	0.507	0.508
	27.423	1.581	-1.000	0.409	10.000	10.817	4.086	0.378	12.887	0.210	8.473	0.506	0.507
	28.923	1.581	-1.500	0.402	10.000	10.804	4.019	0.372	13.102	0.222	8.759	0.508	0.506
	30.423	1.581	-2.000	0.396	10.000	10.792	3.958	0.367	13.305	0.234	9.032	0.507	0.506
	31.923	1.581	-2.500	0.390	10.000	10.780	3.902	0.362	13.494	0.245	9.291	0.505	0.505

CONTROL POINT =BP+1,100.58 m END OF CHUTE=BP+1,125 m

EL	: BTTOM ELEVATION (EL. m)	R	: HYDRAULIC RADIUS (m)
D	: WATER DEPTH (m)	V	: VELOCITY (m/sec)
B	: BOTTOM WIDTH (m)	HF	: FRICTION LOSS (m)
P	: WETTED PERIMETER (m)	HV	: VELOCITY HEAD (m)
A	: AREA OF FLOW (m²)		

APPENDIX A.2.4-4 Detention Pond Capacity Curve



Pond Water Surface		Pond Capacity (1,000 m^3)
Elevation (EL. m)	Area (1,000m^2)	
EL. 1.0	938	0
EL. 2.0	1,209	1,073.5
EL. 4.0	1,783	4,065.5
EL. 6.0	2,675	8,523.5

APPENDIX A.2.5-1 Detailed Hydraulic Design of Sand Settling Basin

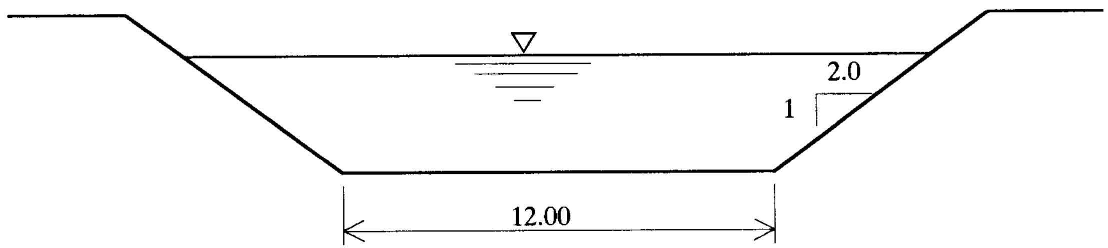
(1) Detailed Hydraulic Properties of Open Canal in Case of Pump Operation

The detailed hydraulic properties of open canal in case of pump operation are shown in Table 1.

(2) Designed Hydraulic Dimensions at Sand Settling Basin

The designed hydraulic dimensions at the sand settling basin are shown in Table 2 - 5.

Table 1 Detailed Hydraulic Properties of Open Canal in Case of Pump Operation



Dimension		
Stage I		
No. of Pump unit	unit	3
Design Discharge	m^3/s	32.48
Stage II		
No. of Pump unit	unit	2
Design Discharge	m^3/s	20.18

	Symbol	unit	Case of Design Discharge		Case of Pump Operation				
			Stage I	Stage II	1 unit	2 units	3 units	4 units	5 units
Design Discharge	Q	m^3/s	32.48	52.66	10.83	21.65	32.48	43.31	54.14
Hydraulic Gradient	I		0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Roughness Coefficient	1/n		55	55	55	55	55	55	55
Assumed Water Depth	h'	m	2.55	3.31	1.39	2.04	2.55	2.98	3.37
Flow Area	A	m^2	43.61	61.63	20.54	32.80	43.61	53.52	63.15
Wetted Perimeter	P	m	23.40	26.80	18.22	21.12	23.40	25.33	27.07
Hydraulic Radius	R	m	1.864	2.300	1.127	1.553	1.864	2.113	2.333
	$R^{2/3}$		1.515	1.742	1.083	1.341	1.515	1.647	1.759
Velocity	V	m/s	0.745	0.857	0.533	0.660	0.745	0.810	0.865
Estimated Discharge	Q'	m^3/s	32.49	52.82	10.95	21.65	32.49	43.35	54.62
Friction Velocity	U_*	cm/s	3.82	4.25	2.97	3.49	3.82	4.07	4.28
Critical Tractive Particle Size	dmax	mm	1.8	2.3	1.1	1.5	1.8	2.1	2.3
Design Water Depth	h	m	2.55	3.31	1.39	2.04	2.55	2.98	3.37

Manning' Formula $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^* / 1.2)^2 \times 10/55.0$

Table 2 Hydraulic Dimensions at KM 108.6365

	Symbol	Unit	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	10.83	52.66
Water Depth	H	m	1.41	3.31
Designed Water Level	WL.	m	LWL.8.80	HWL.10.72
Bottom Elevation	EL.	m	7.41	7.41

Table 3 Hydraulic Dimensions at KM 108.7115

	Symbol	Unit	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	10.83	32.48
Assumed Water Depth	H	m	1.40	3.32
Flow Area	A	m^2	28.00	66.40
Wetted Perimeter	P	m	25.60	33.28
Hydraulic Radius	R	m	1.094	1.995
Roughness Coefficient	1/n		55	55
Velocity	V	m/s	0.387	0.489
Hydraulic Gradient	I		1 / 22,768	1 / 31,771
Loss Head	H_2	m	0.00	0.00
Designed Water Level	WL.	m	LWL.8.80	HWL.10.72
Bottom Elevation	EL.	m	7.40	7.40

Table 4 Hydraulic Dimensions at KM 108.7615

	Symbol	Unit	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	10.83	32.48
Assumed Water Depth	H	M	4.40	6.32
Flow Area	A	m^2	158.40	227.52
Wetted Perimeter	P	M	53.60	61.28
Hydraulic Radius	R	M	2.955	3.713
Roughness Coefficient	1/n		55	55
Velocity	V	m/s	0.068	0.142
Hydraulic Gradient	I		0.0000004	0.0000012
Loss Head	H_3	M	0.00	0.00
Designed Water Level	WL.	M	LWL.8.80	HWL.10.72
Bottom Elevation	EL.	M	4.40	4.40

Table 5 Hydraulic Dimensions at KM 108.855

	Symbol	Unit	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	10.83	32.48
Assumed Water Depth	H	m	4.40	6.32
Flow Area	A	m^2	158.40	227.52
Wetted Perimeter	P	m	53.60	61.28
Hydraulic Radius	R	m	2.955	3.713
Roughness Coefficient	1/n		55	55
Velocity	V	m/s	0.068	0.142
Hydraulic Gradient	I		0.0000004	0.0000012
Loss Head	H_4	m	0.00	0.00
Designed Water Level	WL.	m	LWL.8.80	HWL.10.72
Bottom Elevation	EL.	m	4.40	4.40

