မင်္ဂလာပါ

IWUMD

ဆည်မြောင်းနှင့်ရေအသုံးချမှု စီမံခန့်ခွဲမှု ဦးစီးဌာန

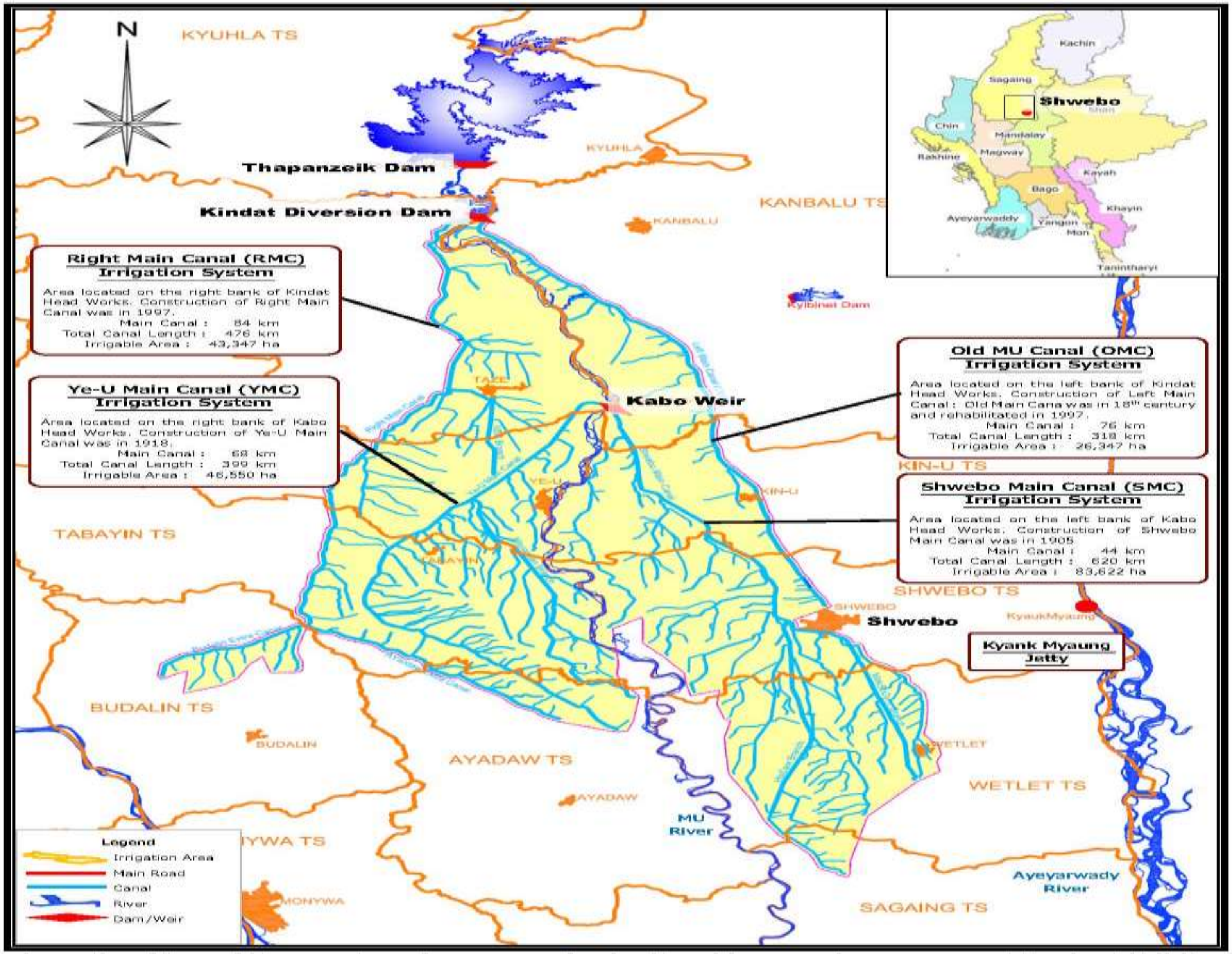
Exp Infrastructure Engineering Consultants Co.,Ltd

STUDY OF KABO WEIR ON MU RIVER

FOR LONG TERM STABILITY USING HYDRAULIC MODELS

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Project Area of Thaphanzeik Irrigation Scheme



Facts of The Kabo Weir (KBW)

- KBW, an important module of Thapanzeik irrigation system, is located across the Mu River at Kabo Village, 48 miles downstream (D/S) of Thapanzeik Reservoir (TPZ).
- KBW was constructed and operated for irrigation Through Shwebo canal system (SMC) and Ye U canal system (YMC) as follows.

1.	Kabo Weir (1911)	…..	455	feet (138.68m)
2.	Shwebo Sluice (1911)	…..	40 x 4	feet (12.19x4m)
3.	Ye U Sluice (1911)	…..	30 x 2	feet (9.14x2m)
4.	SMC Intake structure (1911)	…..	206,640 Ac. (83625 ha)	
5.	YMC Intake structure (1918)	…..	115,030 Ac. (46551 ha)	

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Plan View of The Kabo Weir & Canal Intakes

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir & Canal Intakes as Seen from Downstream

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Shwebo Undersluice of Kabo Weir as Seen from Left Side, D/S

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Shwebo Undersluice of Kabo Weir as Seen from Left Side, U/S

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir as Seen from Left Side, D/S

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Ye U Undersluice of Kabo Weir as Seen from Right Side, D/S

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir & Canal Intakes Seen Under Normal Flow

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir Section U/S as Seen from Ye U Side

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

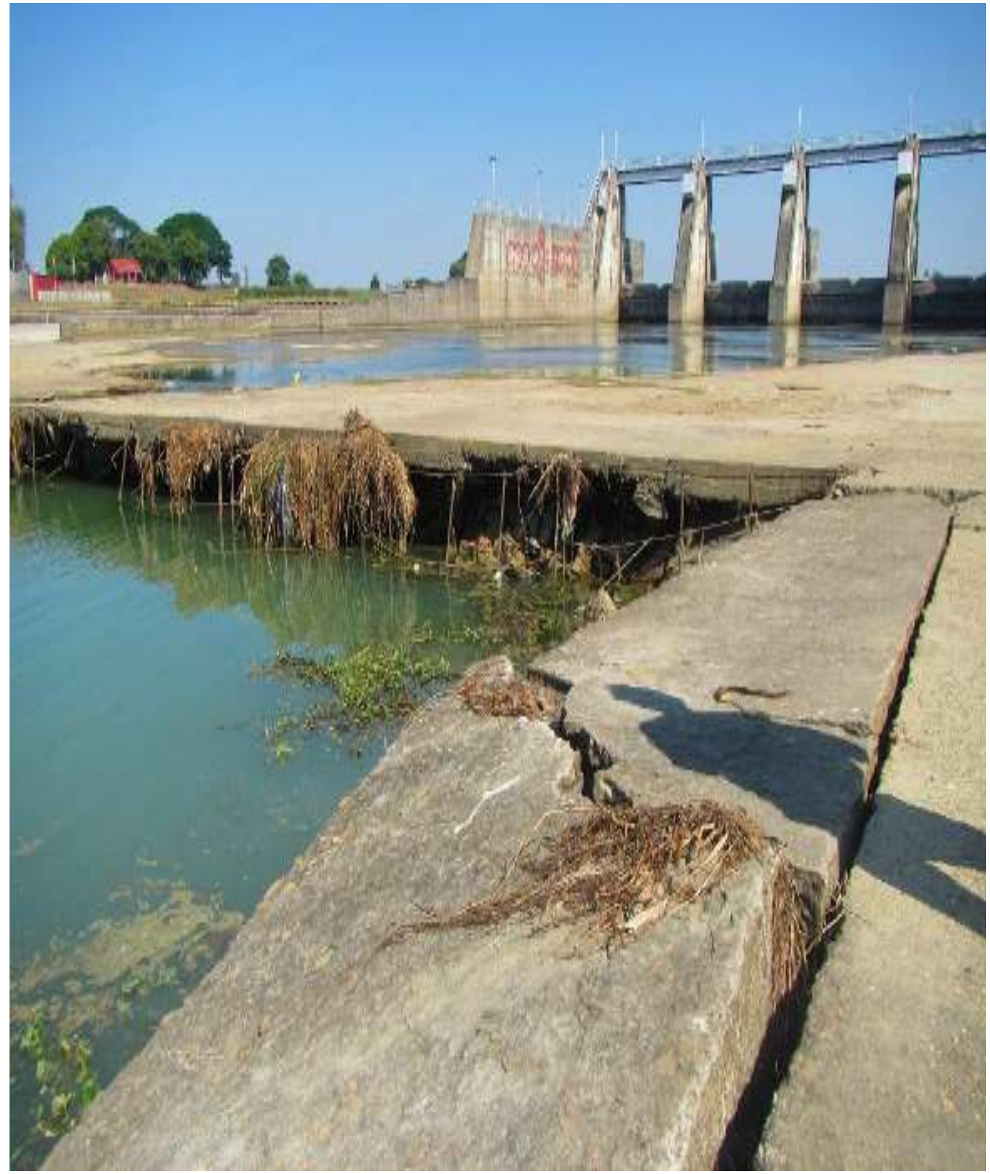
Kabo Weir Section D/S as Seen from Shwebo Side

