


REFERENCE LIST

- [1]-The Follow-Up Study on The Rehabilitation of Hydropower Stations In the Kelani River Basin for Hydropower Optimization in Sri Lanka, Final Report, Volume II, Japan international cooperation agency economic development department, Rep, July 2005
- [2]-CGS Gunasekara and NCP Liyanage, Design of Penstocks [online] Available:
<http://www.freewebs.com/csgunasekara/4.pdf>
- [3]-Adam Harvey with Andy Brown, Priyantha Hettiarachchi and Allen Inversin, Micro Hydro Design Manual ,A guide to small-scale water power schemes, Intermediate Technology publications 103/105 South ampton Row, London WC1B 4HH, UK, pp 124-130
- [4]-Old Laxapana Power Station Upgrading Study, Mott MacDonald Ltd, VicoryHouse, Trafalgar Place, Brighton, Rep., November 1999
- [5]-Er. R.K. Rajput, A Text Book of Fluid Mechanics and Hydraulic Mechanics in SI Units, S Chand & Co. Ltd., Ram Nagar, New Delhi, 2008, pp. 53- 80.
- [6]-Design of Pelton turbines [online] Available:
 <http://www.ivt.mnu.ac.lk/epi/fag/tep4195/innhold/forelesninger/forelesninger%202006/5%20-%20Pelton%20turbine.pdf>
University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.ivt.mnu.ac.lk
- [7]-Statistical digest 2012, Ceylon Electricity Board, Rep, 2013
- [8]-HBrothers, DollarTimes [online]. Available:
<http://www.dollartimes.com/calculators/inflation.htm>
- [9]-Master plan for the electricity supply of Sri Lanka, Phase-E Operation Studies, Data Report I, CEB, Gtz, Lide, CECB,Rep,13 Dec 1989

APPENDIX-I: Penstock Refurbishment Procedure

Penstock refurbishment

1. Water washing

Corroded and mud-accumulated penstock is washed with a high-pressure jet of water to remove particles. The pressure used is around 100 bars.



Figure (a): Corroded penstock (Original in colour)



Figure (b): After water washing (Original in colour)

2. Sand Blasting

This is the main process of corrosion removal. Pressurized sand particles are struck on the penstock surface in order to remove rust and to expose the bare metal. The size of the sand particles used is 35 - 45 microns.



University of Moratuwa, Sri Lanka.

Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Figure (c): After the Sand blasting (Original in colour)

3. Second washing

If the salt content of the metal surface is high, another washing is done.

4. Primer coating

Just after the sand blasting, a primer (epoxy paint) coating is applied on the bare metal of the penstock as an immediate protector to the metal. Otherwise, the metal will corrode and change to a dark colour. Additionally, the primer coating will support the top coat of paint to be applied well on the penstock surface. The thickness of the coating applied is 80-100 microns.



Figure (d): After primer is coated (Original in colour)

5. Intermediate coating

This coat is applied when the primer coat and top/final coat is not compatible.



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

6. Final coats

This coating is the main coating used to keep the penstock protected for a long time. Usually, the thickness of the coating is the factor of duration that the penstock will be protected. Typically, to keep the penstock protected around 20 years, over 500 microns thickness of the coating is used. Usually this thickness is achieved applying about 3-4 coatings. Usually different colours are used for each coating in order not to retain an uncoated area by mistake.



Figure (e): After final coating is applied (Original in colour)