APPENDIX A.2.6-1 Hydraulic Design of No.7 Pumping Station

(1) Calculation of Hydraulic Head Losses of Pumping Station

Calculation of hydraulic head losses for each pump operation between beginning point of pumping station KM108.855 and end point of pumping station KM108.985 are tabulated in the following tables;

Table 1; Head Losses of Pumping Station (3 Pumps Operated)
Table 2; Head Losses of Pumping Station (2 Pumps Operated)
Table 3; Head Losses of Pumping Station (1 Pumps Operated)

Table 1; Head Losses of Pumping Station (3 Pumps Operated)

Calculation of Head Losses (3 pumps operated)

Q= **10.827** $m^3/s/unit$

Σ Q= **32.481** m^3/s

Section	Dimension	L	Q	A	V	hv	n	C	R	I	Head Losses							
											Entrance	Friction	Bend	Valve	Branch	Transition	Sub-total	Total
		(m)	(m^3/s)	(m^2)	(m/s)	(m)			(m)		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
a.Head Losses of Screen																		0.200
b.Head Losses of Suction Pipe																		
①	5.50×3.70	0.840	10.827	20.350	0.532	0.014	0.015		1.106	0.000056	0.003	0.000					0.003	
		3.870								0.000315		0.001				0.002	0.003	
②	2.80×3.00	-	10.827	8.400	1.289	0.085	0.015		0.724	0.000575							-	
		1.660								0.000847		0.001	0.014			0.000	0.016	
③	φ2.80	-	10.827	6.158	1.758	0.158	0.015		0.700	0.001119							-	
		9.590								0.003155		0.030				0.002	0.032	
④	φ2.10	-	10.827	3.464	3.126	0.499	0.015		0.525	0.005191							-	
		2.090								0.007023		0.015	0.149			0.001	0.165	
⑤	φ1.90	-	10.827	2.835	3.819	0.744	0.015		0.475	0.008854							-	0.219
c.Head Losses of Delivery Pipe																		
⑥	φ1.50	7.000	10.827	1.767	6.127	1.915		130		0.014910		0.104		0.460			0.564	
		4.600								0.008075		0.037				0.191	0.229	
⑦	φ2.50	-	10.827	4.909	2.206	0.248		130		0.001239							-	0.793
d.Head Losses of Header Pipe																		
⑧	φ3.80	4.500	10.827	11.341	0.955	0.047		130		0.000161		0.001			0.219		0.220	
⑨	φ2.60	-	10.827	5.309	2.039	0.212		130		0.001024					0.123		0.123	
		0.700								0.001268		0.001				0.000	0.001	
⑩	φ2.40	-	10.827	4.524	2.393	0.292		130		0.001512							-	0.344
e.Head Losses of Pipeline (untill KM108.985)																		
	φ2.40	69.278	10.827	4.524	2.393	0.292		130		0.001512		0.105	0.076	0.035			0.216	0.216
Total											0.003	0.295	0.239	0.495	0.342	0.197		**1.772**

Table 2; Head Losses of Pumping Station (2 Pumps Operated)

Calculation of Head Losses (2 pumps operated)

Q= 11.965 m^3/s/unit

Σ Q= 23.930 m^3/s

Section	Dimension	L (m)	Q (m^3/s)	A (m^2)	V (m/s)	hv (m)	n	C	R (m)	I	Head Losses: Entrance (m)	Friction (m)	Bend (m)	Valve (m)	Branch (m)	Transition (m)	Sub-total (m)	Total (m)
a.Head Losses of Screen																		0.200
b.Head Losses of Suction Pipe																		
①	5.50x3.70	0.840	11.965	20.350	0.588	0.018	0.015		1.106	0.000068	0.004	0.000					0.004	
		3.870								0.000385		0.001				0.003	0.004	
②	2.80x3.00	-	11.965	8.400	1.424	0.103	0.015		0.724	0.000702							-	
		1.660								0.001034		0.002	0.017			0.000	0.019	
③	ϕ2.80	-	11.965	6.158	1.943	0.193	0.015		0.700	0.001367							-	
		9.590								0.003852		0.037				0.002	0.039	
④	ϕ2.10	-	11.965	3.464	3.454	0.609	0.015		0.525	0.006338							-	
		2.090								0.008575		0.018	0.182			0.002	0.202	
⑤	ϕ1.90	-	11.965	2.835	4.220	0.909	0.015		0.475	0.010811							-	0.268
c.Head Losses of Delivery Pipe																		
⑥	ϕ1.50	7.000	11.965	1.767	6.771	2.339		130		0.017938		0.126		0.561			0.687	
		4.600								0.009714		0.045				0.234	0.279	
⑦	ϕ2.50	-	11.965	4.909	2.437	0.303		130		0.001491							-	0.965
d.Head Losses of Header Pipe																		
⑧	ϕ3.80	4.500	11.965	11.341	1.055	0.057		130		0.000194		0.001			0.266		0.267	
⑨	ϕ2.60	-	7.977	5.309	1.502	0.115		130		0.000582					0.088		0.088	
		0.700								0.000720		0.001				0.000	0.001	
⑩	ϕ2.40	-	7.977	4.524	1.763	0.159		130		0.000859							-	0.356
e.Head Losses of Pipeline (untill KM108.985)																		
	ϕ2.40	69.278	7.977	4.524	1.763	0.159		130		0.000859		0.060	0.041	0.019			0.120	0.120
Total											0.004	0.289	0.241	0.580	0.354	0.241		1.909

Table 3; Head Losses of Pumping Station (1 Pump Operated)

Calculation of Head Losses (1 pump operated)