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir: Downstream of Ye U Side

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir: Downstream of Shwebo Under Sluice



Recurring Erosion and Failure of KBW

- **During the catastrophic flood of 1956, Shwebo sluice collapsed due to excessive erosion at the downstream D/S apron.**

  (The flood estimated at that time was 277,000 Cusec and return period can be higher than 1000 year.)

- **There was a second largest flood of the record in 1971 entailing devastating scour at the D/S apron of Shwebo sluice again which also caused significant erosion and on the left bank.**

  (The flood was estimated as 177,000 Cusec and return period is about 50 year)

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Kabo Weir & Canal Intakes as Seen from Downstream

Recurring Erosion and Failure of KBW *(Continued)*

- **In fact, erosion at the D/S of the Shwebo sluice occurred almost every year demanding the cost of annual repair regularly.**

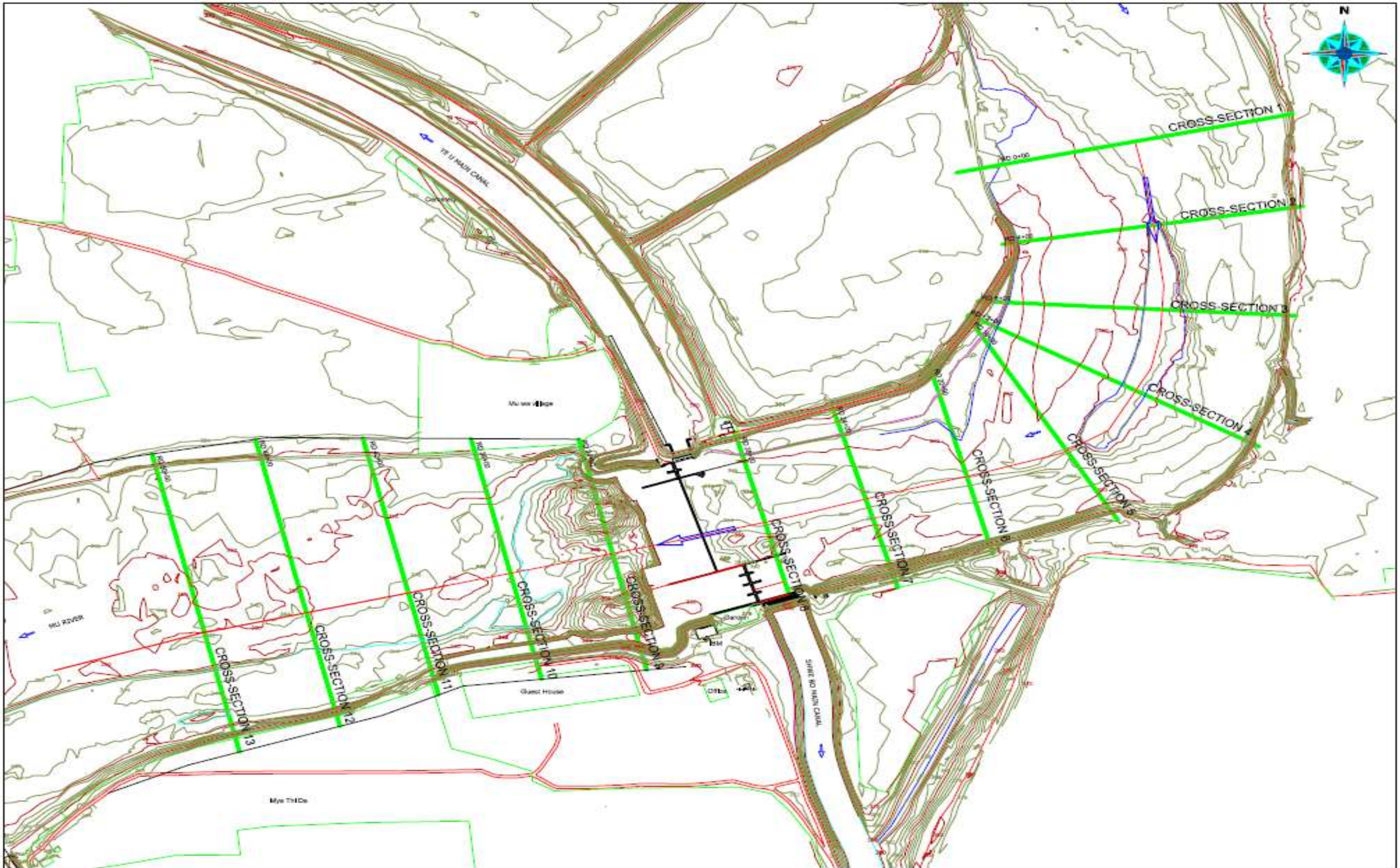
  (Maximum erosion depth at the end of the Shwebo Under-Sluice may be in an order of 50 feet during the floods.)

- **River bed and bank scour at the upstream of the weir also occurred due to 90 degree-bend of the Mu River.**

  (Maximum scour depth at the sharp end may be in an order of 70 feet during the floods.)

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Figure 2.1: Cross Sections of Mu River at Kabo Weir Used in the Erosion Study



Major Components Involved in the Study

1. Frequency analysis of annual flood peaks to produce 10, 20, 50 and 100 year design floods at KBW.
2. Scour study for each XS as shown in the Figure 2.1 using the distributed flows for the above return periods with Blench regime formula.
3. Hydraulic analysis using HEC-RAS model with XS as shown in the Figure 3.1 to observe potential erosion at the D/S of the whole 700 feet-wide KBW section.
4. Estimate & design of safe apron length for Shwebo sluice to ensure no erosion under 100-year design flood using HEC-RAS model.