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

APPENDIX-II :Spill Data of the Ponds and the Calculations

Year	Month	Day	Spilled water volume (million cubic feet)										
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved. by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled per day	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)
2009	May	20	326.7	7.1	37.7	12.6	24.0	3781.3		57.5		19.3	
		21	6.4	6.4	6.4	6.4	1.5	1185.2					
		23	15.7	7.1	15.7	15.7	14.0	311.5					
		24	34.3	7.1	34.3	12.6	11.3	846.9		2.7		0.7	
		25	50.2	7.1	50.2	12.6	16.0	871.1		2.8		3.8	
							799.0			835.0		823.0	
2009	Jun.	27	13.9	7.1	13.9	13.9	4.0	965.3					
		28	8.8	7.1	8.8	8.8	6.0	407.4					
		29	21.9	7.1	21.9	12.6	5.0	1216.7		2.0		23.5	
		30	257.7	7.1	37.7	12.6	22.0	3253.8		41.4		30.5	
							659.0			592.0		685.0	
2009	Jul.	1	230.1	7.1	37.7	12.6	13.3	4823.9		45.3			
		2	268.4	7.1	37.7	12.6	24.0	3106.5		118.6		33.6	
		3	165.4	7.1	37.7	12.6	12.0	3828.7		59.4		17.8	
		4	102.4	7.1	37.7	12.6	22.8	1250.3		28.1		5.2	
		5	26.1	7.1	26.1	12.6	21.8	335.5		0.2			
		6	28.1	7.1	28.1	12.6	24.0	325.2		9.5			
		7	4.7	4.7	4.7	4.7	6.8	193.4		0.4			
		17	9.4	7.1	9.4	9.4	8.0	326.4					
		18	20.9	7.1	20.9	12.6	24.0	241.9					
		19	2.5	2.5	2.5	2.5	2.8	252.5		20.6			
2009	Aug.	27	13.9	7.1	13.9	13.9							
		28											
		29								1.9		23.5	
		30								41.4		30.5	
									247.0			388.0	
2009	Sept.	16	18.2	7.1	18.2	18.2	4.5	1124.7				5.1	
		17	17.8	7.1	17.8	17.8	7.3	682.0				9.7	
							480.0			474.0		477.0	
2009	Sept.	2	72.6	7.1	37.7	12.6	11.3	1792.6		55.3			
		3	62.8	7.1	37.7	12.6	12.3	1424.0		23.8			
		4	97.1	7.1	37.7	12.6	9.5	2840.1		28.3			
		5	50.4	7.1	50.4	12.6	21.5	651.2		17.8			
		6	61.6	7.1	37.7	12.6	22.0	777.8		42.2			
		7	34.8	7.1	34.8	12.6	24.0	402.8		49.8			
		8	63.5	7.1	37.7	12.6	22.3	792.8		48.8			
		9	12.8	7.1	12.8	12.8	5.3	677.2		4.6			
		13								0.9			
		20	7.4	7.1	7.4	7.4	1.5	1370.4		12.4			
22	4.7	4.7	4.7	4.7	1.5	870.4	508.0		402.0		581.0		

Year	Month	Day	Spilled water volume (million cubic feet)											
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)	
2009	Oct.	23	0.9	0.9	0.9	0.9	0.5	500.0						
		29	31.2	7.1	31.2	12.6	20.5	422.8						
		1	135.6	7.1	37.7	12.6	24.0	1569.4		239.0				
		2	583.5	7.1	37.7	12.6	24.0	6753.5		442.3			3.4	
		3	246.2	7.1	37.7	12.6	23.5	2909.6		109.7			7.3	
		4	254.2	7.1	37.7	12.6	24.0	2942.1		259.6			6.8	
		5	183.8	7.1	37.7	12.6	24.0	2127.3		53.4			0.4	
		6	294.8	7.1	37.7	12.6	24.0	3411.5		1.4				
		7	121.5	7.1	37.7	12.6	7.3	4655.2						
		8	26.1	7.1	26.1	12.6	23.0	315.2		7.3				
		9	40.5	7.1	40.5	12.6	24.0	468.8		10.9				
		13	53.9	7.1	53.9	12.6	22.5	665.4		13.7			4.0	
		14	14.8	7.1	14.8	14.8	8.0	513.9		22.4			4.0	
		15	17.1	7.1	17.1	17.1	24.0	197.9		23.7			15.8	
		16	79.6	7.1	37.7	12.6	12.5	1768.9		32.1			15.2	
		17	18.9	7.1	18.9	18.9	24.0	218.8		52.9			22.8	
		18	53.5	7.1	53.5	12.6	21.8	683.3					14.8	
		19	23.4	7.1	23.4	12.6	23.8	273.7		10.3			8.1	
		20	38.1	7.1	38.1	12.6	24.0	441.1		19.3			14.0	
		21	20.7	7.1	20.7	12.6	23.5	244.7		10.6			2.0	
		22	19.4	7.1	19.4	19.4	8.3	651.5		7.7			0.8	
		23	14.3	7.1	14.3	14.3	23.8	166.7		17.9			4.3	
		24	13.7	7.1	13.7	13.7	22.0	172.7		13.0			11.1	
		25	49.6	7.1	49.6	12.6	23.0	598.7		33.4			4.0	
		26	20.2	7.1	20.2	12.6	24.0	233.4		2.0			2.2	
		27	22.8	7.1	22.8	12.6	22.0	287.9		16.9			0.9	
		28											1.6	
		29												
									412.0		402.0			401.0
2009	Nov.	1	11.7	7.1	11.7	11.7	3.0	1083.3						
		10										0.3		
		11										4.6		
		12										13.7		
		13										19.2		
		14										16.7		
		15	1.7	1.7	1.7	1.7	1.8	261.9				16.6		
		16										1.6		
		17										2.8		
		18										6.2		
		19										0.8		
21							217.0		264.0	2.3	338.0			