Q= 12.900 m^3/s/unit

Σ Q= 12.900 m^3/s

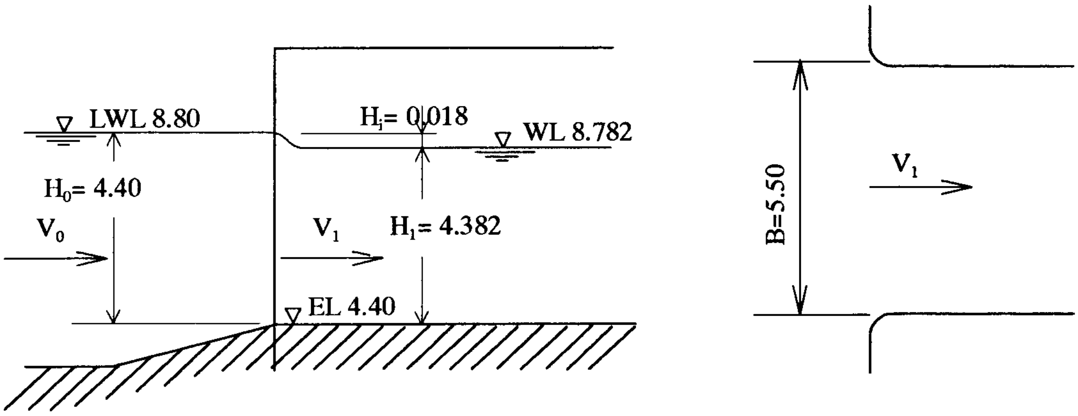
Section	Dimension	L (m)	Q (m^3/s)	A (m^2)	V (m/s)	hv (m)	n	C	R (m)	I	Head Losses: Entrance (m)	Friction (m)	Bend (m)	Valve (m)	Branch (m)	Transition (m)	Sub-total (m)	Total (m)
a.Head Losses of Screen																		0.200
b.Head Losses of Suction Pipe																		
①	5.50×3.70	0.840	12.900	20.350	0.634	0.021	0.015		1.106	0.000079	0.004	0.000					0.004	
		3.870								0.000448		0.002				0.003	0.005	
②	2.80×3.00	-	12.900	8.400	1.536	0.120	0.015		0.724	0.000816							-	
		1.660								0.001203		0.002	0.020			0.001	0.022	
③	φ2.80	-	12.900	6.158	2.095	0.224	0.015		0.700	0.001589							-	
		9.590								0.004478		0.043				0.002	0.045	
④	φ2.10	-	12.900	3.464	3.724	0.708	0.015		0.525	0.007368							-	
		2.090								0.009968		0.021	0.212			0.002	0.234	
⑤	φ1.90	-	12.900	2.835	4.550	1.056	0.015		0.475	0.012568							-	0.311
c.Head Losses of Delivery Pipe																		
⑥	φ1.50	7.000	12.900	1.767	7.300	2.719		130		0.020617		0.144		0.653			0.797	
		4.600								0.011165		0.051				0.272	0.323	
⑦	φ2.50	-	12.900	4.909	2.628	0.352		130		0.001713							-	1.120
d.Head Losses of Header Pipe																		
⑧	φ3.80	4.500	12.900	11.341	1.137	0.066		130		0.000223		0.001			0.308		0.309	
⑨	φ2.60	-	4.300	5.309	0.810	0.033		130		0.000185					0.065		0.065	
		0.700								0.000230		0.000				0.000	0.000	
⑩	φ2.40	-	4.300	4.524	0.951	0.046		130		0.000274							-	0.375
e.Head Losses of Pipeline (untill KM108.985)																		
	φ2.40	69.278	4.300	4.524	0.951	0.046		130		0.000274		0.019	0.012	0.006			0.036	0.036
Total											0.004	0.283	0.244	0.658	0.373	0.279		**2.042**

(2) Hydraulic Calculation of Intake Canal Including Screen

-Water level at the intake; LWL8.80m

-Maximum discharge of the intake canal; Qmax=12.90m3/s

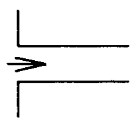
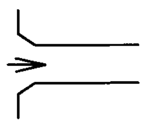
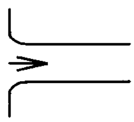
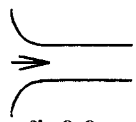
(i)Head loss due to inflow and change of water level (Hi)



Assumed head loss due to inflow and change of water level is Hi =0.018 m, water depth after inflow is estimated H_1 =LWL8.80 m− 0.018 m−EL 4.40 m = 4.382 m.

$$Hi = fi \cdot \frac{V_1^2}{2 \cdot g} + \frac{V_1^2 - V_0^2}{2 \cdot g}$$

Where、 fi ; Coefficient of head loss due to inflow 0.2

Right angle edge	Chamfered edge	Rounded edge	Bell-mouth
			
fi=0.5	fi=0.2	fi=0.1(circular) fi=0.2(square)	fi=0.0 1

Inflow Loss Coefficient by Entrance Shape

V_0 ; Mean velocity before inflow 0 (m/s)

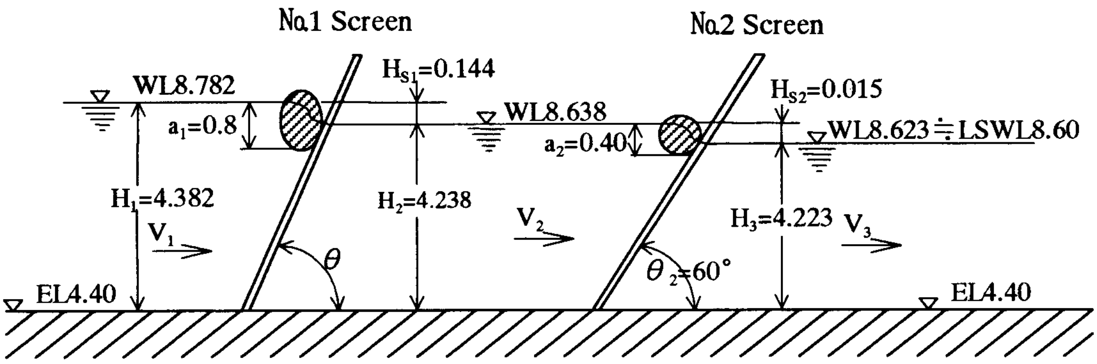
V_1 ; Mean velocity after inflow 0.535 (m/s)

$$V_1 = \frac{Q}{B \cdot H_1} = \frac{12.90}{5.50 \times 4.382} = 0.535\,(m/s)$$

$$\therefore Hi = 0.20 \times \frac{0.535^2}{19.6} + \frac{0.535^2 - 0^2}{19.6} = 0.018\,(m)$$

Therefore、coincide with assumed head loss and change of water level Hi=0.018m. So that, water level after inflow is decided WL 8.80m−0.018 = WL 8.782m.

(ii) Head loss and change of water level due to trashrack (Hs)



The head loss and change of water level due to trashrack are calculated as follows by using the Suzuki's formula.

$$Hs = 6.69 \cdot \sin\theta \cdot \left(\frac{t}{b}\right)^{4/3} \cdot \exp\left(0.074 \cdot rw \cdot \frac{a}{H}\right) \cdot \frac{V_1^2}{2 \cdot g} + \frac{V_2^2 - V_1^2}{2 \cdot g}$$

Where、 θ	; Inclined angle of screen	(75° 、 60°)
t	; Thickness of the screen bars	(9mm、 9mm)
b	; Clear space between bars	(50mm、 100mm)
rw	; Wet unit weight of trash	(200 kg/m³)
a	; Height of trash attached trashrack	(0.80m、 0.40m)
H	; Water depth in the upstream of the screen	(m)
V_1	; Flow velocity in the upstream of the screen	(m/s)
V_2	; Flow velocity in the downstream of the screen	(m/s)

$V_1 = 12.90/(5.50 \times 4.382) = 0.535$m/s

Assumed head loss and change of water level due to No.1 screen is $H_{S1} = 0.144$m;

