IRRIGATION DEPARTMENT

HYDROLOGICAL ANNUAL 2014/15

Hydrology Division
Irrigation Department
Colombo 07
Sri Lanka

Hydrological Annual 2014/15 – Hydrology Division, Irrigation Department. 56th year of publication

EDITORIAL BOARD

Foreword

It's a great pleasure for me to forward the Hydrological Annual of 2014/15 with salient hydrological information pertaining to the water year. Being the 56th volume of the series this bulletin contains a large amount of historical data which will be useful for water resources planners and the developers of the country. The content of the journal has been substantially improved and the demand is eventually increased among the professionals and the researchers in water sector. Over 100 copies of the journal are distributed to the Government departments and educational Institutions every year.

Part I of the Journal provides the general information of the river basins including the catchment areas and the layout of hydro-meteorological stations with their geographical coordinates. This is quite useful for the students and the general public who wish to gather the latest and first hand information based on field measurements.

Part II presents the annual averages of rainfalls and river flows over the Island with their temporal and spatial distributions. Further it provides other hydro-meteorological parameters such as rainfall intensities, open water evaporation, evapo-transpiration etc. which are useful in reservoir operation and cultivation planning.

The Graphical presentation of spatial variations of annual and seasonal rainfalls over the Island is quite useful to the reader to have quick assessment over the water year and identify the changes and the trends of the climatic features over the country due to natural phenomena and also due to human intervention.

Part III of the journal is allocated for the technical papers and research works carried out by the engineers of the Irrigation Department. Findings of these research works are useful for those who are engaged in water related development works.

There was no severe flood hazards experienced within 2014/15 water year. However there was a devastating flood in May 2016 faced by the people of several river basins including the Kelani River. The article 'Hydrological Report on the Kelani River Flood in May 2016' analyses the important hydrological aspects of the flood comparing with the previous events of similar nature. A very comprehensive data series of water levels and river flows at gauging points has been provided at the end of the paper. This will be particularly useful for the flood modelers who are in search of historical data.

The research paper 'Flood Forecasting Model for the Kelani River with HEC HMS Software' is an attempt, made by the engineers of Hydrology Division, to model Kelani River with freely available software called 'HECHMS'. The model was calibrated with hydrological data relevant to minor flood in 2008 and verified with an independent flood event in the same year. The results were quite promising. However, further improvements and verification with major flood events will be needed before validating the model for flood forecasting. The Importance of river modeling is eventually increased with urbanization of river basins and also with the adverse effects of climate change.

Eng. Ms P. Hettiarachchi,
Director of Irrigation (Hydrology)

TABLE OF CONTENTS

PART I

- **Terminology and Abbreviations**
- **Conversion Factors**
- **River Basin Map and Drainage Area**
- **Hydrometric Stations**

TERMINOLOGY AND ABBREVIATIONS USED IN PUBLICATION

Flood Hydrograph	-	A plot of discharge against time.
Annual Flood Peak	-	Highest value of discharge for the year indicated by the hydrograph
Maximum Flood Peak	-	Maximum observed flood peak during the period of observation.
Average Annual Rainfall	-	Arithmetic mean of annual rainfall values for the period of observation.
Rainfall Intensity	-	Cumulative depth of rainfall during a particular duration.
Annual Runoff	-	The total volume of water measured at a particular point for the year.
Average Annual Runoff	-	Arithmetic mean of annual run-off for the period of observation.
Annual Yield	-	Annual yield is the volume of water available to the tank from its own catchment (without diversions) during the year.
Specific Yield	-	$\frac{\text{Yield (MCM)}}{\text{Catchment Area (Sq.Kms)}}$
Duty	-	Duty is the irrigation requirement (issued from the sluice) during a cultivation season for one hectare Duty (meters) = $\frac{\text{Sluice Issue (ha.m)}}{\text{Area Cultivated (ha)}}$
Evaporation	-	The transfer of water into the atmosphere from a free water surface.
Potential Evapotranspiration	-	The evapotranspiration from vegetal cover and from soil surface when the root zone is saturated.

CONVERSION FACTORS

Length

Imperial		Metric / SI
I inch	= 1/12 foot	0.0254 m
1 foot	= 1/3 yard	0.3048 m
1 yard	= 3 feet	0.9144 m
1 Engineering chain	= 100 feet	30.48 m
1 mile	= 52.8 chains = 5280 feet	1609 m

Area

Imperial		Metric / SI
1 square foot	= 144 square inches	0.0929 m^2
1 acre	= 43,560 ft^2	4,047 m^2 = 0.4047 ha
2.47 acres		1 ha
1 square mile	= 640 acres	259 ha = 2.59 km^2

Volume & Discharge

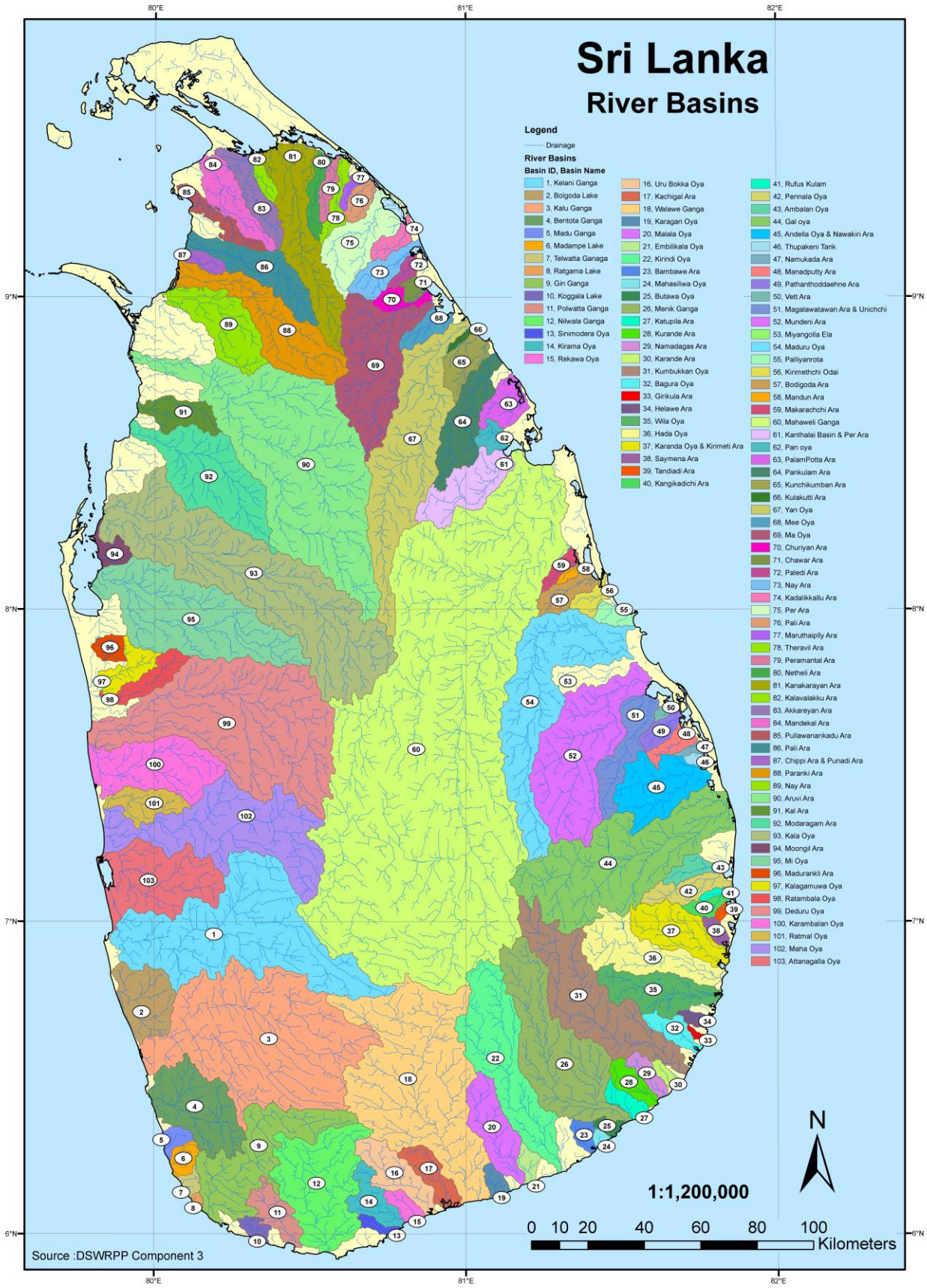
Imperial		Metric / SI
1 cubic foot per second (cusec)		28.317 l/s
1 cusec during 1 day	= 1.983 acre.ft	2,446.57 m^3
1 acre.foot		1,234 m^3
1 acre.foot/day		14.28 l/s = 1234 m^3/d
1 acre.inch	= 3.630 ft^3	102.8 m^3

Map scales

Imperial	Metric / SI
1 inch : 10 feet	1 : 120
1 inch : 20 feet	1 : 240
1 inch : 66 feet	1 : 792
1 inch : 132 feet	1 : 1,584
1 inch : 264 feet	1 : 3,168
1 inch : 528 feet	1 : 6,336
1 inch : I mile	1 : 63,360

Weight

Imperial	Metric / SI
1 pound	0.4536 kg
2.24 pound	1 kg
1 ton	1,016 kg
2,240 pounds	1 Metric Ton = 1000 kg
1 bushel (paddy)	22.88 kg
1 bushel/acre	56.5 kg/ha


Sri Lanka
River Basins
Legend
Drainage
River Basins
Basin ID, Basin Name
1, Kelani Ganga
2, Bolgoda Lake
3, Kalu Ganga
4, Bentota Ganga
5, Madu Ganga
6, Madampe Lake
7, Telwatta Ganaga
8, Ratgama Lake
9, Gin Ganga
10, Koggala Lake
11, Polwatta Ganga
12, Nilwala Ganga
13, Sinimodera Oya
14, Kirama Oya
15, Rekawa Oya
16, Uru Bokka Oya
17, Kachigal Ara
18, Walawe Ganga
19, Karagan Oya
20, Malala Oya
21, Embilikala Oya
22, Kirindi Oya
23, Bambawe Ara
24, Mahasiliwa Oya
25, Butawa Oya
26, Menik Ganga
27, Katupila Ara
28, Kurande Ara
29, Namadagas Ara
30, Karande Ara
31, Kumbukkan Oya
32, Bagura Oya
33, Girikula Ara
34, Helawe Ara
35, Wila Oya
36, Hada Oya
37, Karanda Oya & Kirimeti Ara
38, Saymena Ara
39, Tandiadi Ara
40, Kangikadichi Ara
41, Rufus Kulam
42, Pennala Oya
43, Ambalan Oya
44, Gal oya
45, Andella Oya & Nawakiri Ara
46, Thupakeni Tank
47, Namukada Ara
48, Manadputty Ara
49, Pathanthoddaehne Ara
50, Vett Ara
51, Magalawatawan Ara & Unichchi
52, Mundeni Ara
53, Miyangolla Ela
54, Maduru Oya
55, Palliyanrota
56, Kirimethchi Odai
57, Bodigoda Ara
58, Mandun Ara
59, Makarachchi Ara
60, Mahaweli Ganga
61, Kanthalai Basin & Per Ara
62, Pan oya
63, PalamPotta Ara
64, Panikulam Ara
65, Kunchikumban Ara
66, Kulakutti Ara
67, Yan Oya
68, Mee Oya
69, Ma Oya
70, Churiyan Ara
71, Chawar Ara
72, Paledi Ara
73, Nay Ara
74, Kadalikkallu Ara
75, Per Ara
76, Pali Ara
77, Maruthaipilly Ara
78, Theravil Ara
79, Peramantal Ara
80, Netheli Ara
81, Kanakarayan Ara
82, Kalavalakku Ara
83, Akkareyan Ara
84, Mandekal Ara
85, Pullawanankadu Ara
86, Pali Ara
87, Chippi Ara & Punadi Ara
88, Paranki Ara
89, Nay Ara
90, Aruvi Ara
91, Kal Ara
92, Modaragam Ara
93, Kala Oya
94, Moongil Ara
95, Mi Oya
96, Maduranki Ara
97, Kalagamuwa Oya
98, Ratambala Oya
99, Deduru Oya
100, Karambalan Oya
101, Ratmal Oya
102, Maha Oya
103, Attanagalla Oya
80°E
81°E
82°E
9°N
8°N
7°N
6°N
N
1:1,200,000
0 10 20 40 60 80 100
Kilometers
Source :DSWRPP Component 3

RIVER BASINS OF SRI LANKA

	River Name	Drainage Area Sq.kms		River Name	Drainage Area Sq.kms
1	Kelani Ganga	2340	41	Rufus Kulam	27
2	Bolgoda Ganga	396	42	Pannel Oya	195
3	Kalu Ganga	2839	43	Ambalan Oya	112
4	Bentara Ganga	667	44	Gal Oya	1911
5	Madu Ganga	69	45	Andella Oya	534
6	Madampe Ganga	90	46	Tumpan Keni	18
7	Telwatta Ganga	41	47	Namakada Aru	12
8	Ratgama Lake	13	48	Mandipattu Aru	90
9	Gin Ganga	915	49	Pathantoppu Aru	101
10	Koggala Ganga	55	50	Vett Aru	22
11	Polwatta Ganga	232	51	Magalavatavan Aru	304
12	Nilwala Ganga	1043	52	Mundeni Aru	1373
13	Sinimodara Oya	35	53	Miyangolla Ela	228
14	Kirama Oya	183	54	Maduru Oya	1439
15	Rekawa Oya	70	55	Pulliyanpota Aru	87
16	Urubokka Oya	373	56	Kirimechchi Odai	89
17	Kachigal Ara	208	57	Bodigolla Aru	132
18	Walawe Ganga	2424	58	Mandan Aru	26
19	Karagan Oya	60	59	Makarachchi Aru	59
20	Malala Oya	409	60	Mahaweli Ganga	10266
21	Embilikala Oya	69	61	Kantalai Aru	437
22	Kirindi Oya	1156	62	Palampotta Aru	97
23	Bambawe Ara	66	63	Panna Oya	164
24	Mahaseelawa Oya	13	64	Pankulam Aru	377
25	Buthawa Oya	37	65	Kunchikumban Aru	245
26	Menik Ganga	1301	66	Palakutta Aru	8
27	Katupila Ara	111	67	Yan Oya	1518
28	Kurunda Ara	99	68	Mi Oya	89
29	Nabadagas Ara	110	69	Ma Oya	1042
30	Karambe Ara	54	70	Churiya Aru	105
31	Kumbukkan Oya	1227	71	Chavar Aru	35
32	Bagura Oya	93	72	Palladi Aru	66
33	Girikula Oya	14	73	Manal Aru	194
34	Helawa Ara	38	74	Kodalikallu Aru	92
35	Wila Oya	472	75	Per Aru	392
36	Heda Oya	615	76	Pali Aru	70
37	Karanda Oya	425	77	Maruthapillay Ary	36
38	Seman Aru	72	78	Thervil Aru	104
39	Tandiadi Aru	20	79	Piramanthal Aru	91
40	Kangikadichi Aru	78	80	Methali Aru	114

81	Kanakarayan Aru	604
82	Kalwalappu Aru	68
83	Akkarayan Aru	244
84	Mandekal Aru	208
85	Pallavarayan Kaddu Aru	311
86	Pali Aru	451
87	Chappi Aru	79
88	Parangi Aru	770
89	Nay Aru	717
90	Aruvi Aru	3291
91	Kal Aru	210
92	Moderagama Aru	1001
93	Kala Oya	2526
94	Moongil Aru	78
95	Mee Oya	1555
96	Madurankuli Aru	128
97	Kalagamune Oya	169
98	Rathambala Oya	244
99	Deduru Oya	2622
100	Karambala Oya	693
101	Ratmal Oya	341
102	Maha Oya	1470
103	Attanagalu Oya	811
Area of Jaffna Peninsula including Vadamarachchi Lagoon, but excluding islands of Kayts , Kartivu		1018
Residual area comprising largely, coastal zones intervening between adjacent river basins of Sri Lanka		5049
Total		**65591**

Source: Water Resources Planning Project under component 03 of DSWRPP- 2013

HYDROMETRIC STATIONS FOR 2014/15
(According to River Basin)

Name of Station	River Basin	Coordinates	Catchment Area (Sq.Km)
1. Norwood	Kelani Ganga	(6°50'22'', 80°36'42'')	97
2 . Kithulgala	Kelani Ganga	(6°59'26'', 80°24'44'')	383
3 . Dearaniyagala	Kalani Ganga	(6°55'28'', 80°20'16'')	183
4. Holombuwa	Kelani Ganga	(7°11'07'', 80°15'53'')	155
5. Glencourse	Kelani Ganga	(6°58'28'', 80°10'58'')	1463
6. Hanwella	Kelani Ganga	(6°54'34'', 80°04'46'')	1782
7. Rathnapura	Kalu Ganga	(6°40'42'', 80°23'39'')	603
8. Ellagawa	Kalu Ganga	(6°43'55'', 80°12'36'')	1393
9. Millakanda	Kalu Ganga	(6°37'56'', 80°11'23'')	780
10. Putupaula	Kalu Ganga	(6°36'06'', 80°03'26'')	2598
11. Baddegama	Gin Ganga	(6°10'33'', 80°10'27'')	681
12. Thawalama	Gin Ganga	(6°20'31'', 80°19'49'')	377
13. Pitabeddara	Nilwala Ganga	(6°12'45'', 80°28'34'')	333
14. Panadugama	Nilwala Ganga	(6°08'00'', 80°29'00'')	445
15. Wellawaya	Kirindi Oya	(6°42'35'', 81°06'40'')	172
16. Thanamalwila	Kirindi Oya	(6°28'06'', 81°08'03'')	749
17. Kuda Oya	Kirindi Oya	(6°31'29'', 81°07'24'')	291
18. Kataragama	Menik Ganga	(6°24'56'', 81°19'51'')	787
19. Nakkala	Kumbukkan Oya	(6°53'42'', 81°17'49'')	216
20. Siyambalanduwa	Heda Oya	(6°54'18'', 81°32'36'')	295
21. Padiyathalawa	Maduru Oya	(7°23'01'', 81°11'31'')	159
22. Thaldena	Badulu Oya	(7°05'27'', 81°02'53'')	276
23. Calidonia	Mahaweli Ganga	(6°54'07'', 80°41'52'')	148
24. Demodara	Mahaweli Ganga	(6°56'12'', 81°02'03'')	78
25. Nawalapitiya	Mahaweli Ganga	(7°02'51'', 80°32'04'')	176
26. Peradeniya	Mahaweli Ganga	(7°16'03'', 80°36'30'')	1168
27. Laggala Pallegama	Mahaweli Ganga	(7°34'02'', 80°49'52'')	129
28. Manampitiya	Mahaweli Ganga	(7°54'53'', 81°05'10'')	7418
29. Horowpothana	Yan Oya	(8°34'39", 80°52'43")	720
30. Thantirimale	Malwathu Oya	(8°35'14", 80°16'31")	2116
31. Galgamuwa	Mee Oya	(7°58'07'', 80°15'34'')	299
32. Chilaw	Deduru Oya	(7°36'01'', 79°48'57'')	2610
33. Giriulla	Maha Oya	(7°19'30'', 80°06'53'')	1192
34. Badalgama	Maha Oya	(7°18'00'', 79°58'47'')	1360
35. Dunamale	Attanagalu Oya	(7°06'56'', 80°04'50'')	153

PART II

- **Rainfall**
- **Variation of Rainfall**
- **Rainfall Intensities**
- **Evaporation and Evapotranspiration**
- **Stream Flow Data**
- **Runoff / Rainfall Ratio**
- **Flood Hydrographs**

RAINFALL

MONTHLY RAINFALL AT PRINCIPAL STATIONS

(in mm)

Upper line : Current year 2014/15

Lower line : Long-term average from 1970/71 to 2013/14

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
1 Anuradhapura	384	372	666	16	161	26	288	265	10	0	180	147	1625	890	2515
	242	242	196	84	53	70	166	77	15	28	31	72	887	389	1276
2 Badulla	491	278	669	25	249	114	406	98	189	38	26	201	1827	957	2784
	234	268	268	182	87	100	189	105	33	64	70	124	1139	585	1725
3 Bandarawela	428	207	536	14	127	151	270	105	152	26	16	200	1462	769	2231
	244	245	184	113	66	98	175	108	50	60	57	134	950	585	1535
4 Batticaloa	184	521	1164	14	218	42	44	72	50	23	14	24	2143	227	2370
	167	355	417	243	129	74	54	41	32	33	40	72	1385	273	1658
5 Colombo	450	279	477	33	123	221	268	169	238	37	91	631	1581	1434	3015
	333	333	146	70	67	116	246	313	203	122	108	222	1064	1213	2278
6 Galle	480	354	260	68	115	138	171	282	160	249	153	474	1415	1490	2906
	312	303	175	86	62	94	224	283	202	153	158	248	1033	1269	2301
7 Hambantota	255	205	330	8	37	57	138	49	19	32	159	301	892	697	1590
	125	212	119	65	41	58	92	82	50	35	51	72	621	381	1002
8. Jaffna	262	496	252	1	18	15	52	216	38	0	60	47	1045	412	1457
	239	360	258	76	36	34	63	50	19	28	49	63	1003	273	1276
9 Katugastota	572	308	638	5	106	58	157	142	106	54	140	142	1688	741	2430
	270	291	188	101	70	87	193	134	135	128	100	141	1007	830	1837
10 Katunayaka	369	259	436	6	53	212	161	283	254	20	45	340	1335	1102	2437
	357	309	124	51	66	119	216	281	160	89	99	191	1026	1035	2061
11 Kurunegala	527	204	584	6	34	207	368	160	76	20	74	125	1563	823	2386
	352	315	139	69	72	135	273	182	143	102	88	151	1083	939	2022

MONTHLY RAINFALL AT PRINCIPAL STATIONS

(in mm)

Upper line : Current year 2014/15

Lower line : Long-term average from 1970/71 to 2013/14

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
12. Mahailluppallama	258	271	603	3	82	15	264	143	2	0	134	227	1232	771	2003
	251	262	189	86	73	70	178	87	15	31	34	92	931	438	1368
13. Mannar	59	248	353	0	25	118	281	150	1	1	3	84	802	520	1322
	164	262	200	50	44	43	89	47	8	13	11	49	764	216	980
14. Monaragala	433	293	450	25	115	111	363	138	163	29	25	80	1427	797	2224
***** (2009/10 to 2013/14)	194	226	191	165	114	126	184	124	14	46	101	79	1016	549	1564
15. Nuwara Eliya	260	197	438	2	248	43	124	204	130	97	75	235	1189	865	2053
	236	226	182	117	63	67	136	166	189	176	143	170	891	981	1872
16. Polonnaruwa	319	508	1130	93	208	32	55	188	43	0	64	263	2289	613	2902
***** (2009/10 to 2013/14)	322	310	375	291	175	91	135	85	0	41	62	69	1564	393	1956
17. Potuvil	209	497	659	7	224	106	32	149	54	22	26	78	1702	359	2061
***** (1985/86 to 2013/14)	126	258	302	306	133	77	78	41	11	16	22	56	1202	224	1426
18. Puttalam	250	347	473	8	33	55	239	202	44	1	17	66	1166	568	1733
	226	251	128	53	40	65	167	94	32	22	18	67	763	400	1163
19. Rathmalana	414	225	278	13	70	299	308	262	316	67	107	600	1299	1658	2957
	361	357	162	72	68	115	269	318	200	126	121	242	1136	1275	2410
20. Rathnapura	813	278	444	94	199	88	434	180	272	174	340	397	1915	1797	3712
	444	373	219	124	140	211	363	443	423	299	287	385	1511	2199	3710
21. Trincomalee	160	430	532	36	184	69	48	123	22	10	31	256	1411	489	1900
	207	355	336	141	91	45	53	58	29	58	80	117	1174	397	1571
22. Vavuniya	357	410	469	1	194	82	187	277	8	0	71	174	1513	718	2231
	226	273	243	91	68	56	135	72	19	45	50	98	957	418	1375

Note :- * Denotes Long term average less than specified above.

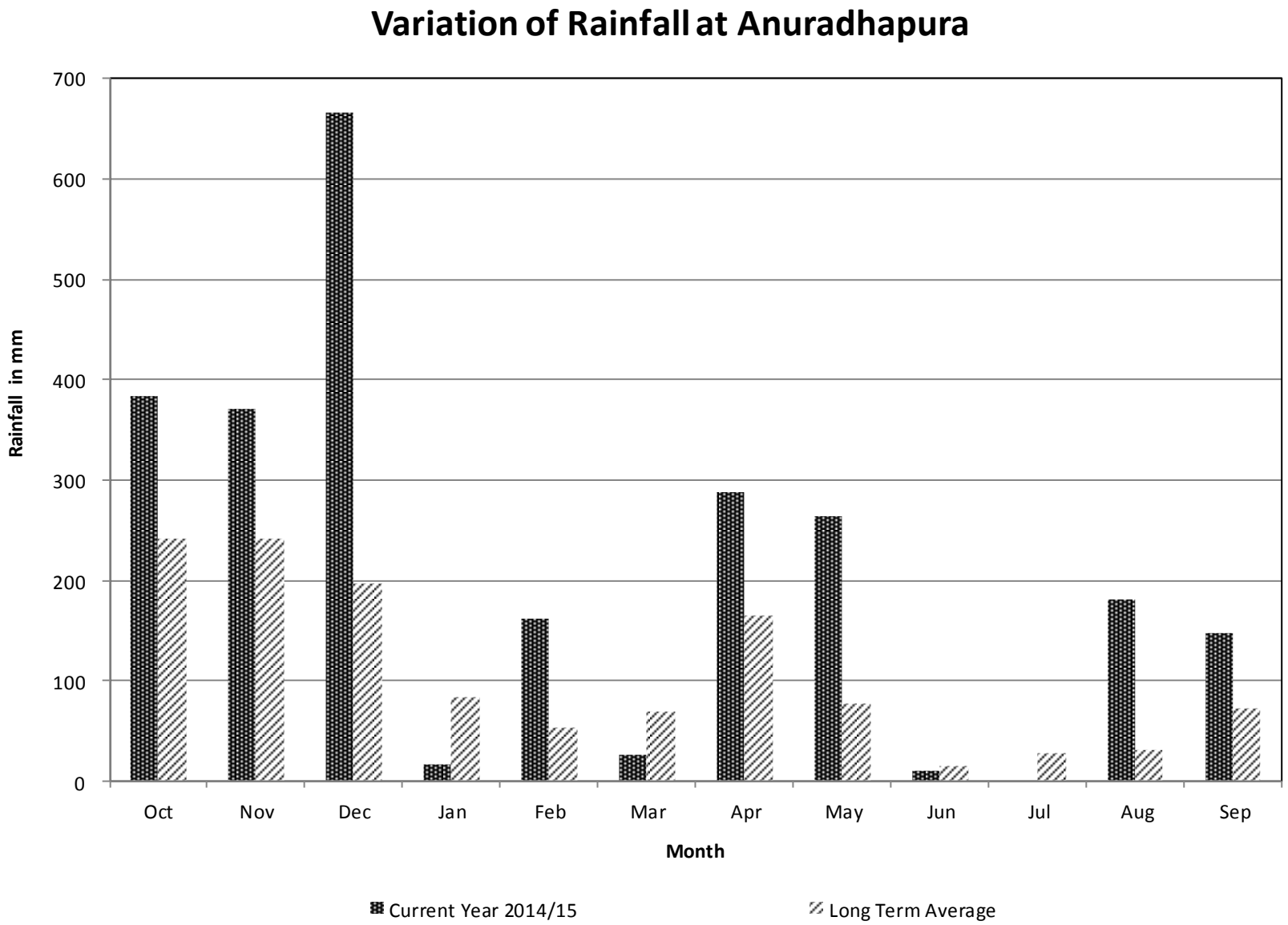
NEM denotes North - East Monsoon, SWM denotes South - West Monsoon

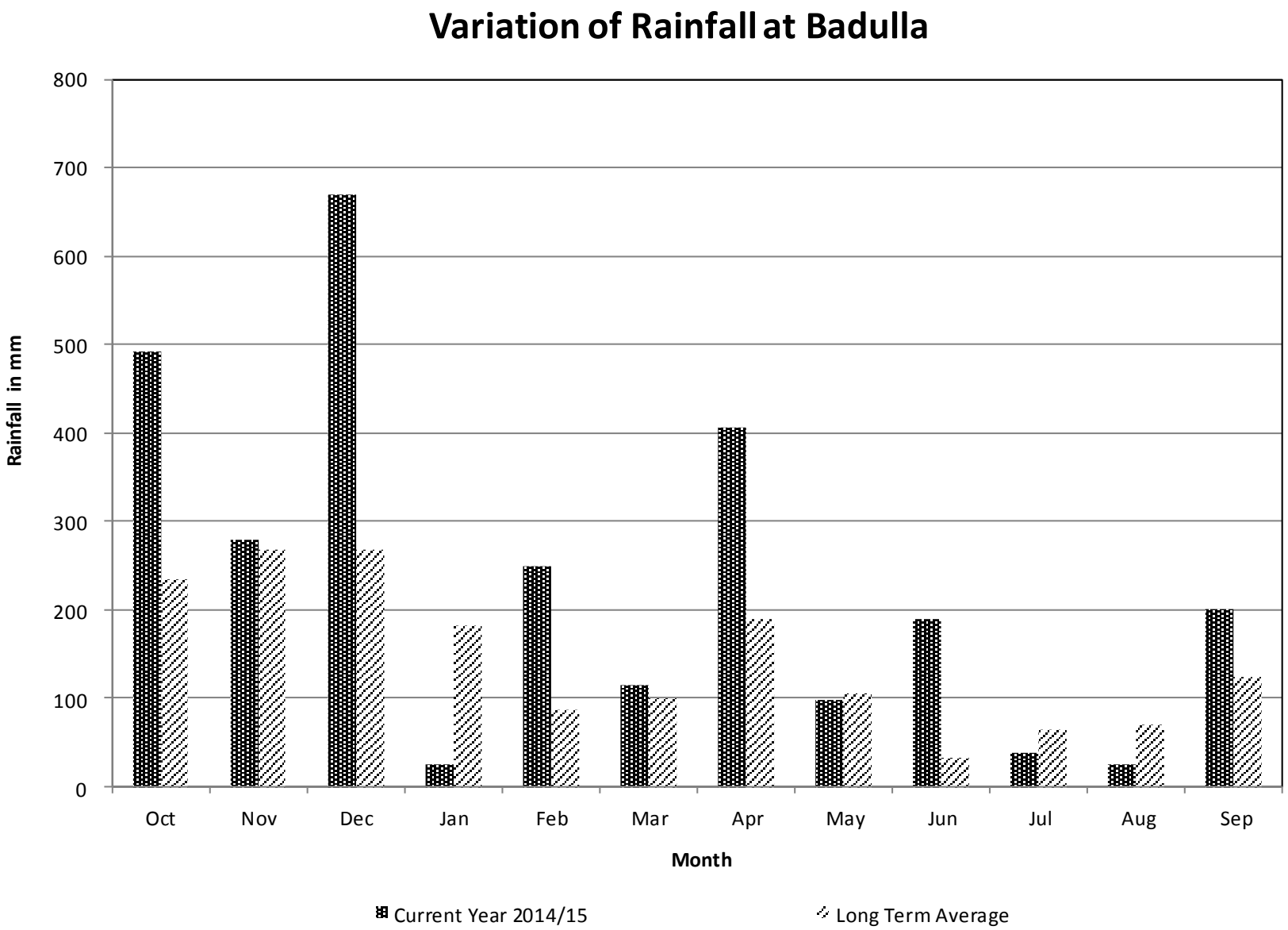
VARIATION OF RAINFALL

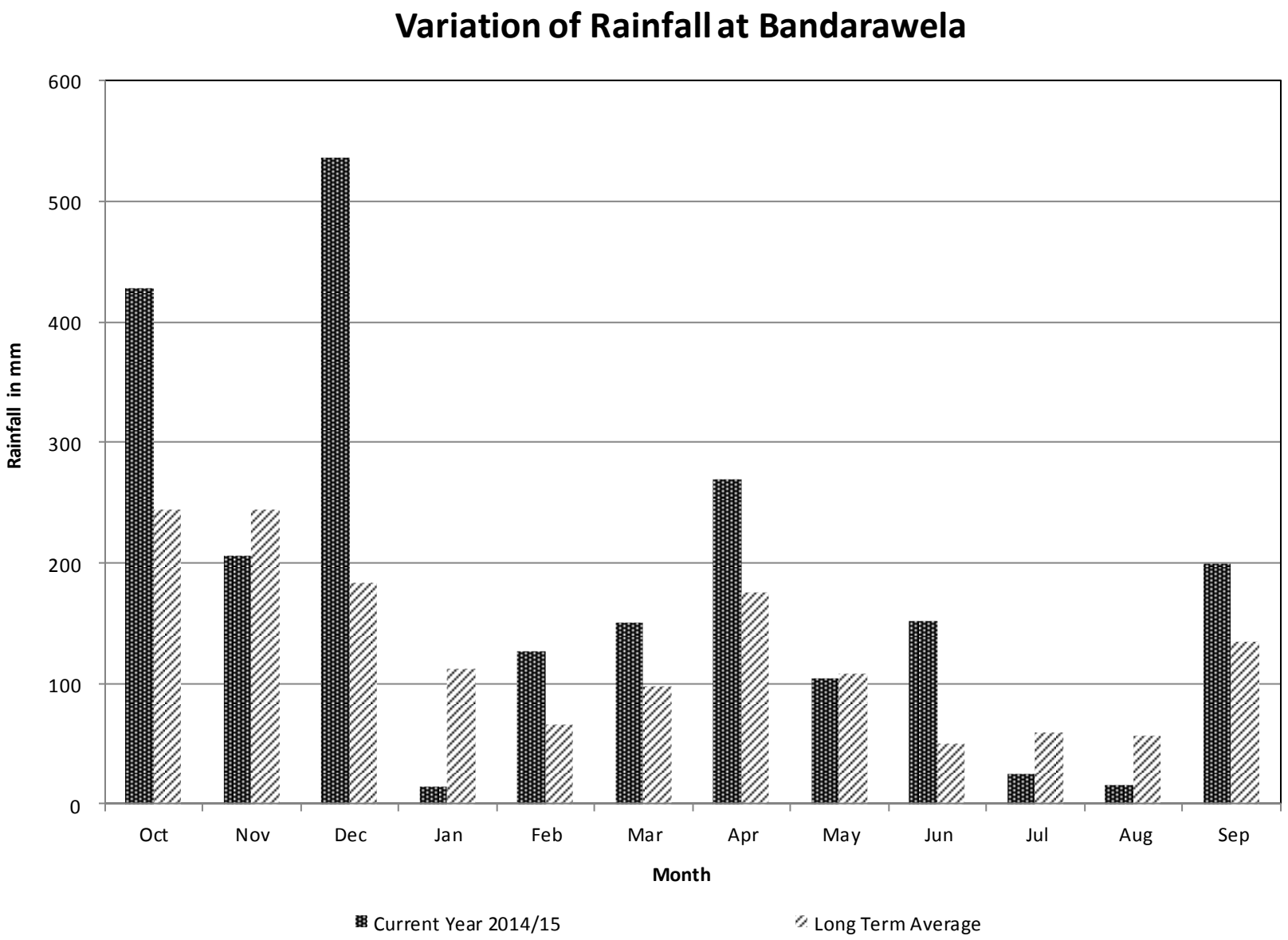
- **Temporal variation at each station**
  (Current year versus Long term average)

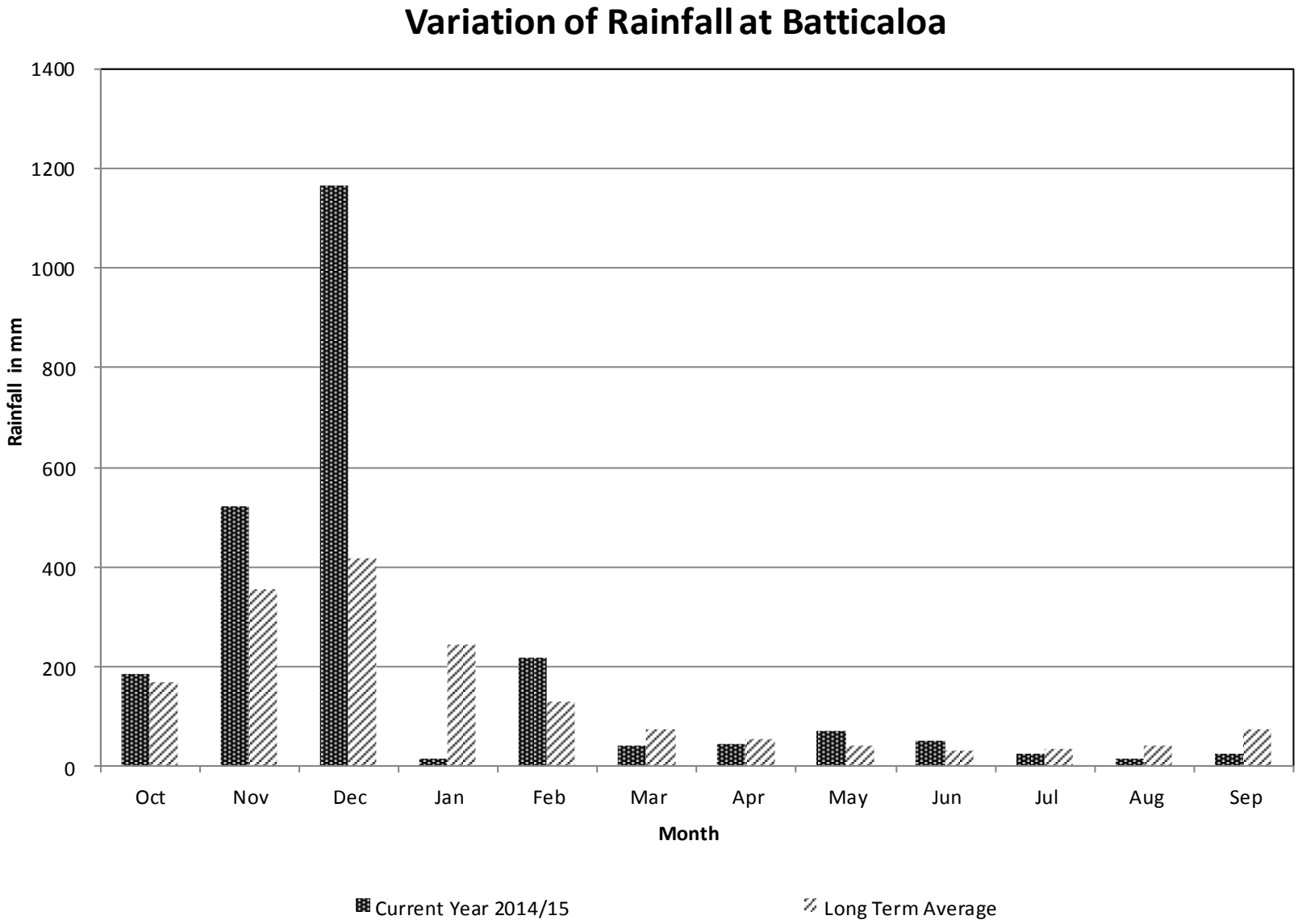
- **Spatial variation of Rainfalls**
  (Current year versus Long term average)

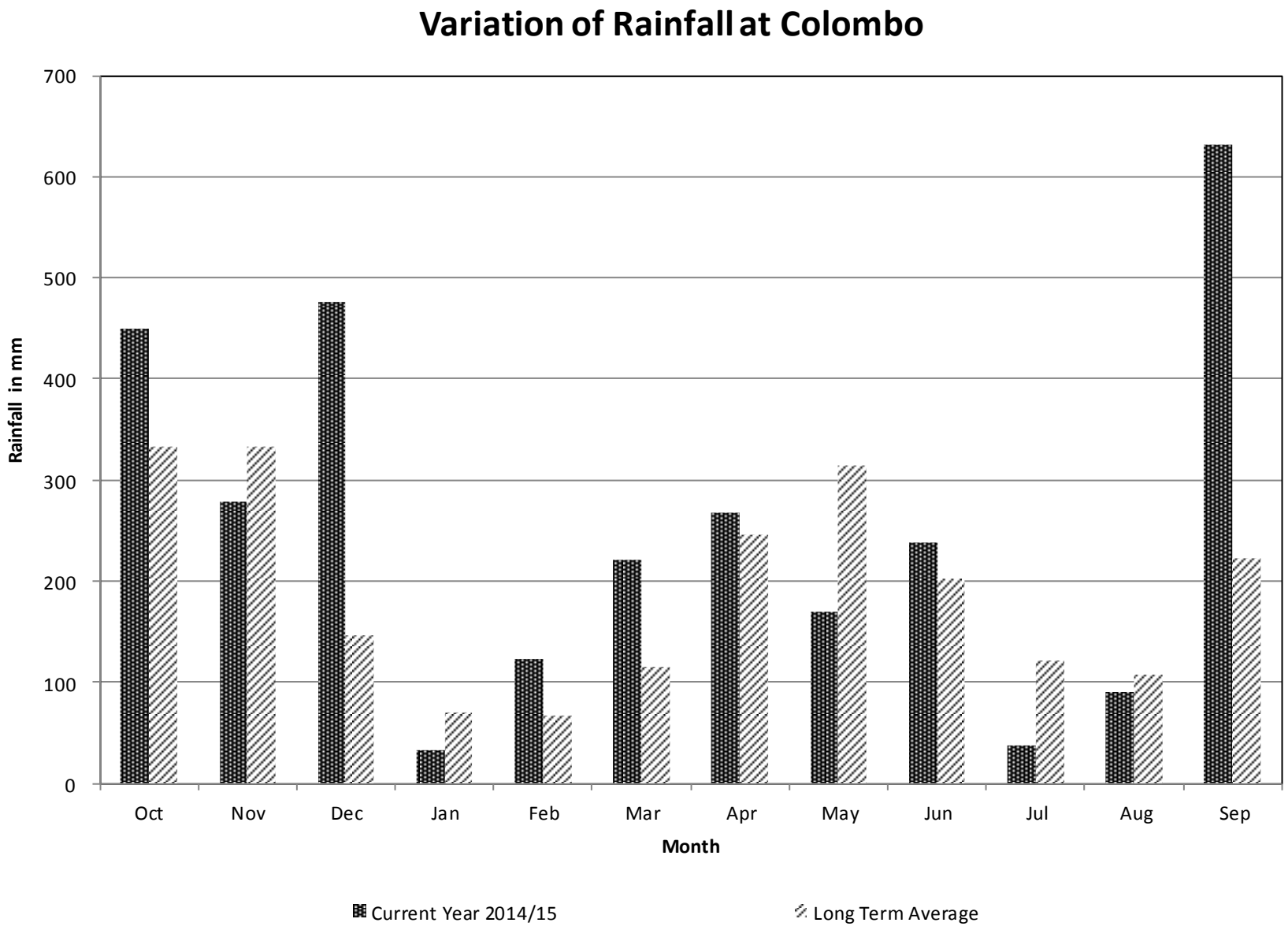
TEMPORAL VARIATION AT EACH STATION

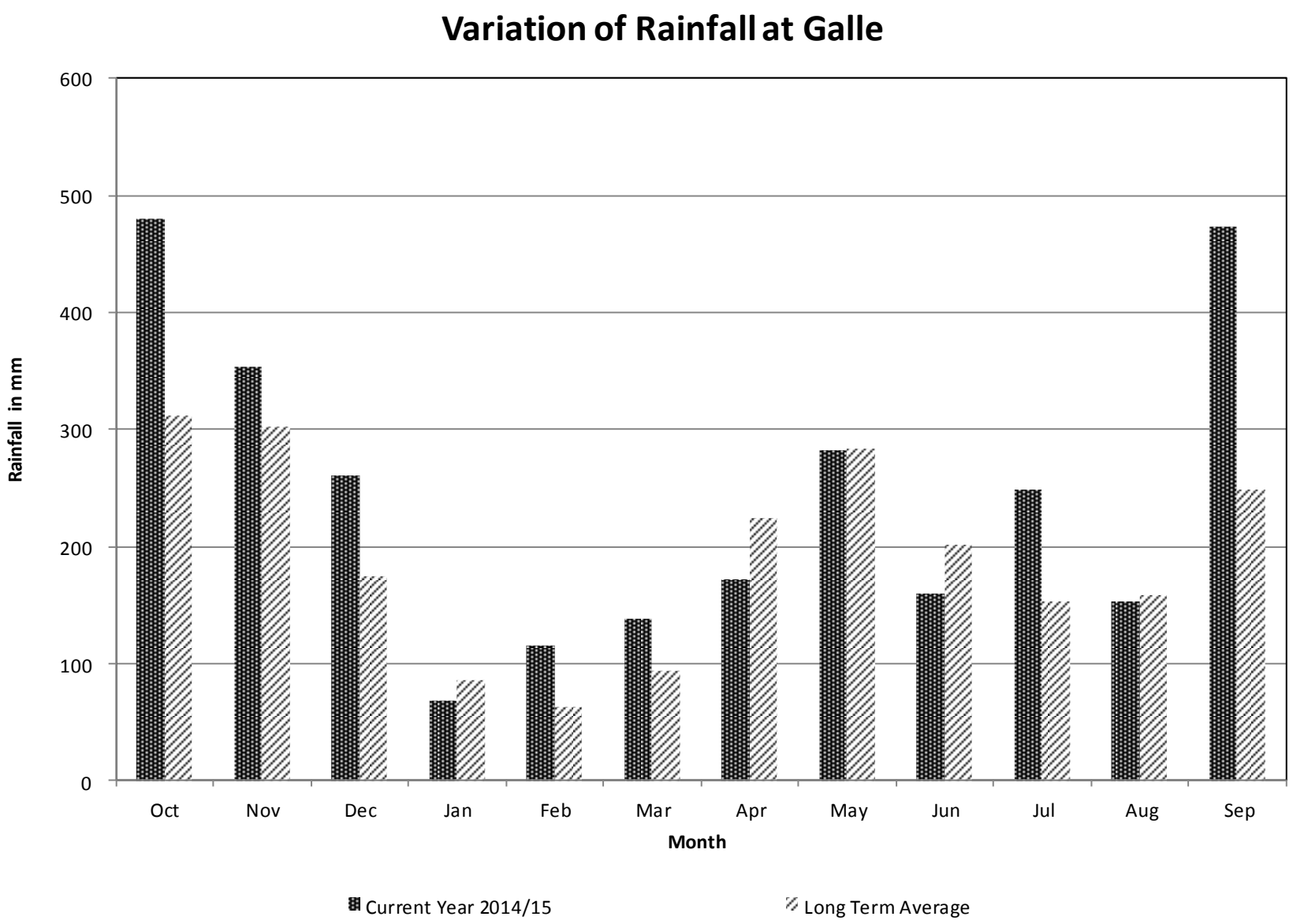

Variation of Rainfall at Anuradhapura
Rainfall in mm
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