Year	Month	Day	Spilled water volume (million cubic feet)											
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)	
2009	Dec.	22											8.8	
		23											3.2	
		7											3.9	
		8							185.0		172.0	0.3	211.0	
2009			Total (spilling)	4502.6	402.1	1611.5	727.4	936.3				2115.1		447.7
			Average	75.0				15.9	1279.1			45.0		9.5
			Max	583.5								442.3		33.6
			Total Rainfall							3507		3529		3910
2010	May.	2	14.1	7.1	14.1	14.1	4.3	921.6						
		5	16.5	7.1	16.5	16.5	12.0	381.3						
		7	0.6	0.6	0.6	0.6	0.3	650.0						
		19	33.6	7.1	33.6	12.6	19.3	484.2						
		20	30.8	7.1	30.8	12.6	14.0	611.1						
		21	13.1	7.1	13.1	13.1	0.8	4861.1						
		22	3.2	7.1	3.2	3.2	3.5	250.0						
		24	8.2	7.1	8.2	8.2	10.0	227.1						
		25	14.6	7.1	14.6	14.6	14.5	279.7						
		26	13.8	7.1	13.8	13.8	22.3	171.7						
		27	2.3	2.3	2.3	2.3	1.5	416.7						
		28	6.8	6.8	6.8	6.8	9.5	197.4						
		31	0.5	0.5	0.5	0.5	0.5	291.7						
										667.0		516.0		647.0
2010	Jun.	6	2.7	2.7	2.7	2.7	3.0	250.0						
		10	11.5	7.1	11.5	11.5	4.3	750.0						
		11	26.0	7.1	26.0	12.6	12.5	578.3						
		12	20.0	7.1	20.0	12.6	22.5	247.4						
		13	9.3	7.1	9.3	9.3	11.8	219.9						
		14	34.1	7.1	34.1	12.6	13.8	687.9						
		15	14.9	7.1	14.9	14.9	24.0	171.9						
		16	11.0	7.1	11.0	11.0	22.3	137.6						
		17	4.2	4.2	4.2	4.2	10.5	111.1						
		23	2.5	2.5	2.5	2.5	0.8	916.7						
24	2.7	2.7	2.7	2.7	1.8	428.6				0.4				
28	0.4	0.4	0.4	0.4	0.3	416.7								
								609.0		593.0		651.0		
2010	Jul.	3	5.0	5.0	5.0	5.0	16.5	83.3	609.0		625.0		719.0	

Year	Month	Day	Spilled water volume (million cubic feet)												
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)		
		14	5.7	5.7	5.7	5.7	2.5	633.3							
		16	29.7	7.1	29.7	12.6	11.3	733.3							
		17	24.9	7.1	24.9	12.6	7.5	922.2							
		18	90.9	7.1	37.7	12.6	24.0	1052.4		39.5					
		19	31.2	7.1	31.2	12.6	24.0	361.1							
		20	6.5	6.5	6.5	6.5	17.5	102.9					25.4		
		21	21.7	7.1	21.7	12.6	18.0	335.5					22.9		
		22	10.6	7.1	10.6	10.6	17.8	165.5					8.6		
		23	9.9	7.1	9.9	9.9	11.0	250.0					13.6		
		24	10.1	7.1	10.1	10.1	20.0	139.6					8.5		
		25	17.1	7.1	17.1	17.1	14.5	327.6					18.0		
		26	4.6	4.6	4.6	4.6	5.0	254.2							
					0.0	0.0									
		2010	Aug.	14	2.4	2.4	2.4	2.4	0.8	888.9					
15	73.5			7.1	37.7	12.6	13.3	1540.9		8.9			5.4		
16	5.7			5.7	5.7	5.7	1.8	904.8							
20	6.8			6.8	6.8	6.8	2.0	937.5							
21	62.0			7.1	37.7	12.6	15.8	1093.9					2.7		
25	0.0			0.0	0.0	0.0							3.9		
29	13.8			7.1	37.7	12.6	6.1	505.7		12.6			16.3		
30	52.3			7.1	52.3	12.6	20.5	708.1					20.9		
31	61.5			7.1	37.7	12.6	23.3	734.8		13.3			31.8		
									676.0		440.0			785.0	
2010	Sept.			1	199.7	7.1	37.7	12.6	24.0	2310.8		26.1			4.3
		2	22.6	7.1	22.6	12.6	14.5	432.5		5.5			3.9		
		3	21.6	7.1	21.6	12.6	24.0	250.0							
		4	21.6	7.1	21.6	12.6	24.0	250.0							
		5	28.1	7.1	28.1	12.6	20.5	380.8							
		6	6.3	6.3	6.3	6.3	19.0	92.1							
		7	5.3	5.3	5.3	5.3	7.5	195.7							
		8	8.4	7.1	8.4	8.4	21.8	107.3							
		9	3.5	3.5	3.5	3.5	13.5	71.0							
		10	11.6	7.1	11.6	11.6	15.0	215.2							
		12	17.0	7.1	17.0	17.0	19.0	247.8							
		13	11.2	7.1	11.2	11.2	12.8	243.5							
		14	17.1	7.1	17.1	17.1	19.0	250.0							
		15	5.2	5.2	5.2	5.2	17.5	82.1							
16	9.1	7.1	9.1	9.1	18.0	140.0									
22	6.4	6.4	6.4	6.4	14.3	124.3									
23	16.6	7.1	16.6	16.6	18.8	245.6									
24	36.6	7.1	36.6	12.6	23.0	442.0									
25	20.8	7.1	20.8	12.6	18.5	311.9									
26	9.0	7.1	9.0	9.0	10.0	250.0	436.0		235.0			430.0			

