IRRIGATION DEPARTMENT

HYDROLOGICAL ANNUAL 2017/18

Hydrology Division
Irrigation Department
Colombo 07
Sri Lanka

Hydrological Annual 2017/18 – Hydrology Division, Irrigation Department.
59th year of publication

Foreword

It is a great pleasure for me to publish the hydrological Annual 2017/18. As the government institution responsible for collecting, processing and issuing of hydrological data and information of the country, the Hydrology Division(HD) of Irrigation Department has continued this publication since 1960 with immense effort and devotion. Being the 59th volume of the series this bulletin contains the information of long term records of available hydrological data and the data collected during the water year 2017/18.(from October 2017 to September 2018)

During the recent years hydro meteorological network of the country has been upgraded and modernized. Most of the manual data recording stations were automated while introducing new stations at important locations. Total of 106 hydro meteorological stations are maintaining by the Irrigation Department.

Part I and II of this journal provide the general information of the river basins and the salient hydrological features pertaining to the current water year.

Part III of this journal is allocated for the technical papers and research work carried out by the engineers of the Irrigation Department. Three technical papers have been included in this year journal.

The paper “River system of Sri Lanka and the issues related to its sustainability” discussed the sustainability of natural river system. Author emphasized the necessity of safe guarding this system as the primary source of water supply is now under threat due to various human activities.

The paper “Flood Risk Assessment in Gin Ganga Basin” discussed about floods & its risk in Gin Ganga basin. According to the study, expected flood damages in Gin Ganga basin are increasing annually due to the climate change, basin developments and increasing population. Accordingly flood mitigation measures need to be assessed in the basin.

The paper “Impacts of Salinity Barrage in Kelani Ganga for floods” discussed the effects on floods in Kelani Ganga due to the Salinity Barrier at Ambathale. The study concluded that even if the barrier is the most feasible solution for Salinity intrusion, it will effect the floods in kelani Ganga. Also the study recommended to move the water intake to the upstream or find a suitable alternative structural measures to minimize the impact of floods.

Eng. (Mrs.) R.M.M.R. Alawathugoda,
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	-	$\frac{\text{Yield (MCM)}}{\text{Catchment Area (Sq.Kms)}}$
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

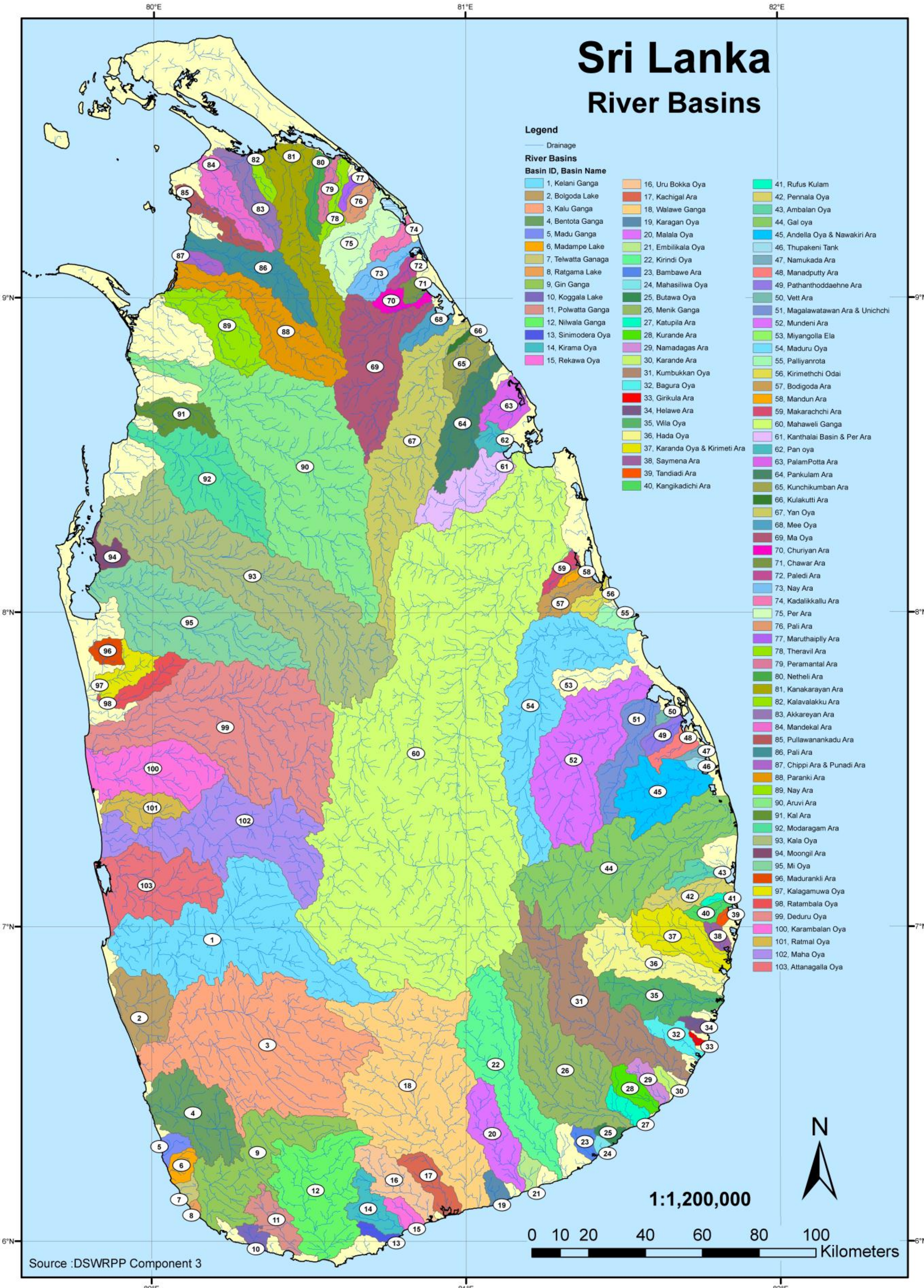
Imperial		Metric / SI
1 cubic foot per second (cusec)		28.317 l/s
1 cusec during 1 day	= 1.983 acre.ft	2,446.57 m^3
1 acre.foot		1,234 m^3
1 acre.foot/day		14.28 l/s = 1234 m^3/d
1 acre.inch	= 3.630 ft^3	102.8 m^3

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, Pankulam 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, Maruthaiplly 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, Madurankli 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.km)		River Name	Drainage Area (Sq.km)
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

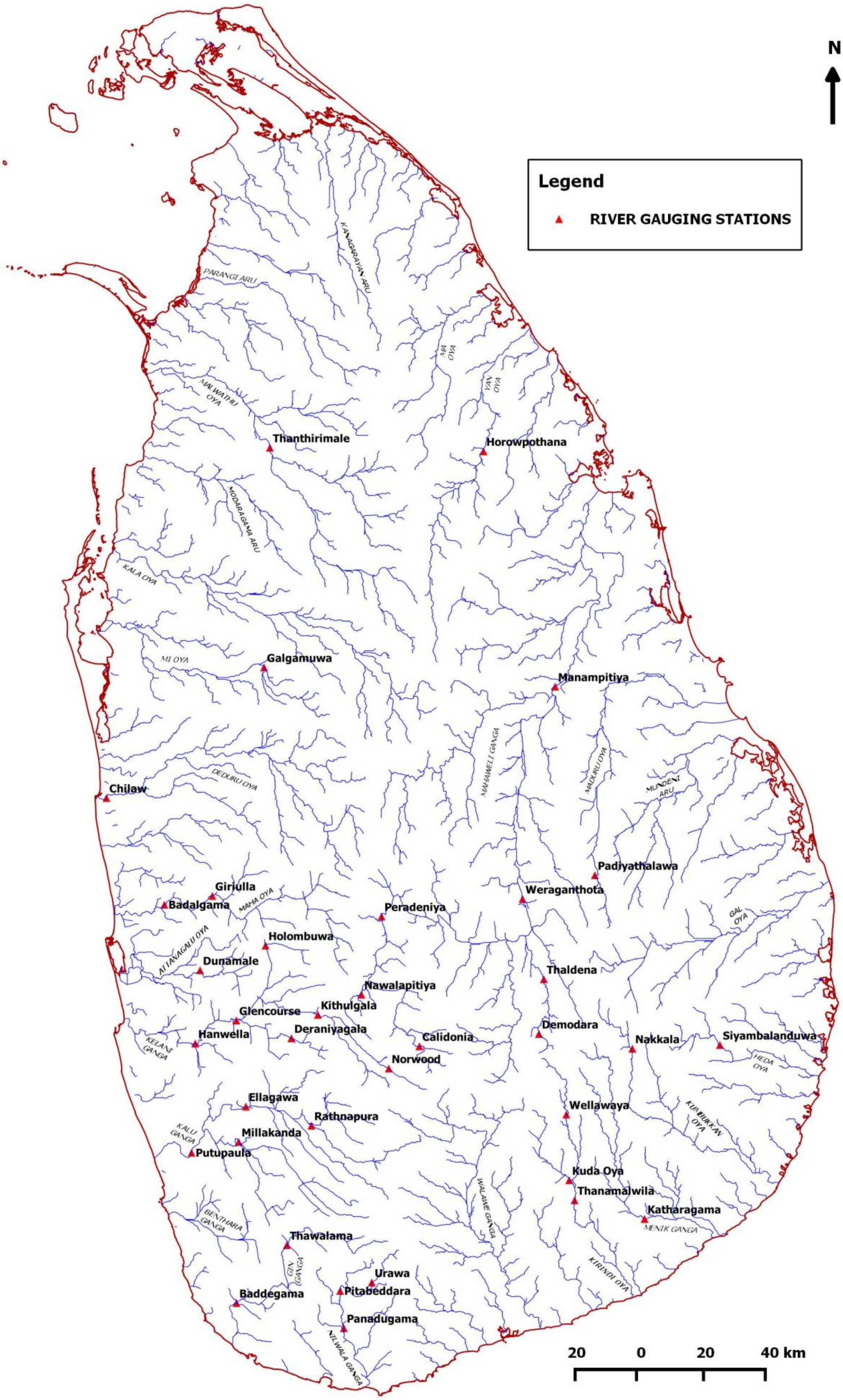
81	Kanakarayan Aru	604
82	Kalwalappu Aru	68
83	Akkarayan Aru	244
84	Mandekal Aru	208
85	Pallavarayan Kaddu Aru	311
86	Pali Aru	451
87	Chappi Aru	79
88	Parangi Aru	770
89	Nay Aru	717
90	Aruvi Aru	3291
91	Kal Aru	210
92	Moderagama Aru	1001
93	Kala Oya	2526
94	Moongil Aru	78
95	Mee Oya	1555
96	Madurankuli 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 - 2017/18
(According to River Basin)

Name of Station	River Basin	Coordinates	Catchment Area (Sq.Km)
1. Norwood	Kelani Ganga	(6°50’22’’N, 80°36’42’’E)	97
2 . Kithulgala	Kelani Ganga	(6°59’26’’N, 80°24’44’’E)	383
3 . Deraniyagala	Kalani Ganga	(6°55’28’’N, 80°20’16’’E)	183
4. Holombuwa	Kelani Ganga	(7°11’07’’N, 80°15’53’’E)	155
5. Glencourse	Kelani Ganga	(6°58’28’’N, 80°10’58’’E)	1463
6. Hanwella	Kelani Ganga	(6°54’34’’N, 80°04’46’’E)	1782
7. Rathnapura	Kalu Ganga	(6°40’42’’N, 80°23’39’’E)	603
8. Ellagawa	Kalu Ganga	(6°43’55’’N, 80°12’36’’E)	1393
9. Millakanda	Kalu Ganga	(6°37’56’’N, 80°11’23’’E)	780
10. Putupaula	Kalu Ganga	(6°36’06’’N, 80°03’26’’E)	2598
11. Baddegama	Gin Ganga	(6°10’26’’N, 80°10’31’’E)	749
12. Thawalama	Gin Ganga	(6°20’31’’N, 80°19’49’’E)	377
13. Urawa	Nilwala Ganga	(6°14’12’’N, 80°34’18’’E)	59
14. Pitabeddara	Nilwala Ganga	(6°12’47’’N, 80°28’31’’E)	310
15. Panadugama	Nilwala Ganga	(6°06’30’’N, 80°28’40’’E)	445
16. Wellawaya	Kirindi Oya	(6°42’35’’N, 81°06’40’’E)	172
17. Thanamalwila	Kirindi Oya	(6°28’06’’N, 81°08’03’’E)	749
18. Kuda Oya	Kirindi Oya	(6°31’29’’N, 81°07’24’’E)	291
19. Katharagama	Menik Ganga	(6°24’56’’N, 81°19’51’’E)	787
20. Nakkala	Kumbukkan Oya	(6°53’42’’N, 81°17’49’’E)	216
21. Siyambalanduwa	Heda Oya	(6°54’18’’N, 81°32’36’’E)	295
22. Padiyathalawa	Maduru Oya	(7°23’01’’N, 81°11’31’’E)	159
23. Demodara	Mahaweli Ganga	(6°56’12’’N, 81°02’03’’E)	78
24. Thaldena	Mahaweli Ganga	(7°05’27’’N, 81°02’53’’E)	276
25. Calidonia	Mahaweli Ganga	(6°54’07’’N, 80°41’52’’E)	148
26. Nawalapitiya	Mahaweli Ganga	(7°02’51’’N, 80°32’04’’E)	176
27. Peradeniya	Mahaweli Ganga	(7°16’03’’N, 80°36’30’’E)	1168
28. Weraganthota	Mahaweli Ganga	(7°19’00’’N, 80°59’18’’E)	4092
29. Manampitiya	Mahaweli Ganga	(7°54’53’’N, 81°05’10’’E)	7418
30. Horowpothana	Yan Oya	(8°34'39"N, 80°52'43"E)	720
31. Thanthirimale	Malwathu Oya	(8°35'14"N, 80°16'31"E)	2116
32. Galgamuwa	Mee Oya	(7°58’07’’N, 80°15’34’’E)	299
33. Chilaw	Deduru Oya	(7°36’01’’N, 79°48’57’’E)	2610
34. Giriulla	Maha Oya	(7°19’30’’N, 80°06’53’’E)	1192
35. Badalgama	Maha Oya	(7°18’00’’N, 79°58’47’’E)	1360
36. Dunamale	Aththanagalu Oya	(7°06’56’’N, 80°04’50’’E)	153

LOCATIONS OF HYDROMETRIC STATIONS



PART II

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

RAINFALL

MONTHLY RAINFALL AT THE PRINCIPAL STATIONS OF METEOROLOGY DEPARTMENT

(In mm)

Upper line : Current year 2017/18

Lower line: Long term average from 1970/71 to 2016/17

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
Anuradhapura	224	421	74	19	18	59	149	225	2	0	26	89	815	491	1306
(8°21'00''N, 80°22'48''E)	246	248	205	82	55	69	166	92	14	27	36	73	905	409	1314
Badulla	262	265	346	86	72	122	250	309	17	74	20	137	1153	809	1962
(6°58'48''N, 81°03'00''E)	239	269	273	176	92	103	188	108	36	65	69	123	1152	590	1741
Bandarawela	356	373	273	49	18	200	165	320	32	44	105	262	1269	927	2197
(6°48'36''N, 80°57'36''E)	249	242	189	110	67	100	172	111	53	59	56	132	957	584	1541
Batticaloa	215	417	147	25	214	133	73	66	50	6	122	9	1150	327	1477
(7°42'36''N, 81°42'00''E)	175	361	426	240	126	74	52	46	32	34	42	71	1402	276	1678
Colombo	467	294	172	46	109	69	265	422	156	69	64	264	1157	1239	2396
(6°54'00''N, 79°51'36''E)	334	338	158	69	69	118	241	320	201	117	104	230	1087	1213	2299
Galle	286	549	75	11	129	120	170	530	137	132	106	230	1170	1304	2474
(6°01'48''N, 80°13'12''E)	317	306	173	88	67	93	219	288	197	155	157	248	1044	1263	2307
Hambantota	76	274	161	23	6	93	94	131	42	13	19	54	633	352	985
(6°07'12''N, 81°07'48''E)	126	211	124	65	42	58	92	84	48	34	52	75	626	385	1011
Jaffna	184	612	101	15	21	49	19	103	22	0	27	63	980	233	1214
(9°40'47''N, 80°01'48''E)	235	376	257	73	35	35	59	61	19	26	51	62	1010	279	1290
Katugastota	288	197	106	20	40	43	216	345	139	48	181	158	694	1086	1780
(7°19'48''N, 80°37'48''E)	276	291	196	97	70	92	187	142	132	123	100	137	1021	821	1843
Katunayaka	418	313	83	24	26	59	269	332	147	35	49	43	922	875	1798
(7°10'12''N, 79°52'48''E)	350	312	129	49	65	119	207	288	162	85	95	194	1025	1030	2056
Kurunegala	367	115	156	6	15	148	179	653	160	45	71	121	808	1227	2035
(7°27'36''N, 80°22'12''E)	350	315	149	67	70	140	273	193	142	98	86	148	1090	940	2030

MONTHLY RAINFALL AT THE PRINCIPAL STATIONS OF METEOROLOGY DEPARTMENT

(in mm)

Upper line : Current year 2017/18

Lower line : Long term average from 1970/71 to 2016/17

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
Mahailluppallama	160	234	164	18	20	68	177	447	19	1	31	129	664	804	1468
(8°07’12’’N, 80°27’36’’E)	251	263	196	85	70	70	176	102	15	29	37	94	935	452	1388
Mannar	126	226	29	65	2	23	48	81	0	0	0	21	471	150	621
(8°58’48’’N, 79°54’36’’E)	157	268	200	50	42	44	89	56	8	13	11	49	761	226	987
Monaragala *	263	240	240	100	52	152	139	250	20	108	54	127	1046	699	1745
(6°51’36’’N, 81°21’00’’E)	241	237	231	131	110	135	184	145	29	49	97	70	1085	573	1658
Nuwara Eliya	208	290	156	95	57	79	216	363	126	172	265	157	885	1298	2184
(6°57’36’’N, 80°45’36’’E)	235	224	186	114	67	69	133	172	182	171	139	168	896	965	1861
Polonnaruwa *	283	214	151	19	153	135	80	114	3	1	127	105	954	429	1383
(7°54’36’’N, 81°01’48’’E)	310	348	467	250	152	89	102	114	5	33	53	90	1615	397	2013
Potuvil *	132	375	199	129	92	200	106	14	20	5	31	41	1127	217	1344
(6°52’48’’N, 81°49’48’’E)	129	272	308	290	136	79	71	53	12	16	22	55	1214	229	1443
Puttalam	147	193	98	12	38	13	290	390	57	1	0	18	501	756	1256
(8°01’48’’N, 79°49’48’’E)	223	257	136	53	41	64	163	101	33	21	18	67	774	402	1175
Rathmalana	538	248	134	10	86	114	249	313	199	89	85	199	1130	1133	2263
(6°48’36’’N, 79°52’48’’E)	361	357	166	72	67	117	266	324	201	121	116	248	1139	1276	2415
Rathnapura	512	509	243	14	92	185	394	586	468	161	185	285	1555	2079	3634
(6°40’48’’N, 80°24’00’’E)	448	370	224	121	138	211	361	457	414	291	286	384	1512	2194	3706
Trincomalee	277	511	143	12	208	15	51	298	92	18	85	26	1166	571	1737
(8°34’48’’N, 81°15’60’’E)	207	359	332	138	90	49	51	66	28	60	79	118	1175	402	1577
Vauniya	198	224	60	28	18	123	111	245	1	16	45	124	650	541	1192
(8°46’00’’N, 80°30’00’’E)	225	275	248	96	70	58	132	87	18	43	52	100	972	432	1404

Note :- ‘ *’ Denotes Long term average less than specified above. ‘NEM’ denotes North-East Monsoon. ‘SWM’ denotes South-West Monsoon.

MONTHLY RAINFALL AT THE GAUGING STATIONS OF IRRIGATION DEPARTMENT

(In mm)

Upper line : Current year 2017/18

Lower line: Long term average from 1989/90 to 2016/17

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
Badalgama	291	217	77	88	62	6	286	567	194	34	27	64	741	1172	1913
(7°18'00''N, 79°58'47''E)	336	254	126	49	57	87	197	224	149	76	101	173	909	920	1829
Calidonia	237	192	151	27	91	137	255	327	278	211	430	186	835	1687	2522
(6°54'07''N, 80°41'52''E)	300	281	135	81	75	123	241	214	252	228	194	160	995	1290	2285
Deraniyagala	813	421	251	28	392	397	647	1501	852	250	236	247	2302	3734	6035
(6°55'28''N, 80°20'16''E)	561	399	174	105	115	233	438	568	457	340	308	435	1587	2546	4134
Dunamale *	444	340	167	112	105	81	389	792	208	53	52	159	1247	1653	2900
(7°06'56''N, 80°04'50''E)	453	318	181	57	68	178	307	399	234	125	142	288	1254	1495	2749
Ellagawa *	750	567	155	48	217	181	358	731	334	109	118	349	1918	2000	3918
(6°43'55''N, 80°12'36''E)	407	374	166	111	134	219	368	439	318	216	275	389	1411	2005	3416
Galgamuwa	65	168	107	12	14	65	159	178	91	4	46	117	431	594	1025
(7°58'07''N, 80°15'34''E)	229	253	195	74	50	84	227	101	21	23	43	73	886	489	1375
Glencourse *	602	506	301	80	233	174	629	665	377	122	130	220	1894	2142	4036
(6°58'28''N, 80°10'58''E)	506	470	213	105	118	286	394	456	331	215	240	331	1698	1968	3665
Hanwella *	479	298	92	33	108	63	281	382	275	82	79	137	1073	1235	2308
(6°54'34''N, 80°04'46''E)	433	369	206	120	100	170	336	393	265	179	185	316	1399	1673	3072
Holombuwa	370	230	112	42	33	151	313	686	320	101	103	221	938	1744	2682
(7°11'07''N, 80°15'53''E)	451	365	188	87	87	191	346	304	255	177	164	251	1370	1498	2868
Horowpothana	272	396	100	19	92	28	2	203	0	18	33	132	906	389	1295
(8°34'39''N, 80°52'43''E)	193	294	331	155	90	45	89	67	16	32	88	88	1108	379	1487
Kithulgala	727	343	218	58	217	328	516	793	805	257	345	344	1892	3059	4951
(6°59'26''N, 80°24'44''E)	601	360	169	93	114	198	422	595	533	445	393	457	1535	2844	4379
Kuda Oya	275	258	290	35	29	116	245	96	4	5	2	292	1002	643	1645
(6°31'29''N, 81°07'24''E)	202	260	152	86	56	98	166	70	11	13	16	47	854	324	1178

MONTHLY RAINFALL AT THE GAUGING STATIONS OF IRRIGATION DEPARTMENT

(in mm)

Upper line : Current year 2017/18

Lower line : Long term average from 1989/90 to 2016/17

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	NEM Total	SWM Total	Annual Total
Nakkala	175	291	229	148	69	172	152	230	10	66	74	185	1084	717	1801
(6°53’42’’N, 81°17’49’’E)	265	358	261	164	122	94	175	109	39	53	92	106	1263	574	1838
Norwood	325	222	170	41	166	282	362	524	325	302	482	226	1207	2221	3427
(6°50’22’’N, 80°36’42’’E)	382	295	152	117	84	183	341	298	333	299	232	217	1213	1720	2932
Padiyathalawa	455	292	187	78	240	130	89	327	18	38	121	29	1382	621	2002
(7°23’01’’N, 81°11’31’’E)	231	369	447	272	157	72	126	89	37	60	99	133	1548	544	2092
Panadugama *	374	523	357	41	210	213	400	397	280	130	123	184	1718	1514	3232
(6°06’30’’N, 80°28’40’’E)	323	306	188	120	130	149	179	328	163	133	179	266	1217	1248	2464
Peradeniya	471	200	212	14	26	60	260	502	243	87	188	246	984	1526	2509
(7°16’03’’N, 80°36’30’’E)	301	260	168	81	61	98	202	181	160	121	100	128	970	891	1861
Putupaula *	502	273	128	42	104	187	544	479	210	51	46	68	1236	1397	2632
(6°36’06’’N, 80°03’26’’E)	282	277	178	93	100	176	178	443	259	144	144	291	1106	1459	2565
Siyambalanduwa	198	308	181	134	69	127	123	241	43	51	41	96	1015	594	1609
(6°54’18’’N, 81°32’36’’E)	230	366	302	217	125	72	144	90	47	67	65	91	1312	503	1815
Thanamalwila	229	356	298	39	6	102	246	167	13	6	7	166	1029	605	1634
(6°28’06’’N, 81°08’03’’E)	198	272	141	80	51	93	171	71	8	10	20	37	836	317	1153
Thawalama	438	498	345	171	453	313	592	708	467	110	180	350	2218	2407	4625
(6°20’31’’N, 80°19’49’’E)	551	445	304	215	191	254	392	521	368	289	281	413	1961	2264	4225
Urawa *	291	596	269	107	267	353	416	442	304	93	127	274	1882	1656	3538
(6°14’12’’N, 80°34’18’’E)	397	414	297	126	175	200	325	372	205	163	163	299	1610	1526	3136
Wellawaya	247	340	337	53	2	276	186	188	39	5	45	142	1255	604	1859
(6°42’35’’N, 81°06’40’’E)	255	366	192	116	99	176	248	116	19	29	33	94	1203	540	1743
Weraganthota *	367	361	403	102	193	191	168	270	5	12	36	130	1618	619	2237
(7°19’00’’N, 80°59’18’’E)	375	442	646	261	230	138	171	113	13	14	27	100	2091	438	2529

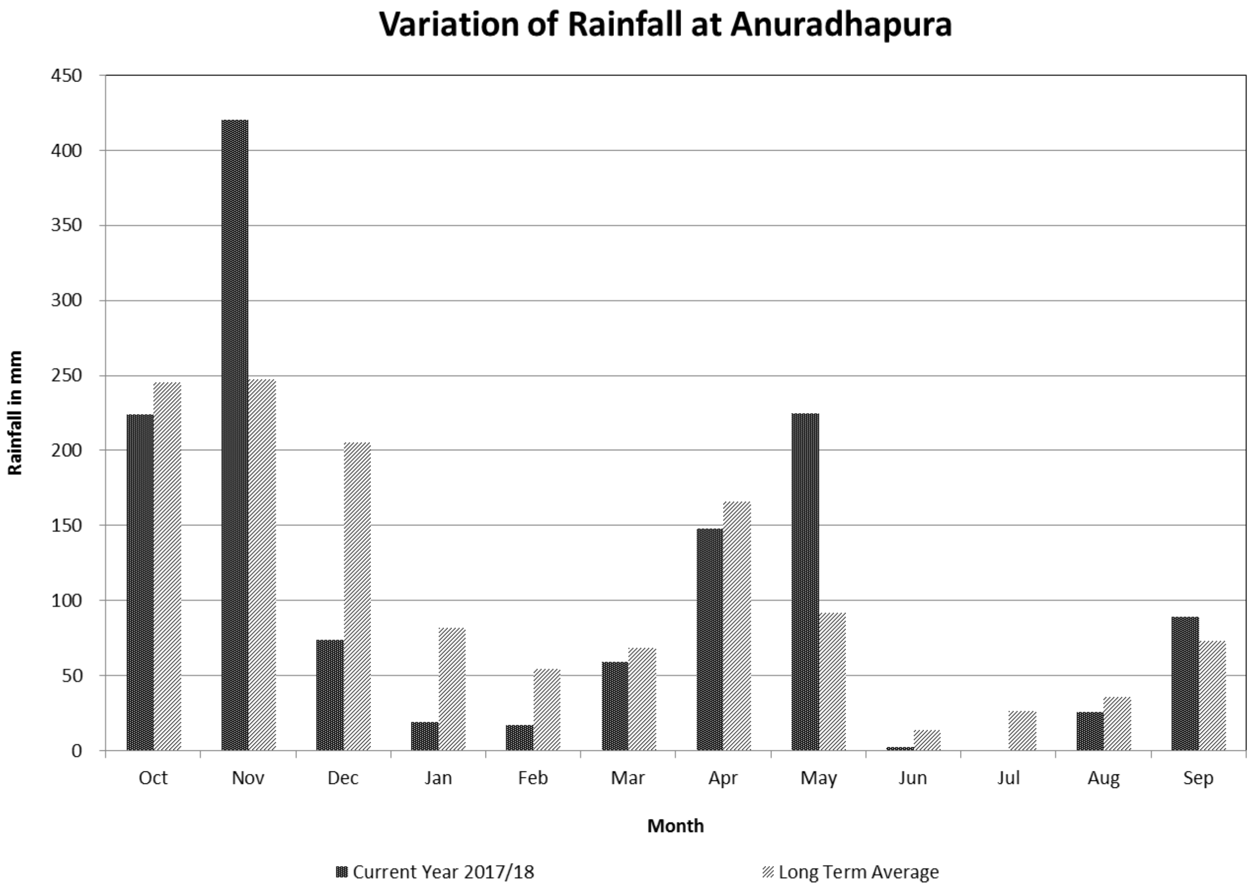
Note :- ‘ *’ Denotes Long term average less than specified above. ‘NEM’ denotes North-East Monsoon. ‘SWM’ denotes South-West Monsoon.

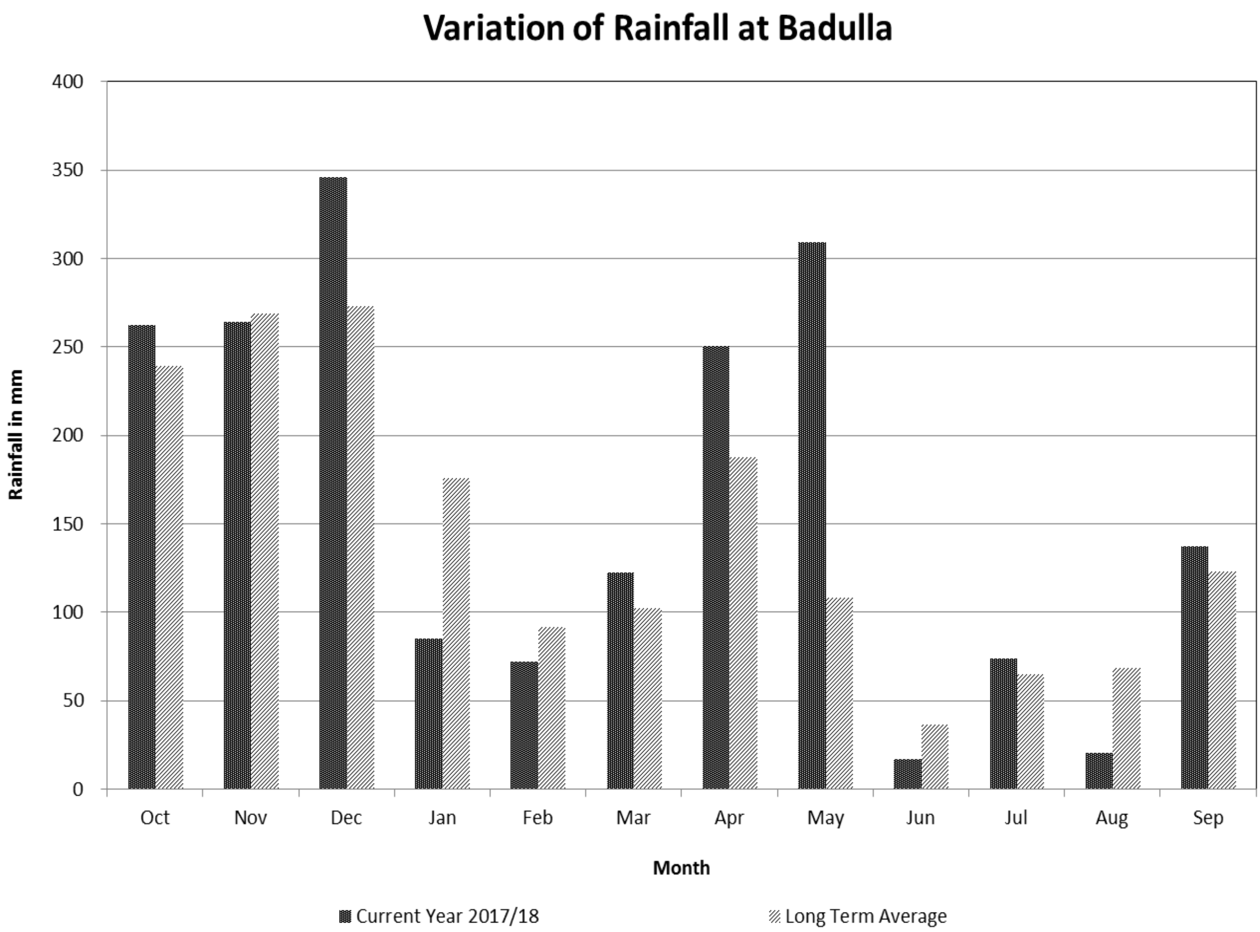
VARIATION OF RAINFALL

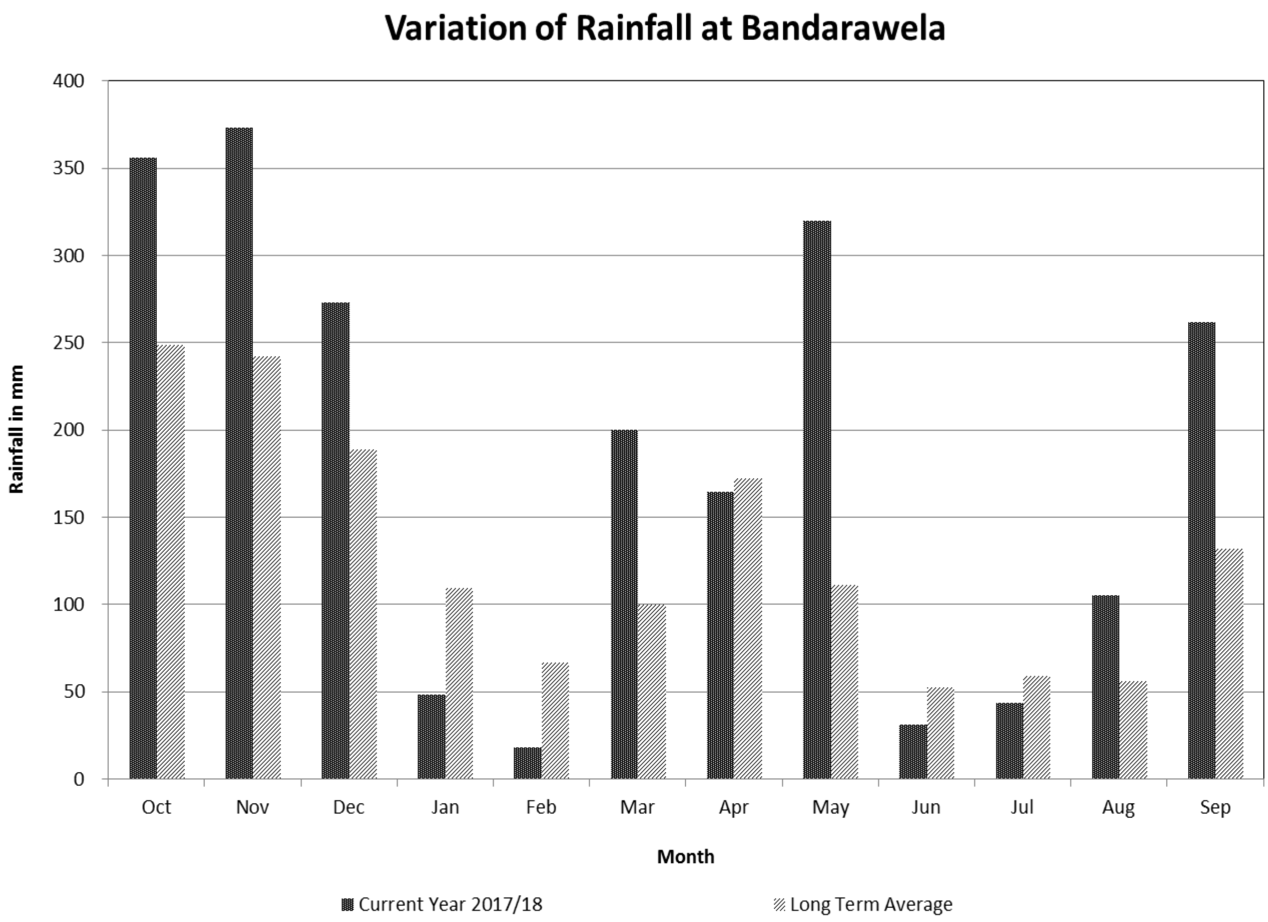
- **Temporal variation of Rainfalls at each station**
  (Current year versus Long-Term average)

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

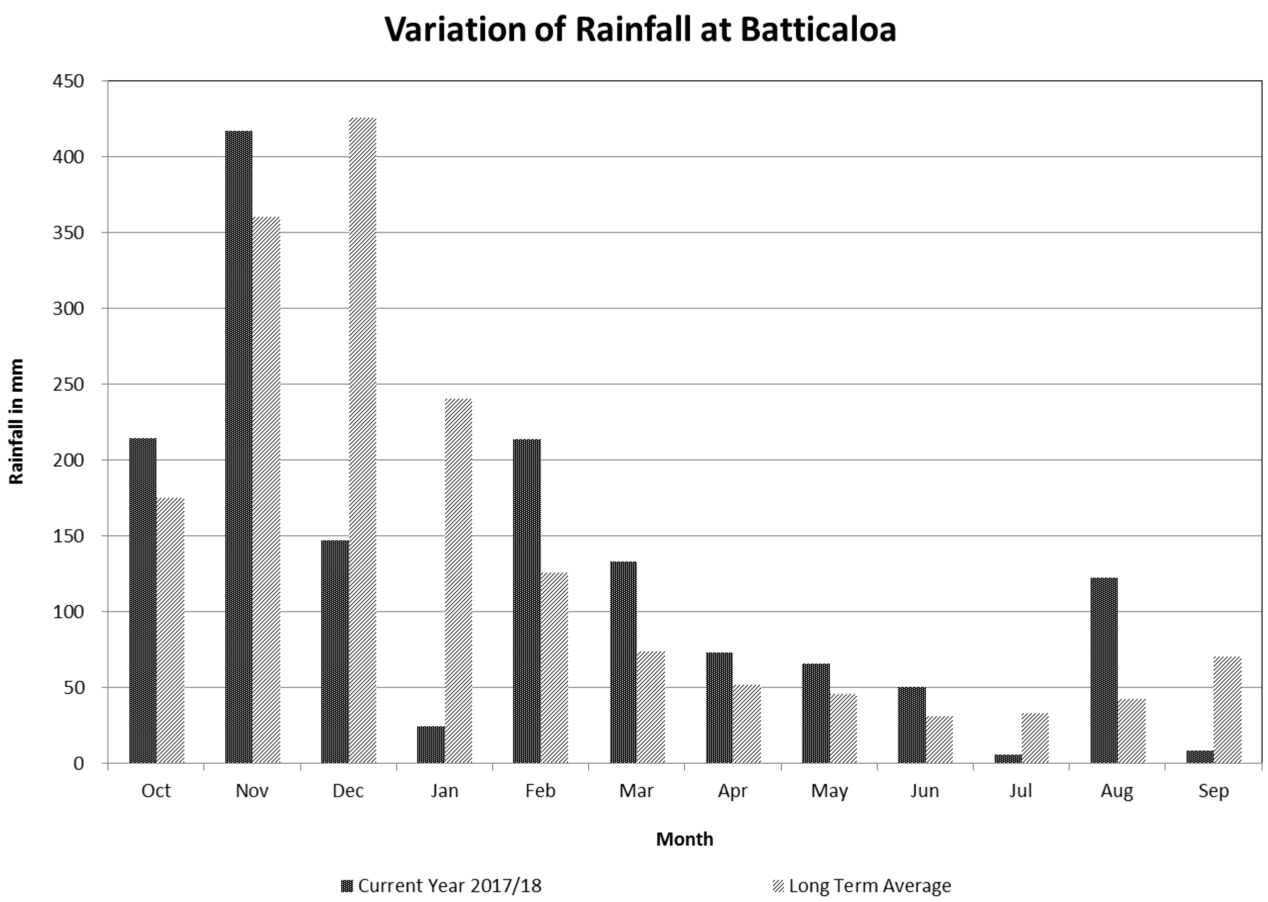
TEMPORAL VARIATION OF RAINFALLS AT EACH STATION


Variation of Rainfall at Anuradhapura
450
400
350
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

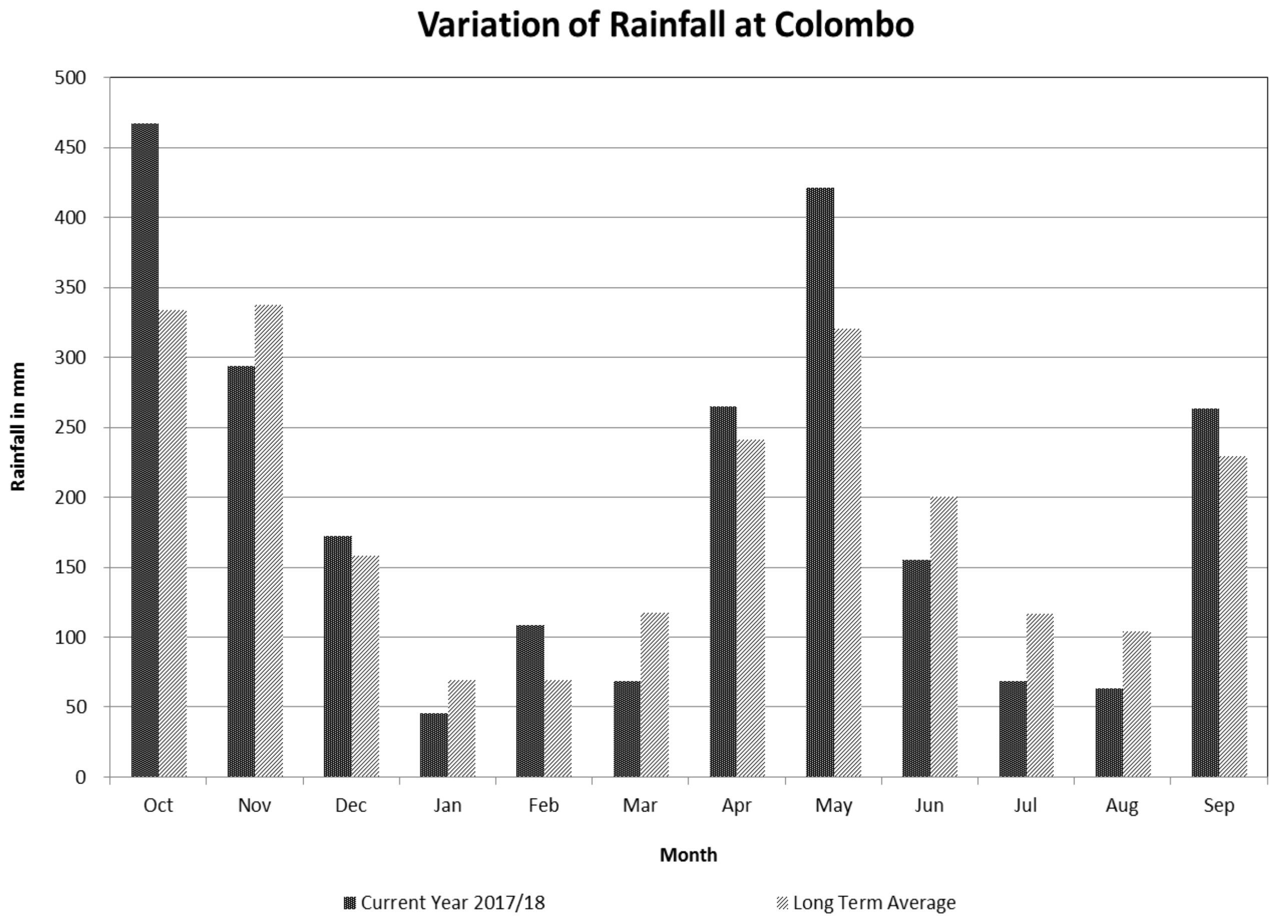

Variation of Rainfall at Badulla
400
350
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average



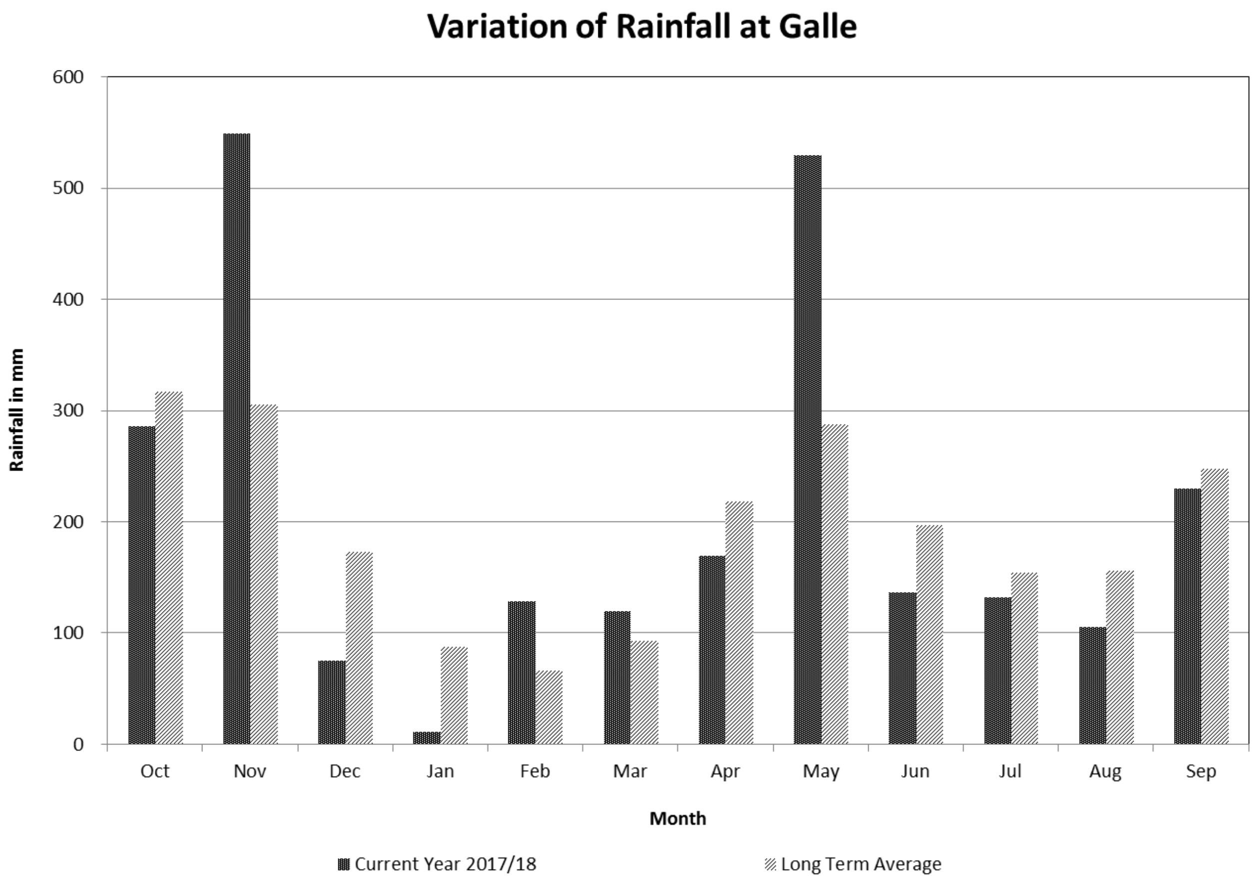
Variation of Rainfall at Bandarawela
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average



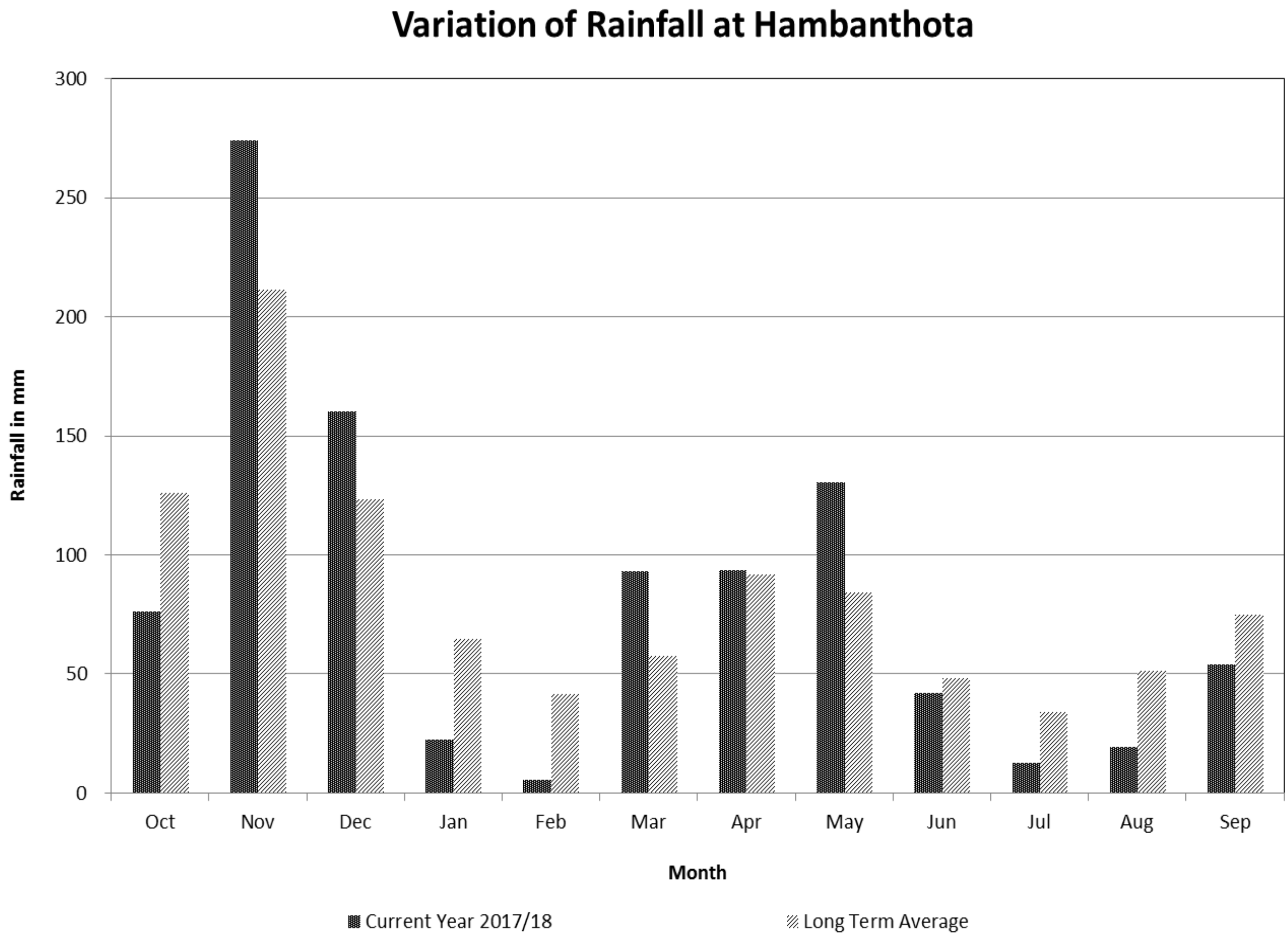
Variation of Rainfall at Batticaloa
Rainfall in mm
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