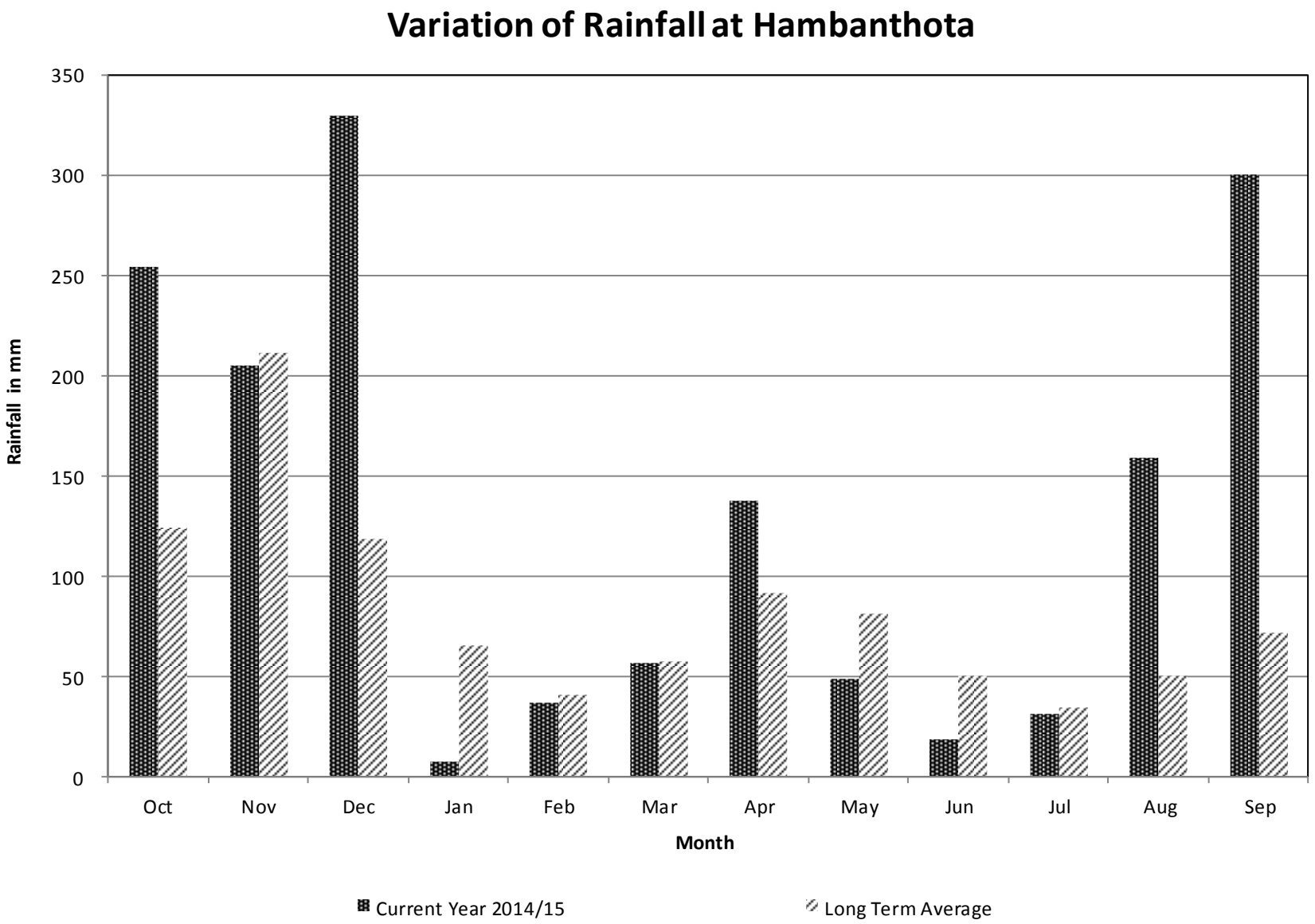

Variation of Rainfall at Badulla
Rainfall in mm
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

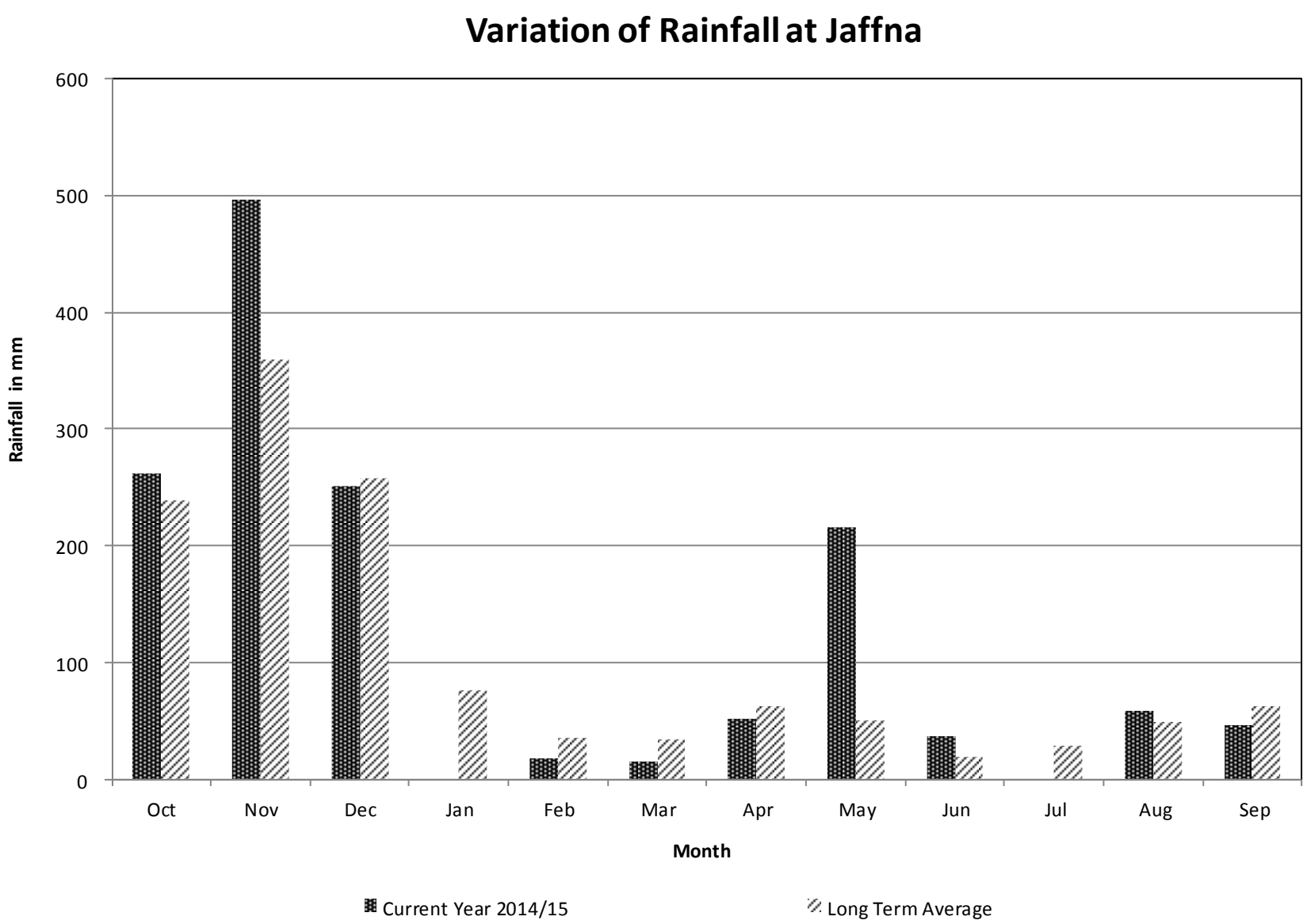

Variation of Rainfall at Bandarawela
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

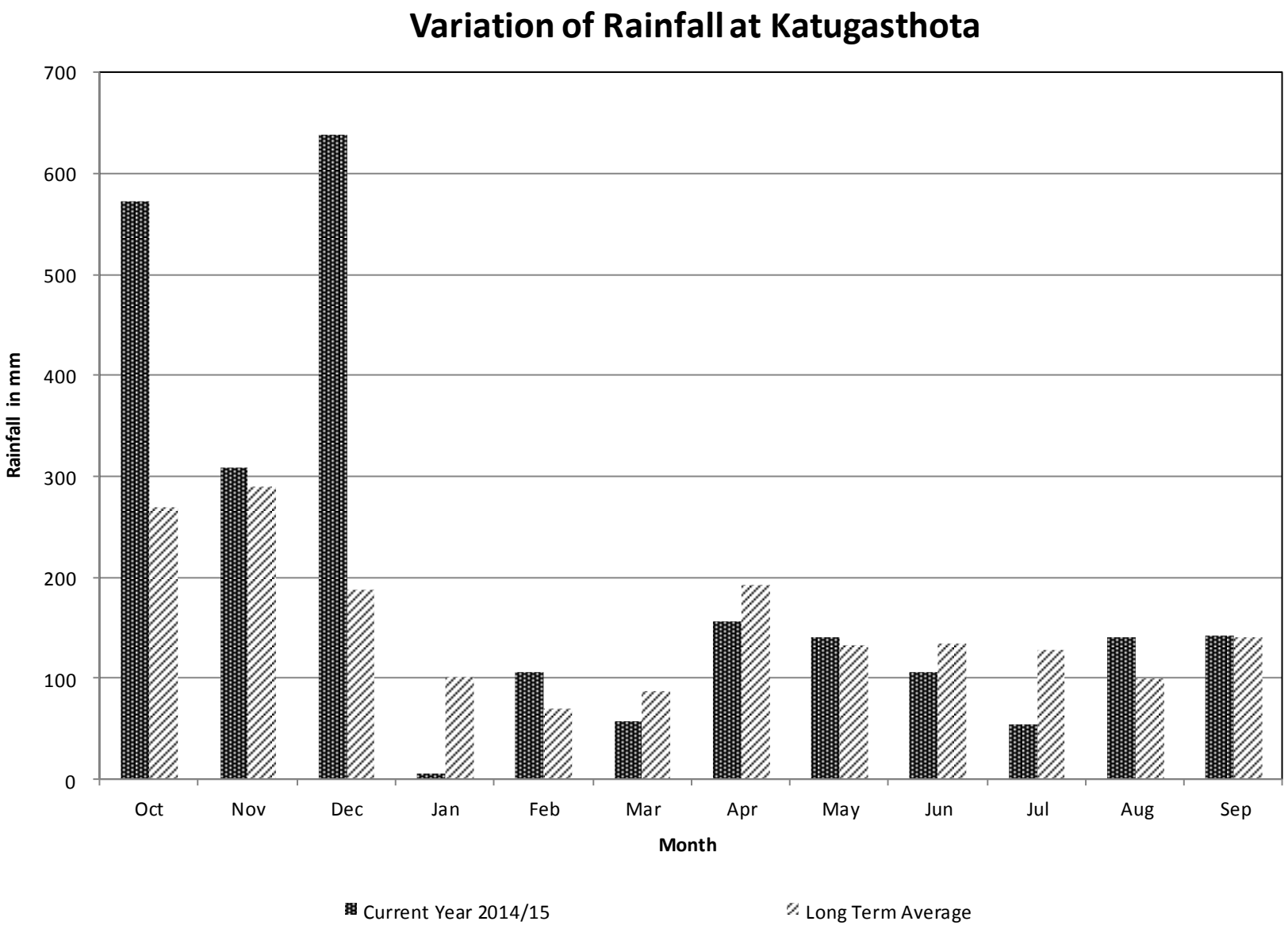

Variation of Rainfall at Batticaloa
1400
1200
1000
800
600
400
200
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

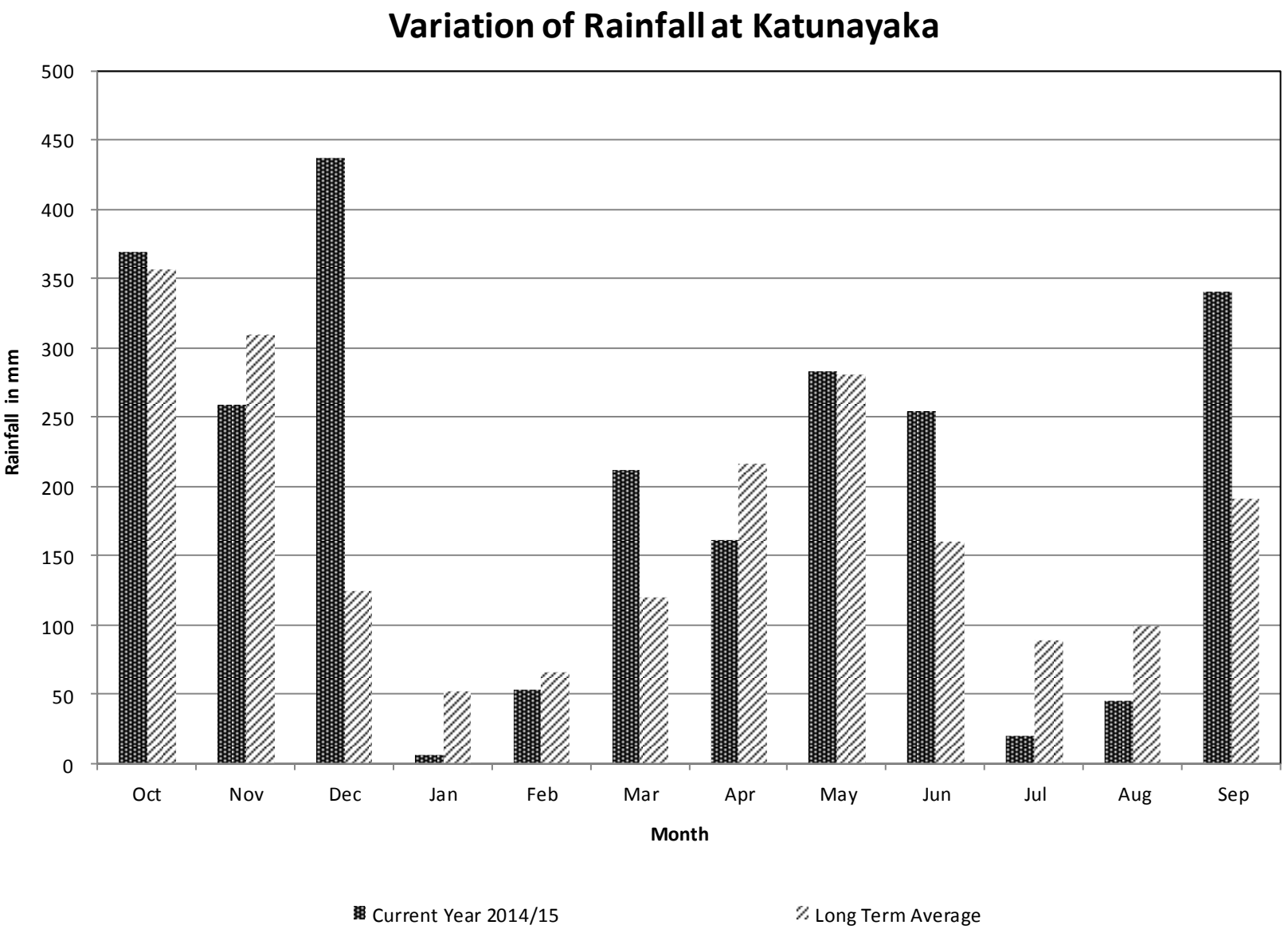

Variation of Rainfall at Colombo
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

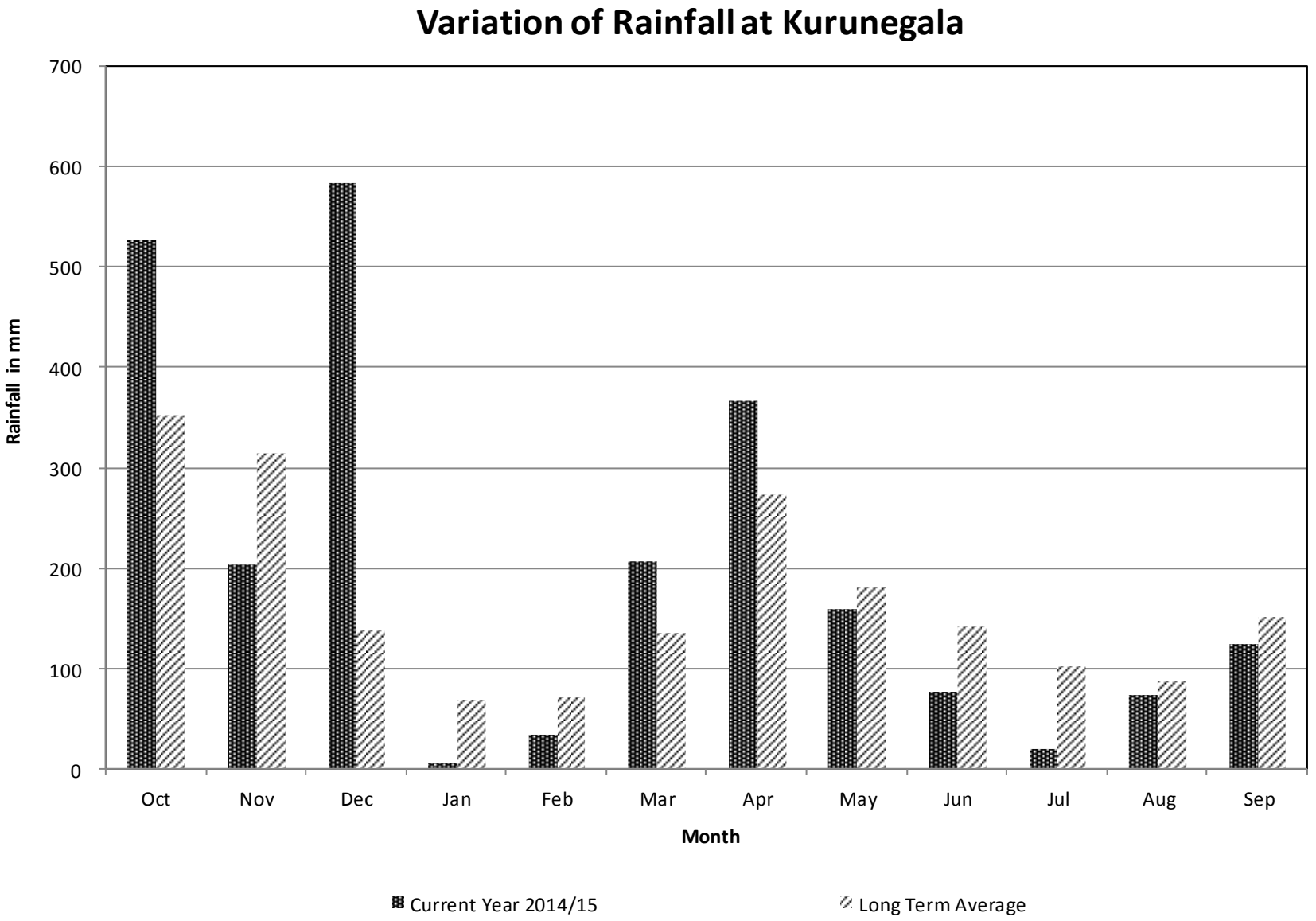

Variation of Rainfall at Galle
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

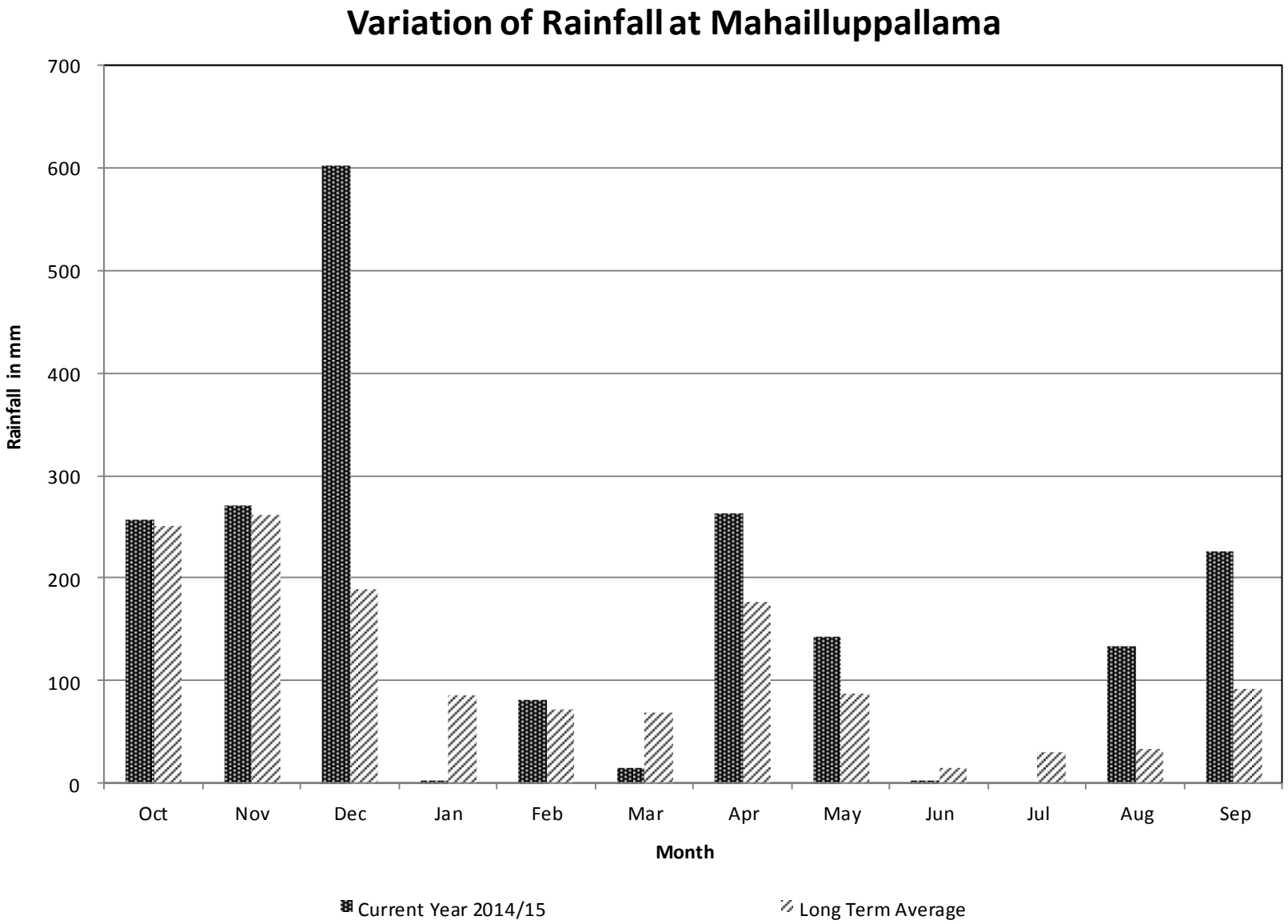

Variation of Rainfall at Hambanthota
Rainfall in mm
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

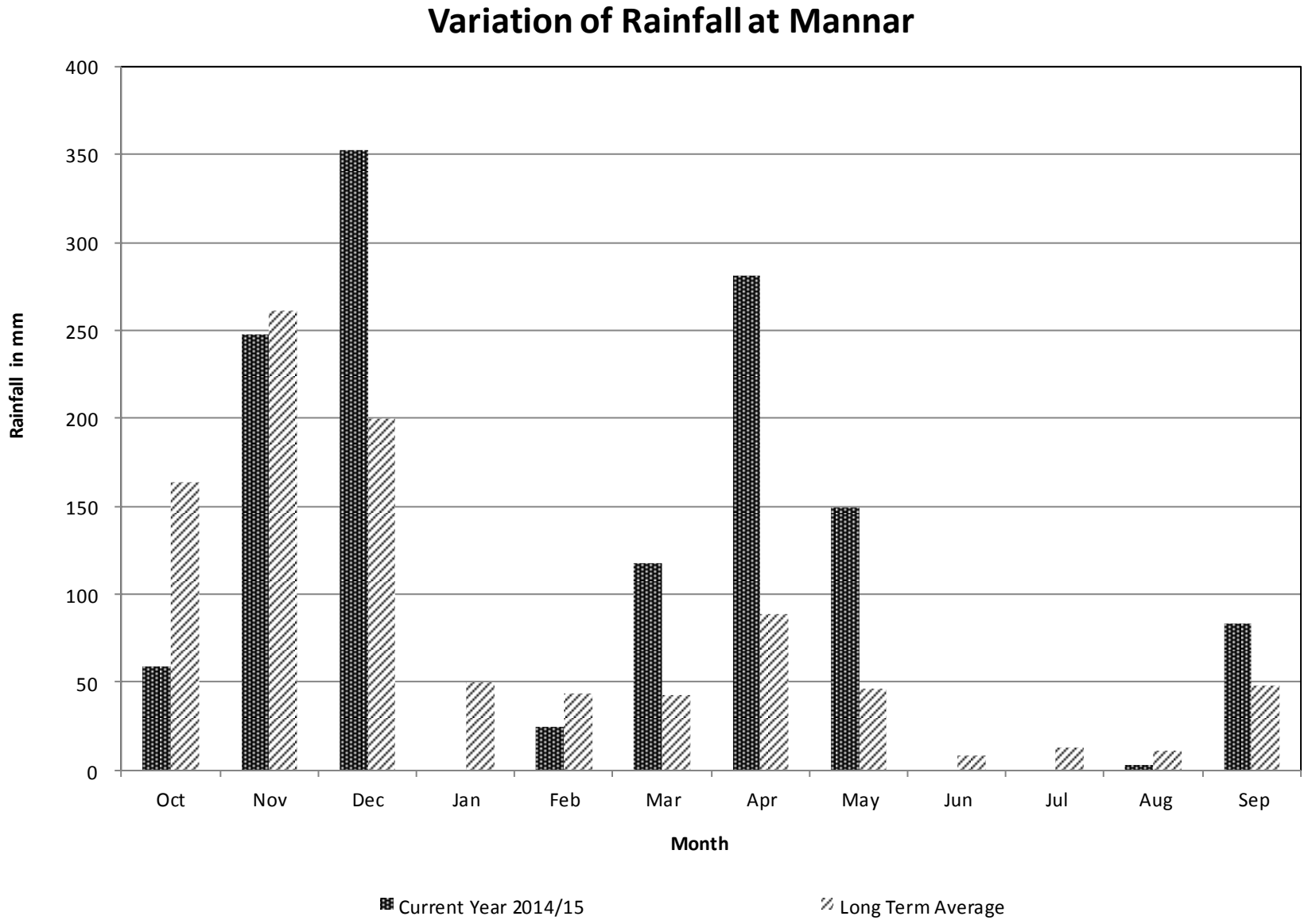

Variation of Rainfall at Jaffna
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

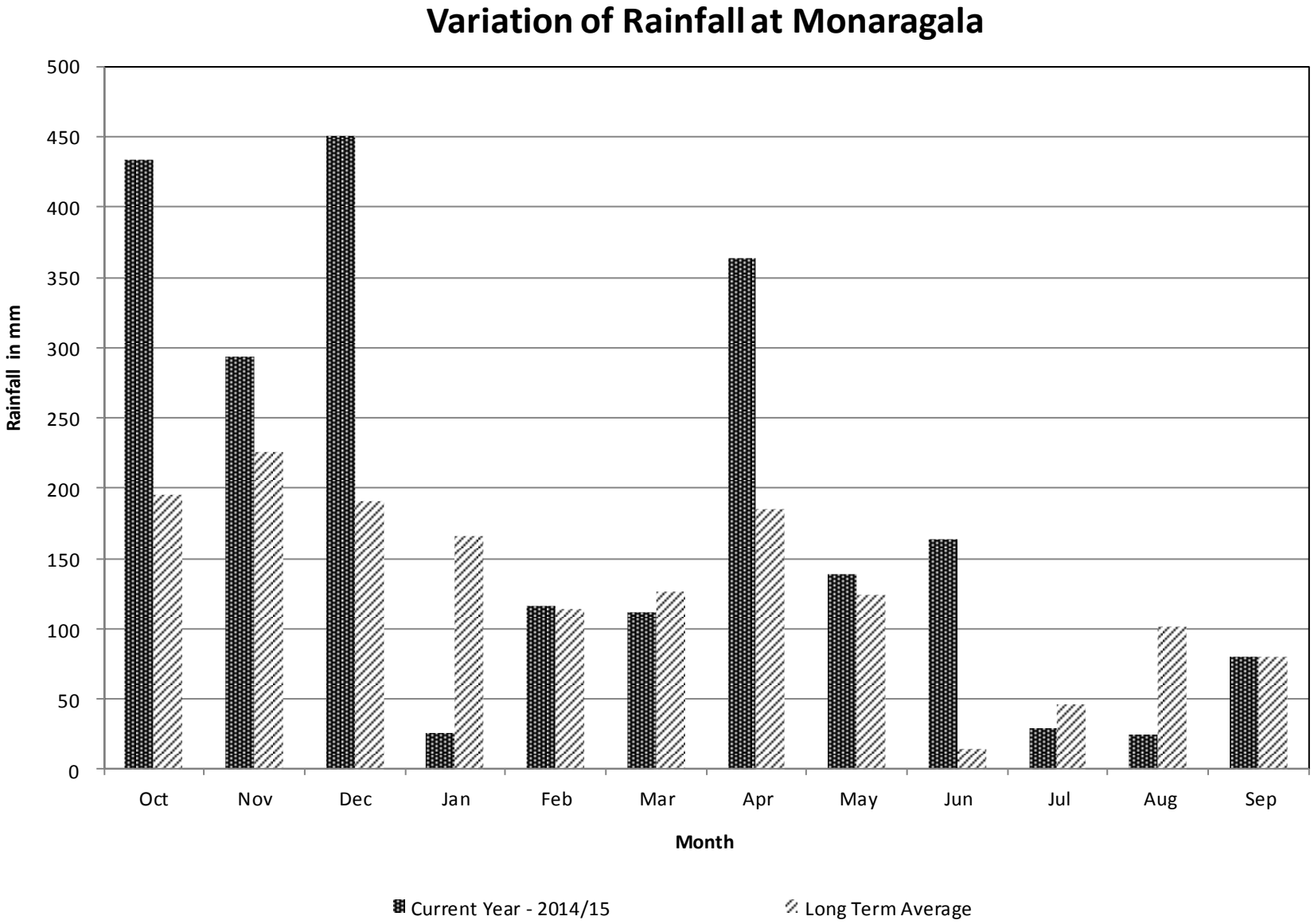

Variation of Rainfall at Katugasthota
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

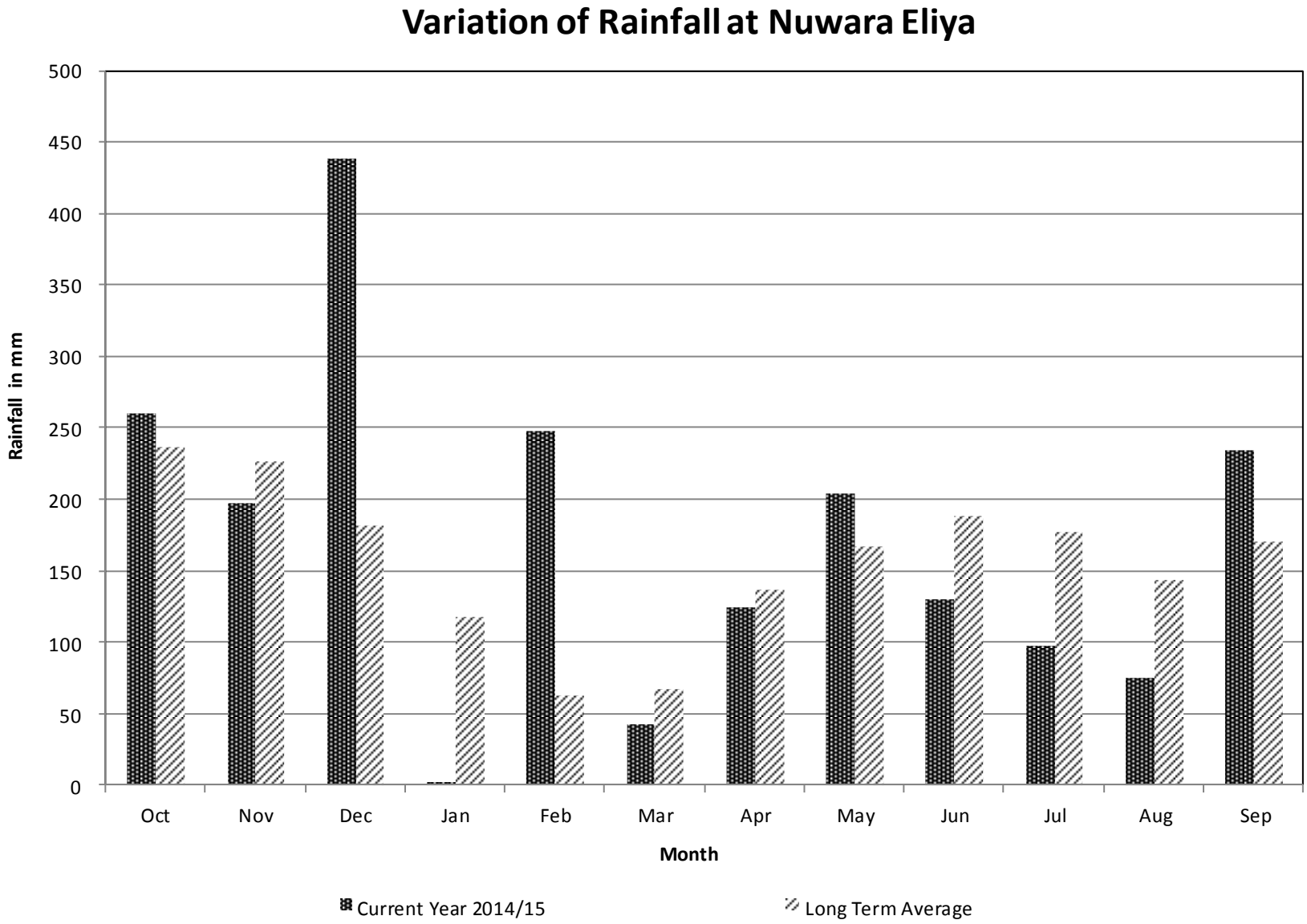

Variation of Rainfall at Katunayaka
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

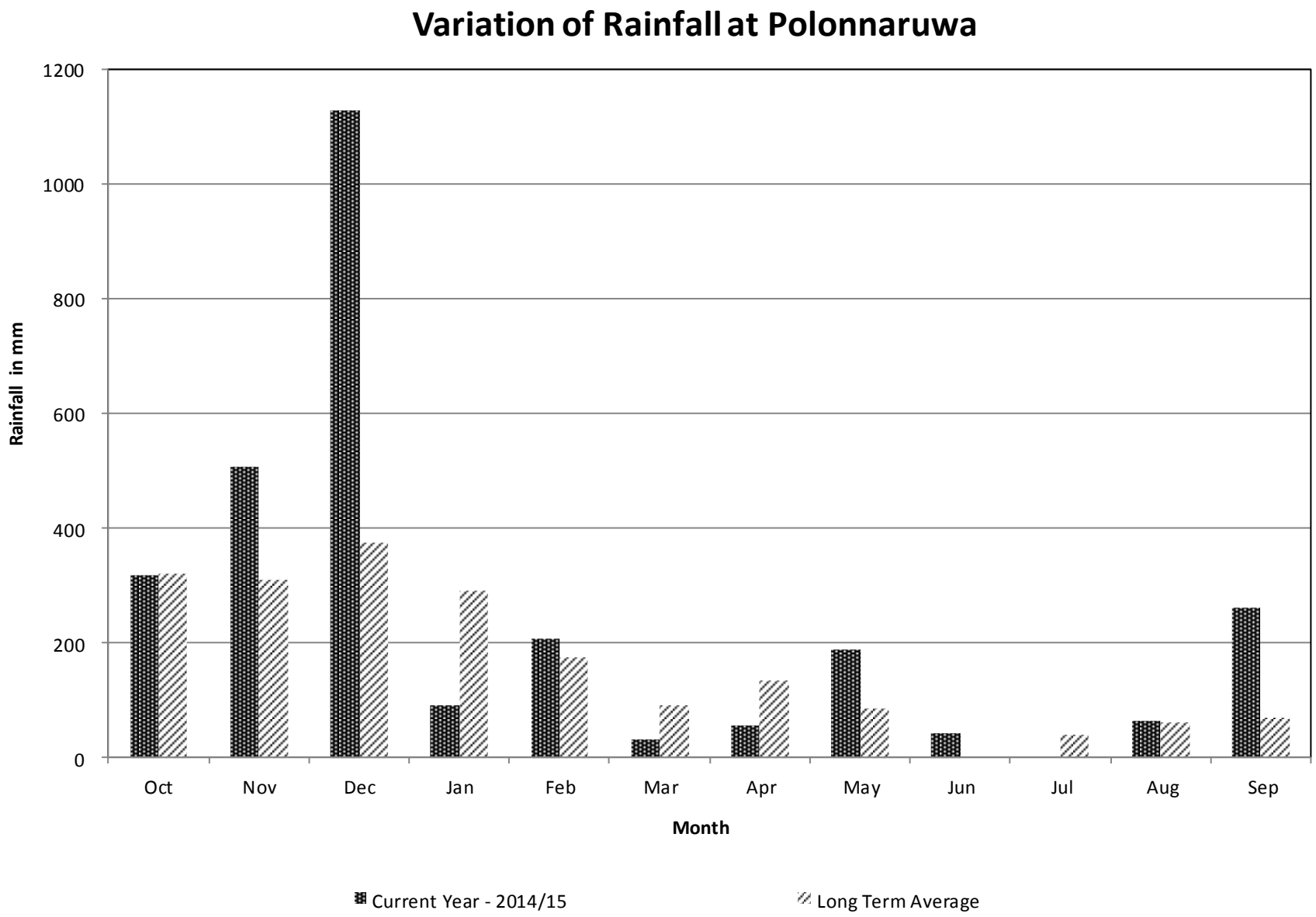

Variation of Rainfall at Kurunegala
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

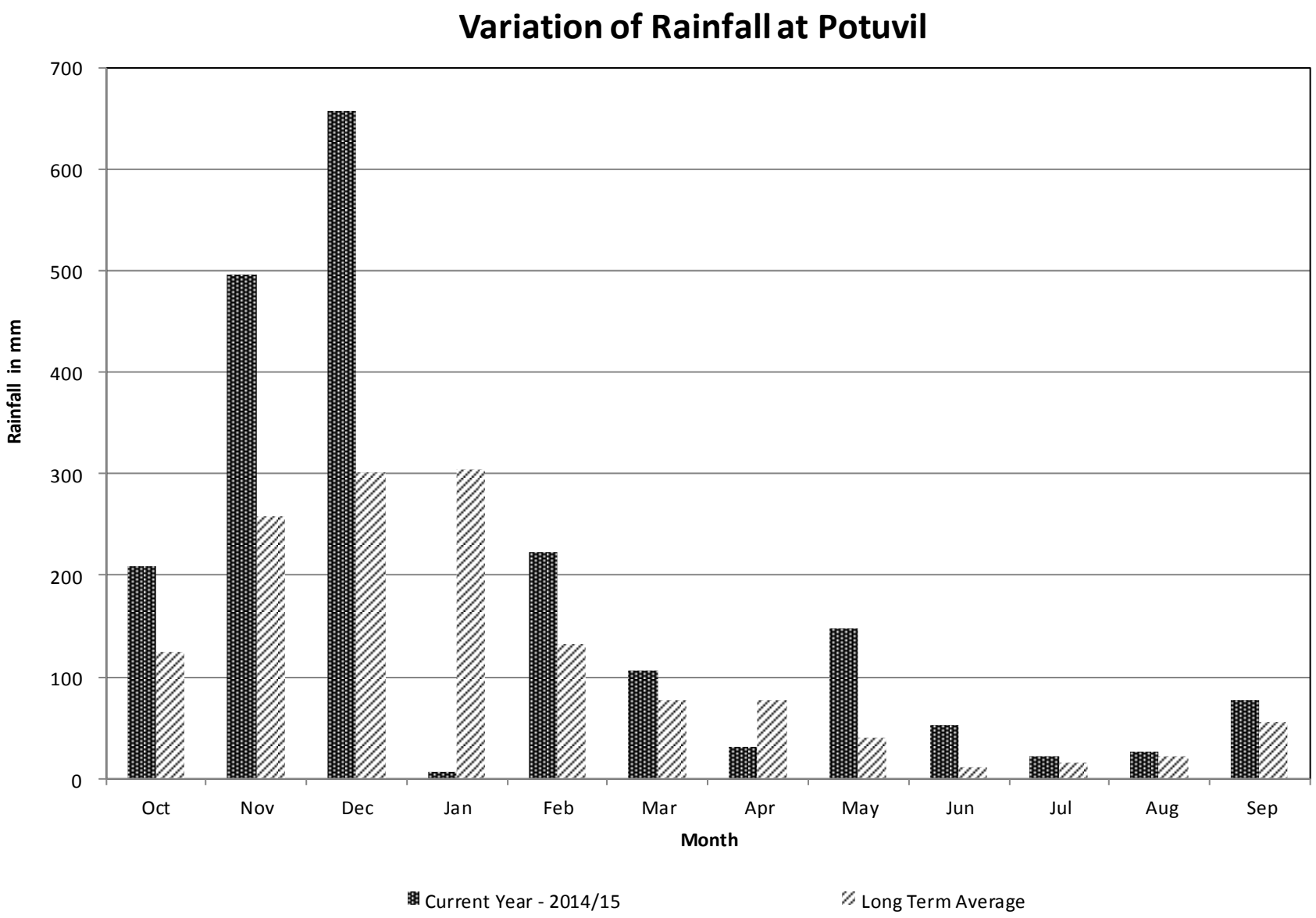

Variation of Rainfall at Mahailluppallama
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

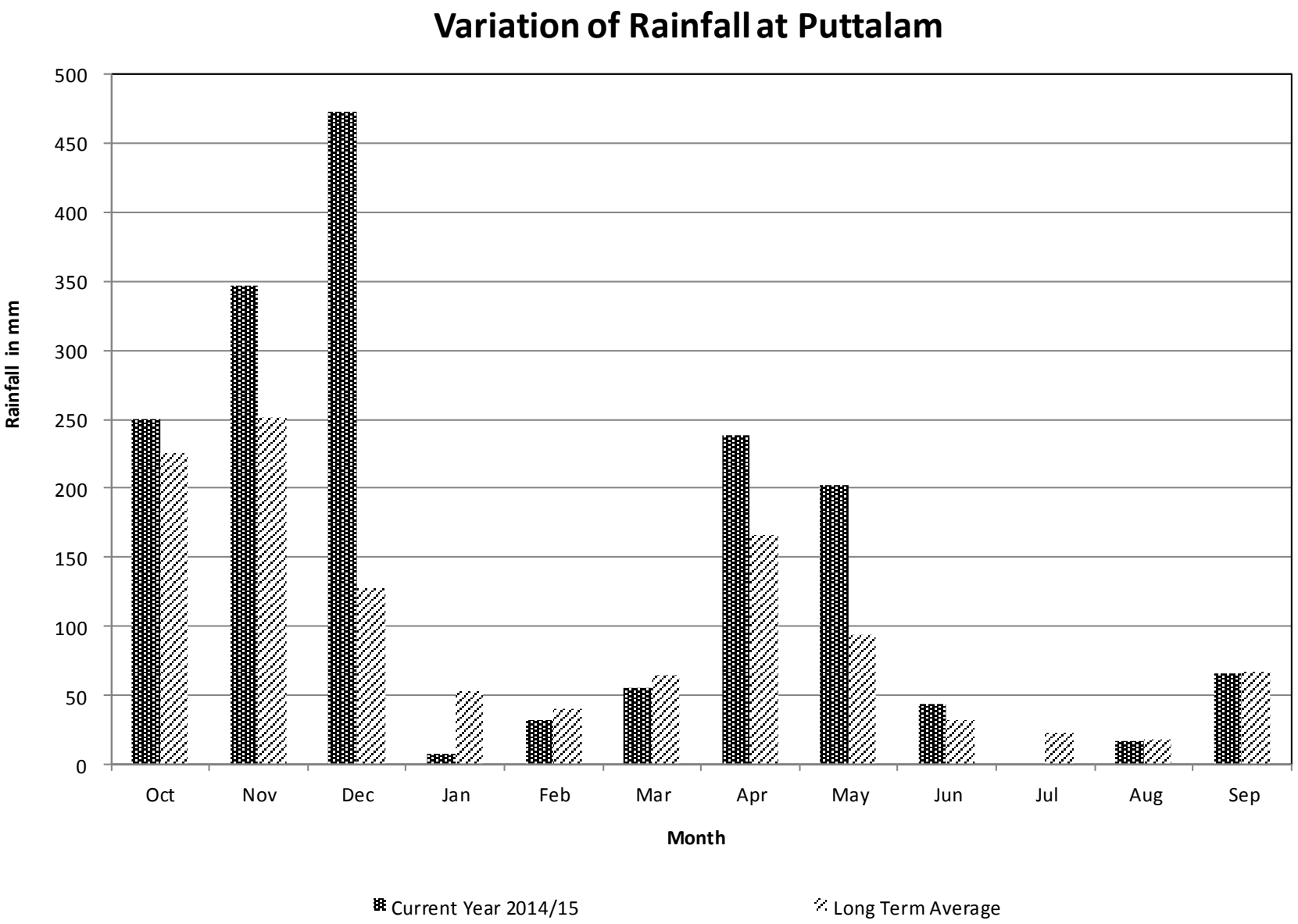

Variation of Rainfall at Mannar
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

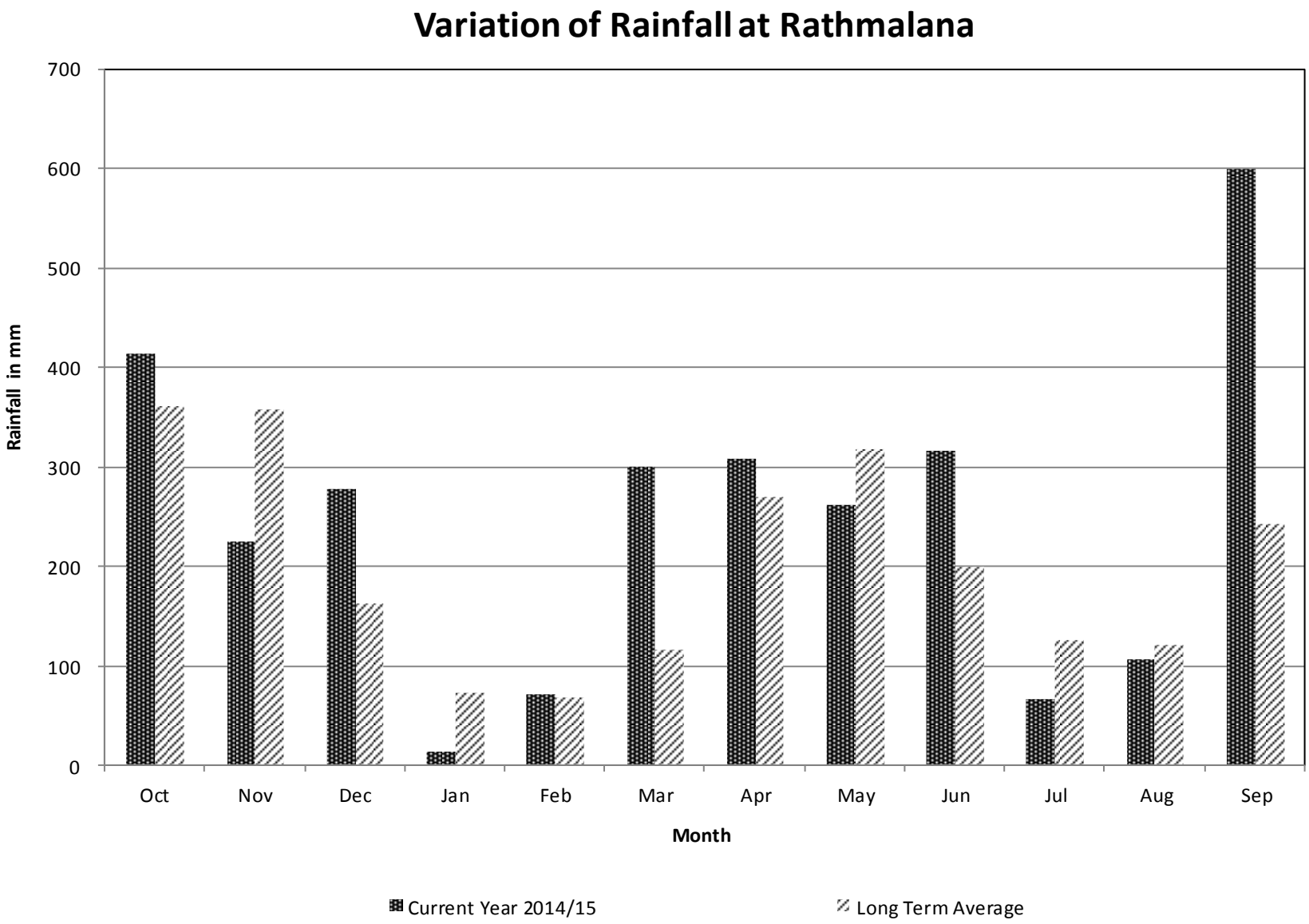

Variation of Rainfall at Monaragala
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average