Year	Month	Day	Spilled water volume (million cubic feet)											
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)	
		27	3.8	3.8	3.8	3.8	4.0	260.4						
		28	5.4	5.4	5.4	5.4	6.0	250.0						
		29	6.3	6.3	6.3	6.3	7.0	250.0						
2010	Oct.	1	2.5	2.5	2.5	2.5	1.3	550.0						
		2	24.4	7.1	24.4	12.6	15.0	451.9						
		3	68.4	7.1	37.7	12.6	22.3	853.9		2.2				
		4	34.4	7.1	34.4	12.6	16.5	578.3						
		5	15.5	7.1	15.5	15.5	24.0	179.7						
		6	29.7	7.1	29.7	12.6	24.0	344.1		5.1				
		7	86.9	7.1	37.7	12.6	23.3	1037.6		18.4		32.8		
		8	86.8	7.1	37.7	12.6	24.0	1004.6		11.1		71.4		
		9	50.4	7.1	50.4	12.6	24.0	583.3		12.8		64.0		
		10	79.3	7.1	37.7	12.6	24.0	917.5		11.9		35.2		
		11	75.9	7.1	37.7	12.6	24.0	878.5		19.4		32.7		
		12	47.4	7.1	47.4	12.6	24.0	548.6		19.7		31.5		
		13	52.1	7.1	52.1	12.6	24.0	602.9		20.0		15.9		
		14	68.0	7.1	37.7	12.6	24.0	786.5						
		15	29.7	7.1	29.7	12.6	24.0	343.8						
		16	17.1	7.1	17.1	12.6	20.0	238.1						
		17	9.4	7.1	9.4	9.4	3.0	867.6						
		18	13.7	7.1	13.7	13.7	15.0	252.8						
									568.0		433.0		571.0	
2010	Nov.	7	7.5	7.1	7.5	7.5	2.0	1041.7				2.3		
		8	20.3	7.1	20.3	12.6	9.0	625.0				1.8		
		26										12.1		
		27										61.6		
		28	2.4	2.4	2.4	2.4	1.3	533.3				42.7		
		29										35.7		
		30										51.1		
									534.0		454.0		618.0	
2010	Dec.	1	0.9	0.9	0.9	0.9	0.5	500.0						
		2	3.2	3.2	3.2	3.2	1.8	500.0						
		3										8.5		
		4								1.4		9.4		
		5	34.7	7.1	34.7	12.6	24.0	401.6		5.3				
		6	24.0	7.1	24.0	12.6	10.8	620.2						
		7	3.2	3.2	3.2	3.2	9.3	94.9						
		8	30.6	7.1	30.6	12.6	9.8	871.8						
		9	25.4	7.1	25.4	12.6	15.0	470.4		7.7				
		10	38.4	7.1	38.4	12.6	24.0	444.4		57.3				
		11								10.3		12.1		
		24							289.0		348.0	20.8	311.0	