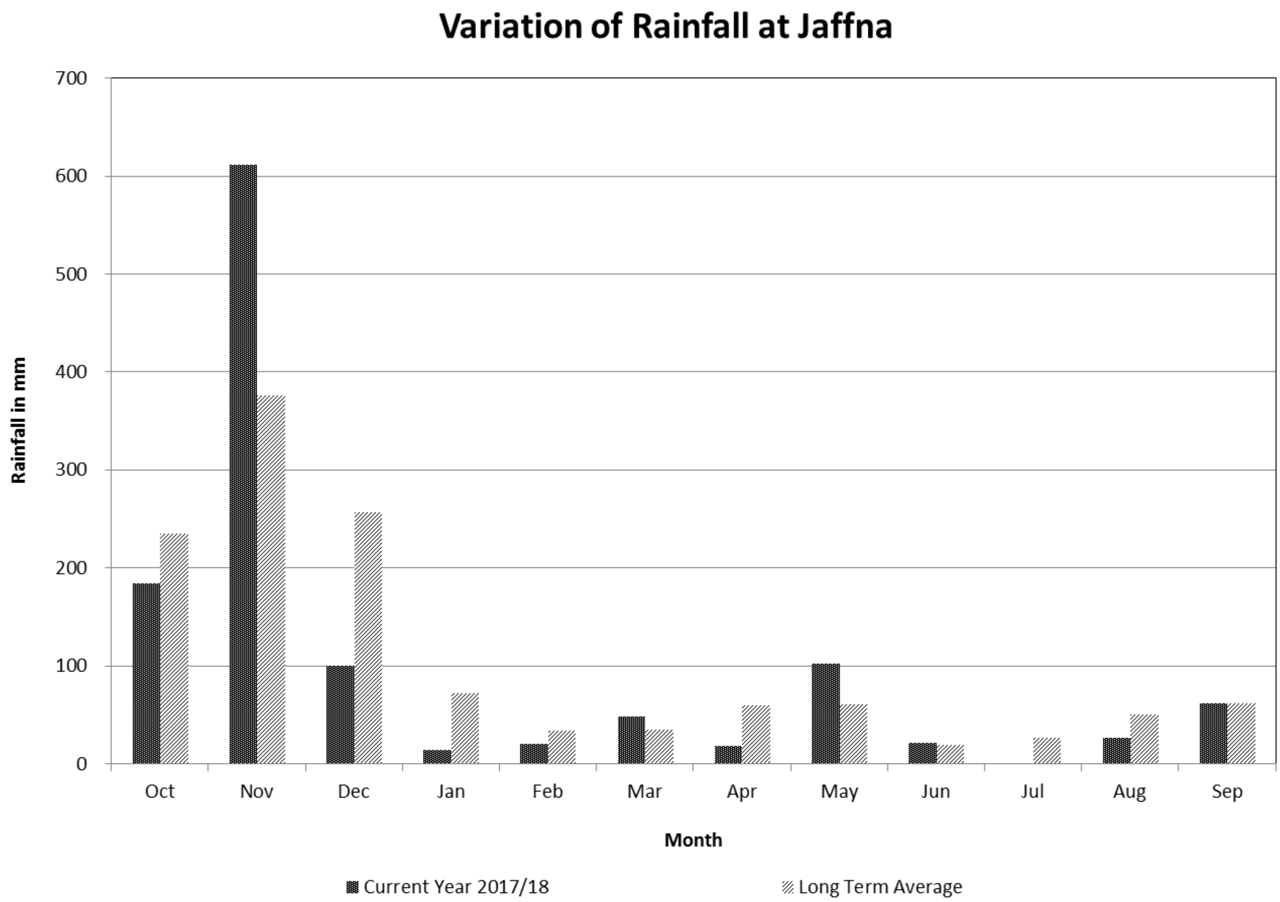


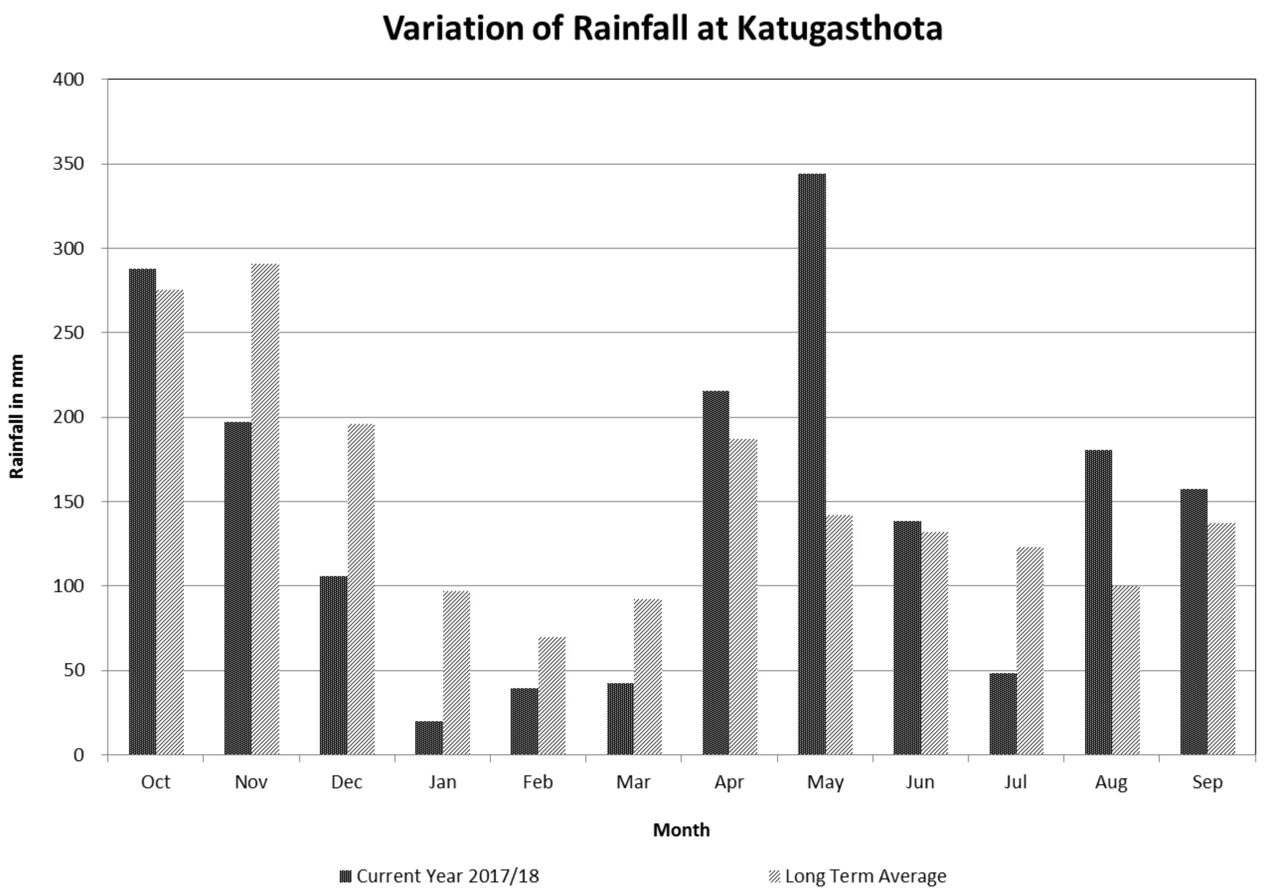
Variation of Rainfall at Colombo
500
450
400
350
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

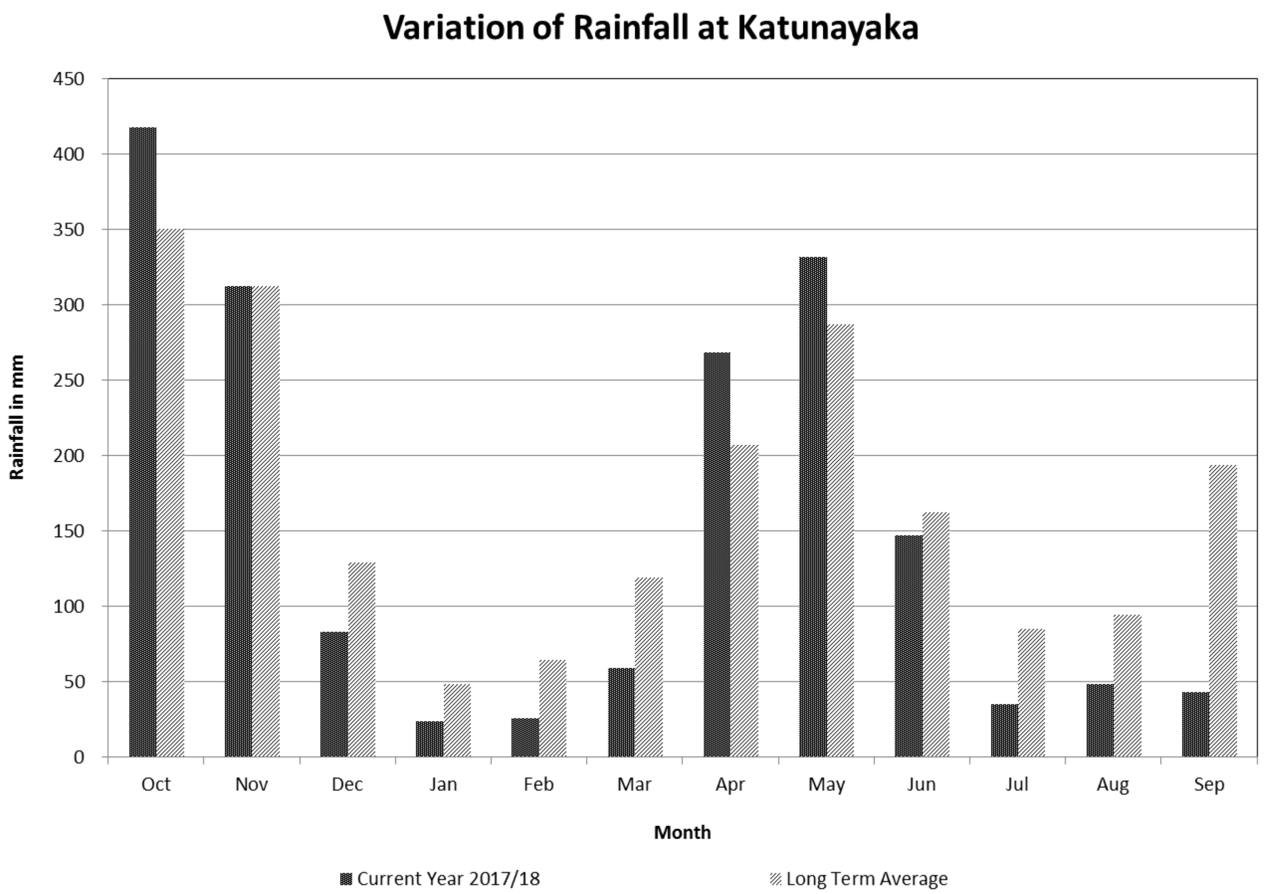


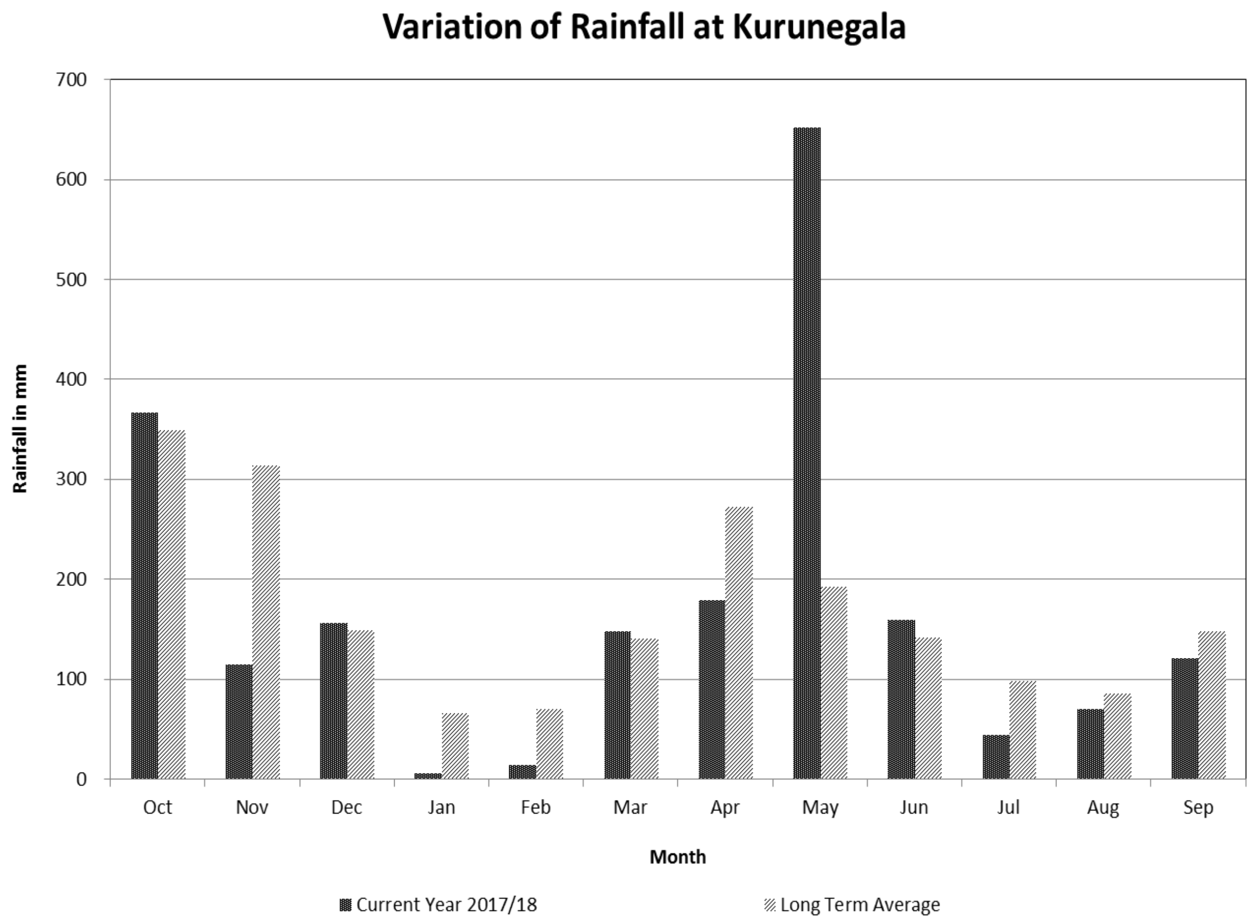
Variation of Rainfall at Galle
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

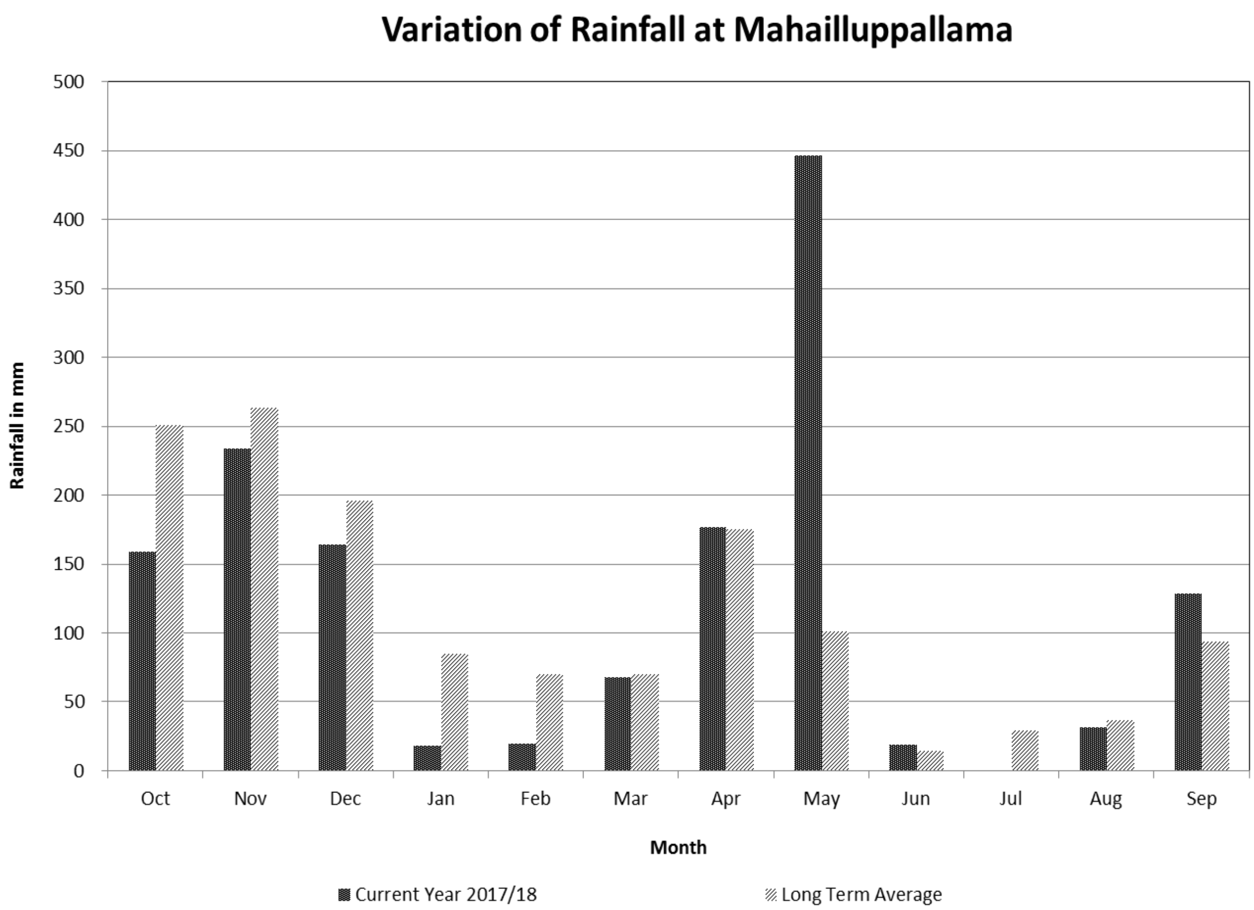

Variation of Rainfall at Hambanthota
Rainfall in mm
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

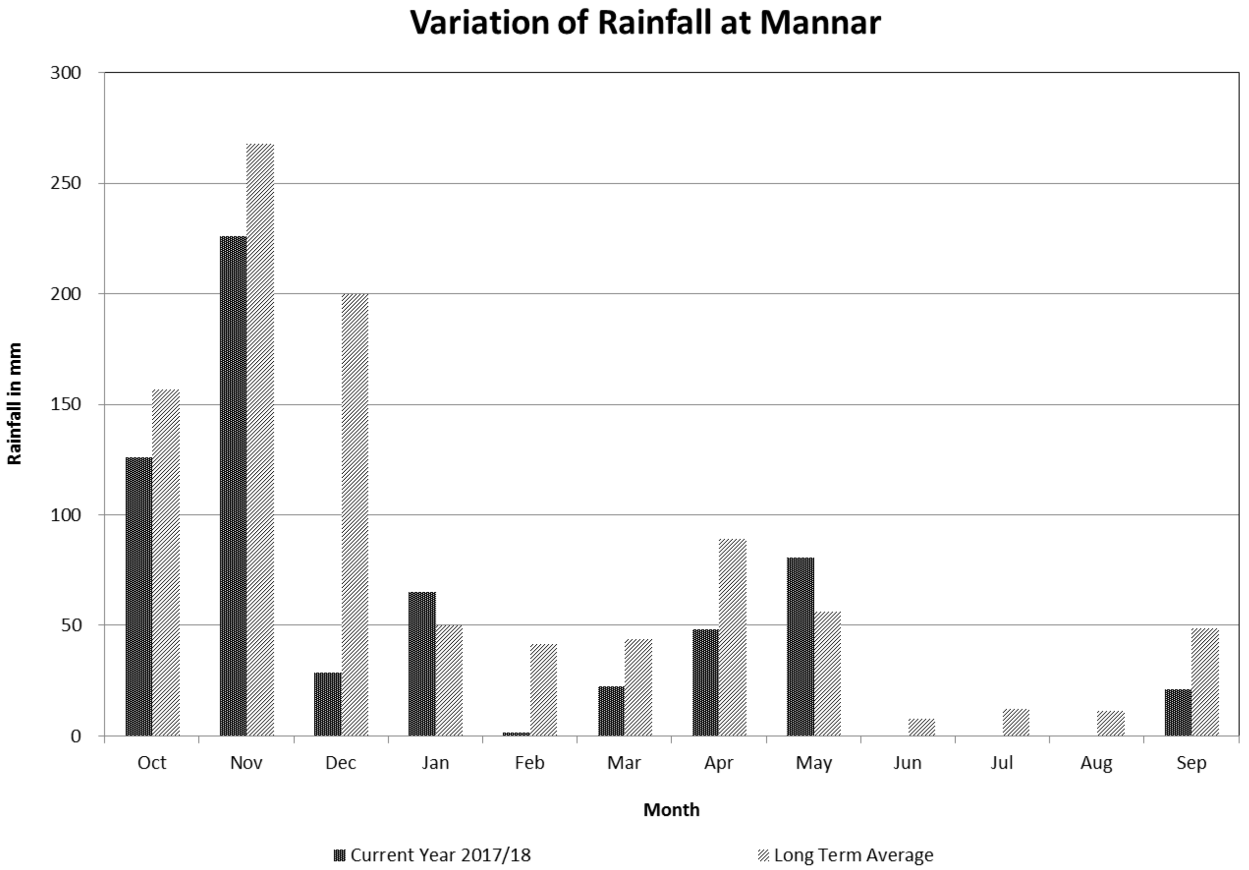

Variation of Rainfall at Jaffna
Rainfall in mm
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

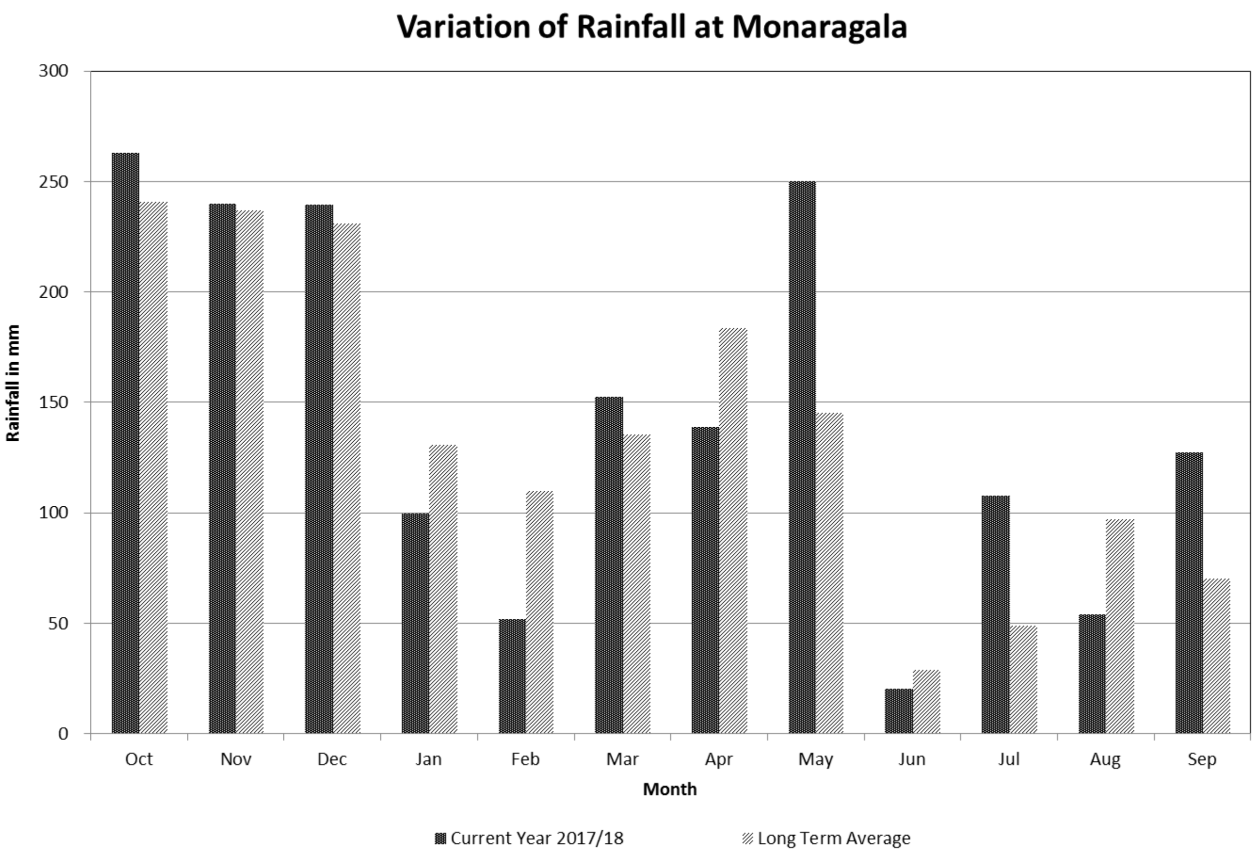

Variation of Rainfall at Katugasthota
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

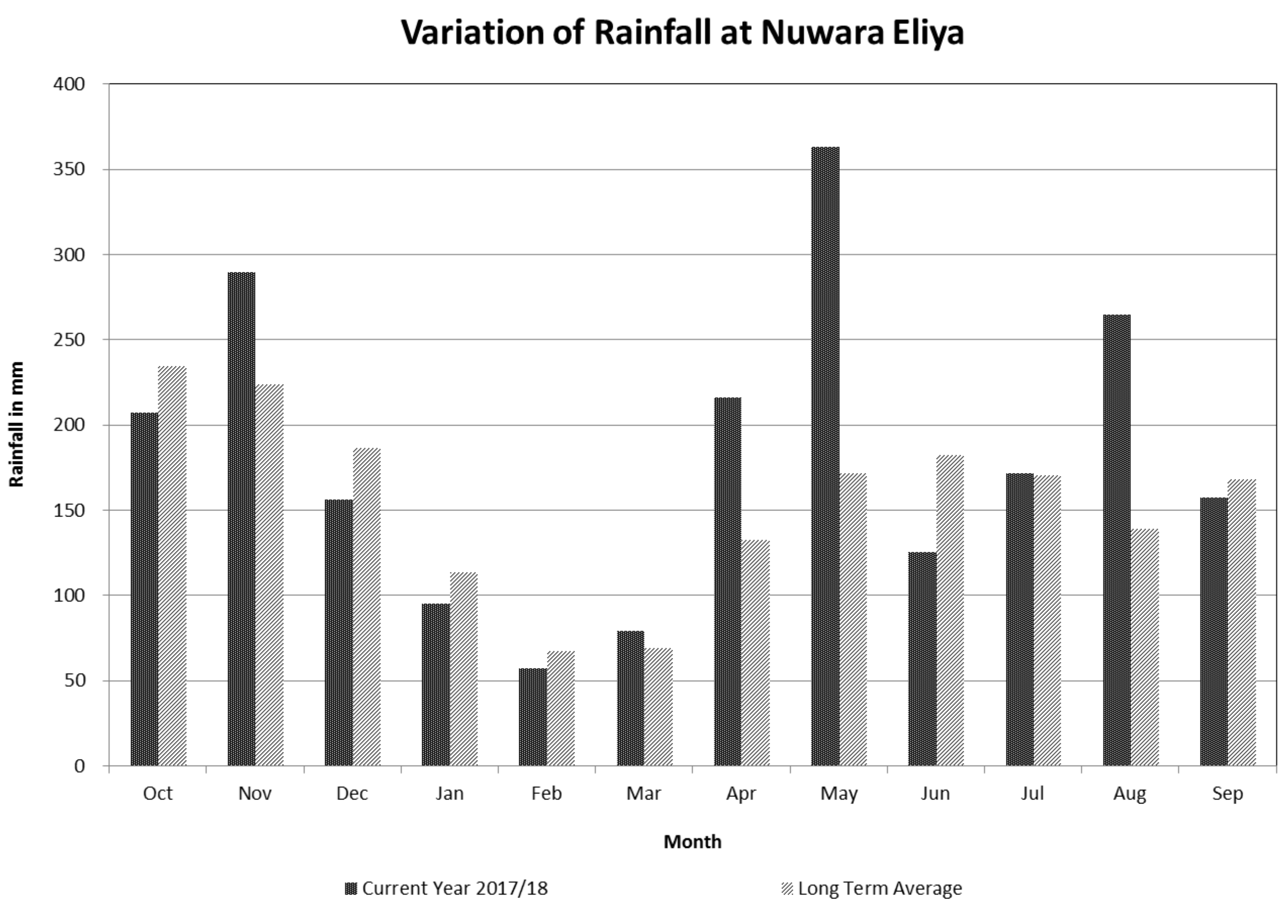

Variation of Rainfall at Katunayaka
Rainfall in mm
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

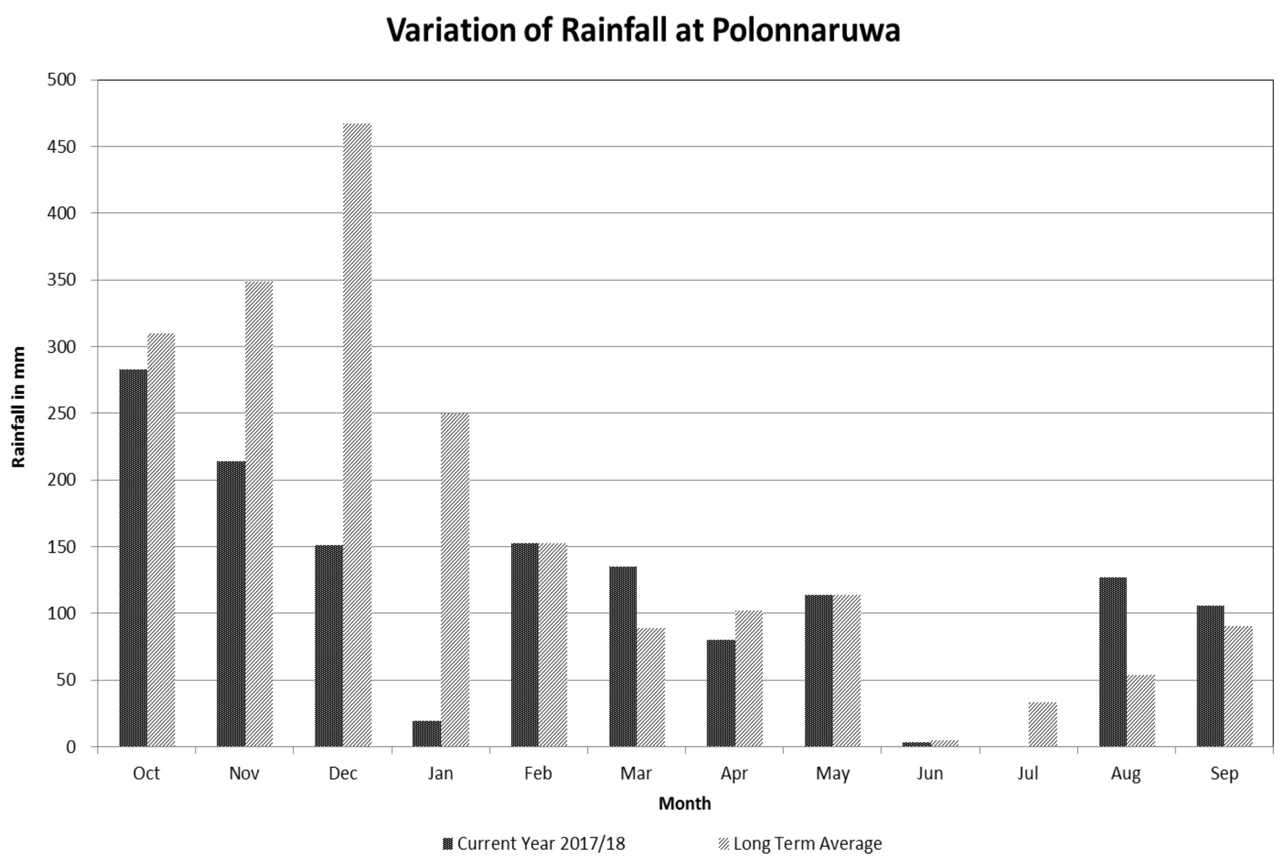

Variation of Rainfall at Kurunegala
Rainfall in mm
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

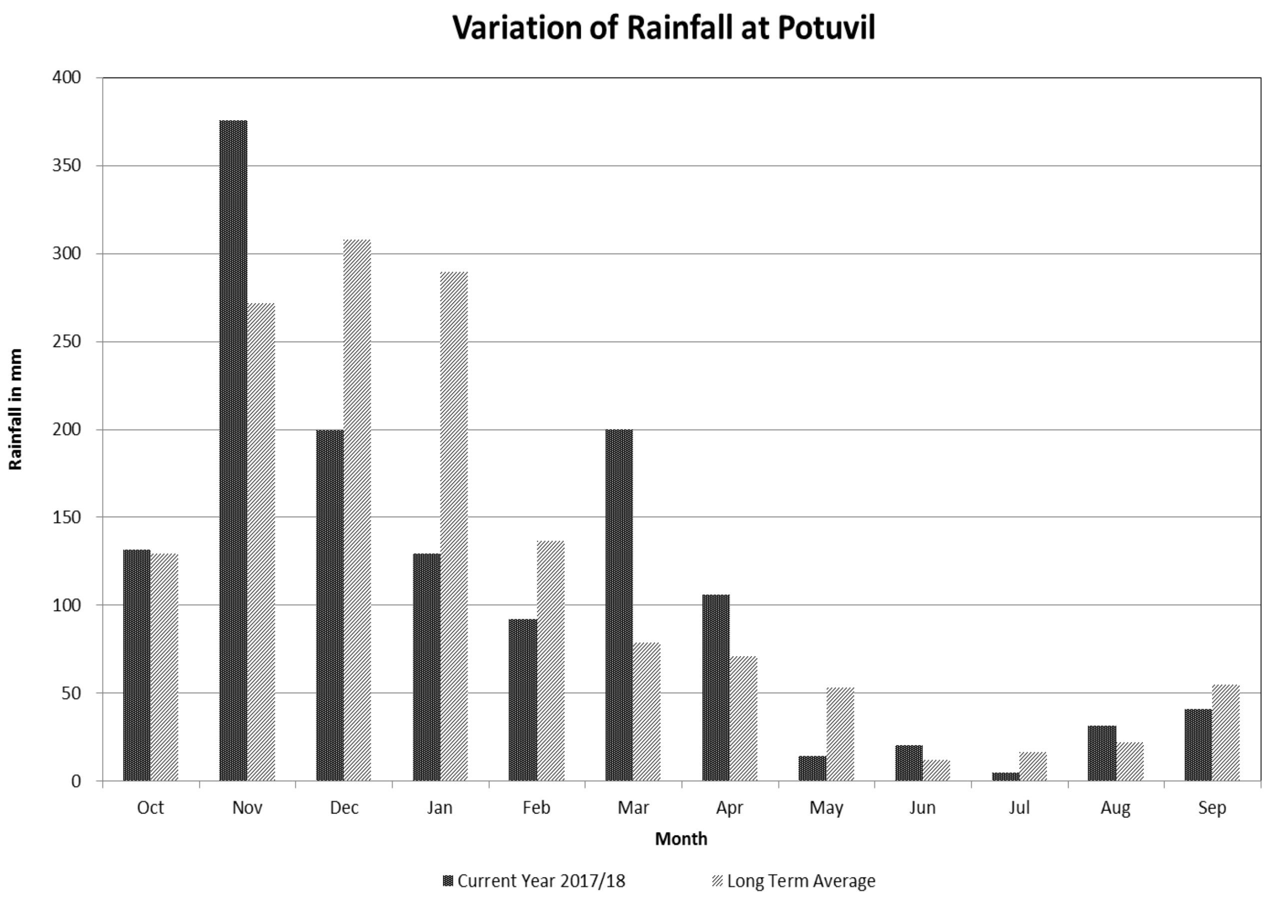

Variation of Rainfall at Mahailluppallama
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

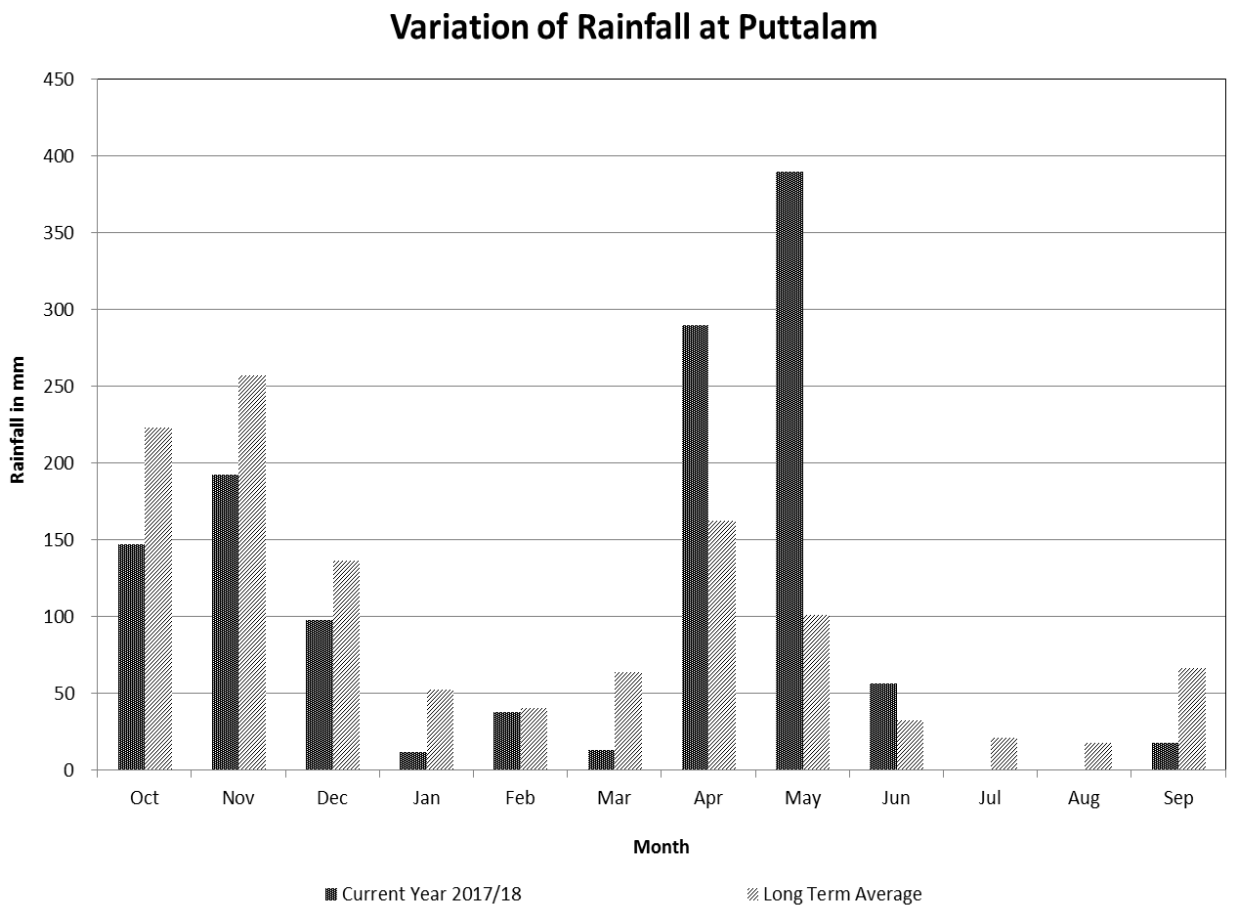

Variation of Rainfall at Mannar
Rainfall in mm
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

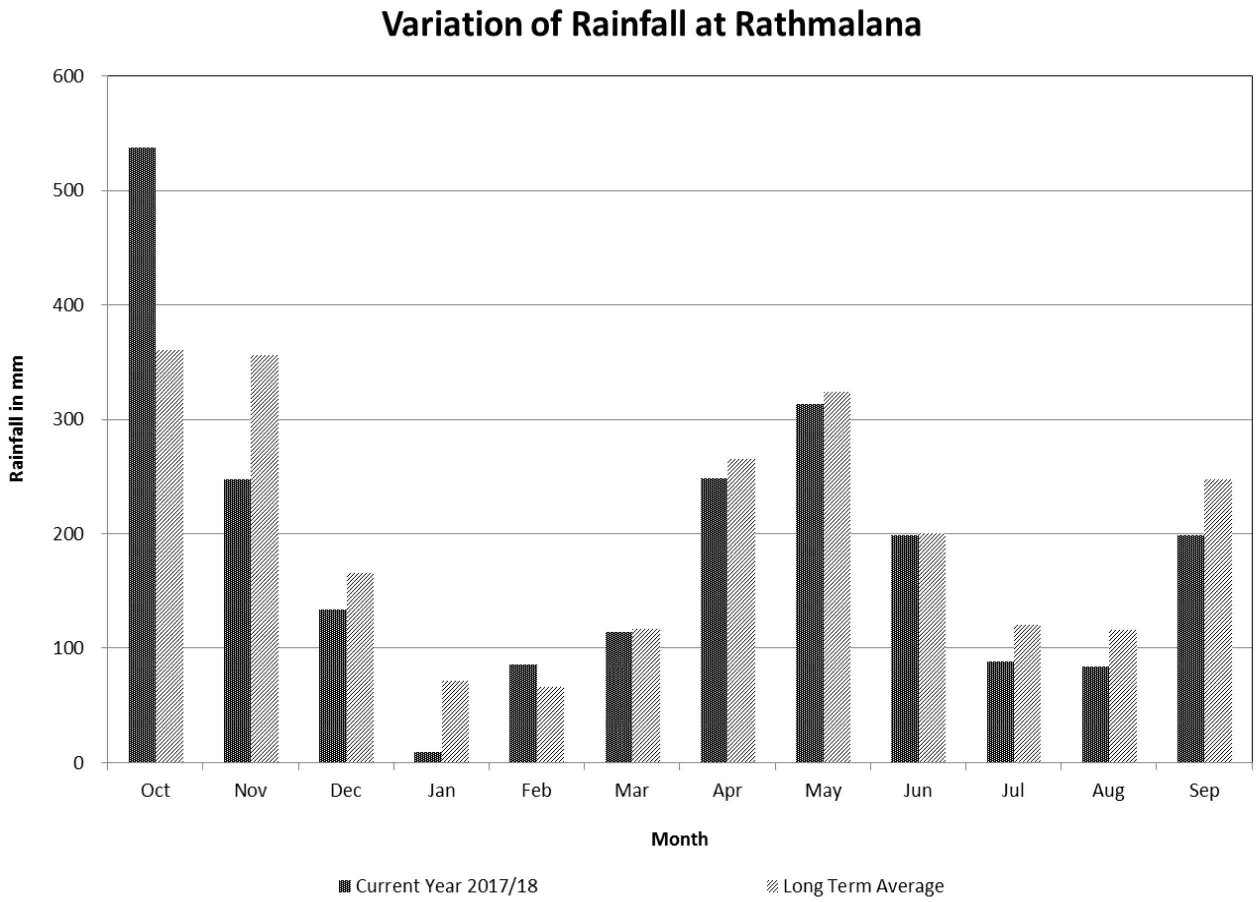

Variation of Rainfall at Monaragala
Rainfall in mm
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

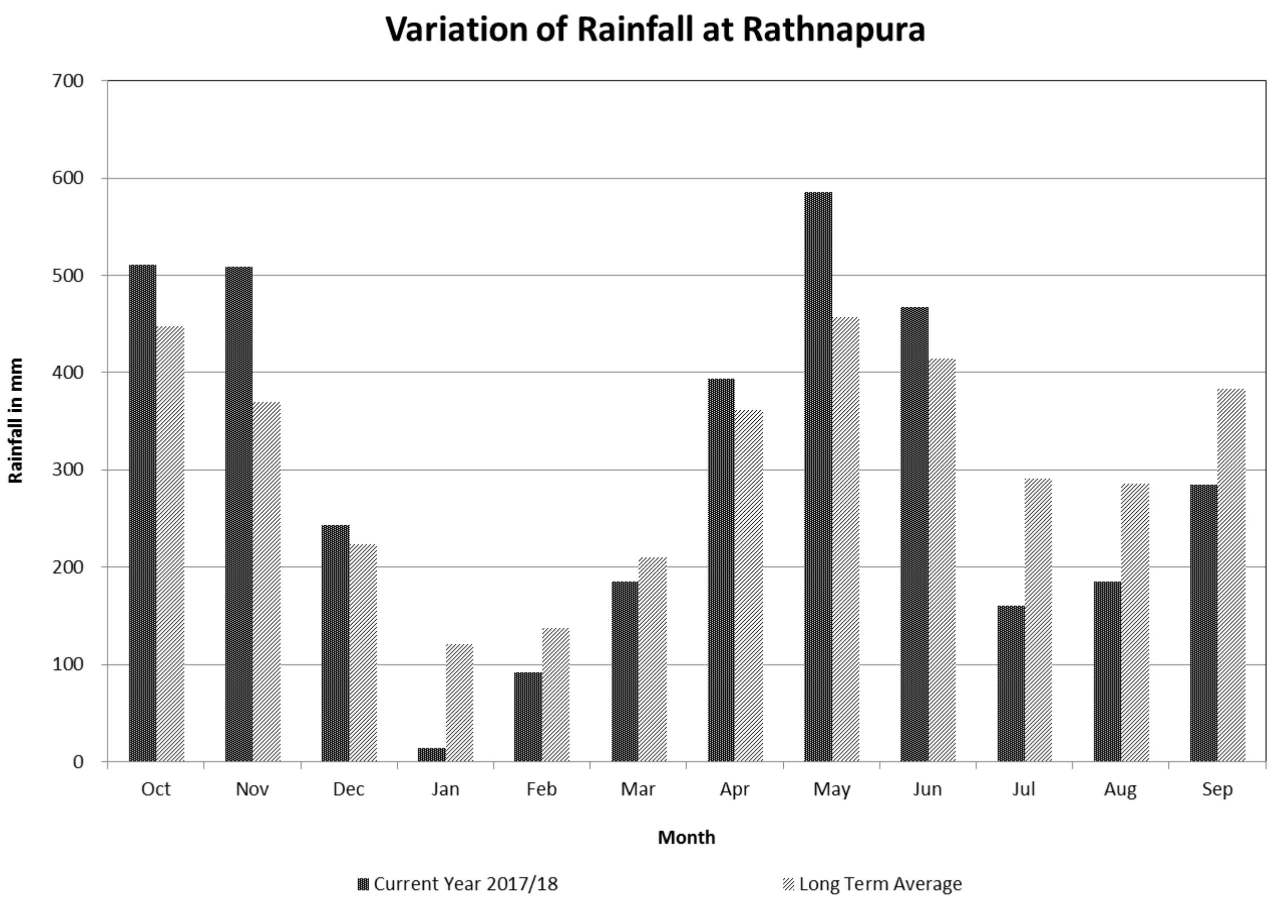

Variation of Rainfall at Nuwara Eliya
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

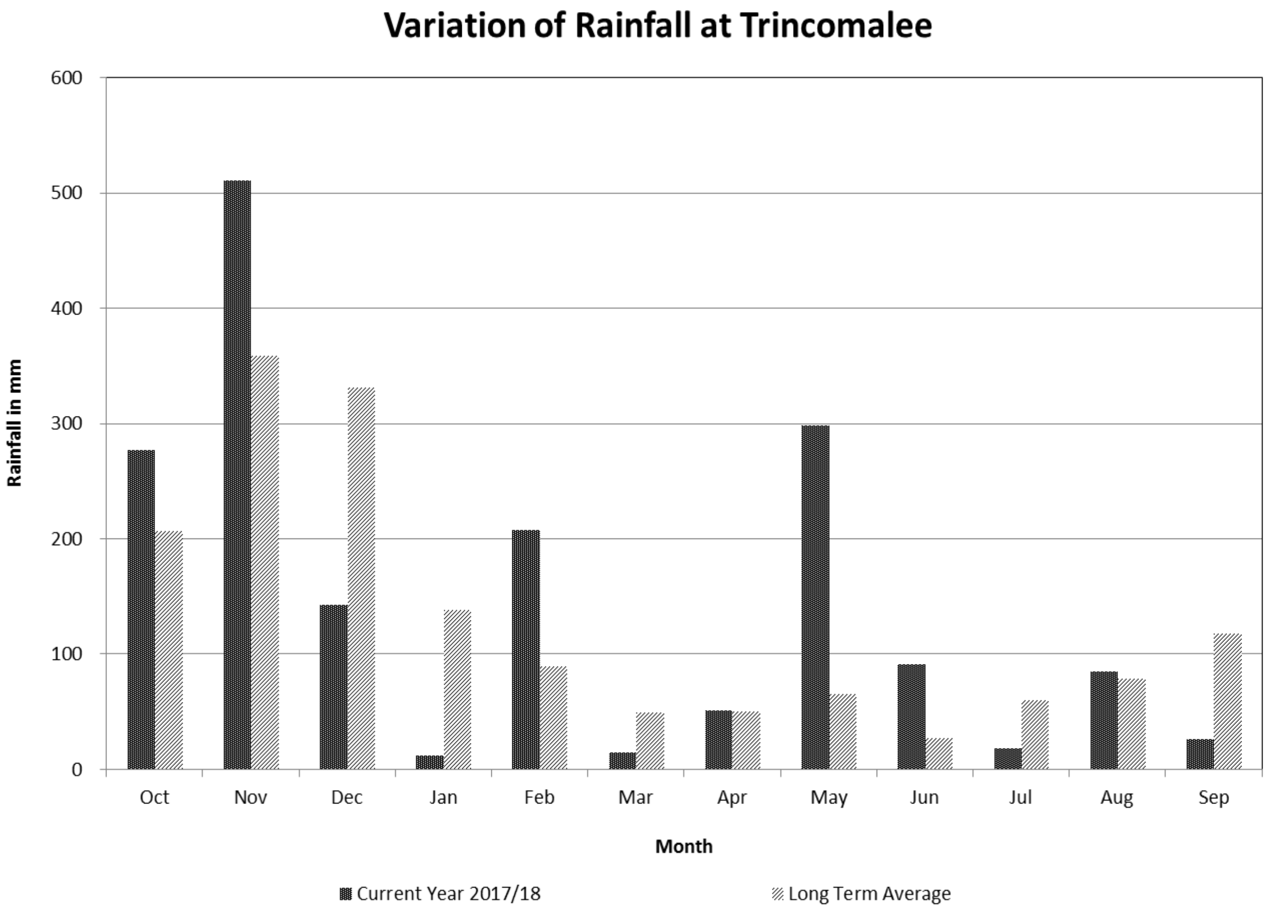

Variation of Rainfall at Polonnaruwa
Rainfall in mm
500
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