$V_2 = 12.90/(5.50 \times 4.238) = 0.553$m/s

$H_{S1} = 6.69 \times \sin 75° \times (9/50)^{4/3} \times \exp(0.074 \times 200 \times 0.80/4.382) \times (0.535^2/19.6) + (0.553^2 - 0.535^2)/19.6$

$= 0.143 + 0.001 = 0.144$m OK

Assumed head loss and change of water level due to No.2 screen is $H_{S1} = 0.015$m;

$V_3 = 12.90/(5.50 \times 4.223) = 0.555$m/s

$H_{S2} = 6.69 \times \sin 60° \times (9/100)^{4/3} \times \exp(0.074 \times 200 \times 0.40/4.233) \times (0.553^2/19.6) - (0.555^2 - 0.553^2)/19.6$

$= 0.015 + 0.000 = 0.015$ m OK

Therefore、 head losses of intake canal including No.1 and No.2 screen is $Hi + H_{s1} + H_{s2} = 0.177$m. So that, counting on a few allowance, head losses of intake canal is decided at **0.20m**.

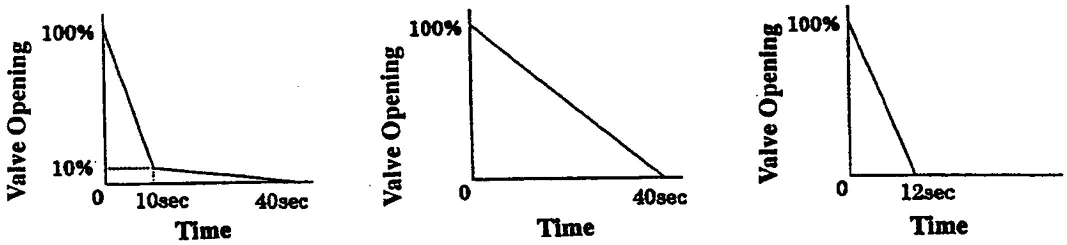
APPENDIX A. 2.7-1 .Studies of Water Hammer Analysis

(1) Valve Condition of Immediate Downstream of Pump

(a) Condition of valve closer time and characteristics

The studies on various closer times have been done and most recommendable one is the case A, which is controlled closer time by the bi-plane valve.

A Controlled closer time, B Proportional closer time, C Non controlled



(b) Result of Estimation

Case	Case-A		Case-B		Case-C	
Vacuum pressure	non	○	non	○	-9m	×
ST-1 Required capacity	approx.210m^3	○	approx.270m^3	△	approx.205m^3	○
ST-2 Required capacity	approx.7 m^3	○	approx.7m^3	○	approx.7m^3	○
Evaluation	○		△		×	
Refer to Figure No,	Figure 2.7-1		Figure 2.7-2		Figure 2.7-3	

Case-A; The case shall be determined to the project.

Case-B; There is much reverse flow to main pump, then required capacity of ST-1 is larger than the other case.

Case-C; There happens minus pressure of 9m at immediate downstream of main pump and big diameter such as 1.5m of quick closer check valve is not generally adopted.

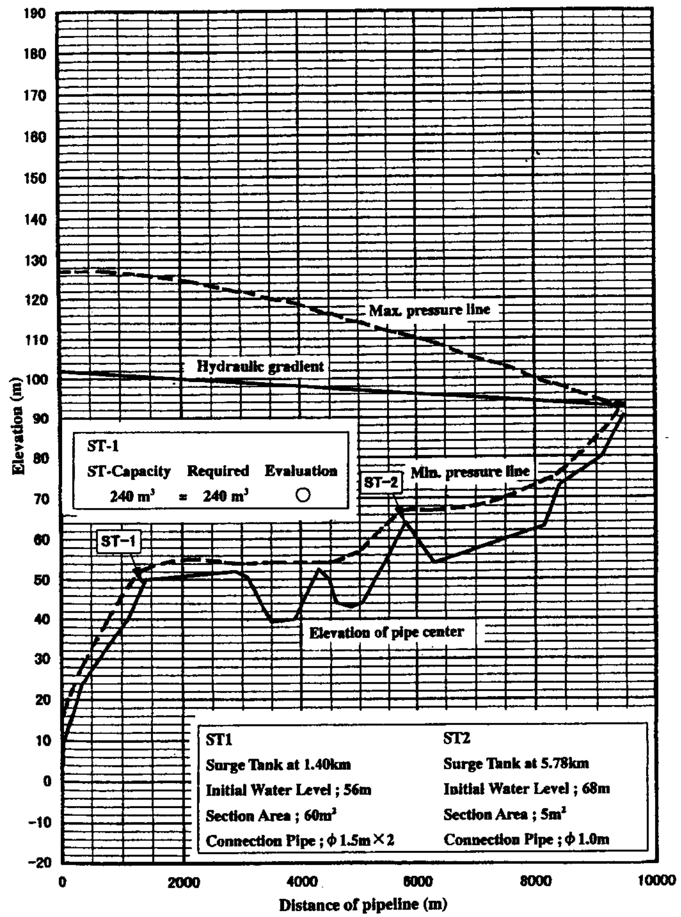


Figure 1 Water Hammer Analysis

(Case A)

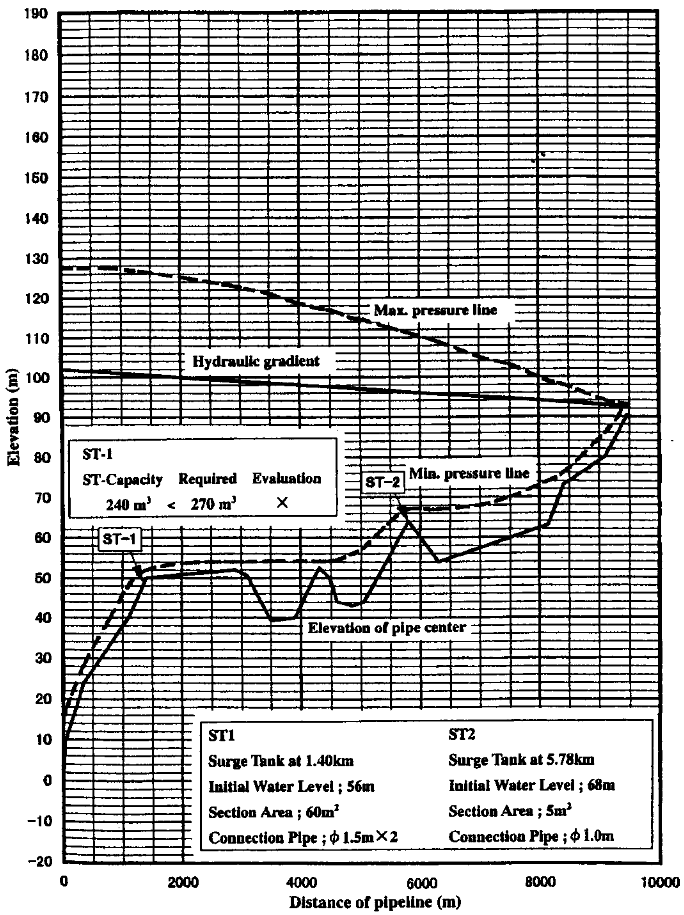


Figure 2 Water Hammer Analysis

(Case B)