Year	Month	Day	Spilled water volume (million cubic feet)											
			Laxapana	Water vol. saved by 0.2MCM capacity improvement	Water vol. saved by 40.8MW generator (million Cubic feet)	water vol. saved by 13.6MW generator (million Cubic feet)	hours spilled	Average spill rate in a day (cusecs)	Laxapana Rainfall (mm)	Canyon	Canyon Rainfall (mm)	Norton	Norton Rainfall (mm)	
2011	May	28	6.4	6.4	19.4	19.4	15.0	118.1						
		31	46.4	7.1			15.0	858.3						
					6.4	6.4								
2011	Jun	1	12.9	7.1	46.4	12.6	24.0	149.3						
		2	8.5	7.1			2.0	1180.6						
		19	5.2	5.2	12.9	12.9	13.3	108.5						
					8.5	8.5			307.0		287.0		331.0	
2011	Jul	25	1.4	1.4	5.2	5.2	2.5	157.8						
		26									0.1			
					1.4	1.4			360.0		437.0		465.0	
2011	Aug	nil							343.0		280.0		353.0	
2011	Sept	10	7.1	7.1			4.5	439.8						
		12	13.7	7.1			5.5	693.2						
		13	106.4	7.1	7.1	7.1	24.0	1231.8				3.2		
		14	34.4	7.1	13.7	13.7	21.3	449.0						
		15	0.8	0.8	37.7	12.6	3.3	64.1						
					34.4	12.6			675.0		462.0		681.0	
2011	Oct	nil			0.8	0.8			323.0		175.0		194.0	
2011	Nov	nil												
2011	Dec	nil									47.0		49.0	
2011	Total	(spilling)	1454.0	162.2	651.6	262.0	428.0				30.1		90.7	
		Average	53.9				15.9	1310.7			5.0		4.8	
		Max	476.8								15.6		21.7	
	Total	Rainfall							3772		3129		3669	

APPENDIX-III: NL Tunnel Leakage Measurement

Table (a): Measurement results of New Laxapana tunnel leakage

Day	Time	Operating power of the Generators		Total operating power(MW)	Leakage discharge measured (m ³ /s)
		Generator Unit No 1 power(MW)	Generator Unit No 2 power(MW)		
1	8:00	11	26	37	0.29
1	8:30	20	24	44	0.28
1	9:00	12	21	33	0.31
1	9:30	20	16	36	0.3
1	10:00	14	22	36	0.27
1	10:30	20	20	40	0.3
1	11:00	20	11	31	0.28
1	11:30	20	27	47	0.28
1	12:00	30	28	58	0.3
1	12:30	15	23	38	0.28
1	13:00	12	12	24	0.28
1	13:30	21	15	36	0.28
1	14:00	18	29	47	0.28
1	14:30	15	15	30	0.28
1	15:00	23	20	43	0.28
1	15:30	11	20	31	0.28
1	16:00	11	23	34	0.28
1	16:30	11	15	26	0.31
1	17:00	17	29	46	0.3
2	8:00	28	39	67	0.27
2	8:30	0	50	50	0.3
2	9:00	0	50	50	0.28
2	9:30	0	50	50	0.28
2	10:00	0	50	50	0.3
2	10:30	0	50	50	0.3
2	11:00	0	50	50	0.27
2	11:30	0	50	50	0.3
2	12:00	0	50	50	0.28
2	12:30	0	50	50	0.28
2	13:00	0	50	50	0.28
2	13:30	0	30	30	0.28
2	14:00	0	50	50	0.28
2	14:30	0	50	50	0.28
2	15:00	0	50	50	0.28
2	15:30	0	50	50	0.28
2	16:00	0	50	50	0.28
2	16:30	0	50	50	0.31



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Day	Time	Operating power of the Generators		Total operating power(MW)	Leakage discharge measured (m ³ /s)
		Generator 1 power(MW)	Generator 2 power(MW)		
2	17:00	0	50	50	0.3
3	8:00	11	26	37	0.27
3	8:30	16	20	36	0.3
3	9:00	29	16	45	0.28
3	9:30	31	26	57	0.28
3	10:00	50	20	70	0.3
3	10:30	39	37	76	0.3
3	11:00	30	30	60	0.27
3	11:30	36	35	71	0.3
3	12:00	50	28	78	0.28
3	12:30	50	40	90	0.3
3	13:00	17	16	33	0.3
3	13:30	23	27	50	0.27
3	14:00	29	27	56	0.3
3	14:30	29	27	56	0.28
3	15:00	18	21	39	0.28
3	15:30	23	19	42	0.28
3	16:00	10	10	20	0.28
3	16:30	10	0	10	0.28
3	17:00	10	0	10	0.28



University of Moratuwa, Sri Lanka
 Electronic Theses & Dissertations
www.lib.mrt.ac.lk

APPENDIX-IV: The Load Curve

Average Load Curve of Sri Lanka in the month of January in 2012 is shown below.