1. Design Flood Analysis for KBW

- **Available annual maximum discharges at the KBW from 2001 through 2018 are taken into account for frequency analysis. The analysis is made using two methods including Log-Pearson Type III and Log-Normal distributions.**

- **Following results are produced by the above two methods and conservative values from Log-Normal distributions are adopted for use in the subsequent scour study.**

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Table 1.1: Design Flood Discharges at Kabo Weir for Various Return Periods

No	Percent Probability	Return Period Year	Design Flood (Log-Normal)		Design Flood (Log-Pearson)		Remark
			Cumec	Cusec	Cumec	Cusec	
1	50	2	590.24	20,844	562.63	19,869	
2	20	5	2346.08	82,851	2170.32	76,644	
3	10	10	3716.37	131,242	3403.72	120,201	
4	5	20	4677.41	165,181	4262.57	150,531	
5	**2**	**50**	**5369.56**	**189,624**	**4878.66**	**172,288**	
6	**1**	**100**	**5622.35**	**198,551**	**5103.22**	**180,218**	
7	0.2	500	5833.11	205,994	5290.28	186,824	
8	0.1	1000	5859.98	206,943	5314.15	187,667	

2. Scour study using distributed flows with Blench regime formula

- **Available topographic survey with two feet contour interval for 13 XS, 8 at U/S of the weir and 5 at D/S, is sufficiently used for the analysis.**
- **The above 13 XS of Mu River at KBW used in the Blench regime scour study are displayed in the Figure 2.1.**
- **To reveal a more realistic situation, scour depth at every 100 feet width of each XS is attempted.**
- **Design maximum scour depths at each section are abstracted in the following Table 2.1.**

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Figure 2.1: Cross Sections of Mu River at Kabo Weir Used in the Erosion Study

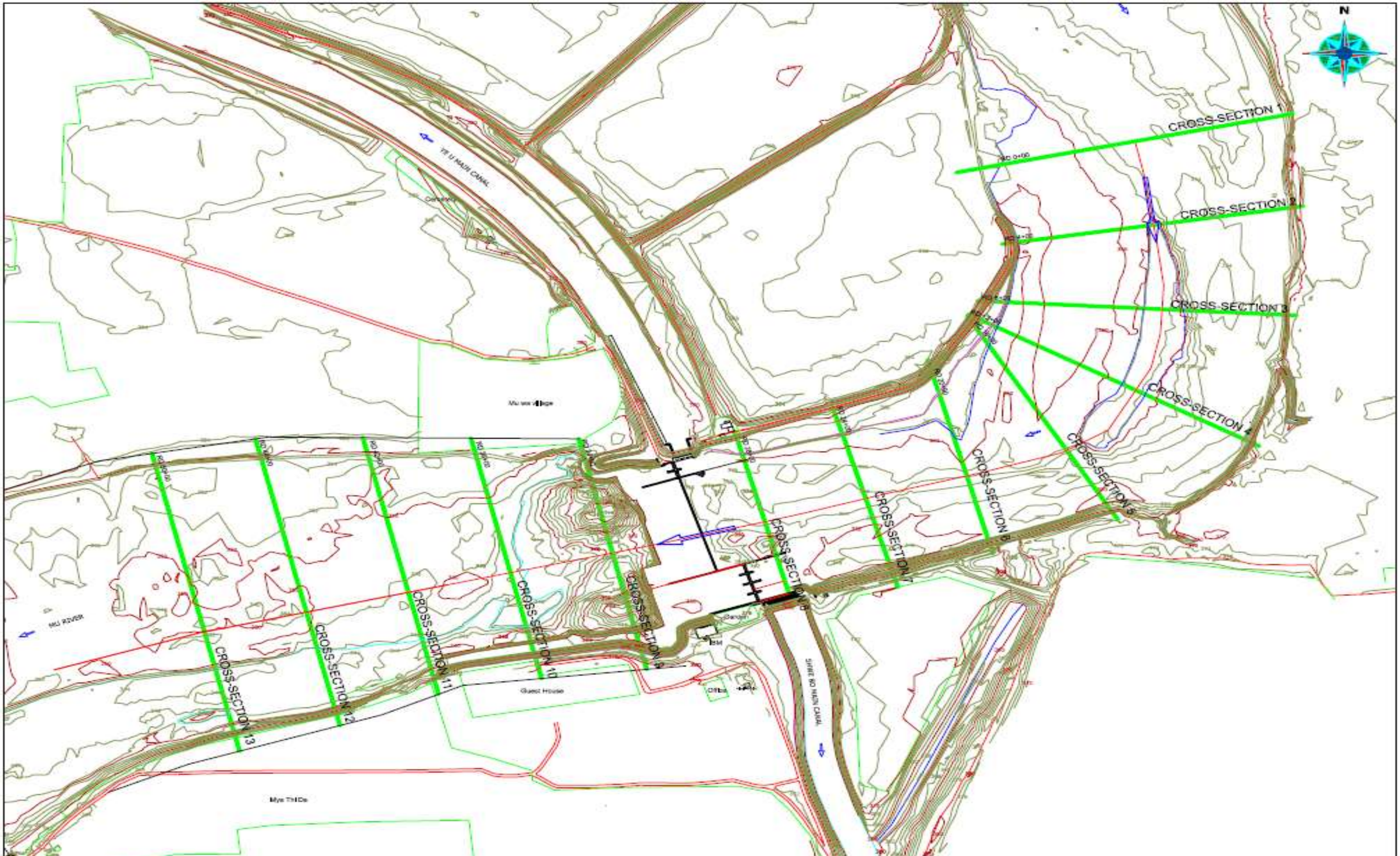


Table 2.1: Design Maximum Scour Depths at Different Sections of KBW

2. Scour study using distributed flows with Blench regime formula *(Continued)*

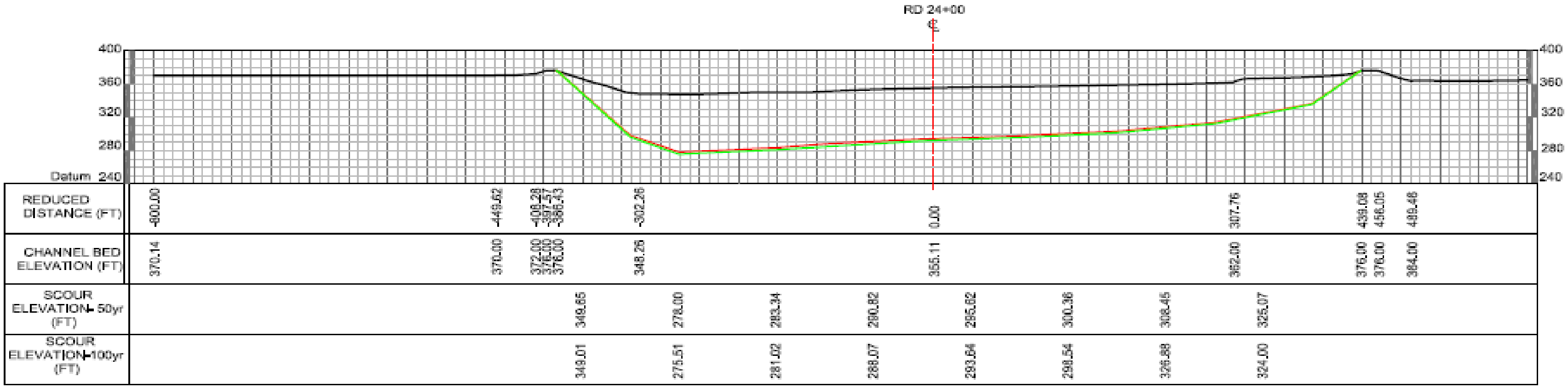
Cross Section No	Chainage meter	Chainage Feet	Maximum Scour Depth,				Remark
			50 – Year		100 - Year		
			m	ft	m	ft	
1	0	0	20.05	65.79	20.70	67.93	
2	121.92	400	14.74	48.36	15.27	50.10	
3	243.84	800	16.86	55.31	17.37	56.99	
4	365.76	1200	16.56	54.33	17.13	56.19	
5	487.68	1600	19.99	65.58	20.69	67.90	
6	609.6	2000	20.60	67.60	21.32	69.95	
7	731.52	2400	21.35	70.05	22.11	72.54	
8	853.44	2800	20.23	66.38	20.92	68.63	
9	1036.32	3400	11.03	36.19	11.77	38.62	
10	1158.24	3800	14.60	47.92	15.17	49.79	
11	1280.16	4200	15.41	50.57	16.05	52.65	
12	1402.08	4600	13.33	43.72	13.87	45.51	
13	1524	5000	13.91	45.65	14.48	47.50	