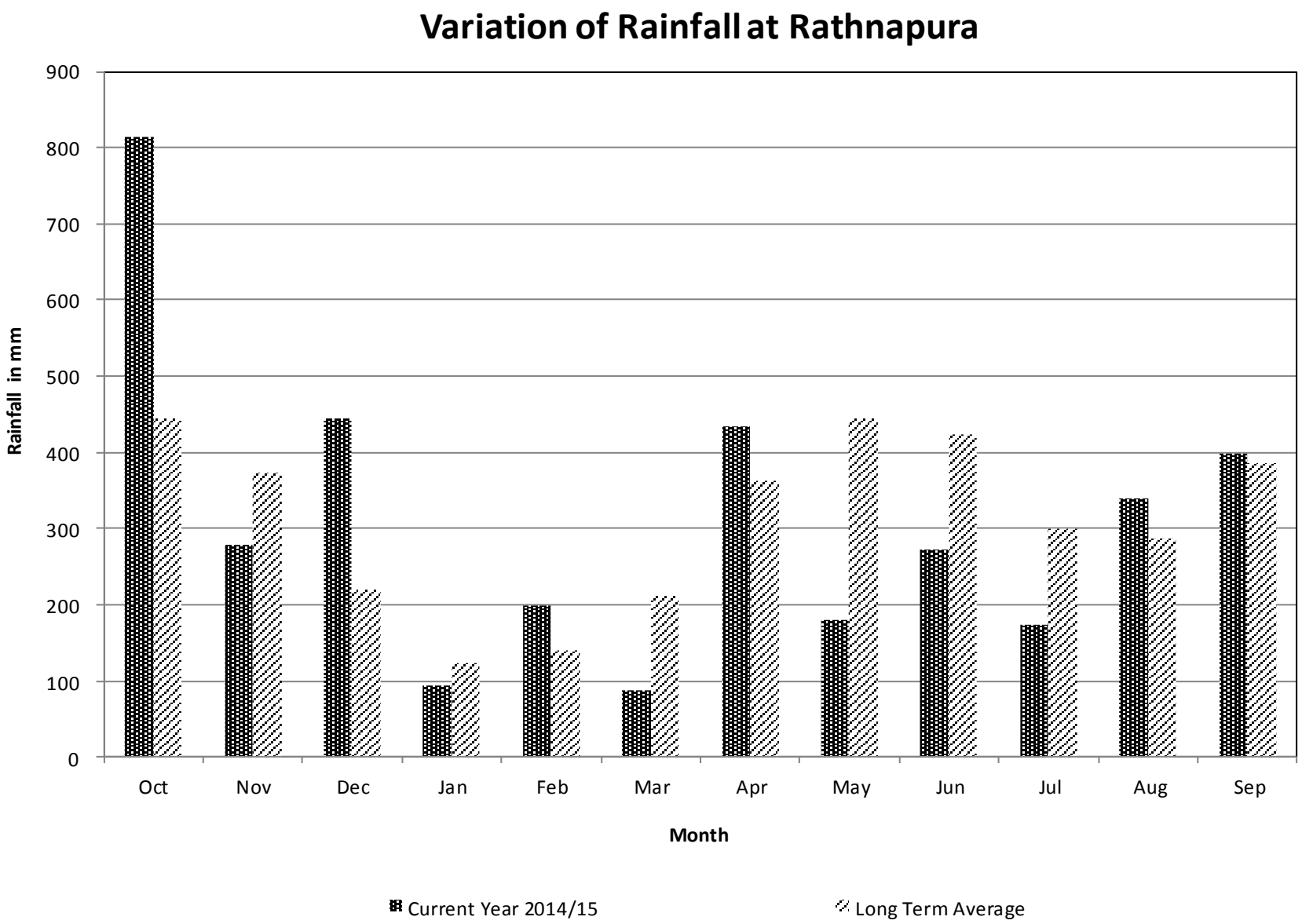

Variation of Rainfall at Nuwara Eliya
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

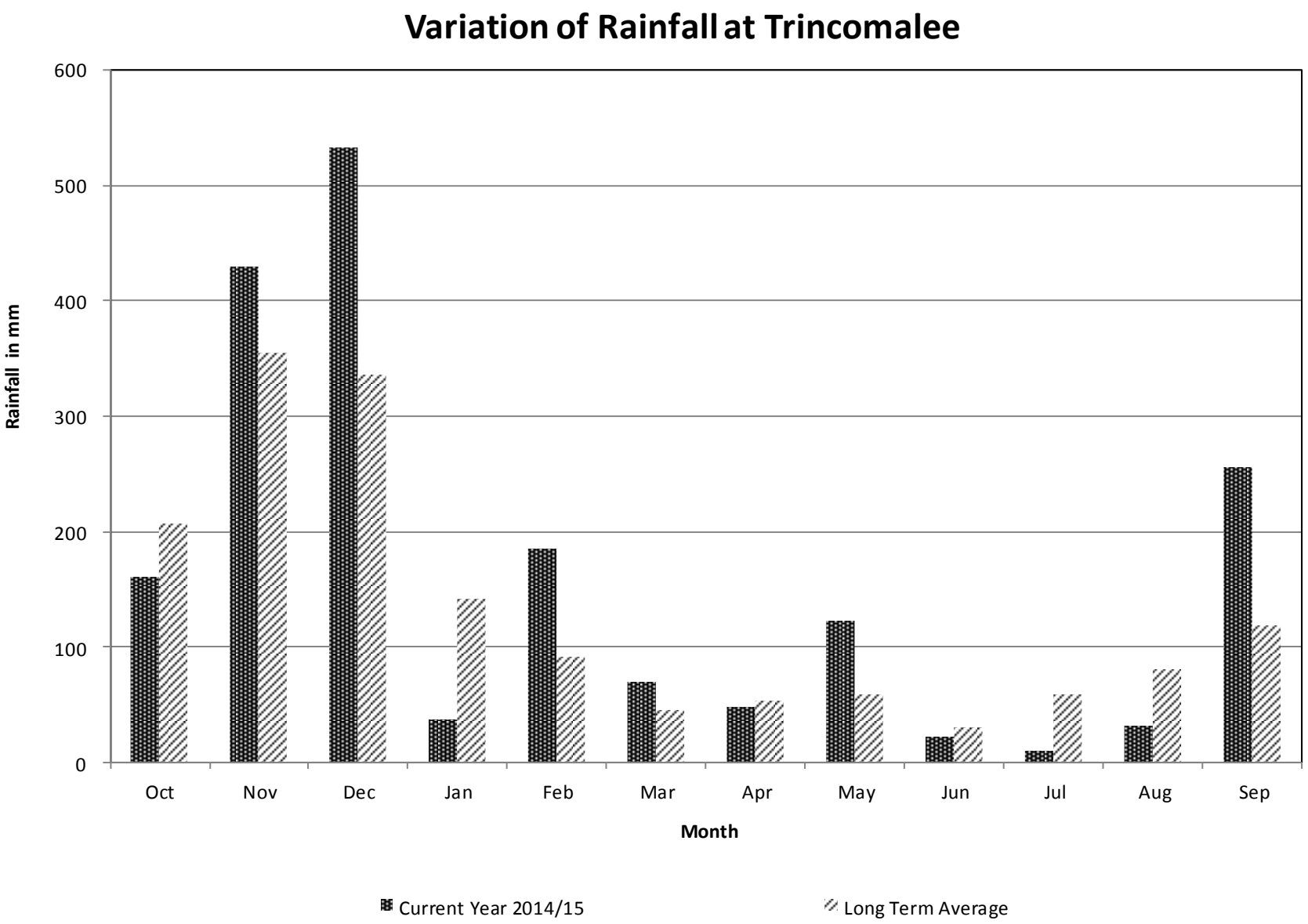

Variation of Rainfall at Polonnaruwa
1200
1000
800
600
400
200
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average

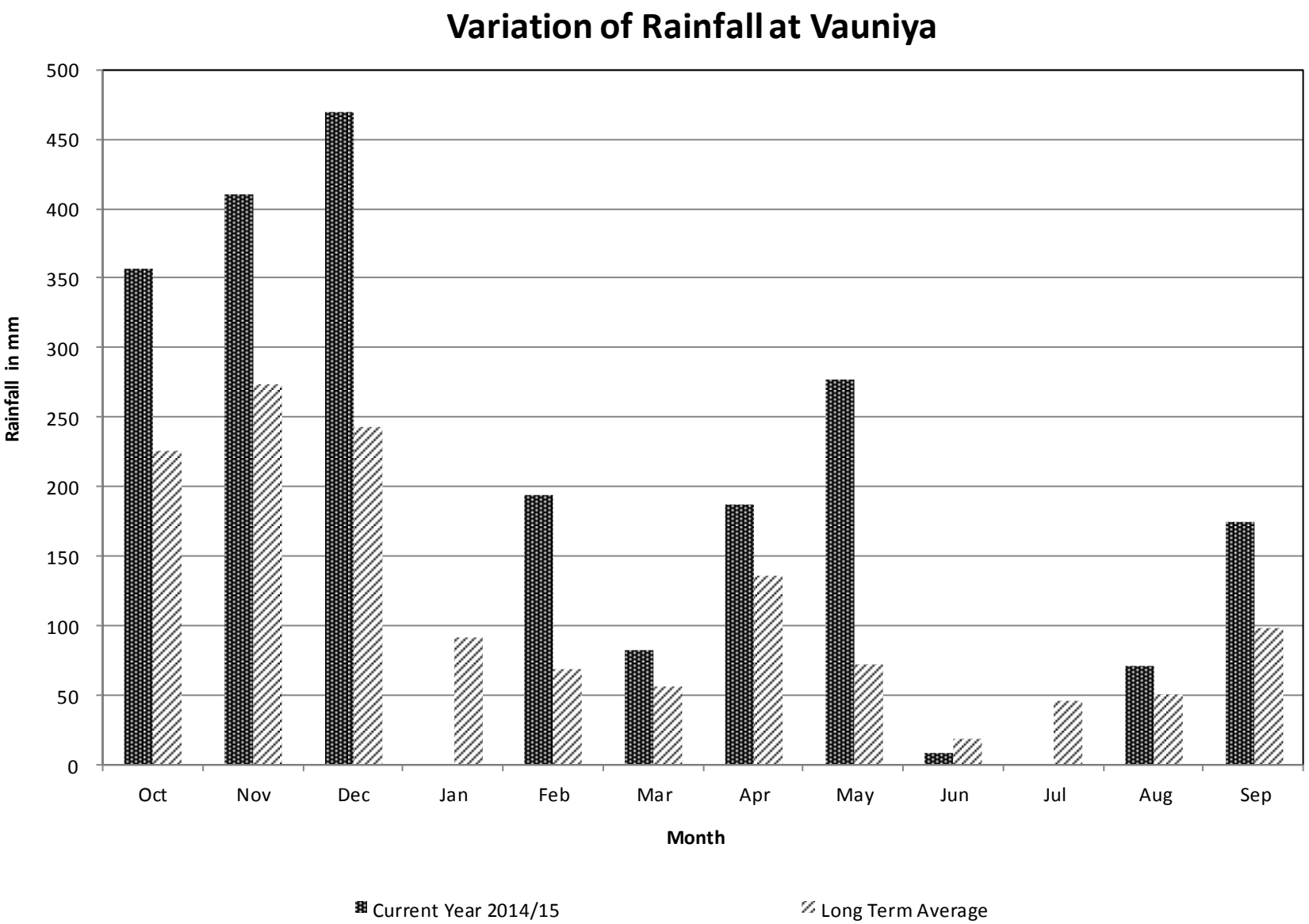

Variation of Rainfall at Potuvil
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average


Variation of Rainfall at Puttalam
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average


Variation of Rainfall at Rathmalana
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average


Variation of Rainfall at Rathnapura
900
800
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average


Variation of Rainfall at Trincomalee
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average


Variation of Rainfall at Vauniya
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2014/15
Long Term Average

SPATIAL VARIATION FOR EACH MONTH / AVERAGE MONTH

➢ Annual Rainfall Distribution

Spatial distribution of the annual rainfall of current water year (2014/15) shows significant deviations from the long term average values. Especially the wet zone of the country including Mahaweli areas has experienced higher rainfall during this year.

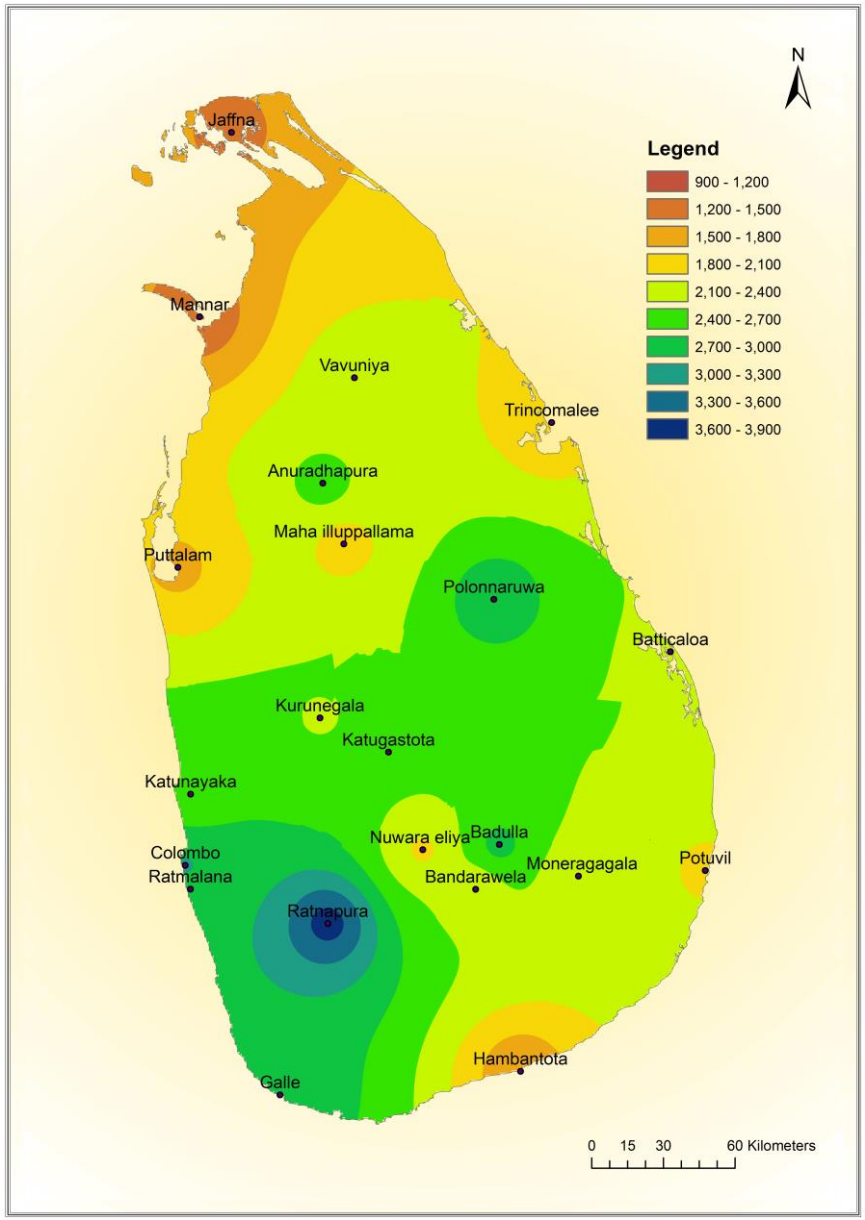
➢ SWM (South-West Monsoon) Rainfall Distribution

The highest rainfall zone with respect to SWM Monsoon lies around Rathnapura district. During the current year this area recorded less rainfall. However the country as a whole, experienced higher rainfall during the season except for the Eastern coastal belt, Mannar district and Jaffna peninsula.

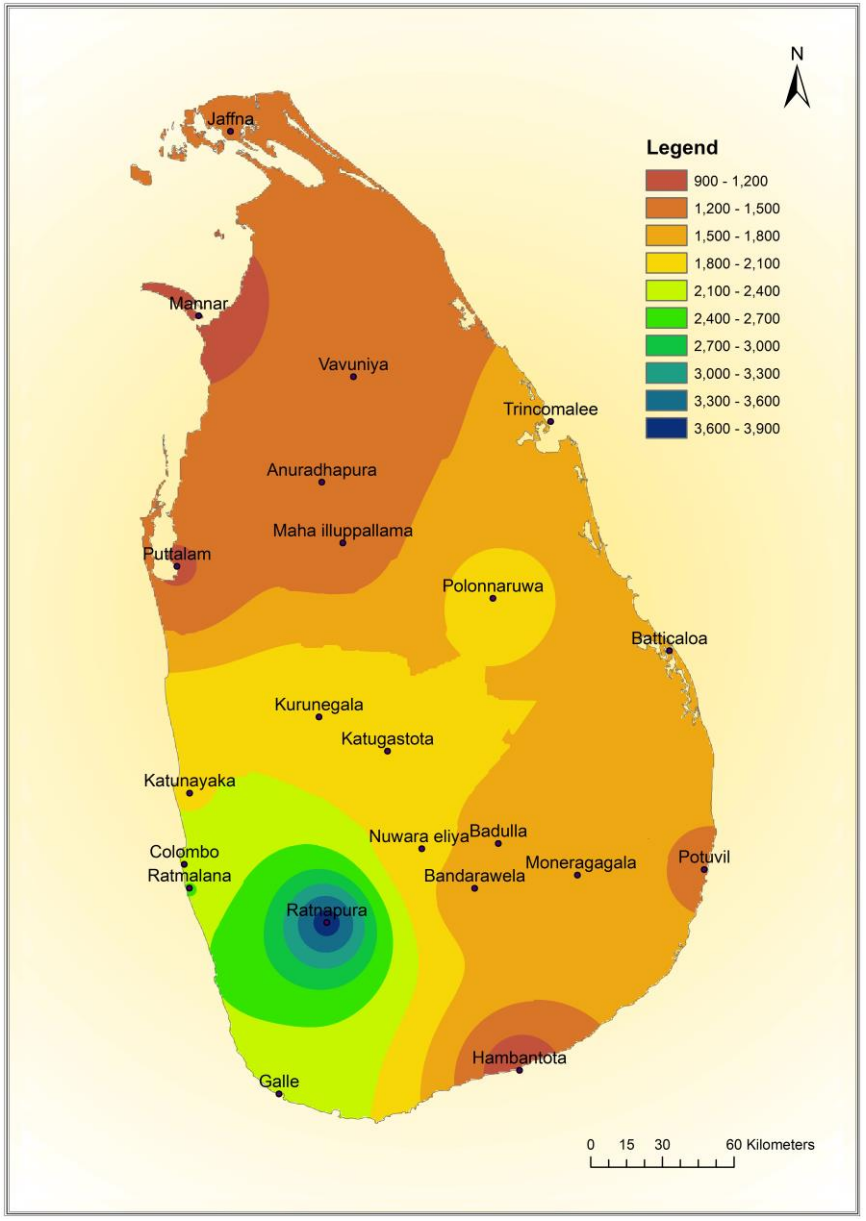
➢ NEM (South-West Monsoon) Rainfall Distribution

Eastern part of the Island including the central hills has recorded remarkable rainfall during the current year. The highest rainfall zone in located around Polonnaruwa and Batticaloa districts and distributed over the eastern plains and Central hills including the Mahaweli upper catchment. Central and North-Central provinces experienced the heaviest flood in this year after the devastating flood in 1957.

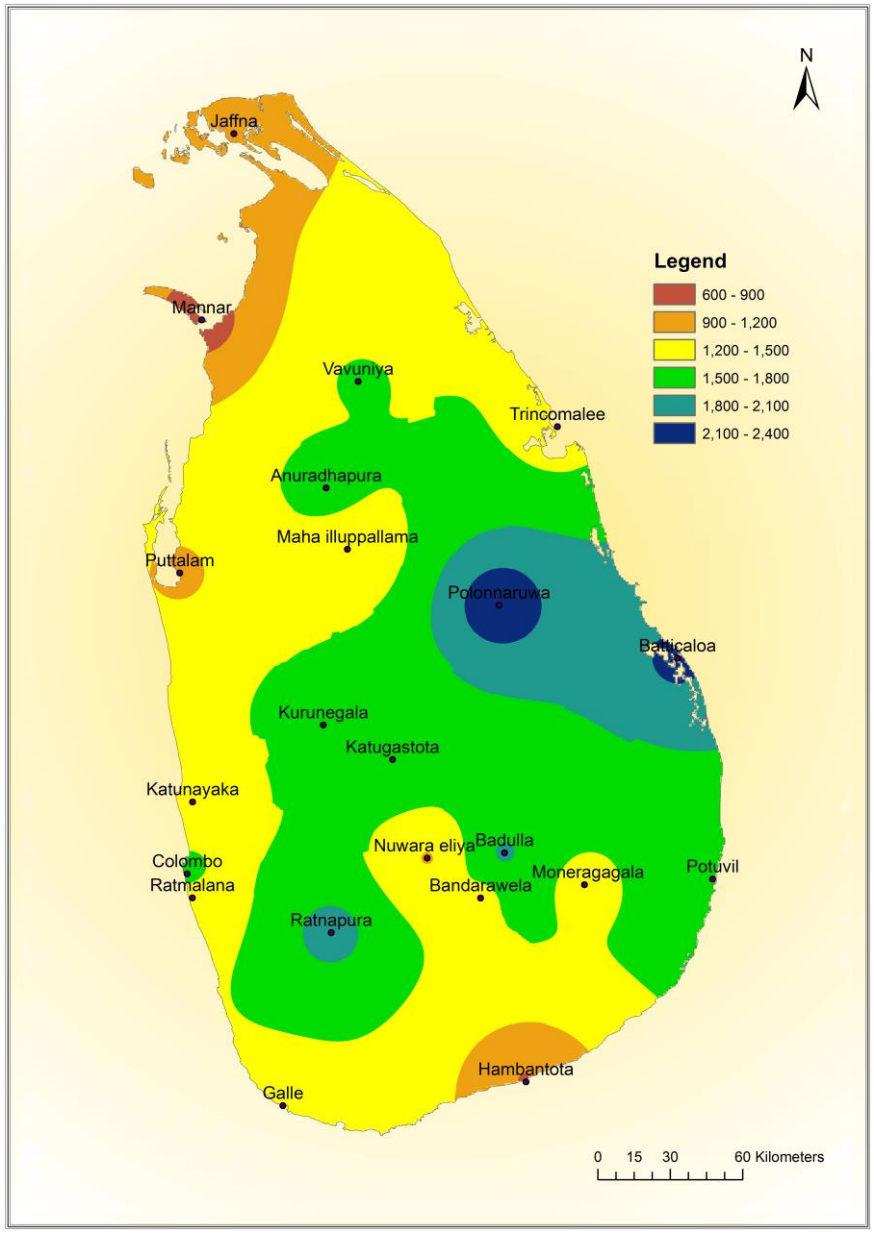
Annual Rainfall Distribution – Current year 2014/15



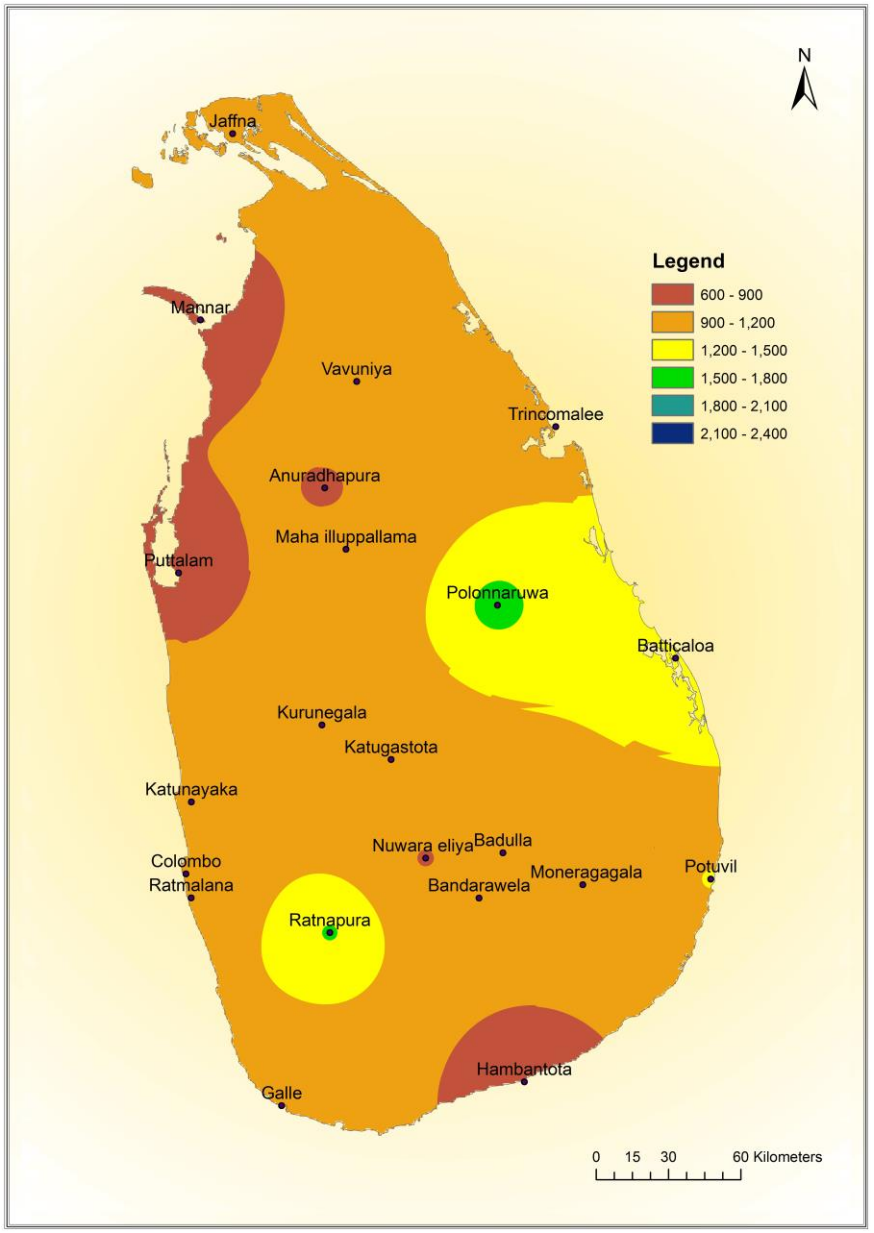
Annual Rainfall Distribution – Long Term Average



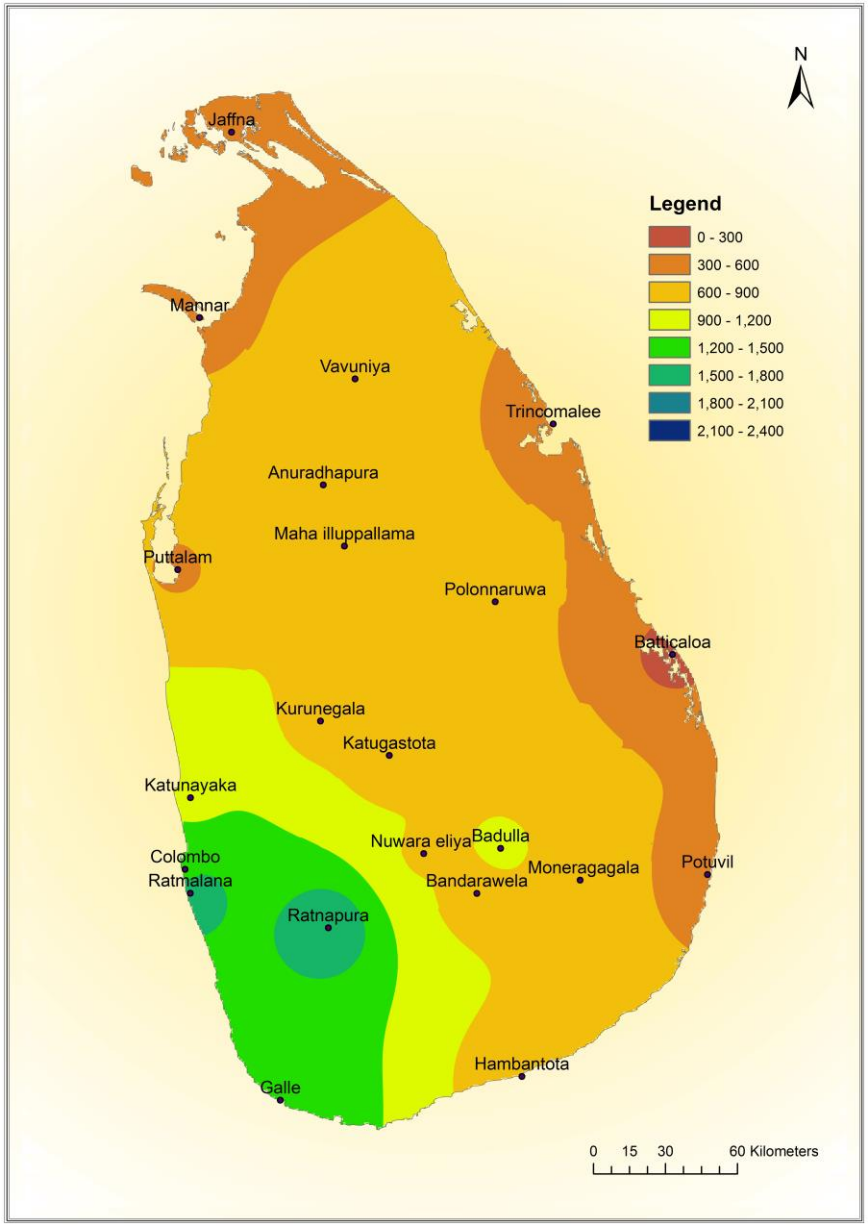
NEM Rainfall Distribution – Current year 2014/15



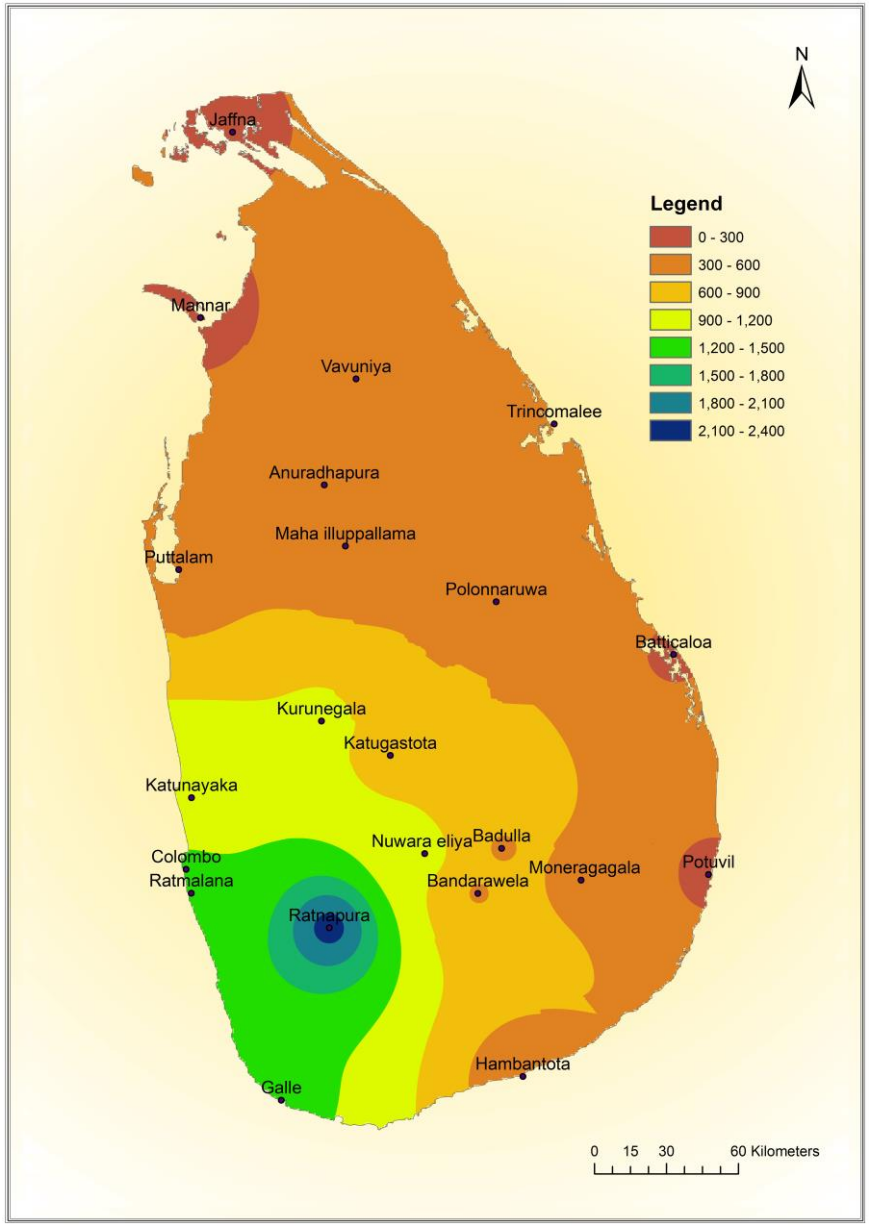
NEM Rainfall Distribution – Long Term Average



SWM Rainfall Distribution – Current year 2014/15



SWM Rainfall Distribution – Long Term Average



RAINFALL INTENSITIES

RAINFALL INTENSITY ANALYSIS
WATER YEAR 2014/15
(MAXIMUM DEPTH OF RAINFALL in mm)

Station	Duration in Hours								
	1	3	6	12	24	48	72	96	120
Badalgama	79	88	107	121	121	149	179	187	198
Baddegama	89	172	205	232	232	242	253	256	283
Calidoniya	54	81	92	106	106	110	123	143	148
Deraniyagala	91	114	122	150	150	167	190	271	286
Dolabodaganda	55	40	55	63	63	99	136	163	199
Dunamale	117	117	148	160	167	185	205	212	251
Galgamuwa	75	81	82	109	111	132	181	193	263
Giriulla	78	89	89	92	122	191	216	227	253
Glencourse	95	96	96	100	105	144	205	241	242
Hanwella	74	74	79	82	98	142	158	161	190
Holombuwa	61	70	102	138	148	231	248	259	266
Horowpothana	49	65	76	83	88	146	201	235	254
Karandagolla	106	106	106	106	106	198	269	322	324
Kitulgala	90	90	92	95	120	146	162	196	206
Kuda Oya	70	112	112	123	123	157	172	202	227
Laggala-Pallegama	70	110	120	163	229	361	433	499	540
Nakkala	75	109	112	120	139	221	257	287	311
Padiyathalawa	98	102	133	174	187	301	322	379	458
Peradeniya	82	93	97	105	107	212	233	281	308
Pitabeddara	110	110	127	127	127	141	175	200	202
Putupaula	72	72	76	89	93	106	129	133	140
Ranugala	71	71	99	114	161	161	264	311	311
Rathnapura	66	91	148	181	185	194	197	198	201
Siyambalanduwa	56	82	83	129	150	235	247	255	265
Thaldena	51	68	92	142	183	264	287	331	421
Thanamalwela	56	76	81	89	114	147	158	164	191
Thawalama	71	90	90	93	133	154	189	198	212
Urawa	78	89	89	89	89	142	162	171	184
Wellawaya	55	72	75	86	110	171	185	193	211

EVAPORATION
AND
EVAPOTRANSPIRATION

MONTHLY PAN EVAPORATION FOR THE WATER YEAR 2014/15

(in mm)

Name of Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total		
													NEM	SWM	Annual
Badalgama	81.0	78.8	73.3	114.4	119.1	106.8	96.1	79.6	78.2	105.1	95.0	81.1	573.3	535.0	1108.3
Bandarawela	74.4	44.7	69.1	79.7	69.0	93.0	71.4	103.9	104.7	107.9	105.4	79.6	429.9	572.9	1002.8
Bombuwela	81.2	77.1	74.4	94.6	97.7	103.9	1.0	88.7	85.8	96.4	84.6	66.6	528.9	423.1	952.0
Colombo	93.6	76.2	70.1	118.4	111.7	121.5	118.2	115.6	95.1	120.9	119.4	94.8	591.5	664.0	1255.5
Dunamale	98.1	86.7	74.9	121.0	100.6	123.4	109.7	113.6	89.3	98.3	96.4	81.6	604.6	588.8	1193.4
Galgamuwa	90.8	67.5	50.5	88.0	80.3	130.5	112.8	110.0	108.4	130.0	133.5	112.9	507.6	707.6	1215.2
Girandurukotte	116.3	-1	-1	82.5	70.8	101.7	111.9	10.2	119.4	142.9	152.8	117.6	-1	654.8	-1
Horowpathana	105.8	73.0	-1	92.4	84.3	115.5	100.0	107.6	126.9	170.4	161.5	133.6	-1	800.0	-1
Kurunegala	81.2	51.0	57.0	118.1	116.3	138.0	98.4	101.1	100.5	122.1	113.8	93.0	561.6	628.9	1190.5
Mahailluppallama	90.2	51.0	49.9	80.9	74.5	110.7	102.6	101.4	119.1	142.6	142.6	111.6	457.2	719.9	1177.1
Padiyatalawa	114.4	75.7	73.7	106.2	102.5	149.7	159.6	150.5	171.5	214.7	184.6	156.1	622.2	1037.0	1659.2
Palugasdamana	112.7	58.1	36.8	95.2	95.0	122.2	122.9	134.7	142.6	188.4	178.8	127.4	520.0	894.8	1414.8
Pelwaththa	-1	-1	-1	116.3	95.8	114.7	110.4	106.3	123.8	155.8	165.9	118.4	-1	780.6	-1
Puttlam	109.7	68.7	63.6	100.4	99.5	136.4	130.2	119.3	137.7	159.7	169.8	144.6	578.3	861.3	1439.6
Rathnapura	53.6	52.8	55.5	90.5	85.8	96.4	93.6	75.3	73.5	76.9	95.5	60.3	434.6	475.1	909.7
Sevanagala	113.5	89.7	85.9	1.3	128.8	141.7	116.7	104.4	124.8	145.1	140.1	103.2	560.9	734.3	1295.2
Seetha Eliya	59.5	61.5	41.5	66.7	66.7	94.5	68.1	56.8	70.2	64.2	70.9	58.8	390.4	389.0	779.4
Talgahagoda	89.6	-1	80.3	94.5	115.2	1.3	137.2	104.1	98.8	87.8	87.6	86.3	-1	601.8	-1

Note :- Missing data is denoted by -1

NEM denotes North - East Monsoon, SWM denotes South - West Monsoon

OPEN WATER EVAPORATION (Eo) & POTENTIAL EVAPOTRANSPIRATION FOR REFERENCE CROP (ETo)

For the Calendar Year : 2015
Weather Station : Pelwaththa
Co-ordinate : 6° 41' N, 81° 12' E
Altitude : 152 m

Month	Temp. Avg. °C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Jan	15.91	65.45	8.25	1.26	128	93
Feb	21.37	65.55	7.16	1.15	144	106
Mar	16.84	63.73	8.64	0.79	150	109
Apr	22.85	70.96	7.62	0.48	160	118
May	28.01	64.98	6.89	0.95	174	134
Jun	26.32	60.53	7.67	1.11	175	135
Jul	28.91	55.20	7.66	1.26	190	151
Aug	29.30	56.63	8.51	1.53	207	166
Sep	27.82	66.58	6.20	1.22	169	132
Oct	28.04	72.86	5.44	0.48	145	110
Nov	26.82	74.37	4.75	0.43	124	92
Dec	15.98	78.91	5.17	0.81	113	84
Annual	24.01	66.31	7.00	0.96	1880	1430

OPEN WATER EVAPORATION (Eo) & POTENTIAL EVAPOTRANSPIRATION FOR REFERENCE CROP (ETo)

For the Calendar Year : 2015
Weather Station : Padiyathalawa
Co-ordinate : 7° 23' N, 81° 11 E
Altitude : 100 m

Month	Temp. Avg. °C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Jan	22.34	63.26	5.50	0.25	116	83
Feb	19.95	64.89	5.48	0.30	118	82
Mar	23.34	57.35	7.35	0.38	157	114
Apr	24.28	61.77	7.84	0.44	167	122
May	25.94	64.35	6.40	0.37	154	114
Jun	25.20	54.90	7.05	0.62	159	118
Jul	26.54	50.87	7.42	0.88	175	134
Aug	26.11	52.29	7.70	0.78	177	135
Sep	24.79	67.33	6.63	0.62	155	116
Oct	24.09	72.71	5.82	0.40	137	103
Nov	22.48	71.87	3.66	0.24	104	73
Dec	26.81	79.29	2.91	0.32	206	182
Annual	24.32	63.41	6.15	0.47	1825	1376

STREAM FLOW DATA

STREAM FLOW DATA - WATER YEAR 2014/15

Upper line : Runoff in MCM
Lower line : Rainfall in mm

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Rainfall 2014/15	Long-term Average of Annual Runoff & Rainfall up to 2013/14		Peak Flood for 2014/15 & Observed Maximum Flood Peak up to 2013/14		
															value	**	cumecs	Time	Date
1	**Badalgama**	338.84	191.73	528.55	67.63	22.64	35.93	118.47	79.10	29.82	9.37	8.88	13.22	1444.18	1265.00	49	1470.27	1:00am	27.12.2014
	R.B. 102	723.3	331.1	708.1	7.0	105.7	254.0	456.8	219.9	250.7	70.5	157.5	180.5	3465.1	2335.9		1982.16	12:00mn	24.09.1971
2	**Baddegama**	417.74	237.91	291.57	118.56	119.45	122.80	206.44	183.82	140.98	170.24	143.28	345.79	2498.58	2347.12	8	336.16	2:00am	30.09.2015
	R.B. 9	584.2	407.4	450.7	110.9	209.0	242.5	289.3	366.5	220.3	296.2	270.6	532.2	3979.8	3421.7		573.43	4:00pm	03.06.2008
3	**Calidonia**	22.73	22.24	50.29	19.22	15.09	10.17	18.27	21.64	13.06	13.08	12.23	15.25	233.27	212.01	30	153.51	7:00am	26.12.2014
	R.B. 60	275.8	140.0	389.0	13.0	217.0	80.5	273.8	161.6	185.4	99.6	143.2	238.8	2217.6	2052.7		178.48	3:00pm	12.06.2014
4	**Chilaw**	115.44	292.32	425.47	213.65	175.94	188.19	186.13	124.47	107.96	88.57	96.94	98.54	2113.62	2414.01	24	801.64	3:00am	28.12.2014
	R.B. 99	371.4	243.3	471.1	9.3	23.7	143.9	268.9	149.5	65.5	20.1	47.2	79.5	1893.4	2030.5		1654.00	6:00am	11.06.1995
5	**Demodara**	11.17	1.98	24.07	2.97	1.28	1.48	4.42	4.12	10.36	0.34	1.16	2.41	65.76	64.58	23	662.93	6:00pm	28.10.2014
	R.B. 60	747.7	243.2	669.2	27.9	157.0	132.9	386.0	204.9	239.3	48.6	61.9	190.9	3109.5	1936.7		628.13	-1	14.03.2008
6	**Deraniyagala**	97.36	47.39	31.50	16.84	17.27	16.59	34.23	42.53	47.61	39.76	33.09	62.93	487.10	605.69	58	252.00	7:00pm	05.06.2015
	R.B. 1	845.0	313.2	307.4	65.1	281.4	213.9	458.4	464.5	476.0	206.4	566.0	601.6	4798.9	5094.4		2313.00	9:00am	31.05.1985
7	**Dunamale**	44.01	29.28	42.93	10.23	2.05	6.30	28.26	28.16	21.27	6.61	4.28	20.93	244.31	197.34	9	40.66	2:00pm	31.10.2014
	R.B. 103	528.9	236.2	604.9	22.1	129.6	248.7	442.4	256.2	386.4	47.2	227.8	307.6	3437.8	3351.8		58.66	11:00pm	31.05.2008
8	**Ellagawa**	489.82	207.02	240.66	59.14	81.03	56.09	150.43	122.94	107.46	91.70	120.00	236.70	1962.99	3379.05	57	516.50	10:00am	11.10.2014
	R.B. 3	600.1	243.3	410.8	81.6	196.1	167.6	413.7	273.8	256.9	172.7	268.6	424.2	3509.4	3730.9		2620.00	4:00am	19.05.2003
9	**Galgamuwa**	5.30	27.72	102.42	6.23	2.23	1.33	7.25	12.48	2.99	1.58	1.55	0.94	172.02	172.08	22	139.88	11:00pm	22.12.2014
	R.B.95	287.2	386.0	512.6	5.8	78.1	84.6	294.6	161.1	141.8	33.7	59.9	76.5	2121.8	1243.2		159.25	1:00pm	19.11.2006
10	**Glencourse**	481.59	281.47	373.63	160.60	138.96	160.38	259.11	246.53	247.17	179.86	166.67	235.43	2931.40	3928.90	66	940.54	1:00pm	26.12.2014
	R.B. 1	623.1	310.9	454.2	57.2	211.5	229.1	448.5	332.7	396.5	210.3	324.7	413.2	4011.9	3615.7		3500.00	10:00am	04.06.1989

Note :- Missing data is denoted by -1 , ** Denotes period of records

STREAM FLOW DATA - WATER YEAR 2014/15

Upper line : Runoff in MCM
Lower line : Rainfall in mm

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Rainfall 2014/15	Long-term Average of Annual Runoff & Rainfall up to 2013/14		Peak Flood for 2014/15 & Observed Maximum Flood Peak up to 2013/14		
															value	**	cumecs	Time	Date
11	Hanwella	656.84	355.84	464.26	90.31	88.63	92.40	244.36	206.44	226.06	104.92	87.75	196.98	2814.79	4164.49	39	1012.80	5:00pm	26.12.2014
	R.B. 1	608.5	309.7	452.4	58.9	209.7	232.3	447.3	321.3	390.1	186.9	295.2	399.5	3911.8	3708.9		2745.58	8:00am	05.06.1989
12	Holombuwa	38.56	29.15	65.67	13.20	5.23	5.82	23.97	15.96	12.89	5.23	4.92	7.32	227.92	260.56	50	289.40	7:00am	26.12.2014
	R.B. 1	595.3	365.1	676.1	27.7	256.7	359.4	641.2	394.9	397.8	252.2	363.1	520.7	4850.2	3060.4		644.47	7:00am	03.06.1989
13	Horowpothana	6.60	100.40	305.69	20.92	42.91	6.36	5.45	20.47	3.31	2.81	3.15	6.30	524.37	162.85	53	304.00	6:00am	21.12.2014
	R.B. 67	255.9	418.1	689.4	18.8	190.9	50.0	157.0	199.5	28.5	0.3	60.2	138.2	2206.8	-1		5662.00	4:00pm	26.12.1957
14	Katharagama	12.30	15.20	42.10	21.30	13.00	13.90	32.30	32.60	14.40	17.10	16.60	16.40	247.20	218.60	69	91.61	9:00am	27.12.2014
	R.B. 26	383.8	267.2	522.5	37.2	19.9	80.4	377.0	174.1	74.4	10.5	51.2	33.3	2031.5	1544.1		1365.00	1:00pm	25.12.1957
15	Kithulagala	119.93	105.61	109.25	81.57	68.06	68.65	64.98	82.33	80.92	83.69	80.13	92.16	1037.28	1155.67	66	151.71	8:00am	26.12.2014
	R.B. 1	500.8	256.7	374.3	35.1	184.8	71.5	290.3	175.2	301.0	263.1	230.0	292.7	2975.5	3458.5		2157.00	5:15pm	30.05.1989
16	Laggala-pallegama	22.06	36.77	205.32	23.88	37.21	25.64	19.85	16.79	7.03	3.94	2.67	4.94	406.10	206.65	25	913.28	5:00am	25.12.2014
	R.B. 60	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		1797.02	12:00mn	17.12.2012
17	Millakanda	311.52	170.17	206.36	54.12	65.89	69.04	165.76	127.23	120.84	103.46	100.38	181.01	1675.78	2136.17	24	240.68	6:00am	09.10.2014
	R.B. 3	666.4	501.9	613.9	150.1	243.8	384.1	658.6	547.0	570.6	355.2	581.1	703.9	5976.4	4246.2		1320.45	12:00mn	01.06.2008
18	Nawalapitiya	69.69	42.16	45.67	23.37	16.74	13.69	18.79	20.17	39.82	57.55	42.41	55.20	445.26	487.61	26	174.21	12:00nn	11.07.2015
	R.B. 60	527.7	338.3	565.8	58.5	260.2	118.5	342.7	204.3	397.3	415.2	323.8	420.6	3972.9	3686.9		360.20	4:00am	28.06.1993
19	Norwood	21.81	21.92	37.73	12.12	13.94	7.71	18.87	17.98	8.43	7.15	6.50	7.85	182.01	132.98	29	83.24	8:00am	26.12.2014
	R.B. 1	401.5	198.9	416.0	52.2	183.0	70.5	345.0	168.0	154.4	139.4	123.4	176.5	2428.8	2600.0		180.98	6:00pm	13.05.2013
20	Padiyathalawa	15.44	39.09	135.74	22.90	24.59	18.19	12.05	14.77	11.29	0.71	0.65	2.02	297.44	145.74	30	806.57	11:00am	26.12.2014
	R.B. 54	310.6	546.9	870.6	111.1	323.6	126.6	249.7	175.3	143.1	97.4	50.4	246.0	3251.4	2098.2		784.16	10:00pm	02.02.2011