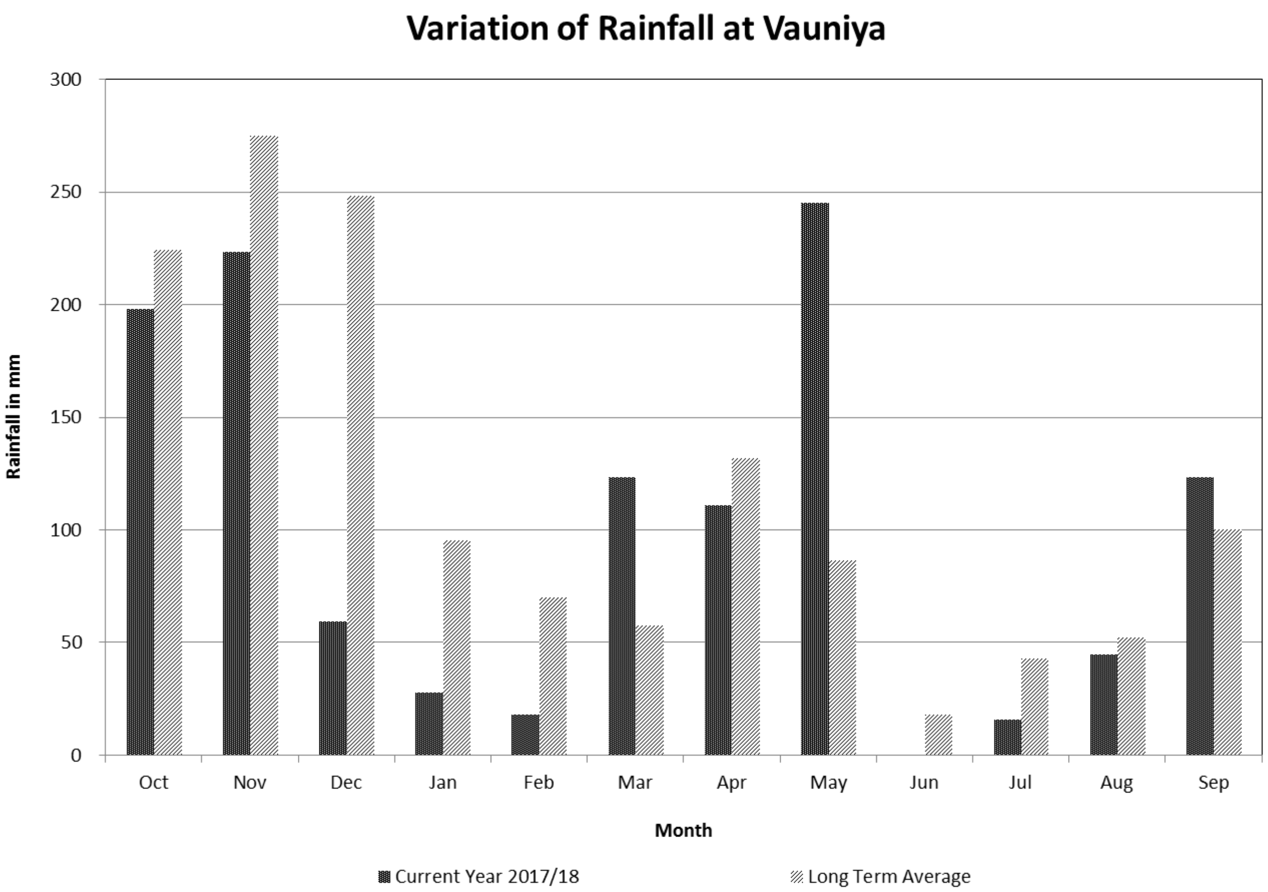

Variation of Rainfall at Potuvil
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

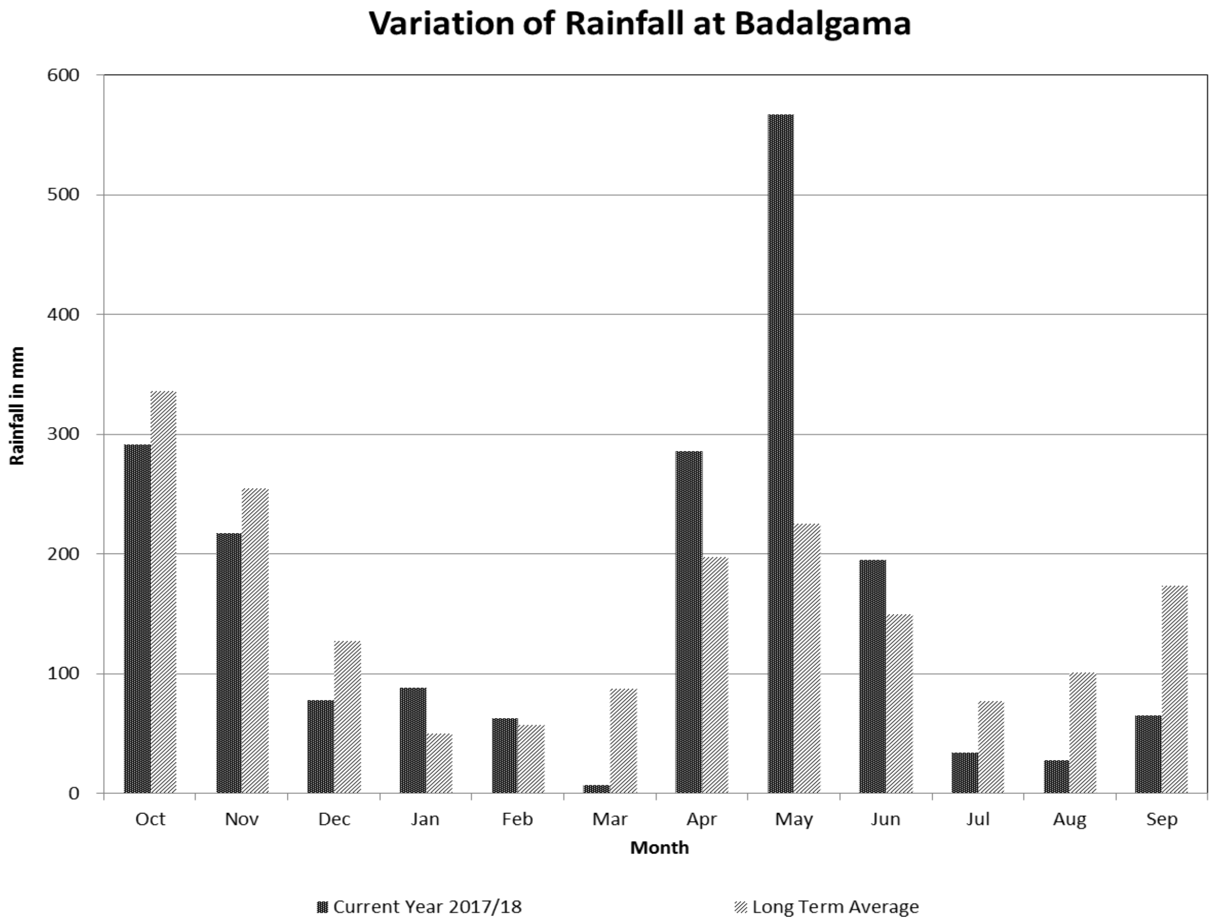

Variation of Rainfall at Puttalam
Rainfall in mm
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

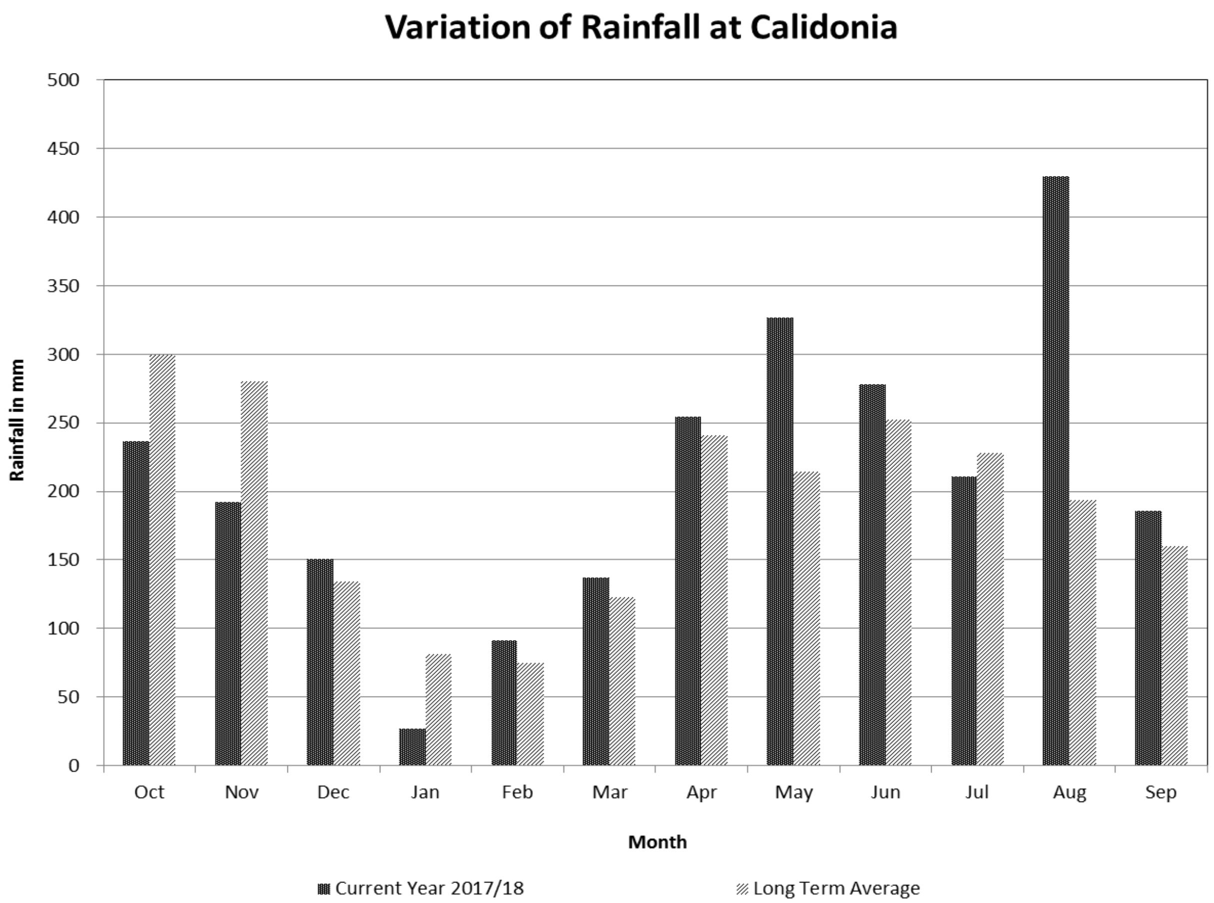

Variation of Rainfall at Rathmalana
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

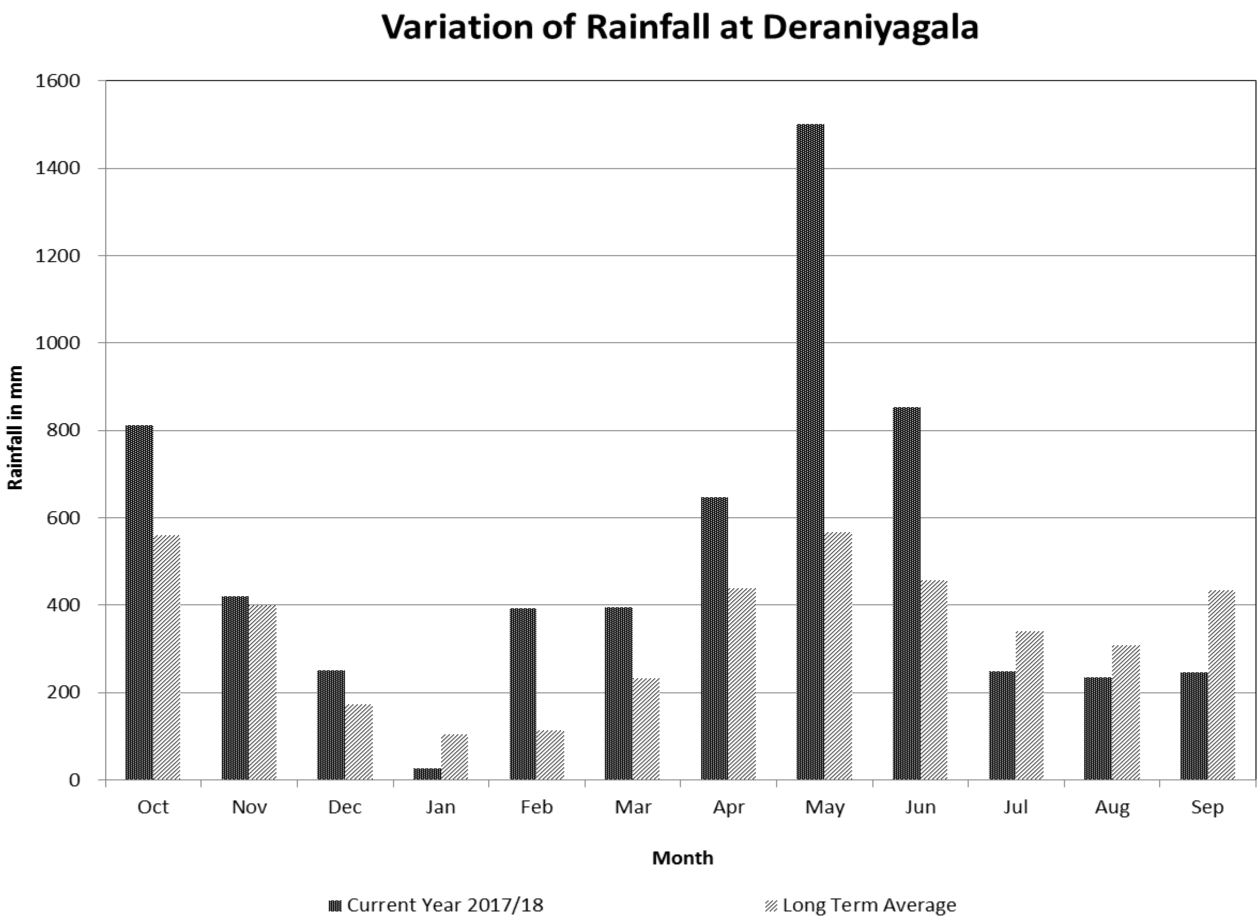

Variation of Rainfall at Rathnapura
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

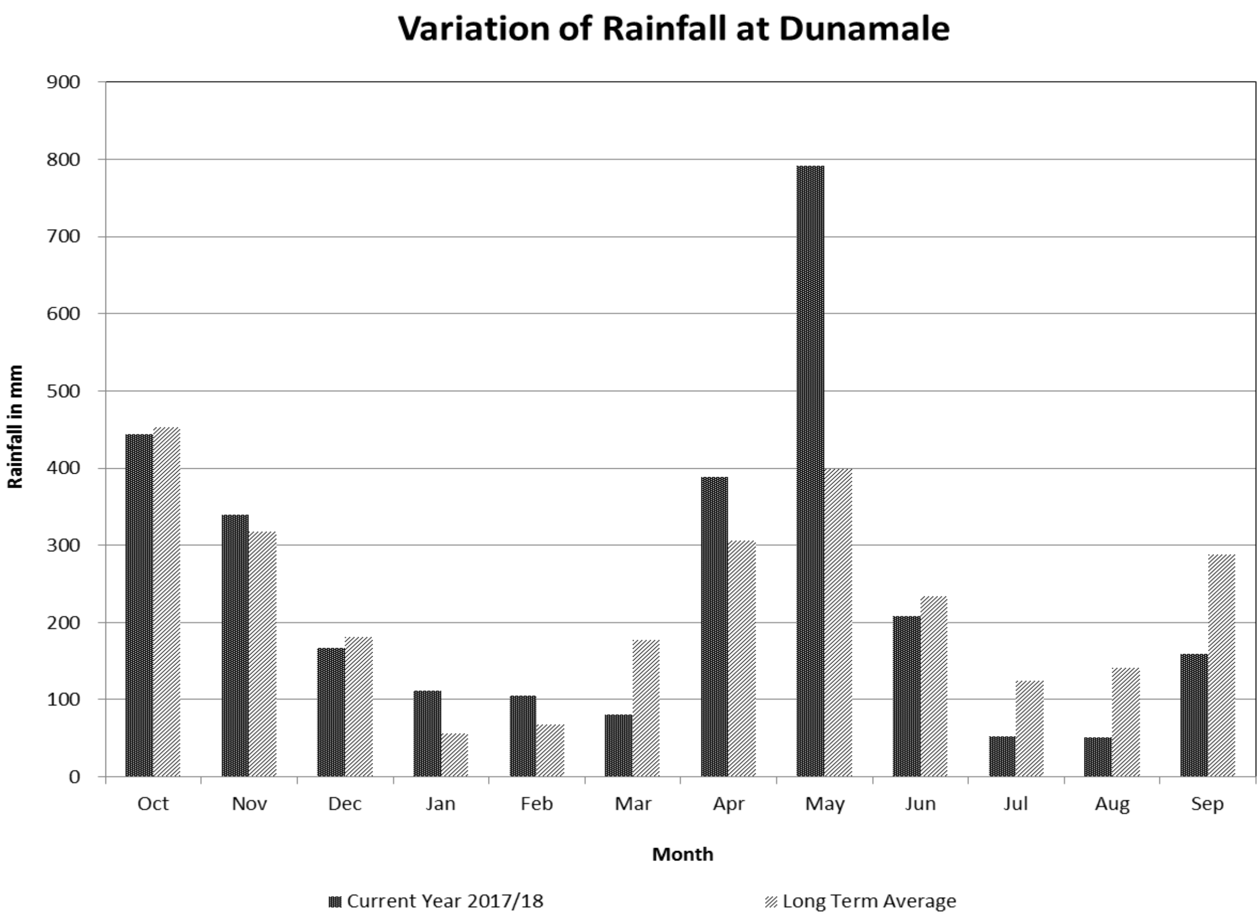

Variation of Rainfall at Trincomalee
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

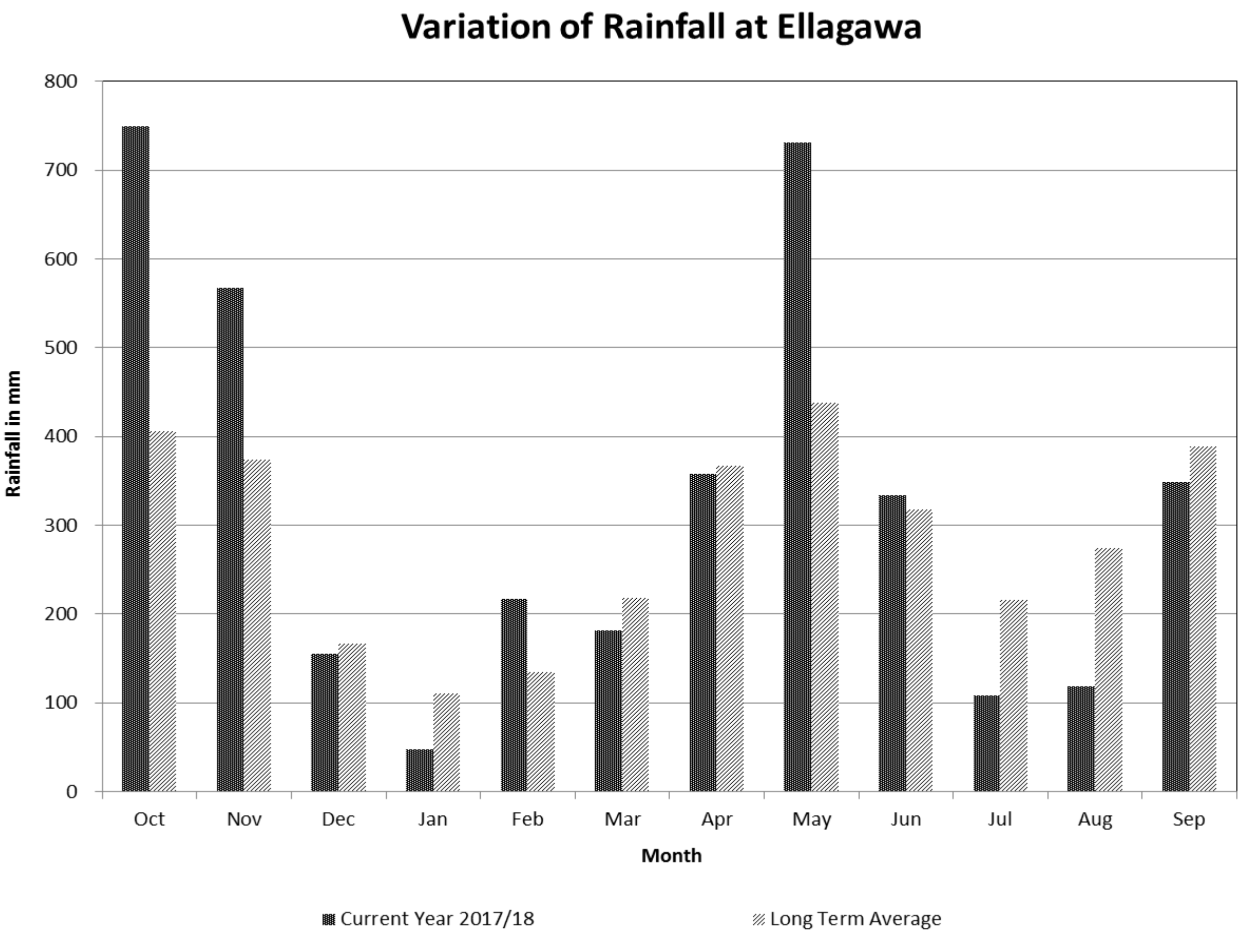

Variation of Rainfall at Vauniya
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average


Variation of Rainfall at Badalgama
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 2017/18
Long Term Average

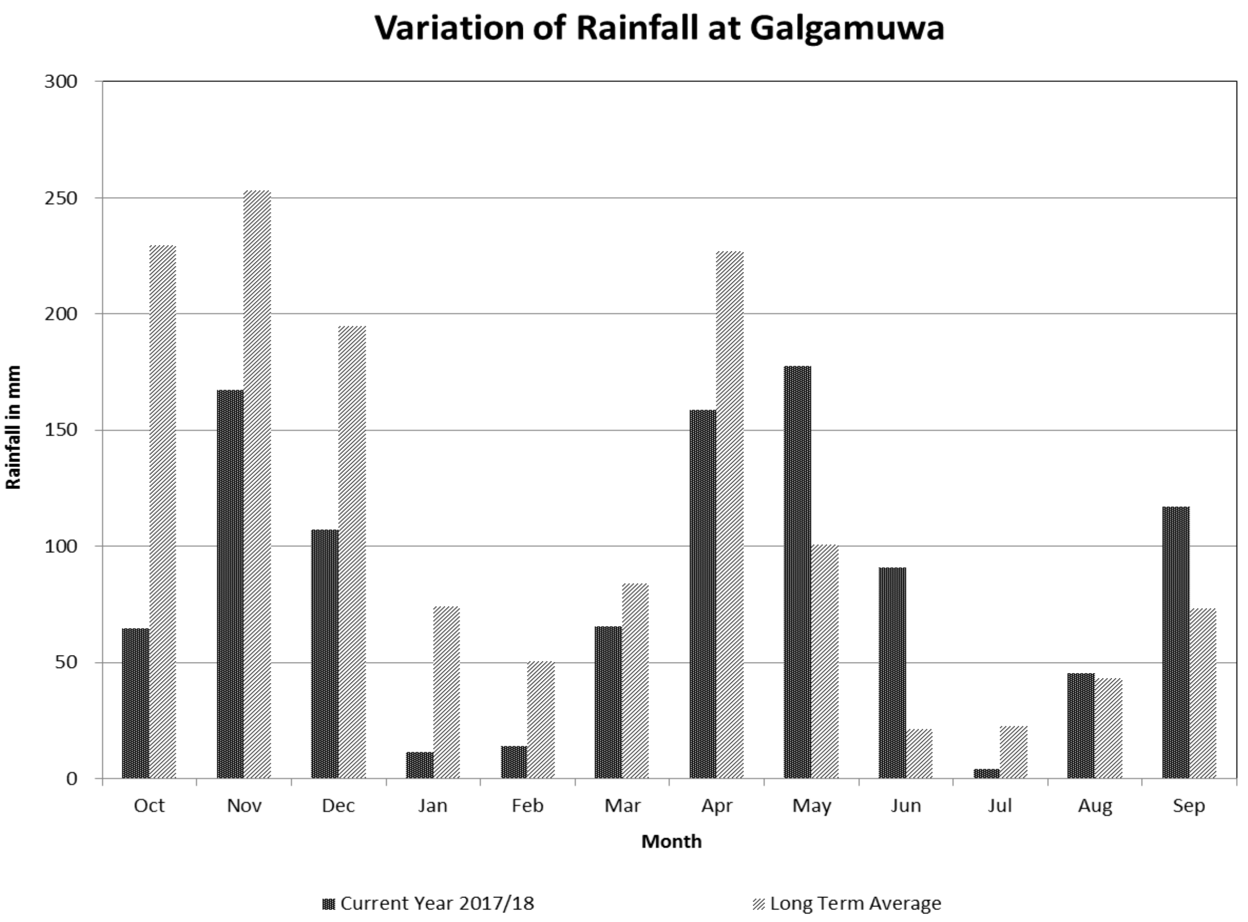

Variation of Rainfall at Calidonia
500
450
400
350
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average


Variation of Rainfall at Deraniyagala
1600
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 2017/18
Long Term Average

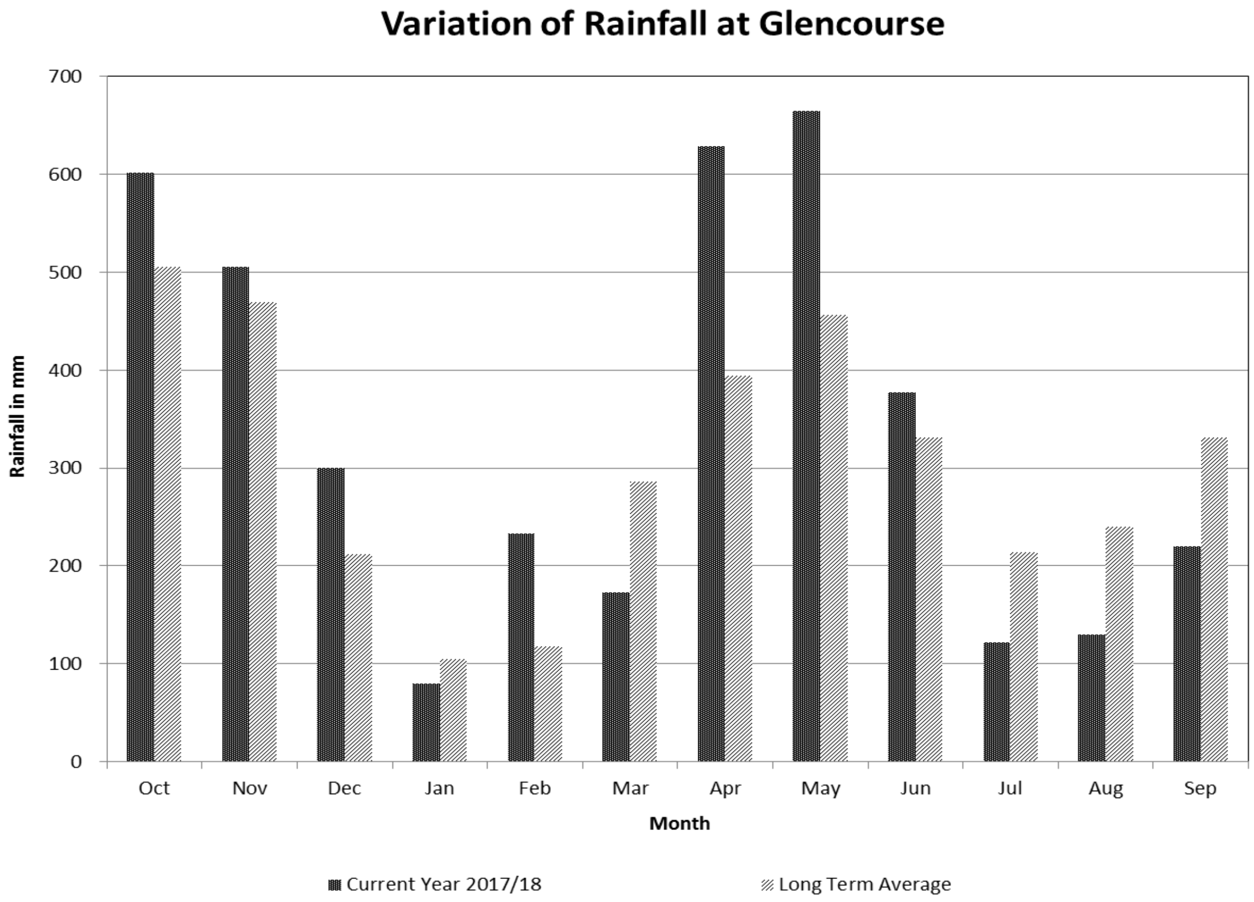

Variation of Rainfall at Dunamale
900
800
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

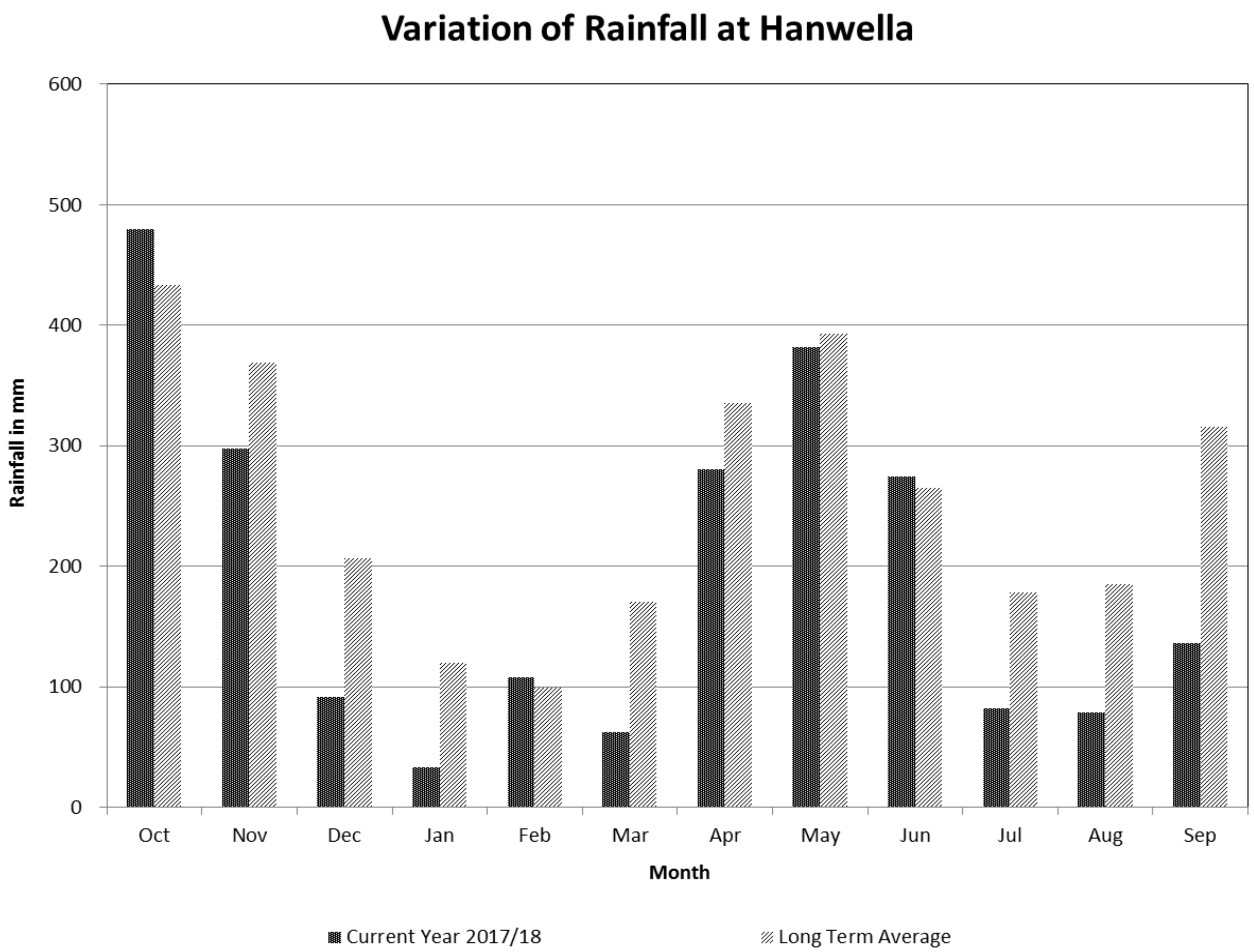


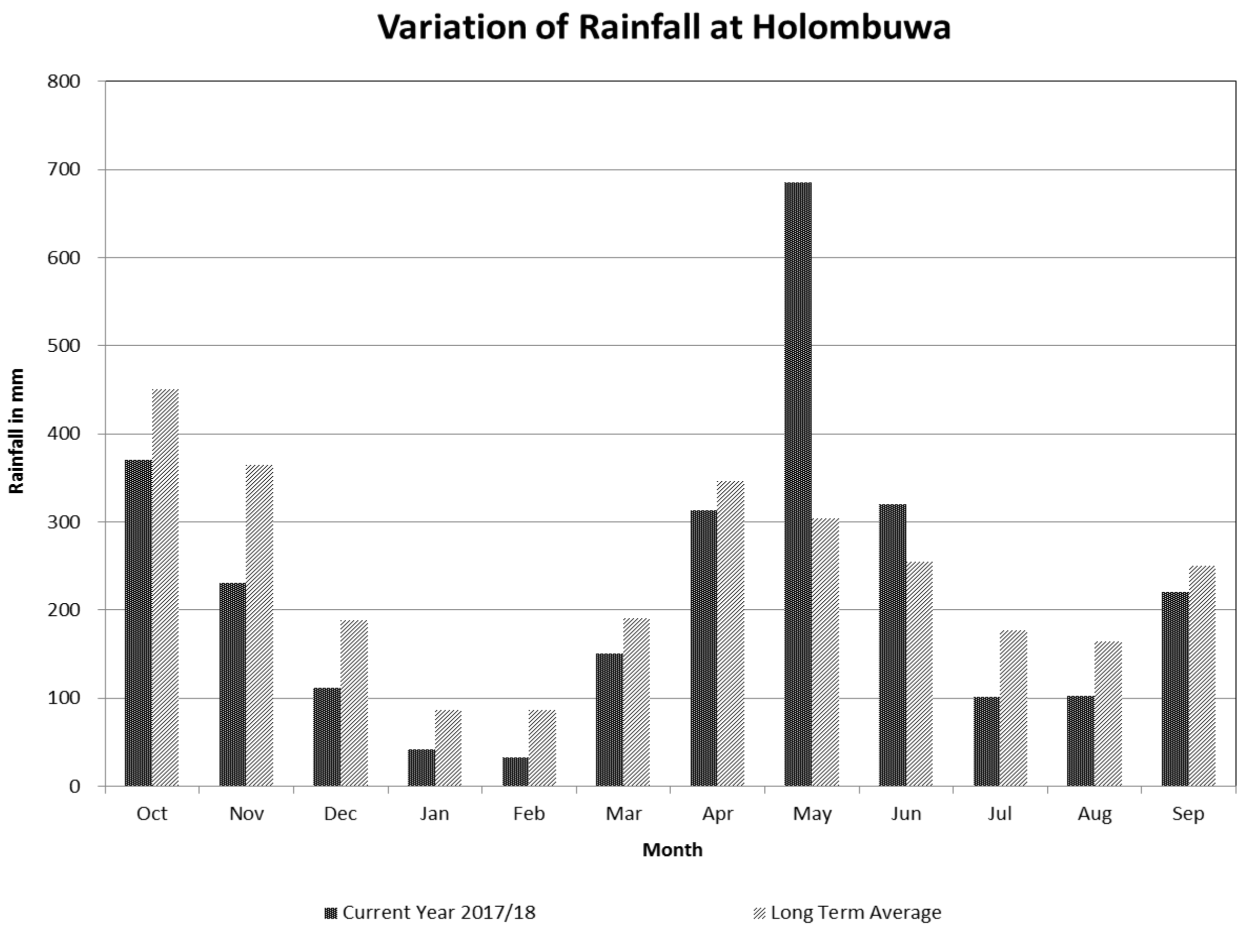
Variation of Rainfall at Ellagawa
800
700
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

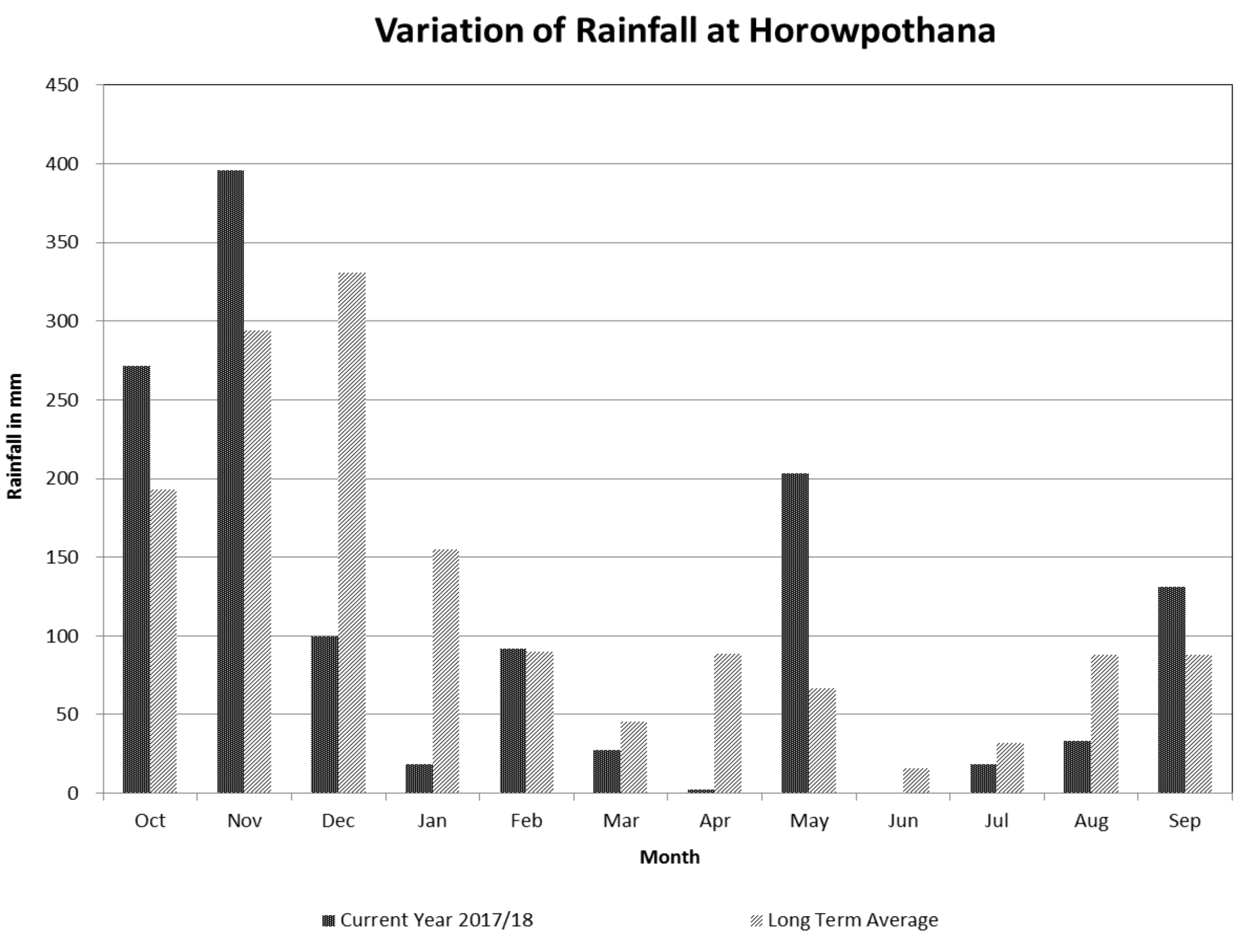


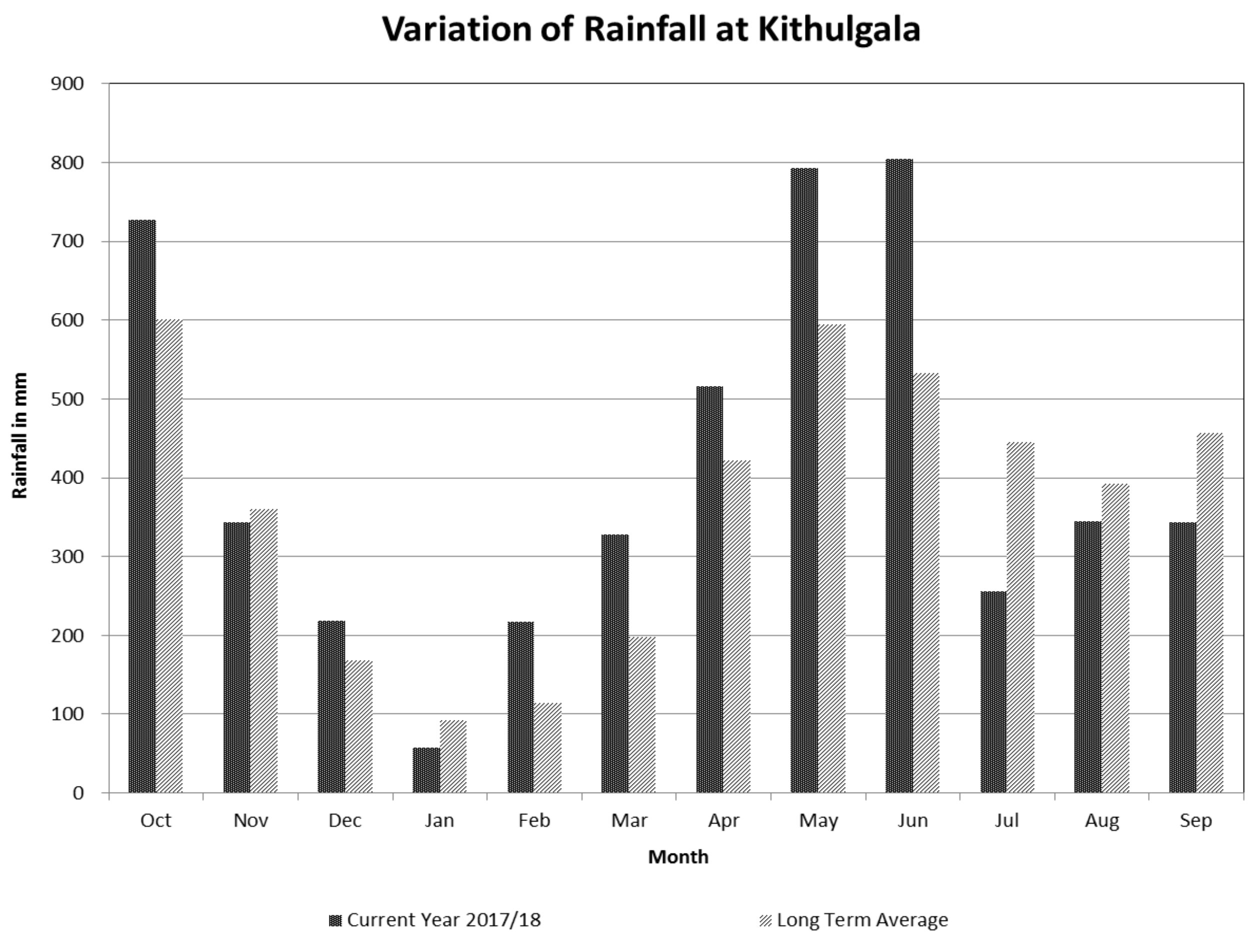
Variation of Rainfall at Galgamuwa
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

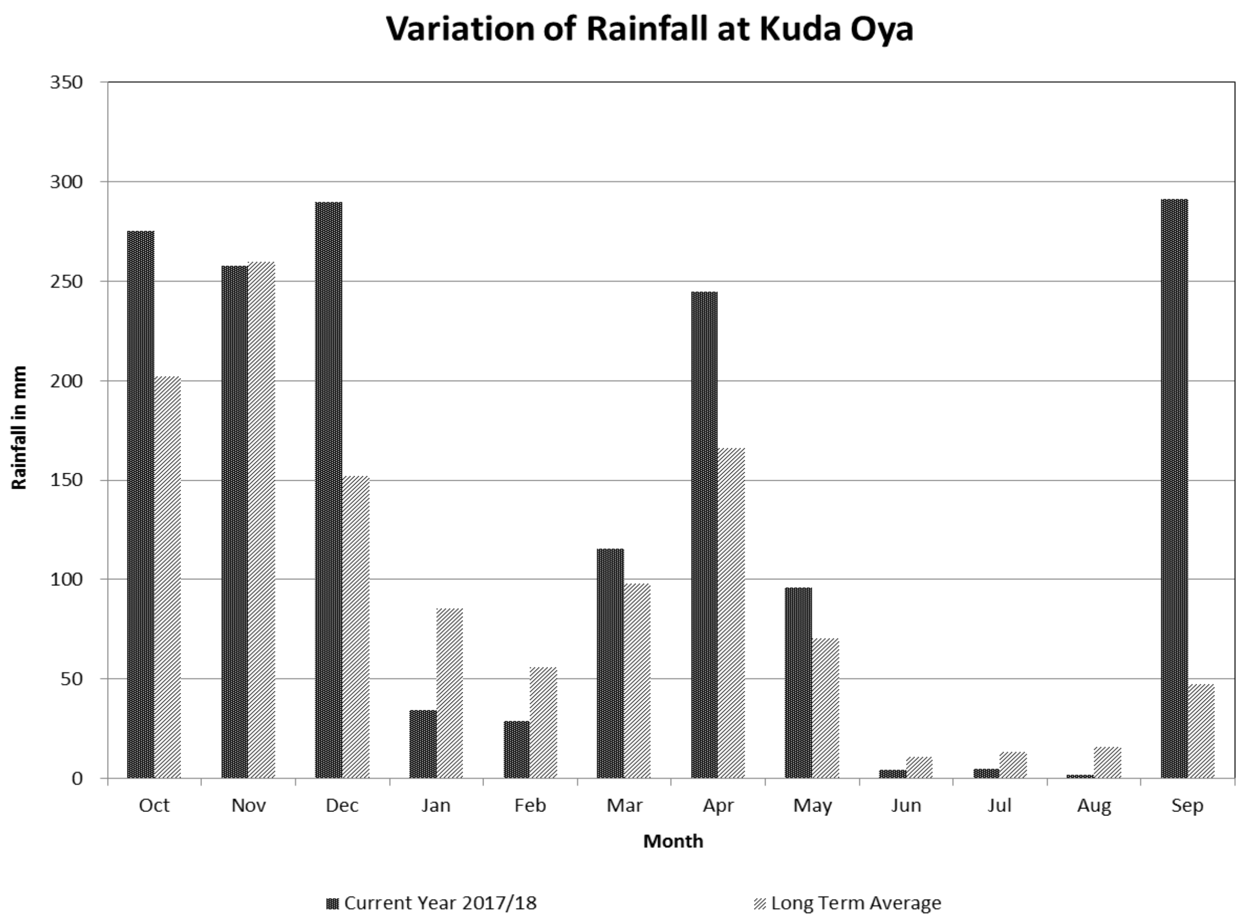

Variation of Rainfall at Glencourse
Rainfall in mm
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

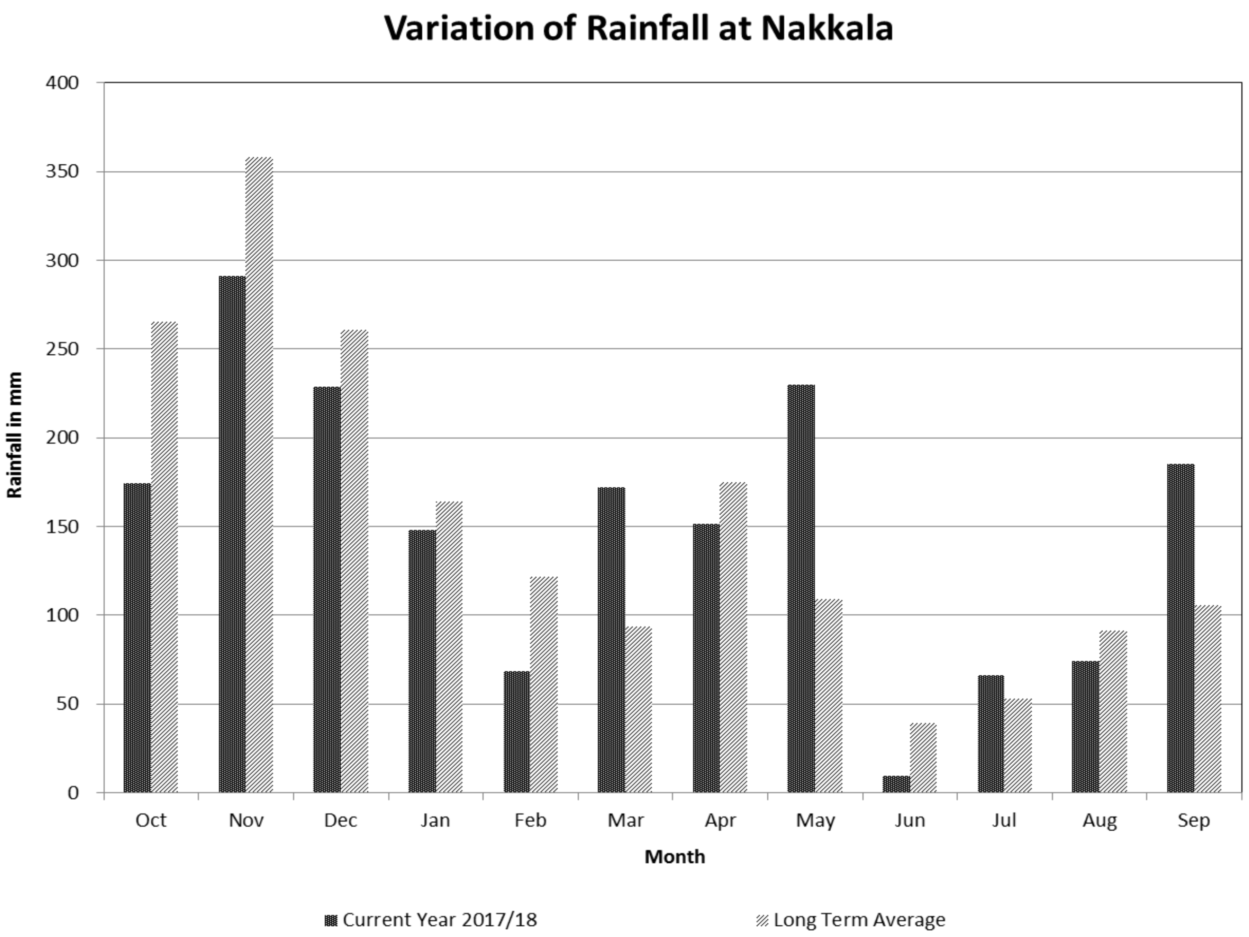

Variation of Rainfall at Hanwella
Rainfall in mm
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