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

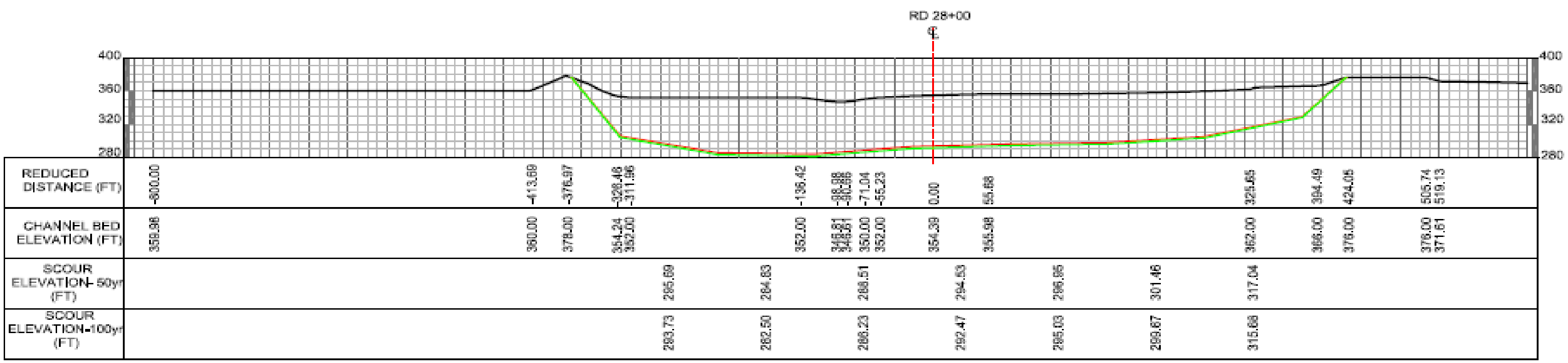
Figure 2.2: Design Scour Depths at Section 7 & 8 of KBW

2. Scour study using distributed flows with Blench regime formula *(Continued)*

Appendix Figure A.3.11 Cross Section 7 Showing Scour Depth of Kabo Weir Upstream Channel



Appendix Figure A.3.12 Cross Section 8 Showing Scour Depth of Kabo Weir Upstream Channel



3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model

The hydraulic study is carried out using two different approaches.

i. First approach is using the hydraulic formulae for checking turbulence relying on the research studies of the Water Resources Engineers such as Professor Van Te Chow. Hydraulic formulae used in the analysis for drop structures are given below.

ii. Flow geometry is governed by the *drop number, D,* as follows.

$D = q^2/(gh^3)$ **where q is discharge per unit width of the hydraulic structure,**

g is gravitational acceleration,

h is height of the drop.

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

iii. Following formulae can be used where all functions base on the drop number, D and drop height, h. (Figure 3.3)

$$L_d = 4.30\, h\, D^{0.27}$$

$$y_p = 1.00\, h\, D^{0.22}$$

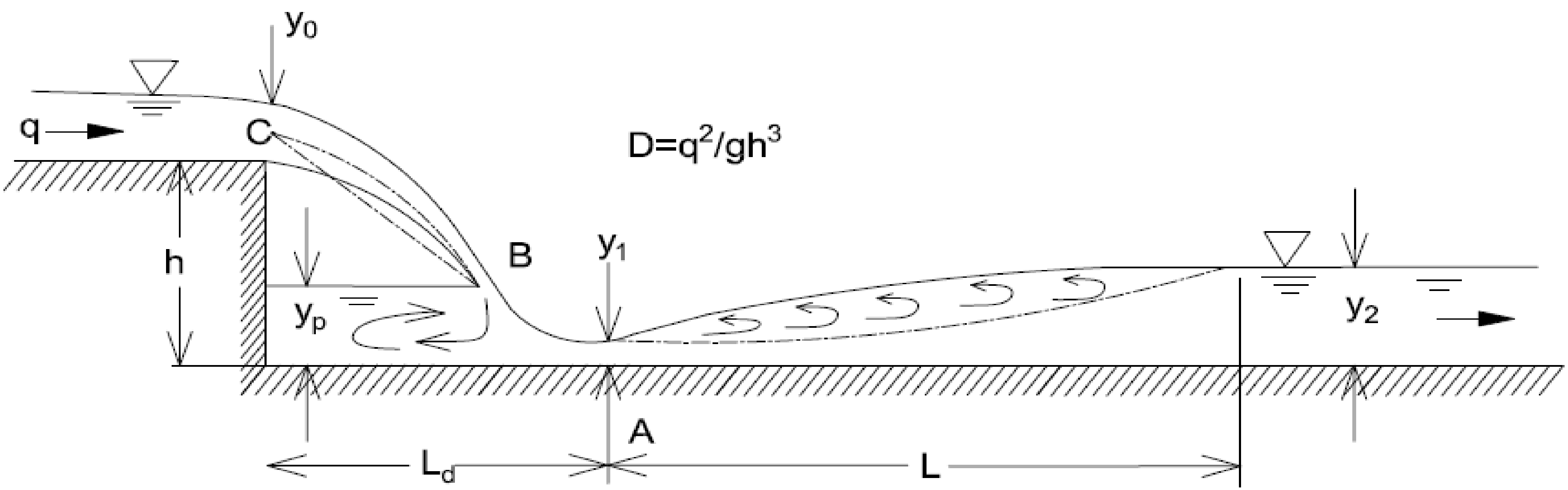
$$y_1 = 0.54\, h\, D^{0.425}$$

$$y_2 = 1.66\, h\, D^{0.27}$$

Where L_d is the drop length, the distance from the drop wall to the position of water depth y_1 or just before the jump begins,

- **y_p is the pool depth under the nappe,**
- **y_1 is the depth at the toe of the nappe or beginning of the jump,**
- **y_2 is the tail-water depth sequent to y_1.**

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model*(Continued)*



Appendix Figure A.4.1 Flow geometry of a straight drop spillway

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

iv. L is jump length between water depth y_1 and y_2 where the flow becomes normal or Froude Number reduces less than 1.

$$L = 6.1 \times y_2 \times F_1$$

where F_1 is the Froude Number at the water depth, y_1, which can be obtained from the relation, $F_1 = (g\ y_1)^{0.5}$

Total length of turbulent flow is $(L_d + L)$.

v. Table 3.1 shows detail calculations for the above hydraulic elements for both return periods of 50 and 100 years. From this table, required apron length below the weir varies but adopted as 110 meters across the River for safety of the value structure.

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

Table 3.1 : Estimation of Required Apron Length for 50 & 100 Year Return Periods

Computation of Hydraulic Parameters At Kabo Weir

No.	Hydraulic Element	Denotation	Unit	50-Year Design Flood			100-Year Design Flood			Remark
				Shwebo Sluice	Spillway	Ye U Sluice	Shwebo Sluice	Spillway	Ye U Sluice	
1	Design Discharge	Q	m3 / sec	1566.260	3565.280	238.220	1639.988	3733.117	249.227	
2	Channel Width	W	meter	48.77	138.68	18.30	48.77	138.68	18.30	
3	Drop Height	h	meter	0.31	2.42	0.31	0.31	2.42	0.31	
4	Unit Discharge	q	$m^3/sec/m$	32.12	25.71	13.02	33.63	26.92	13.62	
5	Drop Number	D	-	3705.56	4.75	608.82	4062.63	5.21	666.38	
6	Drop Length	L1	meter	12.060	15.852	7.406	12.364	16.251	7.589	
7	Depth before Jump	y1	meter	5.413	2.535	2.512	5.629	2.636	2.611	
8	Pool Depth	yp	meter	1.860	3.410	1.250	1.898	3.480	1.275	
9	Depth after Jump	y2	meter	4.656	6.120	2.859	4.773	6.274	2.930	
10	Velocity before Jump	V1	*m / sec*	*5.933*	*10.120*	*5.098*	*5.937*	*10.190*	*5.132*	
11	Velocity after Jump	V2	m / sec	6.898	4.192	4.480	7.002	4.282	4.574	
12	Fraude No before Jump	F1	-	0.814	2.029	1.027	0.799	2.004	1.014	
13	Fraude No after Jump	F2	-	1.021	0.541	0.846	1.023	0.546	0.853	
14	Jump Length	L2	meter	23.12	75.76	17.91	23.26	76.69	18.12	
15	Total Jump Length	L	meter	35.18	91.61	25.31	35.63	92.94	25.71	
16	Adopted Jump Length	L_a	meter	42	110	30	43	112	31	

NOTE :

1. Hydraulic formulae from Van Te Chow " Open Channel Hydraulics " are used to compute the results.

Adopt = 110 meters

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

i. One dimensional HEC-RAS hydraulic model is run to obtain the profiles for 1-year, 50-year and 100-year design floods to observe relevant hydraulic parameters. With the use of the resulted parameters, apron length required at the D/S of the weir structures could be judged for rigid surface to stand against scouring.

ii. Total thirty eight (38) numbers of XS of Mu River at KBW used in the HEC-RAS hydraulic model are displayed in Figure 3.1.