Note :-Missing data is denoted by -1, ** Denotes period of records

STREAM FLOW DATA - WATER YEAR 2014/15

Upper line : Runoff in MCM
Lower line : Rainfall in mm

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Rainfall 2014/15	Long-term Average of Annual Runoff & Rainfall up to 2013/14		Peak Flood for 2014/15 & Observed Maximum Flood Peak up to 2013/14		
															value	**	cumecs	Time	Date
21	**Peradeniya**	295.66	275.80	414.14	191.86	101.39	50.69	126.82	154.34	116.91	157.11	141.16	126.38	2152.26	1801.50	66	947.44	10:00am	26.12.2014
	R.B. 60	465.4	321.3	676.2	18.5	208.7	93.7	358.6	206.5	256.8	199.2	187.3	339.7	3331.9	2928.5		5097.71	2:30am	15.08.1947
22	**Pitabeddara**	123.82	66.67	119.12	50.12	43.23	26.94	118.77	67.11	37.32	38.75	42.14	117.22	851.22	511.06	41	1071.36	10:00pm	20.04.2015
	R.B. 12	512.4	281.4	446.5	123.2	187.1	146.8	252.2	257.4	153.5	210.4	356.7	468.5	3396.2	3058.1		-1	12:20am	19.05.2003
23	**Putupaula**	600.14	363.61	390.71	188.87	183.65	188.85	281.95	252.99	256.31	207.12	228.35	366.53	3509.08	6133.81	70	462.75	12:00mn	11.10.2014
	R.B. 3	615.3	340.6	479.9	104.5	208.2	244.0	477.6	356.9	380.8	232.2	372.4	518.8	4331.1	3186.0		2829.00	9:30am	16.08.1947
24	**Rathnapura**	233.96	93.51	128.03	29.37	33.04	30.83	98.96	60.68	52.83	54.36	43.18	130.59	989.34	1043.57	8	355.02	9:00am	08.10.2014
	R.B. 3	573.0	265.2	417.0	85.1	169.1	134.9	447.1	244.1	221.7	179.8	295.6	432.9	3465.5	3106.7		814.10	12:00nn	31.05.1989
25	**Siyambalanduwa**	5.87	45.45	82.20	6.43	2.73	2.48	10.49	3.49	1.01	0.05	0.00	0.00	160.20	135.51	23	482.40	5:00am	26.12.2014
	R.B. 36	316.0	411.1	231.5	16.5	122.9	145.7	260.2	149.4	211.8	64.0	16.1	70.7	2015.7	1708.9		889.27	4:00pm	12.01.2007
26	**Thanamalwila**	50.41	36.31	102.43	52.49	10.88	10.37	75.95	39.51	8.88	1.64	0.90	2.55	392.30	253.46	27	384.67	7:00am	26.12.2014
	R.B. 22	266.7	312.1	456.3	34.8	136.2	47.6	423.3	140.5	15.1	13.3	29.3	99.0	1974.1	1591.8		824.70	3:00am	24.11.2012
27	**Thawalama**	183.23	106.47	152.51	57.56	57.08	46.17	124.44	83.10	65.44	86.39	68.47	147.55	1178.41	1086.65	41	281.83	5:00am	30.10.2014
	R.B. 9	628.9	360.4	583.6	218.6	270.6	291.3	530.3	301.7	179.7	342.2	336.0	609.6	4652.9	3922.0		1066.40	1:00pm	10.10.1976
28	**Wellawaya**	38.22	25.65	54.89	40.04	14.83	11.18	39.04	23.52	10.31	4.32	3.43	5.15	270.57	110.90	26	570.60	3:00am	01.01.2015
	R.B. 22	440.8	369.5	549.9	70.2	158.5	67.2	349.2	142.1	37.7	35.5	39.9	109.8	2370.0	2043.1		634.50	8:00pm	21.10.2012

Note :-Missing data is denoted by -1, ** Denotes period of records

RUNOFF RAINFALL RATIOS

RUNOFF RAINFALL RATIOS - 2014/15

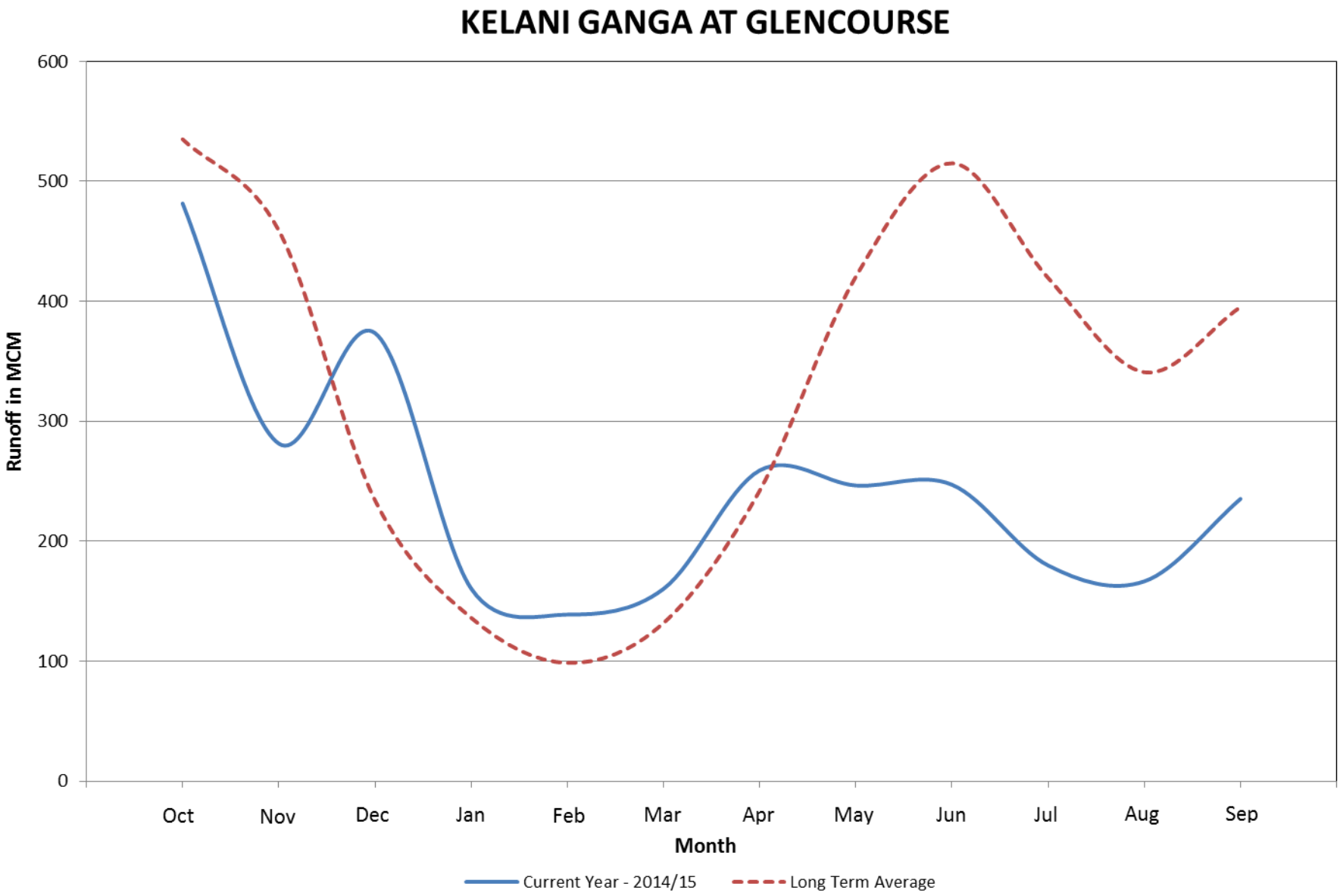
Name of River Basin	Station	Annual Rainfall (mm)	Annual Runoff (mm)	Runoff / Rainfall Ratio %
Kelani Ganga	Norwood	2429	1884	78
Kelani Ganga	Kithulgala	2976	2708	91
Kelani Ganga	Deraniyagala	4799	2662	55
Kelani Ganga	Holombuwa	4850	1470	30
Kelani Ganga	Glencourse	4012	2004	50
Kelani Ganga	Hanwella	3912	1580	40
Kalu Ganga	Rathnapura	3465	1641	47
Kalu Ganga	Ellagawa	3509	1409	40
Kalu Ganga	Millakanda	5976	2148	36
Kalu Ganga	Putupaula	4331	1351	31
Gin Ganga	Thawalama	4653	3127	67
Gin Ganga	Baddegama	3980	3432	86
Nilwala Ganga	Pitabeddara	3396	2558	75
Kirindi Oya	Wellawaya	2370	1570	66
Kirindi Oya	Thanamalwila	1974	524	27
Maduru Oya	Padiyathalawa	3251	1871	58
Badulu Oya	Demodara	3110	849	27
Mahaweli Ganga	Peradeniya	3332	1843	55
Mahaweli Ganga	Nawalapitiya	3973	2530	64
Deduru Oya	Chilaw	1893	810	43
Maha Oya	Badalgama	3465	1062	31

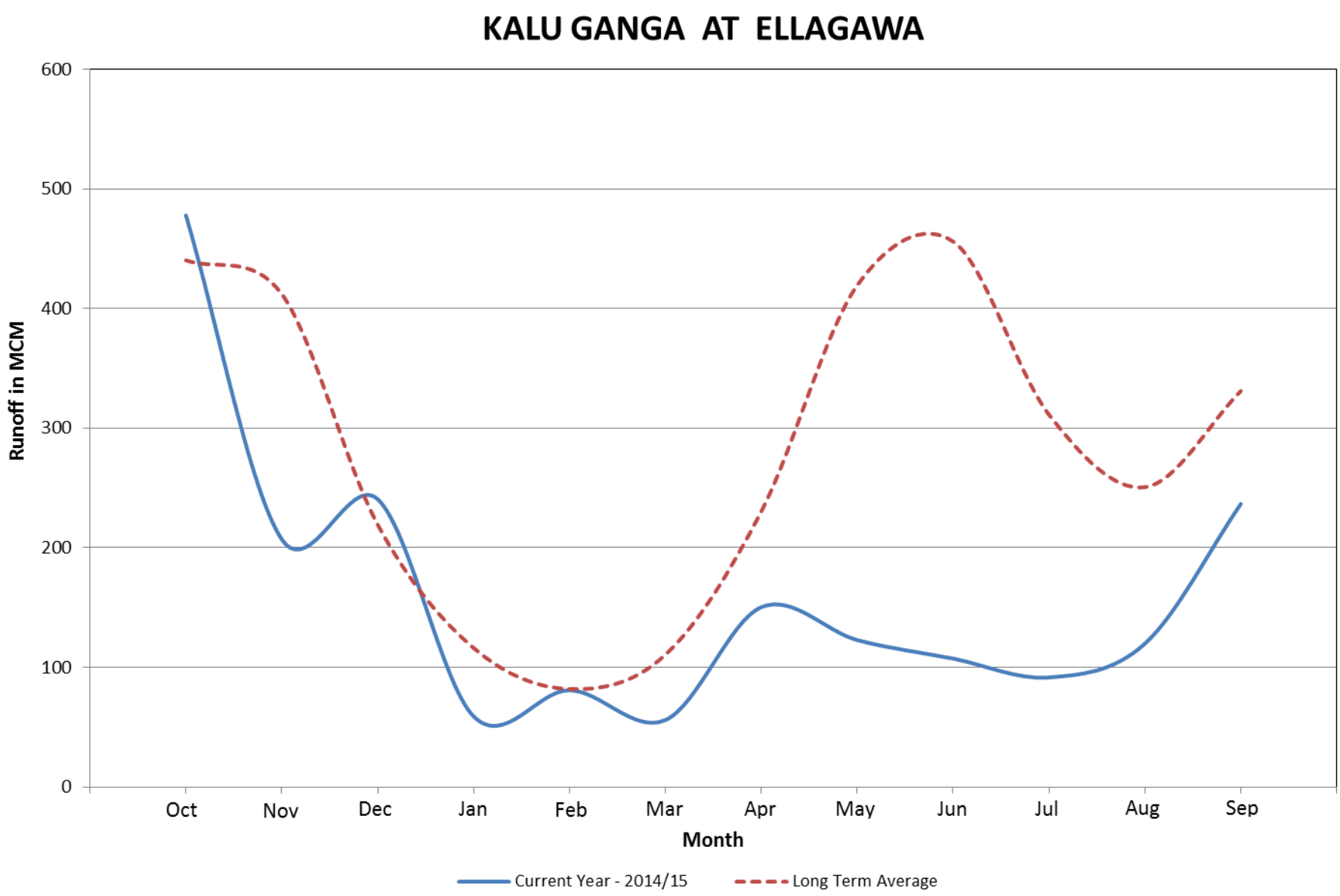
MONTHLY FLOWS IN MAJOR RIVERS

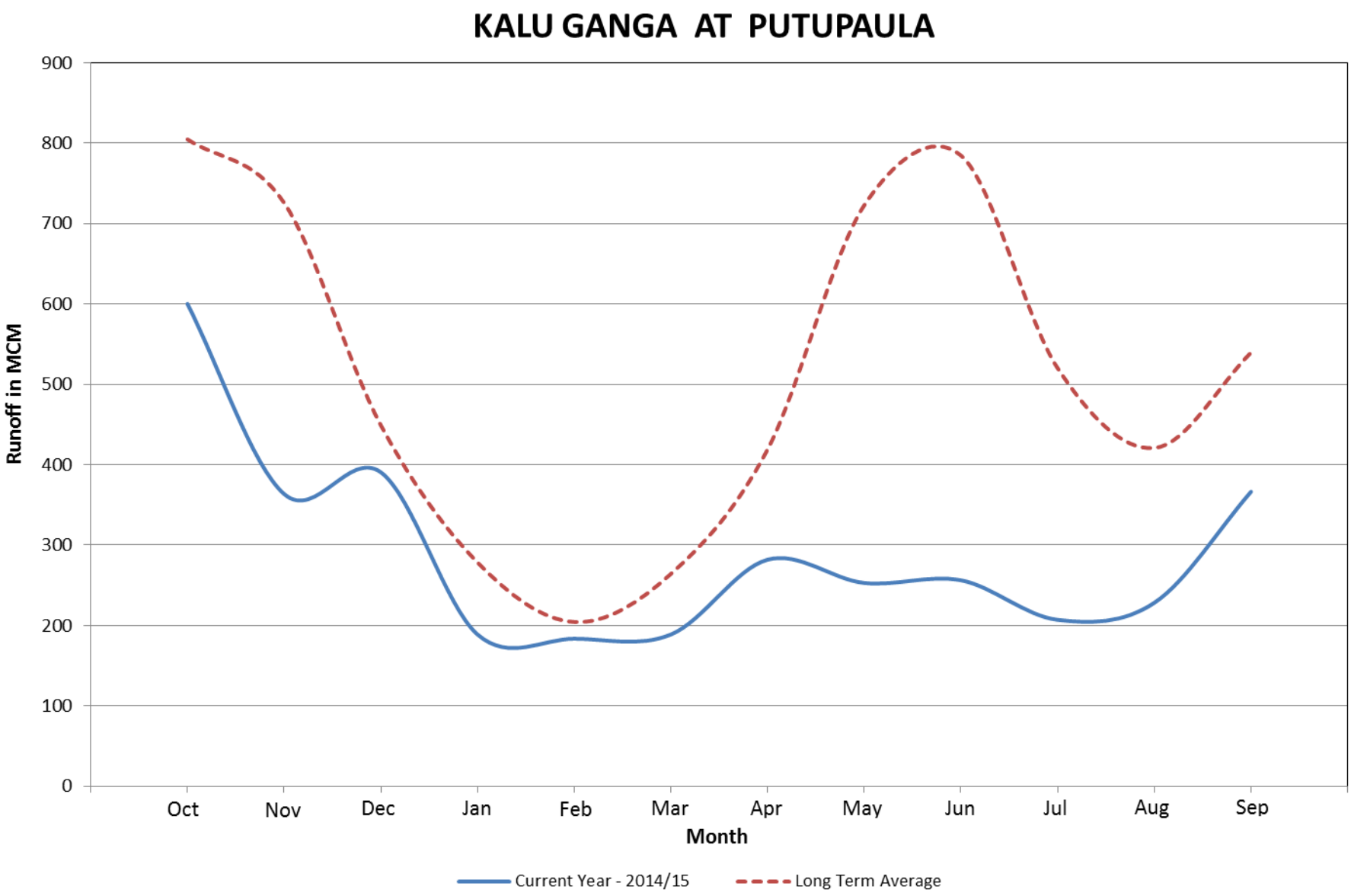
MONTHLY FLOWS IN MAJOR RIVERS (in MCM)

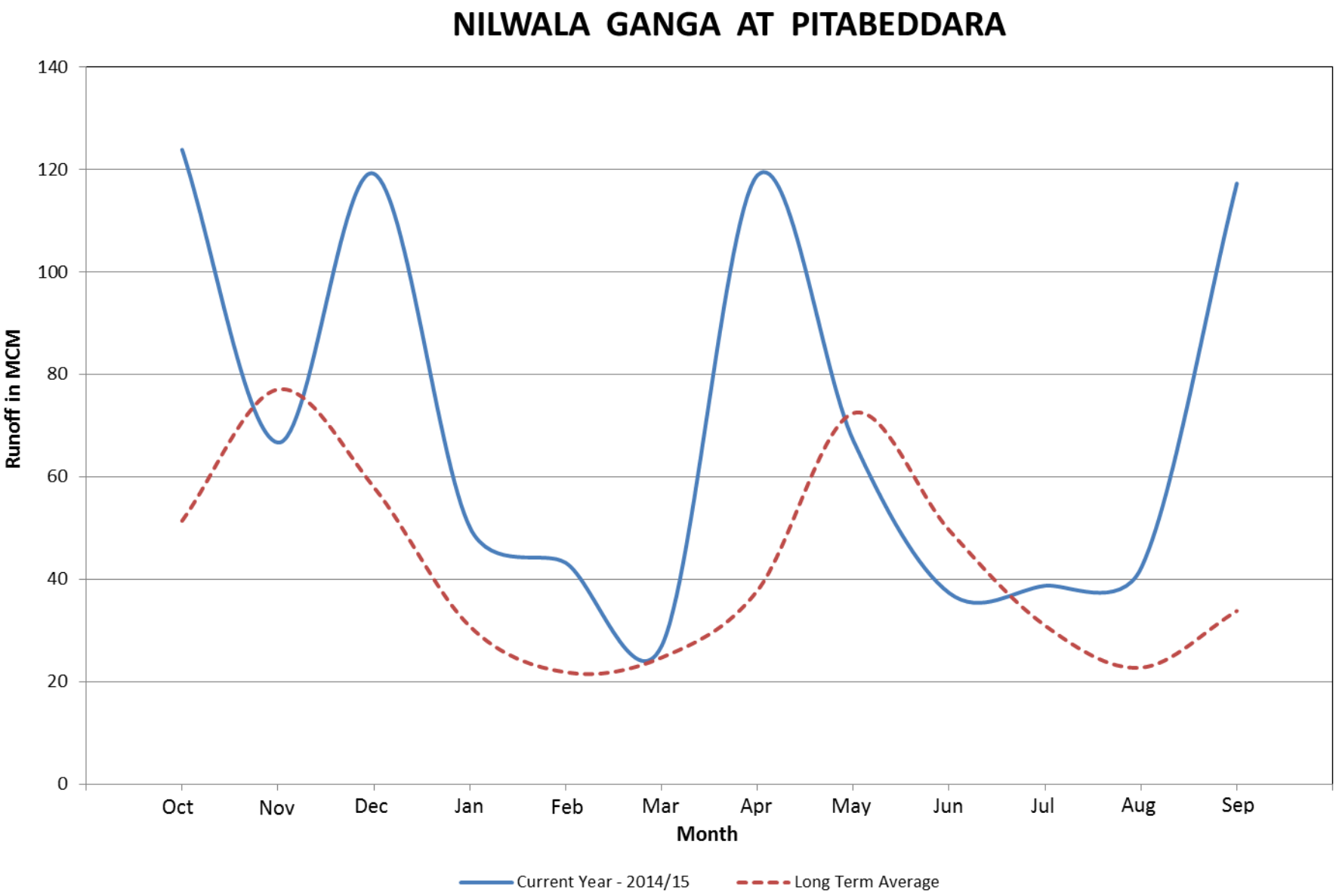
Upper line : Current year 2014/15
Lower line : Long-term average

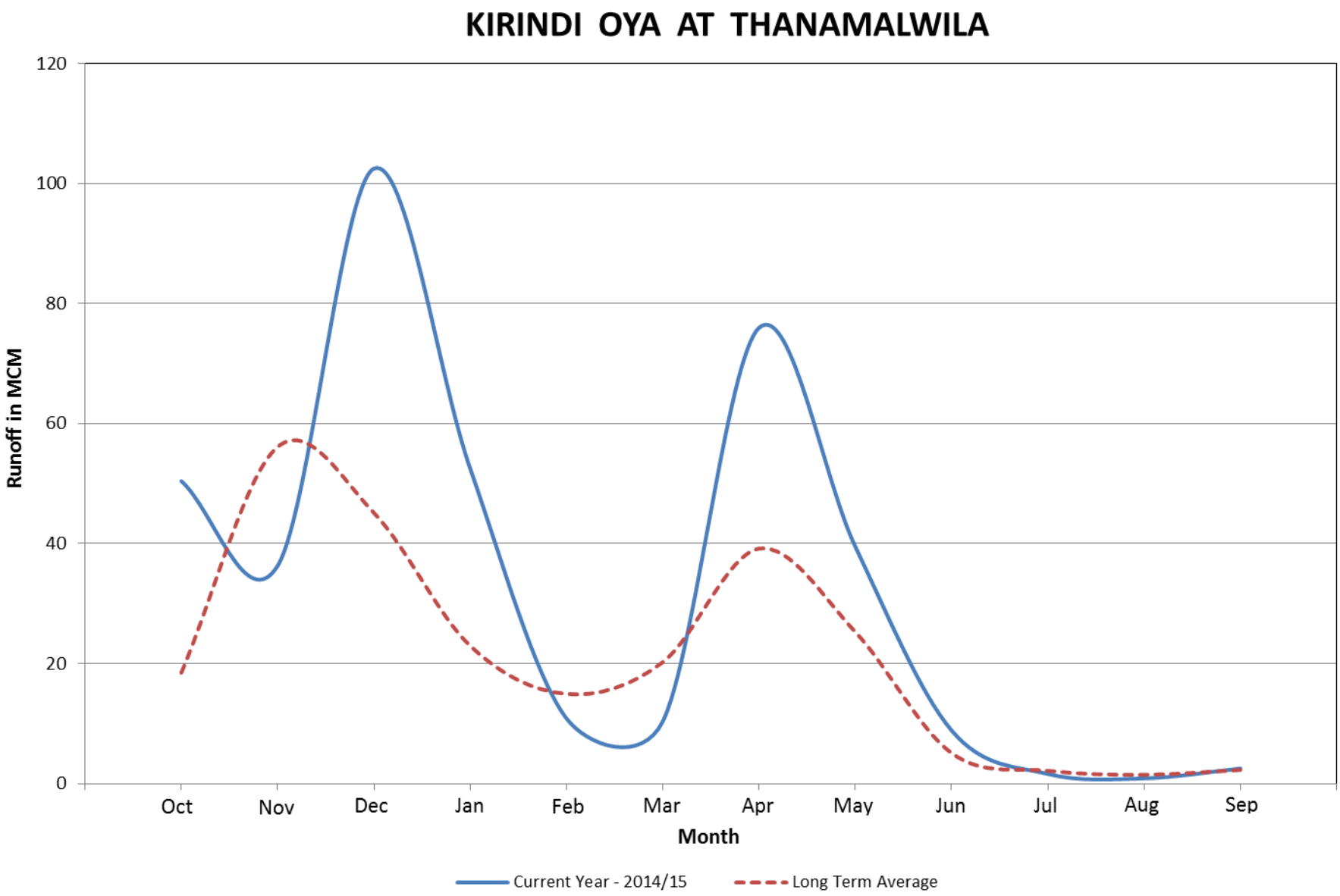
Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Kelani Ganga at Glencourse	481.59	281.47	373.63	160.60	138.96	160.38	259.11	246.53	247.17	179.86	166.67	235.43	2931.40
	535.11	458.99	234.23	136.27	98.68	131.92	242.23	420.60	515.10	419.43	340.95	395.39	3928.90
Kalu Ganga at Ellagawa	477.85	207.02	240.66	59.14	81.03	56.09	150.43	122.94	107.46	91.70	120.00	236.70	1951.02
	440.24	411.97	219.32	116.24	82.01	110.68	230.45	419.32	455.93	311.18	250.65	331.06	3379.05
Kalu Ganga at Putupaula	600.14	363.61	390.71	188.87	183.65	188.85	281.95	252.99	256.31	207.12	228.35	366.53	3509.08
	804.78	725.72	449.11	278.39	204.50	264.20	419.08	722.73	784.70	520.17	420.83	539.60	6133.81
Nilwala Ganga at Pitabeddara	123.82	66.67	119.12	50.12	43.23	26.94	118.77	67.11	37.32	38.75	42.14	117.22	851.22
	51.40	77.03	57.97	30.81	21.85	24.71	37.79	72.41	49.56	30.95	22.75	33.82	511.06
Kirindi Oya at Thanamalwila	50.41	36.31	102.43	52.49	10.88	10.37	75.95	39.51	8.88	1.64	0.90	2.55	392.30
	18.50	56.12	45.13	22.96	14.96	20.24	39.17	25.30	5.11	2.17	1.50	2.30	253.46
Deduru Oya at Chilaw	115.44	292.32	425.47	213.65	175.94	188.19	186.13	124.47	107.96	88.57	96.94	98.54	2113.62
	236.69	321.38	221.43	183.23	167.18	180.81	190.69	210.70	182.33	175.41	172.23	171.91	2414.01

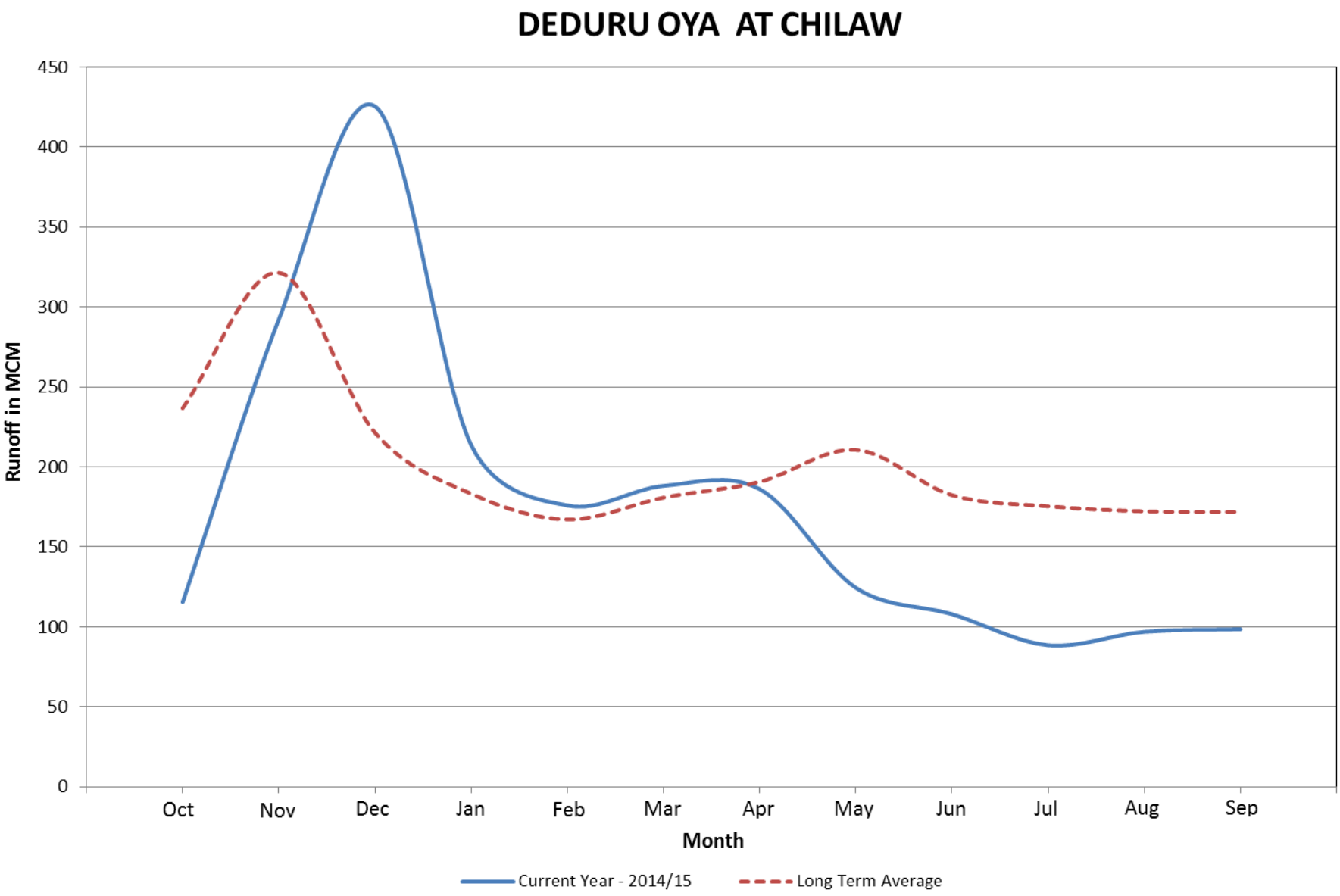

KELANI GANGA AT GLENCOURSE
600
500
400
300
200
100
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average


KALU GANGA AT ELLAGAWA
600
500
400
300
200
100
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average


KALU GANGA AT PUTUPAULA
900
800
700
600
500
400
300
200
100
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average

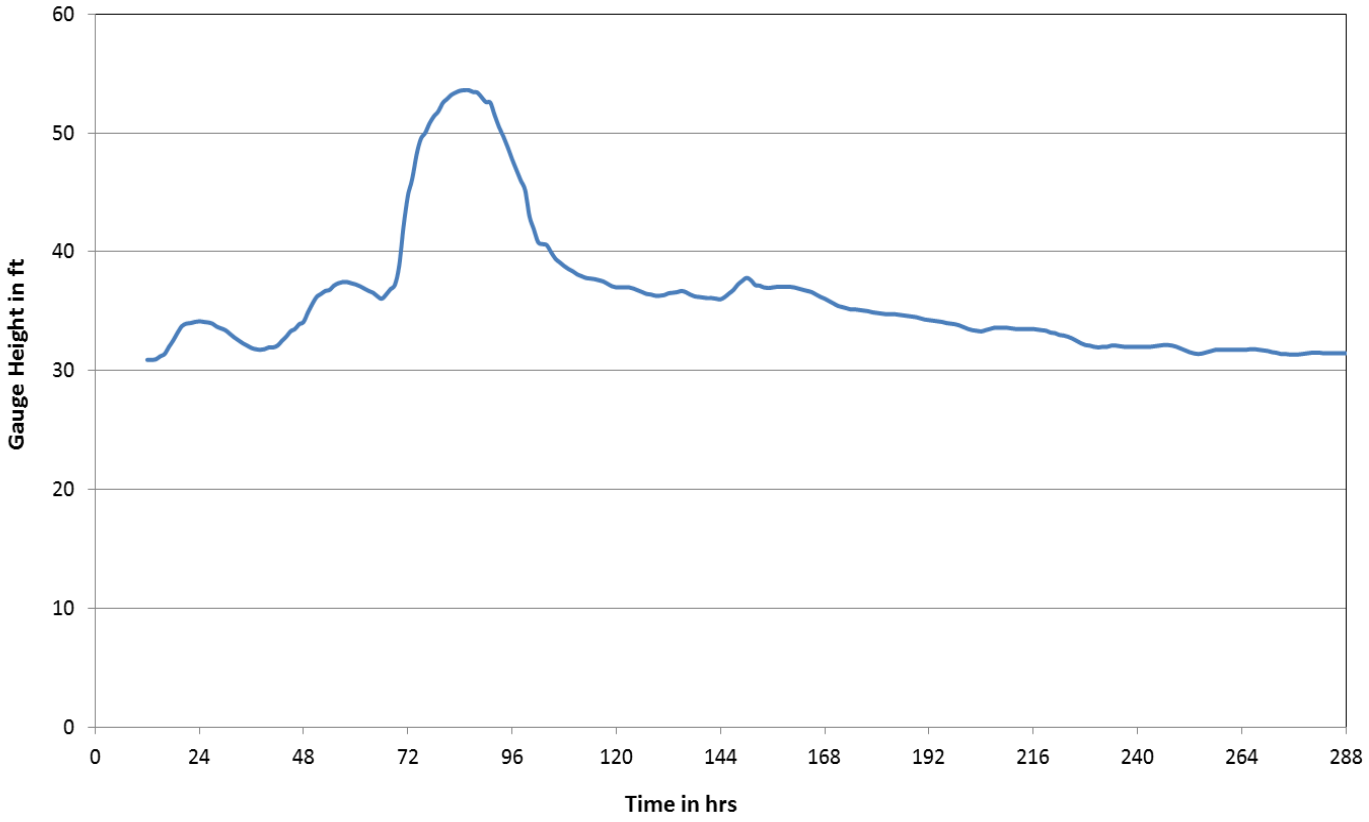

NILWALA GANGA AT PITABEDDARA
140
120
100
80
60
40
20
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average

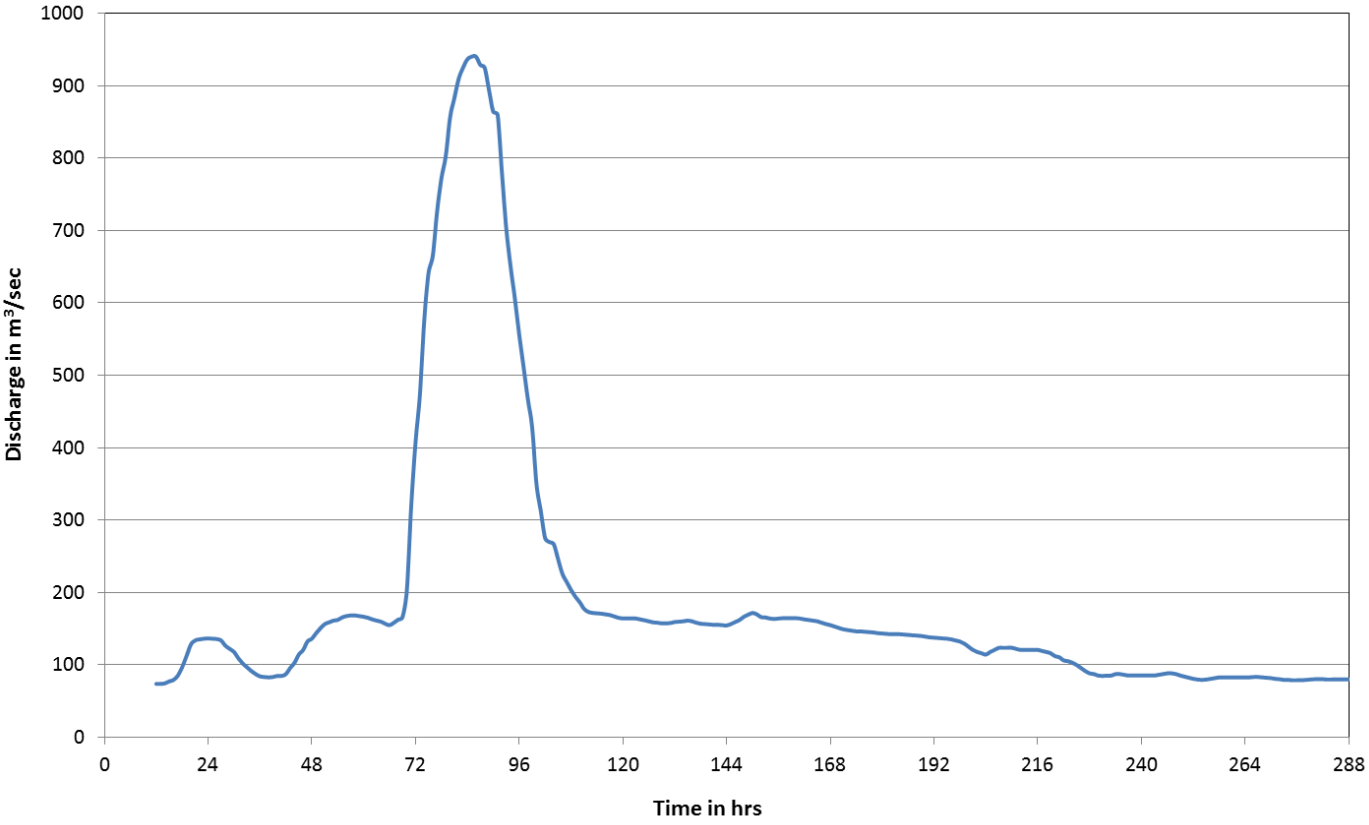

KIRINDI OYA AT THANAMALWILA
120
100
80
60
40
20
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average


DEDURU OYA AT CHILAW
Runoff in MCM
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2014/15
Long Term Average

FLOOD HYDROGRAPHS

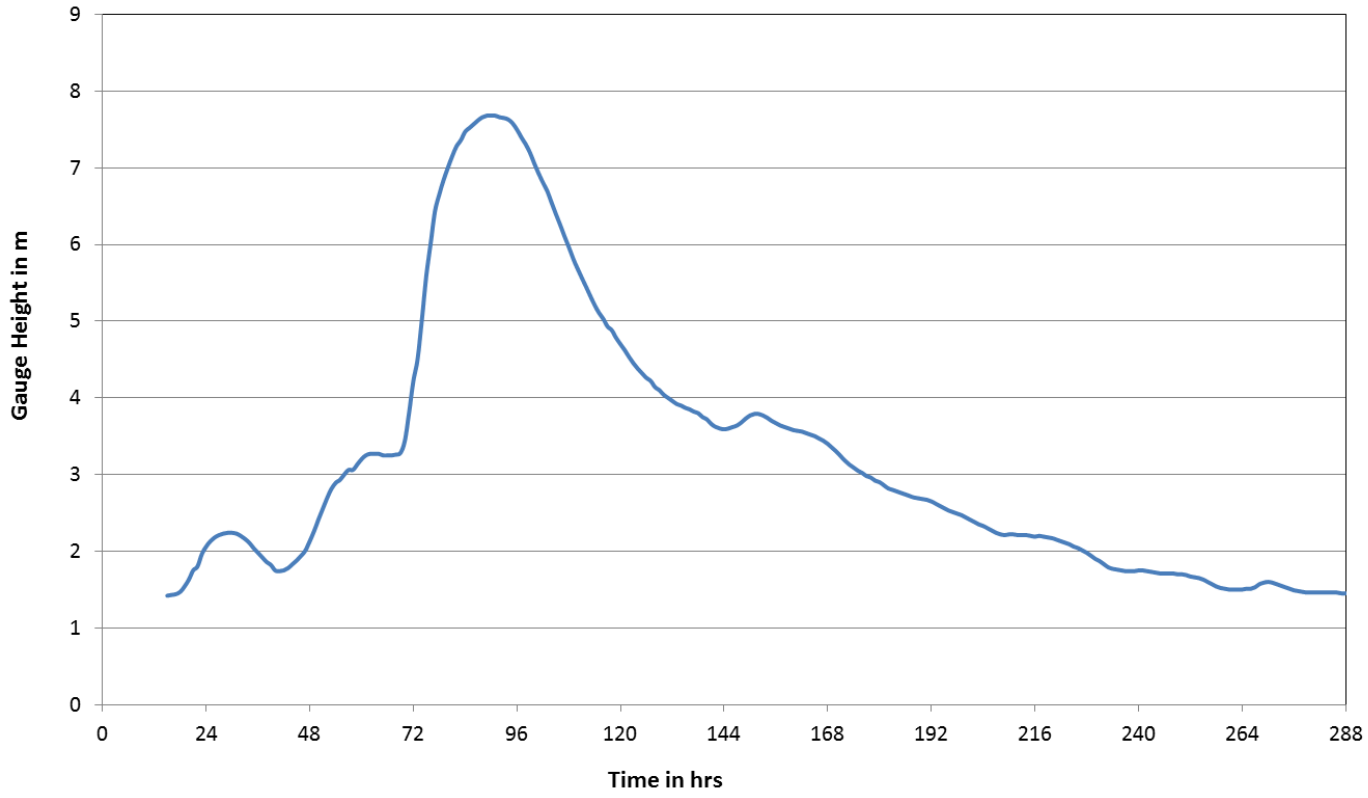
Kelani Ganga at Glencourse
Maximum Flood During 2014/15
December 2014

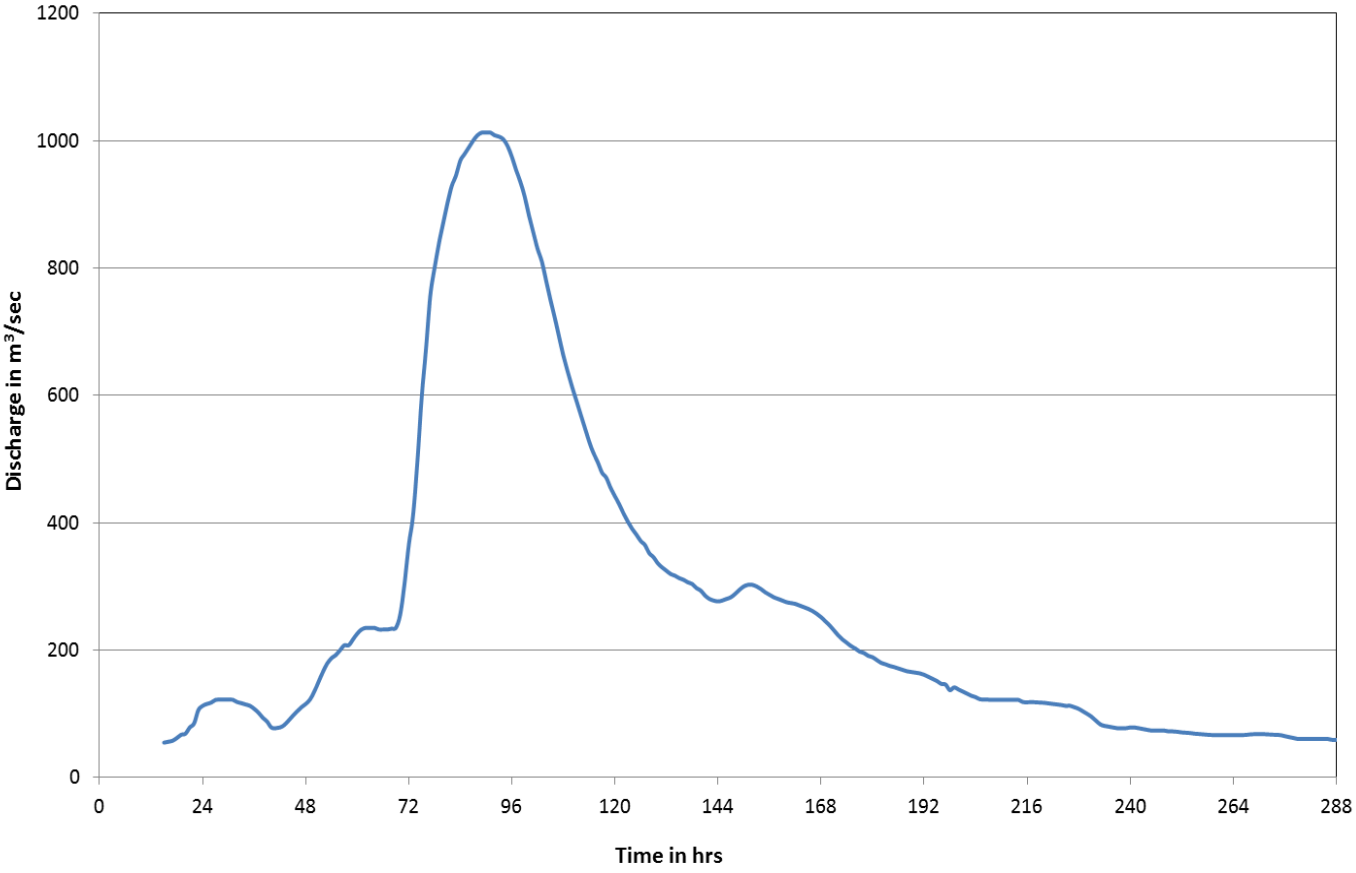




* Initial time - 12:00nn on 23rd December 2014

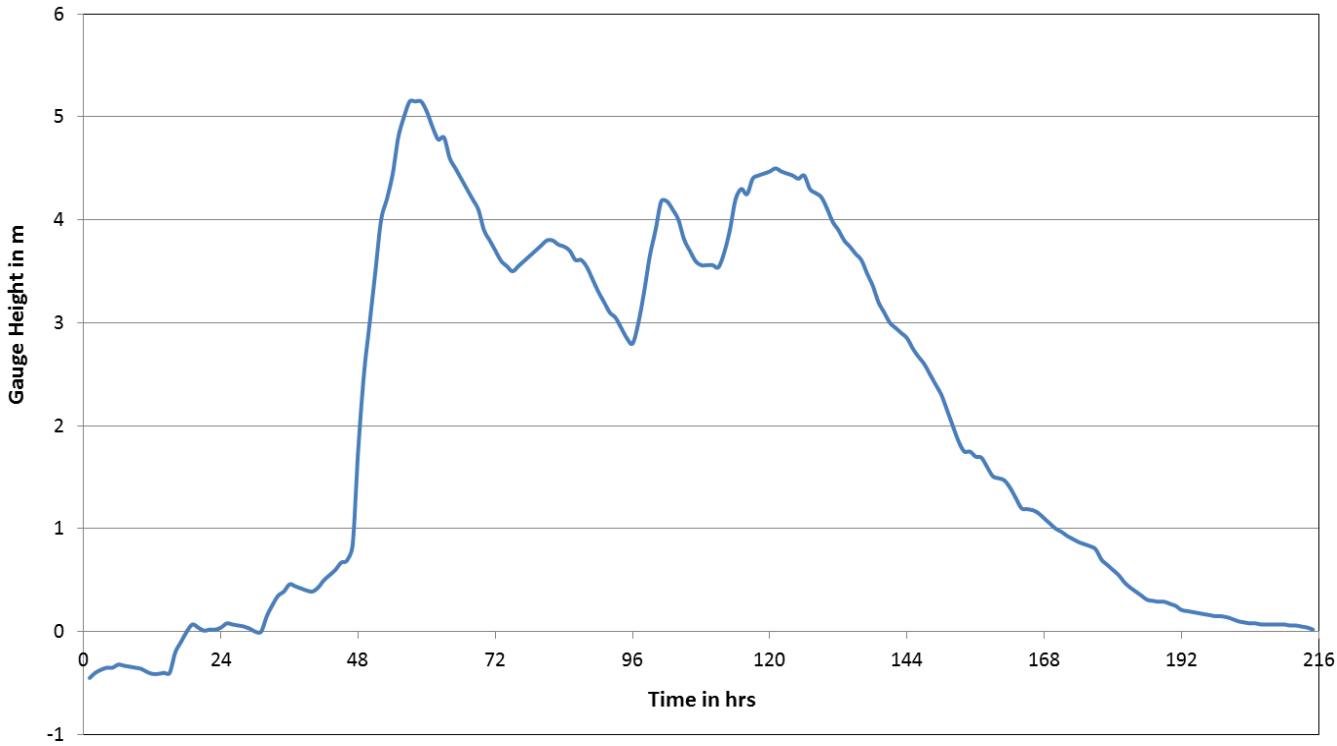
Kelani Ganga at Hanwella
Maximum Flood During 2014/15
December 2014