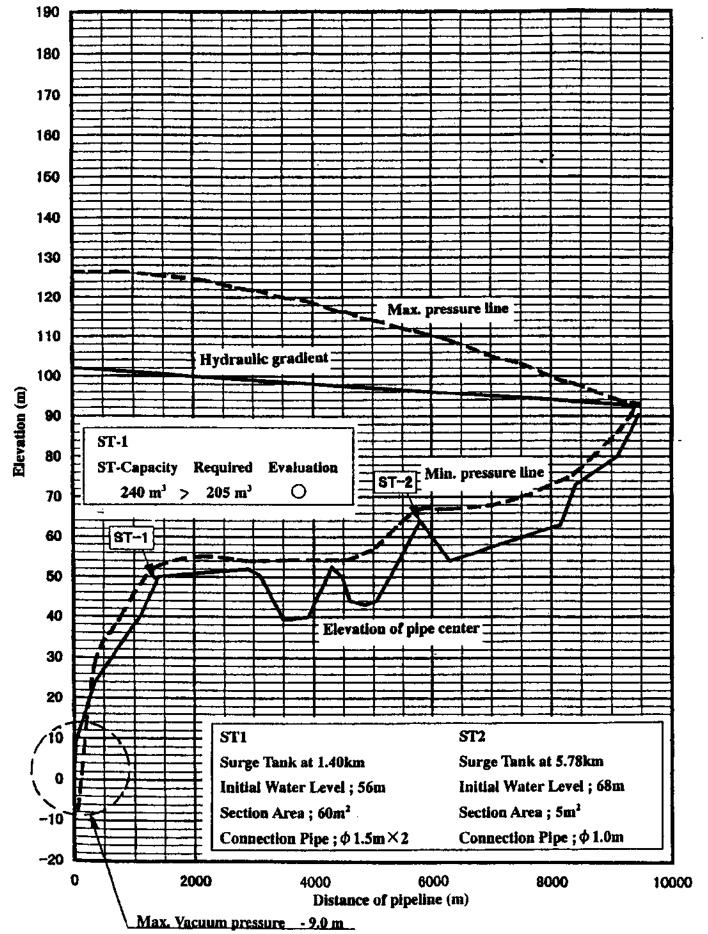


Figure 3 Water Hammer Analysis

(Case C)

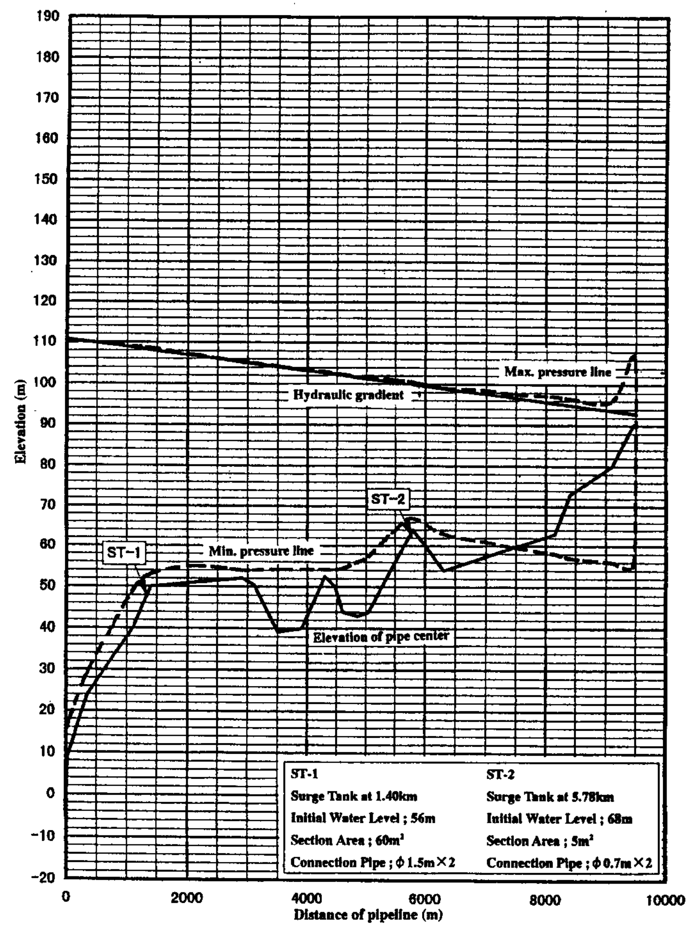


Figure 4 Water Hammer Analysis

(Case A→E)

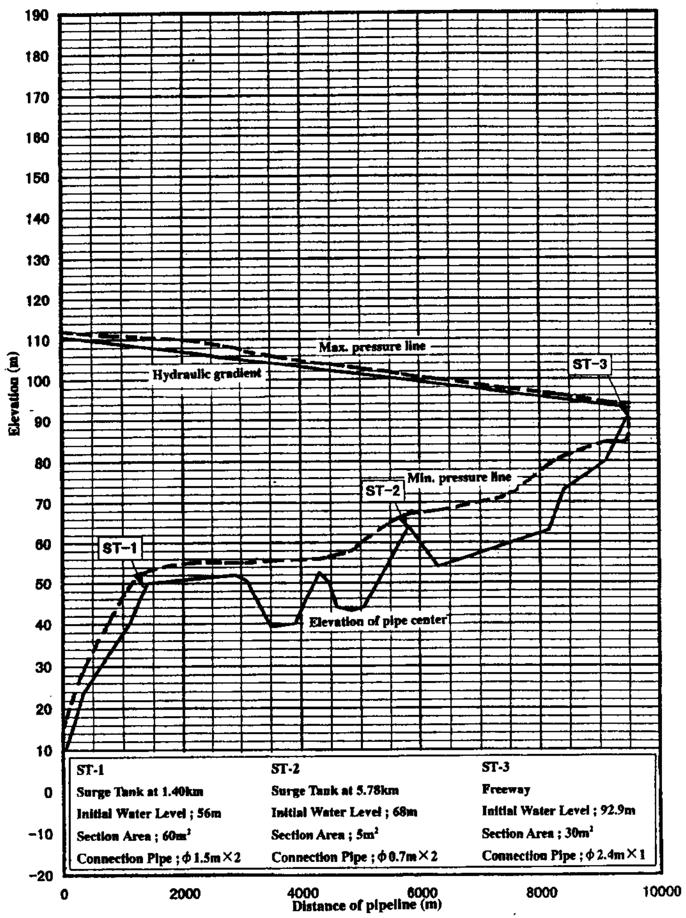


Figure 5 Water Hammer Analysis
(Case A→F)