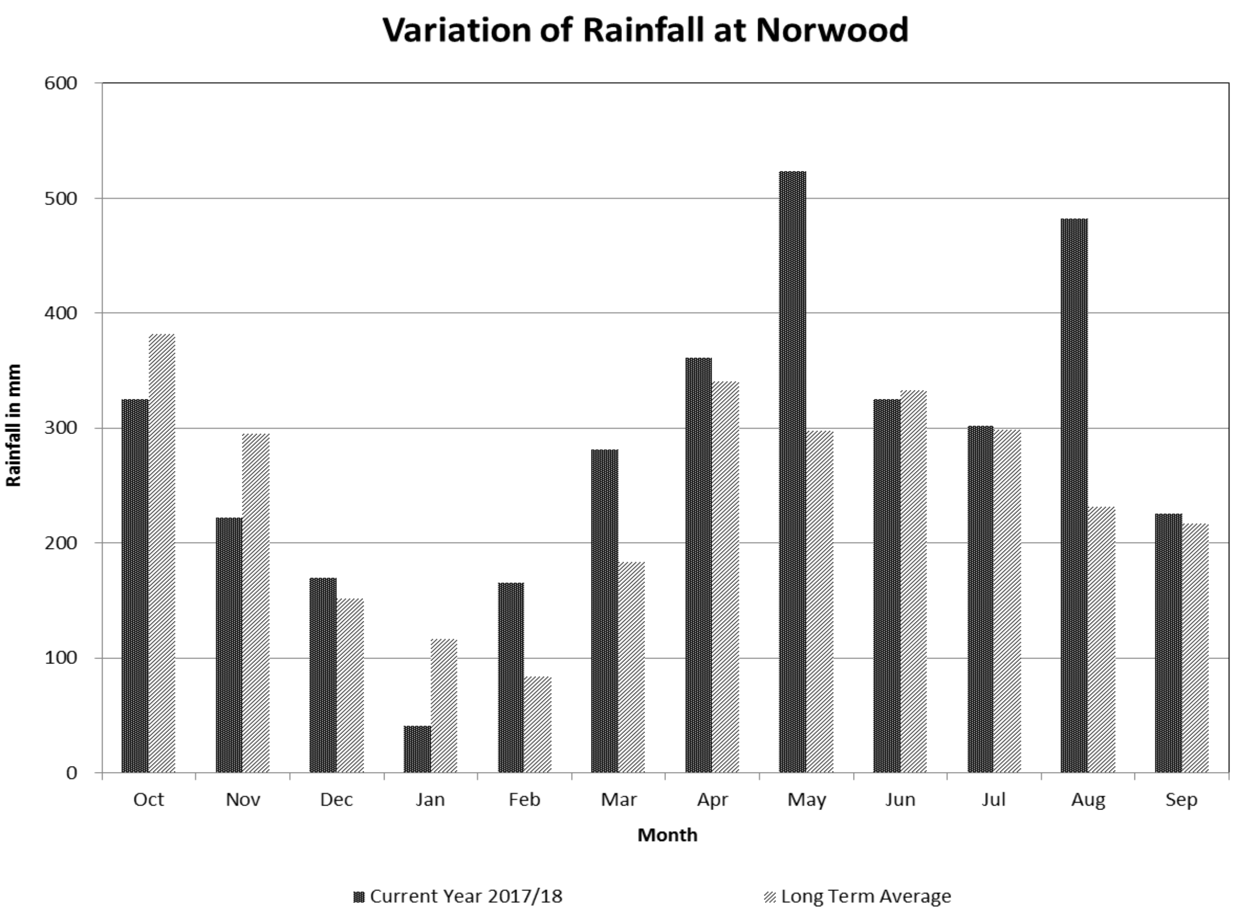

Variation of Rainfall at Holombuwa
Rainfall in mm
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

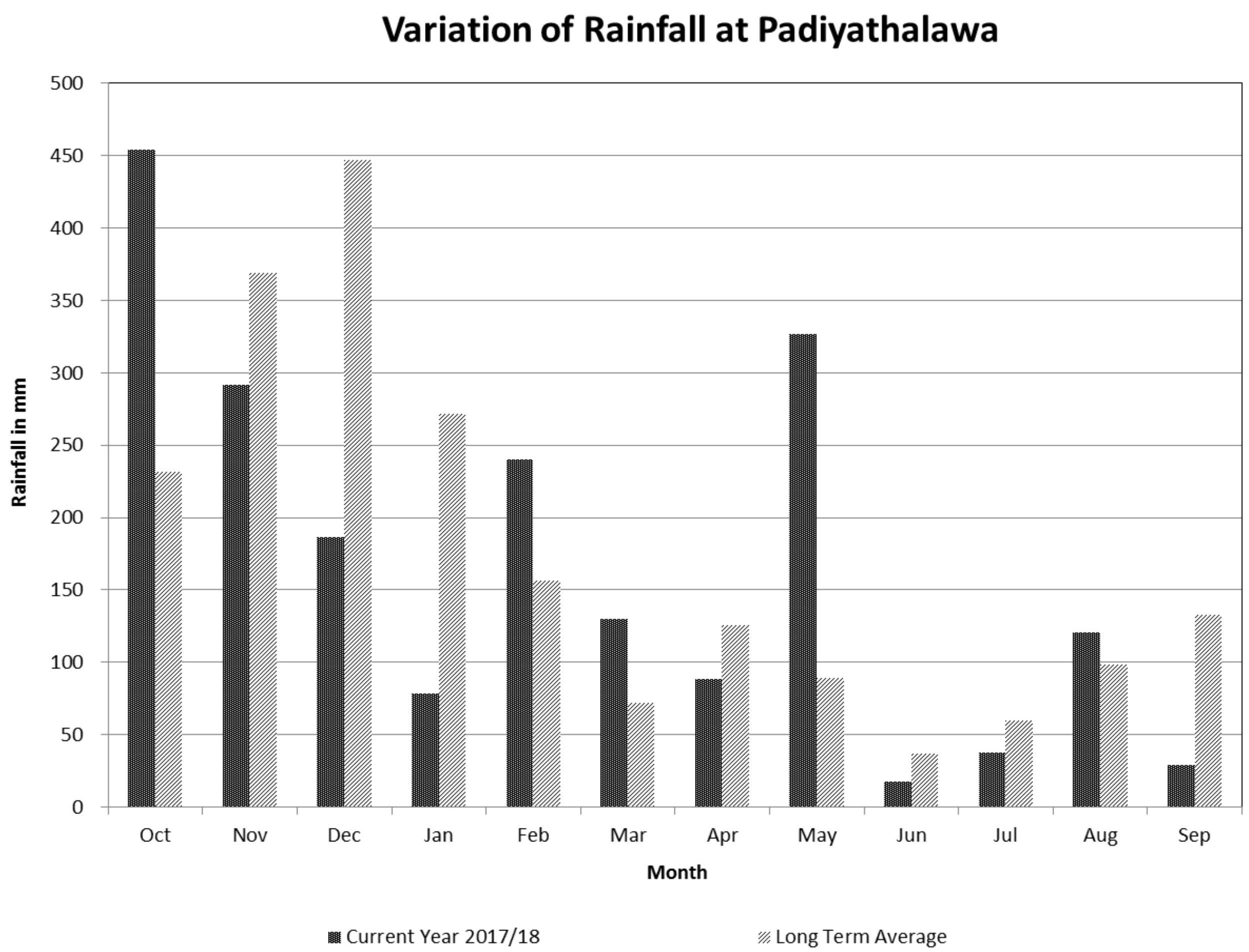

Variation of Rainfall at Horowpothana
Rainfall in mm
450
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

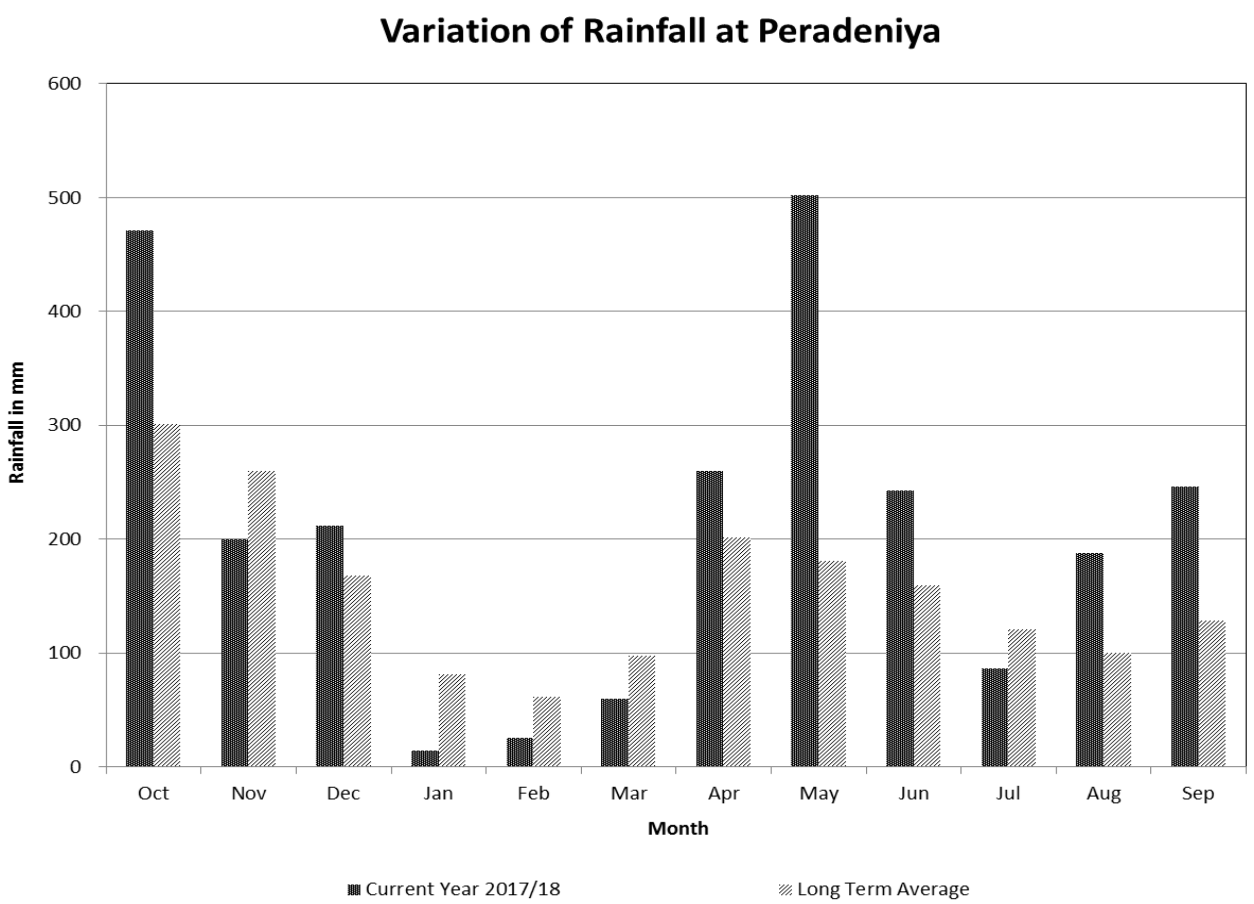

Variation of Rainfall at Kithulgala
Rainfall in mm
900
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

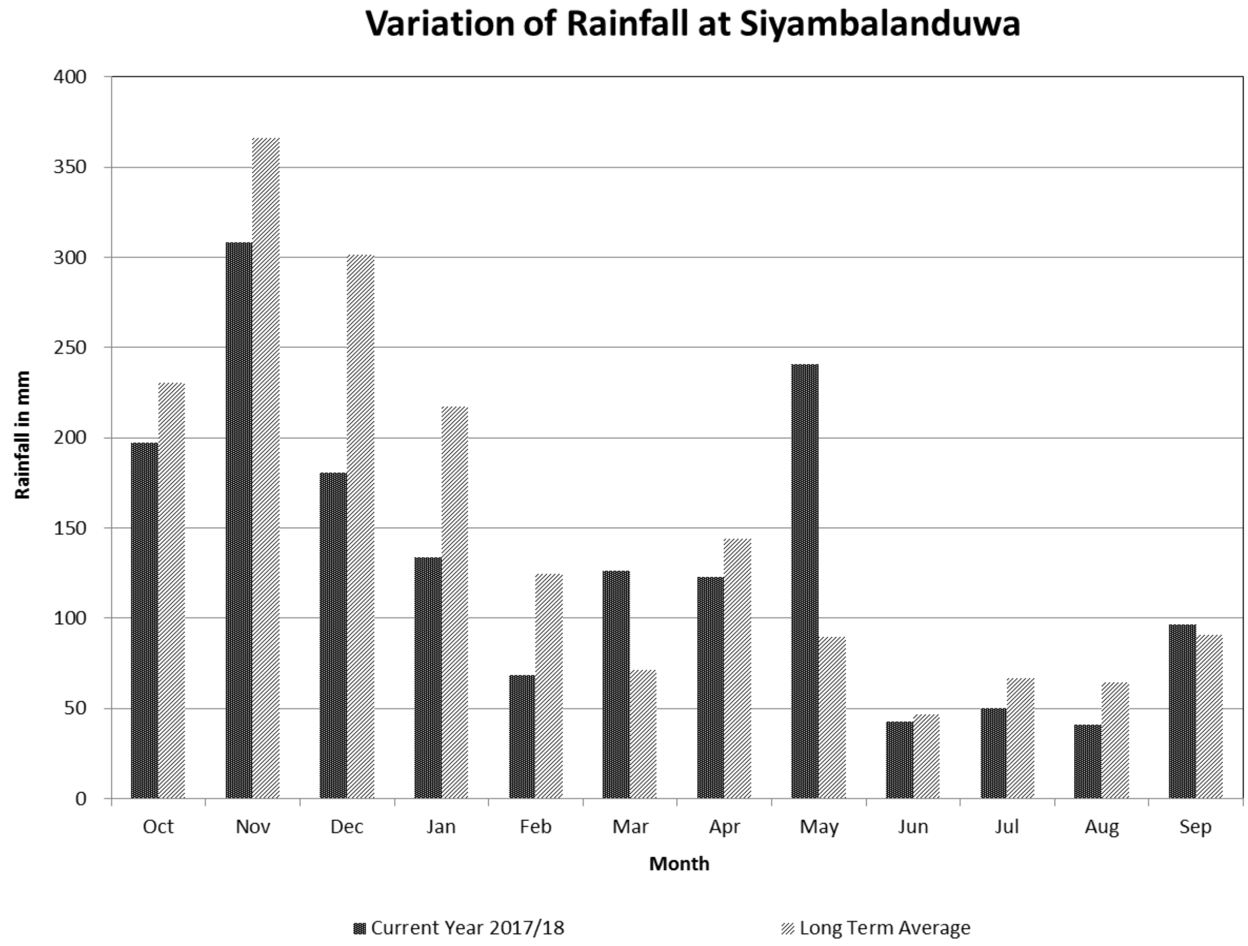

Variation of Rainfall at Kuda Oya
Rainfall in mm
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

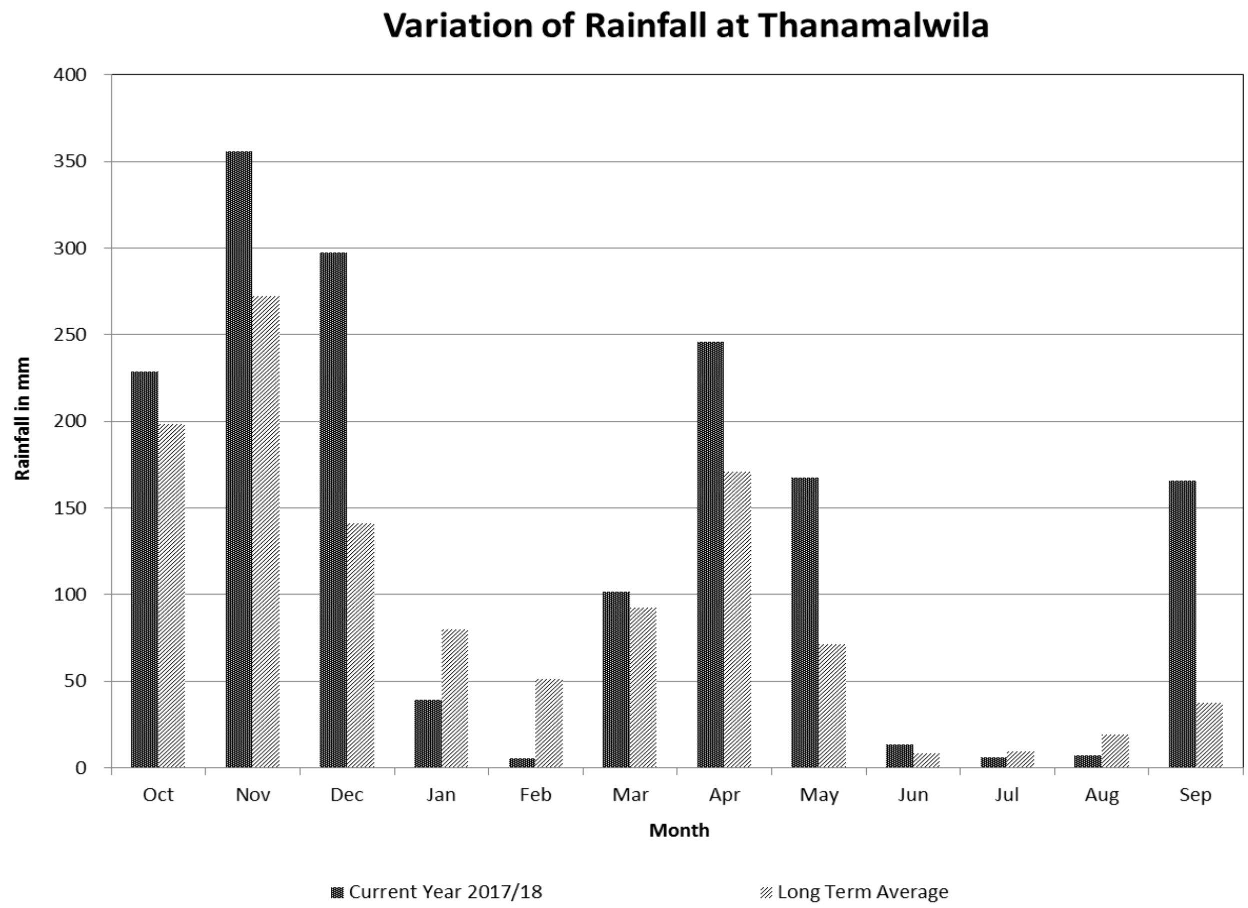

Variation of Rainfall at Nakkala
Rainfall in mm
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

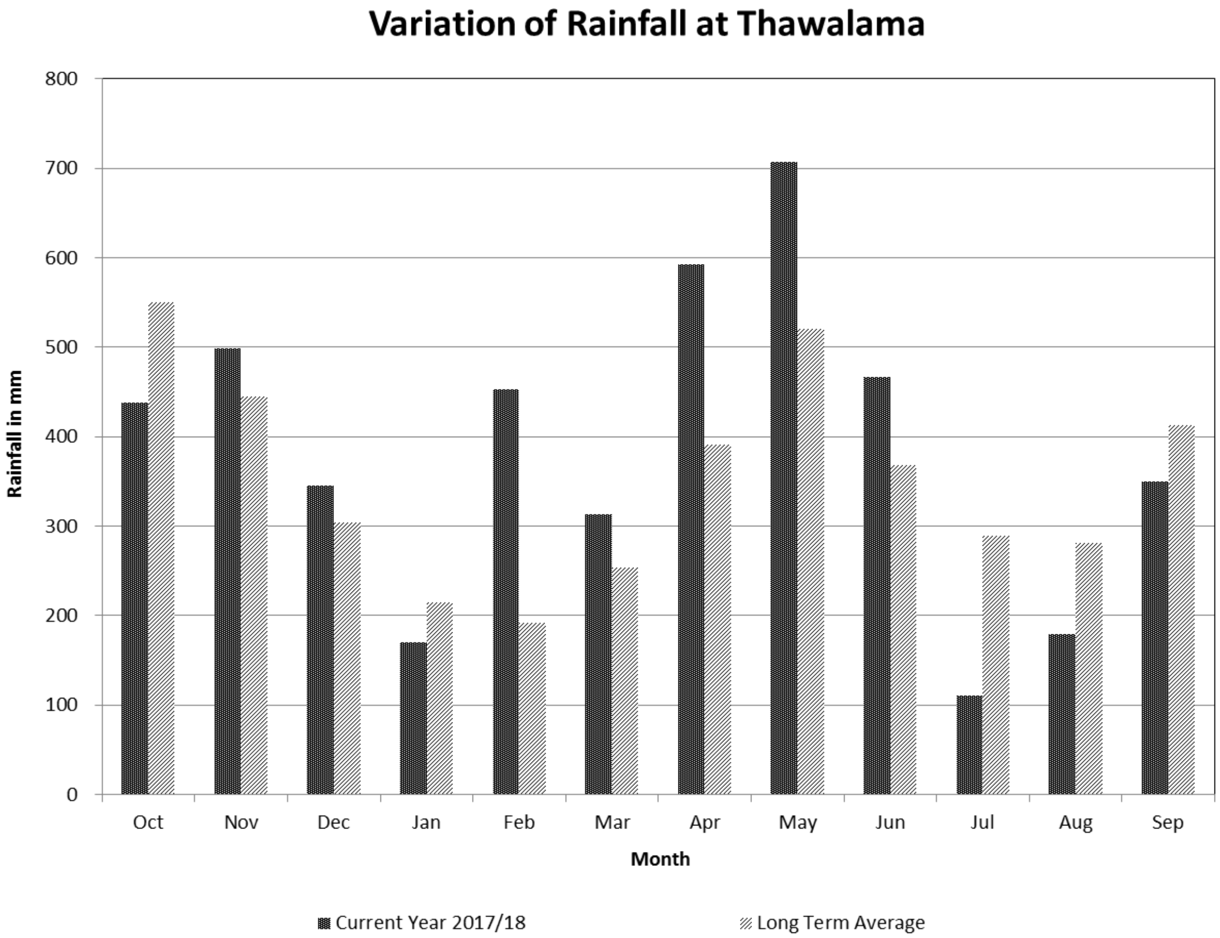

Variation of Rainfall at Norwood
Rainfall in mm
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

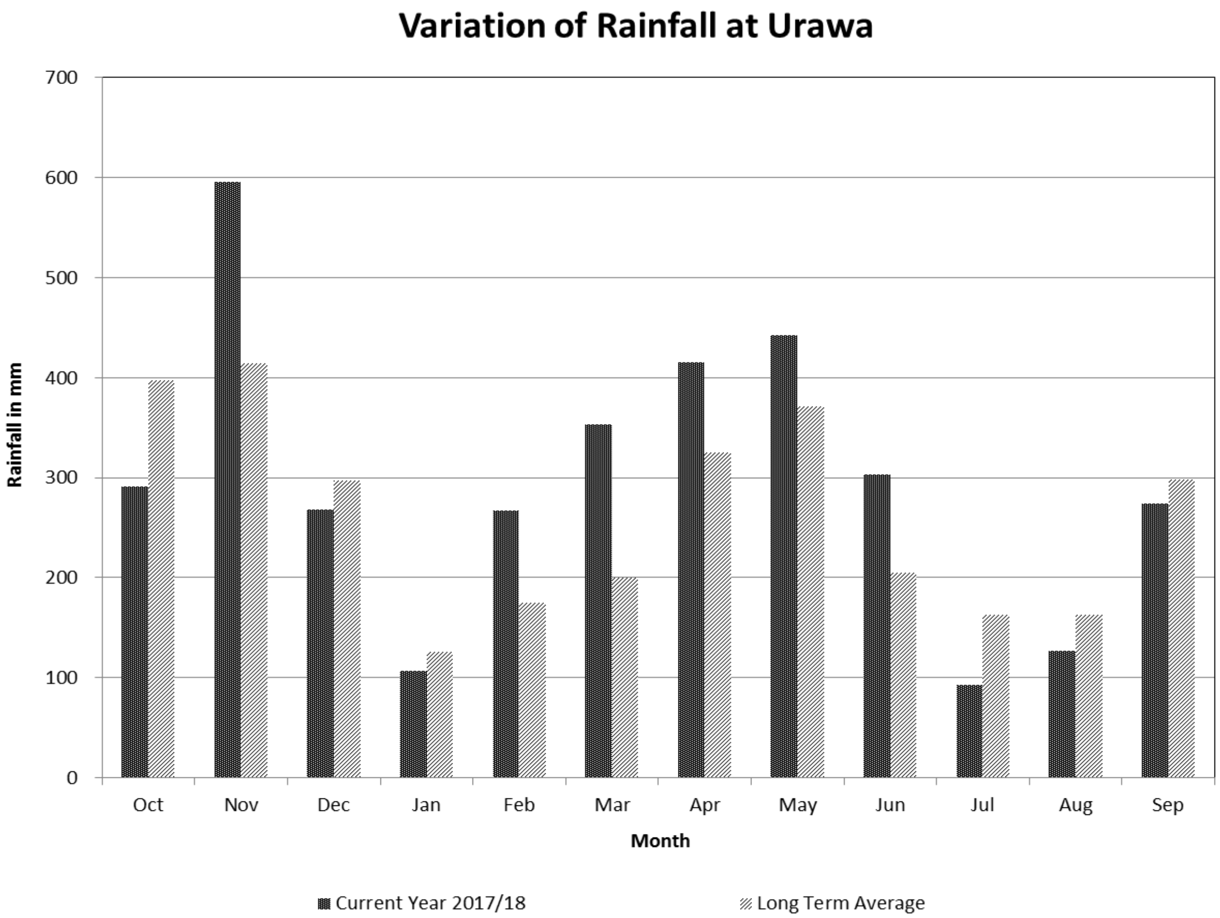

Variation of Rainfall at Padiyathalawa
500
450
400
350
300
250
200
150
100
50
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average

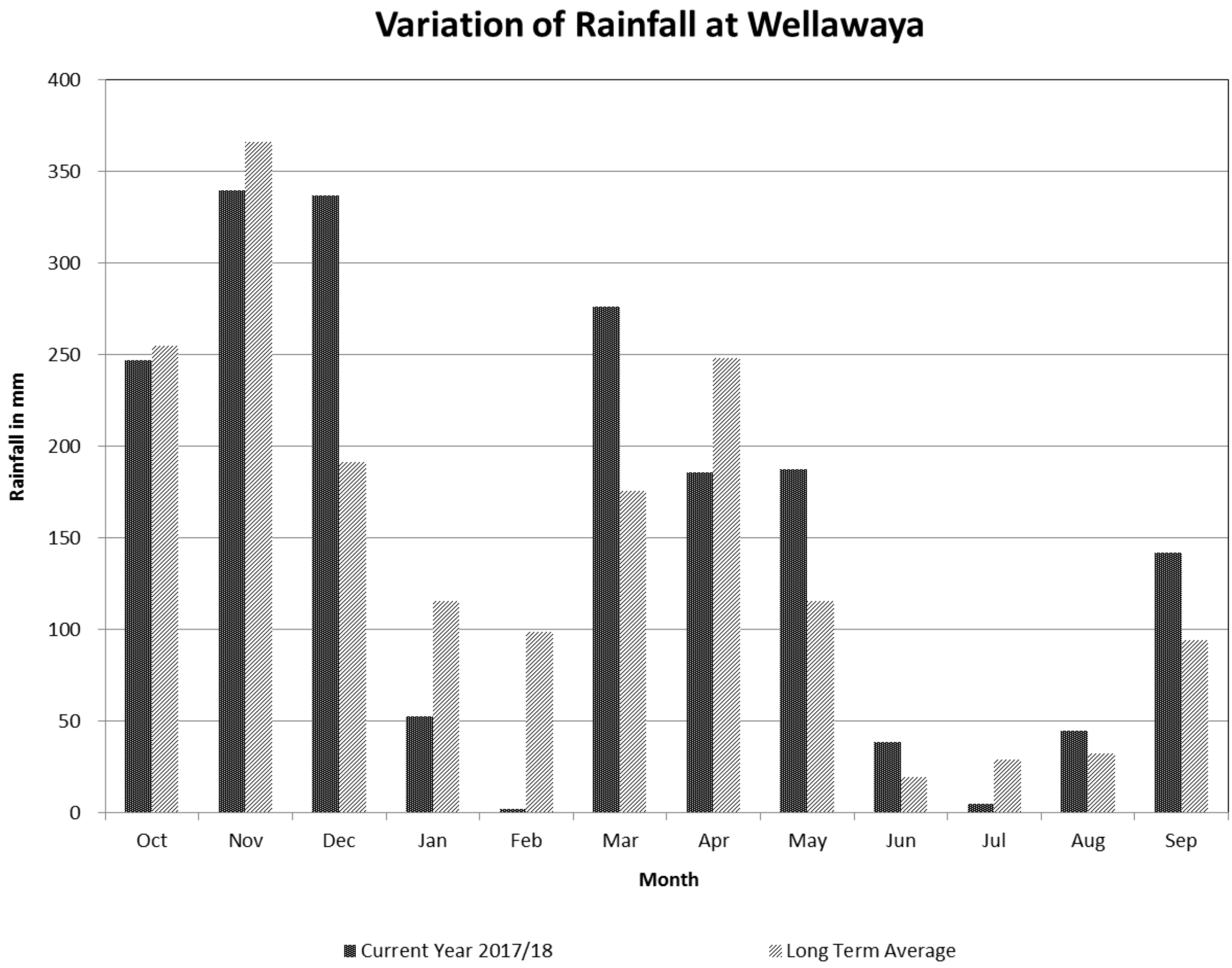

Variation of Rainfall at Peradeniya
600
500
400
300
200
100
0
Rainfall in mm
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year 2017/18
Long Term Average


Variation of Rainfall at Siyambalanduwa
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 2017/18
Long Term Average


Variation of Rainfall at Thanamalwila
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 2017/18
Long Term Average


Variation of Rainfall at Thawalama
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 2017/18
Long Term Average


Variation of Rainfall at Urawa
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 2017/18
Long Term Average


Variation of Rainfall at Wellawaya
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 2017/18
Long Term Average

SPATIAL VARIATION OF RAINFALLS OVER THE ISLAND

- **NEM (North-East Monsoon) Rainfall Distribution**

The country has received less rainfalls in most areas during the North-East monsoon period compared to the long term average. Especially North-Central and Northern parts of the country show a reduction in rainfall.

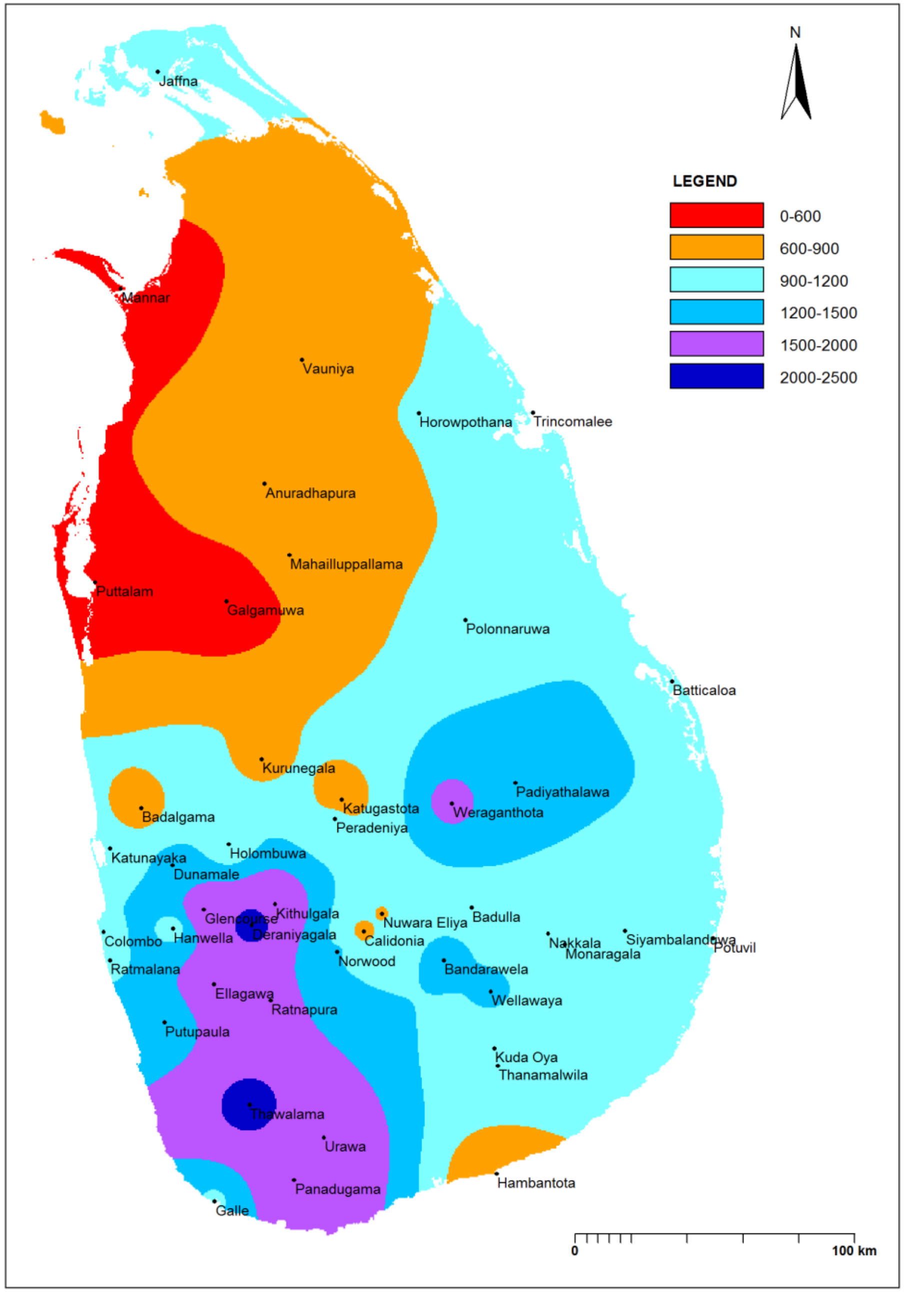
- **SWM (South-West Monsoon) Rainfall Distribution**

The country has received higher rainfalls during South- West monsoon period. The higher rainfalls are concentrated on the South-Western quadrant of the country.

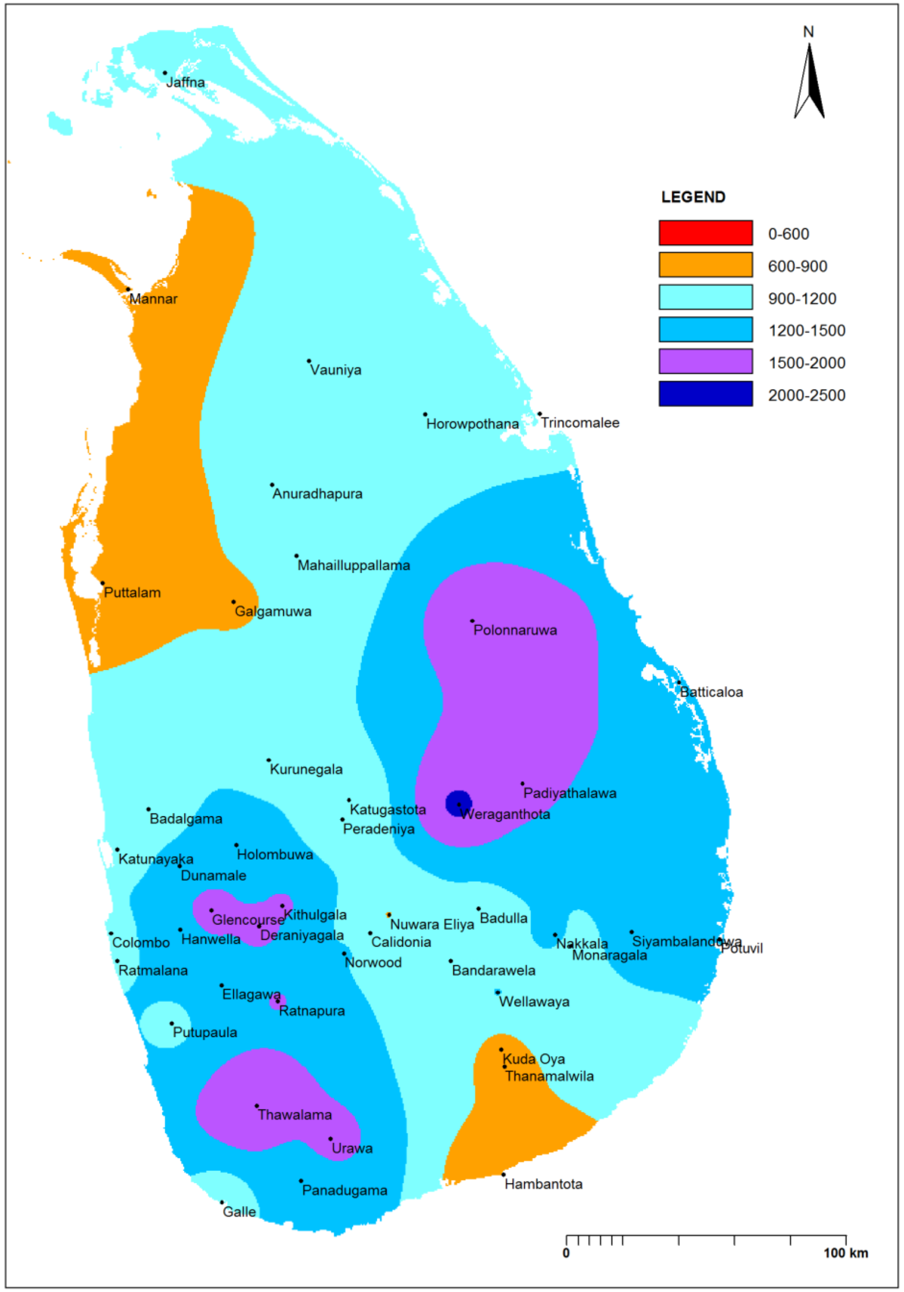
- **Annual Rainfall Distribution**

Annual rainfall distribution of the current year is close to the long term average rainfall. However Mannar district has received low rainfall compared to the annual average.

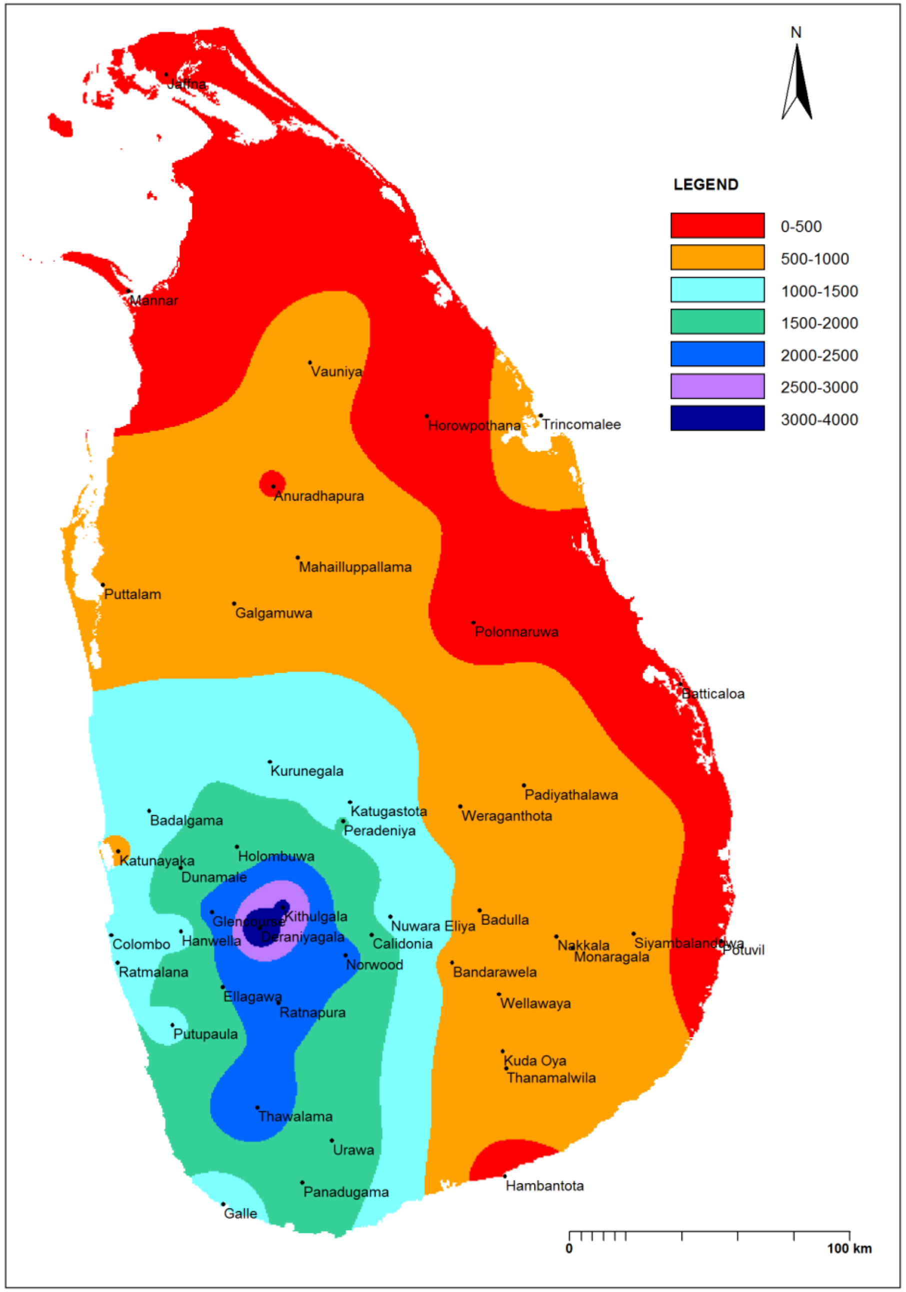
NEM Rainfall Distribution – Current year 2017/18



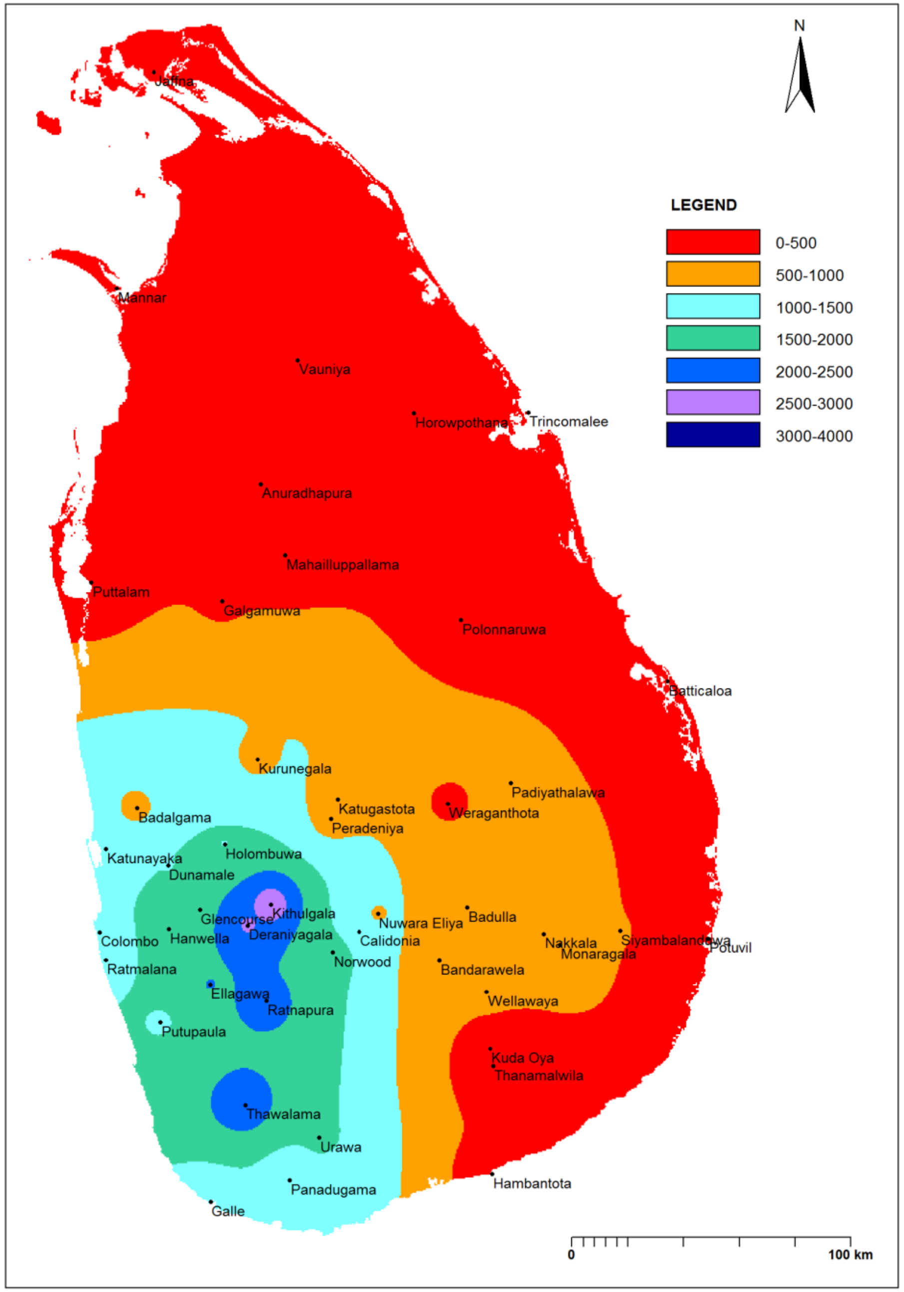
NEM Rainfall Distribution – Long Term Average



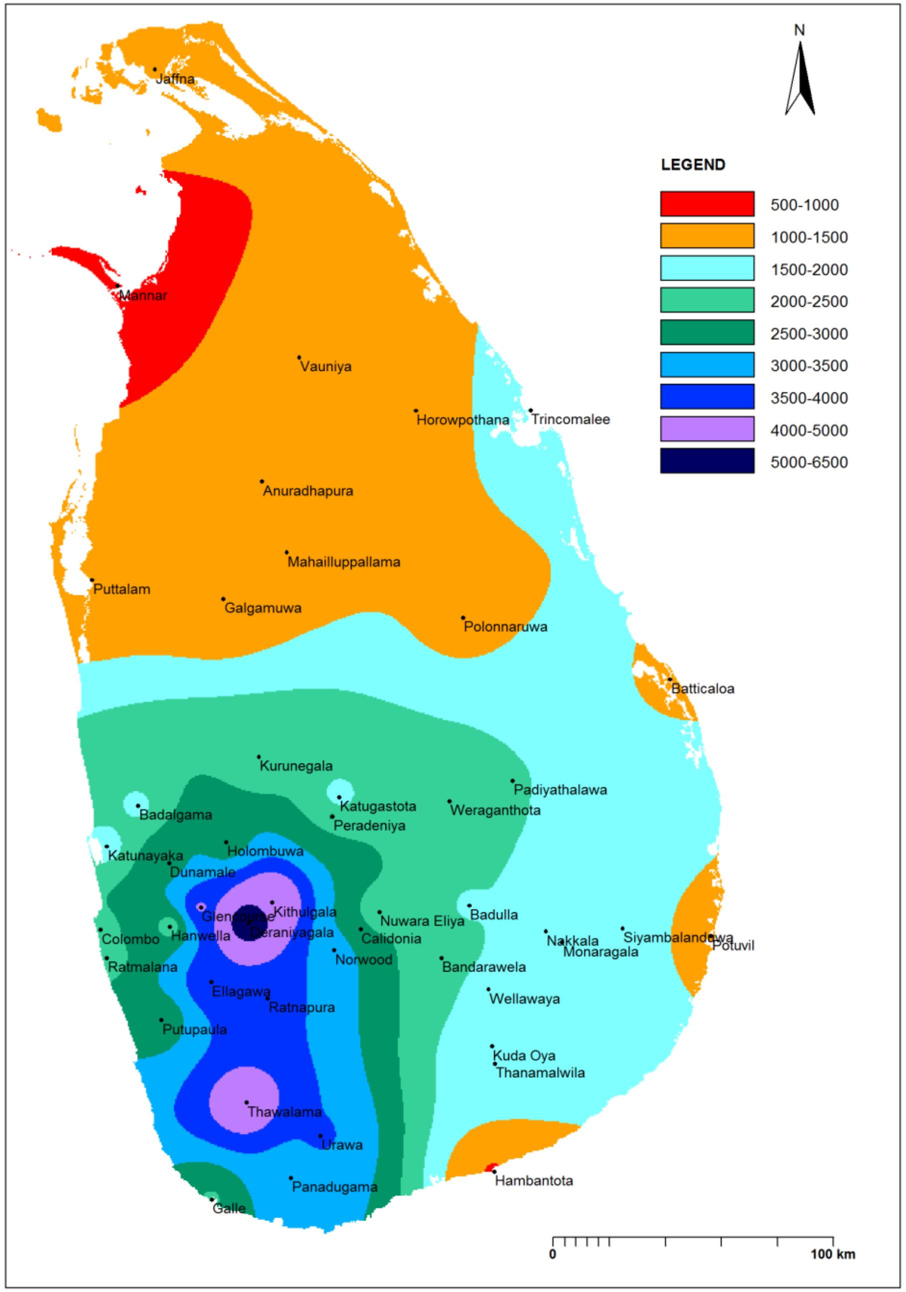
SWM Rainfall Distribution – Current year 2017/18



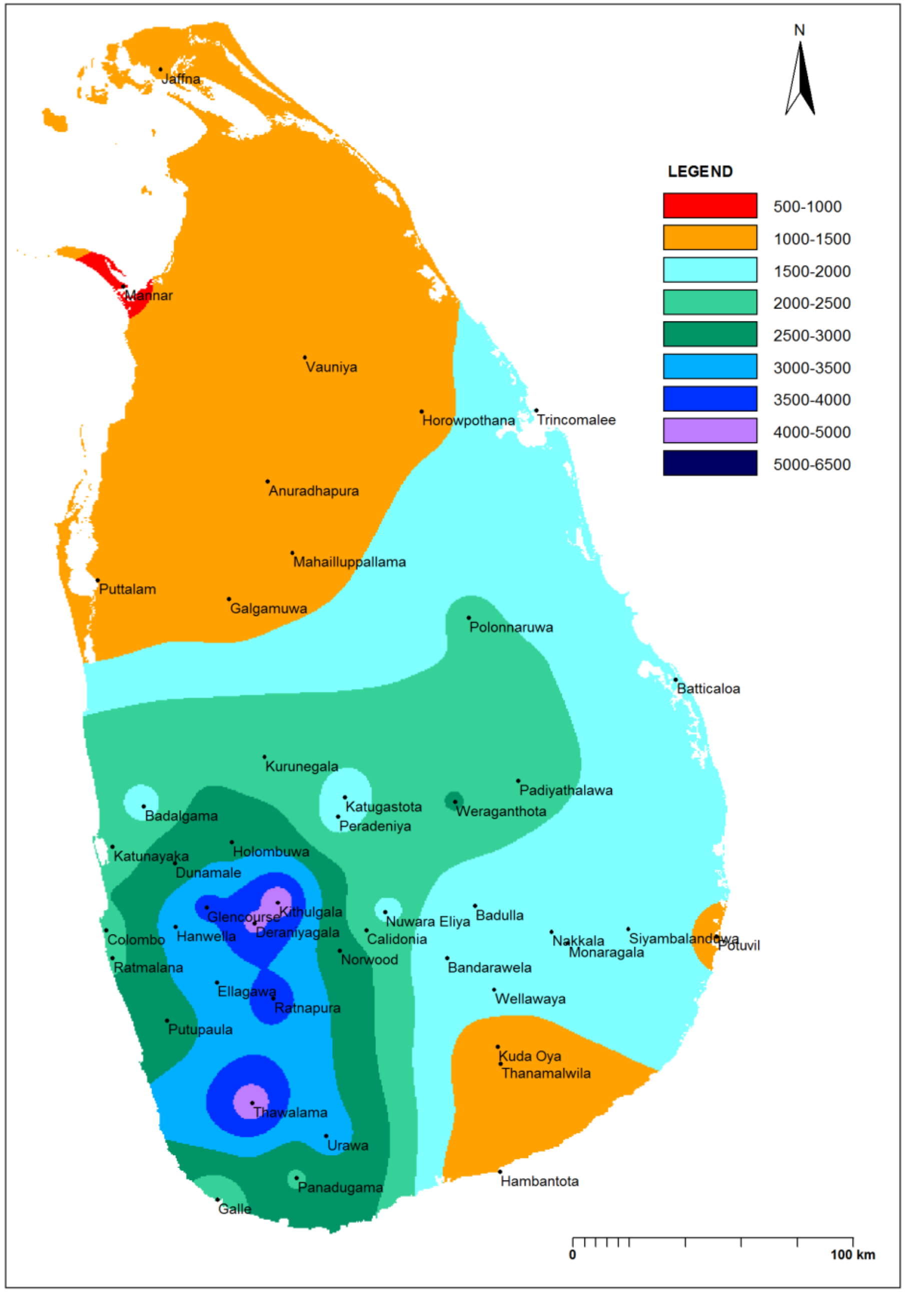
SWM Rainfall Distribution – Long Term Average