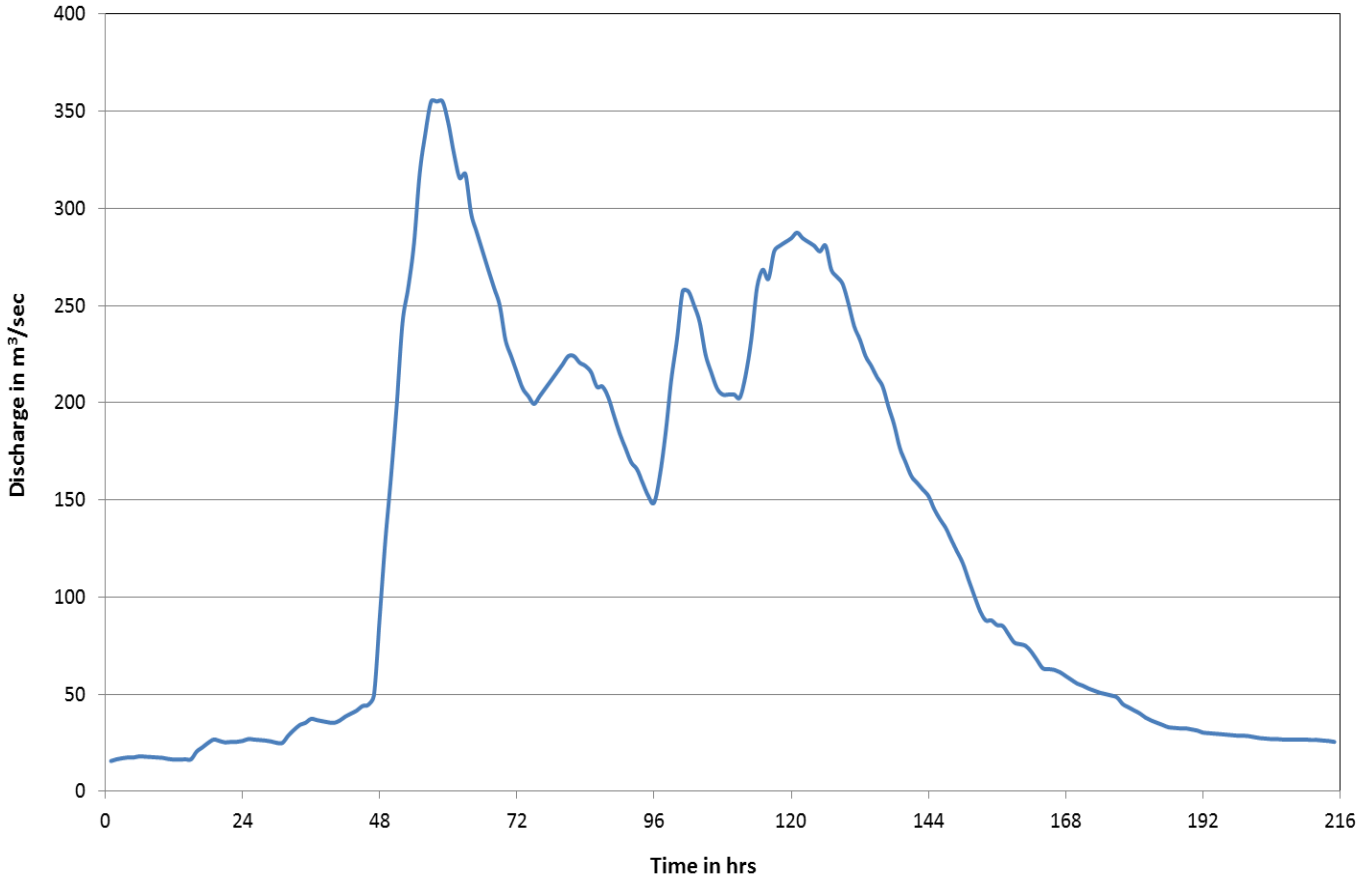




* Initial time - 3:00pm on 23rd December 2014

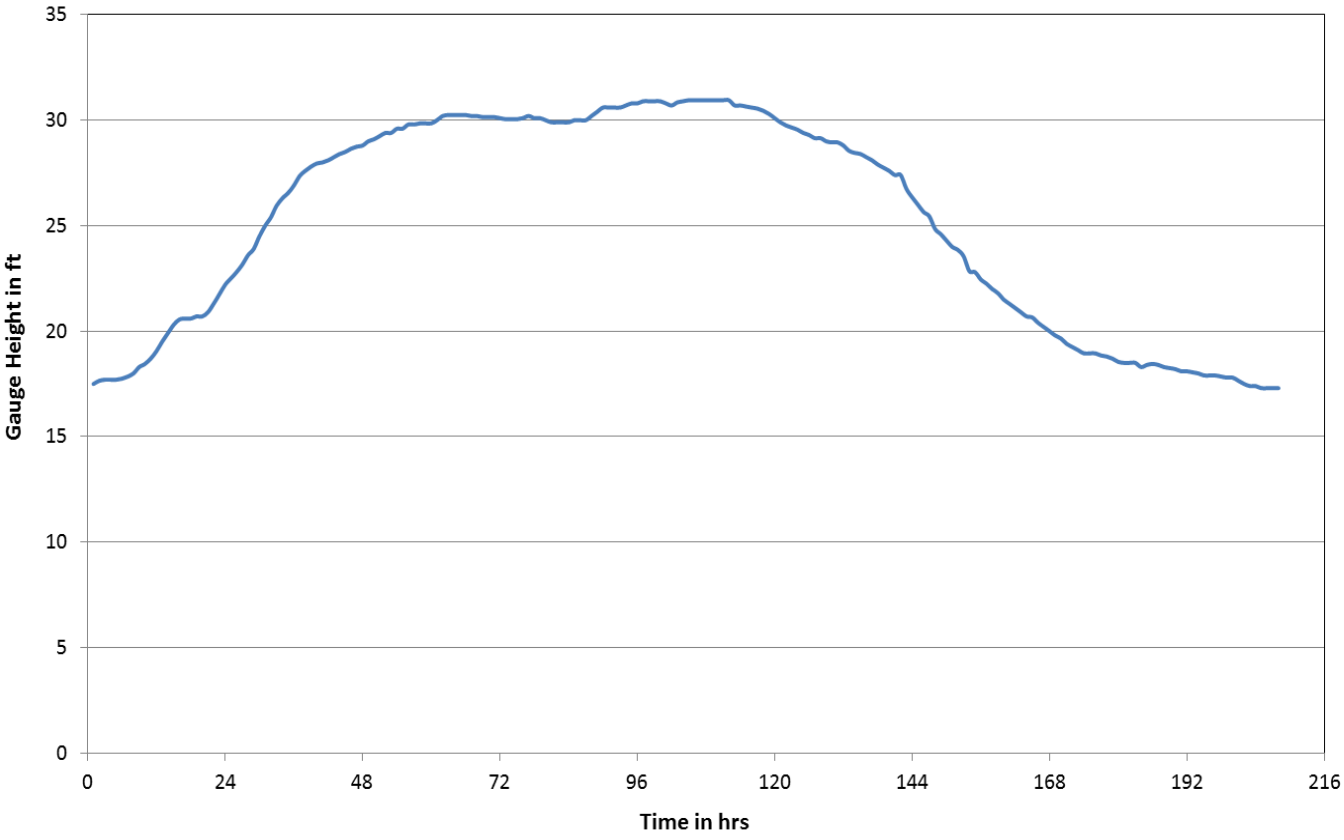
Kalu Ganga at Rathnapura
Maximum Flood During 2014/15
October 2014

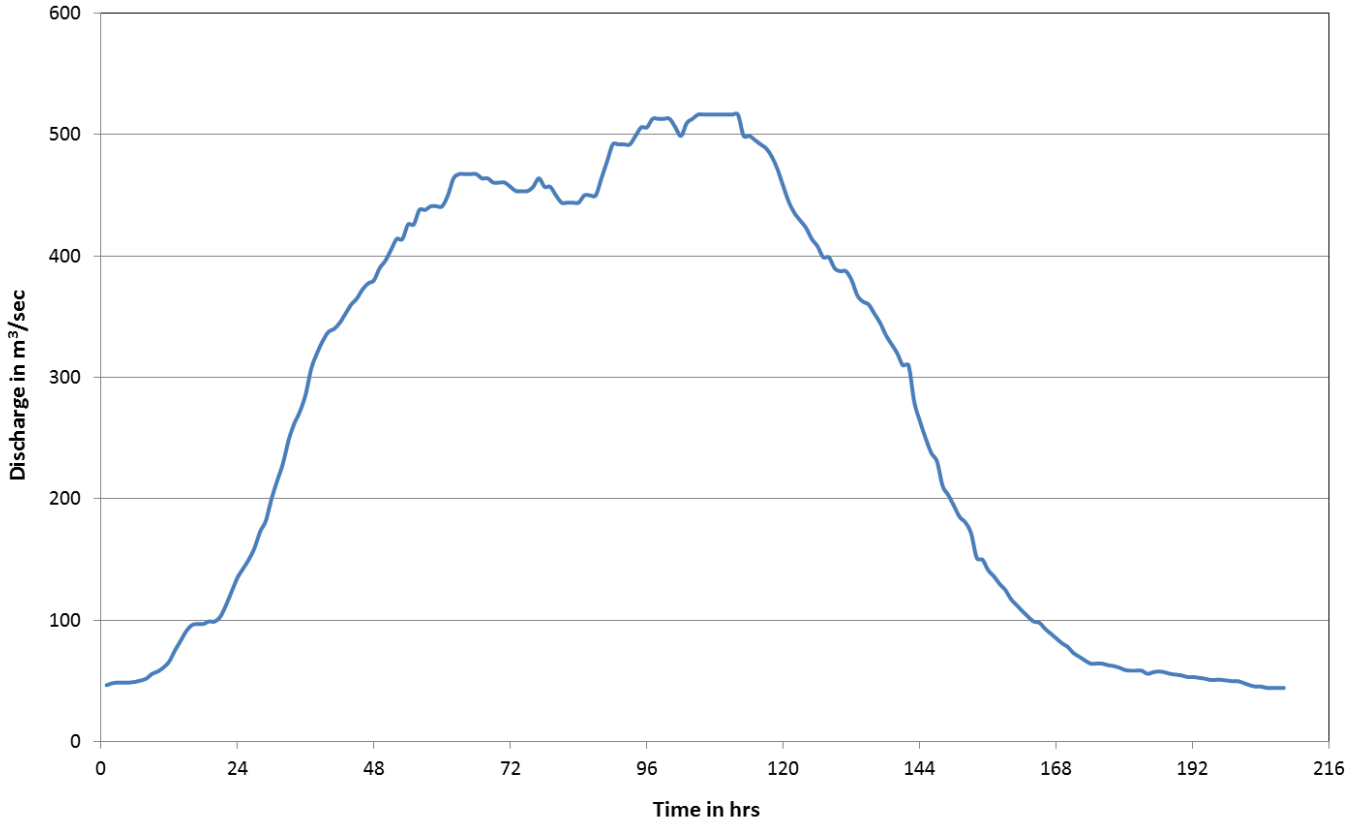




* Initial time - 1:00am on 06th October 2014

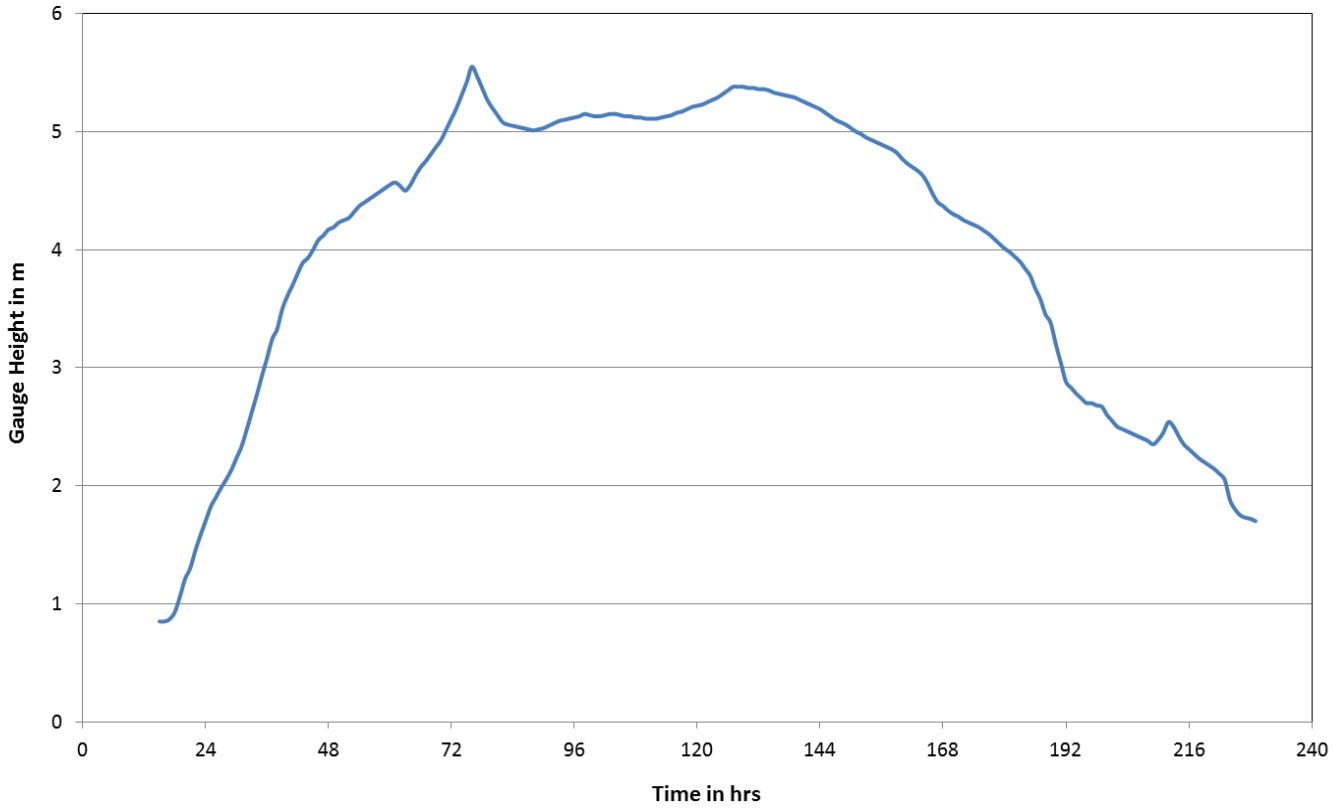
Kalu Ganga at Ellagawa
Maximum Flood During 2014/15
October 2014

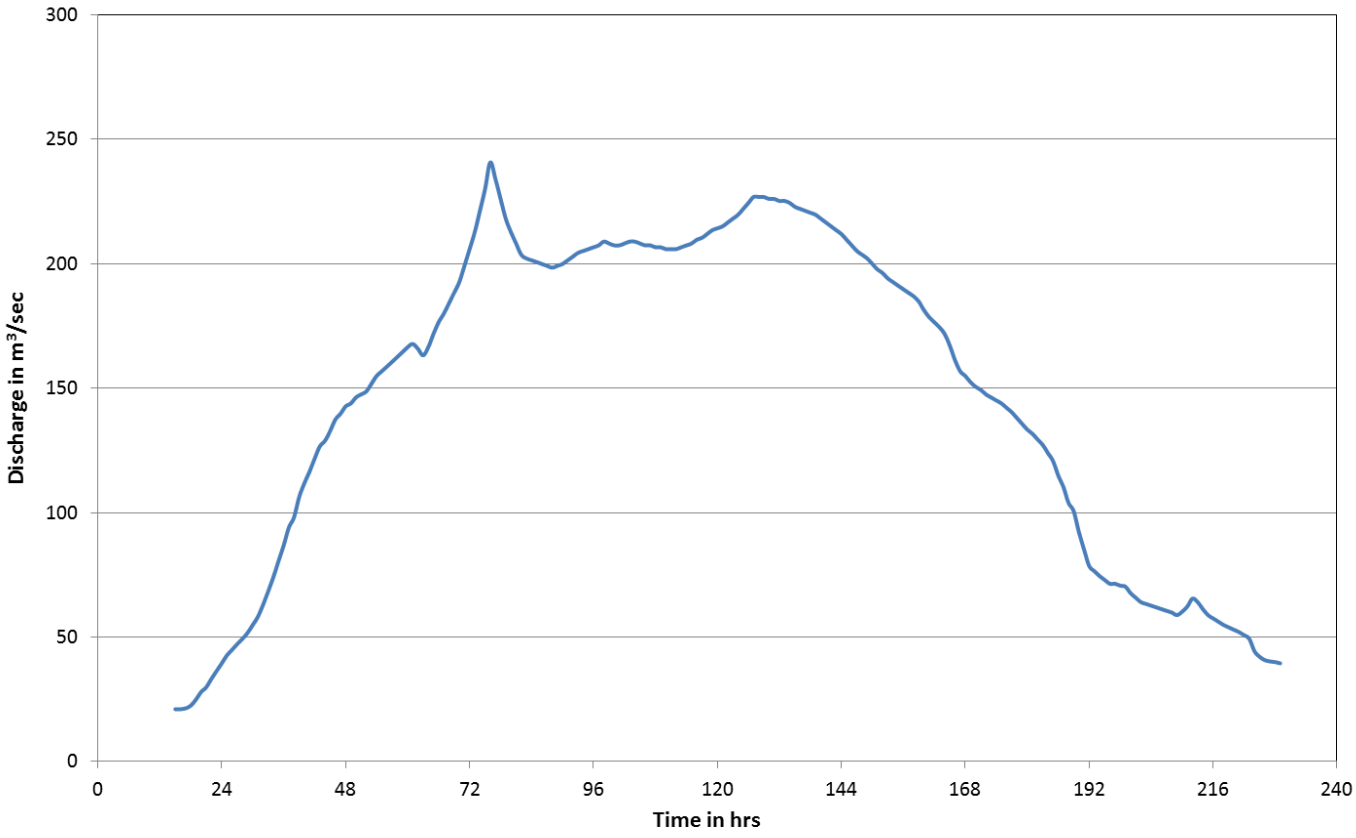




* Initial time - 1:00am on 07th October 2014

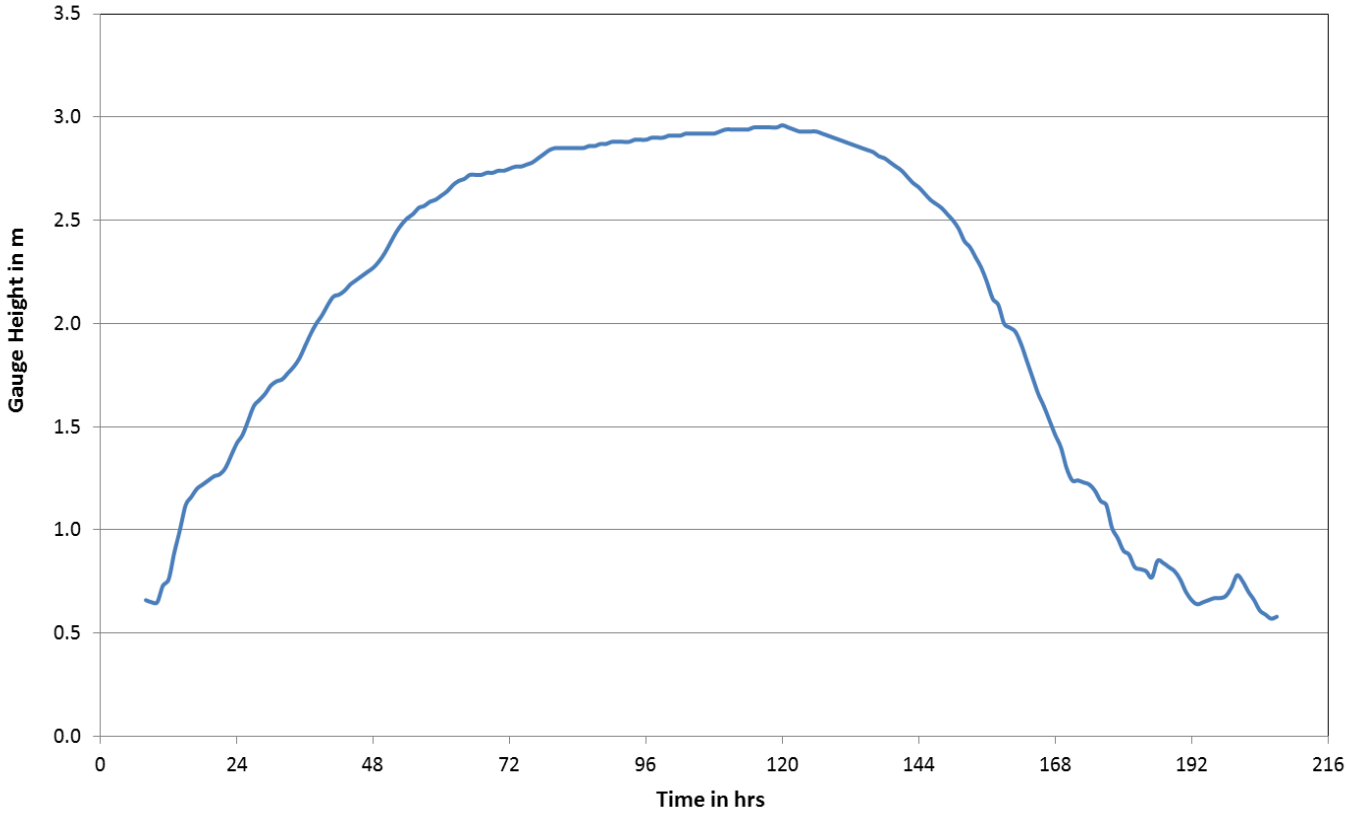
Kalu Ganga at Millakanda
Maximum Flood During 2014/15
October 2014

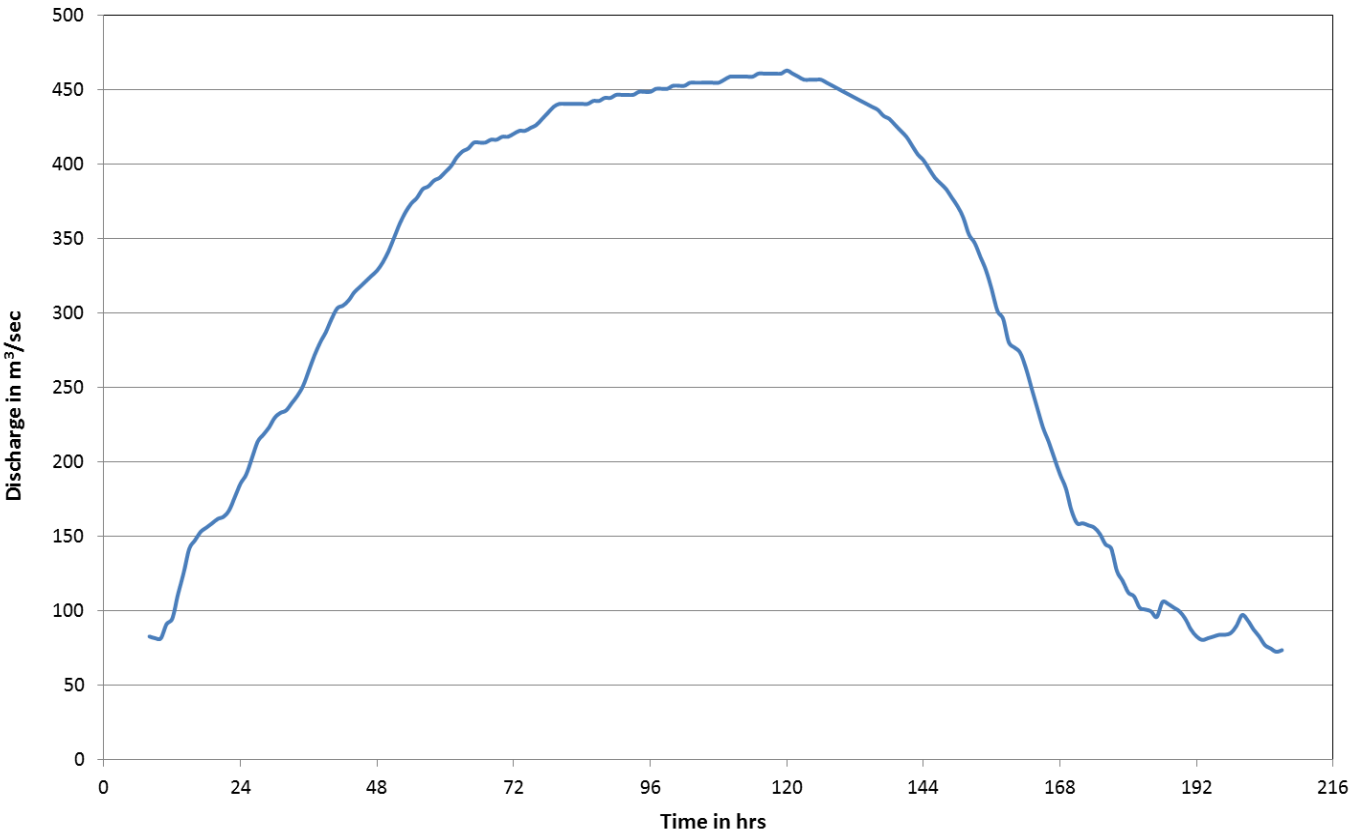




* Initial time - 5:00pm on 06th October 2014

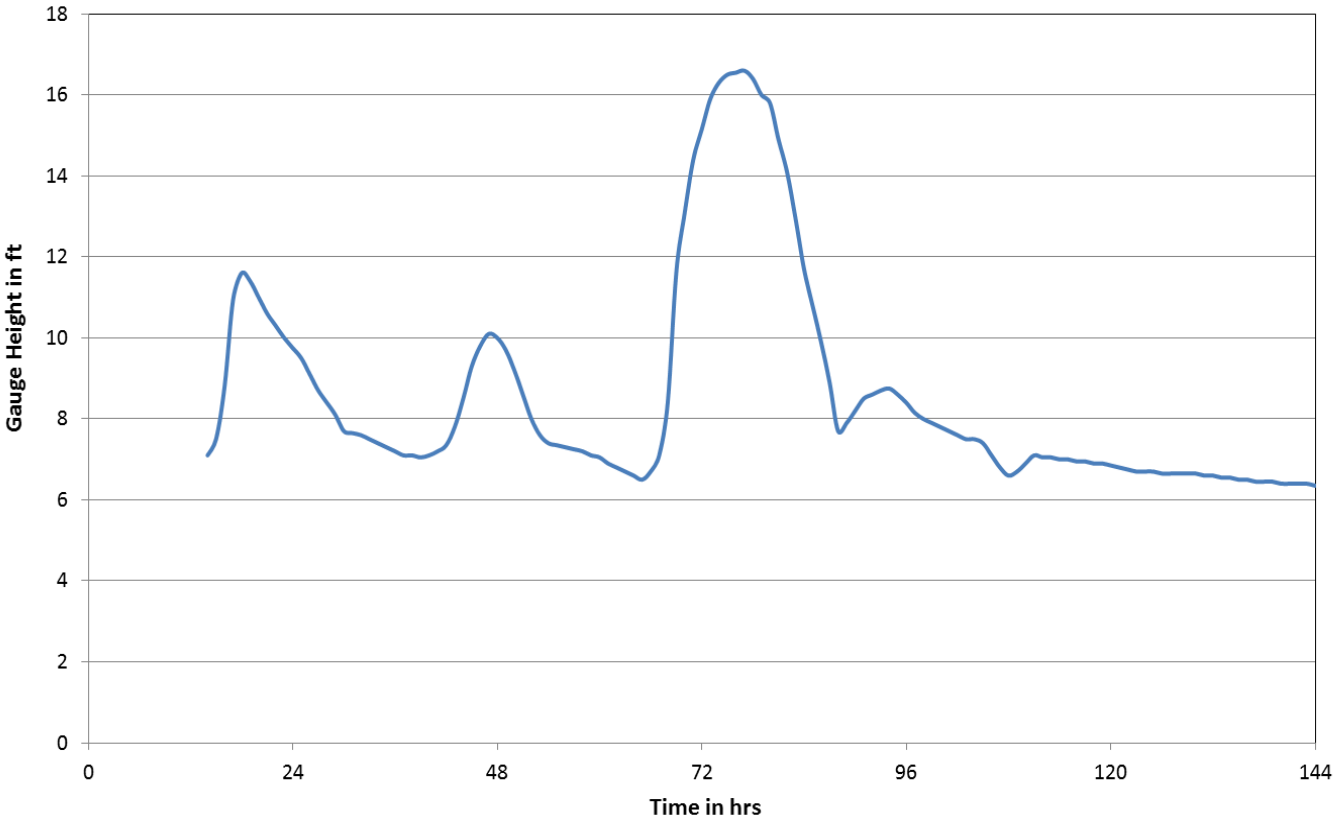
Kalu Ganga at Putupaula
Maximum Flood During 2014/15
October 2014

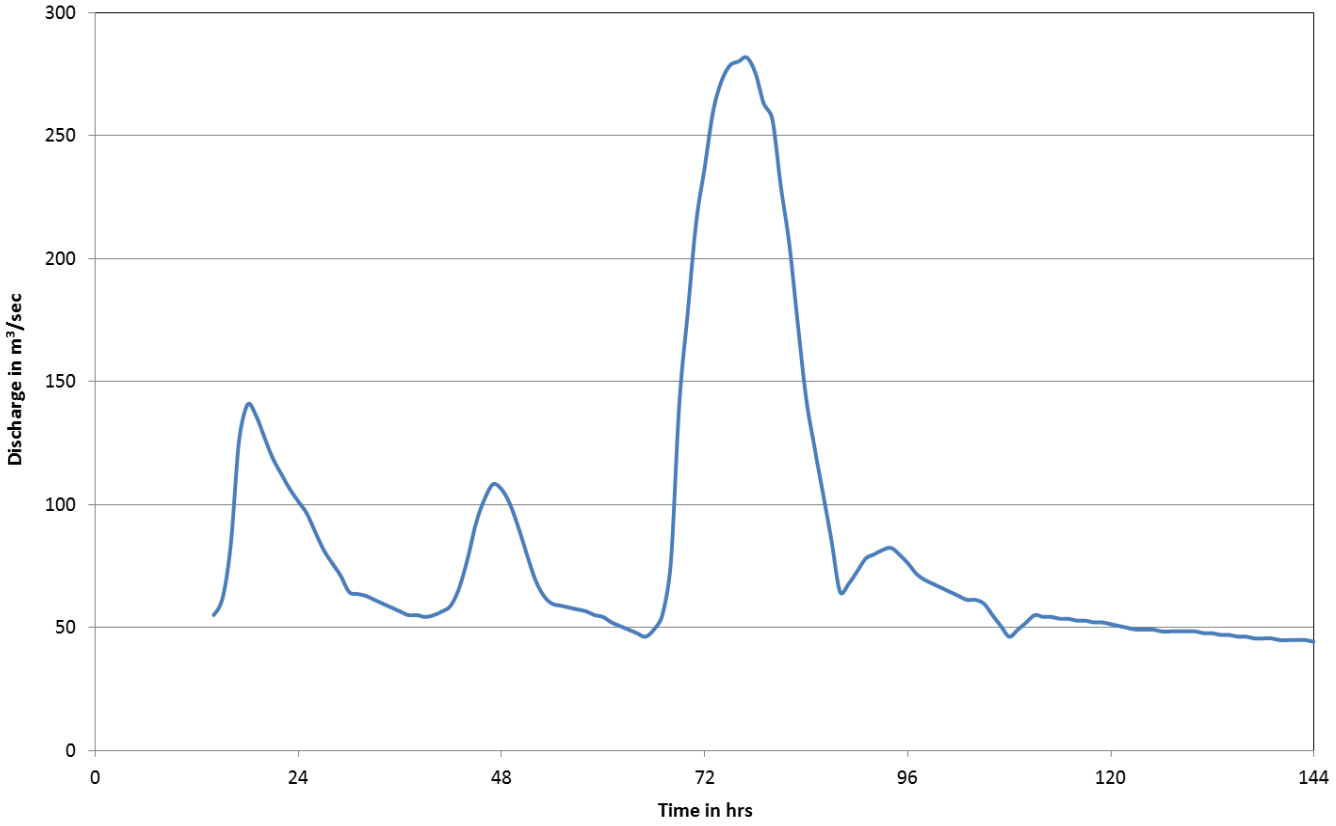




* Initial time - 8:00am on 07th October 2014

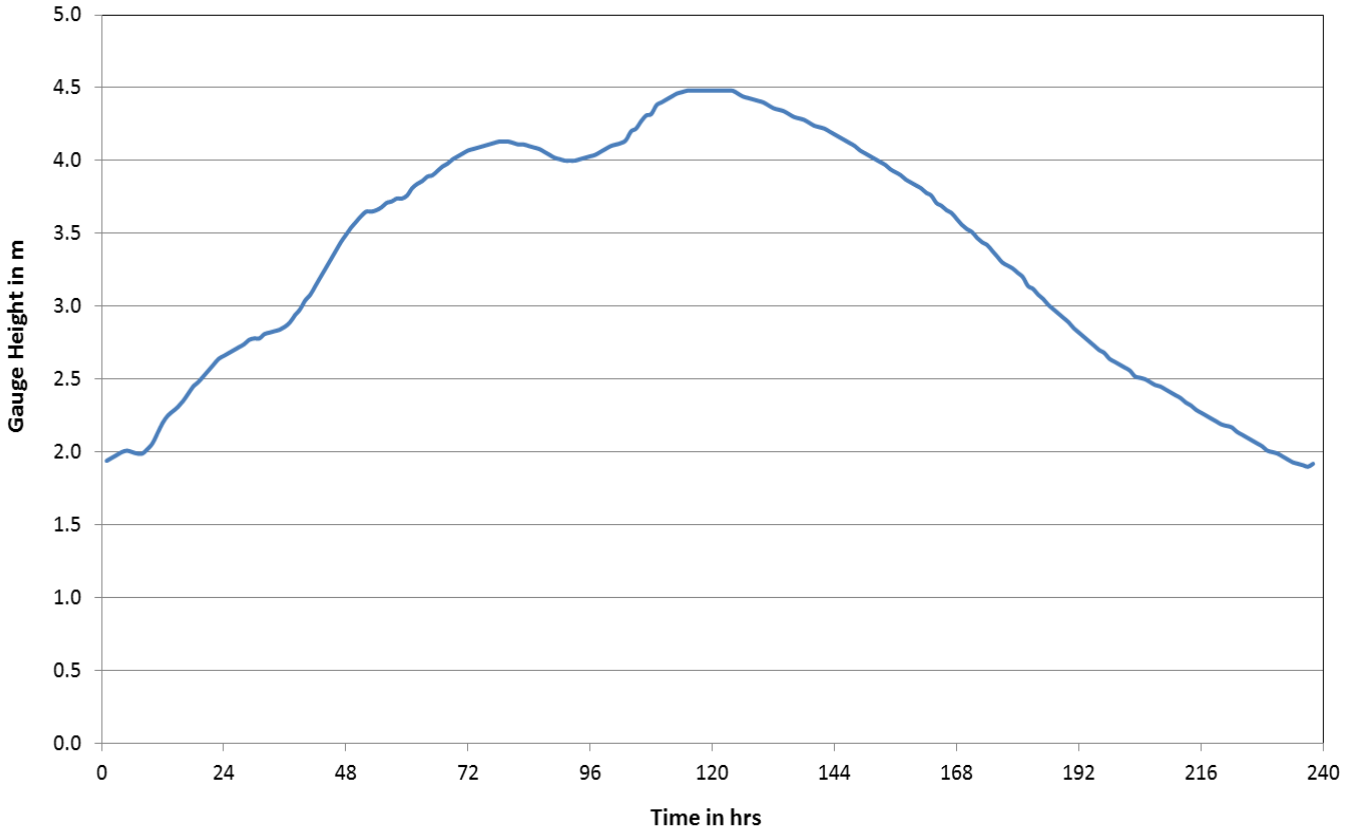
Gin Ganga at Thawalama
Maximum Flood During 2014/15
October 2014

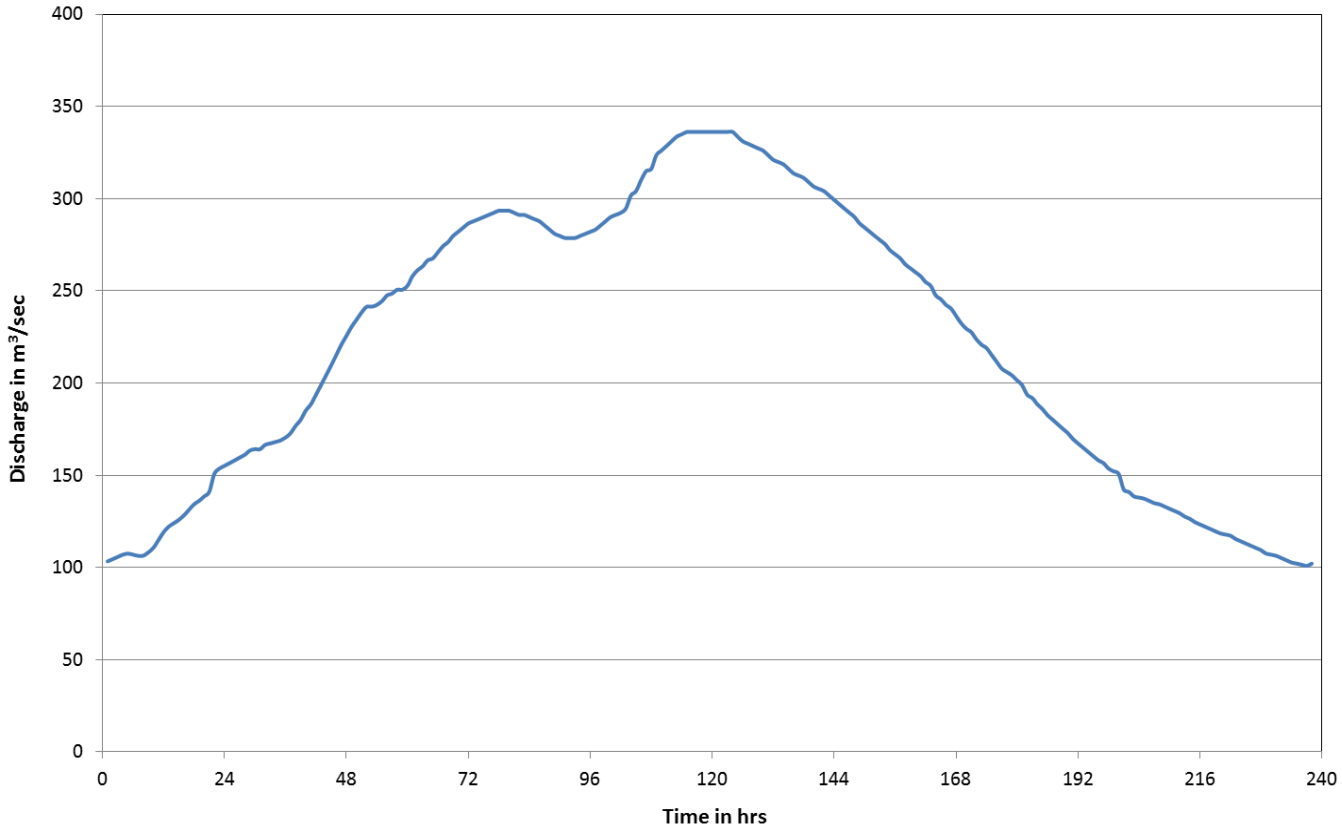




* Initial time - 2:00pm on 27th October 2014

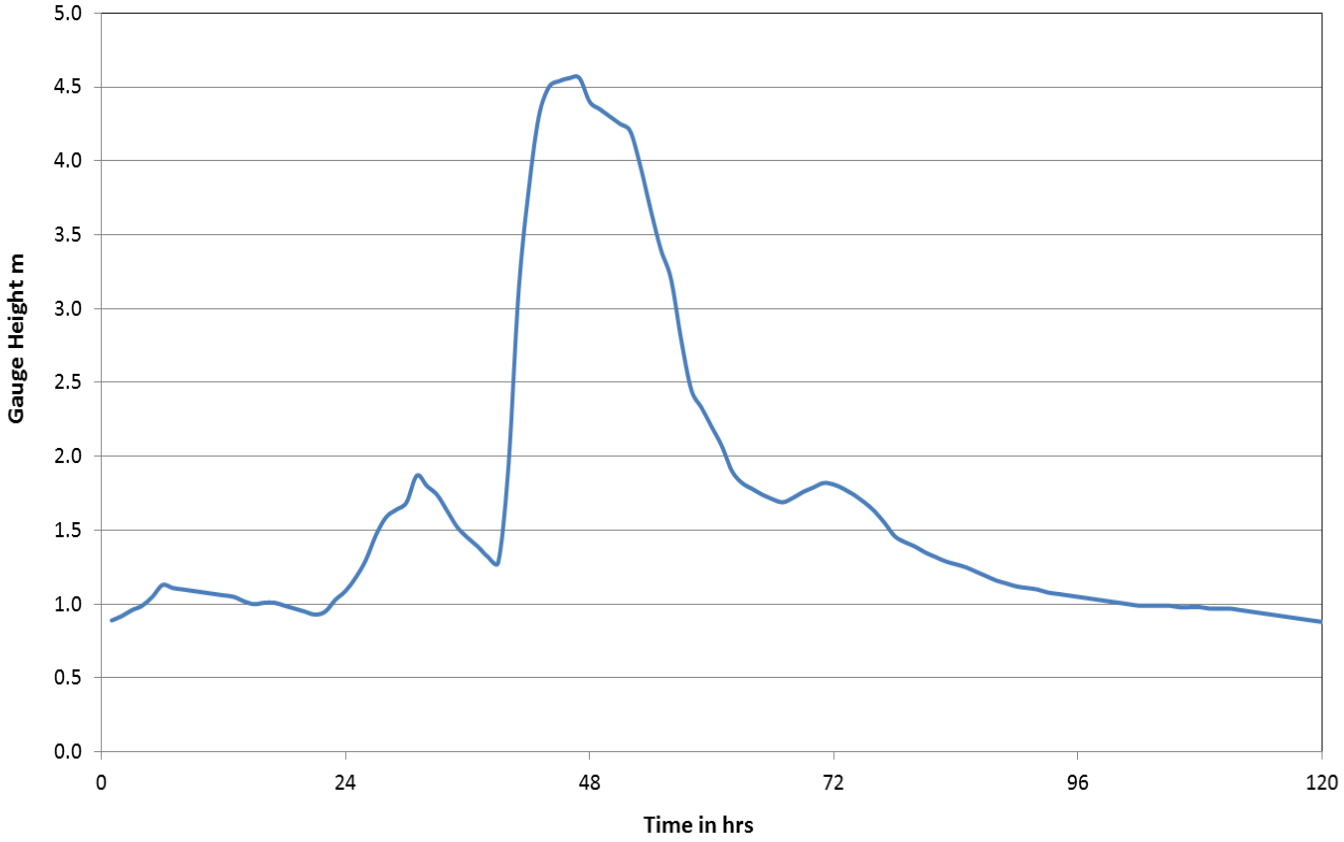
Gin Ganga at Baddegama
Maximum Flood During 2014/15
September 2015

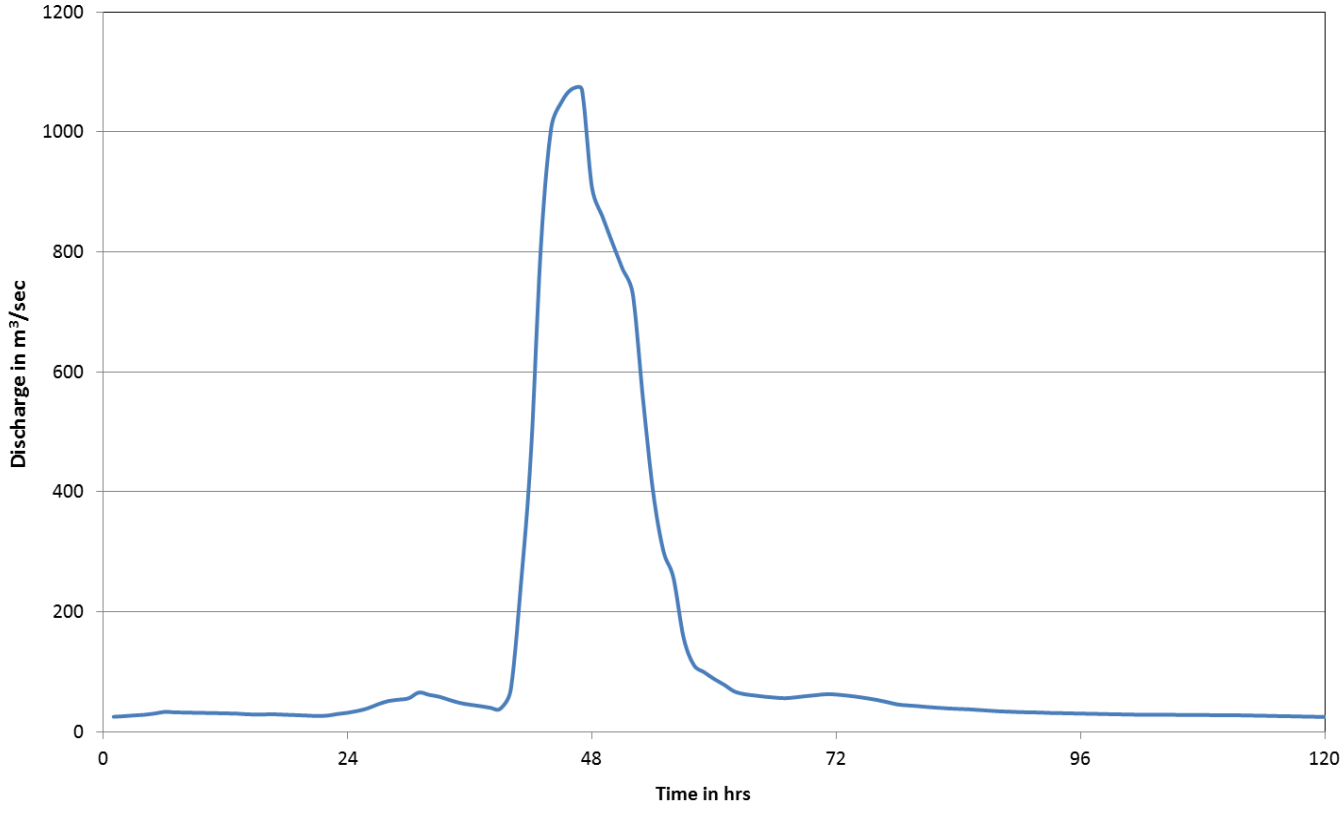




* Initial time - 1:00am on 25th September 2015

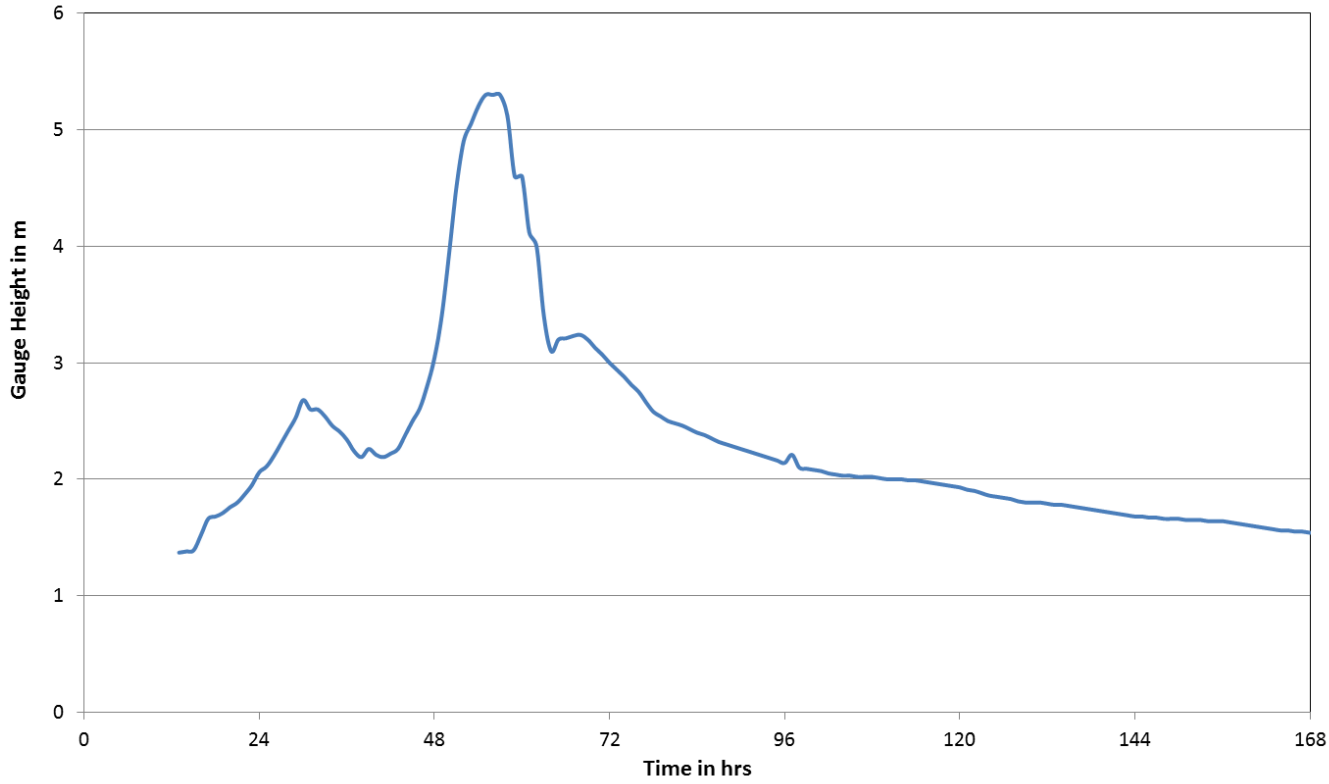
Nilwala Ganga at Pitabeddara
Maximum Flood During 2014/15
April 2015