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

iii. Following input data are used in calibration process

(i)Design flows at critical locations of the streams: **Design floods of 10-year to 100-year return periods at the critical locations generated from the HEC-HMS hydrologic model**.

(ii)Cross sections (XS) at every 100 meters: **XS information of the Mu River.**

(iii) Detail configuration of cross drainage structures: ***Such as bridges, culverts, sluices, weir and associated afflux bunds***

(iv)Stage-discharge rating curve at key location(s): **Discharge measurement records of Mu River available at KBW**

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Figure 3.1: Cross Sections of Mu River at Kabo Weir Used in the HEC-RAS Study

PLAN OF MU RIVER CROSS SECTION NEAR KABO WEIR USED IN HEC-RAS

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model

(Continued)

iv. After several trials for calibration of HEC-RAS model, the following calibrated data are received.

Cross Section Number (HEC-RAS)	Design Discharge (Cusec)	Observed Water Level (ft)	Calibrated Parameters		Calibrated Water Level (ft)	Remark
			Mannings n (Channel)	Mannings n (Overbank)		
3300	99,388	367.80	0.027	0.040	367.87	July 2015

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model

(Continued)

v. Using the above calibrated parameters, KBW model is run with the design floods for 10, 50 and 100 years return periods. Abstract of relevant hydraulic parameters for 50-year flood produced from HEC-RAS model are given below for information and justification.

Chainage (HEC-RAS)	Design Discharge (cusec)	Velocity (ft / sec)	Observed Water Level (ft)	Froude Number (F)	Remark
3200	189624	15.57	370.91	0.69	
3100	189624	17.65	368.23	0.82	
3000	189624	26.80	358.50	1.54	
2900	189624	26.95	370.91	1.57	
2800	189624	28.87	368.23	1.86	
2600	189624	11.31	366.48	0.48	

3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

vi. From the above Table and Appendix Table, length of extended apron is adopted 600 feet or 180 meters taking into account for a factor of safety of 1.20. After this stretch of turbulent flow, River flow consistently reduce the Froude Number well below 1.0 showing the normal flow.

vii. From the above study, an obvious hydraulic irregularity was observed as below which consistently created erosion in the past. Apparently, it has entailed unnecessary financial loss annually.

- Normal Mu River slope at KBW is 0.091 % or 9 ft / 10,000 feet.
- However, the river slope just at the D/S of the KBW is found to be 1.062 % or 1.06 ft / 100 ft.

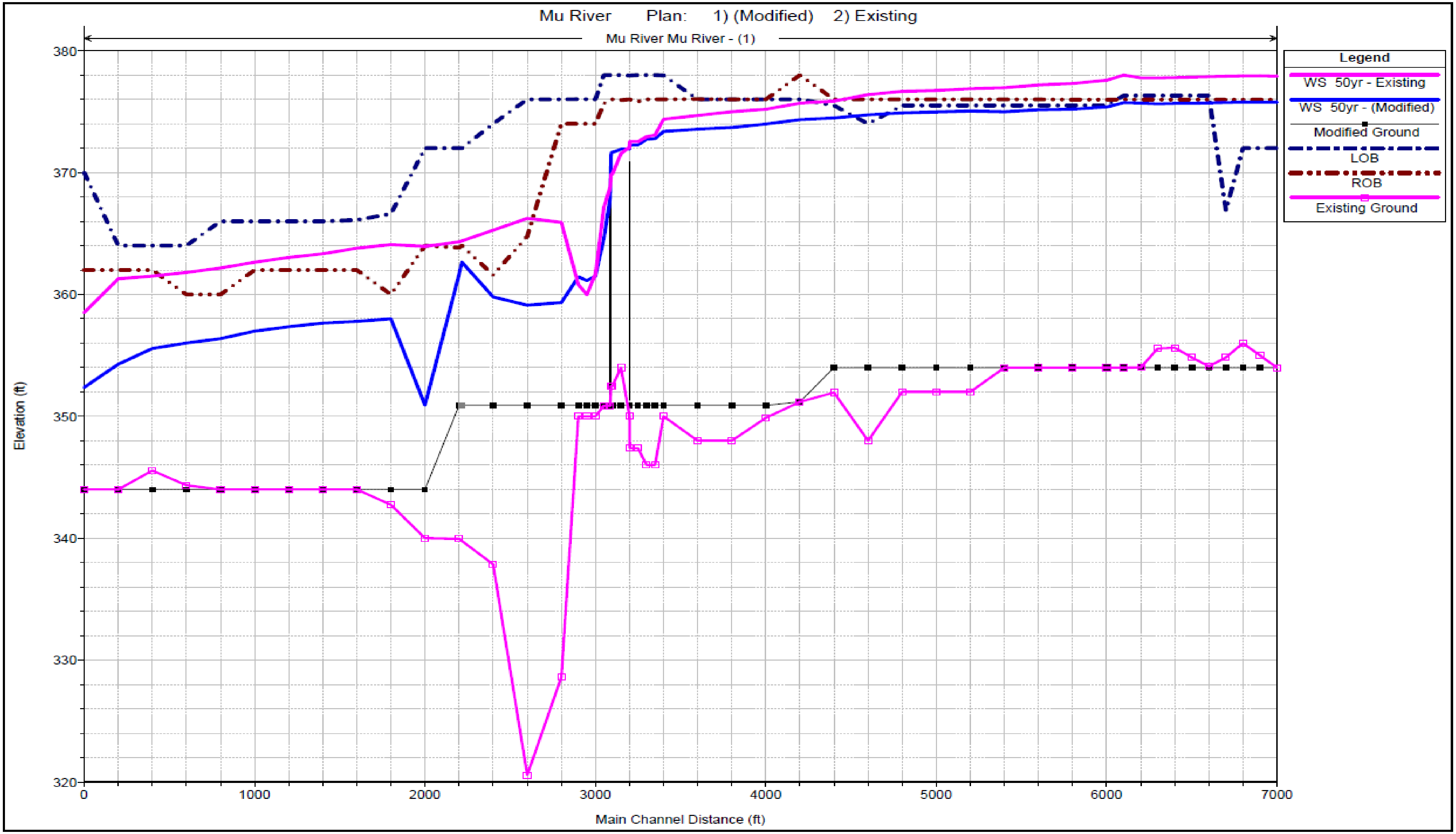
3. Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*

viii. Proposed River Sections: To overcome the hydraulic instability under turbulence flow of the River, XS were modified as follows.