Annual Rainfall Distribution – Current year 2017/18



Annual Rainfall Distribution – Long Term Average



RAINFALL INTENSITIES

RAINFALL INTENSITY ANALYSIS
WATER YEAR 2017/18
(Maximum Depth of Rainfall in mm)

Station	Duration in Hours								
	1	3	6	12	24	48	72	96	120
Badalgama	49	72	112	126	149	169	241	306	382
Baddegama	66	120	123	123	123	231	233	255	276
Deraniyagala	125	164	222	289	350	470	530	551	698
Dolabodakanda	22	22	44	80	130	184	207	218	225
Dunamale	93	150	180	188	198	250	287	324	456
Ellagawa	73	106	150	216	239	371	402	528	540
Galgamuwa	44	53	58	61	61	61	71	102	163
Giriulla	78	92	131	173	241	278	306	330	454
Glencourse	72	86	90	117	121	199	221	267	362
Hanwella	50	56	68	78	87	137	167	187	221
Holombuwa	58	59	93	129	152	220	251	270	373
Horowpathana	52	69	69	73	88	113	146	171	227
Karandagolla	36	36	64	80	80	87	119	159	192
Kithulgala	83	98	102	130	207	286	331	349	416
Kuda Oya	59	115	115	130	130	141	172	207	217
Millakanda	104	172	174	174	174	200	233	244	291
Nakkala	70	82	84	85	85	98	108	138	156
Padiyathalawa	70	91	97	97	97	127	202	250	265
Panadugama	66	88	101	115	118	177	189	197	215
Peradeniya	64	83	85	91	91	137	148	221	253
Pitabeddara	71	90	101	112	113	207	235	245	245
Putupaula	90	124	130	144	164	250	279	281	314
Rathnapura	59	90	125	153	192	270	278	397	411
Siyambalanduwa	57	101	103	105	107	120	123	123	141
Thanamalwila	74	85	102	105	105	113	144	156	156
Thawalama	64	105	146	187	210	228	302	319	337
Wellawaya	47	73	73	76	76	120	151	172	189

EVAPORATION
AND
EVAPOTRANSPIRATION

MONTHLY PAN EVAPORATION
(In mm)

Upper line : Current year 2017/18
Lower line : Long term average up to 2016/17

Name of Station	Period of Records	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total		
														NEM	SWM	Annual
Agalawaththa		73.5	70.5	76.2	91.1	87.7	97.5	99.6	89.7	82.0	69.9	79.5	102.1	496.5	522.7	1019.2
(6°32'00''N, 80°09'00''E)	7	77.3	68.0	69.3	80.3	84.8	103.2	82.5	83.9	73.9	78.3	75.1	72.7	482.9	466.4	949.3
Badalgama		84.1	80.5	103.6	105.8	112.0	115.6	102.8	86.5	84.1	96.0	105.4	122.7	601.7	597.5	1199.2
(7°18'03''N, 79°58'50''E)	11	87.7	71.3	73.2	93.8	107.0	108.2	95.4	84.1	77.1	90.3	95.8	84.5	541.2	527.3	1068.5
Bandarawela *		78.9	74.6	5.4	57.7	75.9	72.5	62.4	50.8	82.5	87.7	94.9	72.0	364.9	450.3	815.2
(6°49'48''N, 80°58'48''E)	24	73.1	56.7	54.7	64.9	77.8	99.3	81.8	96.3	98.1	103.7	106.7	86.1	426.5	572.8	999.3
Batewela		119.1	127.3	118.5	96.4	109.1	128.0	127.8	114.9	129.2	111.9	132.0	150.1	698.3	765.9	1464.2
(6°37'14''N, 80°35'27''E)	1	132.8	126.7	110.3	110.8	94.9	94.1	113.3	139.9	122.4	116.5	141.1	135.7	669.5	768.8	1438.4
Bombuwela *		81.2	67.1	81.5	81.2	88.2	97.0	97.5	99.2	73.8	86.2	86.2	93.3	496.3	536.2	1032.5
(6°33'36''N, 80°01'12''E)	25	89.4	82.0	79.2	88.2	91.2	110.3	97.8	92.5	90.1	91.2	101.3	90.4	540.1	563.3	1103.4
Colombo *		92.4	94.0	121.7	141.7	137.8	131.4	131.4	103.9	112.2	121.5	127.7	135.3	719.0	732.0	1451.0
(6°54'00''N, 79°51'36''E)	24	94.0	86.1	89.1	109.4	108.8	127.3	112.8	106.3	97.1	101.7	116.0	101.5	614.9	635.4	1250.4
Dunamale		88.8	75.8	79.7	79.1	102.2	108.7	94.4	70.9	72.7	99.9	81.2	105.8	534.2	524.9	1059.1
(7°07'00''N, 80°04'55''E)	33	65.2	61.1	61.8	74.6	87.7	95.7	84.7	69.2	63.2	65.9	67.7	72.9	446.1	423.7	869.7
Galgamuwa		102.8	68.2	81.9	88.5	114.3	137.3	130.2	109.6	108.2	130.3	130.8	137.6	593.1	746.7	1339.9
(7°58'13''N, 80°15'18''E)	17	95.6	75.3	69.2	82.6	94.0	127.0	106.3	114.0	112.2	126.9	131.1	112.2	543.7	702.8	1246.5
Giradurukotte *		109.6	68.9	-1	61.7	117.3	157.5	111.6	115.0	-1	-1	-1	-1	-1	-1	-1
(7°24'00''N, 81°04'48''E)	24	108.1	79.1	69.0	73.3	84.4	117.1	114.3	137.4	147.0	159.3	167.0	142.3	531.0	867.2	1398.2
Horowpathana		101.9	78.5	66.7	74.4	79.0	101.8	116.5	108.5	153.6	177.5	166.7	141.5	502.2	864.4	1366.6
(8°34'39''N, 80°52'43''E)	4	123.7	71.5	74.3	76.5	84.2	109.2	123.8	126.7	151.6	172.4	159.9	146.1	539.3	880.4	1419.8
Huruluwewa		141.9	208.6	84.0	92.5	91.1	132.6	142.8	138.0	161.7	185.1	179.9	176.6	750.7	984.2	1734.9
(8°13'28''N, 80°43'04''E)	1	180.5	90.0	100.0	121.0	96.7	138.5	164.8	134.2	160.3	194.1	172.8	156.5	726.7	982.7	1709.3
Kantale		112.5	65.2	91.3	95.6	100.9	120.6	134.1	98.7	156.3	167.0	172.4	143.6	586.1	872.2	1458.3
(8°21'50''N, 80°58'58''E)	17	111.0	69.1	66.6	71.6	90.7	121.7	119.4	133.1	159.9	156.8	157.0	147.4	530.7	873.7	1404.4
Kurunegala *		82.8	64.5	90.6	106.6	133.3	120.6	107.7	93.3	84.0	107.3	102.3	117.3	598.5	611.9	1210.3
(7°28'12''N, 80°20'60''E)	24	85.6	71.2	78.0	97.0	107.6	127.6	94.1	97.1	86.6	93.5	101.4	93.5	567.0	566.3	1133.3
Mahailluppallama *		101.5	70.9	67.4	85.9	112.6	129.3	114.9	98.3	109.8	151.3	147.3	141.3	567.5	762.8	1330.3
(8°07'12''N, 80°27'36''E)	24	98.9	70.3	66.3	75.4	88.9	129.1	111.7	130.2	130.8	143.1	153.4	132.1	528.8	801.3	1330.1

MONTHLY PAN EVAPORATION

(In mm)

Upper line : Current year 2017/18
Lower line : Long term average up to 2016/17

Name of Station	Period of Records	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total		
														NEM	SWM	Annual
Padiyathalawa		135.9	78.1	79.4	92.9	82.5	132.0	126.6	120.9	168.9	159.2	164.5	144.2	600.7	884.3	1485.1
(7°23'00''N, 81°11'30''E)	11	117.4	75.8	62.1	72.1	88.7	118.4	118.0	126.9	144.3	156.7	159.3	129.5	534.5	834.7	1369.2
Palugasdamana		126.0	58.4	81.4	80.1	72.2	109.0	112.8	110.2	147.5	174.2	168.4	135.7	527.1	848.8	1375.9
(7°57'01''N, 81°01'12''E)	27	123.4	70.4	66.1	78.0	95.4	131.9	130.8	156.0	173.0	185.7	181.1	163.8	565.1	990.4	1555.6
Panadugama		80.4	62.2	80.1	90.5	97.2	93.9	87.6	69.1	71.7	110.9	96.2	106.2	504.3	541.7	1046.0
(6°08'00''N, 80°29'00''E)	1	97.4	68.4	88.3	83.2	89.3	92.7	93.1	60.1	66.1	99.4	86.9	90.2	519.3	495.9	1015.2
Parakrama Samudraya		132.8	115.9	70.8	80.1	91.6	109.8	118.5	114.8	163.6	163.7	185.1	161.5	600.9	907.2	1508.1
(7°56'21''N, 80°59'11''E)	1	175.6	68.3	84.8	95.1	87.8	115.0	139.0	148.8	185.9	206.6	187.4	134.9	626.6	1002.7	1629.4
Pelwatta		116.5	75.7	103.5	111.7	121.4	112.4	104.6	91.2	142.4	135.4	148.9	135.6	641.3	758.1	1399.3
(6°24'36''N, 81°07'12''E)	3	112.9	85.6	96.0	119.7	110.8	138.0	115.0	112.7	134.6	147.7	153.2	138.1	662.9	801.3	1464.2
Puttalam *		-1	-1	-1	-1	-1	136.7	136.5	116.3	119.7	134.5	145.7	140.1	-1	792.8	-1
(8°01'48''N, 79°49'48''E)	25	118.6	82.4	79.4	95.7	112.1	148.1	131.9	147.4	146.3	154.0	162.3	147.7	636.4	889.5	1525.9
Rathnapura *		54.5	67.3	66.4	87.1	80.9	82.5	72.9	66.7	57.9	67.6	73.8	83.1	438.6	421.9	860.5
(6°40'48''N, 80°24'00''E)	24	74.0	74.2	71.0	85.2	92.9	112.4	90.5	83.4	79.3	81.3	86.6	78.0	509.7	499.0	1008.7
Rideebandi Ela		109.7	95.3	94.4	106.7	129.2	135.8	129.5	118.6	105.5	123.0	122.8	138.4	671.2	737.8	1409.0
(7°43'45'' N, 80°15'42''E)		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Seetha Eliya *		56.4	56.1	52.5	84.3	78.7	89.6	70.2	62.0	37.8	65.7	53.0	67.8	417.6	356.5	774.1
(6°55'48''N, 80°47'60''E)	23	62.8	60.4	56.4	70.2	87.3	113.8	83.0	84.7	66.9	69.7	71.7	69.8	450.9	445.8	896.7
Senanayaka Samudraya		117.1	94.2	92.6	116.7	108.1	115.9	122.9	126.1	142.1	164.1	161.4	148.8	644.6	865.4	1510.0
(7°13'05''N, 81°32'49''E)	1	153.7	90.9	102.2	101.9	123.4	136.7	135.9	138.1	144.3	165.5	117.8	108.8	708.8	810.4	1519.2
Sewanagala		141.0	85.2	94.4	94.4	126.1	124.2	103.4	98.1	114.2	178.3	163.6	134.4	665.3	792.1	1457.4
(6°22'58''N, 80°54'19''E)	24	123.0	100.2	93.0	112.9	119.0	146.4	121.8	133.5	138.7	166.9	167.2	138.7	694.6	866.8	1561.4
Siyambalanduwa		104.9	64.3	91.8	83.5	81.0	102.0	95.2	94.0	98.9	104.9	119.0	117.7	527.5	629.6	1157.2
(6°54'17''N, 81°32'44''E)	2	101.9	75.4	124.3	90.5	85.7	101.9	98.1	98.4	107.4	114.8	109.5	107.3	579.7	635.5	1215.1
Thanamalwila		130.8	80.7	93.5	85.6	107.7	108.0	95.8	96.3	113.3	164.9	162.2	140.8	606.3	773.3	1379.6
(6°28'06''N, 81°08'03''E)	3	116.6	75.3	86.0	105.6	101.6	109.7	104.1	95.5	123.0	155.3	156.5	139.4	594.8	773.8	1368.6

Note :- Missing data is denoted by -1, '*' Denotes data obtained from Meteorology Department
'NEM' denotes North-East Monsoon, 'SWM' denotes South-West Monsoon

OPEN WATER EVAPORATION (Eo) & POTENTIAL EVAPOTRANSPIRATION FOR REFERENCE CROP (ETo) – 2017/18

Weather Station : Pelwaththa
Co-ordinate : 6° 41' N, 81° 12' E
Altitude : 152 m

Month	Temp. Avg. ^{o}C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	29.00	68.06	6.14	57.04	156.7	118.8
Nov	27.82	71.80	4.82	56.43	126.4	96.4
Dec	27.26	78.91	6.77	66.68	141.6	107.1
Jan	20.78	62.34	7.17	35.11	134.2	100.6
Feb	22.01	60.79	8.53	53.59	150.4	114.3
Mar	22.65	64.57	7.03	136.86	154.9	115.5
Apr	23.00	69.20	7.43	83.41	153.8	113.9
May	23.65	70.87	6.08	99.89	146.2	109.5
Jun	23.69	60.93	8.30	74.68	173.1	133.7
Jul	22.49	56.88	8.01	32.09	167.0	126.2
Aug	22.86	55.70	7.24	51.61	167.0	128.3
Sep	22.62	59.93	6.83	64.75	151.6	114.9
Annual	23.99	65.00	7.03	67.68	1822.8	1379.1

Weather Station : Padiyathalawa
Co-ordinate : 7° 23' N, 81° 11 E
Altitude : 100 m

Month	Temp. Avg. ^{o}C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	23.51	88.48	6.78	39.96	126.5	94.6
Nov	23.30	92.40	3.69	23.53	83.9	63.4
Dec	22.69	93.06	3.69	16.94	77.8	58.6
Jan	21.47	88.90	4.73	19.46	103.9	78.1
Feb	22.36	94.75	5.61	21.45	110.8	84.6
Mar	23.96	90.29	6.93	29.94	151.1	114.8
Apr	25.03	93.20	7.27	32.71	155.3	118.6
May	25.22	97.06	4.66	38.01	129.0	99.0
Jun	25.64	79.27	6.22	69.07	145.8	110.7
Jul	25.54	86.39	5.88	66.13	145.8	110.4
Aug	26.15	76.45	6.30	84.30	159.3	121.7
Sep	25.27	82.60	6.96	53.46	152.3	114.9
Annual	24.18	88.57	5.72	41.25	1541.4	1169.4

OPEN WATER EVAPORATION (Eo) & POTENTIAL EVAPOTRANSPIRATION FOR REFERENCE CROP (ETo) – 2017/18

Weather Station : **Palugasdamana**
Co-ordinate : **8° 00' N, 81° 00' E**
Altitude : **52 m**

Month	Temp. Avg. °C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	30.07	77.32	5.94	21.87	153.2	116.3
Nov	27.61	84.43	2.77	10.53	100.0	75.9
Dec	27.40	87.87	3.93	14.06	108.4	82.7
Jan	26.17	91.10	4.53	20.05	113.4	86.9
Feb	27.42	87.21	5.36	20.93	122.3	93.5
Mar	28.72	89.97	6.23	21.10	159.0	123.3
Apr	29.67	85.07	7.16	21.71	170.6	131.6
May	29.29	84.45	5.05	21.22	147.4	113.9
Jun	30.36	68.40	6.87	62.41	168.3	129.6
Jul	30.41	65.87	6.45	62.88	172.2	132.9
Aug	30.40	67.74	6.01	63.29	169.5	131.3
Sep	32.87	71.93	6.94	34.15	222.3	181.9
Annual	29.20	80.11	5.60	31.18	1806.5	1399.8

Weather Station : **Agalawaththa**
Co-ordinate : **6° 32' N, 80° 09' E**
Altitude : **65 m**

Month	Temp. Avg. °C	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	27.24	80.92	4.32	36.42	116.9	88.4
Nov	27.10	79.38	3.66	33.08	94.2	70.3
Dec	27.39	78.38	4.11	28.79	92.5	68.5
Jan	26.66	72.31	5.65	33.90	108.1	79.3
Feb	27.08	78.86	5.13	36.56	108.5	81.5
Mar	27.74	77.55	5.65	35.17	142.7	107.8
Apr	28.17	79.53	5.50	35.59	147.9	112.8
May	27.66	81.19	3.52	42.56	133.3	102.3
Jun	27.23	83.62	3.83	47.88	131.3	100.7
Jul	27.16	82.58	4.31	52.51	141.8	108.6
Aug	26.88	83.79	5.00	55.45	145.4	110.6
Sep	27.45	78.10	5.92	43.96	144.0	109.1
Annual	27.31	79.68	4.72	40.16	1506.5	1139.8

OPEN WATER EVAPORATION (Eo) & POTENTIAL EVAPOTRANSPIRATION FOR REFERENCE CROP (ETo) – 2017/18

Weather Station : Dunamale
Co-ordinate : 7° 06' N, 80° 04' E
Altitude : 20 m

Month	Temp. Avg. ^oC	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	26.15	91.32	4.41	19.15	123.9	95.5
Nov	27.12	90.83	4.63	11.70	113.4	85.7
Dec	26.89	88.58	5.79	14.54	124.4	94.9
Jan	26.27	85.58	5.99	16.05	127.5	96.4
Feb	27.68	87.68	6.66	19.38	133.3	102.2
Mar	28.03	87.16	6.58	20.97	160.6	123.5
Apr	28.20	88.33	5.98	20.61	151.6	117.1
May	27.32	89.84	3.25	21.73	120.4	93.2
Jun	27.33	90.40	4.29	32.14	125.3	96.5
Jul	27.45	87.26	4.07	37.79	130.0	99.8
Aug	27.24	87.29	2.81	40.76	117.5	90.4
Sep	25.38	85.07	6.19	31.58	143.0	108.5
Annual	27.09	88.28	5.05	23.87	1571.0	1203.6

Weather Station : Galgamuwa
Co-ordinate : 8° 00' N, 80° 15' E
Altitude : 76 m

Month	Temp. Avg. ^oC	Humidity Avg. %	Sunshine hrs	Wind Speed km/day	Eo mm	ETo mm
Oct	27.44	97.32	5.35	72.64	137.8	103.5
Nov	26.23	98.93	3.57	58.11	102.6	77.7
Dec	25.81	97.42	4.65	70.71	109.9	81.8
Jan	25.25	94.03	6.32	88.67	128.3	94.2
Feb	27.01	90.86	7.61	105.04	145.4	107.6
Mar	28.58	93.16	6.80	83.46	166.4	125.3
Apr	28.44	94.00	7.76	52.32	173.0	132.2
May	27.51	95.97	4.91	64.61	139.2	105.7
Jun	27.71	94.30	6.24	88.76	147.4	110.1
Jul	28.09	91.74	6.41	98.13	158.6	118.7
Aug	27.94	91.26	5.90	108.69	155.1	115.6
Sep	28.34	92.23	6.92	89.50	161.3	121.2
Annual	27.36	94.27	6.04	81.72	1724.9	1293.8

STREAM FLOW DATA

STREAM FLOW DATA - WATER YEAR 2017/18

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

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Basin Rainfall 2017/18	Long-term Average of Annual Runoff & Basin Rainfall up to 2016/17		Observed Maximum Peak Discharge for 2017/18 & Observed Maximum Peak Discharge up to 2016/17		
															value	yrs	cumecs	Time	Date
1	**Badalgama**	144.89	157.36	80.53	16.85	9.30	12.94	81.86	535.99	200.89	39.53	49.88	18.23	1348.25	1255.45	52	1988.78	9:00am	22.05.2018
	R.B. 102	420.3	265.5	137.4	107.3	48.2	113.4	332.9	584.8	269.3	79.2	130.5	180.6	2669.3	2368.4		1982.16	12:00mn	24.09.1971
2	**Baddegama**	249.08	208.57	253.10	96.32	117.99	125.35	214.20	338.68	218.16	87.03	87.21	124.27	2119.96	2107.79	11	333.25	4:00am	23.05.2018
	R.B. 9	416.1	475.1	297.5	107.1	281.6	316.5	494.2	667.1	439.0	130.1	156.1	291.0	4071.2	3753.3		691.92	11:00am	28.05.2017
3	**Calidonia**	21.36	30.83	31.15	9.80	7.18	8.09	13.77	37.03	29.60	20.60	47.75	23.55	280.71	209.86	33	158.35	1:00pm	30.12.2017
	R.B. 60	220.6	210.3	156.5	26.1	64.8	131.8	323.0	384.2	188.4	154.8	339.4	257.4	2457.3	1985.3		178.48	3:00pm	12.06.2014
4	**Deraniyagala**	106.09	46.09	34.91	10.29	9.84	12.69	33.26	120.12	108.09	45.02	52.78	30.22	609.40	601.04	61	512.99	10:00am	20.05.2018
	R.B. 1	742.4	295.4	190.0	18.0	186.1	240.8	490.6	875.4	799.1	300.6	340.7	387.6	4866.7	5077.4		2313.00	9:00am	31.05.1985
5	**Dunamale**	46.74	51.97	23.01	10.64	5.04	5.63	26.57	97.81	36.92	8.84	3.19	3.15	319.51	204.17	12	117.87	2:00am	26.05.2018
	R.B. 103	495.5	358.6	225.8	135.6	154.5	118.6	550.2	816.1	295.1	72.1	91.8	157.8	3471.4	3323.9		112.03	2:00pm	14.09.2017
6	**Ellagawa**	542.72	327.60	276.15	51.42	55.74	71.96	203.63	712.61	523.22	123.57	168.65	123.54	3180.81	3328.01	60	973.13	6:00pm	23.05.2018
	R.B. 3	528.1	436.4	241.5	39.5	132.2	197.1	399.8	628.0	472.4	158.5	201.8	304.1	3739.3	3710.7		2620.00	4:00am	19.05.2003
7	**Galgamuwa**	0.00	0.08	0.81	0.16	0.02	0.27	0.40	1.00	0.66	0.03	0.58	0.70	4.71	47.78	28	4.01	8:00am	07.12.2017
	R.B. 95	120.4	230.5	140.3	48.7	34.7	127.7	167.9	216.6	67.7	22.6	43.2	106.8	1327.1	1291.7		159.25	1:00pm	19.11.2006
8	**Giriulla**	85.77	77.41	20.19	6.35	4.86	6.04	23.21	288.25	90.27	9.52	13.30	7.30	632.47	1074.27	17	1365.09	1:00am	22.05.2018
	R.B. 102	435.8	272.8	140.8	114.6	48.2	119.1	322.8	568.1	275.3	84.7	143.6	195.7	2721.4	2646.6		1690.50	4:00pm	26.12.2014
9	**Glencourse**	661.37	363.73	277.94	88.64	62.10	95.19	287.04	854.67	695.34	242.87	360.89	170.19	4159.97	3906.76	69	1484.24	1:00am	22.05.2018
	R.B. 1	602.8	287.3	192.5	47.4	135.4	199.8	486.4	794.5	602.9	260.6	309.5	269.9	4189.0	3621.5		3500.00	10:00am	04.06.1989
10	**Hanwella**	656.64	419.79	261.31	82.65	66.40	85.73	250.85	874.07	654.88	173.36	262.76	127.08	3915.52	4276.56	33	1238.38	9:00am	22.05.2018
	R.B. 1	604.3	308.7	197.0	51.2	141.8	186.6	479.1	755.0	563.0	236.2	278.0	258.1	4059.0	3706.9		2745.58	8:00am	05.06.1989

STREAM FLOW DATA - WATER YEAR 2017/18

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

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Basin Rainfall 2017/18	Long-term Average of Annual Runoff & Basin Rainfall up to 2016/17		Observed Maximum Peak Discharge for 2017/18 & Observed Maximum Peak Discharge up to 2016/17		
															value	yrs	cumecs	Time	Date
11	Holombuwa	35.23	18.05	6.47	1.12	0.64	1.82	10.19	73.36	34.11	4.69	6.14	2.46	194.28	258.17	53	361.59	7:00pm	21.05.2018
	R.B. 1	540.3	200.1	113.1	58.9	34.1	204.7	374.4	874.4	562.9	247.0	233.3	311.8	3755.0	3098.4		644.47	7:00am	03.06.1989
12	Horowpothana	2.87	12.63	9.62	5.04	2.98	3.99	2.53	4.42	2.34	1.99	2.36	2.53	53.30	172.84	56	41.90	3:00pm	27.11.2017
	R.B. 67	244.4	382.1	92.8	15.5	40.2	22.3	5.2	195.7	5.9	31.8	30.6	59.3	1125.8	1443.4		-1	4:00pm	26.12.1957
13	Katharagama	16.69	17.51	-1	-1	-1	-1	-1	21.11	16.68	17.30	16.81	16.02	-1	218.46	72	-1	-1	-1
	R.B. 26	366.3	388.5	240.6	36.4	16.6	178.5	169.5	170.4	4.7	25.5	18.5	140.9	1756.3	1546.3		1365.00	1:00pm	25.12.1957
14	Kithulagala	166.12	116.17	113.11	61.66	31.09	54.17	59.71	119.45	217.55	131.46	225.52	96.77	1392.78	1150.70	69	460.13	5:00pm	07.06.2018
	R.B. 1	454.7	252.3	177.1	31.1	135.4	171.7	321.5	551.5	525.5	336.7	478.0	225.4	3660.9	3431.8		2157.00	5:15pm	30.05.1989
15	Manampitiya	193.65	364.92	653.89	279.54	282.55	402.45	256.30	554.21	317.15	255.00	302.05	214.94	4076.65	4661.51	63	1247.87	8:00am	21.12.2017
	R.B. 60	331.0	284.4	196.3	63.9	76.1	153.5	256.5	401.4	220.2	171.6	274.3	245.7	2674.9	2330.4		-1	11:00am	26.12.1957
16	Millakanda	428.67	249.65	307.01	50.76	102.75	108.50	241.68	518.47	361.45	93.48	108.23	86.91	2657.56	2131.70	27	621.92	5:00am	22.05.2018
	R.B. 3	499.0	594.2	270.8	67.0	209.9	220.9	452.2	594.7	383.9	173.2	174.2	264.9	3904.9	4301.9		1233.16	2:00am	27.05.2017
17	Nakkala	17.22	23.99	38.13	18.35	13.49	31.35	23.64	35.36	14.99	13.62	10.40	14.53	255.07	-1		324.46	8:00pm	12.05.2018
	R.B. 31	218.7	265.6	234.2	124.0	60.3	162.2	145.3	240.3	15.0	87.1	64.0	156.3	1773.0	-1		-1	-1	-1
18	Nawalapitiya	125.27	68.41	53.28	30.97	24.16	24.06	43.56	122.46	152.04	91.73	140.27	48.55	924.76	496.68	29	623.37	12:00nn	21.05.2018
	R.B. 60	363.9	224.8	171.8	50.4	136.0	208.8	449.3	491.0	644.5	495.3	643.3	336.2	4215.3	3673.4		360.20	4:00am	28.06.1993
19	Norwood	15.43	19.08	18.18	8.02	6.92	9.79	16.90	30.74	21.48	15.25	24.59	14.58	200.96	134.52	32	165.87	9:00am	21.05.2018
	R.B. 1	216.0	238.3	141.5	19.4	78.9	127.4	243.6	365.2	238.0	171.4	352.1	173.5	2365.3	2549.3		180.98	6:00pm	13.05.2013
20	Padiyathalawa	15.27	9.97	16.63	3.71	4.65	8.62	2.42	15.49	2.54	0.88	0.47	0.19	80.84	147.86	33	315.32	3:00am	29.10.2017
	R.B. 54	381.0	278.9	194.8	82.3	163.9	180.7	157.8	298.9	35.5	30.9	84.9	69.9	1959.4	2128.0		972.30	9:00am	26.12.2014

Note :-Missing data is denoted by '-1'

STREAM FLOW DATA - WATER YEAR 2017/18

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

	Name of station & River Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annul Runoff & Annual Basin Rainfall 2017/18	Long-term Average of Annual Runoff & Basin Rainfall up to 2016/17		Observed Maximum Peak Discharge for 2017/18 & Observed Maximum Peak Discharge up to 2016/17		
															value	yrs	cumecs	Time	Date
21	**Peradeniya**	262.03	216.62	182.78	108.94	76.76	29.86	63.58	342.25	415.31	236.30	441.45	152.45	2528.33	1805.42	69	866.80	6:00pm	21.05.2018
	R.B. 60	327.3	282.4	116.3	42.0	39.0	100.8	311.9	527.3	377.9	250.8	430.8	353.3	3159.8	2924.2		-1	2:30am	15.08.1947
22	**Pitabeddara**	64.75	81.76	79.45	23.26	21.93	32.67	59.02	89.13	74.99	25.45	17.99	17.43	587.82	504.66	37	274.30	12:00mn	20.05.2018
	R.B. 12	326.6	503.9	260.5	60.6	179.7	269.7	352.7	510.8	365.5	81.8	116.0	199.4	3227.1	2908.6		1559.58	4:00am	26.05.2017
23	**Putupaula**	665.13	397.80	425.22	182.57	168.03	193.01	306.26	923.60	526.60	176.09	200.94	223.33	4388.58	6045.80	73	1198.82	2:00pm	24.05.2018
	R.B. 3	528.0	493.6	241.4	57.0	179.6	209.1	416.1	605.5	415.1	153.8	180.4	285.1	3764.5	3211.2		2829.00	9:30am	16.08.1947
24	**Rathnapura**	135.09	84.32	82.53	33.84	27.26	39.70	61.43	216.51	164.11	50.26	66.36	42.17	1003.58	1010.17	11	430.13	9:00pm	21.05.2018
	R.B. 3	451.8	369.7	237.3	36.2	109.7	188.6	329.4	522.8	449.8	152.3	202.8	238.5	3288.9	3145.3		814.10	12:00nn	31.05.1989
25	**Siyambalanduwa**	1.27	3.01	2.22	2.74	0.01	1.51	0.04	2.20	0.01	0.06	0.00	0.00	13.07	129.57	26	132.97	4:00pm	30.01.2018
	R.B. 36	230.2	274.0	210.2	116.6	60.3	139.5	130.9	250.6	31.5	79.2	47.4	111.9	1682.3	1713.1		889.27	4:00pm	12.01.2007
26	**Thanamalwila**	9.35	28.28	75.82	9.45	2.65	9.31	24.36	48.38	4.91	0.99	0.09	7.73	221.32	255.71	30	399.71	3:00am	14.12.2017
	R.B. 22	239.9	280.8	311.4	52.5	16.6	199.3	219.5	204.6	55.6	21.8	42.4	205.8	1850.2	1592.2		824.70	3:00am	24.11.2012
27	**Thanthirimale**	9.57	40.85	16.77	10.12	7.29	8.00	8.09	33.86	10.10	6.46	6.96	7.18	165.25	-1		135.00	6:00am	06.11.2017
	R.B. 22	164.1	237.9	38.6	27.3	40.7	32.4	117.1	162.6	2.3	2.5	47.7	78.5	951.7	-1		-1	-1	-1
28	**Thawalama**	136.51	118.62	122.07	40.43	47.53	62.48	112.75	178.18	144.75	46.94	42.87	48.17	1101.29	1046.13	37	404.56	4:00am	21.05.2018
	R.B. 9	481.5	484.9	312.7	100.1	344.1	257.8	475.3	706.1	491.0	114.4	176.0	341.6	4285.6	4004.6		1339.07	5:00am	18.05.2003
29	**Urawa**	7.30	12.73	11.86	4.67	4.34	6.55	10.87	12.74	10.98	4.77	3.61	2.84	93.26	79.92	17	55.74	11:00pm	04.03.2018
	R.B. 12	303.5	553.7	286.4	60.2	221.2	287.6	362.6	440.3	276.4	69.9	137.9	255.1	3254.6	3108.8		196.88	1:00am	26.05.2017
30	**Wellawaya**	7.04	19.94	38.42	10.46	5.29	8.71	14.64	34.63	8.18	4.87	2.83	25.38	180.39	119.31	29	279.16	9:00pm	13.12.2017
	R.B. 22	202.3	252.9	315.4	71.0	16.5	234.5	216.4	324.0	120.9	51.6	82.6	173.4	2061.5	2024.4		634.50	8:00pm	21.10.2012

Note :-Missing data is denoted by '-1'

RUNOFF RAINFALL RATIOS

RUNOFF RAINFALL RATIOS - 2017/18

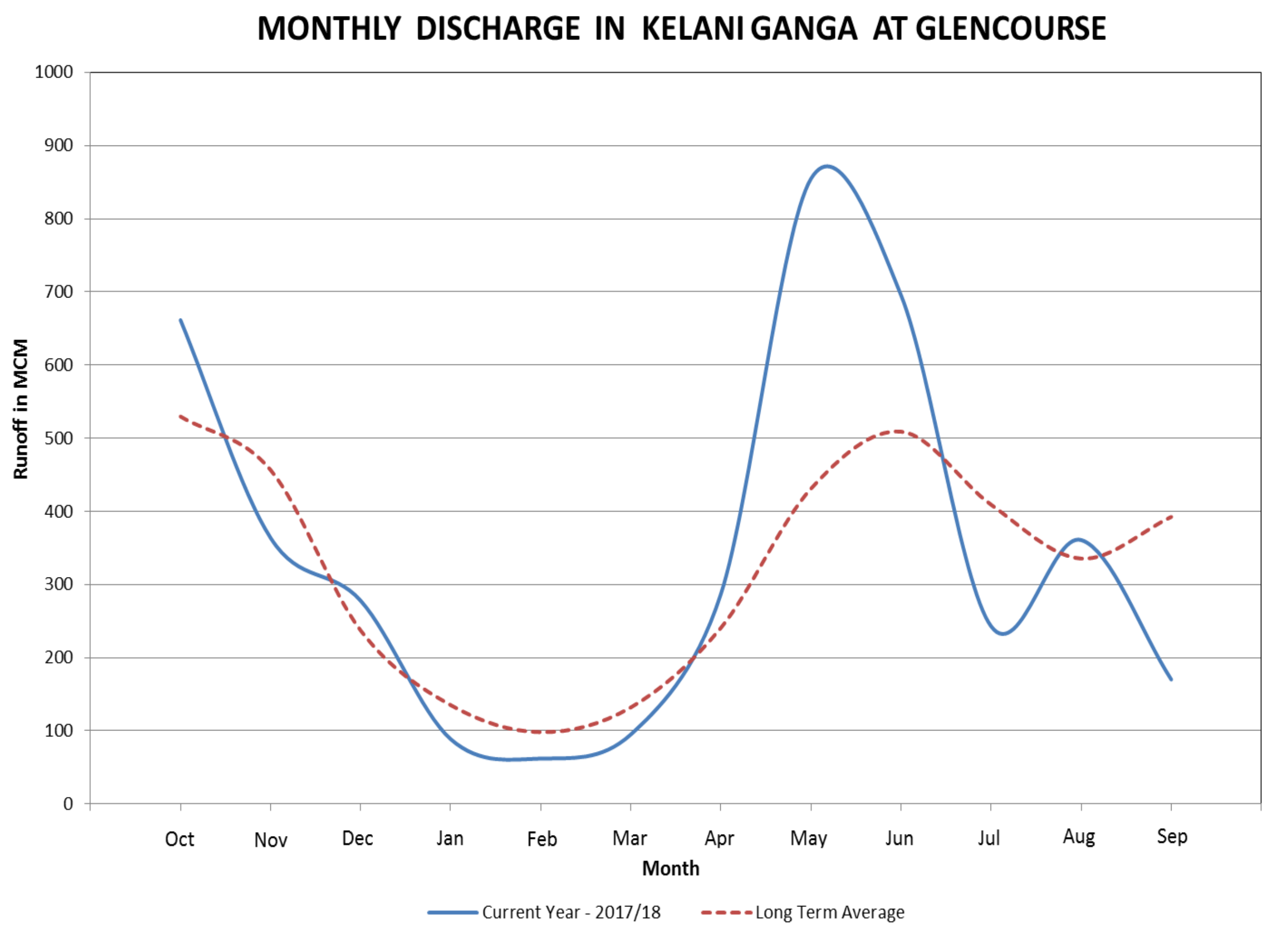
Name of River Basin	Station	Annual Rainfall (mm)	Annual Runoff (mm)	Runoff / Rainfall ratio(%)	Long term average of Runoff / Rainfall ratio(%) up to 2016/17
Kelani Ganga	Norwood	2365	2080	88	48
Kelani Ganga	Deraniyagala	4866	3330	68	68
Kelani Ganga	Holombuwa	3755	1253	33	54
Kelani Ganga	Glencourse	4189	2843	68	69
Kelani Ganga	Hanwella	4059	2197	54	62
Kalu Ganga	Rathnapura	3288	1664	51	48
Kalu Ganga	Ellagawa	3739	2283	61	64
Kalu Ganga	Millakanda	3905	3406	87	65
Kalu Ganga	Putupaula	3765	1689	45	60
Gin Ganga	Thawalama	4286	2921	68	71
Gin Ganga	Baddegama	4071	2830	70	75
Nilwala Ganga	Urawa	3255	1581	49	44
Nilwala Ganga	Pitabeddara	3227	1993	62	59
Kirindi Oya	Wellawaya	2061	1046	51	36
Kirindi Oya	Thanamalwila	1850	295	16	21
Heda Oya	Siyambalanduwa	1682	44	3	24
Maduru Oya	Padiyathalawa	1959	508	26	41
Mahaweli Ganga	Peradeniya	3161	2165	68	45
Mahaweli Ganga	Manampitiya	2675	549	21	29
Yan Oya	Horowpothana	1126	74	7	18
Mee Oya	Galgamuwa	1327	16	1	7
Maha Oya	Giriulla	2721	548	20	35
Maha Oya	Badalgama	2669	991	37	39
Aththanagalu Oya	Dunamale	3471	2091	60	40

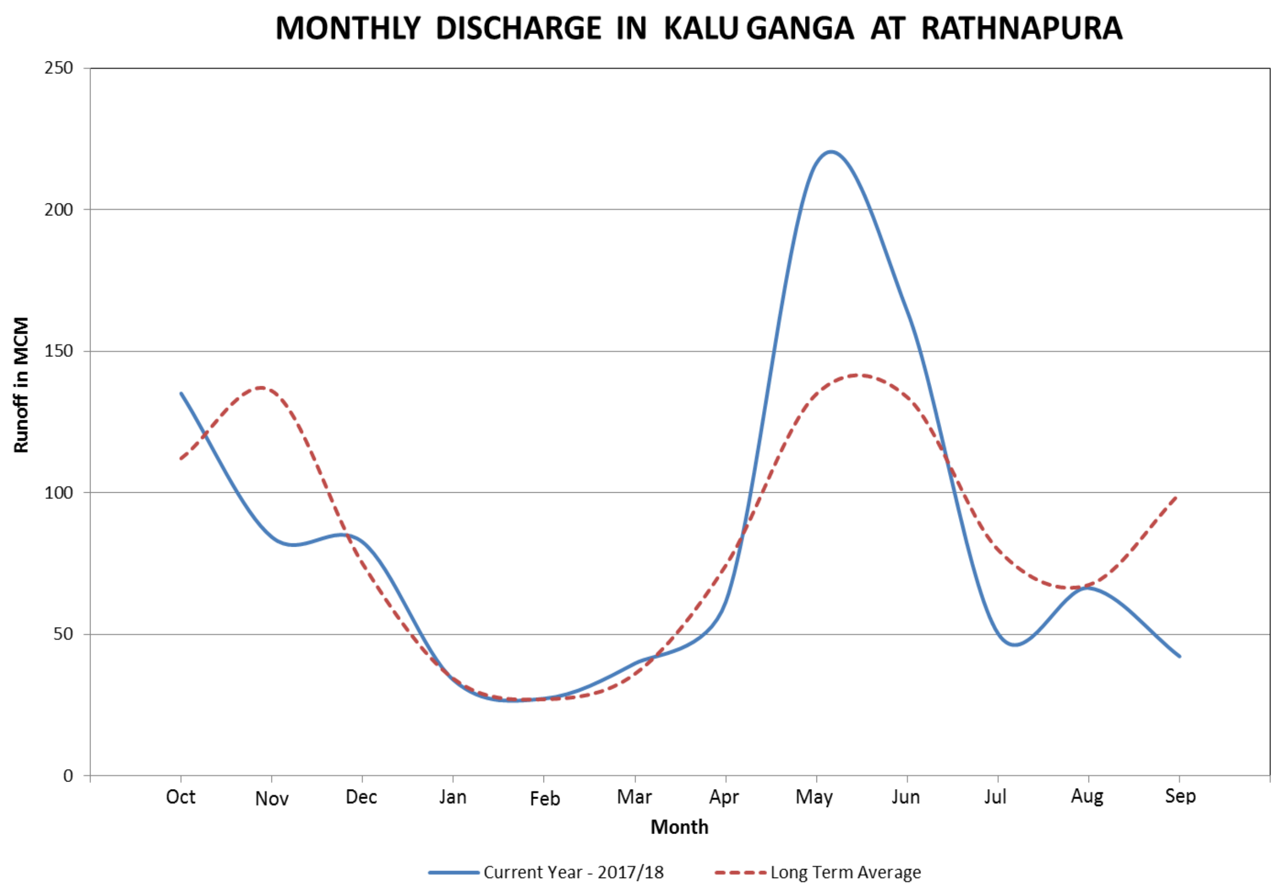
MONTHLY DISCHARGES IN MAJOR RIVERS

MONTHLY DISCHARGES IN MAJOR RIVERS (in MCM)

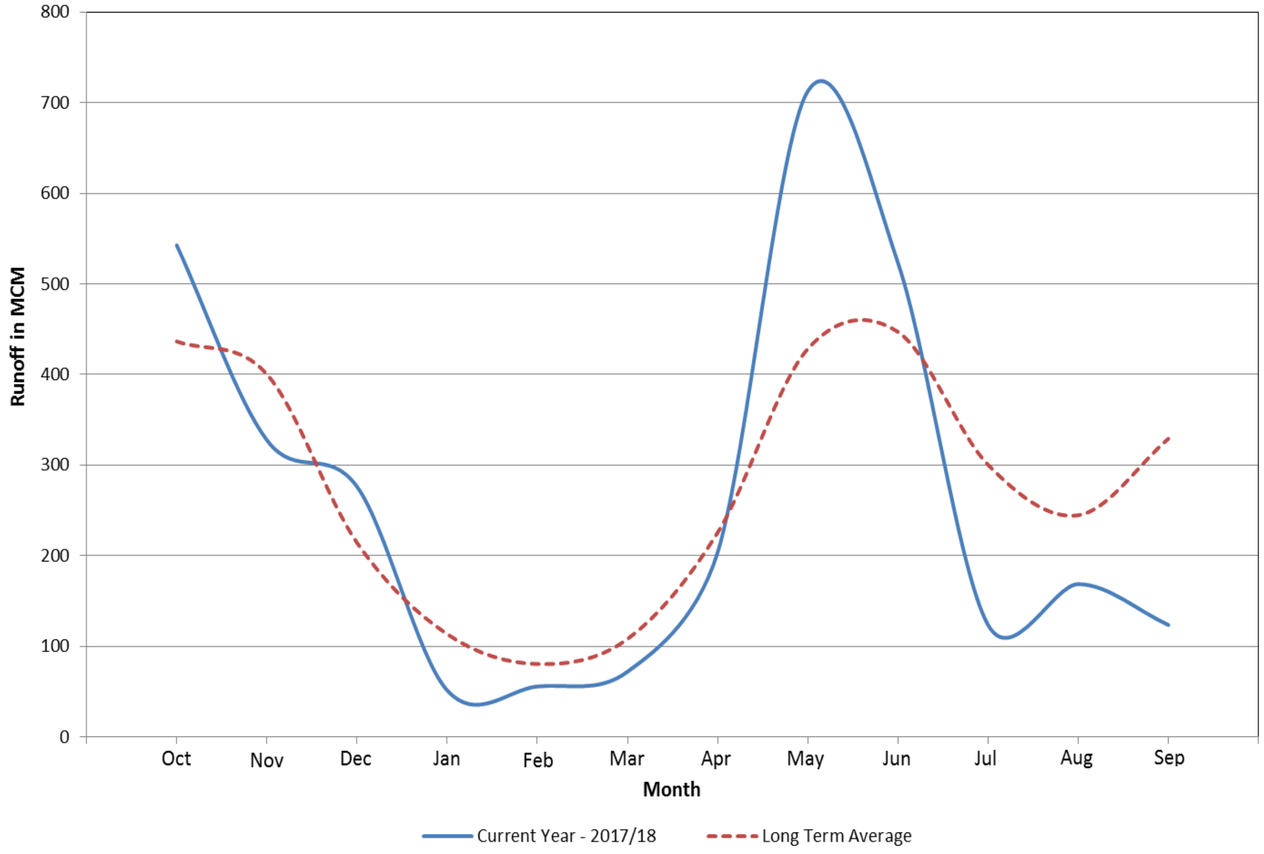
Upper line : Current year 2017/18
Lower line : Long term average

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Kelani Ganga at Glencourse	661.37	363.73	277.94	88.64	62.10	95.19	287.04	854.67	695.34	242.87	360.89	170.19	4159.97
	529.61	456.53	237.18	135.18	98.22	132.09	240.83	431.11	508.97	409.10	335.50	392.43	3906.76
Kalu Ganga at Rathnapura	135.09	84.32	82.53	33.84	27.26	39.70	61.43	216.51	164.11	50.26	66.36	42.17	1003.58
	112.14	135.99	74.86	34.29	27.02	36.01	74.27	134.91	133.73	79.84	67.44	99.67	1010.17
Kalu Ganga at Ellagawa	542.72	327.60	276.15	51.42	55.74	71.96	203.63	712.61	523.22	123.57	168.65	123.54	3180.81
	436.56	400.40	214.29	113.49	80.44	108.06	225.40	428.23	447.05	300.30	244.66	329.14	3328.01
Kalu Ganga at Putupaula	665.13	397.80	425.22	182.57	168.03	193.01	306.26	923.60	526.60	176.09	200.94	223.33	4388.58
	791.50	712.31	443.09	275.15	203.28	261.11	411.35	727.10	768.33	506.31	411.50	534.78	6045.80
Gin Ganga at Thawalama	136.51	118.62	122.07	40.43	47.53	62.48	112.75	178.18	144.75	46.94	42.87	48.17	1101.29
	121.24	130.16	92.08	52.24	37.76	47.82	83.82	125.92	116.95	79.35	67.03	91.76	1046.13
Gin Ganga at Baddegama	249.08	208.57	253.10	96.32	117.99	125.35	214.20	338.68	218.16	87.03	87.21	124.27	2119.96
	243.97	270.64	206.58	103.03	95.79	121.11	167.47	253.89	204.51	133.78	119.78	187.26	2107.79
Nilwala Ganga at Pitabeddara	64.75	81.76	79.45	23.26	21.93	32.67	59.02	89.13	74.99	25.45	17.99	17.43	587.82
	54.52	74.22	57.25	32.76	23.37	24.34	38.24	57.75	50.03	31.01	25.18	35.98	504.66
Mahaweli Ganga at Peradeniya	262.03	216.62	182.78	108.94	76.76	29.86	63.58	342.25	415.31	236.30	441.45	152.45	2528.33
	219.64	217.36	155.51	85.94	54.04	47.54	76.93	130.07	209.83	222.67	205.66	180.22	1805.42
Mahaweli Ganga at Manampitiya	193.65	364.92	653.89	279.54	282.55	402.45	256.30	554.21	317.15	255.00	302.05	214.94	4076.65
	312.70	547.12	970.89	801.61	471.76	283.07	236.55	228.78	205.86	207.26	201.21	194.70	4661.51

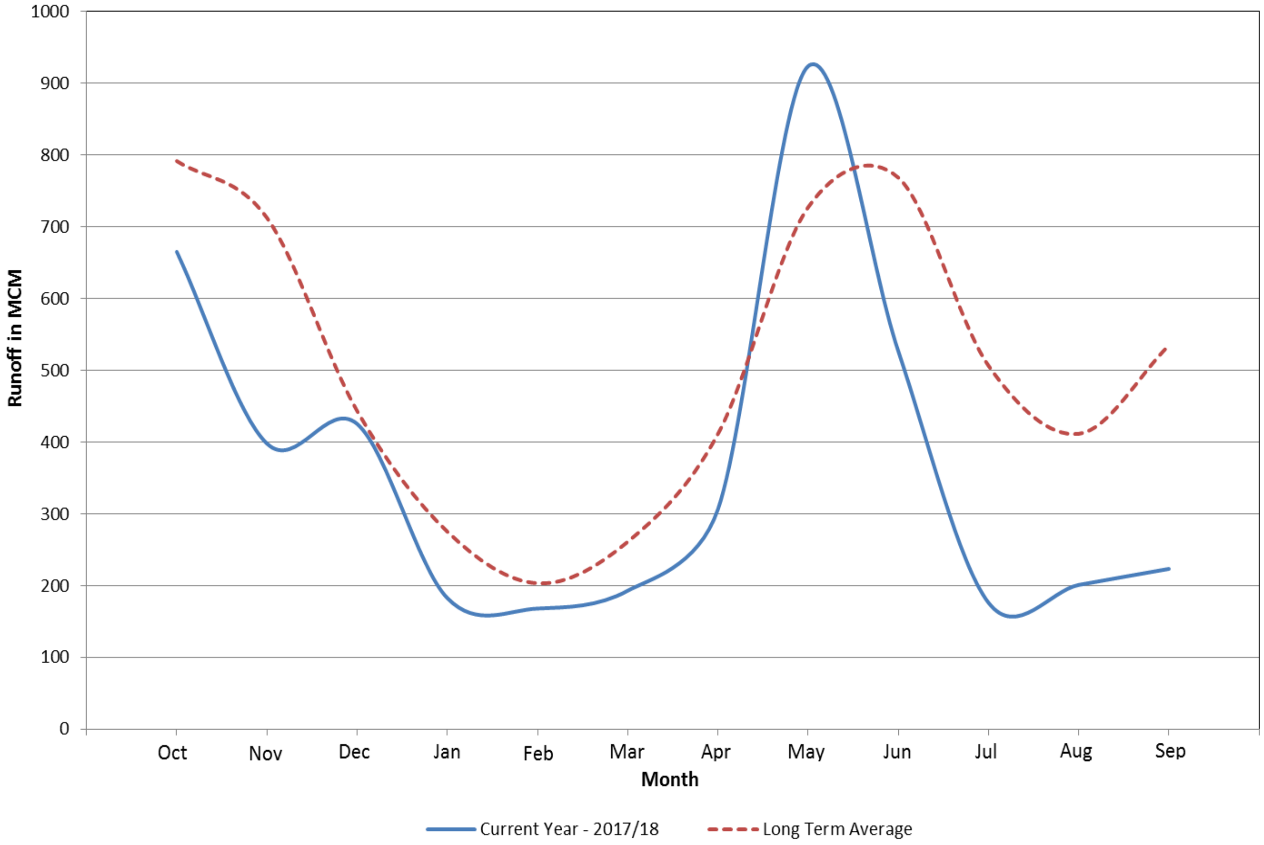

MONTHLY DISCHARGE IN KELANI GANGA AT GLENCOURSE
Runoff in MCM
1000
900
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average