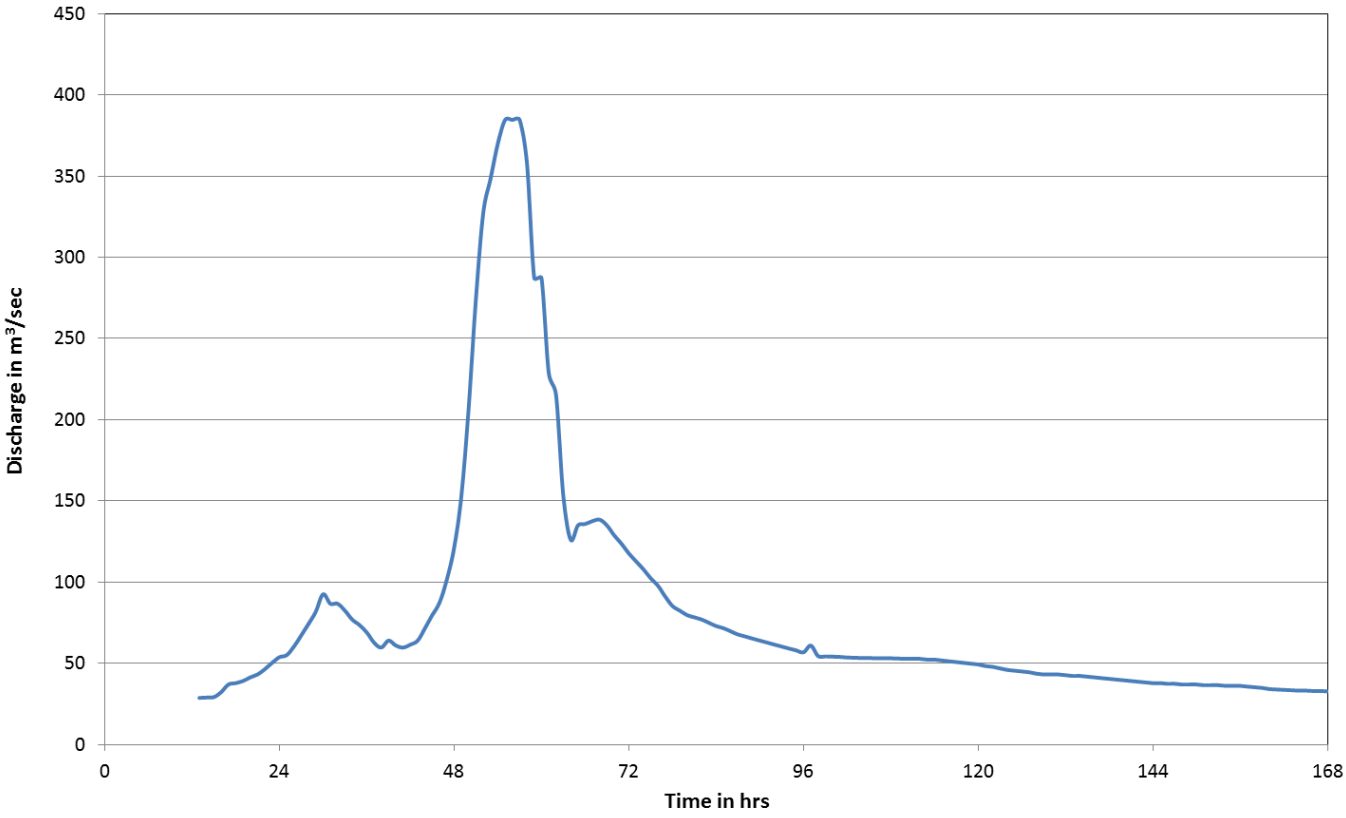




* Initial time - 1:00am on 19th April 2015

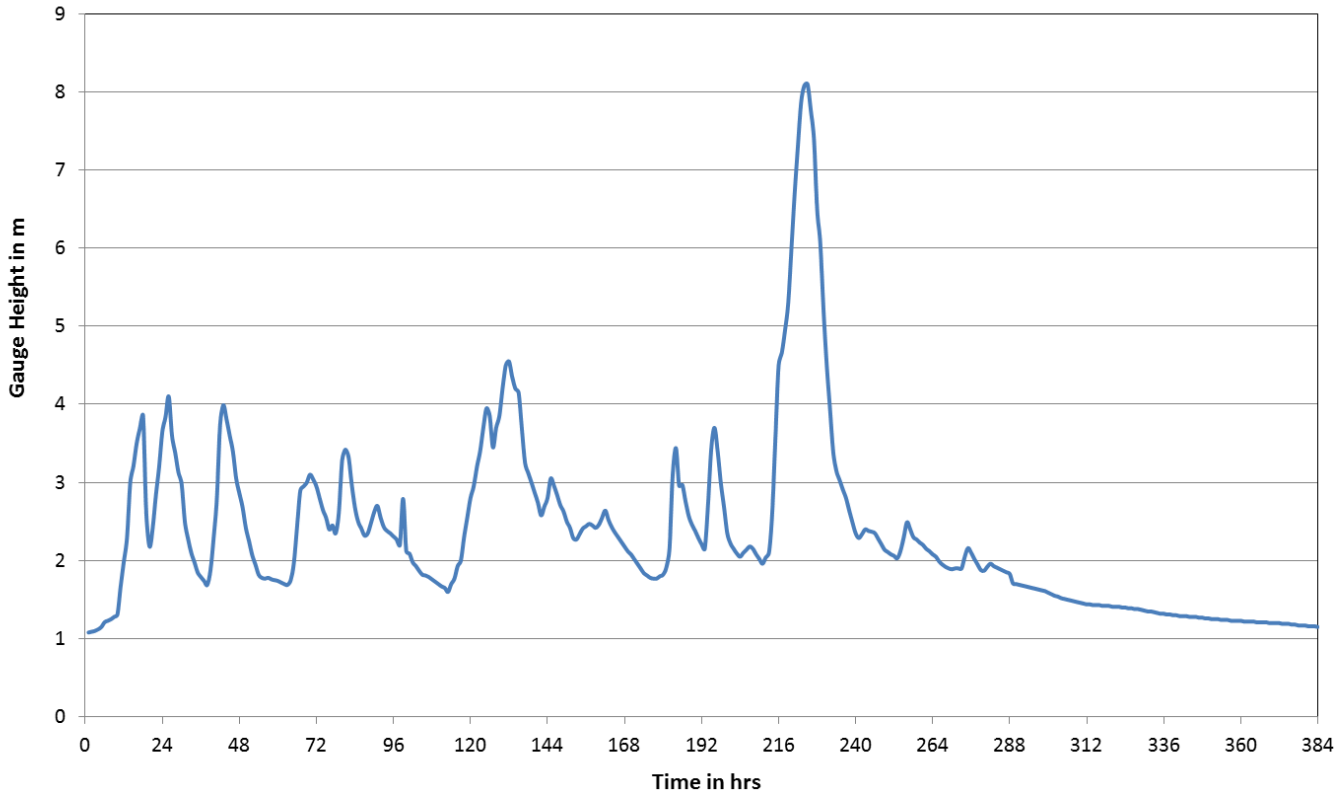
Kirindi Oya at Thanamalwila
Maximum Flood During 2014/15
December 2014

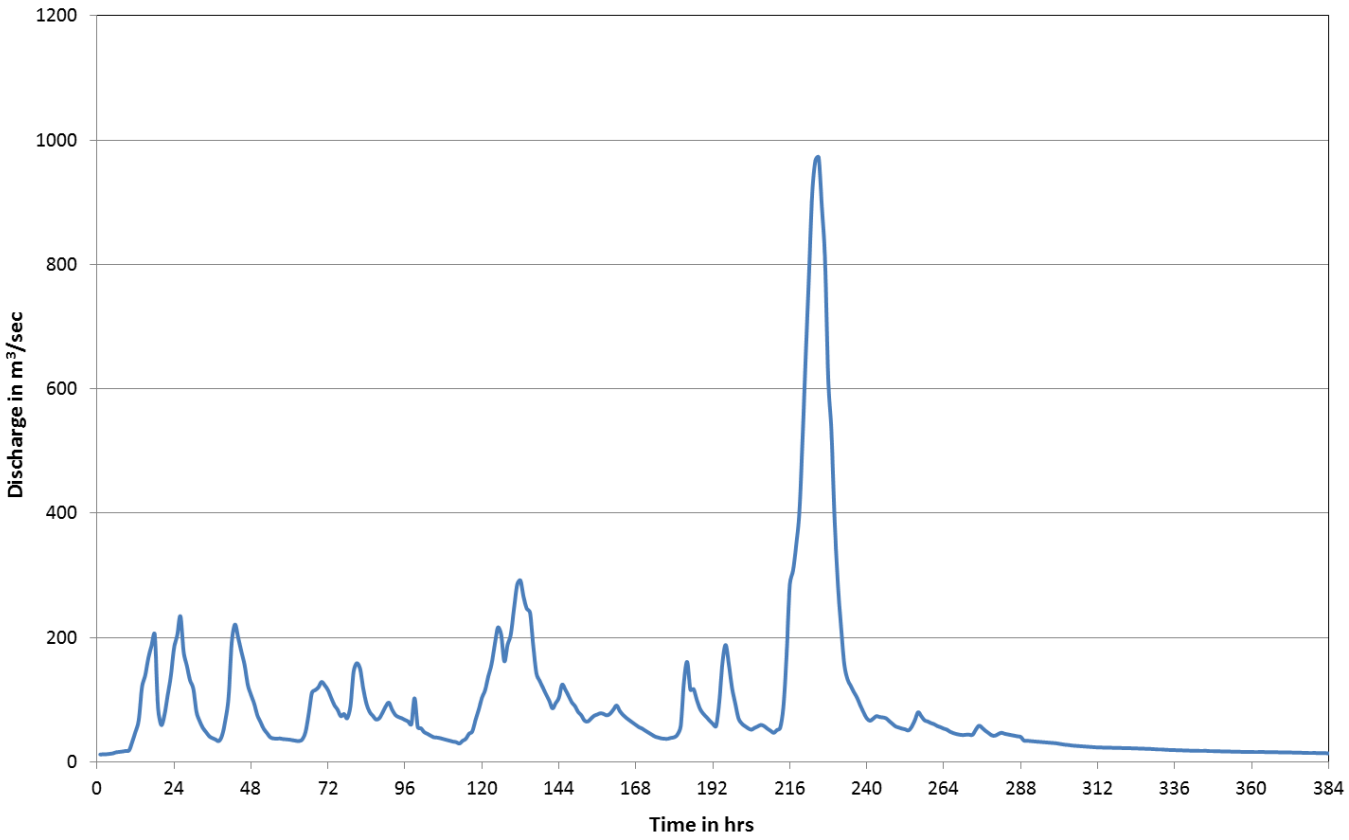




* Initial time - 1:00pm on 24th December 2014

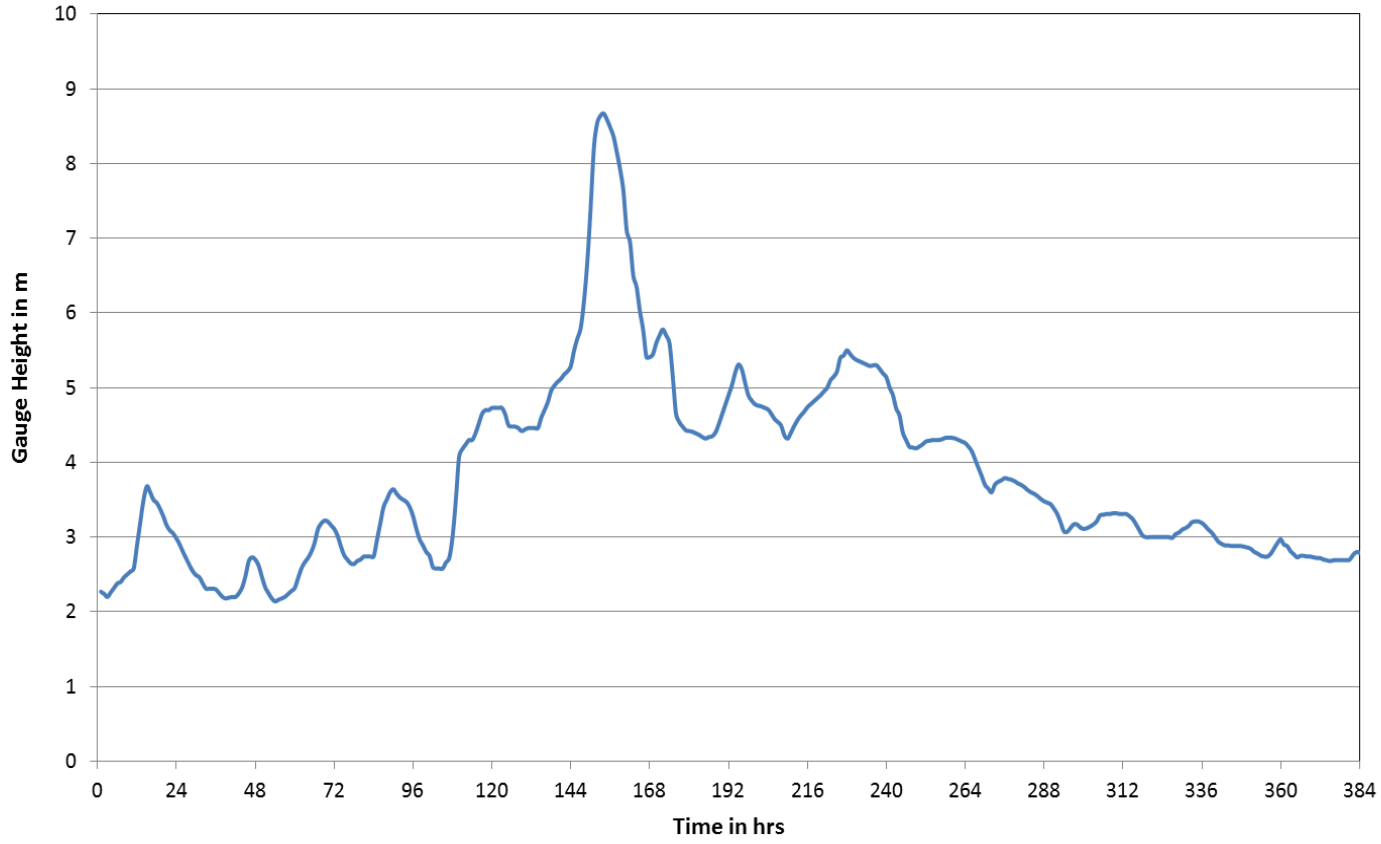
Mahaweli Ganga at Padiyathalawa
Maximum Flood During 2014/15
December 2014

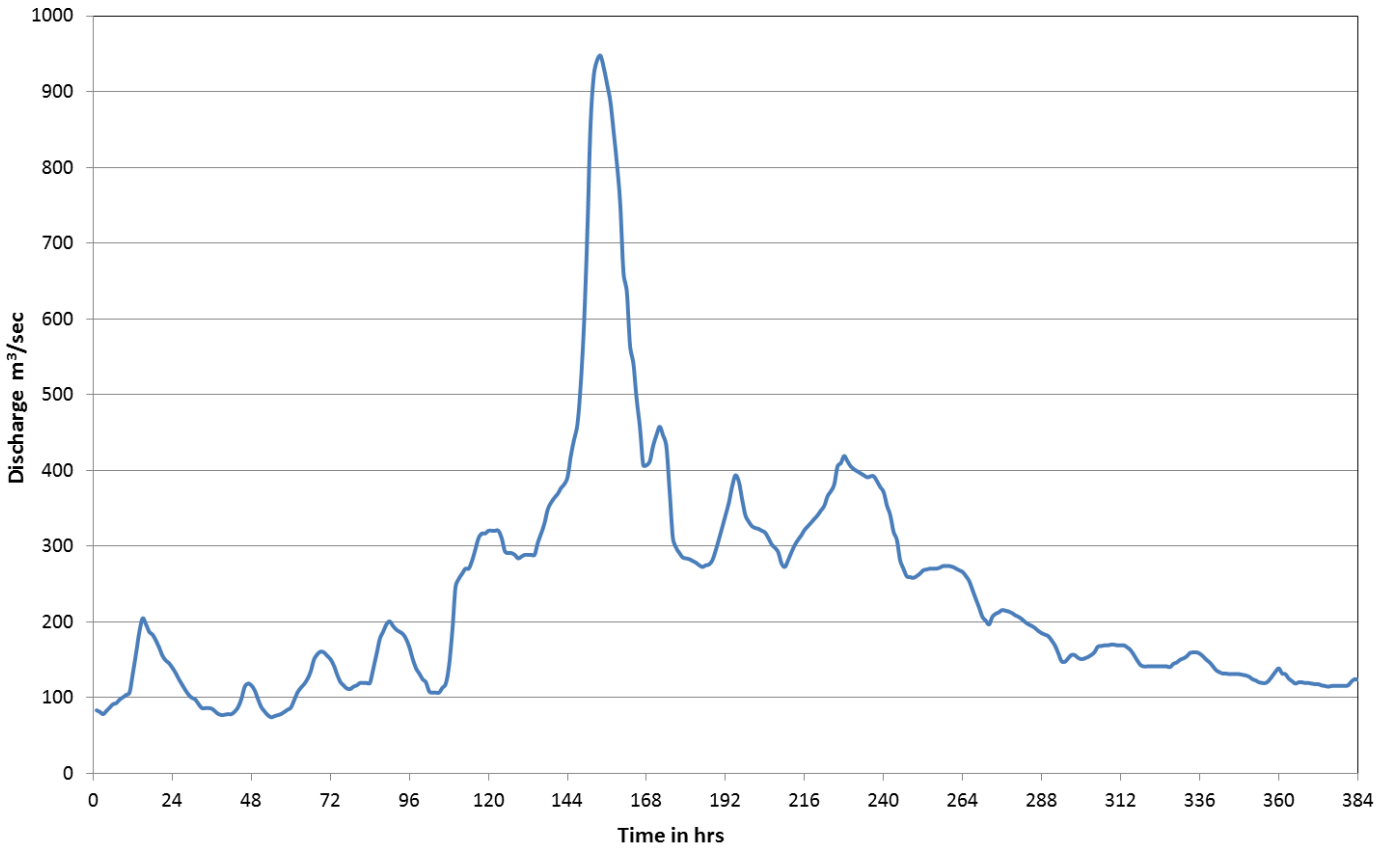




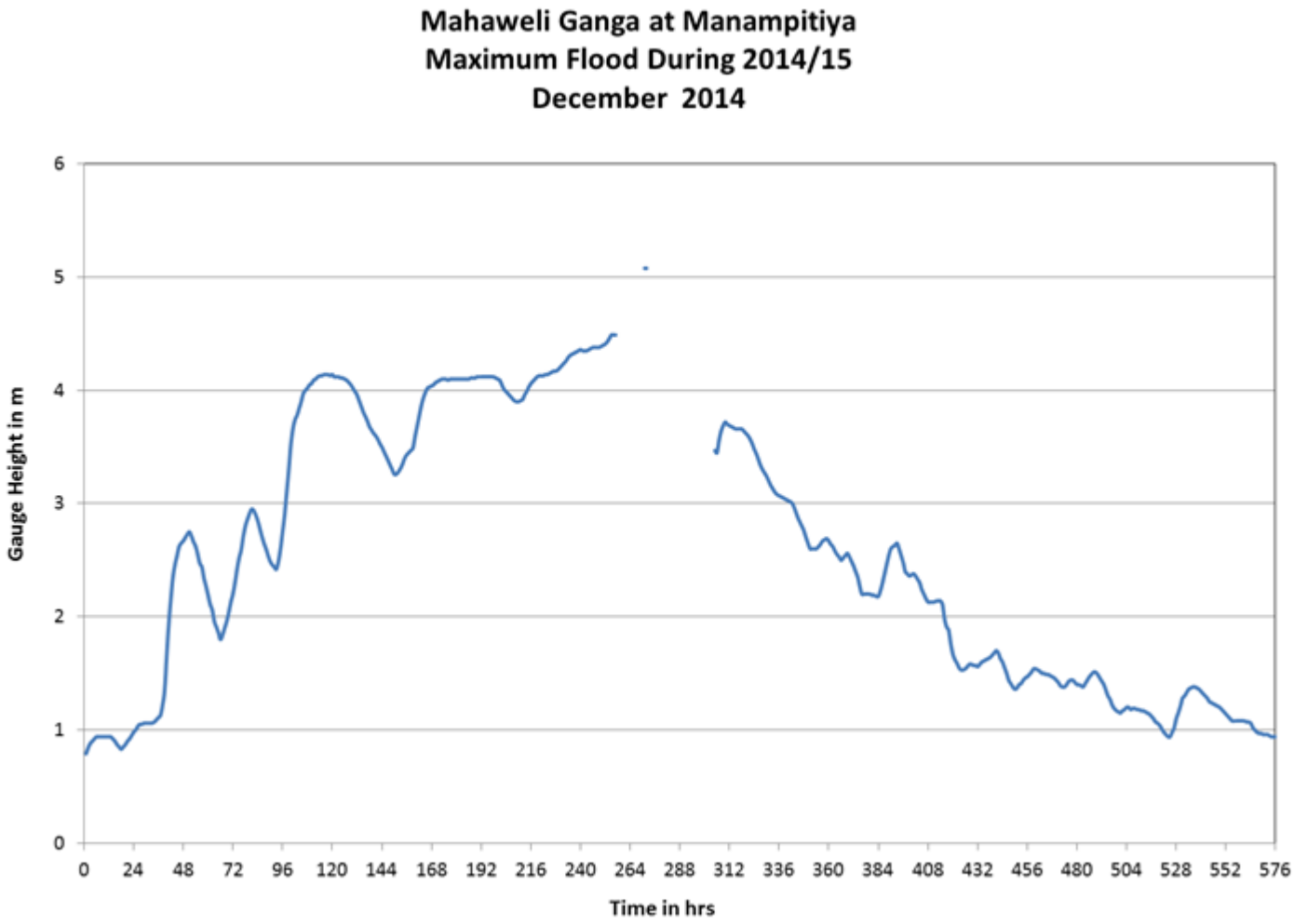
* Initial time - 1:00am on 17th December 2014

Mahaweli Ganga at Peradeniya
Maximum Flood During 2014/15
December 2014





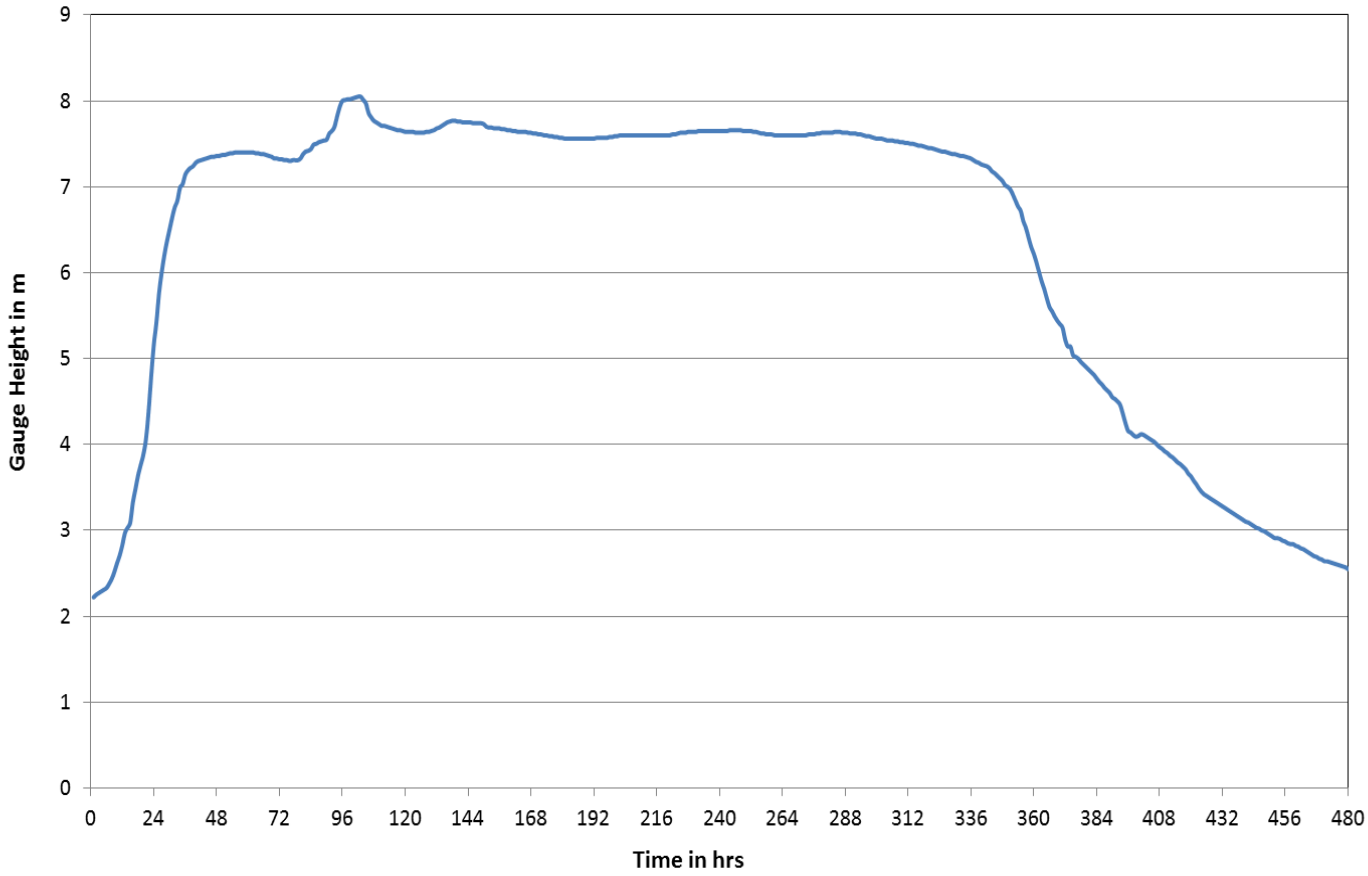
* Initial time - 1:00am on 20th December 2014

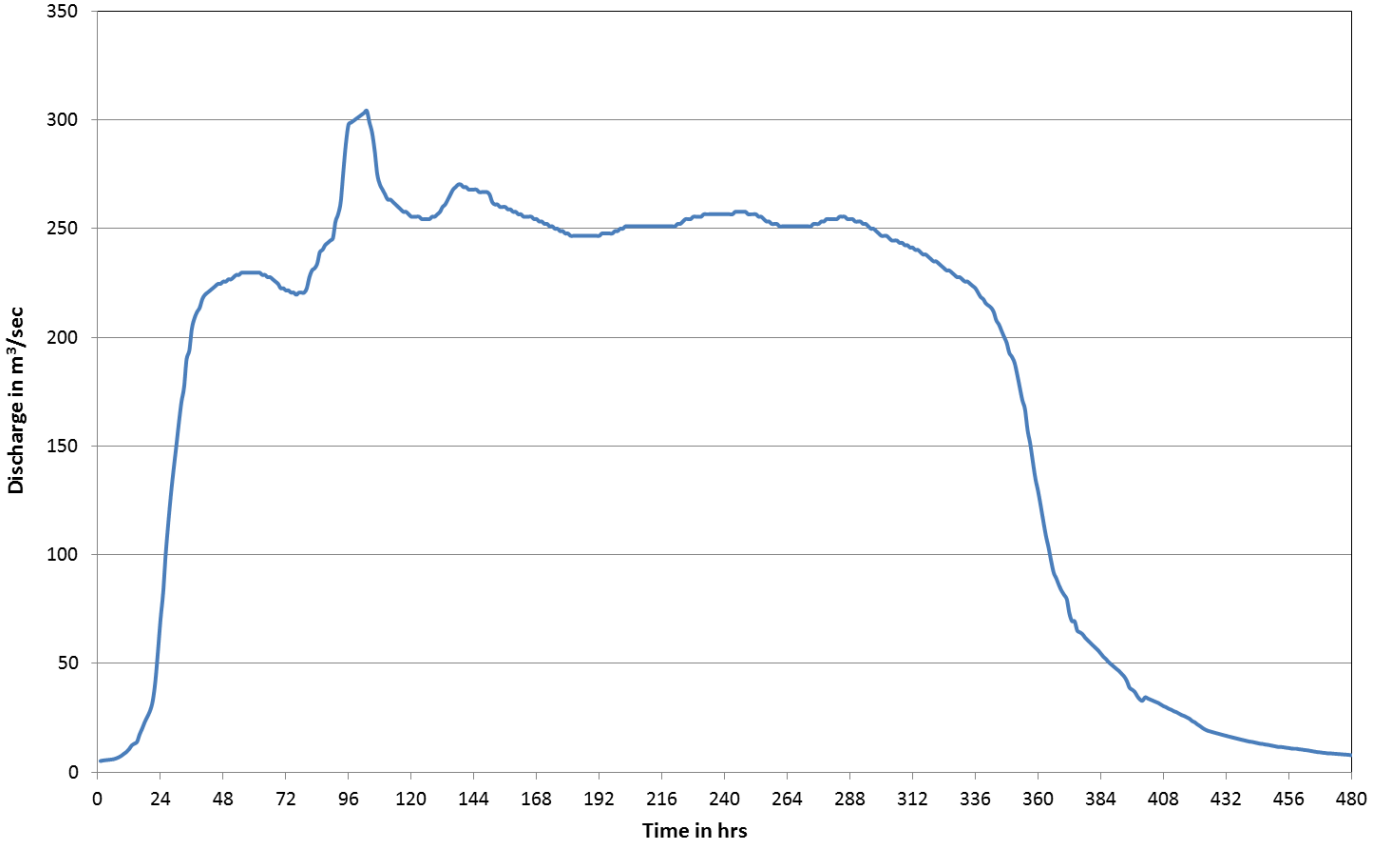


* Initial time - 1:00am on 16th December 2014

*** Station went under water, Gauge reader was evacuated.

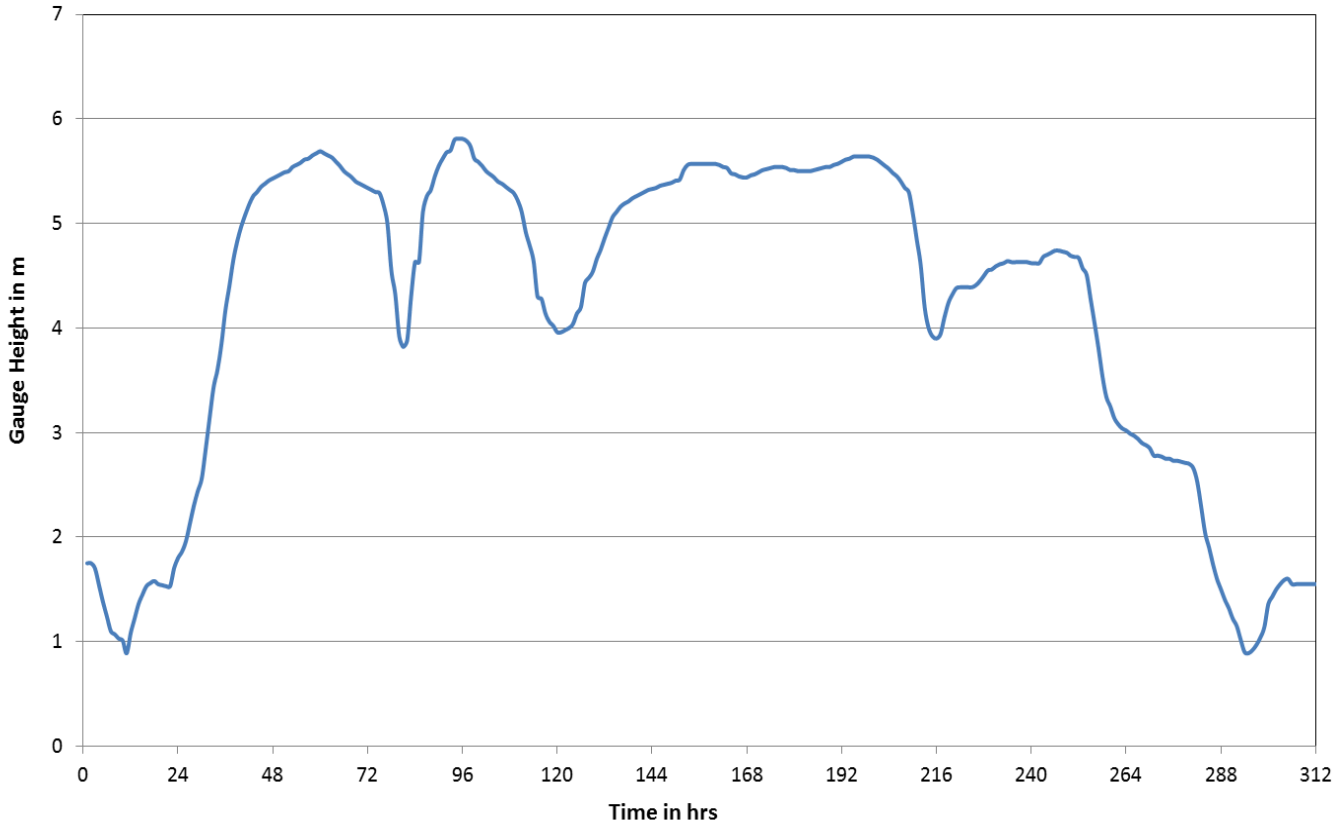
Yan Oya at Horowpothana
Maximum Flood During 2014/15
December 2014

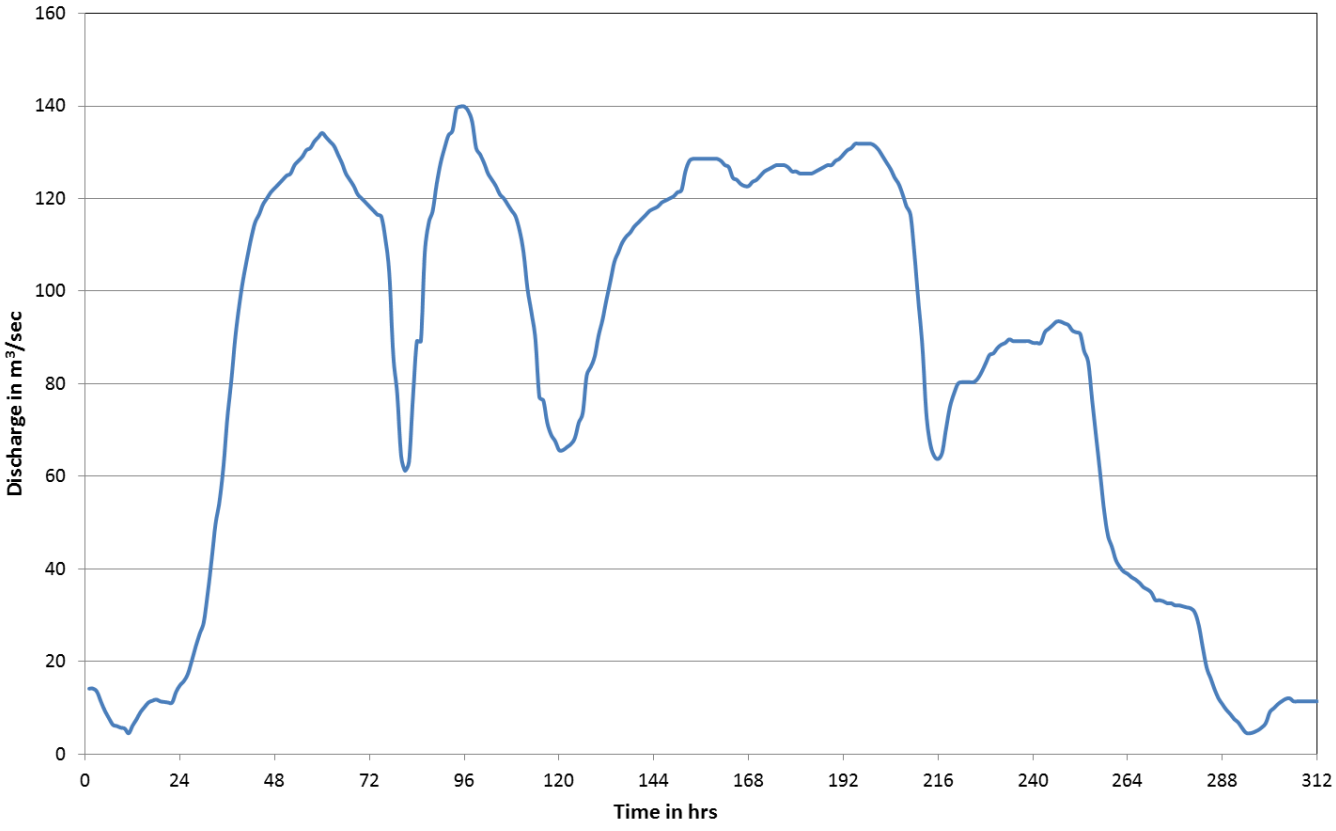




* Initial time - 1:00am on 17th December 2014

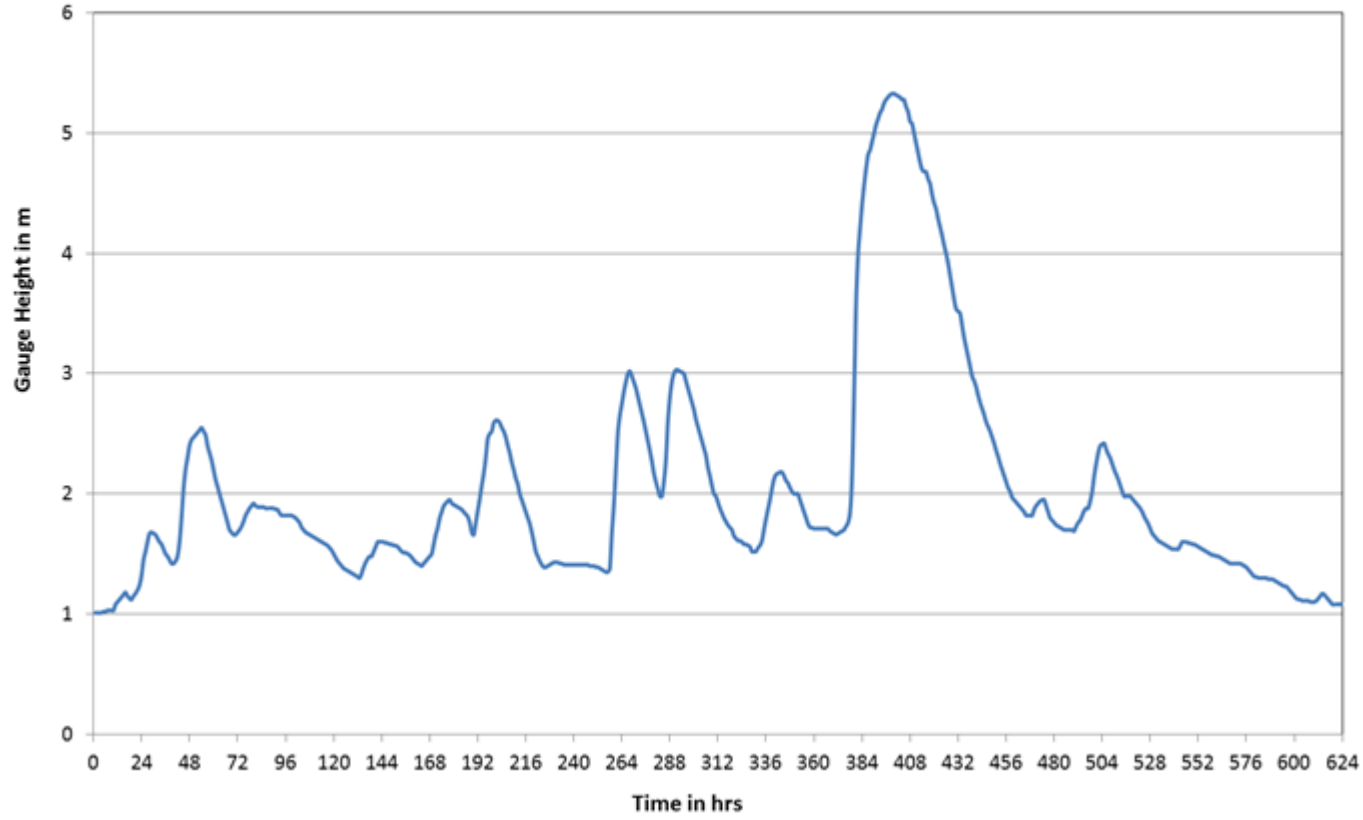
Mee Oya at Galgamuwa
Maximum Flood During 2014/15
December 2014

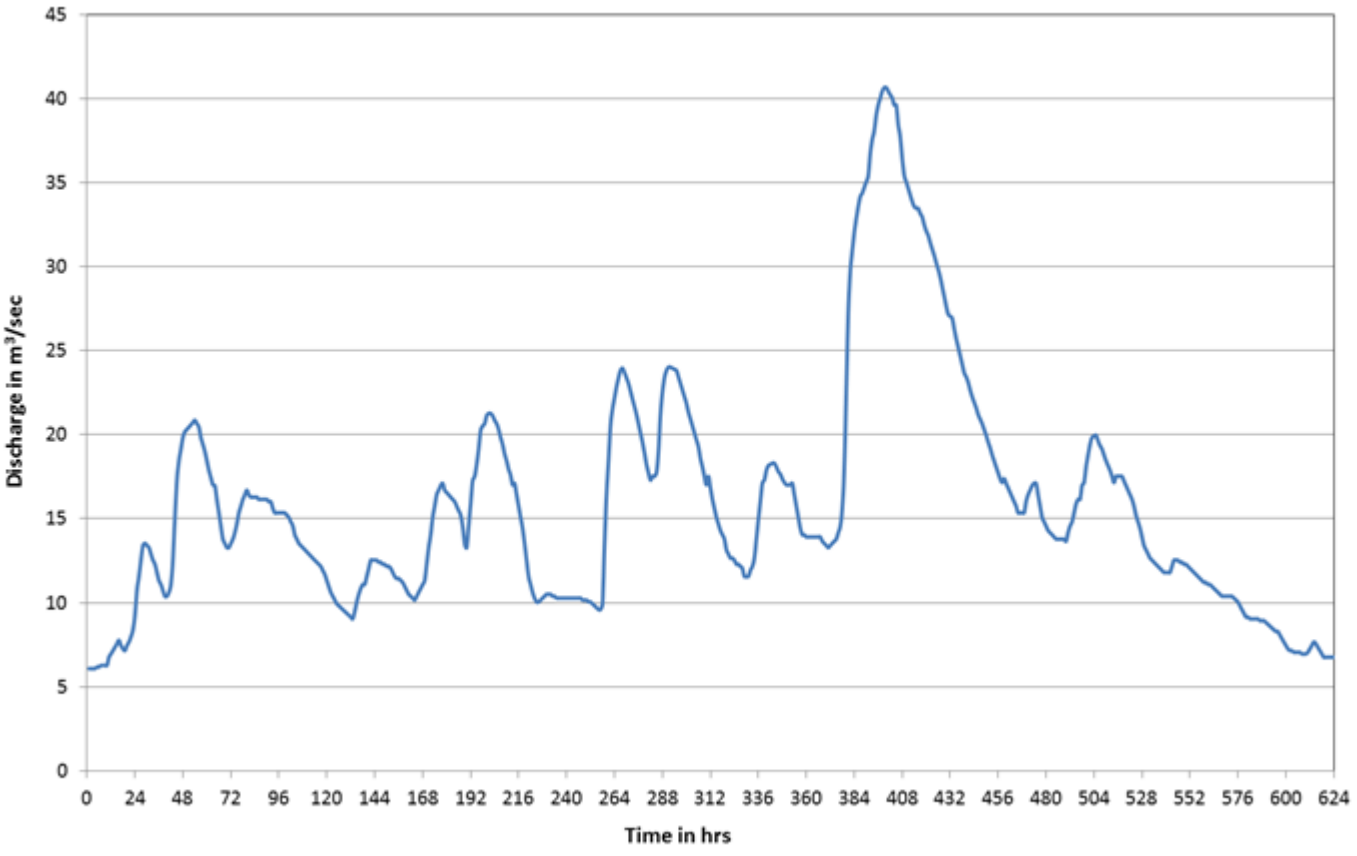




* Initial time - 1:00am on 19th December 2014

Aththanagalu Oya at Dunamale
Maximum Flood During 2014/15
October 2014





* Initial time - 1:00am on 15th October 2014

PART III

- **Hydrological Report on the Kelani River flood in May 2016**

- **Flood Forecasting Model for the Kelani River with HEC HMS software**

Hydrological Report on Kelani River flood in May 2016

Hydrological Report on Kelani River flood in May 2016

Ms. P. Hettiarachchi,
B.Sc (Eng) [Moratuwa], M.Sc (Delft), C.Eng, MIE (SL),
Director of Irrigation (Hydrology),
Hydrology Division,
Irrigation Department, Colombo, Sri Lanka.

Abstract

The recent flood (2016 May) is the most severe hydrological hazard faced by the people of Kelani River basin after the major flood in 1989. The rainfalls caused to two floods were similar in magnitude (8 day total was around 560 mm) but different in spatial and temporal distribution pattern. In 1989, the rainfall stations of Norton, Maussakele and Laxsapana experienced the total rainfalls of 1222.9 mm, 1694.2 mm and 1184.8 mm respectively while the highest rainfall in this time was 898.8 mm at Deraniyagala.

This characteristic was also appeared in the water levels and discharges. 1989 flood hydrographs were characterized with high peaks and short durations while the recent ones show distributed pattern. Some structures, being constructed across the river including their temporary works are supposed to cause retardation of flood wave causing increase of flood levels and durations of inundation. It is advisable to revisit those designs and make amendments required to safeguard the people and properties of low lying areas adjacent to the river.

Flood frequency analysis reveals 1989 flood was equal to 50 year return period at Nagalagam Street and the recent one is only around 15 years. However the damages of 2016 flood were more due to longer durations of inundation and irregular developments taken place in the flood plain. The Kelani Minor Flood Protection Schemes were affected in both floods emphasizing the urgent requirement of modernizing them to suit with the present conditions.

1. River Basin Information

The Kelani is one of major river systems in Sri Lanka. It takes the seventh place in respect of its extent of watershed (2340 km^2). However, it becomes third with respect to water resources aspect (4225 MCM average annual discharge) due to abundant rainfall in the catchment.

The river originates from the central hills near Adam's peak and traverses about 145 km through the south-western slopes of the Island to reach the sea near Colombo.

The Kelani catchment is entirely situated in the wet-zone of the country. The average annual rainfall of the catchment varies from 5700 mm in the upper catchment to 2300 mm in the lower basin. Major portion of the rainfall is received during the South-West monsoon period. However the catchment remains wet throughout the year since it receives considerable amounts of rainfall during the North-East monsoon and inter-monsoonal periods.

Owing to the heavy rainfall and the steep terrain of the upper catchment, the lower basin of the Kelani River is subjected to heavy floods. The Flood plain is formed below Glencourse gorge which is about 53 km upstream of the sea outfall. Below Hanwella (about 35 km from sea), the flood plain becomes wider following the flat landscape.

1.1 Developments in the Kelani River basin

The Kelani River starts at the confluence of two tributaries, Kehelgamu Oya and Maskeli Oya at the upstream of Kithulgala. These two tributaries contribute to a significant part of hydroelectric production of Sri Lanka by housing two major reservoirs (Maussakele and Castlereigh), three ponds (Noorton, Canyon, Laksapana) and five power stations. Castlereigh and Noorton have been constructed across Kehelgamu Oya while Maussakele, Canyon and Laxapana were constructed on the Maskeli Oya. In the lower reaches, some more tributaries connect to the Kelani River, out of which the most significant are Wee Oya at Yatiyantota, Gurugoda Oya at Ruwanwella and Seethawaka Ganga at Avissawella [**Arumugam, S.**]. So far there are no storage reservoirs constructed on those tributaries.

The Wak Oya connects to the Kelani River further downstream where the confluence is situated just above Hanwella hydrometric station. Kalatuwawa and Labugama reservoirs have been constructed on the upper reaches of Wak Oya. Those two reservoirs have been constructed purely for the purpose of domestic water supply to the capital city, Colombo.

Lower basin of the Kelani River has been protected against minor floods by construction of levees across the lower tributaries and the depressions either side of the main river. These levees prevent river water entering to the protected areas during floods. Storm water evacuation from these areas is mainly done by gravity outlets. Therefore the basin drainage has to wait until the river stages fall and discharge through gravity outlets is possible. These schemes have been constructed in a different stages beginning from 1920s to suit with the conditions prevailed at the time of construction (mainly for agriculture purpose). These areas became populated gradually and the protection given is insufficient for the present conditions.