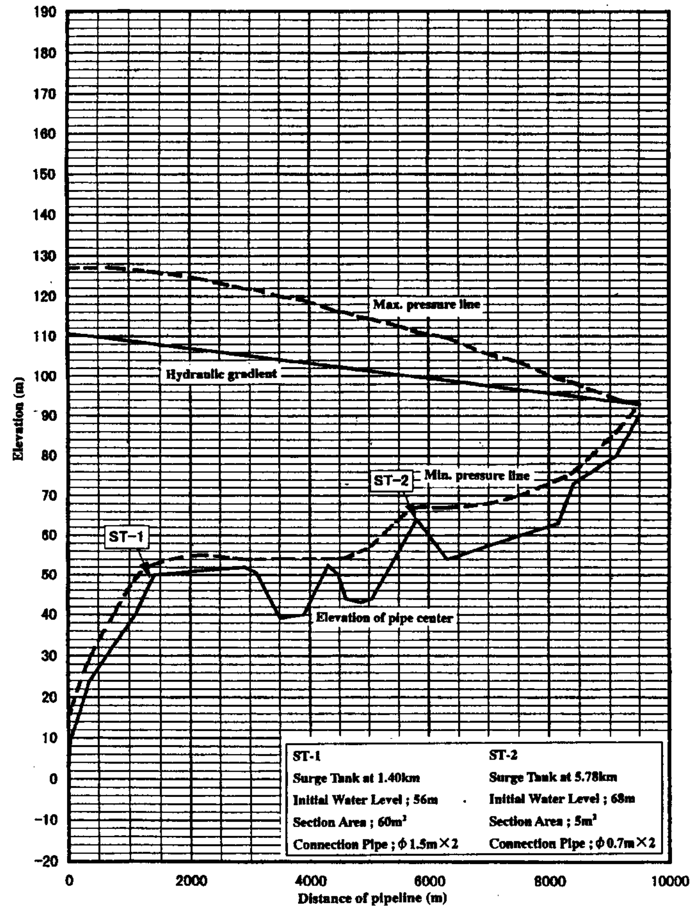


Figure 6 Water Hammer Analysis
(Case A→D→H), (Case A→D→L)
(Double Function of Connection Pipe)

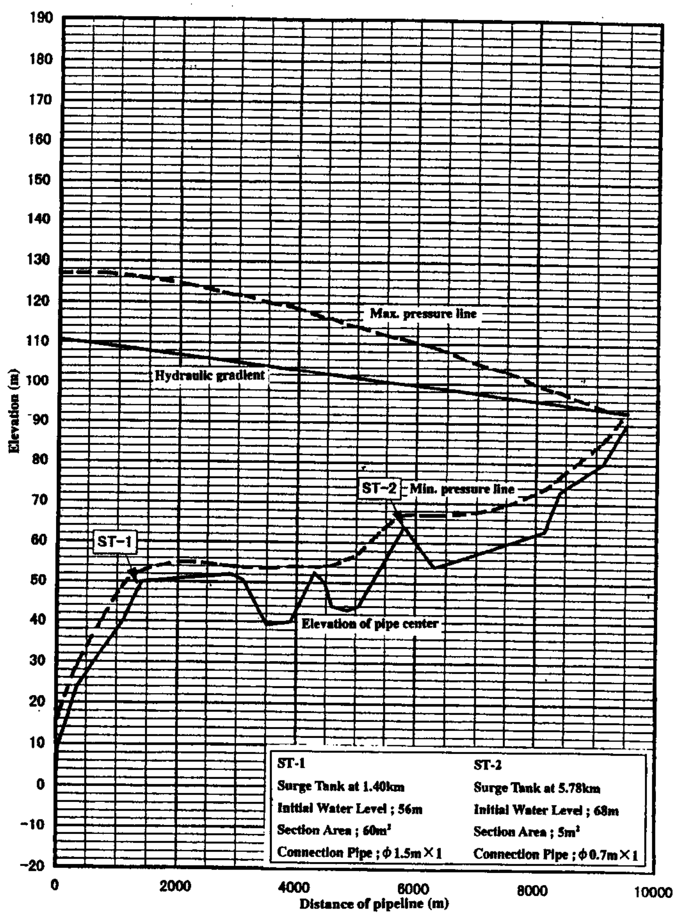


Figure 7 Water Hammer Analysis
(Single Function of Connection Pipe)

(2) Type of Outflow of Discharge Tank

The purpose of this analysis is to determine and to compare the outflow method of discharge tank according to the prior studies.

The case A→D is the most recommendable because of suitable hydraulics and economical reason and referred to Figure A.2.7-7 and -8 of water hammer analysis.
The case A→E is rejected because of vacuum pressure of approx.36m as shown Figure A.2.7-4, and the case A→F is also inadequate because of economical point of view as shown Figure A.2.7-5.

(3) Initial Water Level and Section Area for Surge Tank

The purpose of this analysis is to determine initial water level and section area of surge tank. To lighten the water hammer pressure by the function of surge tank, initial water level and section area are primary factors.
Six studies have been done and the results are tabulated following tables;

Result for ST-1 (in case ϕ1500m×2 of connection pipe)

Case study	Case A→D→G	Case A→D→H	Case A→D→I
Initial water level (m)	54	56	56
Section area (m^2)	60	60	40
Evaluation	×	○	×

Result for ST-2 (in case ϕ700m×2 of connection pipe)

Case study	Case A→D→J	Case A→D→K	Case A→D→L
Initial water level (m)	66	68	68
Section area (m^2)	15	15	5
Evaluation	×	△	○

There is some possibility to suction air to main pipeline in the Case A→D→G, A→D→I. and Case A→D→J. The Case A→D→K is functionally satisfactory but uneconomical because of large section area comparing to the Case A→D→L.
The Case A→D→H and A→D→L are recommendable to the project.

(4) Size and Number of Connection Pipe of the Surge Tank

As stated section 2.7.6 System reliability of water hammer protection, two sets of connection pipe shall be needed for safety of system. Then two cases of analysis are necessary, one case is two sets of connection pipe and the other is one set of these. And the results of both cases shall be satisfied. As shown Figure A.2.7-7 and A. 2.7-8, in case connection pipe one or two sets of ϕ1.5m at ST-1 and in case connection pipe one or two sets of ϕ0.7m at ST-2, the system is sufficiently functioned.