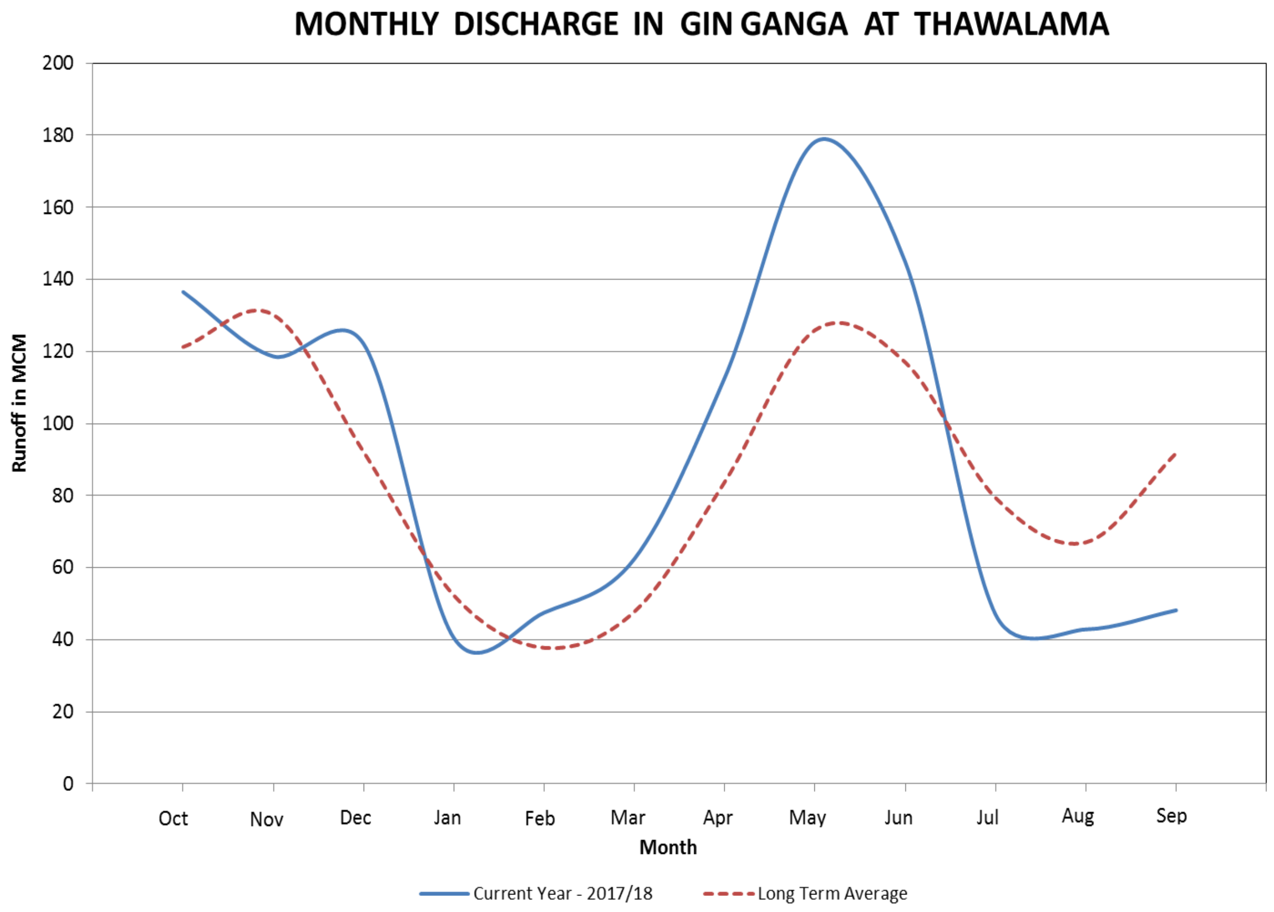

MONTHLY DISCHARGE IN KALU GANGA AT RATHNAPURA
Runoff in MCM
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average

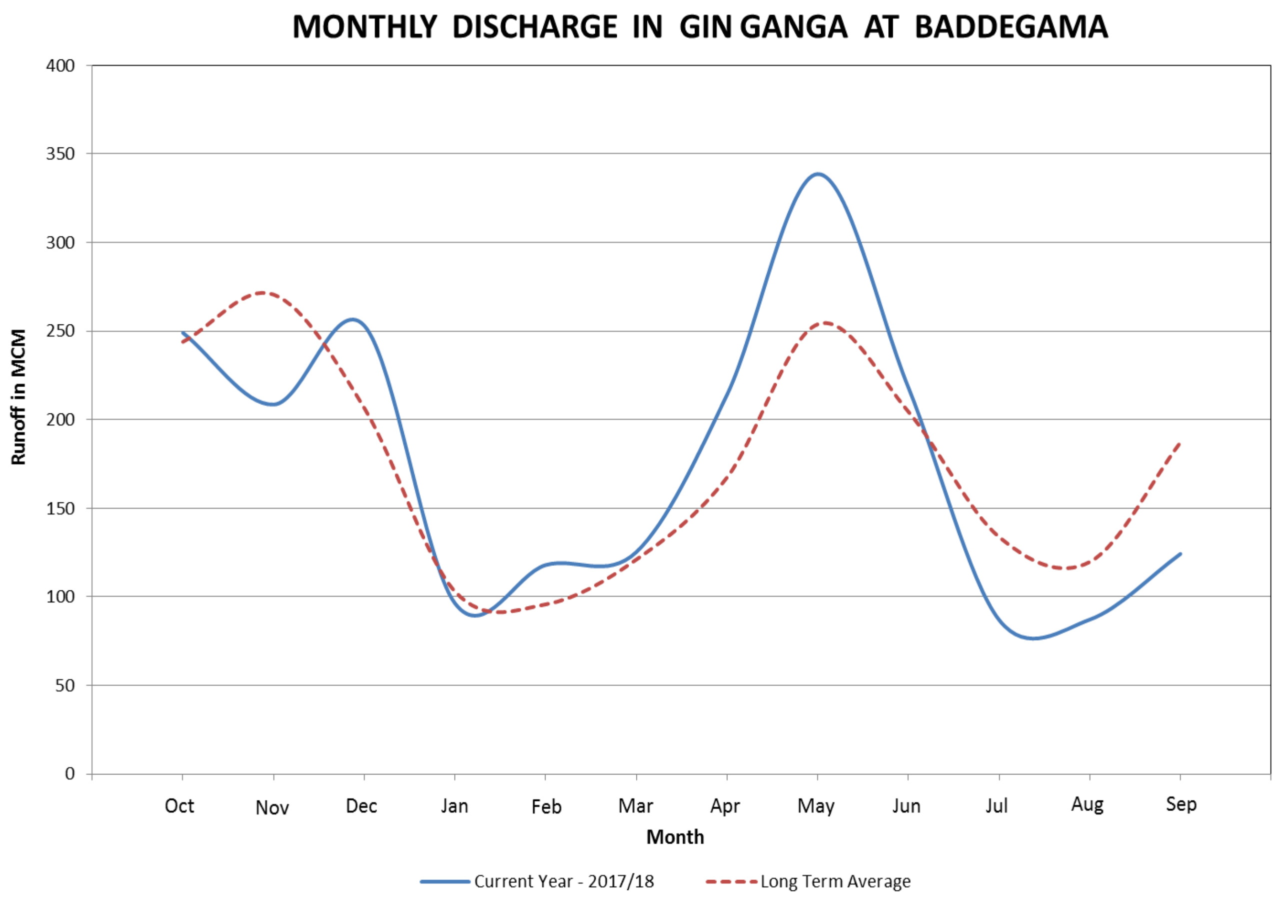
MONTHLY DISCHARGE IN KALU GANGA AT ELLAGAWA

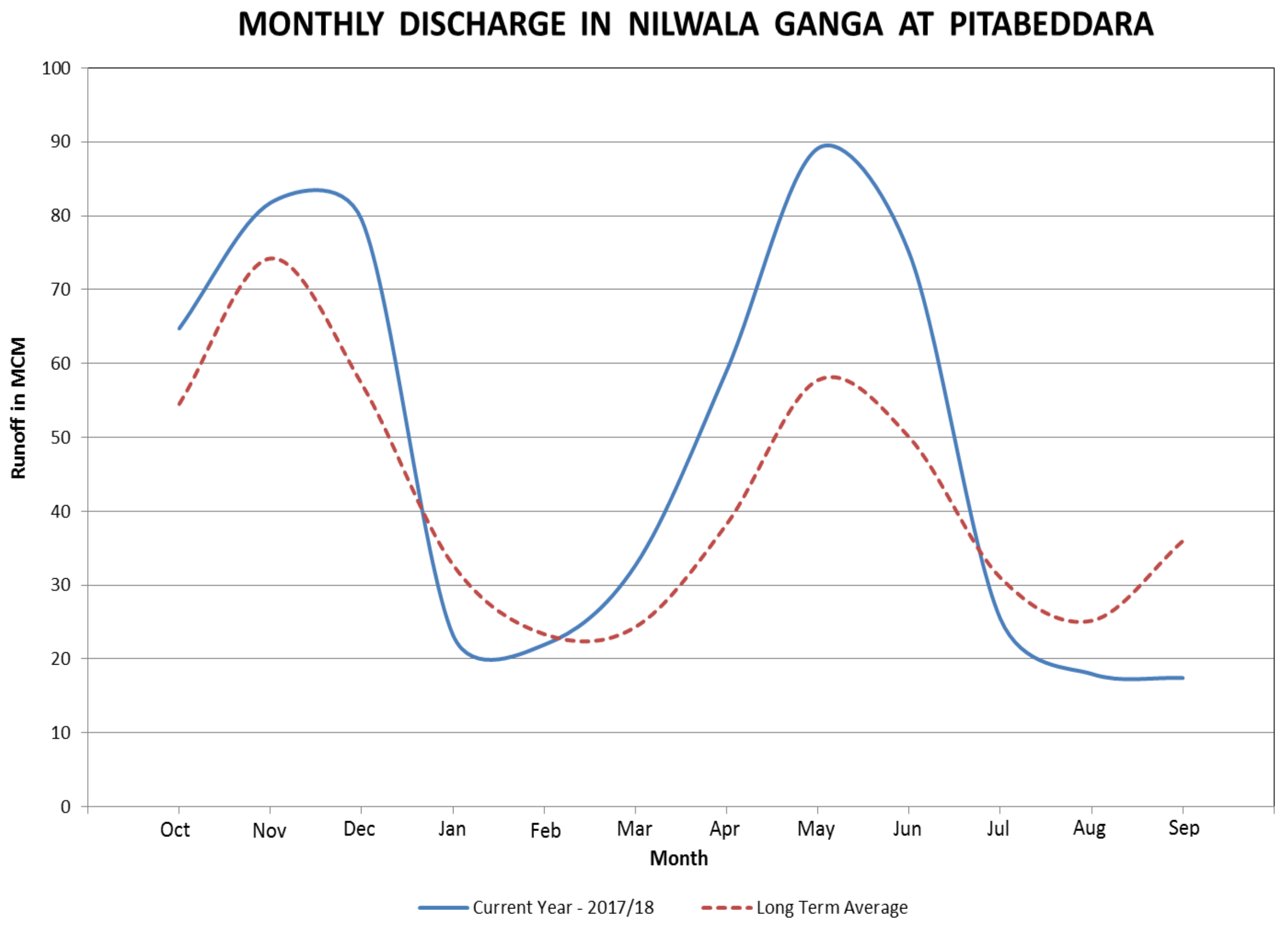


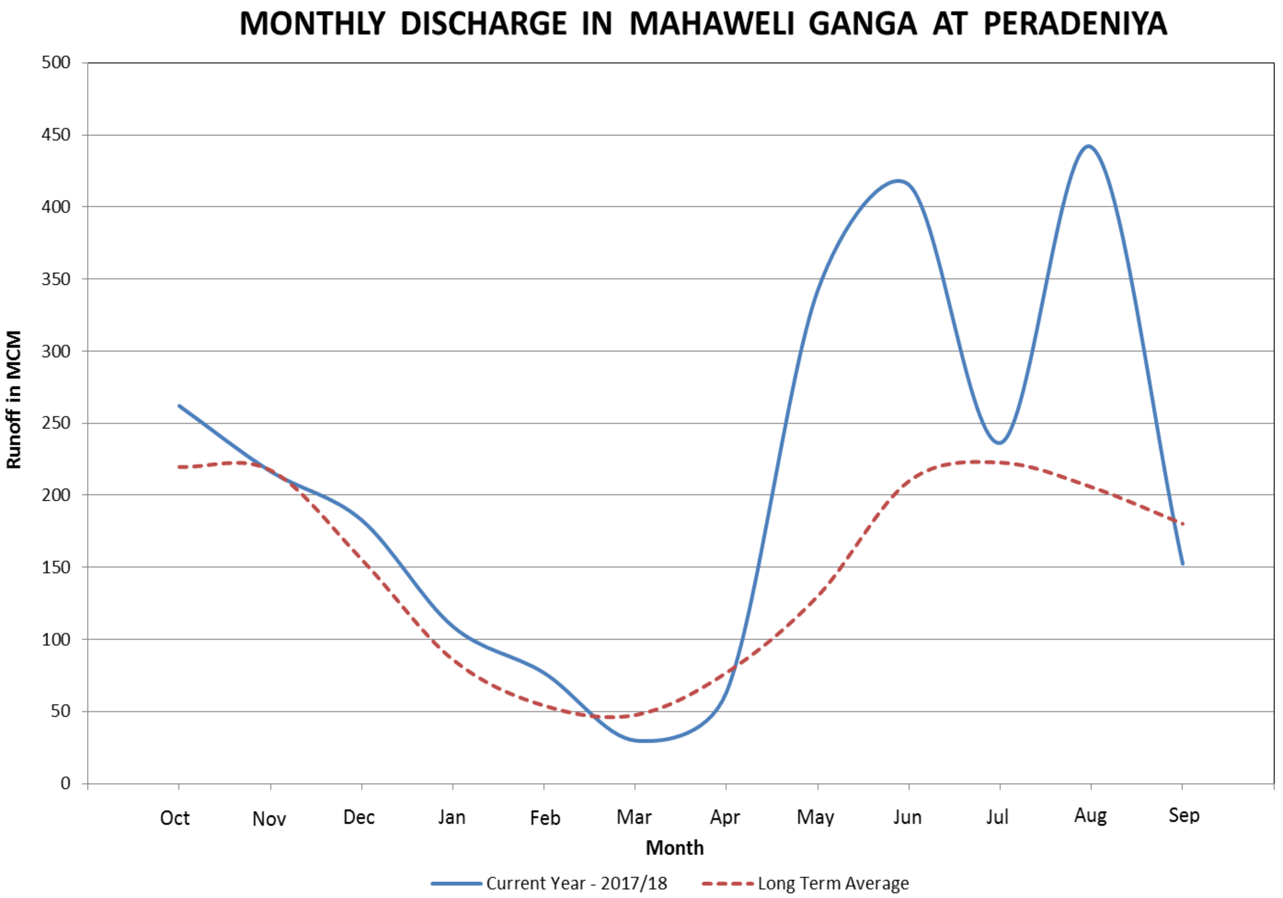
MONTHLY DISCHARGE IN KALU GANGA AT PUTUPAULA

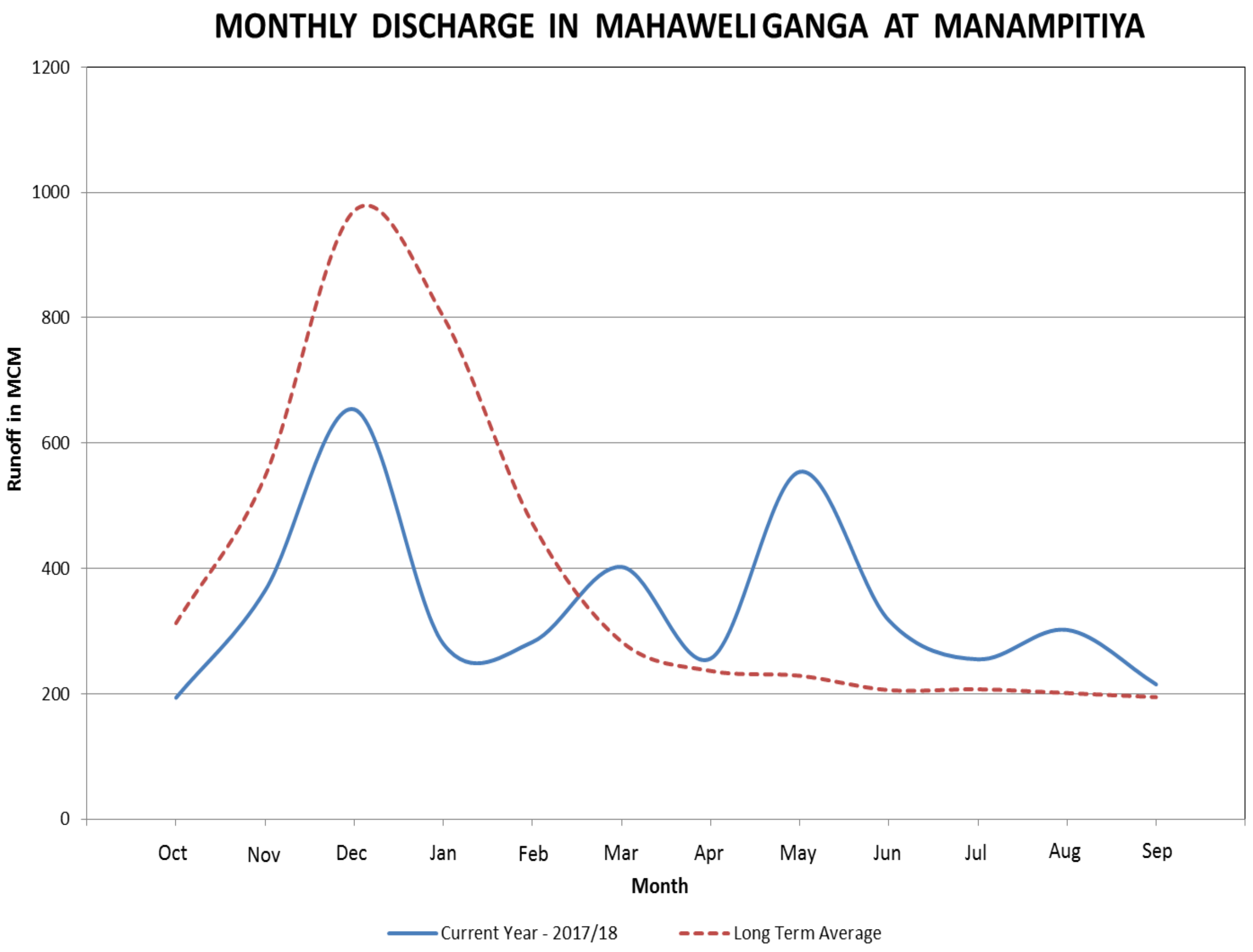



MONTHLY DISCHARGE IN GIN GANGA AT THAWALAMA
Runoff in MCM
200
180
160
140
120
100
80
60
40
20
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average

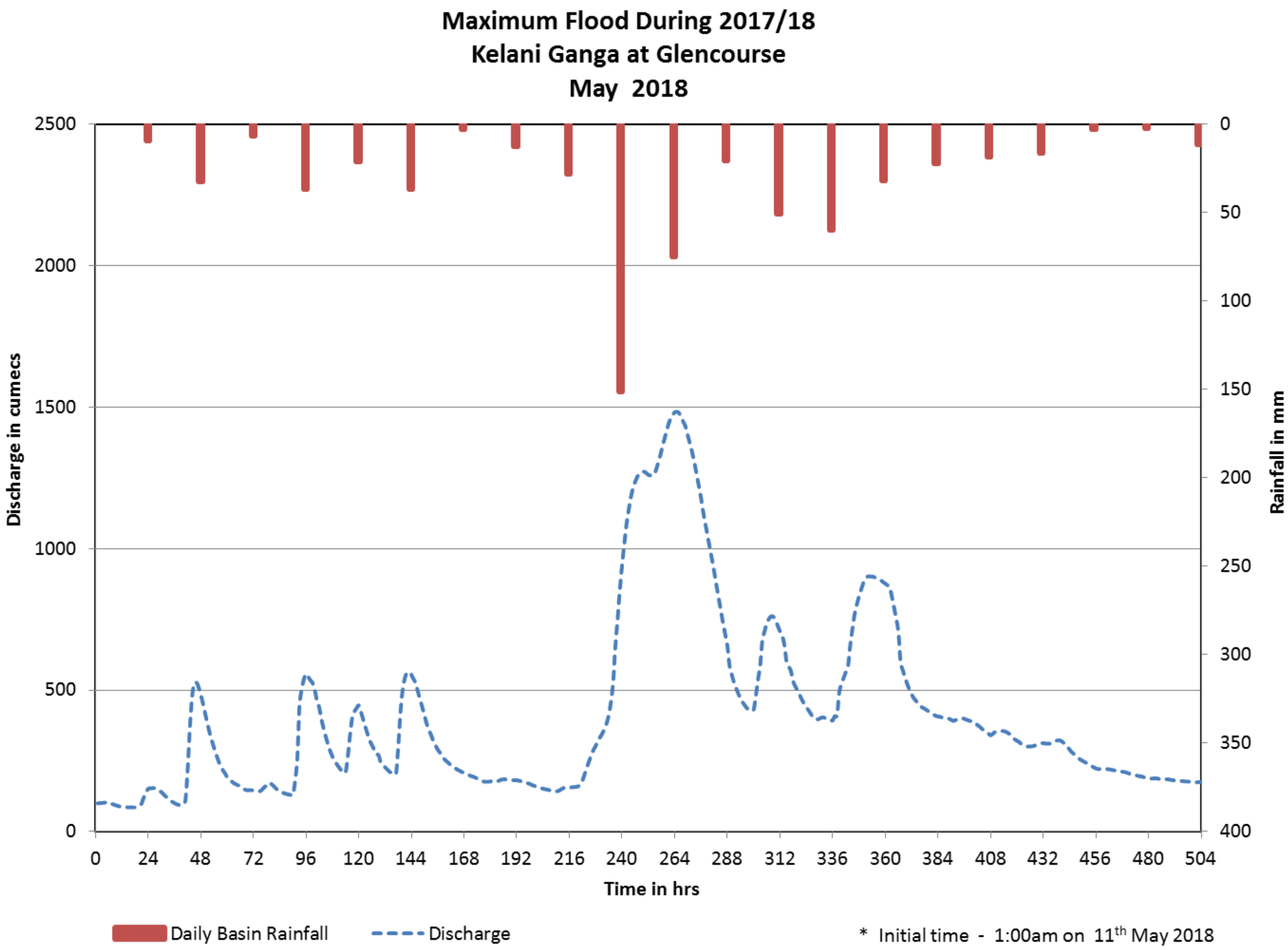

MONTHLY DISCHARGE IN GIN GANGA AT BADDEGAMA
Runoff in MCM
400
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average

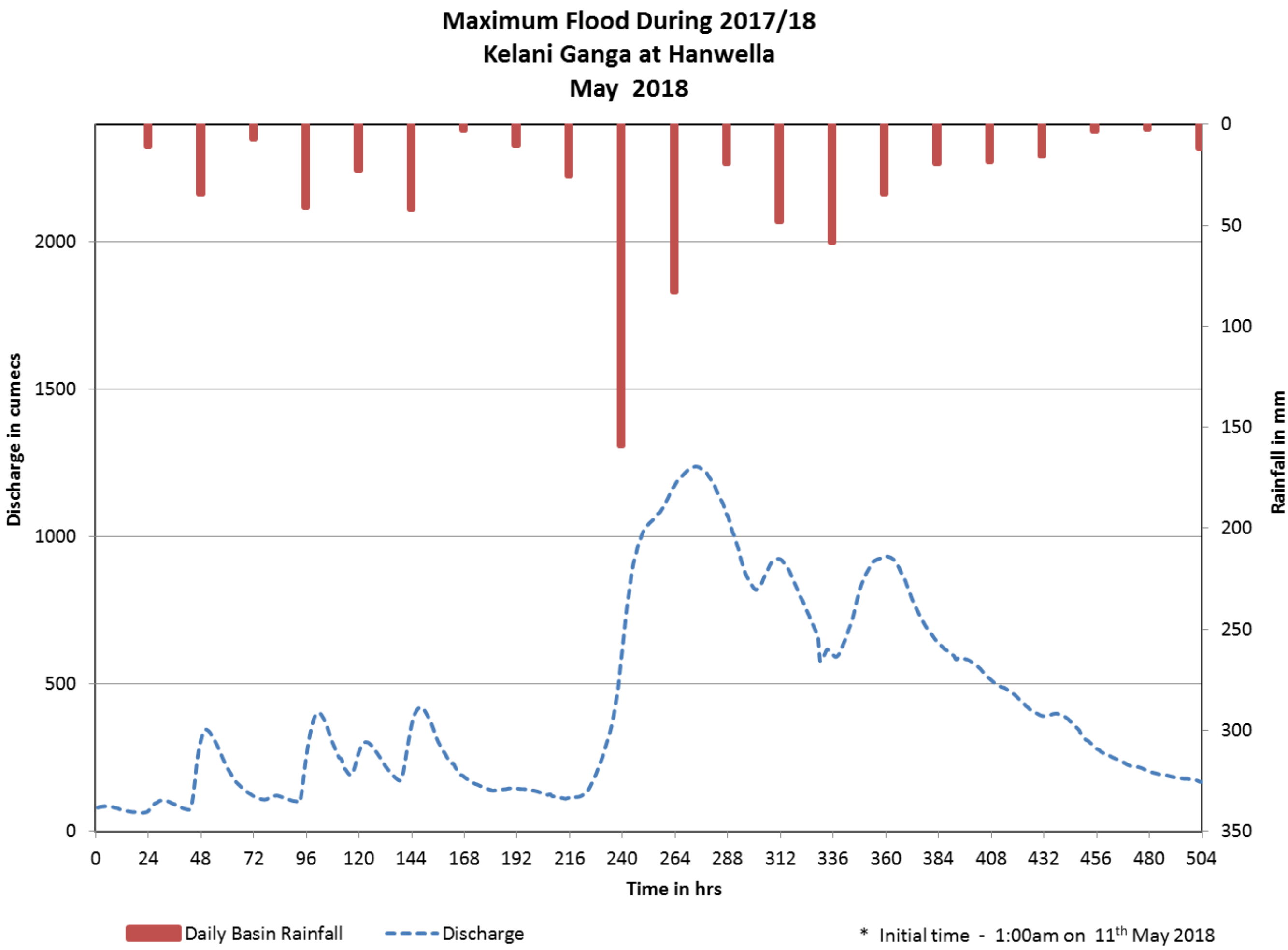

MONTHLY DISCHARGE IN NILWALA GANGA AT PITABEDDARA
Runoff in MCM
100
90
80
70
60
50
40
30
20
10
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average


MONTHLY DISCHARGE IN MAHAWELI GANGA AT PERADENIYA
Runoff in MCM
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 - 2017/18
Long Term Average

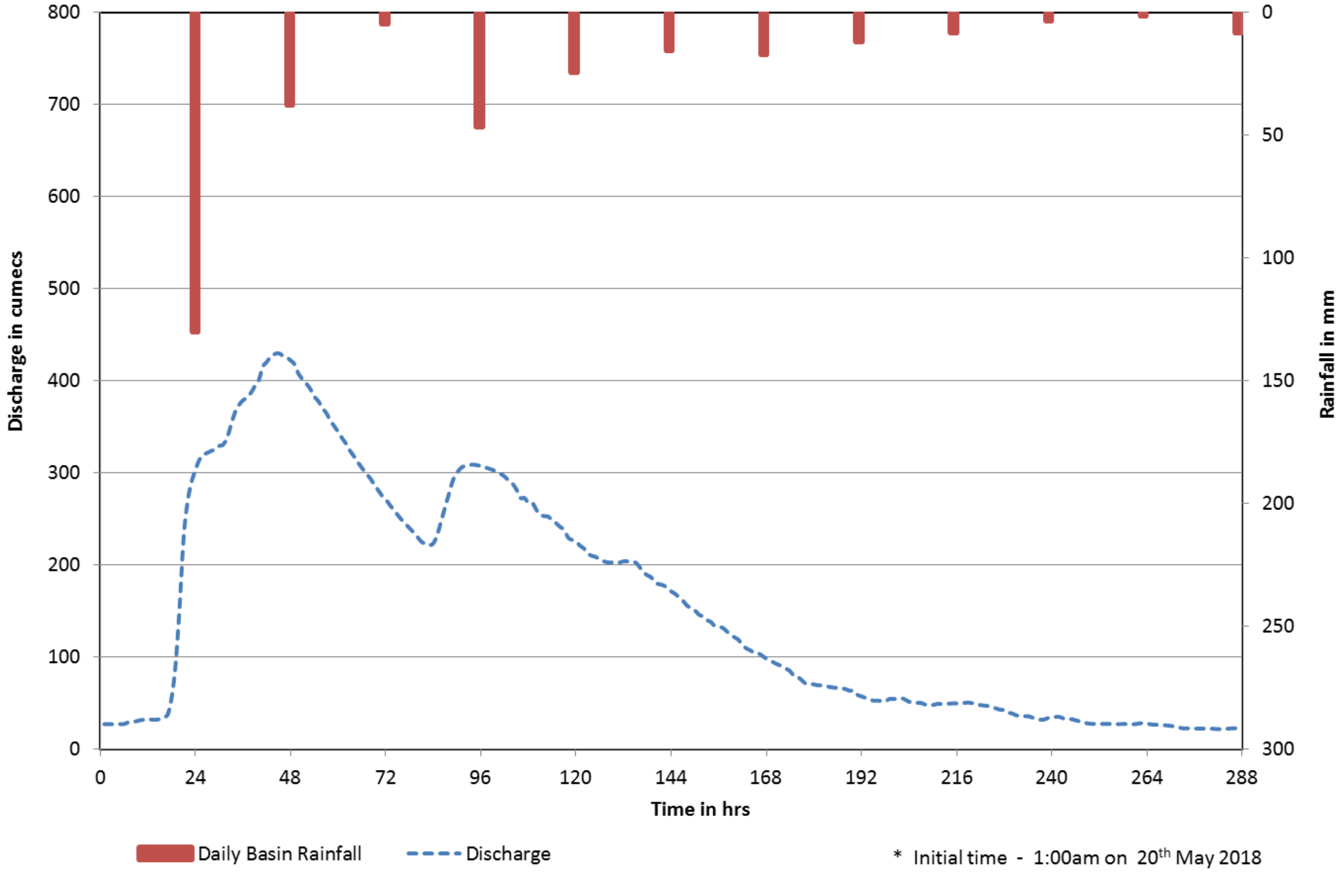

MONTHLY DISCHARGE IN MAHAWELI GANGA AT MANAMPITIYA
1200
1000
800
600
400
200
0
Runoff in MCM
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Current Year - 2017/18
Long Term Average

FLOOD HYDROGRAPHS

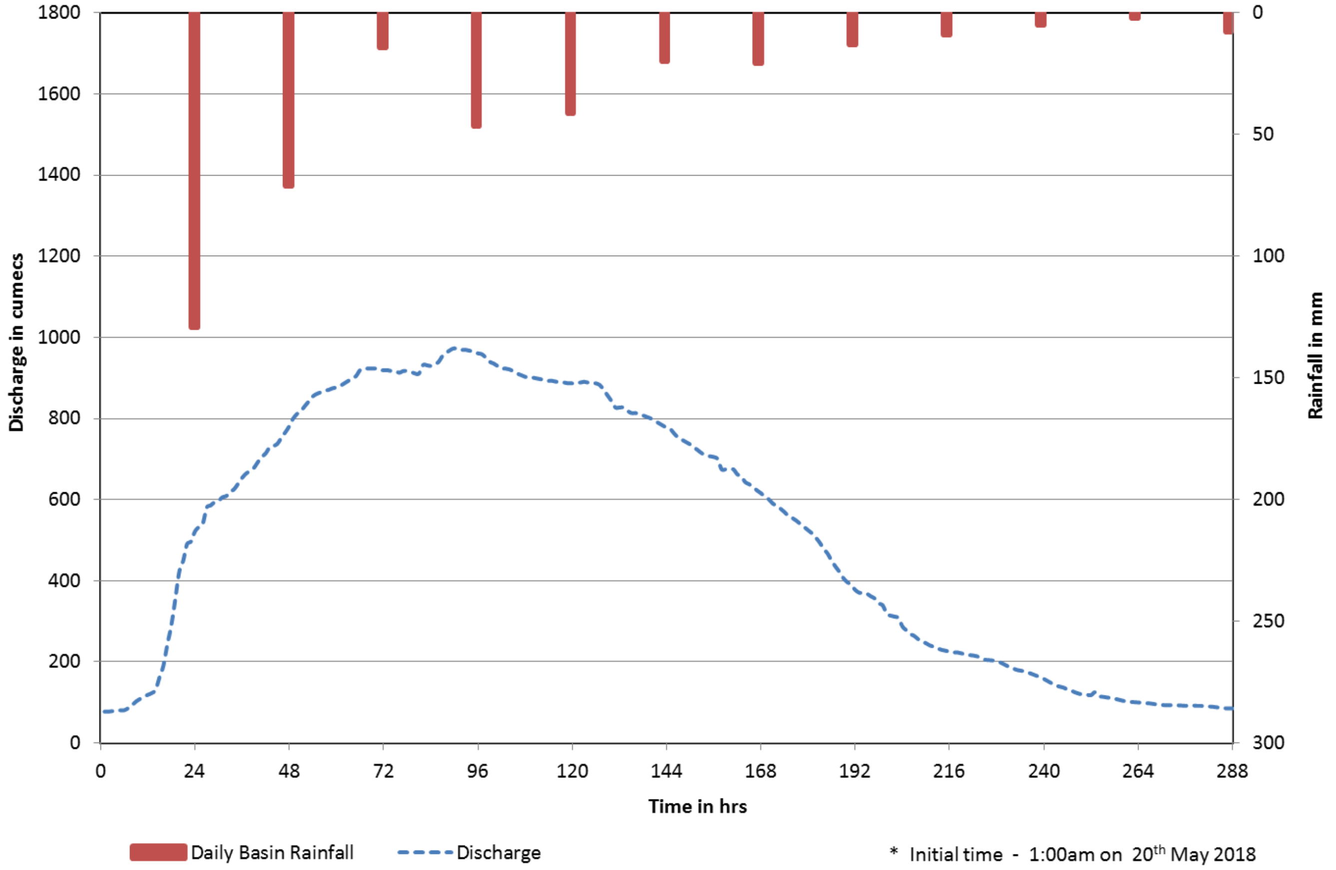

Maximum Flood During 2017/18
Kelani Ganga at Glencourse
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 11th May 2018

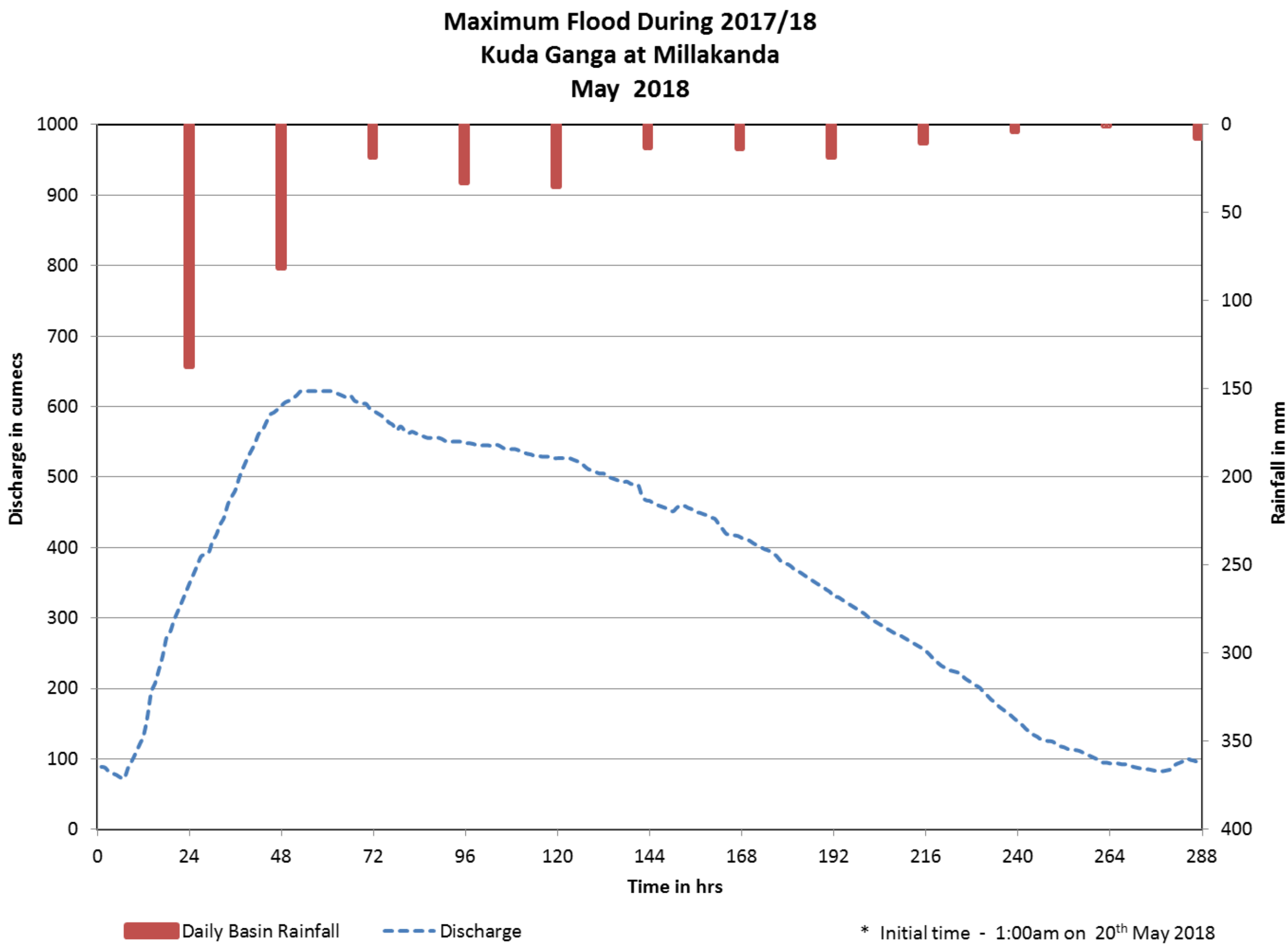

Maximum Flood During 2017/18
Kelani Ganga at Hanwella
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 11th May 2018

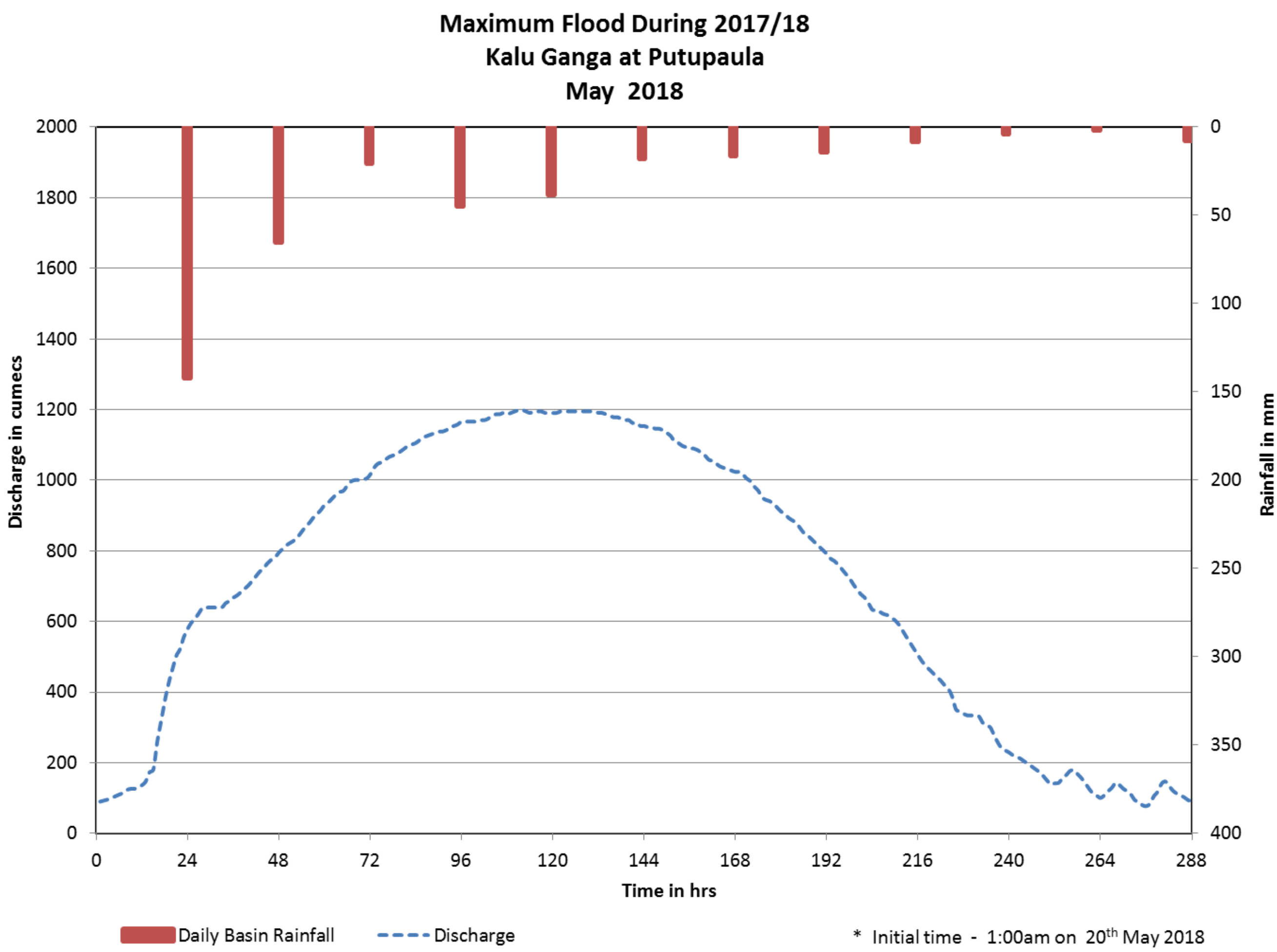
Maximum Flood During 2017/18
Kalu Ganga at Rathnapura
May 2018

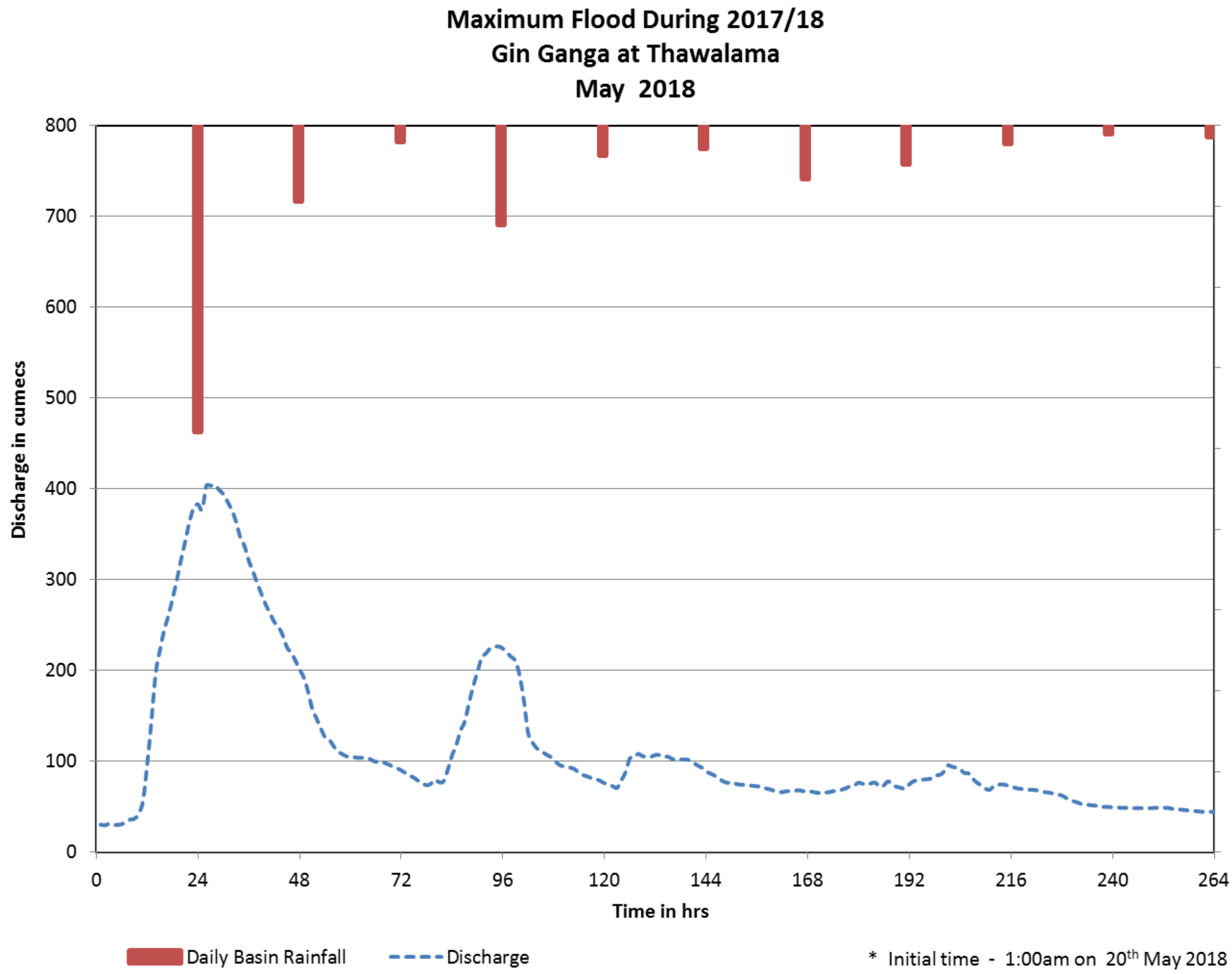


Maximum Flood During 2017/18
Kalu Ganga at Ellagawa
May 2018

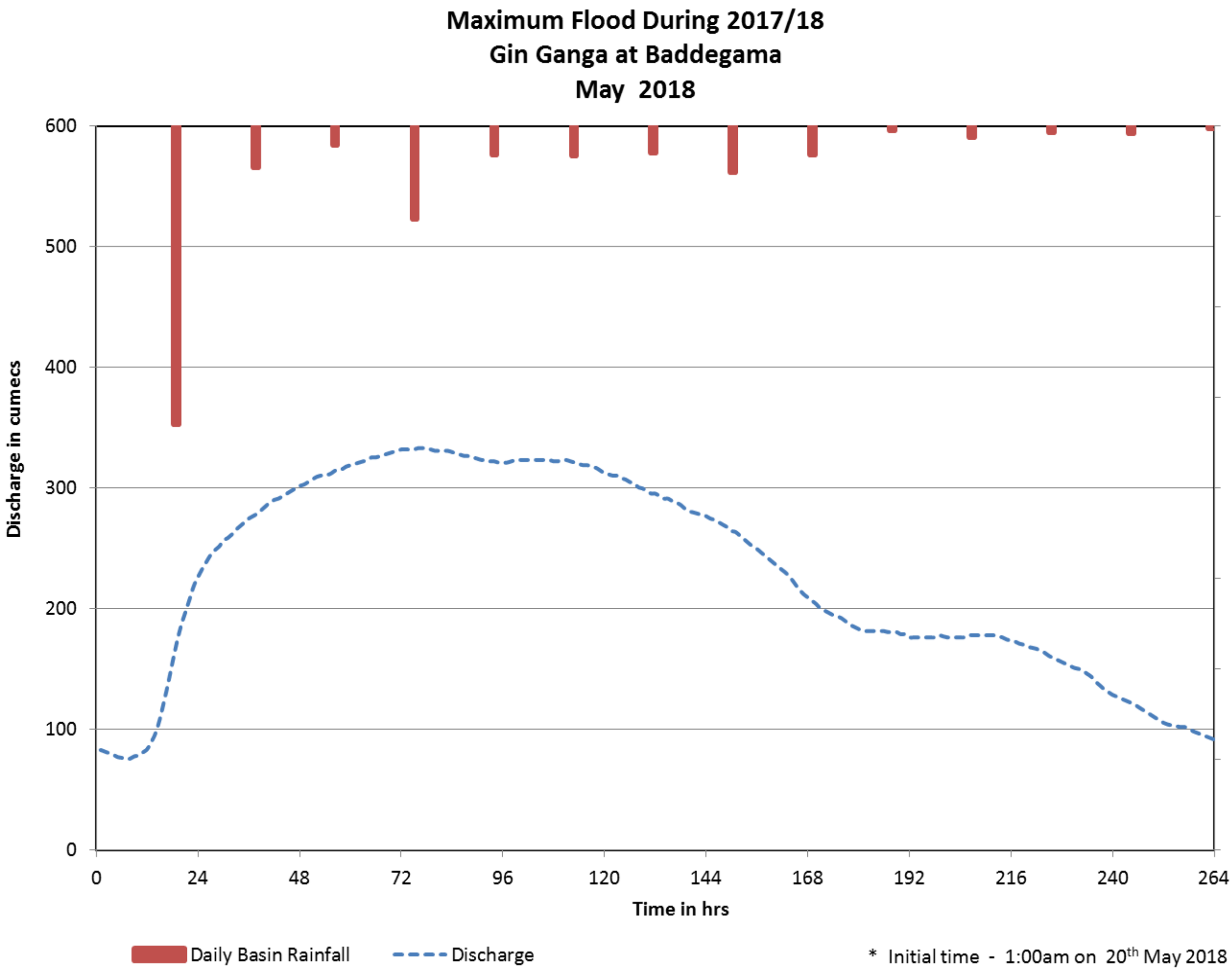



Maximum Flood During 2017/18
Kuda Ganga at Millakanda
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
0 24 48 72 96 120 144 168 192 216 240 264 288
0 100 200 300 400 500 600 700 800 900 1000
0 50 100 150 200 250 300 350 400
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018