- **At the downstream (D/S) of the weir, starting from the extended apron of RD 3000, steps of 0.50 foot drops were provided at every 50 feet length of the apron until the end of 2400 feet.**
- **At the D/S of the weir, turbulent formation was observed only until Rd. 2800 on the reinforced concrete (RC) floor, 400 feet before the end of the RC apron where the RC floor level reaches regime river bed level of 344.0 feet.**
- **At the end of the apron, flow was observed normal at velocity of 9.06 feet per second and Froude's number of .37.**

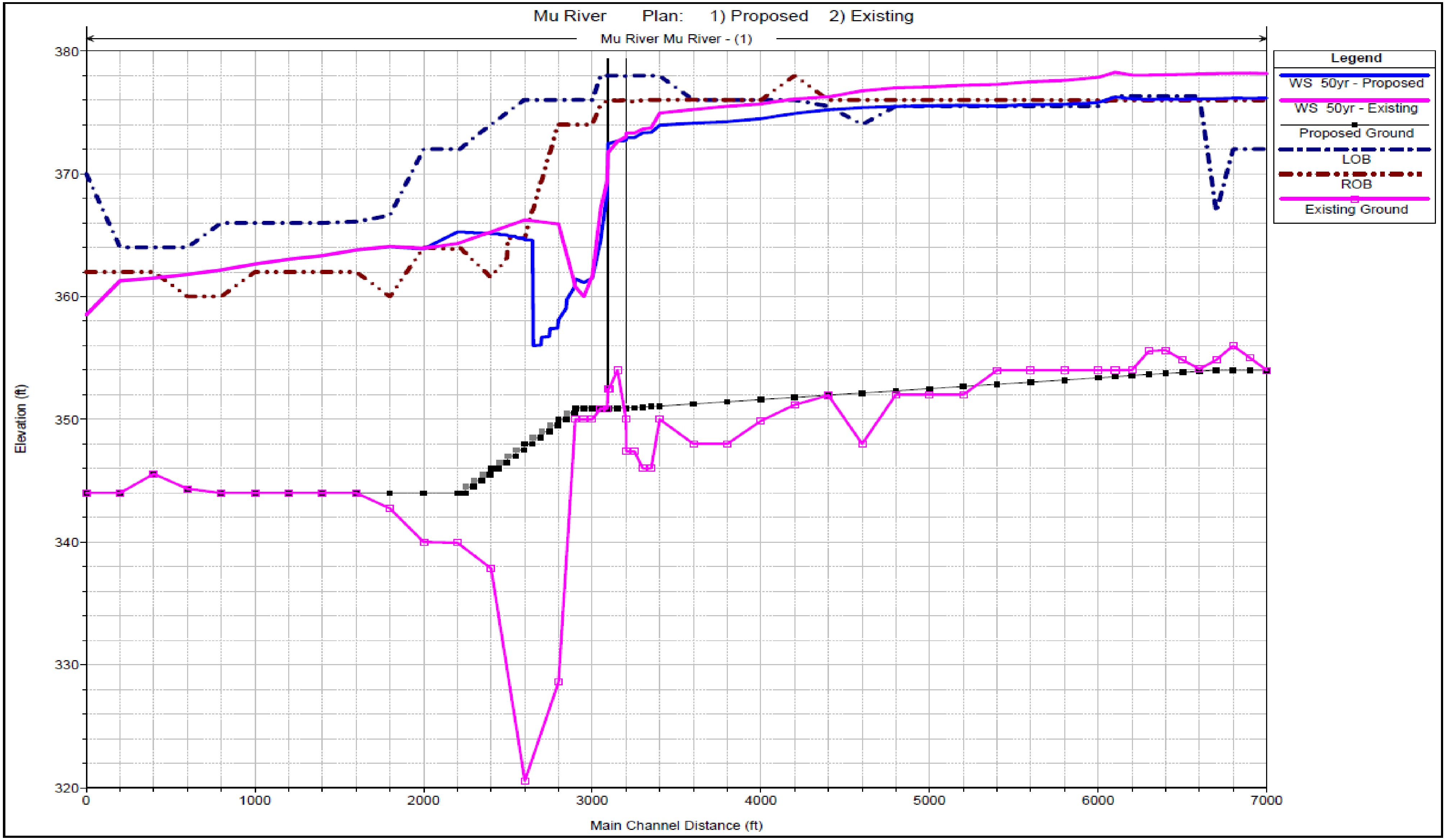
DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model



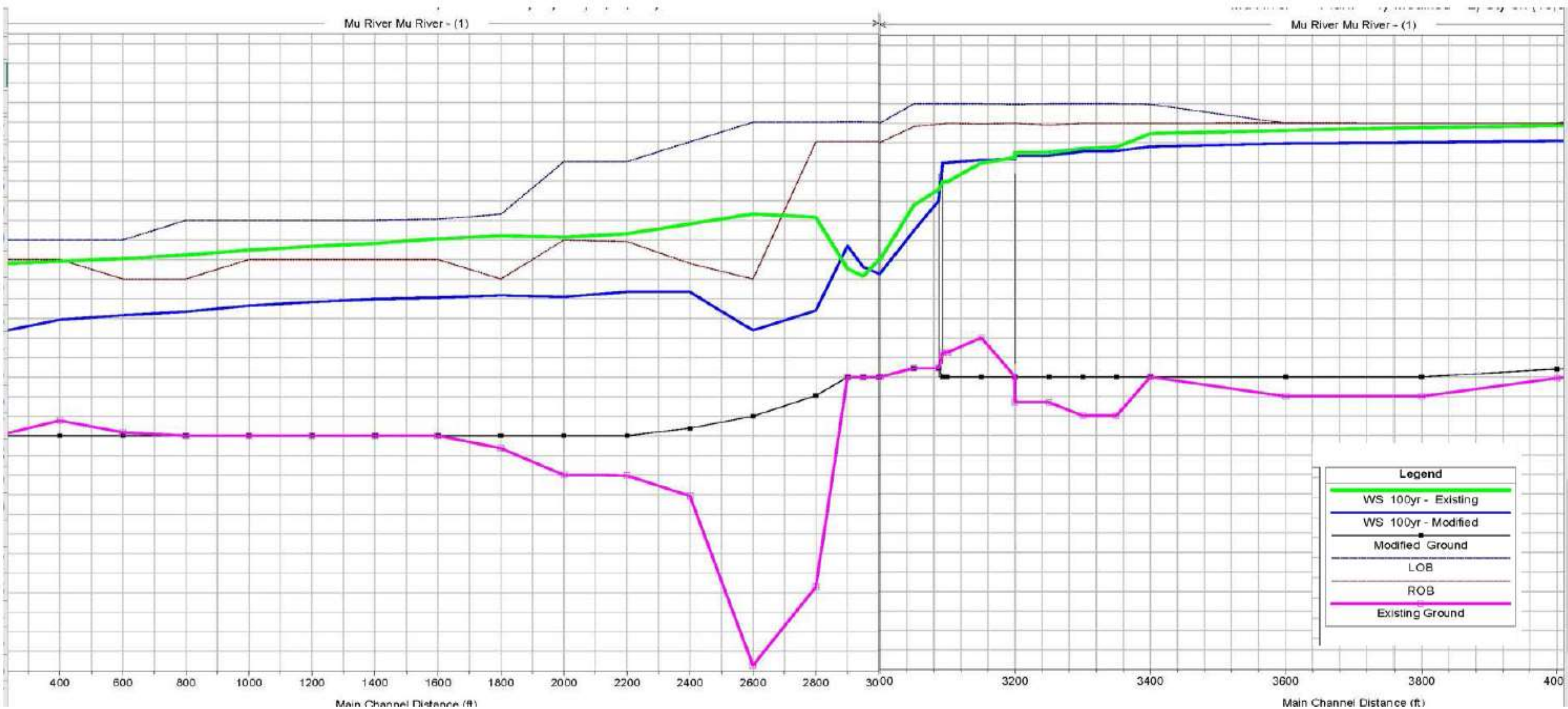
DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*



DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model *(Continued)*



DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model: Output Table

3250	10yr	131242.00	347.39	369.74	364.23	0.001210	0.027	11.44	11475.79	766.	0.52
3250	50yr	189624.00	347.39	372.79	367.11	0.001391	0.027	13.71	13843.52	805.	0.57
3250	100yr	198551.00	347.39	373.34	367.51	0.001384	0.027	13.92	14289.74	814.	0.57
3201					SHWE BO SLUICE						
3200	10yr	131242.00	350.00	368.96	365.20	0.001741	0.027	**12.83**	10225.40	757. 34	0.62
3200	50yr	189624.00	350.00	371.54	367.95	0.002051	0.027	15.57	12181.49	760.	0.69
3200	100yr	198551.00	350.00	372.06	368.34	0.002023	0.027	15.78	12581.76	760.	0.68
3150	10yr	131242.00	354.00	368.67	365.05	0.001863	0.027	13.28	9882.77	721.	0.63
3150	50yr	189624.00	354.00	370.93	367.87	0.002358	0.027	16.47	11515.59	723.	0.73
3150	100yr	198551.00	354.00	371.43	368.27	0.002347	0.027	16.71	11878.91	726.	0.73
3100	10yr	131242.00	352.48	368.22	365.32	0.002225	0.027	14.02	9359.92	728.	0.69
3100	50yr	189624.00	352.48	370.10	368.18	0.002993	0.027	17.65	10741.2	738.	0.82
3100	100yr	198551.00	352.48	370.65	368.60	0.002918	0.027	17.81	11145.3	741.	0.81
3097		Inl Struct		SPILL	WAY &	U					
3050	10yr	131242.00	350.87	364.32	364.32	0.004943	0.027	18.08	7258.16	713.	1.00
3050	50yr	189624.00	350.87	367.15	367.15	0.004607	0.027	20.42	9285.47	718.	1.00
3050	100yr	198551.00	350.87	367.58	367.58	0.004544	0.027	20.70	9591.38	719.	1.00
3000	10yr	131242.00	350.00	359.41	362.06	0.014058	0.027	24.33	5393.71	744.	1.59
3000	50yr	189624.00	350.00	361.65	364.82	0.012112	0.027	26.80	7075.85	754.	1.54
3000	100yr	198551.00	350.00	361.97	365.20	0.011904	0.027	27.13	7318.67	755.	1.54
2900	10yr	131242.00	350.00	358.29	360.99	0.013446	0.027	23.83	5506.74	759.	1.56
2900	50yr	189624.00	350.00	360.29	363.78	0.012599	0.027	26.95	7094.42	905.	1.57
2900	100yr	198551.00	350.00	360.57	364.15	0.012496	0.027	27.35	7350.94	910.	1.57
2800	10yr	131242.00	348.11	362.33	358.32	0.001470	0.027	11.42	12008.3	115	0.57
2800	50yr	189624.00	348.11	356.92	360.98	0.018766	0.027	28.87	6567.49	872.	1.86
2800	**100yr**	**198551.0**	**348.1**	**357.1**	**361.3**	**0.01853**	**0.027**	**29.29**	**6778.**	**87**	**1.85**
2600	10yr	131242.00	346.00	362.74		0.000614	0.027	8.62	15444.7	113	0.38
2600	50yr	189624.00	346.00	365.34	357.36	0.000768	0.027	10.61	18588.5	123	0.44
2600	100yr	198551.00	346.00	365.70	357.70	0.000788	0.027	10.88	19029.7	123	0.44
2400	10yr	131242.00	344.48	362.64		0.000740	0.027	8.40	15645.1	120	0.41
2400	50yr	189624.00	344.48	365.28		0.000849	0.027	10.12	18840.1	121	0.45
2400	**100yr**	**198551. 00**	**344. 48**	**365. 64**		**0.0008 64**	**0.027**	**10.36**	**19278 .58**	**12 14.**	**0.45**
2200	10yr	131242.00	344.00	361.94		0.001173	0.027	10.05	13055.32	1073.19	0.50
2200	50yr	189624.00	344.00	364.32		0.001431	0.027	12.09	15902.62	1295.65	0.57
2200	100yr	198551.00	344.00	364.65		0.001451	0.027	12.36	16335.17	1327.24	0.57
2000	10yr	131242.00	344.00	361.53		0.001397	0.027	10.49	12614.50	1210.44	0.54
2000	50yr	189624.00	344.00	363.86		0.001617	0.027	12.48	15661.66	1380.09	0.60
2000	100yr	198551.00	344.00	364.19		0.001634	0.027	12.74	16123.67	1404.85	0.61

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model

HEC-RAS Plan: Proposed River: Mu River Reach: Mu River - (1) Profile: 50yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Mu River - (1)	7000	50yr	189624.00	354.00	376.16	364.15	377.09	0.000337	7.80	25190.11	1424.92	0.30
Mu River - (1)	6900	50yr	189624.00	354.00	376.15	364.08	377.05	0.000302	7.63	25774.01	1447.27	0.30
Mu River - (1)	6800	50yr	189624.00	354.00	376.16	363.85	377.00	0.000304	7.40	26298.60	1410.71	0.29
Mu River - (1)	6700	50yr	189624.00	354.00	376.12	364.01	376.97	0.000304	7.50	26508.00	1387.62	0.29
Mu River - (1)	6600	50yr	189624.00	353.91	376.09	363.56	376.94	0.000275	7.42	25785.56	1267.47	0.28
Mu River - (1)	6500	50yr	189624.00	353.82	376.07	363.40	376.91	0.000268	7.34	25883.84	1226.64	0.28
Mu River - (1)	6400	50yr	189624.00	353.73	376.07	363.20	376.87	0.000256	7.18	26767.89	1339.42	0.27
Mu River - (1)	6300	50yr	189624.00	353.65	376.05	363.16	376.85	0.000255	7.18	26714.92	1325.05	0.27
Mu River - (1)	6200	50yr	189624.00	353.56	376.11	362.59	376.79	0.000216	6.63	28672.94	1342.77	0.25
Mu River - (1)	6100	50yr	189624.00	353.47	376.25	362.12	376.70	0.000154	5.63	39611.55	2481.32	0.21
Mu River - (1)	6000	50yr	189624.00	353.38	375.79	363.15	376.64	0.000272	7.44	26170.74	1403.84	0.28
Mu River - (1)	5800	50yr	189624.00	353.20	375.66	363.23	376.58	0.000293	7.72	25209.71	1364.37	0.29
Mu River - (1)	5600	50yr	189624.00	353.03	375.63	362.86	376.51	0.000289	7.54	25958.13	1387.54	0.28
Mu River - (1)	5400	50yr	189624.00	352.85	375.51	362.93	376.44	0.000311	7.75	25180.55	1443.34	0.29
Mu River - (1)	5200	50yr	189624.00	352.67	375.58	362.21	376.34	0.000254	7.01	27679.91	1488.55	0.26
Mu River - (1)	5000	50yr	189624.00	352.49	375.53	362.02	376.28	0.000249	6.96	27946.98	1496.71	0.26
Mu River - (1)	4800	50yr	189624.00	352.32	375.48	361.87	376.23	0.000247	6.97	27187.53	1231.26	0.26
Mu River - (1)	4600	50yr	189624.00	352.14	375.38	361.95	376.17	0.000313	7.14	27138.15	1510.96	0.28
Mu River - (1)	4400	50yr	189624.00	351.96	375.21	361.96	376.10	0.000284	7.58	25014.92	1112.55	0.28
Mu River - (1)	4200	50yr	189624.00	351.79	374.91		376.01	0.000480	8.62	24163.28	1522.95	0.35
Mu River - (1)	4000	50yr	189624.00	351.61	374.48		375.88	0.000541	9.84	22648.26	1547.99	0.37
Mu River - (1)	3800	50yr	189624.00	351.43	374.23		375.75	0.000623	10.24	21575.49	1554.63	0.40
Mu River - (1)	3600	50yr	189624.00	351.25	374.12		375.62	0.000582	10.14	21437.67	1555.86	0.39
Mu River - (1)	3400	50yr	189624.00	351.08	373.95		375.50	0.000595	10.29	20665.99	1402.68	0.39
Mu River - (1)	3350	50yr	189624.00	351.03	373.38	364.06	375.42	0.000761	11.46	16545.20	786.03	0.44
Mu River - (1)	3300	50yr	189624.00	350.99	373.34	364.04	375.38	0.000761	11.46	16542.57	785.84	0.44
Mu River - (1)	3250	50yr	189624.00	350.94	372.94	364.93	375.31	0.000958	12.33	15390.80	808.17	0.49
Mu River - (1)	3201		Inl Struct	Shwe Bo Sluice Gate								
Mu River - (1)	3200	50yr	189624.00	350.90	372.69	364.31	374.96	0.000236	12.10	15668.26	759.00	0.47
Mu River - (1)	3150	50yr	189624.00	350.90	372.67	363.87	374.95	0.000236	12.11	15654.02	735.76	0.46
Mu River - (1)	3100	50yr	189624.00	350.90	372.45	364.41	374.92	0.000267	12.60	15049.38	747.69	0.50
Mu River - (1)	3097		Inl Struct	Spillway & Ye-U Sluice Gate								
Mu River - (1)	3050	50yr	189624.00	350.90	364.59	364.59	371.08	0.001226	20.43	9279.55	713.87	1.00
Mu River - (1)	3000	50yr	189624.00	350.90	361.49	363.73	370.73	0.002373	24.38	7776.70	753.36	1.34
Mu River - (1)	2950	50yr	189624.00	350.90	361.14	363.70	370.58	0.002553	24.68	7855.81	927.92	1.38
Mu River - (1)	2900	50yr	189624.00	350.90	361.44	363.69	370.28	0.002299	23.89	8153.68	936.15	1.32
Mu River - (1)	2895	50yr	189624.00	350.50	360.79	363.30	370.22	0.002530	24.65	7819.90	916.95	1.38
Mu River - (1)	2850.00*	50yr	189624.00	350.50	359.77	362.76	370.01	0.003167	25.68	7445.39	937.10	1.51
Mu River - (1)	2845	50yr	189624.00	350.00	359.05	362.29	369.93	0.003482	26.46	7170.67	876.31	1.58