In addition to above there are some major flood protection and drainage schemes constructed for the purpose of protection of Colombo city and suburbs from the Kelani River floods. The level of protection of these areas is fairly high but most of the facilities provided by the schemes are now deteriorated due to various reasons.

1.2 Influence of the reservoirs on flooding

Castlereigh (43,830 acft) and Maussakele (93,000 acft) reservoirs regulate the inflows from the Kehelgamu Oya and Maskeli Oya to some extent. The Influences of Norton, Canyon and Laksapana ponds are negligible. Gurugoda Oya and Seethawaka Ganga contribute huge amount of water to the river during flood periods.

Similarly, the water from the upper catchment of Wak Oya also regulated to some extent by the domestic water reservoirs Kalatuwawa and Labugama. Impact of all these reservoirs on Kelani River flooding is positive since they retard the flood wave and attenuate the peak floods to some extent.

2. Hydrometric Network on the Kelani River

Seven hydrometric stations on the Kelani River are operated at 1 hr intervals by Hydrology Division (HD) of the Irrigation Department (ID). All seven stations are equipped with manual rain gauges which record rainfalls at the same interval. There are some other rainfall stations located at the upper catchments of the tributaries to record daily rainfalls by different organizations. Locations of all the stations are shown on the River Basin Map (Fig. 1) and some important parameters are tabulated in Table 1.

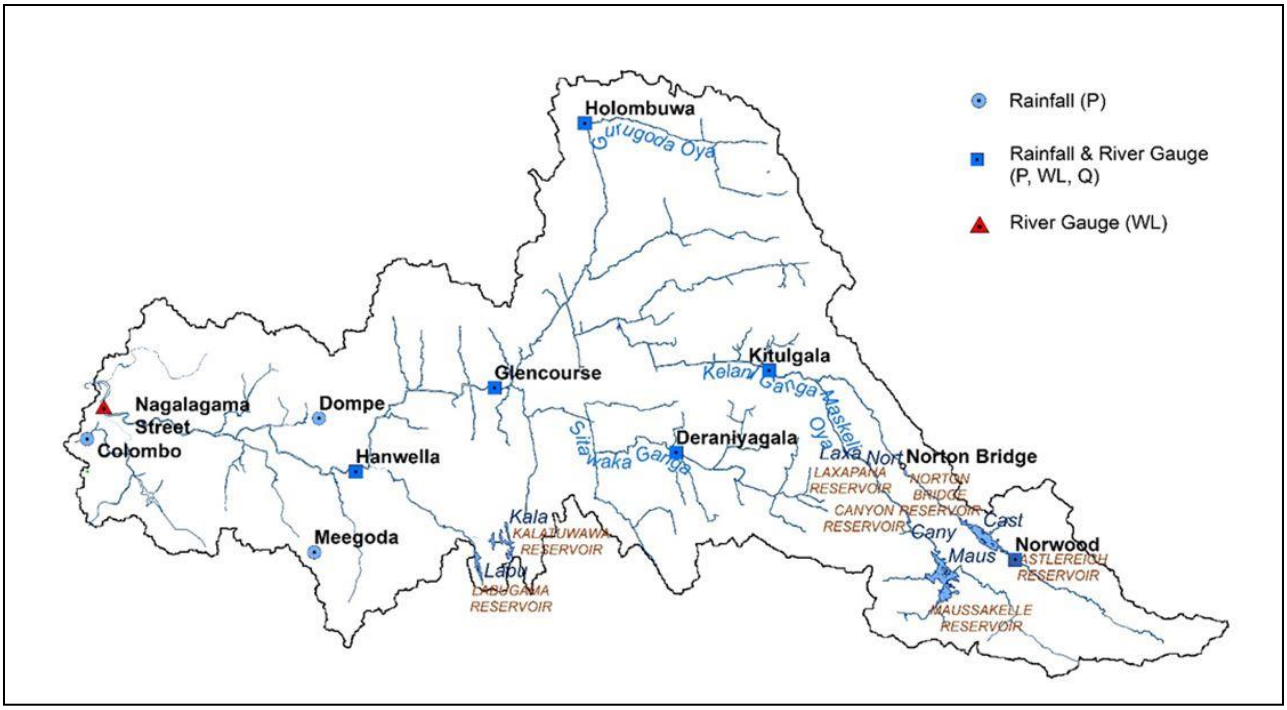


Figure 1. The Kelani River Basin Map

	Station Name & Implementing Agency	Location (X *Y)	Type of data collected
1	Norwood (ID)	182,051*182,230	Record water levels and rainfalls at 1 hour intervals. Rating curves are available to convert water levels to discharge. All six stations are maintained by the Hydrology Division of Irrigation Department.
2	Holombuwa (ID)	143,948*220,765	
3	Kithulgala (ID)	160,270*198,922	
4	Deraniyagala (ID)	152,036*191,688	
5	Glencourse (ID)	135,963*197,396	
6	Hanwella (ID)	123,689*189,980	
7	Nortonbridge (CEB)	172,111*190,453	Record 1 day Rainfalls by Ceylon Electricity Board
8	Castlereigh (CEB)	177,105*185,797	
9	Maussakele (CEB)	175,140*182,642	
10	Canyon (CEB)	172,680*185,725	
11	Laxapana (CEB)	168,936*190,719	
12	Nagalagam Street (ID)	101,112*195,586	Hydrology Division records Water Level at 1hr interval. No rainfall data collected.
13	Colombo (DOM)		Record continuous Rainfalls by the Department of Meteorology (DOM)

Table 1. Rainfall Stations presently functioned in the Kelani Catchment.

3. Historical Floods

Colombo floods have been categorized based on the water levels at the river gauge at Nagalagam Street which has been maintained from 1830s. The floods above 7 ft MSL at Nagalagam Street are considered as major floods. Summary of information on historical major floods, as available at the Hydrology Division, is presented below (Table 2).

Year & Month	W.L. Max. ft	Year & Month	W.L. Max. ft	Year & Month	W.L. Max. ft
1837	13.5	1928 July	9.08	1942 July	8.17
1872	11.9	1930 May	10.91	1947 August	12.85
1891	9.8	1930 Oct.	9.83	1952 May	8.25
1904	9.9	1933 May	9.95	1955 Oct.	8
1906	10.8	1936 May	9.43	1966 Sept.	8.67
1913	11	1937 May	10.33	1966 Oct.	9
1922	12.6	1939 May	9.35	1967 Oct.	9.17
1925	11.5	1940 May	11	1971 Sept.	7.33
				1989 Jun	9.2

Table 2. Historical Floods Recorded at Nagalagam Street [4].

Out of those historical floods, most of the information with respect to 1989 flood has been recorded by the Hydrology Division. After 1989 there was no major flood occurred in the Kelani basin until the recent flood in May 2016.

4. Flood in May 2016

The recent flood is the most severe hazard recorded after the 1989 flood. Some of the dominant features of this flood are discussed below.

4.1 Extreme Rainfalls Caused Flooding

Extreme weather forecast was issued by the Department of Meteorology on 14 May 2016 stating heavy storms (above 150 mm) will be expected covering the North Western and the Western parts of the country. Hydrology Division used to monitor daily rainfalls from the following stations as depicted in Table 3.

Station	Rainfall mm								Total
	13th May	14th May	15th May	16th May	17th May	18th May	19th May	20th May	RF mm
Castlereigh(CEB)	6.20	15.60	137.50	116.30	72.00	15.80	68.20	11.60	443.2
Norton(CEB)	20.90	11.70	201.50	200.50	109.40	12.10	77.00	47.00	680.1
Maussakelle(CEB)	6.00	14.50	155.00	82.00	84.50	19.50	62.30	7.00	430.8
Canyon(CEB)	30.50	13.00	179.20	187.50	87.10	22.90	64.00	12.10	596.3
Laxapana(CEB)	20.60	12.00	158.50	167.90	129.10	12.70	78.50	20.20	599.5
Norwood	11.80	37.70	86.00	35.40	68.60	17.10	45.00	2.70	304.3
Kitulgala	23.10	32.90	336.90	70.00	66.90	51.60	138.70	21.90	742.0
Deraniyagala	142.60	22.80	355.50	91.70	69.40	58.20	144.30	14.30	898.8
Holombuwa	37.80	16.60	201.60	88.70	101.30	10.30	40.30	11.10	507.7
Glencourse	60.40	16.10	225.80	78.00	73.70	26.60	108.90	1.40	590.9
Hanwella	7.00	11.60	160.70	17.90	48.70	9.30	108.30	1.30	364.8
Colombo(ID)	2.60	82.60	217.40	7.60	13.40	1.70	10.10	0.00	335.4
Colombo(MET)	2.80	76.40	256.90	26.00	19.50	0.90	9.80	0.80	393.1

Table 3. Daily Rainfalls throughout the Flood Period

According to above, only Deraniyagala had recorded high rainfall (142.6 mm) on 13th May (before the event). The next day, there were no significant rains in the upper catchment but the lower basin (Colombo) experienced heavy rains (around 80 mm). The entire catchment prevailed wet before experiencing torrential rainfall in the evening of 15th Sunday. Deraniyagala recorded the highest one day rainfall (355.5 mm) on 15th May and the same location recorded the highest 8 day total rainfall (898.8 mm) during the flood. The entire catchment experienced heavy and long duration rainfalls during the period.

4.2 Flood Levels

Norwood station reached minor flood level at 12.00 Noon on 15th May. That was prevailed only for 7 hours and became normal by 7 pm of the same day. This doesn't have much influence on the Kelani River floods since this is located at the upstream of Castlereigh reservoir.

The entire river below Kithulgala remained normal up to 6 pm on 15th May. Kithulgala reached minor flood level at 5 pm of 16th May and remained for 14 hours. But it never reached to major flood level during the flood period.

Deraniyagala recorded the highest rainfall during the flood period. But the flooding was limited to 7 hours of minor flood situation and 2 hours at major flood level. According to that the Kelani upper catchment did not much affected by the recent flood. The flood is mainly dominated by the rainfalls of the middle parts of the catchment and the lower basin.

A middle reach tributary, Gurugoda oya (at the elevation of about 50 m MSL), and the entire basin below Avissawella were severely affected by the flood. A summary of flood levels and the periods of inundation are presented in Table 4. A detail record of water level and discharge variation along the river is presented in Annex I.

Station	Minor Flood Level m MSL	Major Flood Level m MSL	Minor Flood Start at	Major Flood Start at	Major Flood Stopped at	Minor Flood Stopped at	Major Flood Period hr	Total Flood Period hr
Nagalagam	1.52	2.13	7hr 16th	13hr18th	13hr21st	18hr22nd	73	155
Hanwella	8.48	10	4hr 16th	5hr19th	5hr19th	12hr21st	57	128
Glencourse	16.76	19.81	24hr 15th	17hr16th	17hr16th	17hr18th	1	65
Holombuwa	47.91	49.43	15hr15th	24hr15th	12hr16th	8hr18th	12	65
Deraniyagala	79	79.61	24hr15th	2hr16th	3hr16th	6hr16th	2	7
Kithugal	55.73	57.72	17hr16th	-	-	6hr17th	-	14
Norwood	1099.76	1099.91	12hr15th	-	-	18hr15th	-	7

Table 4. Recorded Flood Level at the different stations and periods of Inundation

The torrential rainfall causing floods occurred in the night of 15th May and the highest intensity was recorded at the midnight. Entire basin up to Nagalagam Street was flooded within 7 hours causing severe damages to low lands either side of the river.

5. Analysis of Flood

The floods are normally classified as flash floods if the response time (time between the rainfall and flood) is less than 6 hours. Those floods are not possible to forecast with adequate lead time by hydrological or hydrodynamic models. Secondly such floods are characterized with high peaks and low durations of inundation. Floods in the upper reaches of the Kelani River are of the nature of flash floods.

The floods in the lower reach (below Avissawella) are more critical due to large areas of spread and longer durations of inundation. Further those areas are highly developed and densely populated.

According to past experiences, the Kelani Floods are mainly dominated by the torrential rainfalls of the upper catchments while the lower basin is experiencing fair weather. In such situation, there is sufficient time to forecast and get precautions to minimize damages. During the recent flood Hydrology Division was trying to forecast the flood levels with mathematical models and also by river routing methods. In both cases, Glencourse station (53 km away from the outfall) was taken as the upper boundary. However the time lag between Glencourse and Hanwella (only 4 hours) and also from Hanwella to Nagalagam Street (3 hour) was not sufficient to give effective forecasts. This condition is clearly visible in Figure 5. The main reason behind this was the pattern of distribution of rainfalls over the catchment. The entire catchment received relatively uniform and heavy rainfalls and the floods were mainly dominated by the rainfalls of the middle reach.

5.1 Comparison of the recent flood with the historical flood 1n 1989

5.1.1 Rainfall Pattern

Since the catchment area and the duration of flood are fairly large rainfall periods of 8 days were selected for the comparison of two events. The weighted average rainfalls of the catchments above Glecourse, Hanwella and Nagalagam street hydrometric stations were selected for the comparison.

Catchment	Year	Day 01	Day 02	Day 03	Day 04	Day 05	Day 06	Day 07	Day 08	Total mm
Glencourse	2016	49.1	22.1	238.3	91.7	82.3	30.8	93.3	13.0	620.7
	1989	125.1	32.0	10.5	122.2	188.4	87.0	76.2	27.6	669.1
Hanwella	2016	47.1	20.8	231.5	85.1	79.1	28.9	95.9	11.0	599.4
	1989	107.2	27.6	12.5	113.6	174.4	81.0	67.3	23.7	607.5
Nagalagam Street	2016	39.4	22.9	224.0	73.1	71.7	24.8	92.4	9.2	557.5
	1989	91.0	23.2	16.1	114.9	158.6	76.7	57.3	20.9	558.9

Table 5. Weightet Average Rainfall of the gross Catchments above Glencourse, Hanwella and Nagalagam Street

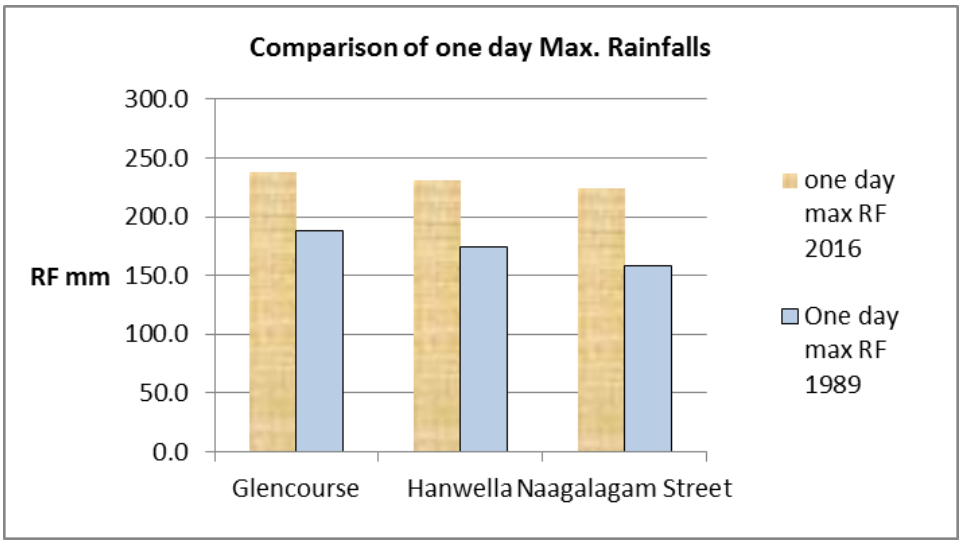


Figure 3. Comparison of One Day Maximum Rainfalls of Different Catchments.

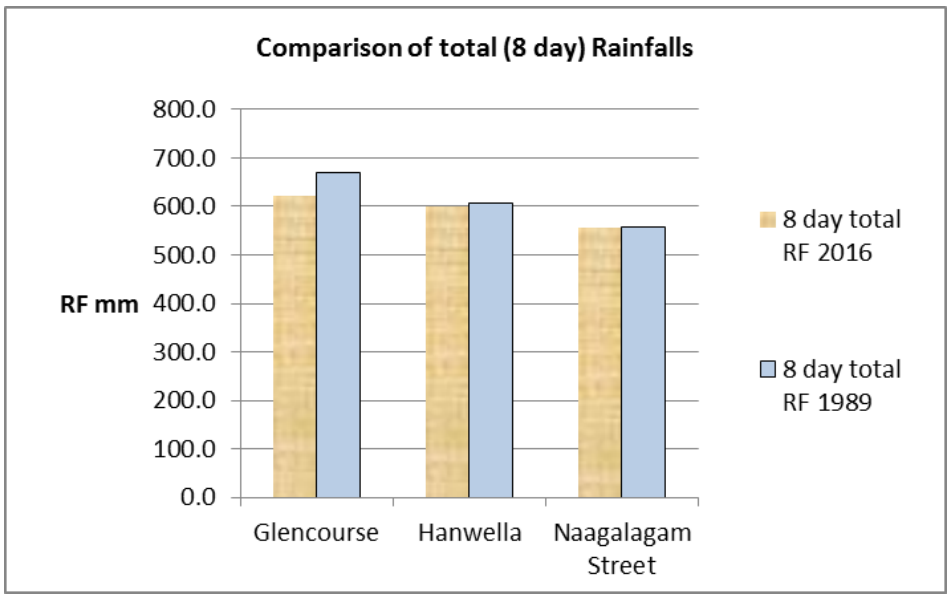


Figure 4. Comparison of Total Rainfalls of the different Catchments.

5.1.2 Characteristics of the Flood Hydrographs

When comparing the flood waves of two extreme events, the following characteristics of hydrographs are of prime importance.

1. Peak Discharge or Water Level
2. Time to peak discharge (or Water Level) at each station
3. Durations of flood at each section.

The above characteristics of two floods are presented in two Figures 5 and Figure 6.

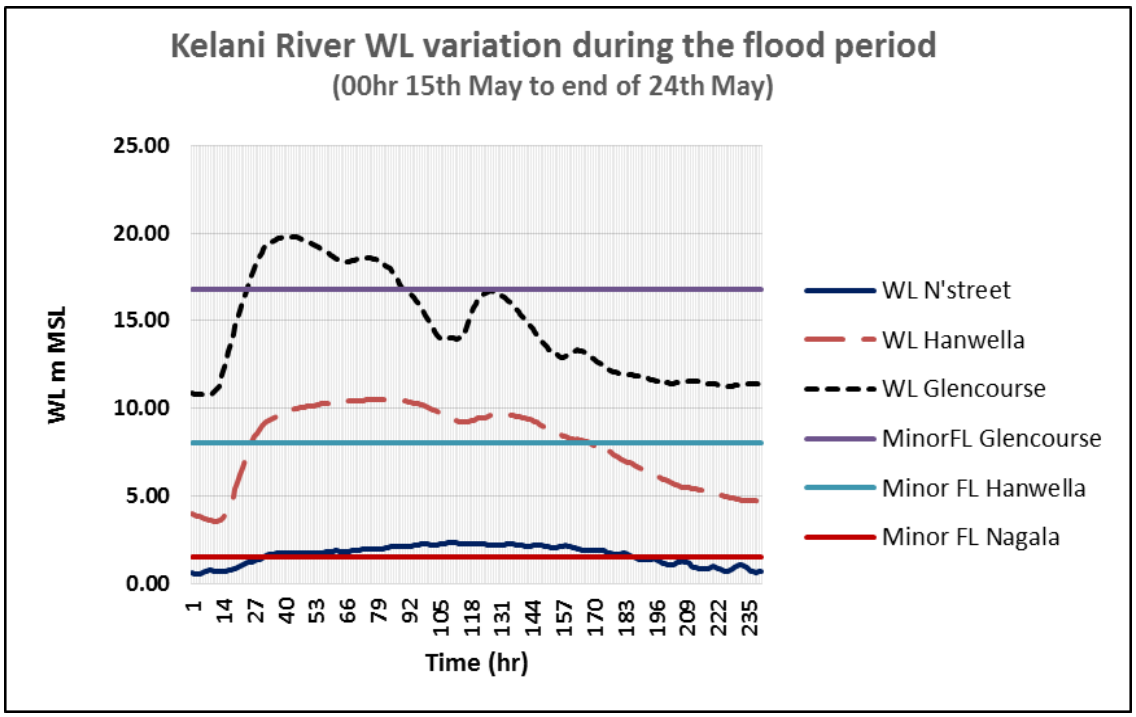


Figure 5. Water Level Variation of Three Stations during 2016 Flood

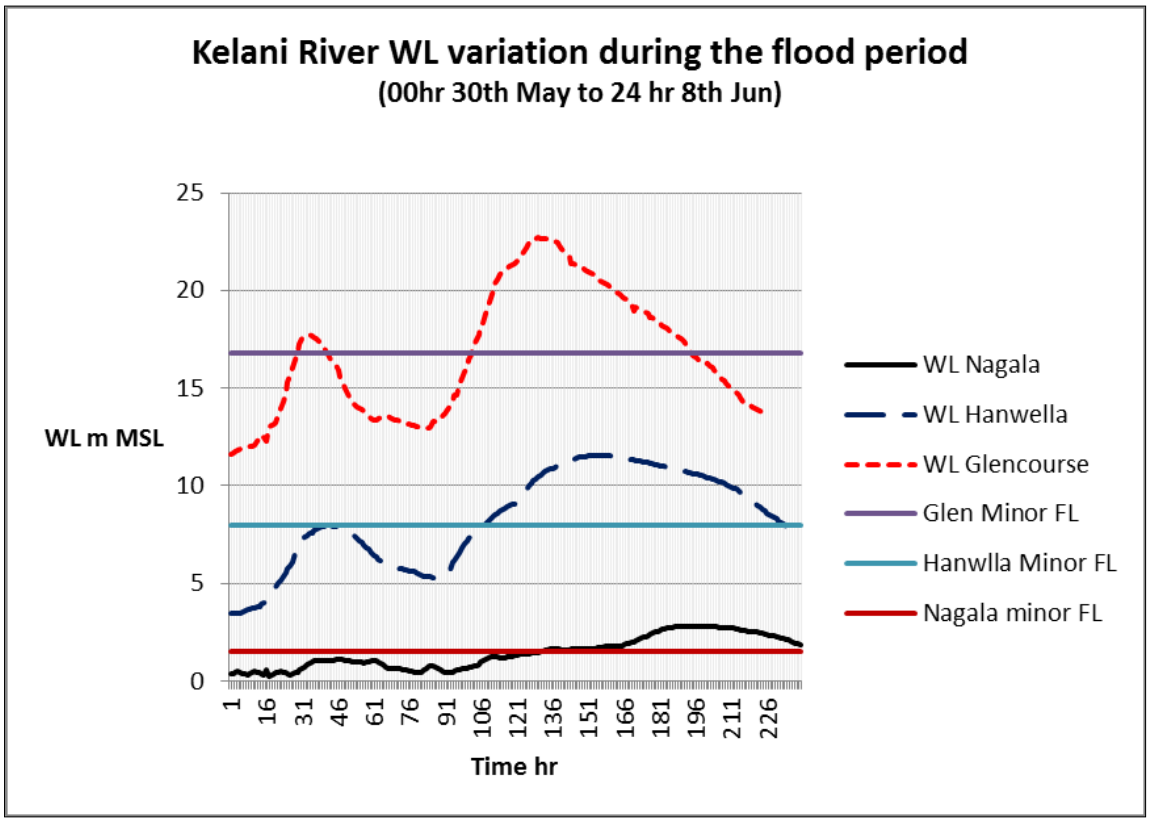


Figure 6. Water Level Variation at Three Stations during 1989 Flood.

2016 May Flood	1989 May/ June Flood
Low Peaks	High Peaks
Early Peaks	Late peaks
Longer durations	Short durations
Rainfall distributed throughout the catchment	Rainfall concentrated in the upper catchment
Very short alert periods	Longer alert periods
No sufficient time to forecast and warning	Ample time for forecast and warning
Heavy damages	Comparatively less damages

Table 6. Comparison of the Characteristics of 2016 Flood with 1989 Flood

6. Characteristics of Flow Hydrographs

Rating Curve of Hanwella river gauging station had not been updated for a long period before 2016 flood. Hydrology Division took prompt actions to conduct flow measurements during the flood period with ADCP (Acoustic Doppler Velocity Profiler) instrument. They managed to get several measurements during the high flows and used them to update the rating curve of Hanwella.

Similarly a number of measurements were taken at the Kelani Bridge at the vicinity of the river gauge of Nagalagam Street. Developing unique relationship between river stage and discharge at this location is not possible due to tidal influence. However, it was possible to develop approximate relationship using the flow measurements taken during the flood. For the gauge station at Glencourse, there was a rating curve developed before the flood.

Using water level measurements and the updated rating curves, flow hydrographs were developed for all three stations as presented in Figure 7 below.

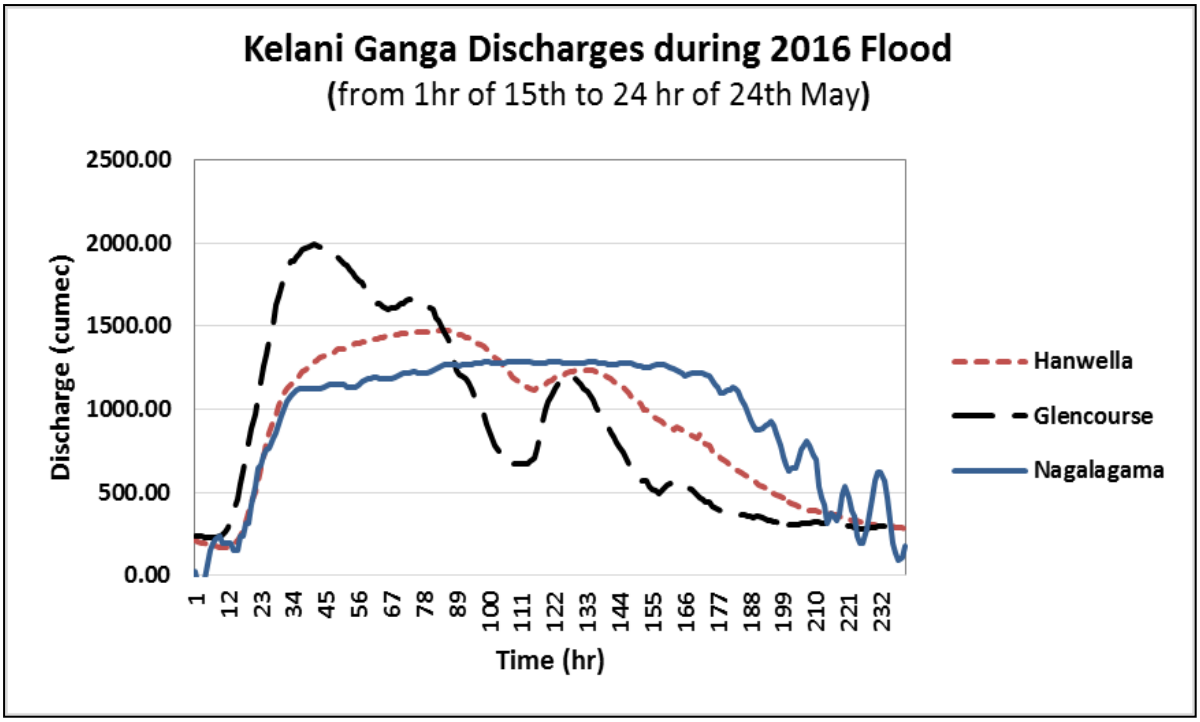


Figure 7. Flow Hydrographs during the Flood Period 2016 May, at three stations

The figure shows that all three stations were at normal levels up to 15th May. Rapid rise of discharge was observed by the evening of 15th May. Glencourse flood wave shows two low peaks after the high peak (1991 cumec). The highest discharge at Hanwella (1467 cumec) was also followed by a second peak of 1233 cumec. Such divisions were visible in the time series of rainfalls also. The high peaks were caused by the rainfall of 15th May and second and third peaks were resulted by the high rainfalls of following (16,17,19) days. It is important to mention these long duration rainfalls were not continuous and especially the day time experienced fair weather.

Station	Year	May 13	May 14	May 15	May 16	May 17	May 18	May 19	May 20
Glencourse	2016	49.1	22.1	238.3	91.7	82.3	30.8	93.3	13.0
Hanwella	2016	47.1	20.8	231.5	85.1	79.1	28.9	95.9	11.0
Nagalagam St.	2016	39.4	22.9	224.0	73.1	71.7	24.8	92.4	9.2

Table 6. Rainfall distribution over the flood period from 13th to 20th May.

However such divisions were not appeared in the flow hydrograph of Nagalagam Street. It remained at nearly constant discharge (above 1000 cumec) for a long (6.5 days) period. There were many reasons for this behavior. Discharge capacity of this reach of the river is comparatively low due to mild bed slopes (around -4 mMSL). Secondly the contribution of slow lateral flows from small tributaries and flood plains also affect the river flow. Structures constructed across the river may have some influence. Especially it is recommended to check the impact of the salinity barrier, recently constructed at Ambatale.

Finally, Nagalagam Street gauge is situated in the tidal zone of the river where flows are highly influences by the tidal levels of the sea. Tidal range at Colombo during the period was recorded from 0.04 m to 0.68 m.

According to literature a higher discharge was recorded at this station during 1989 flood. It was around 2267 cumecs at 9.2 ft, maximum water level at that time [4].

7. Checking River Discharges with Water Balance Studies.

Rainfall period from 13th to 20th May (8 days) was taken for the analysis of 2016 flood. Relatively fair weather was experienced before and after this period. Flood level rising began on 15th May and it took about 10 days to come back to normal levels. Therefore these periods were selected for the water balance study for three catchments. The results are summarized in the table below.

	Nagalagam St.	Hanwella	Glencourse
Weighted Average Rainfall over the catchment (8 day total mm)	558.9	607.5	669.1
Total catchment area above the station km^2 [**Hydrological Annual**]	2085	1782	1463
Total (8 day) Rainfall Volume in MCM	1165.31	1082.57	978.89
Average discharge over the 10 day period ((cumecs)	965.1	913.94	889.93
Total volume of discharge MCM	833.85	789.65	765.9
Runoff/Rainfall Ratio	72%	73%	79%

Table 7. Checking Discharges with Water Balance Study.

Runoff ratios found from the above calculation seems comparable to the past records of flood analysis. Further the discharge at Glencourse and Hanwella became equal by the afternoon of 18th may (85th hr in Figure 7). After this time the flood levels of the river reach (above Hanwella) decreased gradually. Similarly the discharges of Hanwella and Nagalagam Street become comparable by the morning of 19th may. There was no extensive water level rise in the lower Kelani River after this time.

This information reveals that the discharges computed by the newly developed rating curves are reliable and realistic.

8. Flood Frequency Analysis

Hourly records of water levels were available for fairly long periods with respect to all hydrometric stations on the Kelani River. The graphical method of Gumbel EV1 distribution was used to carry out frequency analysis using annual maximum rainfalls at each station. Return periods of two floods (2016 and 1989) at three main stations (Glencourse, Hanwella and Nagalagam Street) were analysed and presented in Table 7 below.

Hydrometric Station	Data Period	2016 flood	1989 Flood
Glencourse	43 years	10 year	50 year
Hanwella	40 years	10 year	25 year
Nagalagam Street	52 years	15 year	50 year

Table 8. Recurrence intervals of two floods at three stations

9. Conclusions and Recommendations

Mitigation of flood hazards is addressed in two different approaches, namely structural and non structural measures. Structural measures provide solutions to protect certain areas from flooding by means of embankments, diversions, detention reservoirs etc. while the non structural measures focus on lessening the damages by flood forecasting, early warning and evacuation of people and the properties from vulnerable areas. Apart from those two approaches, adaptation to natural environment by changing life styles and livelihoods, construction of buildings and infrastructure facilities suitable for flood situations (elevated structures, floating structures) etc. also in use. When considering highly developed and densely populated areas like Kelani River basin, a combination of all these approaches will be most appropriate.

The existing Kelani flood protection schemes were developed in the period from early 1920 s to late 1950s to protect the low lying areas adjacent to the river against river floods by construction of series of levees along the river. Evacuation of storm water from the interior catchments of the protected areas was mainly done by gravity. These schemes served for a long period successfully except in few occasions in which overtopping or failure of flood bunds were experienced.

Therefore, first priority should be given to the rehabilitation and modernization of existing flood protection schemes. The protection levels of original schemes may be insufficient for the present conditions since most of the agricultural lands in the past have been converted to residential areas with urbanization and increase of population. Therefore the levels of protection should be increased at least up to 50 year return period (which is comparable to 1989 flood). Further, storm water evacuation by gravity is also problematic in the cases of long duration floods. Therefore pumping facilities should be provided, in addition to gravity outlets, for evacuating storm water quickly from the protected areas.

Non structural measures such as flood forecasting and early warning is also helpful in minimizing damages to properties. However this method doesn't help much in the cases of flash floods similar to the recent flood. However, it can be adopted very effectively in the cases similar to 1989 flood in which the flood is mainly dominated by the rainfalls of upper catchment and there is enough time for warning and evacuation. Even in the cases of flash floods, this method can be adopted effectively by running hydrological models with the forecasted rainfalls by meteorological models. However, the uncertainty of such forecasts will highly affect the model results.

Adaptation to flood situations by changing land use pattern, structures, lifestyles etc. can also be applied for the flood mitigation. Even the areas highly susceptible for flooding can be utilized for some commercial and recreational purposes. However, optimum care should be taken to minimize environmental hazards that can be resulted by such developments.

References :

1. **Arumugam, S., Water Resources of Ceylon its Utilization and Development, 1969**
2. **Hydrological Annual, Hydrology Division of Irrigation Department**
3. **Scheme of Organization and Standing Orders to Safeguard the city of Colombo from Floods in the Kelani River, Hydrology Division, Irrigation Department.**
4. **Darmasena, G.T., Hydrological Annual 1988/89, Hydrology Division, Irrigation Department.**

Annex : Page I

Kelani Water Levels & Discharges During 2016 Flood Period

Date	Time	Ho= 0 mMSL			Ho = 0 m MSL			Ho= 6.5 mMSL		
		Nagalagam Street			Hanwella			Glencourse		
		WL ft	WL mMSL	Q cumec	WL m	WLmMSL	Q Cumec	WL ft	WL mMSL	Q Cumec
2016.05.15	1:00:00 AM	2.00	0.61	23.34	3.53	4.01	210.31	35.60	10.85	237.38
	2:00:00 AM	1.80	0.55	-66.85	3.45	3.93	202.38	35.55	10.84	235.72
	3:00:00 AM	1.80	0.55	-66.85	3.38	3.86	195.60	35.50	10.82	234.07
	4:00:00 AM	1.90	0.58	-21.37	3.34	3.82	191.79	35.40	10.79	230.77
	5:00:00 AM	2.10	0.64	67.26	3.30	3.78	188.03	35.40	10.79	230.77
	6:00:00 AM	2.30	0.70	152.78	3.24	3.72	182.46	35.35	10.78	229.13
	7:00:00 AM	2.40	0.73	194.38	3.19	3.67	177.91	35.35	10.78	229.13
	8:00:00 AM	2.45	0.75	214.88	3.14	3.62	173.42	35.35	10.78	229.13
	9:00:00 AM	2.50	0.76	235.19	3.12	3.60	171.65	35.55	10.84	235.72
	10:00:00 AM	2.40	0.73	194.38	3.10	3.58	169.89	35.85	10.93	245.75
	11:00:00 AM	2.40	0.73	194.38	3.10	3.58	169.89	36.30	11.07	261.09
	12:00:00 PM	2.40	0.73	194.38	3.12	3.60	171.65	37.00	11.28	285.67
	1:00:00 PM	2.40	0.73	194.38	3.16	3.64	175.21	38.40	11.71	337.48
	2:00:00 PM	2.30	0.70	152.78	3.30	3.78	188.03	39.80	12.13	392.81
	3:00:00 PM	2.30	0.70	152.78	3.52	4.00	209.31	41.30	12.59	456.00
	4:00:00 PM	2.50	0.76	235.19	3.78	4.26	236.26	43.50	13.26	556.00
	5:00:00 PM	2.50	0.76	235.19	4.10	4.58	272.10	45.00	13.72	629.18
	6:00:00 PM	2.70	0.82	314.49	4.49	4.97	319.76	46.60	14.21	711.68
	7:00:00 PM	2.70	0.82	314.49	4.95	5.43	381.62	48.25	14.71	801.59
	8:00:00 PM	3.00	0.91	427.60	5.34	5.82	438.84	49.75	15.17	887.57
	9:00:00 PM	3.30	1.01	533.72	5.74	6.22	502.08	51.15	15.59	971.47
	10:00:00 PM	3.65	1.11	648.67	6.12	6.60	566.43	52.75	16.08	1071.67
	11:00:00 PM	3.70	1.13	664.31	6.58	7.06	649.89	54.20	16.52	1166.45
	12:00:00 AM	3.90	1.19	724.95	6.92	7.40	715.49	55.55	16.94	1258.10
2016.05.16	1:00:00 AM	4.00	1.22	754.10	7.35	7.83	803.23	56.60	17.26	1331.64
	2:00:00 AM	4.05	1.23	768.38	7.60	8.08	856.69	57.80	17.62	1418.12
	3:00:00 AM	4.25	1.30	823.57	7.90	8.38	923.22	59.00	17.99	1507.18
	4:00:00 AM	4.40	1.34	862.92	8.08	8.56	964.39	60.55	18.46	1626.06
	5:00:00 AM	4.60	1.40	912.66	8.33	8.81	1023.11	61.20	18.66	1677.19
	6:00:00 AM	4.80	1.46	959.30	8.50	8.98	1064.06	62.00	18.90	1741.17
	7:00:00 AM	5.00	1.52	1002.82	8.63	9.11	1095.95	62.75	19.13	1802.20
	8:00:00 AM	5.20	1.59	1043.23	8.73	9.21	1120.80	63.35	19.31	1851.75
	9:00:00 AM	5.40	1.65	1080.54	8.83	9.31	1145.95	63.80	19.45	1889.33
	10:00:00 AM	5.50	1.68	1098.02	8.89	9.37	1161.17	63.85	19.47	1893.53
	11:00:00 AM	5.60	1.71	1114.73	8.96	9.44	1179.06	64.15	19.56	1918.82
	12:00:00 PM	5.65	1.72	1122.79	9.05	9.53	1202.28	64.35	19.62	1935.77
	1:00:00 PM	5.65	1.72	1122.79	9.13	9.61	1223.11	64.60	19.70	1957.05
	2:00:00 PM	5.65	1.72	1122.79	9.19	9.67	1238.85	64.75	19.74	1969.88
	3:00:00 PM	5.65	1.72	1122.79	9.24	9.72	1252.05	64.80	19.76	1974.16
	4:00:00 PM	5.65	1.72	1122.79	9.32	9.80	1273.32	64.95	19.80	1987.04
	5:00:00 PM	5.65	1.72	1122.79	9.36	9.84	1284.02	65.00	19.82	1991.34
	6:00:00 PM	5.65	1.72	1122.79	9.40	9.88	1294.77	64.95	19.80	1987.04
	7:00:00 PM	5.65	1.72	1122.79	9.45	9.93	1308.27	64.85	19.77	1978.45
	8:00:00 PM	5.70	1.74	1130.65	9.48	9.96	1316.41	64.85	19.77	1978.45
	9:00:00 PM	5.75	1.75	1138.33	9.52	10.00	1327.29	64.85	19.77	1978.45
	10:00:00 PM	5.80	1.77	1145.81	9.55	10.03	1335.49	64.75	19.74	1969.88
	11:00:00 PM	5.85	1.78	1153.09	9.56	10.04	1338.23	64.50	19.66	1948.52
	12:00:00 AM	5.85	1.78	1153.09	9.60	10.08	1349.21	64.30	19.60	1931.52

Annex : Page II

Date	Time	Ho= 0 mMSL			Ho = 0 m MSL			Ho= 6.5 mMSL		
		Nagalagam Street			Hanwella			Glencourse		
		WL ft	WL mMSL	Q cumec	WL m	WLmMSL	Q Cumec	WL ft	WL mMSL	Q Cumec
216.05.17	1:00:00 AM	5.85	1.78	1153.09	9.64	10.12	1360.23	64.15	19.56	1918.82
	2:00:00 AM	5.85	1.78	1153.09	9.66	10.14	1365.76	63.85	19.47	1893.53
	3:00:00 AM	5.80	1.77	1145.81	9.66	10.14	1365.76	63.65	19.41	1876.76
	4:00:00 AM	5.70	1.74	1130.65	9.68	10.16	1371.30	63.50	19.36	1864.23
	5:00:00 AM	5.70	1.74	1130.65	9.72	10.20	1382.42	63.25	19.28	1843.44
	6:00:00 AM	5.70	1.74	1130.65	9.75	10.23	1390.79	63.00	19.21	1822.76
	7:00:00 AM	5.70	1.74	1130.65	9.77	10.25	1396.38	62.70	19.12	1798.10
	8:00:00 AM	5.85	1.78	1153.09	9.78	10.26	1399.18	62.40	19.02	1773.59
	9:00:00 AM	5.95	1.81	1167.07	9.80	10.28	1404.80	62.30	18.99	1765.46
	10:00:00 AM	6.00	1.83	1173.78	9.81	10.29	1407.60	61.90	18.87	1733.11
	11:00:00 AM	6.05	1.84	1180.28	9.83	10.31	1413.23	61.50	18.75	1701.05
	12:00:00 PM	6.10	1.86	1186.59	9.84	10.32	1416.05	61.20	18.66	1677.19
	1:00:00 PM	6.15	1.88	1192.71	9.85	10.33	1418.87	60.95	18.58	1657.43
	2:00:00 PM	6.15	1.88	1192.71	9.87	10.35	1424.52	60.70	18.51	1637.79
	3:00:00 PM	6.10	1.86	1186.59	9.88	10.36	1427.35	60.65	18.49	1633.87
	4:00:00 PM	6.10	1.86	1186.59	9.89	10.37	1430.19	60.50	18.45	1622.15
	5:00:00 PM	6.10	1.86	1186.59	9.91	10.39	1435.86	60.30	18.38	1606.59
	6:00:00 PM	6.10	1.86	1186.59	9.93	10.41	1441.55	60.25	18.37	1602.71
	7:00:00 PM	6.10	1.86	1186.59	9.94	10.42	1444.39	60.30	18.38	1606.59
	8:00:00 PM	6.15	1.88	1192.71	9.94	10.42	1444.39	60.35	18.40	1610.48
	9:00:00 PM	6.20	1.89	1198.63	9.96	10.44	1450.10	60.50	18.45	1622.15
	10:00:00 PM	6.30	1.92	1209.90	9.98	10.46	1455.81	60.65	18.49	1633.87
	11:00:00 PM	6.35	1.94	1215.24	9.98	10.46	1455.81	60.70	18.51	1637.79
	12:00:00 AM	6.40	1.95	1220.38	9.98	10.46	1455.81	60.90	18.57	1653.50
2016.05.18	1:00:00 AM	6.40	1.95	1220.38	9.98	10.46	1455.81	61.00	18.60	1661.38
	2:00:00 AM	6.45	1.97	1225.33	10.00	10.48	1461.54	61.00	18.60	1661.38
	3:00:00 AM	6.45	1.97	1225.33	10.00	10.48	1461.54	61.00	18.60	1661.38
	4:00:00 AM	6.40	1.95	1220.38	10.01	10.49	1464.40	61.00	18.60	1661.38
	5:00:00 AM	6.40	1.95	1220.38	10.02	10.50	1467.27	60.80	18.54	1645.63
	6:00:00 AM	6.40	1.95	1220.38	10.02	10.50	1467.27	60.65	18.49	1633.87
	7:00:00 AM	6.40	1.95	1220.38	10.02	10.50	1467.27	60.50	18.45	1622.15
	8:00:00 AM	6.45	1.97	1225.33	10.02	10.50	1467.27	60.30	18.38	1606.59
	9:00:00 AM	6.55	2.00	1234.65	10.02	10.50	1467.27	60.25	18.37	1602.71
	10:00:00 AM	6.70	2.04	1247.17	10.03	10.51	1470.15	59.55	18.16	1548.87
	11:00:00 AM	6.8	2.07	1254.54	10.03	10.51	1470.15	59.35	18.09	1533.65
	12:00:00 PM	6.90	2.10	1261.14	10.03	10.51	1470.15	58.90	17.96	1499.66
	1:00:00 PM	7.00	2.13	1266.96	10.03	10.51	1470.15	58.40	17.80	1462.33
	2:00:00 PM	7.00	2.13	1266.96	10.03	10.51	1470.15	57.85	17.64	1421.78
	3:00:00 PM	7.00	2.13	1266.96	10.03	10.51	1470.15	57.30	17.47	1381.77
	4:00:00 PM	7.00	2.13	1266.96	10.02	10.50	1467.27	56.10	17.10	1296.37
	5:00:00 PM	7.00	2.13	1266.96	10.01	10.49	1464.40	55.20	16.83	1234.02
	6:00:00 PM	6.95	2.12	1264.15	9.96	10.44	1450.10	54.80	16.71	1206.78
	7:00:00 PM	7.00	2.13	1266.96	9.94	10.42	1444.39	54.70	16.68	1200.01
	8:00:00 PM	7.00	2.13	1266.96	9.90	10.38	1433.02	54.50	16.62	1186.54
	9:00:00 PM	7.05	2.15	1269.58	9.89	10.37	1430.19	54.10	16.49	1159.80
	10:00:00 PM	7.10	2.16	1272.00	9.84	10.32	1416.05	53.50	16.31	1120.23
	11:00:00 PM	7.20	2.20	1276.26	9.82	10.30	1410.42	52.85	16.11	1078.09
	12:00:00 AM	7.30	2.23	1279.75	9.78	10.26	1399.18	52.25	15.93	1039.87