APPENDIX A.2.7-2 Theoretical Water Hammer Calculation Comparison with Experimental Result

The comparisons of calculation and experimental result drawn in the chart are shown as following Figures;

Figure 8 Transient Phenomena on Normal Stop
Figure 9 Transient Phenomena on One Pump Trip When Two Pump Operating
Figure 10 Transient Phenomena on Simultaneous Trip of Two Pump

The charts in above Figures indicated both of calculation and experimental result are expressed that both of results of curves are well corresponded even some differences of pressure within some percentage and its occurring time within one or two seconds. Then the program will be addressed to reproduce the transient phenomena of water hammer with sufficient accuracy.

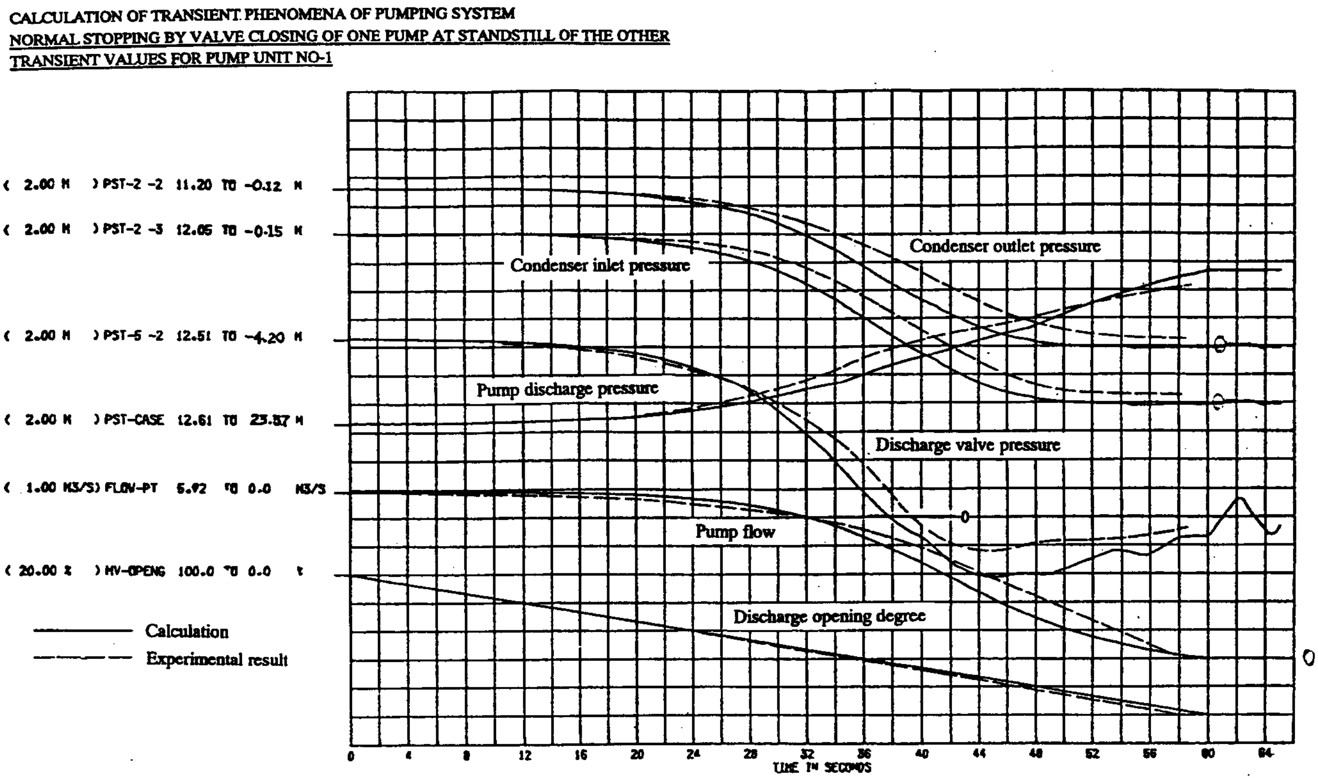


Figure 8 Transient Phenomena on Normal Stop

CALCULATION OF TRANSIENT PHENOMENA OF PUMPING SYSTEM
TRIP OF ONE PUMP WITH VALVE CLOSING WHEN TWO PUMPS OPERATING
TRANSIENT VALUES FOR PUMP UNIT NO-1

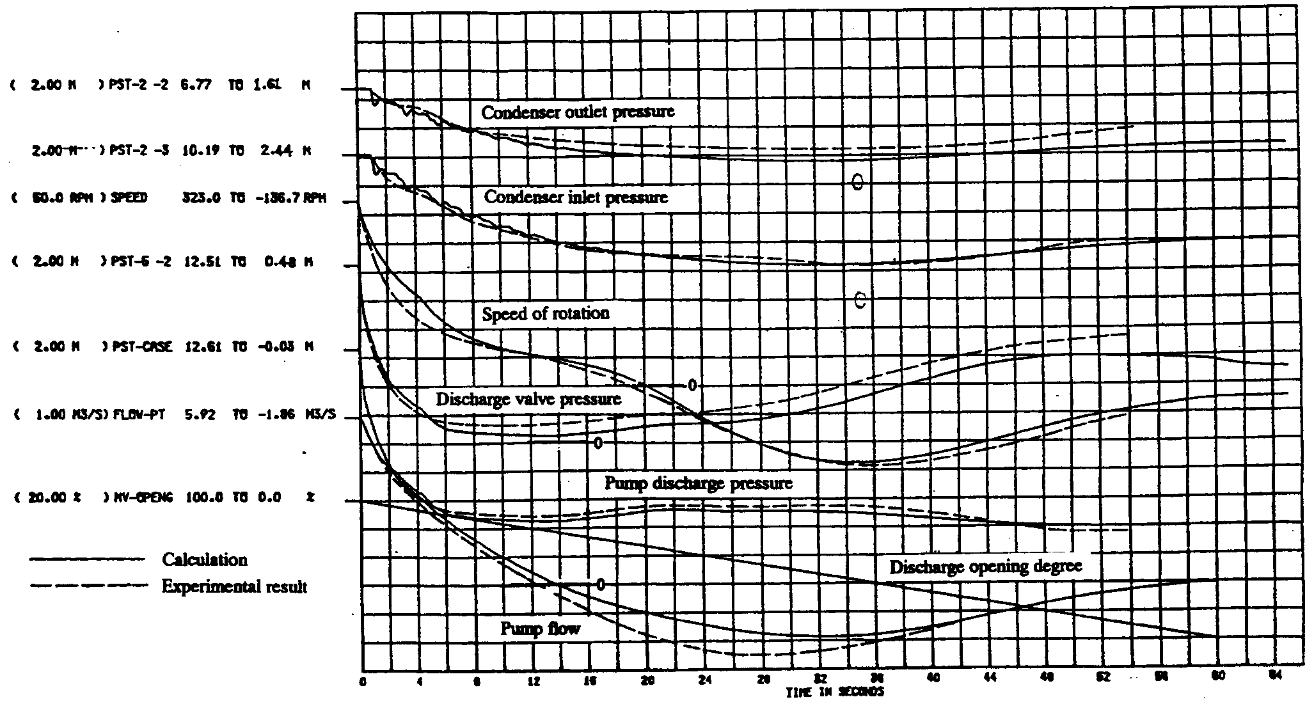


Figure 9 Transient Phenomena on One Pump Trip When Two Operating

CALCULATION OF TRANSIENT PHENOMENA OF PUMPING SYSTEM
SIMULTANEOUS TRIP OF TWO PUMPS WITHOUT VALVE OPERATION
TRANSIENT VALUES FOR PUMP UNIT NO-1