DETAIL STUDY OF KABO WEIR (KBW) ON MU RIVER FOR LONG TERM STABILITY USING HYDRAULIC MODELS

Study for Apron Length Using Hydraulic Profile & HEC-RAS Model

HEC-RAS Plan: MCA(DS) River: Mu River Reach: Mu River - (1) Profile: 50yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Mu River - (1)	2800	50yr	189624.00	350.00	358.09	361.64	369.69	0.004219	27.32	6945.55	922.43	1.71
Mu River - (1)	2795	50yr	189624.00	349.50	357.42	361.14	369.60	0.004560	27.99	6774.46	874.46	1.77
Mu River - (1)	2750.00*	50yr	189624.00	349.50	357.39	360.99	369.32	0.004500	27.71	6843.41	888.24	1.76
Mu River - (1)	2745	50yr	189624.00	349.00	356.74	360.50	369.23	0.004845	28.36	6686.76	886.04	1.82
Mu River - (1)	2700.00*	50yr	189624.00	349.00	356.68	360.31	368.94	0.005084	28.08	6752.31	899.68	1.81
Mu River - (1)	2695	50yr	189624.00	348.50	356.04	359.84	368.85	0.005439	28.71	6604.11	897.35	1.87
Mu River - (1)	2650.00*	50yr	189624.00	348.50	356.00	359.71	368.53	0.005358	28.40	6678.00	910.98	1.85
Mu River - (1)	2645	50yr	189624.00	348.00	364.59	359.23	367.02	0.000387	12.53	15558.84	1219.38	0.55
Mu River - (1)	2600	50yr	189624.00	348.00	364.62	359.13	366.99	0.000375	12.34	15363.08	954.81	0.54
Mu River - (1)	2595	50yr	189624.00	347.50	364.74		366.93	0.000351	11.89	16209.93	1177.42	0.51
Mu River - (1)	2550.00*	50yr	189624.00	347.50	364.80	358.74	366.88	0.000327	11.57	16656.90	1229.65	0.51
Mu River - (1)	2545	50yr	189624.00	347.00	364.90		366.84	0.000332	11.18	17241.88	1229.84	0.48
Mu River - (1)	2500.00*	50yr	189624.00	347.00	364.94		366.80	0.000292	10.95	17562.22	1224.48	0.48
Mu River - (1)	2495	50yr	189624.00	346.50	365.02		366.76	0.000333	10.61	18189.91	1224.63	0.46
Mu River - (1)	2450.00*	50yr	189624.00	346.50	365.05		366.73	0.000360	10.43	18419.20	1219.14	0.46
Mu River - (1)	2445	50yr	189624.00	346.00	365.11		366.70	0.000328	10.14	18934.84	1219.25	0.44
Mu River - (1)	2400	50yr	189624.00	346.00	365.11		366.68	0.000365	10.06	18958.84	1213.64	0.44
Mu River - (1)	2395	50yr	189624.00	345.50	365.16		366.65	0.000335	9.80	19458.67	1213.73	0.43
Mu River - (1)	2350.00*	50yr	189624.00	345.50	365.14		366.64	0.000328	9.84	19387.33	1229.86	0.43
Mu River - (1)	2345	50yr	189624.00	345.00	365.19		366.62	0.000302	9.59	19891.84	1232.41	0.41
Mu River - (1)	2300.00*	50yr	189624.00	345.00	365.17		366.60	0.000290	9.61	19893.12	1291.19	0.41
Mu River - (1)	2295	50yr	189624.00	344.50	365.22		366.58	0.000267	9.37	20402.39	1293.15	0.39
Mu River - (1)	2250.00*	50yr	189624.00	344.50	365.21		366.57	0.000251	9.35	20563.31	1340.48	0.39
Mu River - (1)	2245	50yr	189624.00	344.00	365.26		366.55	0.000231	9.12	21078.30	1342.26	0.37
Mu River - (1)	2216.40	50yr	189624.00	344.00	365.26		366.54	0.000220	9.08	21258.15	1374.01	0.37
Mu River - (1)	2200	50yr	189624.00	344.00	365.26		366.53	0.000490	9.06	21328.91	1385.47	0.37
Mu River - (1)	2000	50yr	189624.00	344.00	363.88		366.25	0.001588	12.41	15751.90	1380.76	0.59
Mu River - (1)	1800	50yr	189624.00	344.00	364.06		365.80	0.001129	10.59	18102.20	1397.26	0.50
Mu River - (1)	1600	50yr	189624.00	344.00	363.79		365.57	0.001157	10.69	17749.30	1308.07	0.51
Mu River - (1)	1400	50yr	189624.00	344.00	363.33		365.30	0.001347	11.27	16858.58	1293.54	0.55
Mu River - (1)	1200	50yr	189624.00	344.00	363.03		365.02	0.001409	11.33	16761.87	1319.04	0.56
Mu River - (1)	1000	50yr	189624.00	344.00	362.64		364.72	0.001534	11.57	16418.72	1359.52	0.58
Mu River - (1)	800	50yr	189624.00	344.00	362.16		364.38	0.001695	11.96	15894.35	1343.05	0.60
Mu River - (1)	600	50yr	189624.00	344.34	361.80		364.03	0.001827	11.99	15835.16	1391.30	0.62
Mu River - (1)	400	50yr	189624.00	345.55	361.50		363.65	0.001764	11.77	16116.29	1399.29	0.61
Mu River - (1)	200	50yr	189624.00	344.00	361.27		363.25	0.001657	11.29	16800.22	1483.54	0.59
Mu River - (1)	0	50yr	189624.00	344.00	358.52	358.52	362.51	0.005354	16.03	11832.24	1488.38	1.00

Conclusion and Remark

- On data analysis and processing, well known and world recognized statistical, hydrological and hydraulic software are applied to produce most reliable results of various scenarios for reasonable and easier judgement of the decision makers.
- Main objective of the study is to secure a most cost-effective flood erosion protection scheme to prevent the ongoing erosion problems of Mu River at Kabo Weir.
- As the results, it could be ensured that there will not be significant erosion problem of Mu River at Kabo Weir after implementation of the above scheme.

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Exp Infrastructure Engineering Consultants Co.,Ltd