Annex : Page III

Date	Time	Ho= 0 mMSL			Ho = 0 m MSL			Ho= 6.5 mMSL		
		Nagalagam Street			Hanwella			Glencourse		
		WL ft	WL mMSL	Q cumec	WL m	WLmMSL	Q Cumec	WL ft	WL mMSL	Q Cumec
2016.5.19	1:00:00 AM	7.35	2.24	1281.20	9.75	10.23	1390.79	51.70	15.76	1005.40
	2:00:00 AM	7.40	2.26	1282.46	9.71	10.19	1379.64	51.10	15.58	968.42
	3:00:00 AM	7.45	2.27	1283.52	9.66	10.14	1365.76	50.10	15.27	908.22
	4:00:00 AM	7.45	2.27	1283.52	9.60	10.08	1349.21	49.40	15.06	867.15
	5:00:00 AM	7.30	2.23	1279.75	9.52	10.00	1327.29	48.62	14.82	822.43
	6:00:00 AM	7.30	2.23	1279.75	9.46	9.94	1310.98	47.95	14.62	784.88
	7:00:00 AM	7.25	2.21	1278.10	9.40	9.88	1294.77	47.25	14.41	746.52
	8:00:00 AM	7.25	2.21	1278.10	9.32	9.80	1273.32	46.50	14.18	706.39
	9:00:00 AM	7.35	2.24	1281.20	9.25	9.73	1254.70	46.05	14.04	682.80
	10:00:00 AM	7.40	2.26	1282.46	9.16	9.64	1230.97	45.90	13.99	675.02
	11:00:00 AM	7.50	2.29	1284.39	9.10	9.58	1215.27	45.80	13.96	669.85
	12:00:00 PM	7.60	2.32	1285.54	9.02	9.50	1194.51	45.85	13.98	672.44
	1:00:00 PM	7.65	2.33	1285.83	8.96	9.44	1179.06	45.90	13.99	675.02
	2:00:00 PM	7.65	2.33	1285.83	8.90	9.38	1163.72	45.90	13.99	675.02
	3:00:00 PM	7.65	2.33	1285.83	8.86	9.34	1153.55	45.90	13.99	675.02
	4:00:00 PM	7.65	2.33	1285.83	8.80	9.28	1138.37	45.85	13.98	672.44
	5:00:00 PM	7.50	2.29	1284.39	8.76	9.24	1128.31	45.90	13.99	675.02
	6:00:00 PM	7.40	2.26	1282.46	8.74	9.22	1123.30	46.10	14.05	685.41
	7:00:00 PM	7.35	2.24	1281.20	8.72	9.20	1118.30	46.55	14.19	709.04
	8:00:00 PM	7.35	2.24	1281.20	8.77	9.25	1130.82	47.55	14.50	762.85
	9:00:00 PM	7.35	2.24	1281.20	8.79	9.27	1135.85	48.95	14.92	841.21
	10:00:00 PM	7.35	2.24	1281.20	8.81	9.29	1140.89	50.40	15.37	926.09
	11:00:00 PM	7.35	2.24	1281.20	8.86	9.34	1153.55	51.55	15.72	996.09
	12:00:00 AM	7.40	2.26	1282.46	8.90	9.38	1163.72	52.35	15.96	1046.19
2016.5.20	1:00:00 AM	7.45	2.27	1283.52	8.96	9.44	1179.06	53.00	16.16	1087.75
	2:00:00 AM	7.50	2.29	1284.39	9.00	9.48	1189.35	53.54	16.32	1122.84
	3:00:00 AM	7.45	2.27	1283.52	9.01	9.49	1191.93	54.00	16.46	1153.16
	4:00:00 AM	7.40	2.26	1282.46	9.01	9.49	1191.93	54.45	16.60	1183.18
	5:00:00 AM	7.30	2.23	1279.75	9.04	9.52	1199.69	54.60	16.65	1193.27
	6:00:00 AM	7.25	2.21	1278.10	9.10	9.58	1215.27	54.70	16.68	1200.01
	7:00:00 AM	7.20	2.20	1276.26	9.13	9.61	1223.11	54.70	16.68	1200.01
	8:00:00 AM	7.20	2.20	1276.26	9.15	9.63	1228.34	54.60	16.65	1193.27
	9:00:00 AM	7.20	2.20	1276.26	9.16	9.64	1230.97	54.45	16.60	1183.18
	10:00:00 AM	7.20	2.20	1276.26	9.16	9.64	1230.97	54.25	16.54	1169.79
	11:00:00 AM	7.30	2.23	1279.75	9.17	9.65	1233.59	53.95	16.45	1149.84
	12:00:00 PM	7.32	2.23	1280.35	9.17	9.65	1233.59	53.60	16.34	1126.78
	1:00:00 PM	7.45	2.27	1283.52	9.17	9.65	1233.59	53.30	16.25	1107.18
	2:00:00 PM	7.50	2.29	1284.39	9.17	9.65	1233.59	52.90	16.13	1081.30
	3:00:00 PM	7.50	2.29	1284.39	9.16	9.64	1230.97	52.55	16.02	1058.90
	4:00:00 PM	7.40	2.26	1282.46	9.14	9.62	1225.72	51.80	15.79	1011.62
	5:00:00 PM	7.30	2.23	1279.75	9.09	9.57	1212.67	51.35	15.66	983.75
	6:00:00 PM	7.20	2.20	1276.26	9.07	9.55	1207.47	50.90	15.52	956.23
	7:00:00 PM	7.15	2.18	1274.23	9.04	9.52	1199.69	50.35	15.35	923.10
	8:00:00 PM	7.10	2.16	1272.00	9.01	9.49	1191.93	49.80	15.18	890.51
	9:00:00 PM	7.05	2.15	1269.58	8.97	9.45	1181.63	49.30	15.03	861.35
	10:00:00 PM	7.05	2.15	1269.58	8.91	9.39	1166.27	48.85	14.89	835.50
	11:00:00 PM	7.05	2.15	1269.58	8.87	9.35	1156.08	48.20	14.70	798.80
	12:00:00 AM	7.15	2.18	1274.23	8.82	9.30	1143.42	47.70	14.54	771.08

Annex : Page IV

Date	Time	Ho= 0 mMSL			Ho = 0 m MSL			Ho= 6.5 mMSL		
		Nagalagam Street			Hanwella			Glencourse		
		WL ft	WL mMSL	Q cumec	WL m	WLmMSL	Q Cumec	WL ft	WL mMSL	Q Cumec
2016.5.21	1:00:00 AM	7.20	2.20	1276.26	8.76	9.24	1128.31	47.20	14.39	743.81
	2:00:00 AM	7.20	2.20	1276.26	8.72	9.20	1118.30	46.50	14.18	706.39
	3:00:00 AM	7.20	2.20	1276.26	8.64	9.12	1098.42	45.90	13.99	675.02
	4:00:00 AM	7.15	2.18	1274.23	8.54	9.02	1073.82	45.30	13.81	644.30
	5:00:00 AM	7.05	2.15	1269.58	8.49	8.97	1061.63	44.75	13.64	616.70
	6:00:00 AM	6.95	2.12	1264.15	8.43	8.91	1047.10	44.30	13.51	594.53
	7:00:00 AM	6.90	2.10	1261.14	8.36	8.84	1030.27	43.80	13.35	570.31
	8:00:00 AM	6.80	2.07	1254.54	8.20	8.68	992.35	43.80	13.35	570.31
	9:00:00 AM	6.80	2.07	1254.54	8.20	8.68	992.35	43.80	13.35	570.31
	10:00:00 AM	6.80	2.07	1254.54	8.14	8.62	978.32	43.00	13.11	532.51
	11:00:00 AM	6.90	2.10	1261.14	8.06	8.54	959.77	42.60	12.99	514.04
	12:00:00 PM	7.00	2.13	1266.96	8.00	8.48	945.98	42.40	12.93	504.91
	1:00:00 PM	7.00	2.13	1266.96	7.96	8.44	936.84	42.20	12.87	495.86
	2:00:00 PM	7.10	2.16	1272.00	7.90	8.38	923.22	42.50	12.96	509.47
	3:00:00 PM	7.05	2.15	1269.58	7.86	8.34	914.20	42.90	13.08	527.87
	4:00:00 PM	6.95	2.12	1264.15	7.80	8.28	900.76	43.20	13.17	541.85
	5:00:00 PM	6.80	2.07	1254.54	7.79	8.27	898.53	43.45	13.25	553.63
	6:00:00 PM	6.70	2.04	1247.17	7.68	8.16	874.18	43.65	13.31	563.14
	7:00:00 PM	6.55	2.00	1234.65	7.75	8.23	889.64	43.70	13.32	565.53
	8:00:00 PM	6.50	1.98	1230.09	7.73	8.21	885.21	43.60	13.29	560.76
	9:00:00 PM	6.35	1.94	1215.24	7.70	8.18	878.58	43.50	13.26	556.00
	10:00:00 PM	6.25	1.91	1204.36	7.66	8.14	869.79	43.20	13.17	541.85
	11:00:00 PM	6.30	1.92	1209.90	7.60	8.08	856.69	42.95	13.09	530.19
	12:00:00 AM	6.35	1.94	1215.24	7.55	8.03	845.86	42.60	12.99	514.04
2016.5.22	1:00:00 AM	6.35	1.94	1215.24	7.49	7.97	832.95	42.25	12.88	498.12
	2:00:00 AM	6.35	1.94	1215.24	7.44	7.92	822.27	42.01	12.81	487.32
	3:00:00 AM	6.35	1.94	1215.24	7.57	8.05	850.18	41.60	12.68	469.13
	4:00:00 AM	6.35	1.94	1215.24	7.37	7.85	807.44	41.30	12.59	456.00
	5:00:00 AM	6.30	1.92	1209.90	7.30	7.78	792.76	41.00	12.50	443.04
	6:00:00 AM	6.25	1.91	1204.36	7.25	7.73	782.35	40.90	12.47	438.75
	7:00:00 AM	6.00	1.83	1173.78	7.10	7.58	751.57	40.40	12.32	417.60
	8:00:00 AM	5.80	1.77	1145.81	7.10	7.58	751.57	40.20	12.26	409.26
	9:00:00 AM	5.70	1.74	1130.65	7.02	7.50	735.42	39.85	12.15	394.85
	10:00:00 AM	5.50	1.68	1098.02	6.87	7.35	705.64	39.65	12.09	386.71
	11:00:00 AM	5.50	1.68	1098.02	6.82	7.30	695.85	39.55	12.06	382.67
	12:00:00 PM	5.60	1.71	1114.73	6.75	7.23	682.27	39.40	12.01	376.64
	1:00:00 PM	5.60	1.71	1114.73	6.67	7.15	666.93	39.35	12.00	374.64
	2:00:00 PM	5.70	1.74	1130.65	6.60	7.08	653.65	39.25	11.97	370.65
	3:00:00 PM	5.65	1.72	1122.79	6.52	7.00	638.65	39.15	11.94	366.68
	4:00:00 PM	5.55	1.69	1106.47	6.46	6.94	627.53	39.10	11.92	364.70
	5:00:00 PM	5.30	1.62	1062.27	6.40	6.88	616.50	39.00	11.89	360.76
	6:00:00 PM	5.10	1.55	1023.42	6.33	6.81	603.77	39.00	11.89	360.76
	7:00:00 PM	4.90	1.49	981.45	6.26	6.74	591.18	38.85	11.84	354.88
	8:00:00 PM	4.70	1.43	936.37	6.20	6.68	580.50	38.85	11.84	354.88
	9:00:00 PM	4.55	1.39	900.52	6.13	6.61	568.18	38.75	11.81	350.98
	10:00:00 PM	4.45	1.36	875.65	6.07	6.55	557.72	38.85	11.84	354.88
	11:00:00 PM	4.45	1.36	875.65	6.00	6.48	545.66	38.80	11.83	352.93
	12:00:00 AM	4.50	1.37	888.18	5.95	6.43	537.13	38.55	11.75	343.24

Annex : Page V

Date	Time	Ho= 0 mMSL			Ho = 0 m MSL			Ho= 6.5 mMSL		
		Nagalagam Street			Hanwella			Glencourse		
		WL ft	WL mMSL	Q cumec	WL m	WLmMSL	Q Cumec	WL ft	WL mMSL	Q Cumec
2016.5.23	1:00:00 AM	4.55	1.39	900.52	5.90	6.38	528.67	38.35	11.69	335.56
	2:00:00 AM	4.60	1.40	912.66	5.89	6.37	526.98	38.25	11.66	331.76
	3:00:00 AM	4.65	1.42	924.61	5.75	6.23	503.72	38.15	11.63	327.97
	4:00:00 AM	4.55	1.39	900.52	5.69	6.17	493.92	38.00	11.59	322.31
	5:00:00 AM	4.35	1.33	850.00	5.61	6.09	481.02	37.90	11.55	318.57
	6:00:00 AM	4.10	1.25	782.47	5.55	6.03	471.47	37.50	11.43	303.77
	7:00:00 AM	3.85	1.17	710.08	5.50	5.98	463.58	37.60	11.46	307.44
	8:00:00 AM	3.70	1.13	664.31	5.45	5.93	455.77	37.55	11.45	305.60
	9:00:00 AM	3.60	1.10	632.83	5.36	5.84	441.89	37.55	11.45	305.60
	10:00:00 AM	3.63	1.11	642.36	5.28	5.76	429.75	37.48	11.43	303.03
	11:00:00 AM	3.65	1.11	648.67	5.24	5.72	423.75	37.40	11.40	300.11
	12:00:00 PM	3.80	1.16	695.02	5.18	5.66	414.84	37.55	11.45	305.60
	1:00:00 PM	4.00	1.22	754.10	5.13	5.61	407.49	37.65	11.48	309.28
	2:00:00 PM	4.10	1.25	782.47	5.08	5.56	400.21	37.75	11.51	312.98
	3:00:00 PM	4.20	1.28	810.06	5.04	5.52	394.44	37.80	11.52	314.84
	4:00:00 PM	4.10	1.25	782.47	5.01	5.49	390.14	37.85	11.54	316.70
	5:00:00 PM	3.90	1.19	724.95	4.99	5.47	387.29	37.90	11.55	318.57
	6:00:00 PM	3.80	1.16	695.02	4.98	5.46	385.87	37.90	11.55	318.57
	7:00:00 PM	3.30	1.01	533.72	4.97	5.45	384.45	37.90	11.55	318.57
	8:00:00 PM	3.10	0.95	463.75	4.96	5.44	383.03	37.80	11.52	314.84
	9:00:00 PM	3.00	0.91	427.60	4.04	5.42	380.92	37.85	11.54	316.70
	10:00:00 PM	2.70	0.82	314.49	4.90	5.38	374.60	37.85	11.54	316.70
	11:00:00 PM	2.85	0.87	371.92	4.87	5.35	370.43	37.85	11.54	316.70
	12:00:00 AM	2.80	0.85	352.97	4.82	5.30	363.52	37.70	11.49	311.13
2016.5.24	1:00:00 AM	2.75	0.84	333.83	4.80	5.28	360.78	37.45	11.42	301.94
	2:00:00 AM	2.85	0.87	371.92	4.75	5.23	353.98	37.45	11.42	301.94
	3:00:00 AM	3.15	0.96	481.53	4.70	5.18	347.25	37.50	11.43	303.77
	4:00:00 AM	3.30	1.01	533.72	4.65	5.13	340.59	37.40	11.40	300.11
	5:00:00 AM	3.10	0.95	463.75	4.63	5.11	337.95	37.35	11.39	298.29
	6:00:00 AM	2.90	0.88	390.68	4.60	5.08	334.00	37.20	11.34	292.85
	7:00:00 AM	2.80	0.85	352.97	4.58	5.06	331.39	37.10	11.31	289.25
	8:00:00 AM	2.50	0.76	235.19	4.55	5.03	327.49	37.00	11.28	285.67
	9:00:00 AM	2.40	0.73	194.38	4.52	5.00	323.61	36.90	11.25	282.10
	10:00:00 AM	2.40	0.73	194.38	4.48	4.96	318.49	36.90	11.25	282.10
	11:00:00 AM	2.60	0.79	275.23	4.45	4.93	314.67	36.90	11.25	282.10
	12:00:00 PM	2.85	0.87	371.92	4.41	4.89	309.63	37.00	11.28	285.67
	1:00:00 PM	3.10	0.95	463.75	4.38	4.86	305.88	37.10	11.31	289.25
	2:00:00 PM	3.40	1.04	567.53	4.35	4.83	302.15	37.15	11.33	291.05
	3:00:00 PM	3.55	1.08	616.80	4.32	4.80	298.45	37.20	11.34	292.85
	4:00:00 PM	3.55	1.08	616.80	4.30	4.78	295.99	37.25	11.36	294.66
	5:00:00 PM	3.40	1.04	567.53	4.28	4.76	293.55	37.30	11.37	296.47
	6:00:00 PM	3.10	0.95	463.75	4.30	4.78	295.99	37.30	11.37	296.47
	7:00:00 PM	2.75	0.84	333.83	4.30	4.78	295.99	37.45	11.42	301.94
	8:00:00 PM	2.40	0.73	194.38	4.28	4.76	293.55	37.40	11.40	300.11
	9:00:00 PM	2.25	0.69	131.70	4.26	4.74	291.12	37.35	11.39	298.29
	10:00:00 PM	2.15	0.66	88.94	4.24	4.72	288.70	37.45	11.42	301.94
	11:00:00 PM	2.20	0.67	110.41	4.21	4.69	285.10	37.50	11.43	303.77
	12:00:00 AM	2.35	0.72	173.68	4.19	4.67	282.71	37.50	11.43	303.77
Average Q				965.10			913.94			889.93
Max Q				1285.83			1470.15			1991.34
Fllod Volume MCM (for 10 days)				833.85			789.65			768.90
Catchment km^2				2085			1782			1463
Total RF (8 day)				558.9			607.5			669.1
RF volume				1165.31			1082.57			978.89
RF/Runoff Ratio (approximate)				0.72			0.73			0.79

Flood Forecasting Model for the Kelani River with HEC HMS software

Flood Forecasting Model for the Kalani River with HEC HMS Software

Eng. Ms P. Hettiarachchi (Director Hydrology) & Eng. Kasun Bandara Udowita,
Hydrology Division,
Irrigation Department, Colombo, Sri Lanka.

Abstract

Kelani River basin is subjected to frequent floods due to heavy rainfall in the upper catchment. The lower basin of the river is highly developed and densely populated. Therefore, the floods are normally associated with loss of properties and heavy damages to the infrastructure facilities. A significant portion of those losses and damages can be avoided by implementing an effective early warning system. Effectiveness of a flood warning system depends not only upon the accuracy of the forecast but also on the length of lead time.

Flood forecasting and early warning has been practiced for the Kelani River for decades using conventional flood routing methods and mathematical models. However, those forecasting methods have not been developed up to the standard expected by the present society.

Hydrodynamic model, using MIKE 11 software, has been developed for the river reach from Glencourse (Awissawella) to sea outfall. Glencourse hydrometric station was taken as the upstream boundary for the model since river cross sections were not available beyond that point. However the flood prone area of the river goes several kilometers upstream beyond Avissawella inundating the lowlands adjacent to river. Therefore the model developed cannot be used for flood forecasting for the upper portion of the floodplain. Even the lead time provided for the lower reach is not sufficient to evacuate the people and valuables before flooded. Therefore adopting Rainfall Runoff model, which could provide longer lead time, is very important for the Kelani basin.

The objective of this attempt is to validate HEC HMS hydrological model for the Kelani River in order to introduce more effective flood warning system. The outcome of the work is highly encouraging and it can be improved further by using the 'real time data collection and transmission system', being developed under the 'Hydro-Meteorological Information System' (HMIS), Component II of 'Dam Safety and Water Resources Planning' (DSWRP) project.

1. River Basin Information

The Kelani is one of 103 major river systems in Sri Lanka. It takes the seventh place in respect of its extent of watershed, 2340 km^2, [1]. However, it becomes third with respect to water resources aspect (4225 MCM average annual discharge) due to abundant rainfall in the catchment.

The river originates from the central hills near Adam's peak and traverses about 145 km through the south-western slopes of the Island to reach the sea near Colombo.

The Kelani catchment is entirely situated in the wet-zone of the country. The average annual rainfall of the catchment varies from 5700 mm in the upper catchment to 2300 mm in the lower basin. Major portion of the rainfall is received during the south-west monsoon period. However the catchment remains wet throughout the year since it receives considerable amounts of rainfall during the North-East monsoon and inter-monsoonal periods.

Owing to the heavy rainfall and the steep terrain of the upper catchment, the lower basin of the Kelani River is subjected to heavy floods. The Flood plain is formed below Glencourse gorge which is about 52 km upstream of the sea outfall. Below Hanwella (about 35 km from sea), the flood plain becomes wider following the flat landscape.

The heaviest flood in the Kelani basin (for last 50 years) was recorded in May 1989.

2. Storage Reservoirs on the Kelani River

The Kelani River starts at the confluence of two tributaries Kehelgamu Oya and Maskeli Oya at an elevation of 2398 m MSL. These two tributaries contribute to a significant part of hydroelectric production

of Sri Lanka by housing two major reservoirs (Maussakele and Castlereigh), three ponds (Noorten, Canyon, Laksapana) and five power stations. Castlereagh and Norton have been constructed across Kehelgamu Oya while Maussakele, Canyon and Laxapana were constructed on the Maskeli Oya. In the lower reaches, some more tributaries connect to the Kelani River, out of which the most significant are Wee Oya at Yatiyantota, Gurugoda Oya at Ruwanwella and Seethawaka Ganga at Avissawella. So far there are no storage reservoirs constructed on those tributaries [2].

The Wak Oya connects to the Kelani River further downstream where the confluence is situated just above Hanwella hydrometric station. Kalatuwawa and Labugama reservoirs have been constructed on the upper reaches of Wak Oya. Those two reservoirs have been constructed purely for the purpose of domestic water supply to the capital city, Colombo.

2.1 Operational Procedure of Hydropower Complex

Laxapana Hydropower Complex is utilizing water from Castlereigh and Maussakele reservoirs and small ponds to generate electricity at five power stations namely Wimalasurendra, Canyon, Old Laxapana, New Laxapana and Polpitiya. Those power stations have been located to take optimum use of river flows and the potential head of water at different elevations. Total capacity of five reservoirs is about 170 MCM and those reservoirs utilize water from nearly 300 km^2 extent of the Kelani catchment.

2.2 Domestic Water Reservoirs

Two reservoirs, Labugama and Kalatuwawa, constructed on the Wak Oya are used for domestic water supply to Colombo city and suburbs. Total catchment intercepted by two reservoirs is only 23.28 km^2 and the capacity of two reservoirs is 26.5 MCM.

3. Hydrometric Network on the Kelani River

Seven hydrometric Stations on the Kelani River are operated at 1 hr intervals by Hydrology Division. All seven stations are equipped with manual rain gauges which record rainfalls at 3 hour intervals. There are some other rainfall stations located at the upper catchments of the tributaries which record daily rainfalls by different organizations. Locations of all the stations are shown on the River Basin Map (Fig. 1) and some important parameters are tabulated in Table 1.

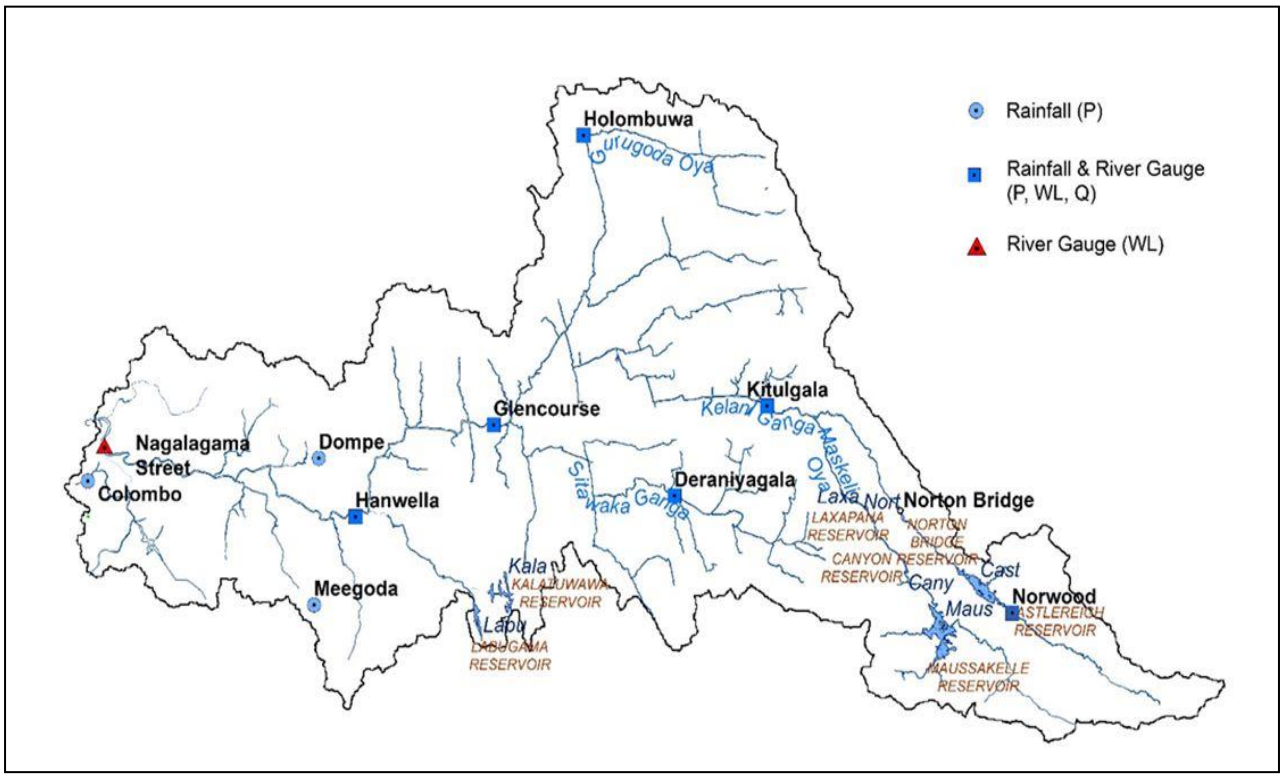


Fig.1. The Kelani River Basin Map

	Station Name	Location (X *Y)	Type of data collected
1	Norwood	182,051*182,230	Record water levels at 1 hour interval and rainfalls at 3 hr interval. Rating curves are available to convert water levels to discharge. All six stations are maintained by the Hydrology Division of Irrigation Department.
2	Holombuwa	143,948*220,765	
3	Kithulgala	160,270*198,922	
4	Deraniyagala	152,036*191,688	
5	Glencourse	135,963*197,396	
6	Hanwella	123,689*189,980	
7	Nortonbridge	172,111*190,453	Record 3 hr Rainfalls by Ceylon Electricity Board
8	Nagalagam Street	101,112*195,586	Hydrology Division records Water Level at 1 hr interval. No discharge data is available.
9	Kenilworth	167,353*199,244	Record daily rainfalls. Stations are maintained by different organizations and private parties (plantations). Long term records are available.
10	Maliboda	161,349*187,538	
11	Yataderiya	199,248*202,424	
12	Dunadin	144,816*204,234	
13	Digalla	148,288*194,152	
14	Neluwaththuduwa	129,016*190,713	
15	Labugama	134,228*183,050	
16	Kotiyagala	189,565*176,088	
17	Maussakele	175,102*182,647	

Table 1: Hydrometric Stations on the Kelani River

4. Hydro-meteorological Data Used for model Calibration

HEC HMS software is a Rainfall Runoff model which uses rainfall data as the input and the stream flows as the output. A sufficient number of rainfall stations, fairly well distributed over the catchment, could be found to get rainfall data. However, only seven stations record data at small (3 hour) time intervals while the others record rainfalls at 24 hour intervals. The time of recording daily rainfalls were also vary between 8.00 to 9.00 hours. Therefore it should be noticed that there are some discrepancies of the input data to the model.

Hydrology Division maintains 7 hydrometric stations on the river and rating curves are available for 6 stations. A rating curve has not been developed for the lowermost station, Nagalagam Street, where it is not possible to develop unique relationship between river stage and discharge due to tidal influence.

4.1 Data Periods used for Model Calibration and Verification

Out of the long records of data available, two flood events occurred in 2008 (From 24/4/2008 to 8/5/2008) and 2011 (26/5/2011 to 5/6/2011) were selected for model calibration and verification. Both events record fairly high floods throughout the catchment. Total rainfalls recorded during the periods are tabulated in Table 2. In both events, Kenilworth recorded the highest rainfall and the 2011 event was comparatively high.

	Calibration Period		Verification Period	
	24/4/2008, 9 am -8/5/2008, 9 am		26/5/2011, 9 am - 5/6/2011, 9 am	
Station Name	Interval hr	Total RF mm	Interval hr	Total RF mm
Kenilworth	24	615.0	24	1046.8
Maliboda	24	399.5	24	831.1
Yataderiya	24	279.0	24	541.0
Dunadin	24	520.1	24	591.3
Digalla	24	245.9	24	529.1
Neluwaththuduwa	24	473.9	3	162.3
Labugama	24	326.1	24	387.1
Kotiyagala	24	251.4	24	88.4
Maussakele	24	266.8	24	197.7
Noorwood	24	283.5	3	161.5
Norton Bridge	3	510.6	3	646.5
Holombuwa	3	237.0	3	422.4
Kithulgala	3	384.3	3	728.6
Deraniyagala	3	272.8	3	503.2
Glencourse	3	481.3	3	305.8
Hanwella	3	385.4	3	202.2
Average		370.8		459.1

Table 2 : Rainfall events used for model calibration and verification.

Total record of rainfalls used for model calibration and verification are tabulated in the **Annex I**. Water level and discharge records with respect to all hydrometric stations (at 1 hr interval) were available for both events and the total data set is given in the **Annex II**.

5. HEC HMS Model Structure

HEC HMS software is suitable for simulating river flows in complex river systems with several sub-catchments, reservoirs, reaches and sources etc. taking rainfall as the primary input. The Kelani basin is having a number of operating tanks which influence the river flows from sub catchments as mentioned in the previous chapters. Out of them Castlereigh and Maussakele reservoirs have significant influence on the flows from the uppermost tributaries, Kehelgamu Oya and Maskeli Oya. Secondly the operational procedure of the hydroelectric system is rather complex due to the diversions of water among sub systems causing uncountable delays and losses. Further it is difficult to get real time data on the water releases from those reservoirs in order to operate real time flood forecasting model.

Estimation of spillway discharges is also difficult due to complexity of operation procedures of control gates and flash boards (used to increase storage capacities) of those reservoirs. Such complex situations cannot be modeled by simple software like HEC HMS. In order to avoid such complexities, Kithulgala hydrometric station which is situated at the just downstream of hydropower complex is selected as the upper boundary for the model.

Further, the influence of domestic water reservoirs was also neglected since their capacities and the catchments intercepted are small when comparing to the Kelani Catchment. However these reservoirs may cause to increase the initial losses and the basin time lag of the Hanwella sub-catchment.Based on the above assumptions the basin model of the Kelani flood model was structured as shown in Figure 2.

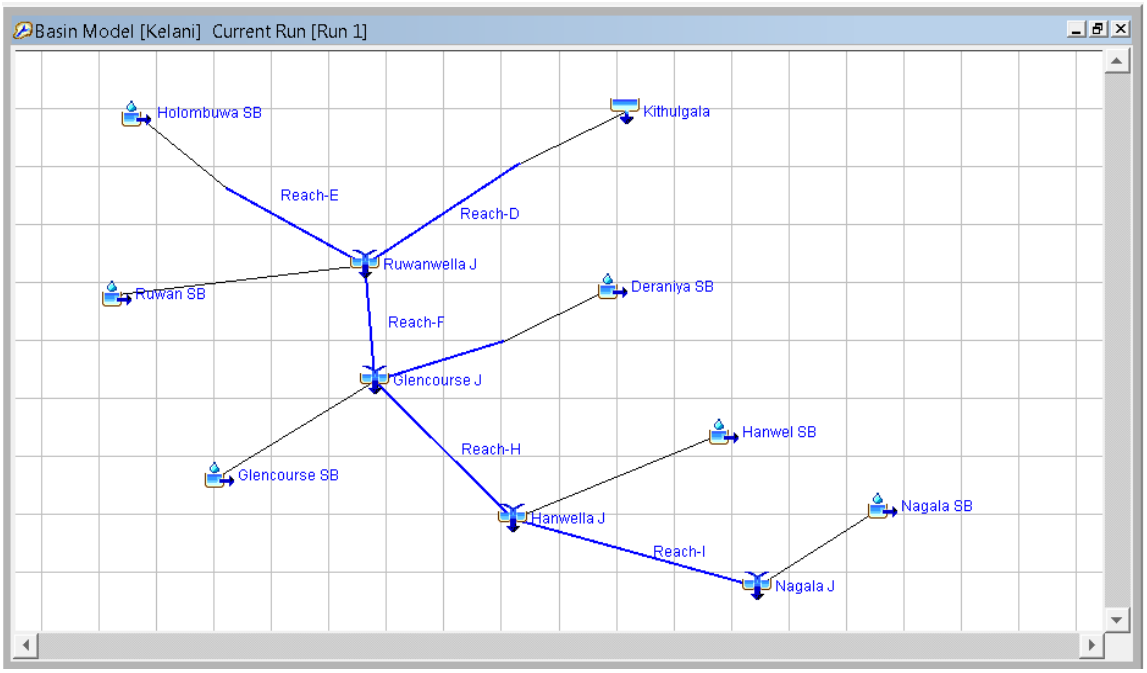


Fig. 2. Kelani Basin Model

Observed river flow data at Holobuwa and Deraniyagala sub catchments and Glencourse and Hanwella junctions, with respect to 2008 flood, were used to calibrate the model parameters.

6. Setting Thiessen Weights

Considering the locations of sub catchments and the layout of rainfall stations, Thiessen weights of each sub-catchment were found from the appropriate methods and tabulated below (Table 3).

Rain Gauging Station	Sub Catchment (Name and Area km^2)					
	Holombuwa (153 km^2)	Ruwanwella (454 km^2)	Deraniyagala (179 km^2)	Glencourse (326 km^2)	Hanwella (304 km^2)	Nagalagam Street (410 km^2)
Kenilworth	-	0.0947	-	-	-	-
Maliboda	-	-	0.6201	0.0123	-	-
Yataderiya	0.6234	0.2357	-	-	-	-
Dunadin	-	0.3347	-	0.1103	-	-
Diggala	-	0.0485	-	0.2730	0.1579	-
Neluwaththuduwa	-	-	-	-	0.2303	0.1634
Labugama	-	-	-	0.089	-	0.0634
Maussakele	-	-	0.0391	-	-	-
Nortonbridge	-	-	0.0391	-	-	-
Holombuwa	0.3766	0.1388	-	-	-	-
Kithulgala	-	0.1256	0.1173	-	-	-
Deraniyagala	-	0.0220	0.1844	0.2577	-	-
Glencourse	-	-	-	0.2577	0.4901	-
Hanwella	-	-	-	-	0.1217	0.7732

Table 3 : Catchment areas and Thiessen weights of sub catchments used for the Basin Model

Depth weights of the sub-catchments were set as shown in Table 3 and appropriate time weights were found by careful inspection of the time distributions of rainfall at each station. Normally the higher weights were given to the stations where the rainfalls are recorded at lesser (3 hr) intervals.

The results of model calibration are discussed in the next chapter.

6. Model Parameters

6.1 Routing parameters for canal reaches

Muskingum method was used for routing flows through the canal reaches. Initially the model parameters were computed by theoretical methods. The technique of curve fitting was used to ajust the parameters. Optimization techniques were also used for fine adjustment of parameters taking peak weighted RMS error as the test statistic. Final values of Muskingum parameters, with respect to all the reaches above Hanwella Junction, are shown in Table 4.

Reach	From … to …	Maskingam K	Maskingam X	No: of sub reaches
Reach D	Kithulgala to Imbulana	10	0.29282	2
Reach E	Hollombuwa to Imbulana	10	0.01389	2
Reach F	Imbulana to Glencourse	15	0	2
Reach G	Deraniyagala to Glencourse	15	0	2
Reach H	Glencourse to Hanwella	14	0	1
Reach I	Hanwella to Nagalagam street	10	0	1

Table 4 : Routing parameters of Reaches

6.2 Loss, Transform and Base Flow parameters for Sub basins.

Initial and constant loss method, SCS unit hydrograph method and base flow recession method were used for all the sub basins and the optimized parameters are given in Table 5.

Sub Basin Name	Loss			Transform	Base Flow		
	Initial mm	Constant mm/hr	Imperviousness %	SCS Lag-min	Initial m^3/sec	Recession constant	Threshold m^3/sec
Holombuwa	40	3.5	0	217.01	0.58	0.24566	35
Ruwanwella	32.458	1.9698	0	286.33	12.178	0.654	49.49
Deraniyagala	22.825	0.5	0	178.33	3	0.6	46.118
Glencourse	20	4	0	450	**6.34**	0.9	22.05
Hanwella	30	4	0	450	20	0.9	40
Nagalagam Street	50	2.5	0	400	50	0.9	100

Table 5 : Calibrated parameters for sub-basins

7. Results of Model Calibration and Verification

Model verification was done using the same parameters with an independent set of data, relevant to 2011 flood, and the results with respect to 4 river gauging points are graphically presented in Fig. 3a, 3b,3c and 3d.

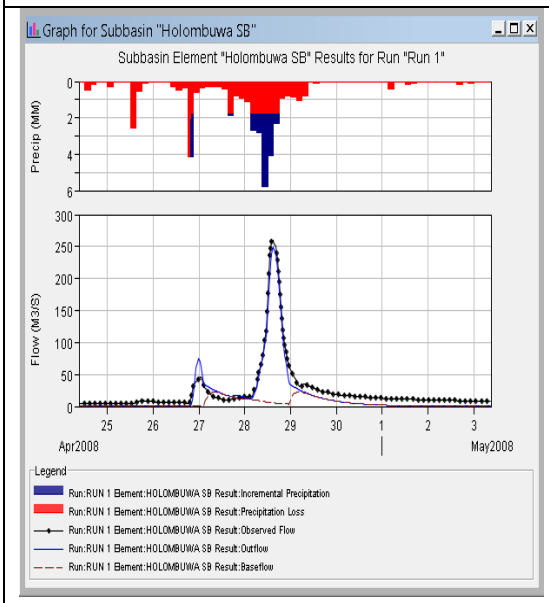
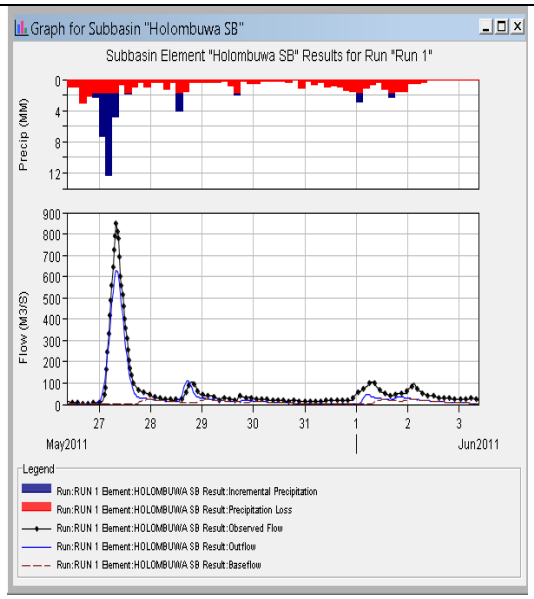
Calibration	Verification
	

Fig 3 a. Results of model calibration and verification, Holombuwa Sub-Catchment

Timing of flood peaks is perfect with both calibration and verification events. The magnitudes of peak discharges in the verification are somewhat under estimated.

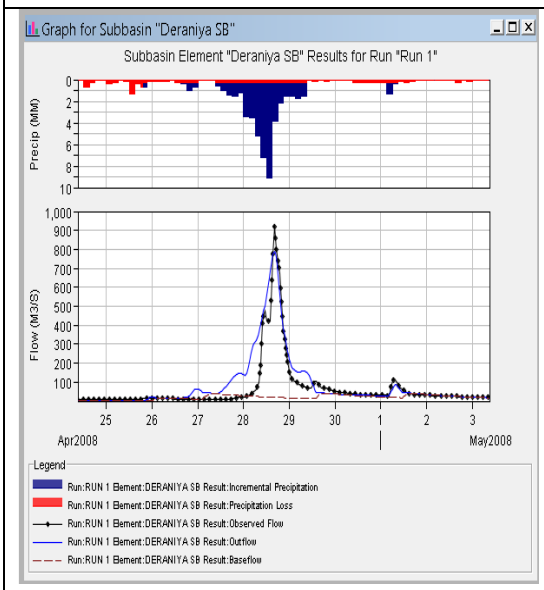
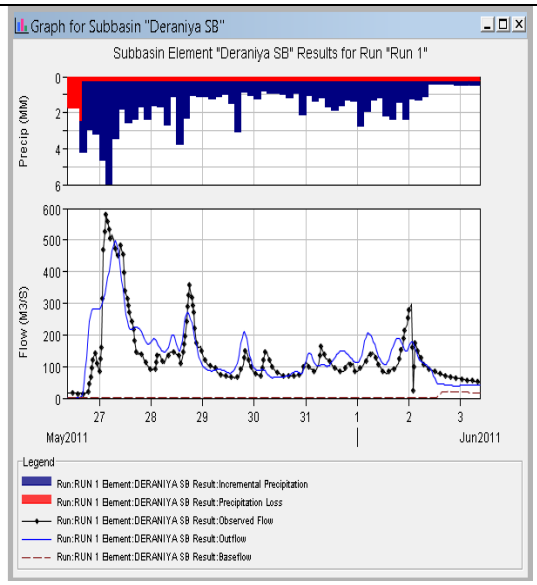
Calibration	Verification
	

Fig 3 b. Results of model calibration and verification, Deraniyagala Sub-Catchment

The results are somewhat poor when comparing with other stations. But the model has captured all the flood peaks with little differences with respect to time and magnitude.

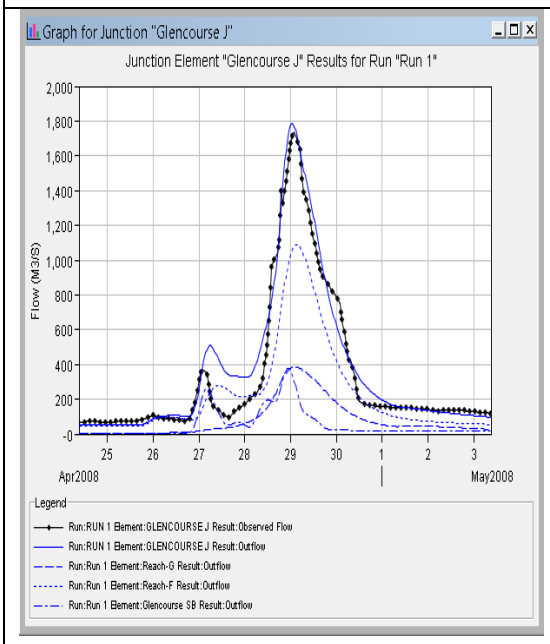
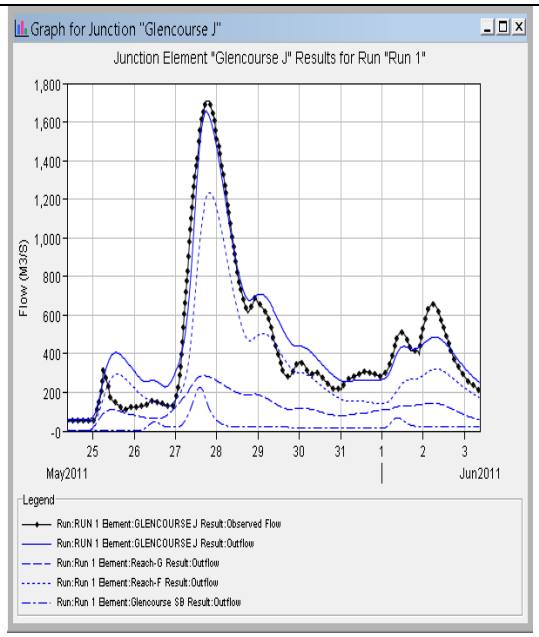
Calibration	Verification
	

Fig 3 c. Results of model calibration and verification, Glencourse Junction

The peak discharge, with respect to time and amount, is perfectly matching with the observed data in both calibration and verification events. However the simulation of low flows is not that perfect.

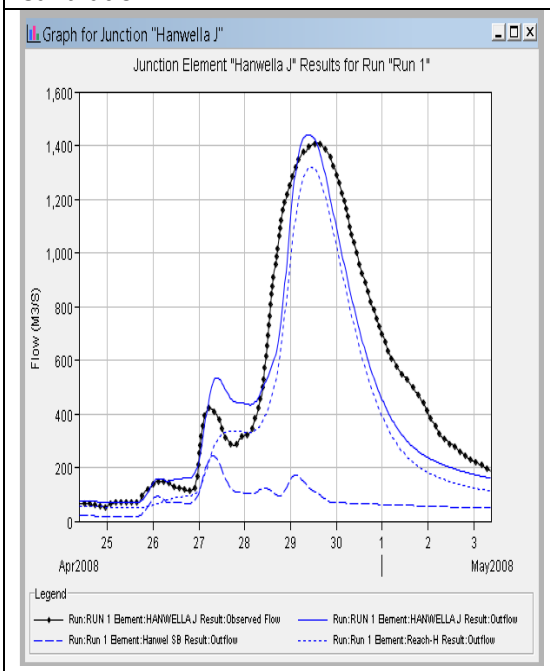
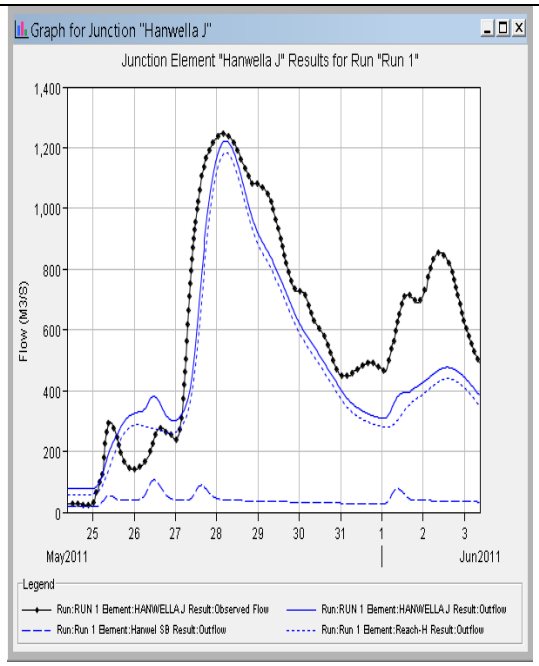
Calibration	Verification
	

Fig 3 d. Results of model calibration and verification, Hanwella Junction

There are some small discrepancies with respect to timing and simulation of flow rates. But the results are generally satisfactory and can be used for flood forecasting with confidence.

Component		Computed	Observed	Error	Error as a % of observed flow
Holombuwa Subbasin	Peak Flow m^3/sec	248.47	259.40	10.93	4.2 %
	Time of peak hr	28/04/2008, 15:00	28/04/2008, 15:00 hrs	0 hr	
Deraniyagala Subbasin	Peak Flow m^3/sec	786.59	920.00	133.41	14.55%
	Time of peak hr	28/04/2008, 16:00	28/04/2008, 16:00 hrs	0 hr	
Glencourse Junction	Peak Flow m^3/sec	1827.72	1733.30	-94.42	5.4%
	Time of peak hr	29/04/2008, 00:30	29/04/2008, 02:00	1.5 hr	
Hanwella Junction	Peak Flow m^3/sec	1405.92	1407.50	1.58	0.1%
	Time of peak hr	29/04/2008, 10.30	29/04/2008, 13:00	2.5 hr	

Table 6 : Results of Model Calibration

Component		Computed	Observed	Error	Error as a % of observed flow
Holombuwa Subbasin	Peak Flow m^3/sec	583.62	846.77	263.15	31.1 %
	Time of peak hr	27/05/2011, 08:00	27/05/2011, 08:00 hrs	0 hr	-
Deraniyagala Subbasin	Peak Flow m^3/sec	469.25	580.00	110.75	19.1%
	Time of peak hr	27/05/2011, 07:30	27/05/2011, 03:00 hrs	-4.5 hr	-
Glencourse Junction	Peak Flow m^3/sec	1655.30	1705.72	50.42	2.9%
	Time of peak hr	27/05/2011, 18:00	27/05/2011, 18:00	0 hr	-
Hanwella Junction	Peak Flow m^3/sec	1222.85	1247.20	24.7	1.9%
	Time of peak hr	28/05/2011, 05.30	28/05/2011, 02:00	-3.5 hr	-

Table 7 : Results of Model Verification

According to above the model performs fairly well with both calibration and verification data sets. Glencourse and Hanwella junctions show better performance when compare to upstream sub catchments, Holombuwa and Deraniyagala. Basin lags (lead times) in the upstream sub catchments are short (217 at Holombuwa and 178 at Deraniyagala) hardly sufficient to issue effective warning. However the flooding in these areas are not much problematic and warning is not that important.

Lower basin (Glencourse, Hanwella and Nagalagam Street) can be issued early warning with stuffiest lead times. However the actual lead time for a particular event is depended upon the temporal and spatial distribution of rainfalls over the catchment. Glencourse floods can be originated from Kithulgala, Deraniyagala or Holombuwa sub- catchments causing different lag times. The floods may be more severe when the entire catchment experiences heavy rains. Depending on the origin of the rainfall, it is possible to analyze lead times for different stations as illustrated in Table 8.

Station	Path	Lead Time in hours	Minimum
Glencourse	From Kitulgala via Ruwanwella	10+15 = 25	18 hours
	From Holombuwa via Ruwanwella	3.6+10+15 = 28.6	
	From Deraniya gala	3+15 = 18	
Hanwella	From Kitulgala via Glencourse	25+14 = 39	32 hours
	From Holombuwa via Glencourse	28.6+14 = 42.6	
	From Deraniyagala via Glencourse	3+15+14 = 32	
Nagalagam Street	From Kitulgala via Glencourse and Hanwella	39+10 = 49	42 hours
	From Holombuwa via Glencourse and Hanwella	42.6+10 = 52.6	
	From Deraniyagala via Glencourse and Hanwella	32+10 = 42	

Table 8 : Minimum lead times to stations with different scenarios

8. Conclusions and Recommendations

The above research reveals that the HEC-HMS software can be used effectively to implement flood forecasting system for the Kelani River Basin. Model calibration and verification were done using the historical data collected for some other purposes. Spatial distribution of rainfall stations is somewhat satisfactory but the time resolution is hardly sufficient to capture the time distribution of rainfalls. This type of drawbacks in the input data may lead to errors in model parameters, particularly with respect to small sub-catchments like Holombuwa and Deraniyagala. However, this can be avoided in future by using the data collected from newly established stations under the Dam safety and Water Resources Planning (DSWRP) Project. The Kelani River basin has been provided with well distributed observation network with continuous data collection and effective system of communication.

HEC HMS software doesn't require river cross sectional data which is not available for most of the river basins. This is an advantage in this type of models. Therefore this model can be adopted for modeling river basins with sufficient number of hydro-meteorological observation stations and effective system of data transmission.

References :

1. **Arumugam, S., Water Resources of Ceylon its Utilization and Development, 1969**
2. **Hydrological Annual, Hydrology Division of Irrigation Department.**