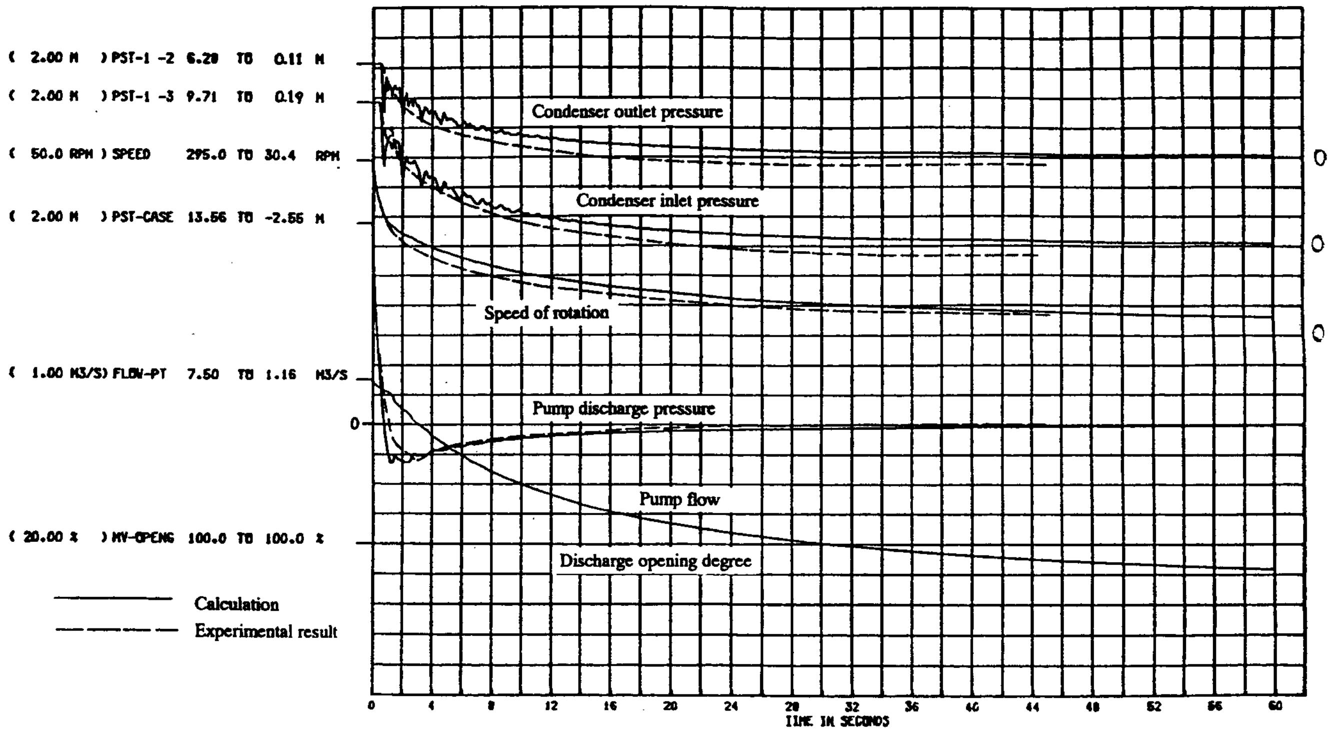


Figure 10 Transient Phenomena on Simultaneous Trip of Two Pump

APPENDIX A.2.8-1 Detailed Hydraulic Design of Discharge Tank

The designed hydraulic dimensions at the discharge tank are shown in Table 1 – 4.

Table 1 Hydraulic Dimensions at KM 118.560

	Symbol	Unit	Stage I Max. Discharge	Stage II Max. Discharge
Design Discharge	Q	m^3/s	32.48	54.14
Water Depth	H	m	2.55	3.37
Flow Area	A	m^2	43.61	63.15
Wetted Perimeter	P	m	23.40	27.07
Hydraulic Radius	R	m	1.864	2.333
Roughness Coefficient	1/n		55	55
Hydraulic Gradient	I		1 / 12,500	1 / 12,500
Velocity	V	m/s	0.745	0.865
Designed Water Level	WL.	m	HWL. 91.12	HWL.91.94
Bottom Elevation	EL.	m	88.57	88.57

Table 2 Hydraulic Dimensions at KM 118.410

	Symbol	Unit	Stage I Max. Discharge	Stage II Max. Discharge
Design Discharge	Q	m^3/s	32.48	54.14
Water Depth	H	m	2.55	3.37
Velocity	V	m/s	0.745	0.865
Designed Water Level	WL.	m	HWL. 91.13	HWL.91.95
Bottom Elevation	EL.	m	88.58	88.58

Table 3 Hydraulic Dimensions at KM 118.380

	Symbol	Unit	Stage I Max. Discharge	Stage II Max. Discharge
Design Discharge	Q	m^3/s	32.48	54.14
Assumed Water Depth	H	m	2.55	3.37
Flow Area	A	m^2	73.44	102.58
Wetted Perimeter	P	m	35.10	38.78
Hydraulic Radius	R	m	2.092	2.645
Roughness Coefficient	1/n		55	55
Velocity	V	m/s	0.442	0.528
Hydraulic Gradient	I		1 / 41,428	1 / 39,691
Loss Head	H_2	m	0.00	0.00
Designed Water Level	WL.	m	HWL. 91.13	HWL.91.95
Bottom Elevation	EL.	m	88.58	88.58

Table 4 Hydraulic Dimensions at KM 118.370

	Symbol	Unit	Stage I	Stage II
			Max. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	32.48	54.14
Assumed Water Depth	H	m	3.03	3.85
Flow Area	A	m^2	68.18	86.63
Wetted Perimeter	P	m	40.68	45.60
Hydraulic Radius	R	m	1.676	1.900
Roughness Coefficient	1/n		55	55
Velocity	V	m/s	0.476	0.625
Hydraulic Gradient	I		1 / 26,579	1 / 18,224
Loss Head	H_3	m	0.00	0.00
Designed Water Level	WL.	m	HWL. 91.13	HWL.91.95
Bottom Elevation	EL.	m	88.10	88.10