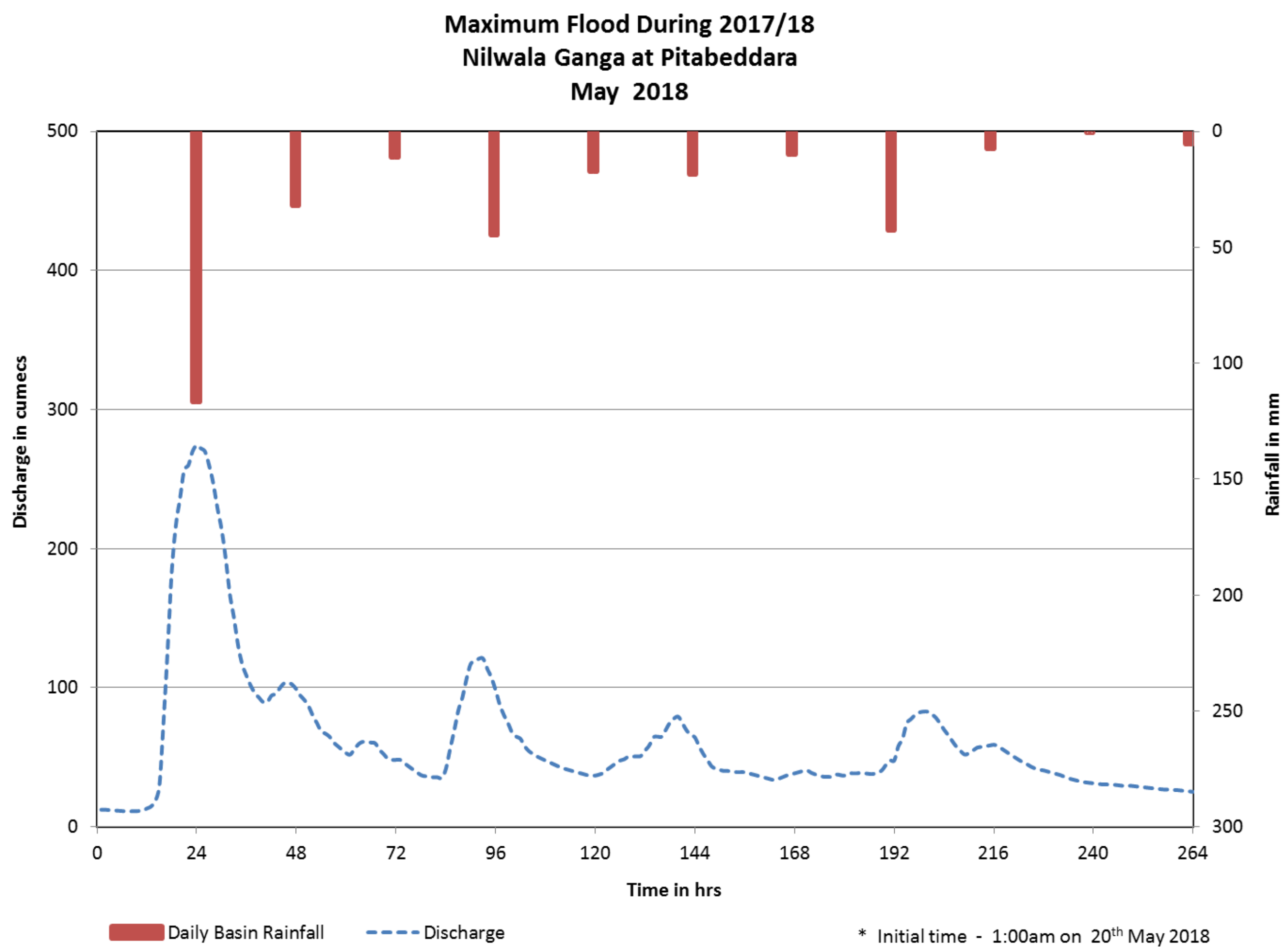

Maximum Flood During 2017/18
Kalu Ganga at Putupaula
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
0 24 48 72 96 120 144 168 192 216 240 264 288
0 200 400 600 800 1000 1200 1400 1600 1800 2000
0 50 100 150 200 250 300 350 400
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018

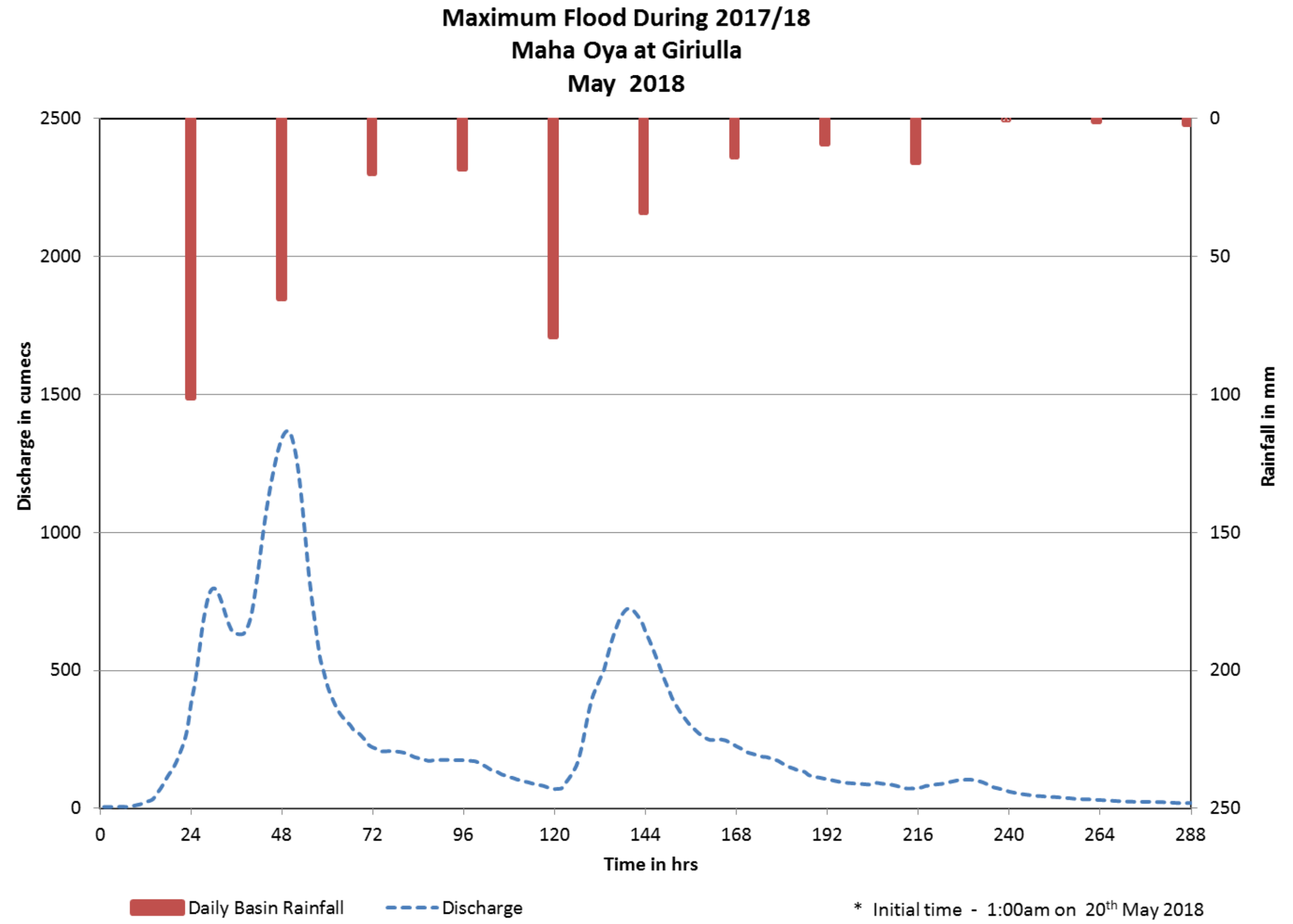


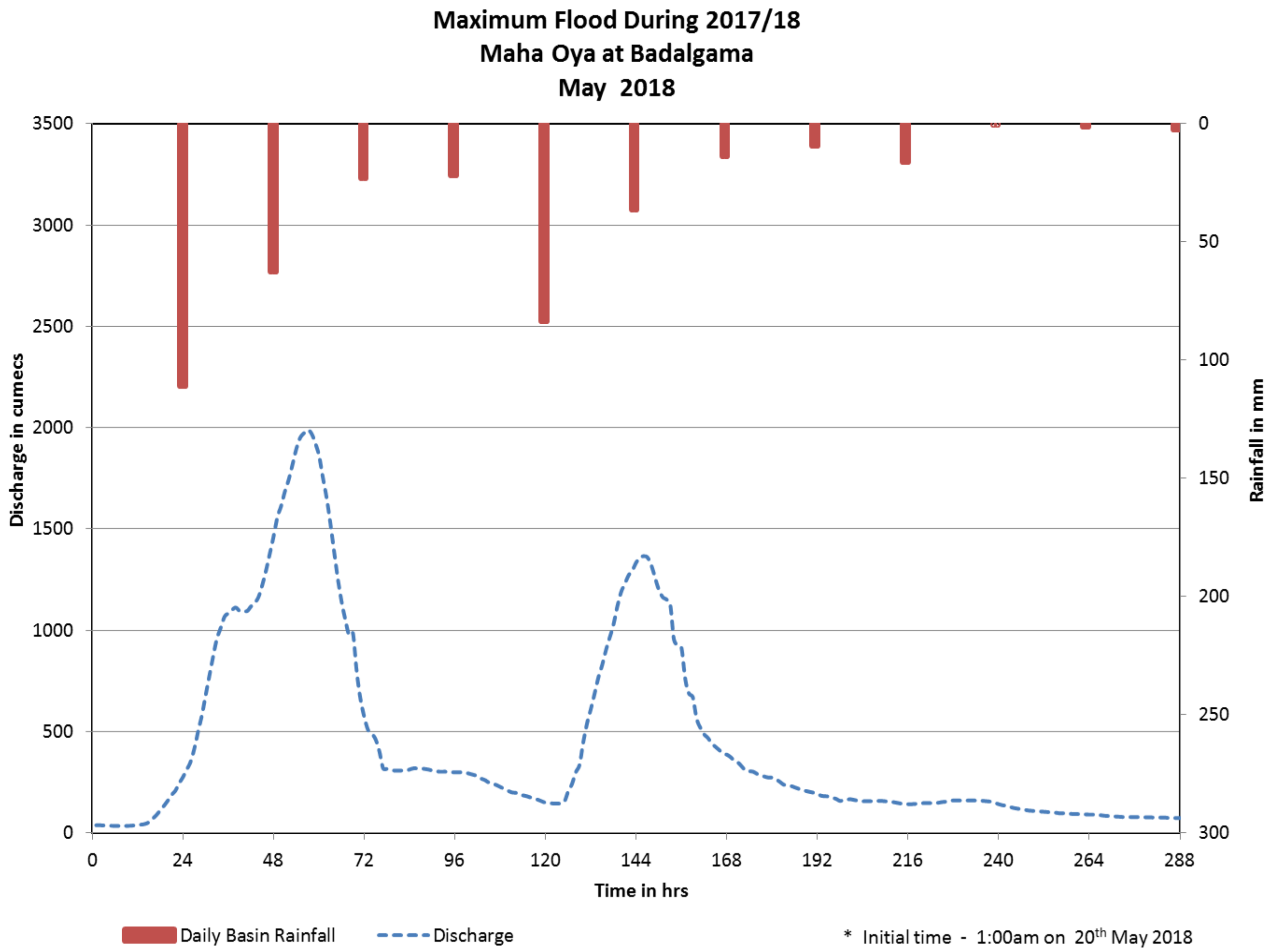
Maximum Flood During 2017/18
Gin Ganga at Thawalama
May 2018
800
700
600
500
400
300
200
100
0
Discharge in cumecs
0
50
100
150
200
250
300
350
400
450
Rainfall in mm
0
24
48
72
96
120
144
168
192
216
240
264
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018

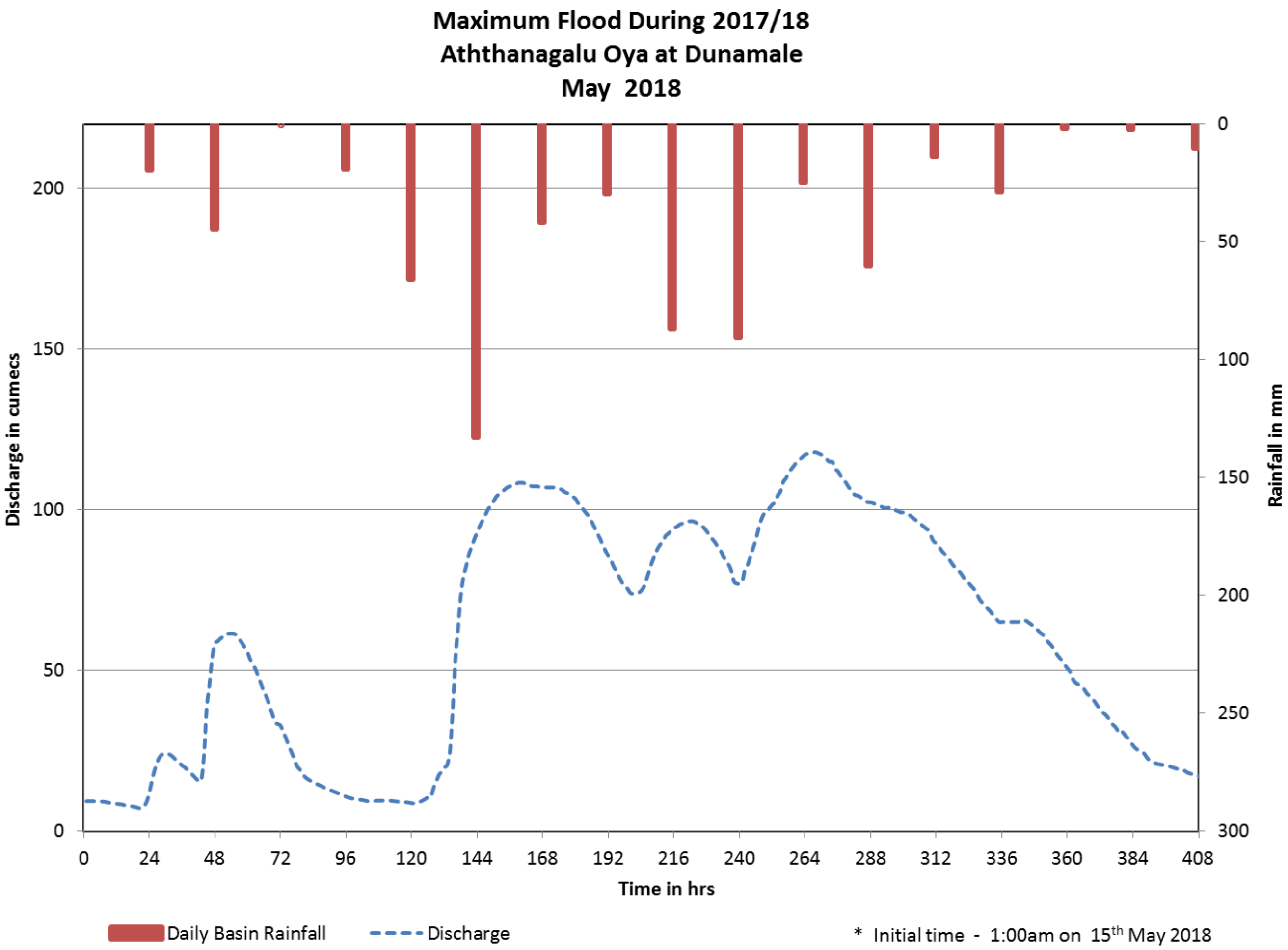


Maximum Flood During 2017/18
Gin Ganga at Baddegama
May 2018
600
500
400
300
200
100
0
Discharge in cumecs
0
50
100
150
200
250
300
350
400
Rainfall in mm
0
24
48
72
96
120
144
168
192
216
240
264
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018


Maximum Flood During 2017/18
Nilwala Ganga at Pitabeddara
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018


Maximum Flood During 2017/18
Maha Oya at Giriulla
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018


Maximum Flood During 2017/18
Maha Oya at Badalgama
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 20th May 2018


Maximum Flood During 2017/18
Aththanagalu Oya at Dunamale
May 2018
Discharge in cumecs
Rainfall in mm
Time in hrs
Daily Basin Rainfall
Discharge
* Initial time - 1:00am on 15th May 2018

PART III

- **River System of Sri Lanka and the Issues Related to its Sustainability**
- **Flood Risk Assessment in Gin Ganga Basin under Development of Basin Investment Plans (DBIP), Climate Resilience Improvement Project (CRIP)**
- **Flood Impact Assessment of Salinity Barrage in Kelani Ganga using 1D-2D hydraulic model built by Flood Modeller and TUFLOW software**

River System of Sri Lanka and the Issues Related to its Sustainability

River System of Sri Lanka and the Issues Related to its Sustainability

Eng. Ms. P. Hettiarachchi,
B.Sc. Eng. (Civil), M.Sc. Hydrology (IHE), C. Eng. (MIESL)

Abstract

Sri Lanka is blessed with 103 rivers, fairly distributed over the country. The country receives high rainfalls in North-East and South-West monsoon periods. The average annual rainfall of the country varies from 900 mm in the north-western coastal plains to over 5000 mm in the western slopes of central hills. However, due to uneven distribution of the rainfall over the country, majority of lands which belong to the dry zone suffer from scarcity of water. Further, the rainfall of dry zone is mainly concentrated to the North-East monsoon period. This area receive heavy rains in October, November and December and while remaining 9 months experience dry weather.

Being an agricultural country where staple food is rice, the irrigation sector consumes large amount of water. Despite to shortage of water, the all other conditions in the dry zone (flat terrain, fertile soil and sunshine) are favorable for cultivation. To overcome the shortage of water, the ancient Sinhalese built storage reservoirs and diversion structures throughout the country. That was the background for acquiring a supreme hydraulic civilization by the country.

However, the sustainability of natural river system, the primary source of water supply, is now under threat due to various human activities which will be explained in the latter part of this paper. Violating all the rules and regulations enforced for the protection of river system, those illegal activities are increasing at an alarming rate. The objective of this paper is to draw the attention of the responsible authorities to prevent such harmful activities and to protect the natural river system for future generations.

1. Introduction

The country comprises of 103 river systems of different sizes originate from central mountains and radially distributed towards the coastal plains (Figure on page 04). Those 103 river basins cover the land extent of nearly 59424 km^2 while the remaining area is covered by Jaffna Peninsula (1018 km^2) and small coastal basins (5049 km^2). Including the islands of Kayts and Kachetive, the total extent of the country becomes about 65600 km^2 [1].

Out of 103 rivers, 20 have been designated as Wet Zone Rivers. These river basins cover about 12676 km^2 of land extent mainly belongs to the Wet Zone of the country. Even though this area is nearly 20% of the country's territory, it is responsible for nearly half (25830 MCM) of the annual yield (runoff) of the country. The other 83 river basins in the Dry Zone represent the 80 % of the island's land area. Average annual yield of those rivers (25495 MCM) is comparable to the yield from the Wet Zone Rivers [2].

Thirty six rivers have catchment area above 145 square miles (371 km^2) and they are designated as major rivers [2]. Among them, 7 major rivers (Kelani, Kalu, Benthara, Gin, Nilwala, Maha Oya and Attanagalu Oya) belong to Wet Zone rivers. Generally those river basins receive high rainfalls from April to September and are remaining wet even during the other months. The area is highly populated and well developed.

Similarly, 26 major river basins are designated as Dry Zone Basins [2]. Unlike the Wet Zone, these areas form large and extensive parts of the country which cannot be cultivated without irrigation. These areas receive significant rainfalls during the North-East Monsoon (October, November and December). Agriculture production and the prosperity of the country depend upon the irrigation development of these areas. Realizing that, the ancient rulers of the country developed many irrigation works in these river basins (e.g. Malwathu Oya, Kala Oya, Deduru Oya etc.).

The two rivers, Mahaweli and Walawe, receive appreciable benefits from both monsoons and sometimes designated as bi-monsoonal rivers [2]. The Mahaweli has a unique feature of getting collected storm water from a large extent of central mountains which are benefited by both monsoons and carries to the eastern plains in the dry zone which are highly suitable for agriculture. The Walawe is also an important river basin which carries water from the central hills to southern coastal area which is also having ample potential for irrigated agriculture. The Deduru Oya, though strictly not considered as a bi-monsoonal river, has its source in mid-country receiving high rainfalls in both monsoons and flows down to the Dry Zone.

Twenty one rivers which are most important in the Hydrological point of view (catchment area above 800 km^2) are listed in Table 01, sorted in descending order of catchment size. The annual yield does not essentially follow the same order due to climatic reasons.

Rank based on Basin Area	Name of the River	Catchment Area km^2	Average Annual Discharge to sea MCM	Type	Specific Features
1	Mahaweli Ganga	10256	5474	Bi-monsoonal	Longest River
2	Malwathu Oya	3291	710	Dry -Zone	Oldest Civilization
3	Kalu Ganga	2839	7211	Wet-Zone	Highest Yield
4	Deduru Oya	2622	1199	Bi-monsoonal	
5	Kala Oya	2526	435	Dry -Zone	Ancient Civilization
6	Walawe Ganga	2424	543	Bi-monsoonal	
7	Kelani Ganga	2340	4969	Wet-Zone	Frequently flooded
8	Gal Oya	1911	854	Dry -Zone	
9	Mee Oya	1555	22	Dry -Zone	Semi-Arid basin
10	Yan Oya	1518	255	Dry -Zone	
11	Maha Oya	1470	1603	Wet-Zone	Worst eroded river
12	Maduru Oya	1439	808	Dry -Zone	Augmented by Mahaweli
13	Mundeni Aru	1373	1062	Dry -Zone	
14	Menik Ganga	1301	312	Dry -Zone	Augmented by Kirindi Oya
15	Kumbukkan Oya	1227	319	Dry -Zone	
16	Kirindi Oya	1156	122	Dry -Zone	
17	Nilwala Ganga	1043	1167	Wet-Zone	Frequently flooded
18	Maa Oya	1042	292	Dry -Zone	
19	Modaragam Aru	1001	166	Dry -Zone	
20	Ginganga	915	1951	Wet-Zone	Frequently flooded
21	Attanagalu Oya	811	911	Wet-Zone	Frequently flooded

Table1: Salient Features of the Major Rivers of the Country (SOURCE : Dam Safety & Water Resources Planning project (DSWRP.)

2. Distribution of Rainfall

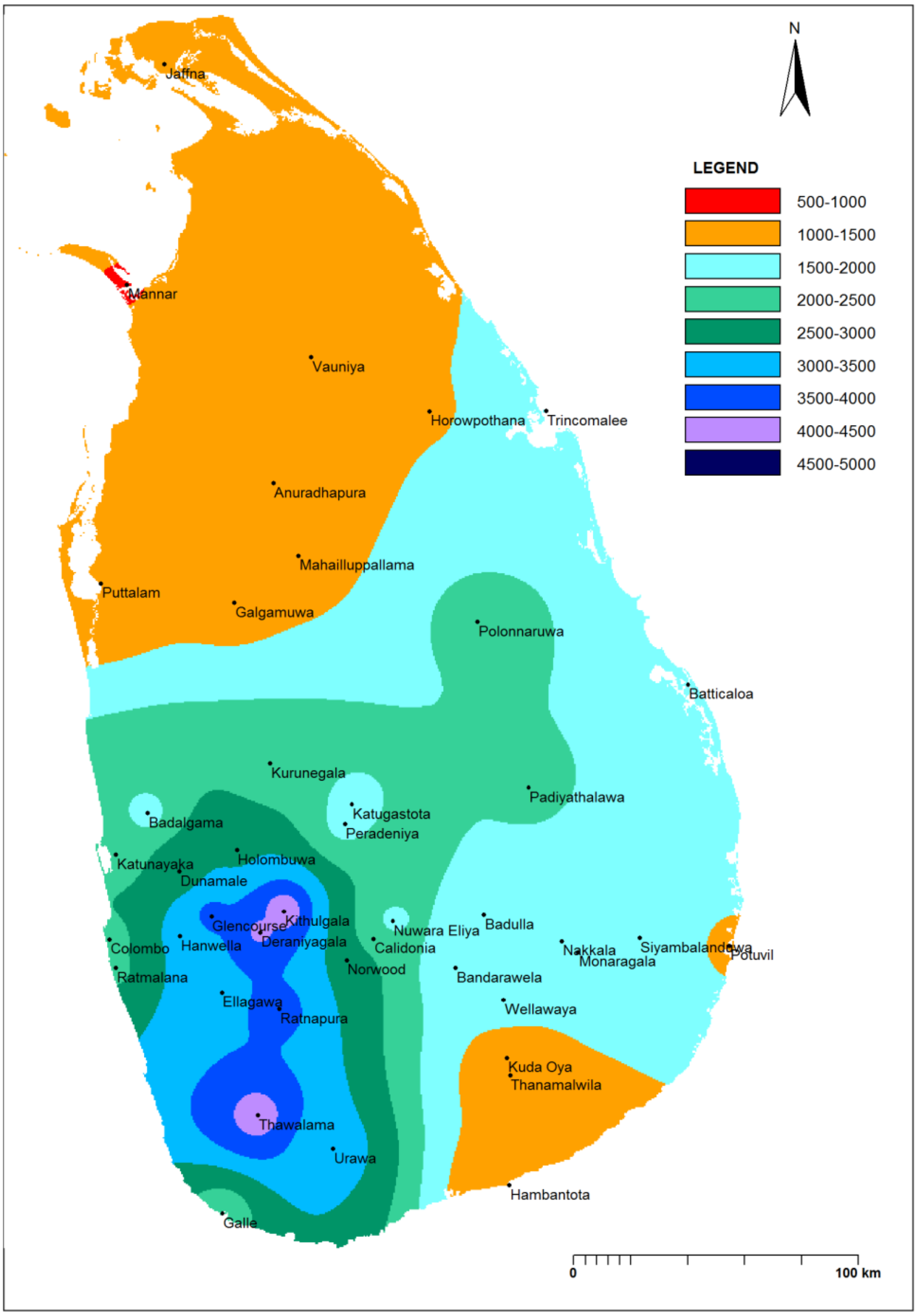


Figure 1 : Spatial Distribution of Rainfalls based on Long-term Records [1]

The average annual rainfall of the country is generally high (Fig.1). However there exists significant spatial and seasonal variation over the country. Annual rainfall depth varies from 900 mm in coastal plains to 5000 mm in the central hills.

Entire country receives high rainfalls in October, November and December. Wet Zone receives considerable rainfall over April, May and June too. Figure 2 presents the temporal variation of rainfalls in Dry Zone over the 12 months of the year [2]. According to that the dry zone suffers from scarcity of water for 8 months from February to September.

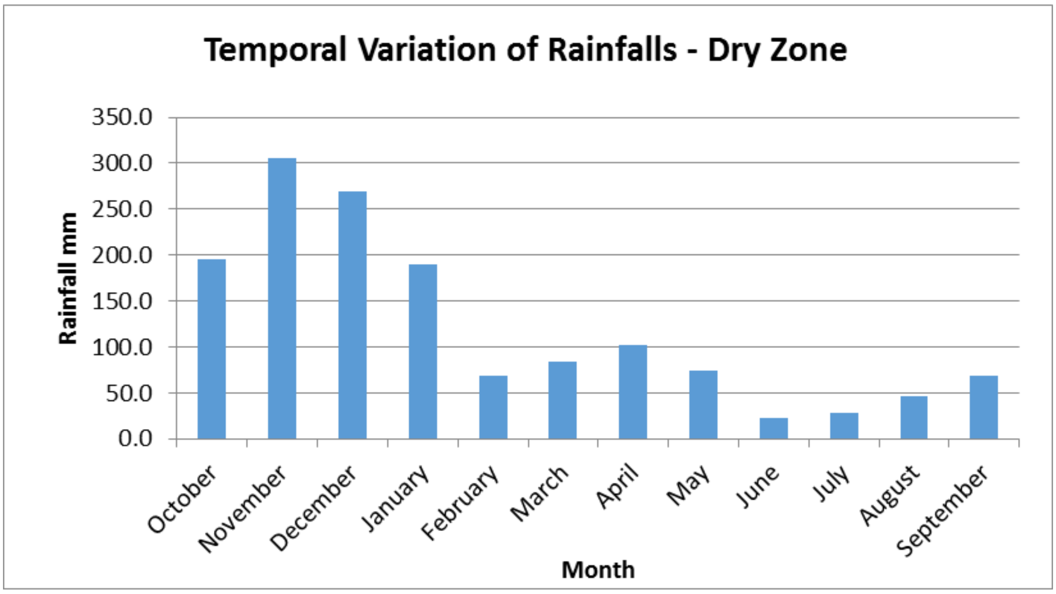


Figure 2 : Temporal variation of rainfalls over the Dry Zone [2]

Figure 3 shows the temporal variation of rainfall over the Wet Zone. It shows that the Wet Zone rainfalls are fairly well distributed over the year. Any cultivation including paddy can be cultivated in this area without supplementary irrigation.

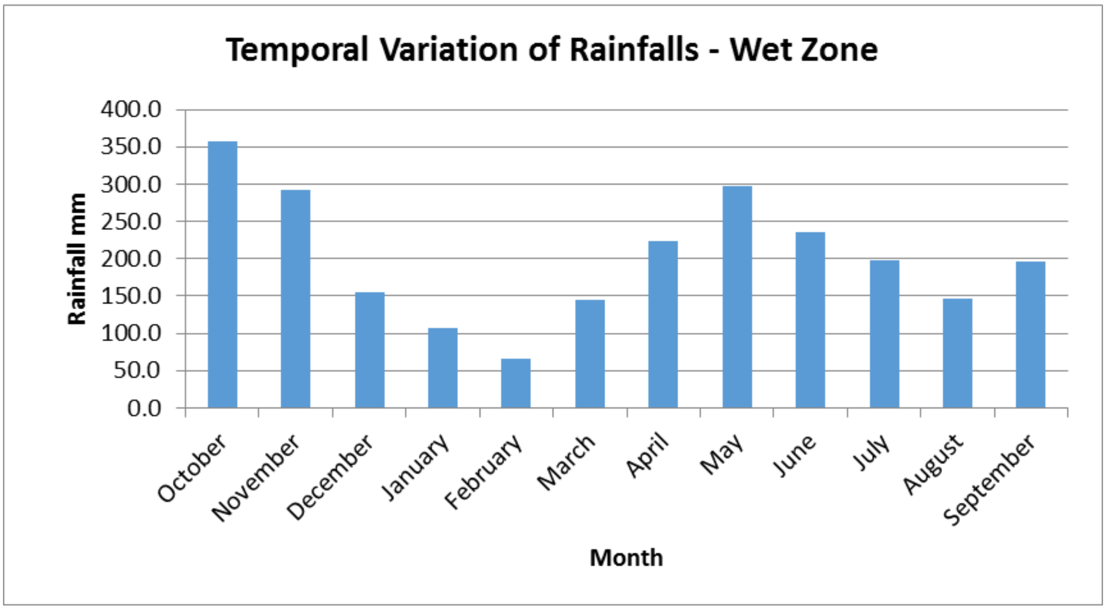


Figure 3 : Temporal variation of rainfalls over the Wet Zone [2]

There are also significant variations of soil texture land slopes etc. over the Island. Therefore the country has to be divided into small units for comprehensive studies of water resources. River basin (more precisely the sub basin) is the natural and ideal unit to study the water resource concerning rainfall, stream flow, soils and vegetation etc. and the potential of developing water resources for various usages over the Island.

3. Water Resources Development of the Country

The Mahaweli is the largest river basin of the country. The size is nearly the 1/6 of the territory of the Island. The river begins from the central mountains which receive high rainfalls from both monsoons. The river traverses nearly 335 km through the mountains providing high potential for hydro-power generation and the dry eastern plains ideal for agriculture. The Mahaweli water has been impounded for power generation and agriculture by construction of dams, Polgolla barrage (1977), Bowatenna (1981), Kotmale (1985), Victoria (1985), Maduru Oya (1986), Randenigala (1986), Rantembe (1990), and Moragahakanda (2016). The river is equally contributing for the hydropower generation and the agriculture development. Similarly most of the dry zone river basins have been developed for agriculture by construction of reservoirs or diversion structures. Apart from the Mahaweli, Gal oya, Walawe Ganga, Kirindi Ora, Mee Oya, Rambakan Oya, Deduru oya and Menik Ganga are some of the rivers harnessed for irrigation by construction of large reservoirs after the independence of the country. Out of them, Senanayaka Samudraya which was constructed across the Gal Oya is the largest reservoir in the country. This was responsible for remarkable increase in rice production by providing irrigation water for nearly 125,000 acres in the Eastern Province. Yan Oya reservoir is still under construction while Lower Malwathu Oya and Mundeni Aru reservoirs will be commenced in near future. Malwathu Oya and Kala Oya were the best examples for ancient hydraulic civilization of the country.

The Kalu Ganga, the largest water resource of the country, remains untouched while there is potential for diversion to the Walawe basin which suffers severely from the scarcity of water. Most of the other Wet Zone Rivers also produce substantial amounts of water but the potential for diversion and hydropower generation is limited due to low potential head.

A flood protection scheme has been constructed over the Gin Ganga basin. This was implemented in 1970s with the technical assistance of Chinese Government. Seventy Flood bunds and 10 pumping stations comprised of 37 electrical pumps have been constructed under this project.

Similarly, the Nilwala Ganga Flood Protection Scheme was implemented in 1980s with the technical assistance of the French Government. This project was not that successful since the right bank protected area could not be cultivated due to soil salinization. Further, the protection level of the scheme is not sufficient to cater the present requirements. The flood protection bunds were overtopped, twice in 2003 and 2017 after the construction resulting inundation of residential areas.

3.1 Hydropower Development of the Country

The first commercial hydro-power project in the world was commissioned in Michigan, USA in 1880. Not long since, the first hydropower plant in the island was set up in 1887 with 11 KW capacity. Since then there was a lot of interest by private sector developers in developing mini hydro-power plants using the potential of water falls in the central mountains of the Island. The present capacity of mii hydro-power is around 170 MW. A recent study carried out by Dam Safety and Water Resources Planning Project (DSWRP) found that the balance potential for developing mini hydropower in the country is around 250 MW.

The Kelani River has been harnessed for hydro-power generation since beginning of the last century. In 1911, Rylands, the Government Electrical Engineer, in his report, indicated the potential of Laxapana for development of hydro-power. In 1918, D.J. Wimalasurendra, Assistant Electrical Engineer read his historic paper titled “Economics of Power Utilization in Ceylon” before the Engineering Association of Ceylon and this triggered off a lot of interest in the subject.

The first hydropower plant on the Kelani River (Laxapana) was named by the name of its founder D. J. Wimalasurendra. Subsequently, the Kelani river was developed for large scale power plants by construction of series of reservoirs including Castelreigh and Maussakele in mid of the last centuary. In 1980s, with the Mahaweli Development Project, the hydropower sector in Sri Lanka acquired a remarkable progress. According to the sources of Ceylon Electricity Board, over 50% of the total grid capacity was met by hydroelectricity in 2000–2010. Apart from that, the Deduru Oya, Walawe Ganga and Kukule Ganga also contribute to hydro power generation of the country. As per 2016 Generation Report of Ceylon Electricity Board, the present capacity of hydropower generation in Sri Lanka is 1726 MW which represents nearly 43% of total installed power generation capacity of the country.

4. Threats to the sustainability of River System

As mentioned in the previous sections, economy and the prosperity of the country highly depend upon the existence of the natural river system. Having realized this, the rulers of the country beginning from ancient Sinhalese kings, paid their attention for the protection and further development of water resources by construction of storage reservoirs and diversion structures. Even today, it should be given high priority by the present authorities responsible for water sector developments and environmental protection. For that, it is necessary to identify the challenges and the threats for the existence of natural river system and the actions to be taken to preserve them for the use of future generations.

4.1 Deforestation

Natural forest cover of the country was nearly 49 % of the land extent in 1920s. This was reduced up to 35% by the end of 1990s and it has become 33 % by now [3]. Natural forest cover infiltrates the rainwater into soil mass, slow down flow velocities and maintain the dry weather flow of the rivers. In other words, it is acting as an underground reservoir that find its inflow from rain water and release slowly through the river system for the usage of dry periods. Deforestation not only damages these natural phenomena but also create other environmental problems such as flooding, landslides, soil erosion and siltation of rivers.

4.2 Catchment Mismanagement

Implementation of land use policies can play a vital role in this regard. The lands of elevations higher than 5000 ft had been declared as reserved in the law passed in 1938. This is highly important for the sustainability of river system. Highly sloping lands susceptible for erosion also should be given a similar attention. Construction in the upper catchments should be discouraged as far as possible. If it is unavoidable, precautions should be taken to prevent activities causing exposure of soil surface and directing untreated waste water to river channels.

Provision of infrastructure facilities such as electricity, pipe borne water, roads, housing, schooling etc. also encourage the settlements in preserved areas. The government should impose strict rules to prevent providing such facilities to unauthorized settlements.

4.3 Lack of Awareness

Lack of awareness also causes for many activities harmful to the rivers. If the real beneficiaries of the river system make aware of the adverse effects of human activities, they would tend to prevent them naturally (Fig. 4). Therefore awareness and enforcement of local community also will be helpful to preserve the natural river system.

Figure 4 : Local People protests against the excessive sand mining in the Yan Oya

4.4 Organizational problems

Geological Survey and Mines Bureau (GSMB) is the government institution mandated to deal with mining activities in Sri Lanka [3]. Some other institutions including Central Environmental Authority (CEA) are responsible for environmental issues related to mining. GSMB takes the clearance of the relevant government organizations depending on the location where mining is taken place.

Irrigation Department (ID) issues clearance for river sand mining except for the coastal zone (2 km from the river mouth) which is under the purview of the Coast Conservation Department (CCD). Concerning the Mahaweli, these responsibilities and legal powers are coming under the Mahaweli Authority. ID is taking actions to define the natural profile for each river with the help of past survey data to control over excavation which is causing adverse environmental damages such as bank erosion, sea water intrusion and drawdown of ground water. However, the control of crown lands including river beds and inland lakes comes under the district and divisional secretaries. As such there is no single authority responsible to safeguard the river system of the country. Joint effort of all these organizations is required to take any action against harmful activities.

4.5 Encroachment of reservations

Stream reservations which were defined originally in the Crown Land Ordinance and the Land Development Ordinance No: 19 of 1935 are presented in the Table 2.

River Width (m)	Width of the stream reservation
Less than 4.6 m	20 m from the bank of each side
Between 4.6 and 15.2 m	40 m from the bank of each side
More than 15.2 m	60 m from the bank of each side

Table 2 : Reservation of rivers [4]

However when there are private lands present within the river reservations this legislation become invalid. The legislation has been neglected by the government authorities when issuing temporary permits for crown lands even after passing the ordinance. Same authorities are reluctant to take actions against the encroachers since it creates unpleasant reactions from both inhabitants and the local politicians. As such it seems implementing above law is difficult. However, still there are possibilities to introduce land use policies for the river reservations to control the activities undesirable for the sustainability of the river. Removal of garbage and disposal of raw sewage to river system are very common problems inherent to those illegal settlements (Fig. 5 and 6).

Figure 5 : Removal of Solid Waste to River Flows

Figure 6 : Disposal of Raw Sewage to River Flows

4.6 Sand Mining

There is an annual production of sand in a river system depending on the flow and catchment characteristics. This quantity can be extracted without damaging the riverine environment. Local community used to extract river sand as their livelihood (Fig. 7) for centuries with indigenous methods without harming much to the rivers systems. Therefore, river sand mining must be allowed, to some extent, under the strict rules and regulations to control over extraction.

Figure 7 : River Sand Mining with Indigenous methods

Figure 8 : River Bank erosion due to mining in the Mahaweli at Trincomalee

However, sand mining became a profitable business with the expansion of construction industry and the increase of the prices of construction materials. This became a major environmental issue during past few decades creating problems such as bank erosion (Fig. 8), collapse of houses, loss of agricultural lands, depletion of ground water level, degradation of river beds, salt water intrusion etc.

Mainly, large scale miners are responsible for this issue irrespective of whether they are having license or not. Getting license is not that difficult, bypassing rules and regulations, under the political influence and bribery. Mechanical mining is prohibited in the rivers of Sri Lanka under the National Environmental Act 47 of 1980 and the supreme court order in 2004 [5]. Any damage to river bank is prohibited and the extraction should be done in the river 7 m away from the bank. Mining in highly sensitive rivers, Deduru Oya and Maha oya, has been banned. However, according to media (Figure 8 and 9), it is practiced everywhere, violating all the rules and regulations, under the negligence of respective government agencies.

Figure 9 : Mechanized Sand Mining in the Yan Oya

4.7 Gem Mining

Gem mining in the rivers is even more harmful to the stability of river bed and banks (Fig. 10 and 11). Most of the countries have banned this since it makes irrecoverable damage to the river by removing hard material from the bed. Even though there are many organizations which are supposed to control this, gem mining is continued under the patronage of political authorities. Supervision of mining activities is very low due to corruption in law enforcement agencies. License holders usually neglect license rules to get high profit [6].

Figure 10 : Large scale Riverbed Gem Mining Using Gravel Suction pumps, Seethawaka Ganga

Figure 11 : Bed Material Removed from a Gem Mine in the Seethawaka Ganga

The above snapshots were taken from a large-scale gem mine in the Seethawaka Ganga, a main tributary of the Kelani River. This is a legal mine which has been in operation for a long time and still being continued.

The extent of damage doesn't depend on whether it is legal or not but the magnitude and the speed of mining and the method adopted. Mechanized mining damage the rivers rapidly while the damage caused by indigenous methods (Fig. 12) are somewhat slow.

Figure 12 : Riverbed Gem Mining carried out using indigenous methods

Indigenous gem mining method has been proven to be sustainable through time. Local gem miners have been practicing indigenous methods for 2000 years and until now, no major adverse impacts have been reported [6].

5. Conclusions and Recommendations

The age of natural systems is measured in Geological Years which is in the order of billions of calendar years. These systems have evolved to the forms which we see today by elapsing such a long period. The stability of them may be destroyed within a short period by human activities with the support of modern technology. The natural river systems of entire world faced this challenge in the recent past, but the developed countries could overcome the challenge by enforcing strict rules and regulations. Sri Lanka also should implement such system to safeguard the river systems and other water bodies in the country including the ground water system.

Mining (clay, sand, gem etc.) not only destroy the river system but also the aquifer system around the country leading to desertification of arable lands. Aquifer is a sand layer underlined by impervious clay layer, functioning as underground reservoir facilitating plant growth and maintaining dry weather flows of rivers. It is not possible to recover once destroyed by removal of sand layer. That should not be sacrificed for addressing the problems in construction industry or poverty alleviation. Now, the construction field is expanding rapidly under the foreign loans or under their direct investment. The demand of construction materials cannot be fulfilled with natural sources of the country and therefore alternatives should be investigated.

Some of the environmental problems can be addressed by enforcing rules and regulations and strengthening government institutions. The changing of attitudes by educating people is also vital in this regard.

References :

1. Hydrological Annual 2016-17, Hydrological Division, Irrigation Department.
2. Arumugam s., Water Resources of Sri Lanka.
3. Mines and Mineral Act No: 33 of 1992.
4. Land Development Ordinance No: 19 of 1935
5. www.slideshare.net/pabasarag/environmental-policies-regarding-river-sand-extraction-of-sri-lanka
6. Nandalal, K D W., Department of Civil Engineering, University of Peradeniya.

Flood Risk Assessment in Gin Ganga Basin under Development of Basin Investment Plans (DBIP), Climate Resilience Improvement Project (CRIP)

Flood Risk Assessment in Gin Ganga Basin under Development of Basin Investment Plans (DBIP), Climate Resilience Improvement Project (CRIP)

Eng. M. D. Thilini Wasana Kumari[1], Eng. M.A. Jayakody[2], Eng. P. A. A. P. K. Pannala[3]

[1] Irrigation Engineer, Irrigation Department, Sri Lanka.
[2] Chief Engineer, Water Resources Planning, Irrigation Department, Sri Lanka.
[3] Director (Irrigation Special Project) / Deputy Project Director (CRIP-DBIP), Ministry of Agriculture, Rural Economic Affairs, Livestock Development, Irrigation And Fisheries & Aquatic Resources Development, Sri Lanka.

Abstract

Gin Ganga Basin is located entirely within the Wet Zone in the southwestern area of Sri Lanka. Gin River is starting near Gonagala Kanda (Abey Rock) at Deniyaya and flowing in mainly a Southwestern direction to enter the sea at Gintota near Galle.

One of the objectives of the CRIP-DBIP study is to carry out the flood risk assessment in the selected river basins. The purpose of the flood risk assessment is to assess and quantify the risk of the flood with the impact of climate change at a basin scale. The calculated economic cost through the Annual Average Damage (AAD) for Flood will be used when planning and decision-making for future investments in order to mitigate flood and the impacts of climate change.

Flooding is the major issue in the Gin Ganga basin and hence this basin was selected as one of the 10 river basins for CRIP-DBIP study to carry out flood risk assessments, and identify potential flood risk mitigation interventions through modelling and other forms of analysis.

This paper describes the results of the flood risk assessment in the Gin Ganga basin.

Key Words: Climate Change, Flood Risk Assessment, Damage Assessment, Pessimistic, Optimistic, Gin Ganga Basin, Annual Average Damage (AAD)

1 Introduction

Climate Resilience Improvement Project (CRIP) is an ongoing project since 2014 under the World Bank fund. Development of Basin Investment Plans (DBIP) study is one of the main components under CRIP. The main objective of the study is to develop a long-term investment plan to mitigate associated flood and drought risks in a basin. It was selected 10 river basins for the DBIP study considering the historical flood and/or drought issues and their severity, damages to the public and private properties, and potential for water resources development. The selected 10 river basins are: (i) Kelani Ganga; (ii) Attanagalu Oya; (iii) Nilwala Ganga; (iv) Gin Ganga; (v) Malwathu Oya; (vi) Mahaweli Ganga; (vii) Maha Oya; (viii) Deduru Oya; (ix) Kala Oya ; and (x) Gal Oya.

Gin Ganga basin was selected for the DBIP study due to its flooding issues in the basin as this is a major environmental hazard in Galle district. Drought issue is not much significant compared to flood, since basin is entirely within the Wet zone. It has a catchment area of 943 km^2 and average river length around 113 km according to the DEM developed by CRIP-DBIP.

Flood risk assessment in Gin Ganga basin is carried out to identify the critical assets at risk due to floods and to calculate the associated flood damages. Using the flood damage information, it can be calculated the economic values associated with the damages and these can be mapped to show the spatial distribution of the economic values of flood damages. In conclusion, the flood risk assessment shows that required area to invest for flood mitigation to minimize the economic damages currently being experienced by flood events in the Gin Ganga basin.

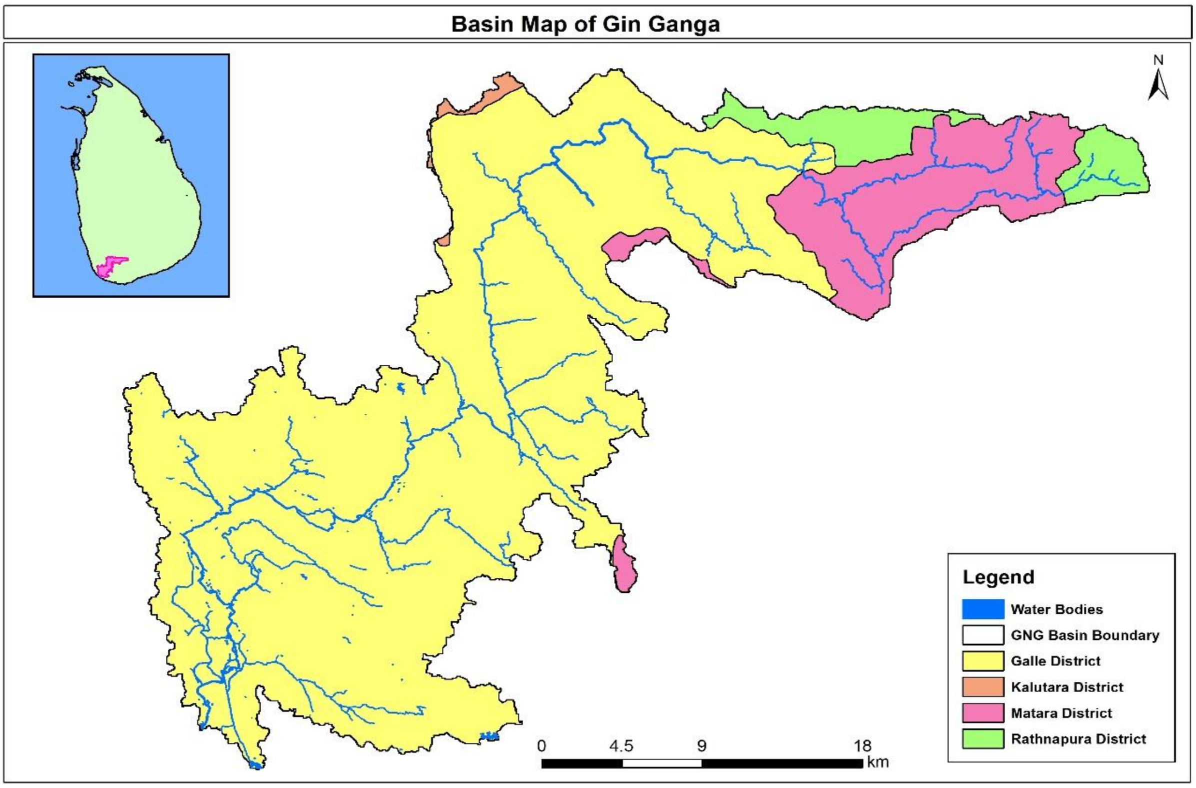


Figure 1 : Gin Ganga Basin Map

2 Methodology

Flood risk assessment will assess the risk due to flood in entire Gin Ganga basin for the seven scenarios: current climatic conditions and 3 future climatic scenarios and present and projected basin conditions, as follows, (FDRAR-Gin, pp. 3-1)

1. Current climatic conditions, land use, water demand, irrigation practices, hydraulic infrastructure and reservoir operation (Case 1, Base Case)
2. Future climatic conditions (3 scenarios - Pessimistic, Average & Optimistic) and current land use, water demand, irrigation practices, hydraulic infrastructure and reservoir operation (Cases 2, 3, 4)
3. Future climatic conditions (3 scenarios - Pessimistic, Average & Optimistic), and projected land use and water demand, irrigation practices, hydraulic infrastructure and reservoir operation (Cases 5, 6, 7).

Climatic Conditions		Basin Development	
		Current 'no basin development'	Future (2040) 'basin development'
Current Climate		Case 1 (base case)	-
Future Climate	Pessimistic	Case 2	Case 5
	Average	Case 3	Case 6
	Optimistic	Case 4	Case 7

Figure 2 : Selected seven scenarios for Flood Risk Assessment

The overall process for Flood risk assessment consists of 7 component as shown in the below figure 3.

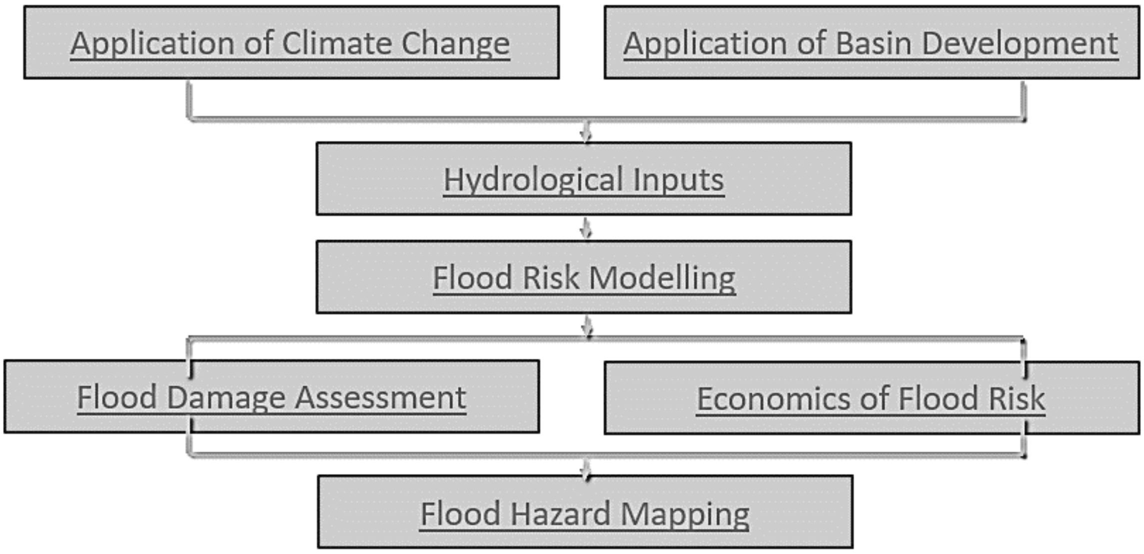


Figure 3 : Overall Flood Risk Assessment Process

2.1 Application of Climate Change

The stochastic weather generation tool was used to generate the rainfall data to get the climate change (CC) impact for the assessment. This tool uses statistics of observed weather data and produced daily rainfall data for 99 years for baseline & 10 future scenarios at specific locations (rainfall stations). The ten future data series were selected from the available Global Circulation Models (GCM) associated with the Representative Concentration Pathways (RCP) (CFR, Volume 1, pp. 4-1 - 4-21). The climatic factor for three climatic scenarios (Pessimistic, Optimistic and Average) was selected from the ten future generated data series based on rainfall depth change factors (higher rainfall depth change factor as “Pessimistic”). Pessimistic CC factor was applied for case 2 and 5 defined above. Optimistic CC factor was applied for case 4 and 7 while Average CC factor was applied for case 3 and 6. (FDRAR-Gin, pp. 4-4)

2.2 Application of Basin Development

Basin Development of Gin Ganga basin in the year 2040 was applied through three categories: Population Change, Land Use Changes and the Hydraulic Infrastructure Changes. These changes were applied only for future cases: Case 5, 6, and 7.

2040 population was calculated using 2012 census data with the census growth projections at Grama Niladhari division wise. Land use changes in the year 2040 were taken considering the national policy plans, urbanization and township developments. Land use maps for the year 2012 and 2040 are shown below (Figure 4). (FDRAR-Gin, pp. 4-5)

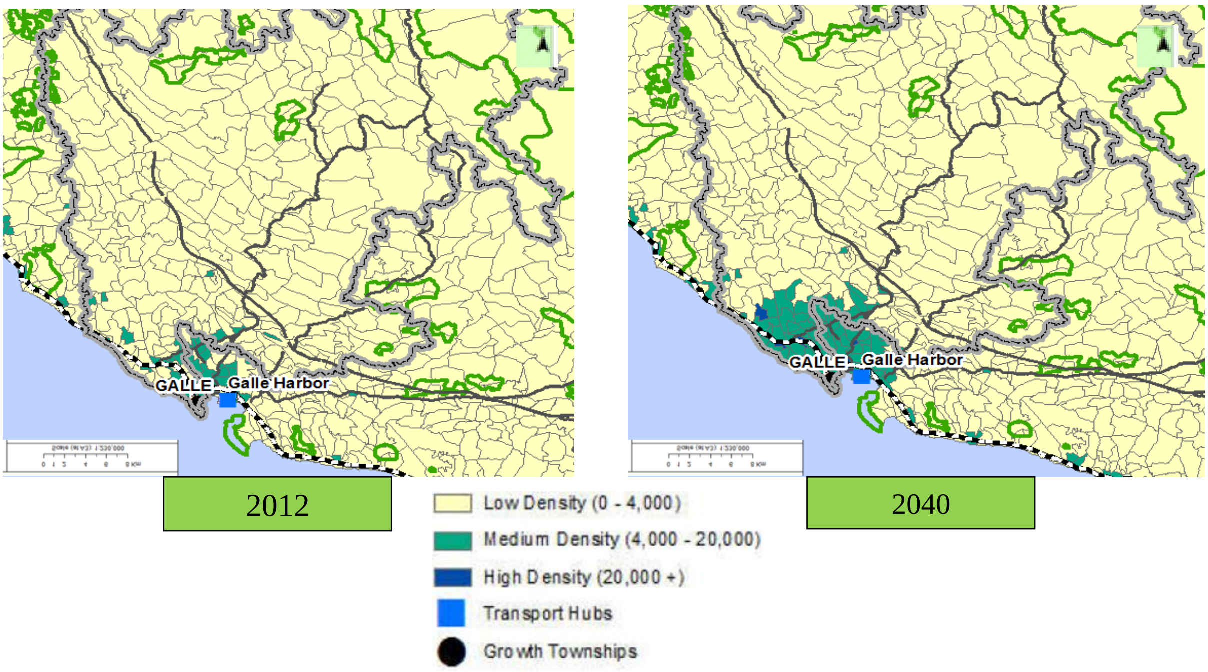


Figure 4 : Land Use Changes - Year 2012 and Year 2040

In Gin Ganga basin, there is no any proposed hydraulic infrastructure that will be implemented before 2040 except Madugate reservoir for Proposed Gin Nilwala Diversion Project (GNDP). The capacity of the proposed Madugate reservoir is very low for flood detention purpose since this is mainly for diversion of excess water from Gin Ganga basin to Dry Zone area. Considering these factors, Madugate reservoir was not included as a proposed Hydraulic Infrastructure in the model to analyse the worst risk due to flood. (FDRAR-Gin, pp. 4-5)

2.3 Hydrological Inputs

Design rainfall package is the key hydrological input for the Flood Risk Assessment. It was prepared through three stages; Development, Application and Validation. (FDRAR-Gin, pp. 4-5 - 4-9)

2.3.1 Development of Design Rainfall Package

Four components used for the development of design rainfall package are described below.

i). Rainfall Depth – Rainfall depths of the rain gauges used for the model (within Gin Ganga basin and nearby) for each return period (5, 10, 25, 50 and 100 years) were derived from Intensity-Duration-Frequency (IDF) analysis for the two distributions of Gumbel / EV1 and Pearson Type III.

ii). Rainfall storm duration – General storm durations of the Gin Ganga basin were derived from historical flood event analysis. According to the analysis, it was selected 3 days, 4 days and 5 days as rainfall storm duration in the Gin Ganga basin.

iii). Storm Profile – Three storm profiles (‘***high intensity’***, ‘***moderate intensity***’ and ‘***low intensity’***) were developed from the two sub-daily rain gauges within and nearby Gin Ganga basin (Galle and Ratnapura). First, for each sub-daily rain gauges, it was derived a ‘high intensity’ and a ‘low intensity’ storm profiles for each examined storm duration selected under step ii) above. ‘high intensity’ profile, selection was made on the basis which the profile as relatively flat at the beginning, steep during the middle and flat at the end of the event, while the ‘low intensity’ profile has more gradual increase through the entire event without steep. Median of selected ‘high intensity’ profiles of each rain gauges taken as the basin-wide ‘**high intensity’** rainfall profile. Same procedure was applied for the basin-wide ‘***low intensity’*** profile selection and an average of the basin-wide ‘high intensity’ and ‘low intensity’ profiles was taken as the ‘***moderate intensity***’ rainfall profile. These three selected profiles were applied to the flood depths calculated in step i) above to get the design rainfall at each rain gauges. Selected basin-wide profiles are showing below (Figure 5).

iv). Areal Reduction Factor – ARF at key monitoring station (Agaliya) was calculated and applied to each rain gauge to ensure that design rainfall for a particular return period does not occur at the same time for all rainfall stations in a basin.

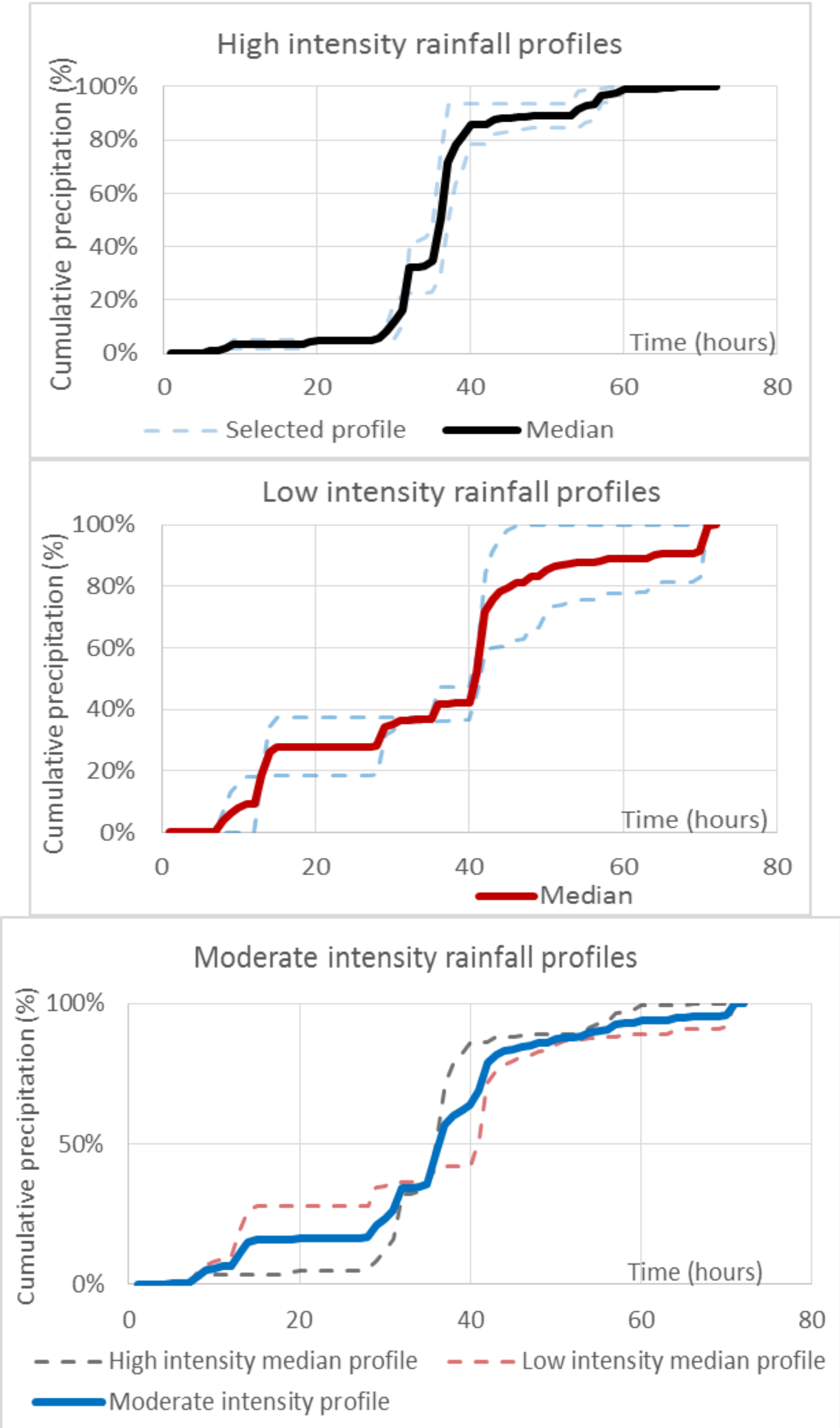


Figure 5 : Derived basin-wide 'high intensity', 'low intensity' & 'moderate intensity' Rainfall profiles in Gin Ganga basin

2.3.2 Application of Design Rainfall Package

Rainfall data developed under section 2.3.1 was applied to the validated flood model after creating a different rainfall packages combining the data. For example, 18 combinations for 25 years was prepared (2 distributions X 3 storm duration X 3 storm profiles). Total number of prepared rainfall packages are 90 for selected 5 return periods (5, 10, 25, 50 and 100 years).

2.3.3 Validation of Design Rainfall Package

Validation of the design rainfall packages are carried out under flood risk modelling task which is described below under Flood Risk Modelling.

2.4 Flood Risk Modelling

Validated flood model (TUFLOW) is used for the flood risk assessment for different return periods. Rainfall packages prepared under section 2.3.2 is applied for the validated model (18 models were run for one return period). It was selected a one rainfall package for a return period after plotting the model outputs (hydrograph) at the key monitoring station (Agaliya) for different model runs of each return period, considering the following criteria. (FDRAR-Gin, pp. 4-13 - 4-21)

- Statistical estimated peak flow at the key monitoring station for a return period was checked with the peak from model runs and selected some of the runs which is within the statistical estimated peak flow (with some uncertainty range for statistical peak flow +/- 15%)
- Then the historical flood hydrographs were scaled to the same statistically estimated peak flow at key monitoring station and from the selected model runs, it was checked the hydrograph shape with scaled historical event.
- Finally, one model run per return period which represent the good match to the statistical peak flow and the hydrograph shape was selected.
- For the selected hydrograph for the model run, the climatic factors were applied for the 6 scenarios (case 2-7 described above) of each return period (Figure 6).

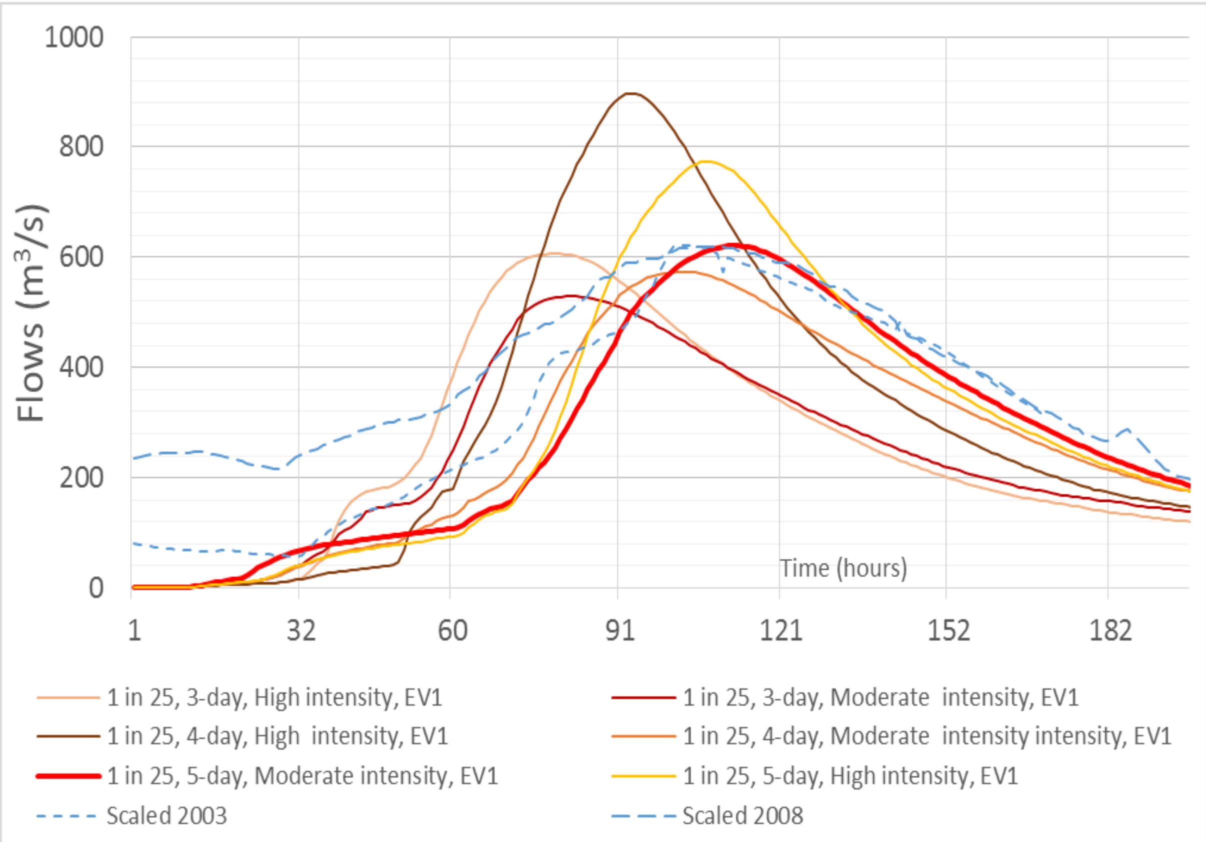


Figure 6 : Selection of Design Rainfall Package for 25 year return period

2.5 Flood Damage Assessment

TUFLOW is the hydraulic model that used for assessing the flood risk in the basin. Output results of TUFLOW model (flood depth & inundation area) for 7 cases of each return period, together with collected exposure data and developed depth-damage functions used for flood damage assessment. Flood damages were assessed for each case (case 1-7) and for each selected return period. Depth damage function used for Buildings is shown below (Figure 7). (FDRAR-Gin, pp. 4-23 - 4-28)

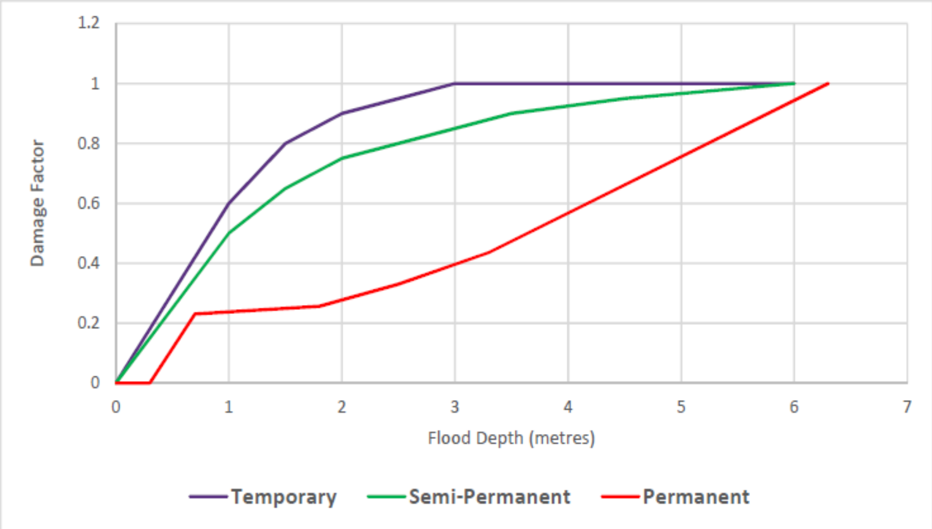


Figure 7 : Depth Damage Function for Buildings

2.6 Economics of Flood Risk

From the results of damage assessment, the Annual Average Damage (AAD) was calculated for each 7 cases. AAD represents the average damage due to flood in a particular basin which could be expected in any given year. (FDRAR-Gin, pp. 4-38 - 4-41)

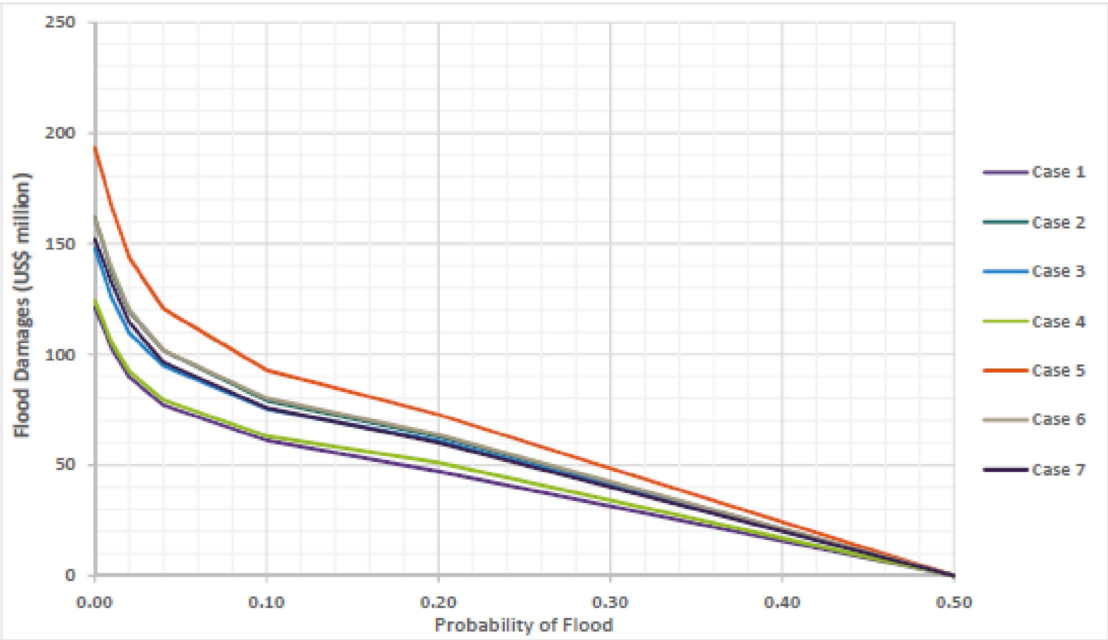


Figure 8 : Deriving of Annual Average Damage (AAD) for Gin Ganga Basin

2.7 Flood Hazard Mapping

Results of the flood damage assessment and the economics due to flood were mapped under various categories, such as: (FDRAR-Gin, pp. 4-28 - 4-37)

- Maximum Flood extends – for different return period for each of the seven cases
- Maximum Flood depths – for different return period for each of the seven cases
- Annual Average Population at risk at Grama Niladhari division wise – for case 1 and comparison for other cases with case 1
- Annual Average Damage - The AAD at a 1 km grid for Case 1 and AAD difference comparing Cases 2 through to 7against Case 1

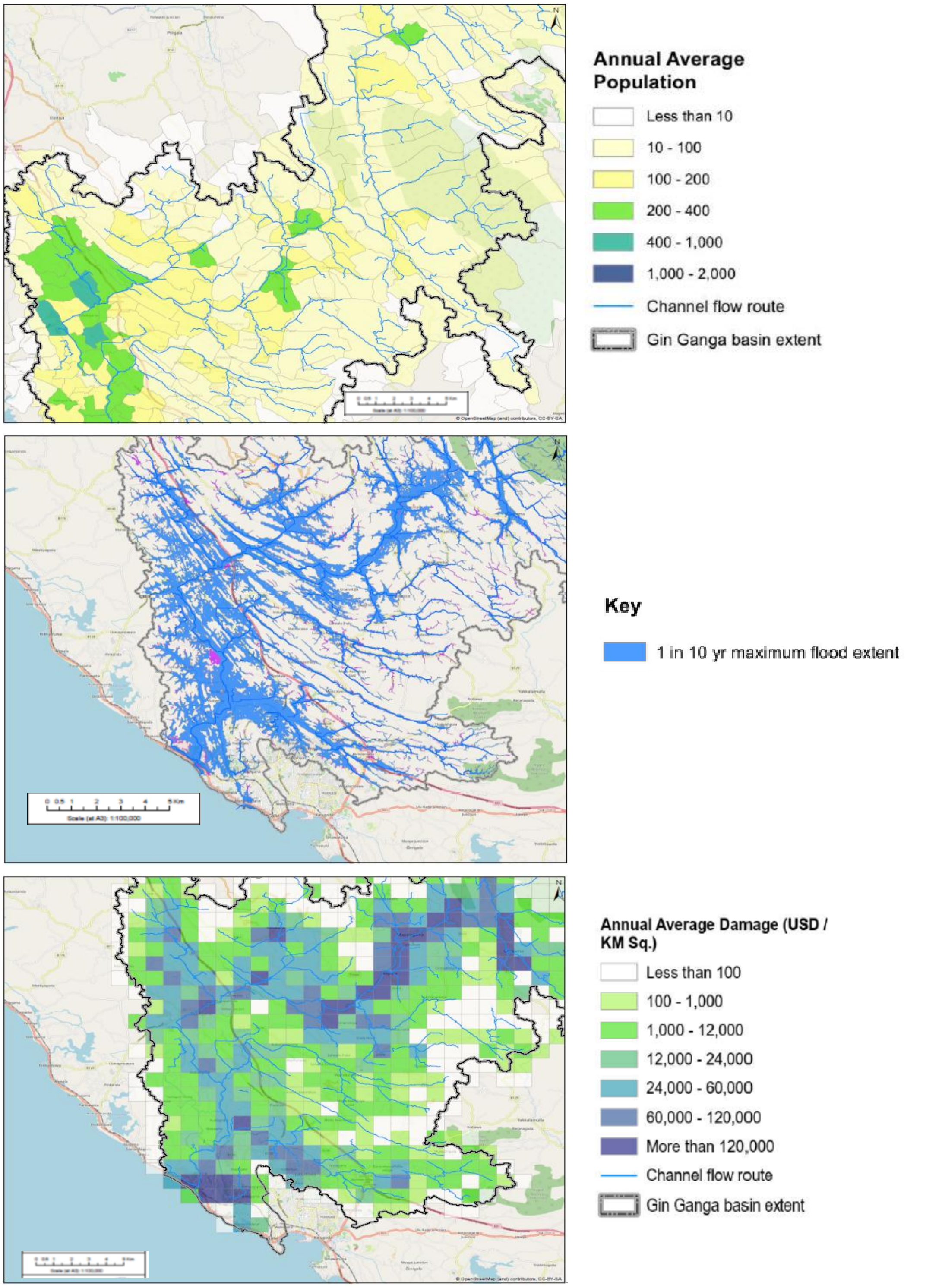


Figure 9 : Flood Hazard Maps (Annual Average Affected Population-Top left, Maximum flood extent for 1:10 year flood of Case 01 -Top right, AAD for Case 01-Bottom)

3 Results & Discussion

Results of the flood damage assessment of the Gin Ganga basin are shown in Table 1 and Figure 10 below. According to the figure, calculated Annual Average Damage (AAD) for the Gin Ganga Basin is in the order of $ 21M. The main cause for this damage is damage to the buildings (Case 1). This could be increased up to $ 27M because of climate change (Cases 2-4). This could further increase up to $ 32M due to the future basin developments.

Economic Asset	Average Annual Damage (USD million)						
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Roads	0.64	1.27	1.14	1.1	1.42	1.29	1.24
Railways /Embankment	0.03	0.05	0.04	0.04	0.05	0.04	0.03
Agriculture	2.53	2.9	2.65	2.57	2.43	2.23	2.16
Building Fabric	8.32	11.04	9.21	8.62	13.11	11.16	10.52
Building Contents : Residential	7.63	9.99	11.22	7.9	10.07	8.48	7.96
Building Contents : Other	1.2	1.61	1.35	1.24	3.8	3.42	3.26
Vehicles	0.0	0.01	0.0	0.0	0.71	0.6	0.57
Average Annual Damage	20.35	26.87	25.61	21.47	31.59	27.22	25.74

Table 2 : Average Annual Damages under alternative climate change and development scenarios

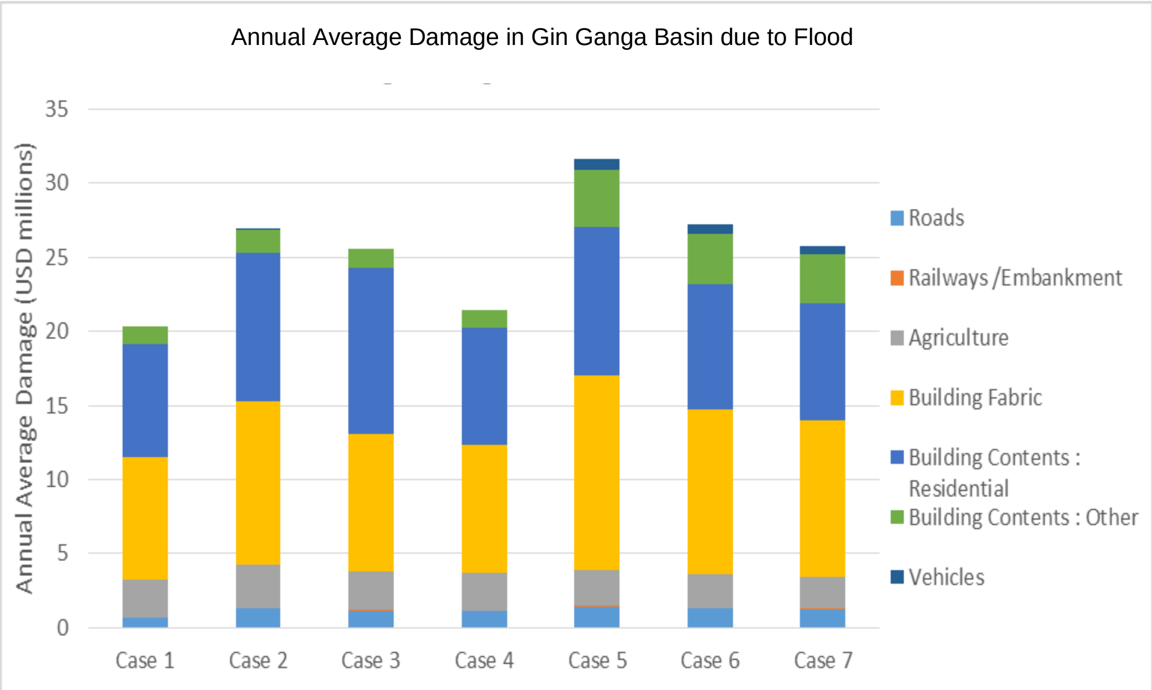


Figure 10 : Annual Average Damage in Gin Ganga Basin Due to Flood

4 Conclusions

According to the study, it shows that expected flood damage in the Gin Ganga basin will be increased annually due to the climate change. And this will be further increased due to the proposed / expected basin developments and increasing population.

In conclusion, the flood risk assessment indicates that improvement of the basin against the flood damage is required in the Gin Ganga basin to minimize the economic loss to the country due to the currently being experienced by floods in the basin. Accordingly, flood mitigation measures are to be found out to reduce the affected population and assets that are currently under flood risk to reduce economic losses.

5 Bibliography

WS ATkins International Ltd. (2018). *Computational Framework Report for Gin Ganga Basin, Volume 5.*

WS Atkins International Ltd. (2018). *Volume 1: Computational Framework Overview for Phase 1 Basins.*

WS Atkins International Ltd. (2019). *Flood and Drought Risk Assessment for the Gin Ganga Basin – Volume 1 – Final.*

Flood Impact Assessment of Salinity Barrage in Kelani Ganga using 1D-2D hydraulic model built by Flood Modeller and TUFLOW software

Flood Impact Assessment of Salinity Barrage in Kelani Ganga using 1D-2D hydraulic model built by Flood Modeller and TUFLOW software

K.K.G.I.L. Siriwardena[1], S. Widanapathirana[2] and P.A.A.P.K. Pannala[3]

[1] Project Engineer(Climate Resilience Improvement Project), Sri Lanka.
[2] Chief Engineer(Dam Safty), Irrigation Department, Sri Lanka.
[3] Director (Irrigation Special Project) / Deputy Project Director (CRIP-DBIP), Ministry of Agriculture, Rural Economic Affairs, Livestock Development, Irrigation And Fisheries & Aquatic Resources Development, Sri Lanka.

Abstract

Kelani Ganga is the main source of water supply to cater domestic and industrial requirement of Colombo and Gampaha Districts, Sri Lanka. The main water treatment plant located at Ambatale is currently supplying water to Colombo and its suburbs, with a capacity of 0.56 MCM/day. By 2040, with the expanding water requirement of the Port City in Colombo, the demand gap of Ambatale WTP will be increased up to about 15.2 m3/s (1.31 MCM/day).

Due to excessive sand mining, Kalani river bed has been considerably lowered changing river morphology since 1990s. As a result bank erosion also has taken place. The intake at Ambathale was frequently subjected to salinity intrusion during the dry periods. As a result, NWS&DB constructed a barrage across the river just downstream of the Ambathale intake to overcome this problem. With the introduction of this new barrage, the water levels to the upstream of barrage has been increased beyond the expectable levels during the recent floods.

After flood in 2016, a cross sectional survey was carried out to collect information on prevailing situation of the river and the hydro-dynamic 1D-2D Model study was conducted to assess the impact of the existing barrage on flood levels in Kelani Ganga. Also it helped to analyze the behavior of the river at the barrier, with the observed water levels. This paper describes the results of the model (the water level rise) for 2016 and 2017 flood events.

Key words: Salinity Barrier, Hydro-dynamic 1D-2D Model, Water level rise

1. Introduction

Kelani Ganga basin is the seventh largest river basin in Sri Lanka with a catchment area of 2,292 km^2. River itself is considered to begin on the slopes of the western rim of the Central Highlands at about 1,500 mAMSL. River annually carries about 4225 MCM of water to the sea at the sea outfall after passing about 145km.

While Kelani river basin is bounded to the north by Attanagalu Oya and Maha Oya basins, in the east it is bounded by Mahaweli Ganga basin and in the south, by the Kalu Ganga basin.
There is an abrupt change in the slope of the Kelani River around Hanwella which is 35 km upstream of the sea, as shown in Figure 2-2. Up to Hanwella river has only a mild slope.

This change in the slope of the river plays a large role from flooding perspective. While the higher slopes above Hanwella create a fast flowing river, its high energy hits the

downstream area creating flood conditions to the lower part which includes, notably, the northern part of Colombo. River gauging stations along Kelani ganga maintained by ID are shown in Figure 1.

River flow varies from 2.5 m3/sec in the dry season to 1,500 m3/sec during floods, or as much as 2,500 m3/sec during larger flood events (such as May, 2016 flood). (WS Atkins International Ltd, 2018) It is estimated that 65% of this flow discharges into the sea.

Being the main source of water supply for domestic and industrial needs of Colombo and its suburbs, around 80% of the greater Colombo area is supplied from Ambathale WTP. Salinity intrusion has become an ever increasing problem in the lower reach of the

Kelani Ganga and it has threatened the Ambathale water intakes several times in the past. The seriousness of the problem of salinity at Ambathale had been recognized for two decades and the problem has been aggravated due to lowering of the river bed due to excessive sand mining.

As the demand for sand has been increased in Greater Colombo area, sand mining was continued lowering the river bed, leading more salinity intrusion during the dry season.

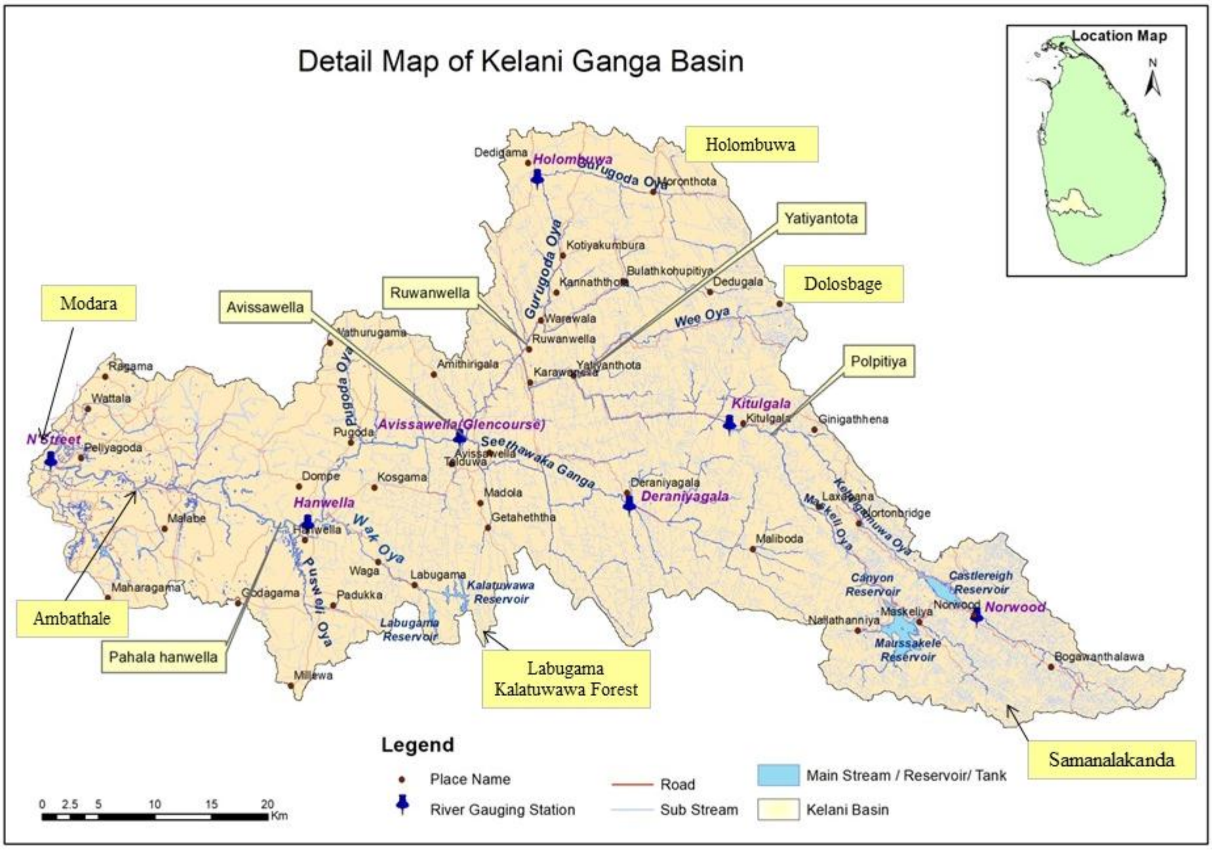


Figure 1 : Kelani River Basin

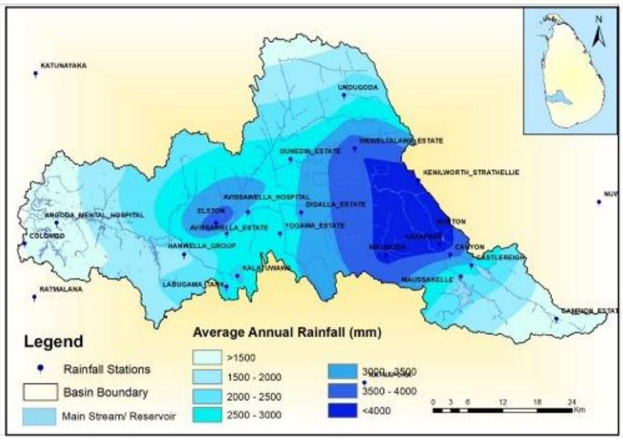


Figure 2 : Rainfall variation in Kelani River

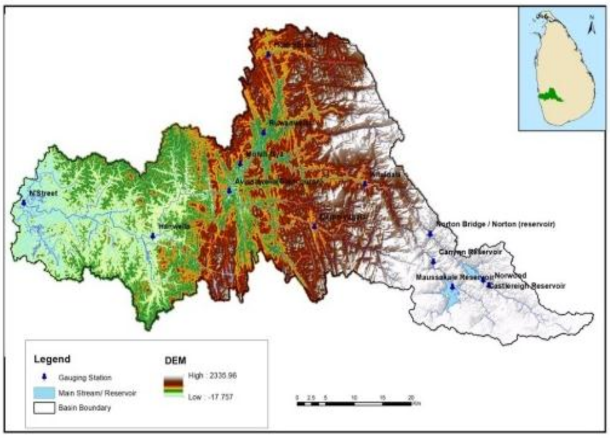


Figure 3 : Elevation variation in Kelani River

In the Kelani ganga, it was found that the saline wedge extends upstream around 15 km and it moves up and down around 4 km by flood and ebb tides (DHI 1993). The lengthening of the saline wedge during the low flow period has suspended water abstraction partially or fully at the Ambathale intake several times in the past.

Although providing a barrage across the river at Ambathale was the only immediate solution to prevent salinity, its impacts on flooding had to be assessed carefully as it may increase the flood levels in upstream.

However the construction of the barrage was completed in 2011/2012.

1D-2D linked Hydraulic model was built using Flood Modeller Pro and TUFLOW software packages to predict the river water levels using cross sections, which were surveyed after 2016 flood event to assess the impact of the salinity barrier to the floods in 2016 and 2017.

2. Materials and Methods

2.1 Floods in Kelani ganga and its impact

Recently, floods are become more frequent and occurred in every year. As a result people and properties in either sides of the lower reach of the river suffered by flash floods.

Kelani ganga has a long history of flooding. A river gauge has been placed in Nagalagam Street since 1837 and it has continuous operation up to now. According to the flood classification (Table 1), 3 critical floods have occurred since 1870s, while, there has been a flood of 'minor or higher' classification 27 times within 180 years for all flood events. During last 50 years, there were 3 dangerous, 3 major floods and 2 minor floods occurred, as shown in Table 2. Therefore, 2016 flood is considered as 'Major flood', while 2017 flood is considered as 'Minor flood'.

However, several limitations need to be considered when interpreting historical event data, including how and where the indicative ranking of events has been assessed. The impacts of infrastructure developments and other changes in the basin over the time, such as sand bar removal at sea mouth, sand mining, encroachments of the structures in floodplain and rapid urbanization have to be considered in the lower basin of Kelani ganga.

Table 1 : Flood Classification at Nagalagam Street (Source : Hydrology Division, ID)

No.	Flood Classification	Water Level at Nagalagam Street (ft amsl)
1	Minor Flood	> 5 ft.
2	Major Flood	> 7 ft.
3	Dangerous Flood	> 9 ft.
4	Critical Flood	> 12 ft.

It is observed that channel capacity is increased, as to the lowering the river bed due to sand mining.

Table 2 : Historic Floods at Nagalagam Street and their Classification for last 5 decades (Source : Hydrology Division, ID)

Year/Month	Water level (ft at msl) at Nagalagam Street	Flood Classification
1966 Sept	8.67	Major
1966 Oct	9.00	Dangerous
1967 Oct	9.17	Dangerous
1971 Sept	7.33	Major
1989 Jun	9.20	Dangerous
2011 May	5.41	Minor
2016 May	7.64	Major
2017 May	6.00	Minor

Figure 4 : Location Map of Salinity Barrier (Source : Google Earth)

2.2 Model Description

Flood Modeller Pro is a computer program that simulates the flow of water through river channels and across floodplains using a range of one- and two-dimensional hydraulic solvers, developed by Jacobs and is the successor to ISIS, which was in development for almost 40 years.

TUFLOW is an established 1D and 2D modelling software for simulating flood and tidal flow. Powerful solvers have been successfully applied to a wide range of applications for over 25 years. Jacobs is a distributor for TUFLOW and it is particularly suited for modelling flooding of rivers and creeks with complex flow patterns, overland and piped flows through urban areas, estuarine and coastal tide hydraulics as well as inundation from storm tides and tsunamis.

TUFLOW provides robust 1D and 2D solvers for simulating flood and tidal flow. The proven 2D solver uses an Alternating Direction Implicit (ADI) scheme to solve the full 2D free surface shallow water flow equations. It is particularly well suited towards establishing flow and inundation patterns in floodplains, coastal waters, rivers and urban areas.

The TUFLOW link is a dynamic link between Flood Modeller and TUFLOW, including its 1D component, ESTRY. It enables an integrated approach to modelling, combining open-channel, closed pipe and overland flow, suitable for modelling flood risk in urban areas, amongst other scenarios.

As a result of sand mining, the bed and banks were eroded making the river wider and deeper. It is evident that changes in river morphology taken place in last 25 years that could alter the flood levels and conveyance capacity of the river rapidly. The cross sections were used for the model, which was surveyed in 2016 (after the flood occurred) from Glencourse to Sea outfall to investigate the impact of the Salinity barrage at Ambathale for the flood events in 2016 and 2017.

2.3 Barrier Details for Sensitivity Analysis

Ambathale Salinity Barrier is located about 15m downstream to existing Ambathale intake. The main features of the structure are given in below. (Figure 5 and 6)

1) The main barrier of 75 m length with sill level at -0.5 mAMSL
2) Raft package of 15 m length with sill level at -2.0 mAMSL
3) Sedimentation excluding channel with sill level at -2.0 mAMSL
4) Barrier top level, when it is inflated is +1.0 mAMSL

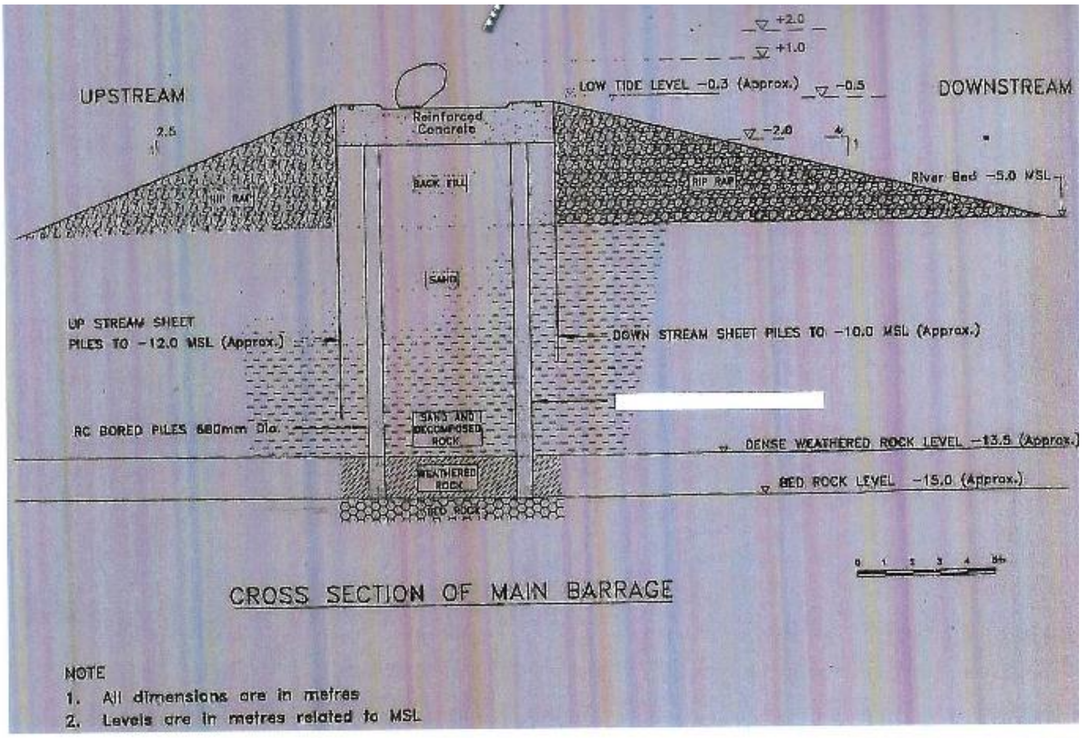


Figure 5 : Cross section of Main Barrage (Source : NWS&DB)

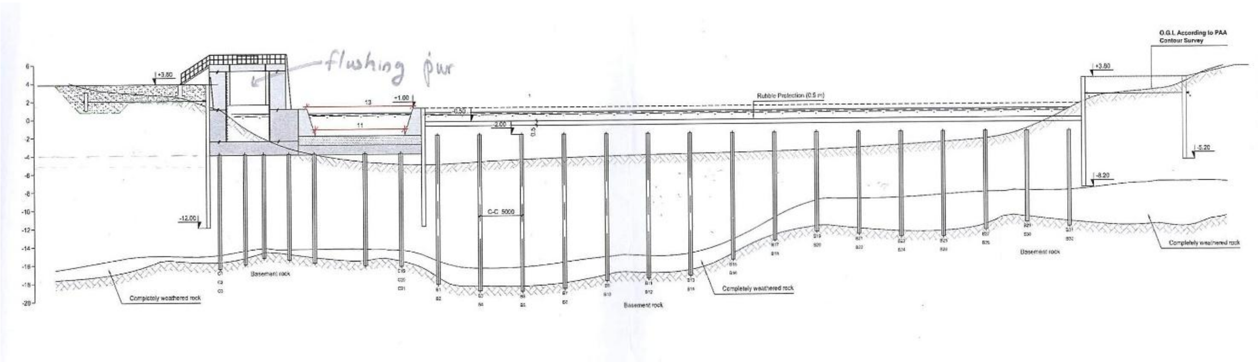


Figure 6 : Cross Section along the Salinity Barrier (Source : NWS&DB)

The head loss across the Salinity Barrier is estimated by head loss factors in Flood Modeller hydraulic model and this model was calibrated for 2016 and verified for 2017 flood events respectively for unsteady flows.

2.4 Data used for modelling

Rainfall data is used as hourly time step by considering the whole catchment from Glencourse gauging station (Figure 7) and roughness is used based on the land use of the basin and infiltration loss is calculated in 2D floodplain to TuFLOW model using Green Ampt equation based on the soil parameters. Surveyed Cross sections are used from Bathematic Survey, which was done by Navy and surveyed cross sections from DBIP-CRIP. Re-rated flow for Glencourse Gauging station and observed tidal data was given as upstream boundary condition, and downstream boundary condition to the model respectively.

The back water effect of the salinity barrier is analyzed for the respective events.

Steady Flows

Steady flows were used to ensure the initial conditions of the Flood Modeller hydrodynamic model.

3. Model Results and Discussion

3.1 Observed levels during 2016 and 2017 flood

Observed levels at the Ambathale Barrier for 2016 and 2017 flood event (Table 3).

3.2 Influence of the barrier

Model was run for 2016 and 2017 event and possible impacts on flood levels of the river was analyzed with and without the barrier and Comparison of water levels and flows are given in Table 4 and Table 5 respectively. Longitudinal profile of the 1D Hydraulic model using Flood Modeller software are given in Figure 8 and the head loss can be clearly showed in the figure, due to the Salinity Barrier during 2016 and 2017 flood events.

Mainly two flood events were considered for this analysis and 2016 and 2017 events were considered as flood of 20 year return period and about 4 year return period respectively with respective to Glencourse gauging station as GEV distribution.

Table 3 : Observed levels at the Ambathale Barrier for 2016 and 2017 flood event

Description	Observed Water levels (m AMSL)
Maximum water level for 2016 event with sand bags to the top level at 0.4 m AMSL	6.22
Maximum water level for 2017 event with sand bags to the top level at -0.2 m AMSL	5.55

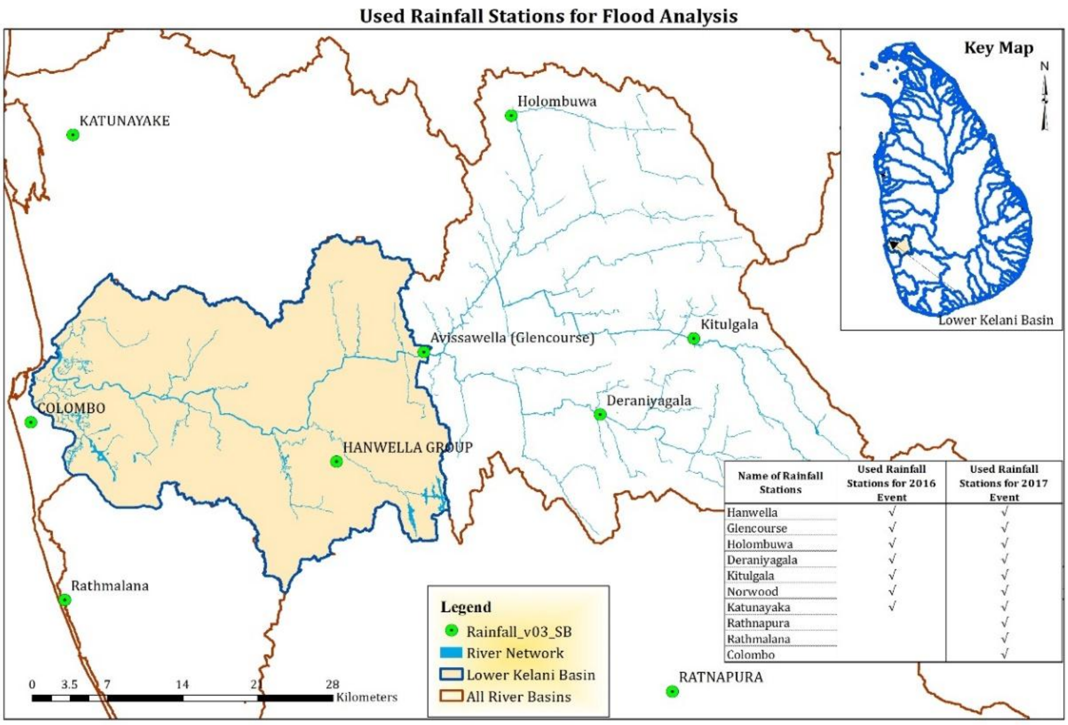


Figure 7 : Used Rainfall stations for the Flood Analysis of Lower Kelani Basin

Table 4 : Comparison of maximum water levels (m MSL) for 2016 and 2017 floods

Location	2016 Flood (m AMSL)		2017 Flood (m AMSL)	
	With Barrier	Without Barrier	With Barrier	Without Barrier
Hanwella	10.62	10.62	10.25	10.25
Kaduwela	8.35	8.3	7.97	7.93
Just upstream of Salinity Barrier	6.22	5.73	5.82	5.35
Nagalagam Street	2.33	2.33	1.89	1.89

Table 5 : Comparison of maximum flows (m MSL) for 2016 and 2017 floods

Location	2016 Flood (cumecs)		2017 Flood (cumecs)	
	With Barrier	Without Barrier	With Barrier	Without Barrier
Hanwella	2083	2087	1916	1914
Kaduwela	1812	1829	1721	1728
Just upstream of Salinity Barrier	1645	1900	1545	1670
Nagalagam Street	1936	1936	1636	1636

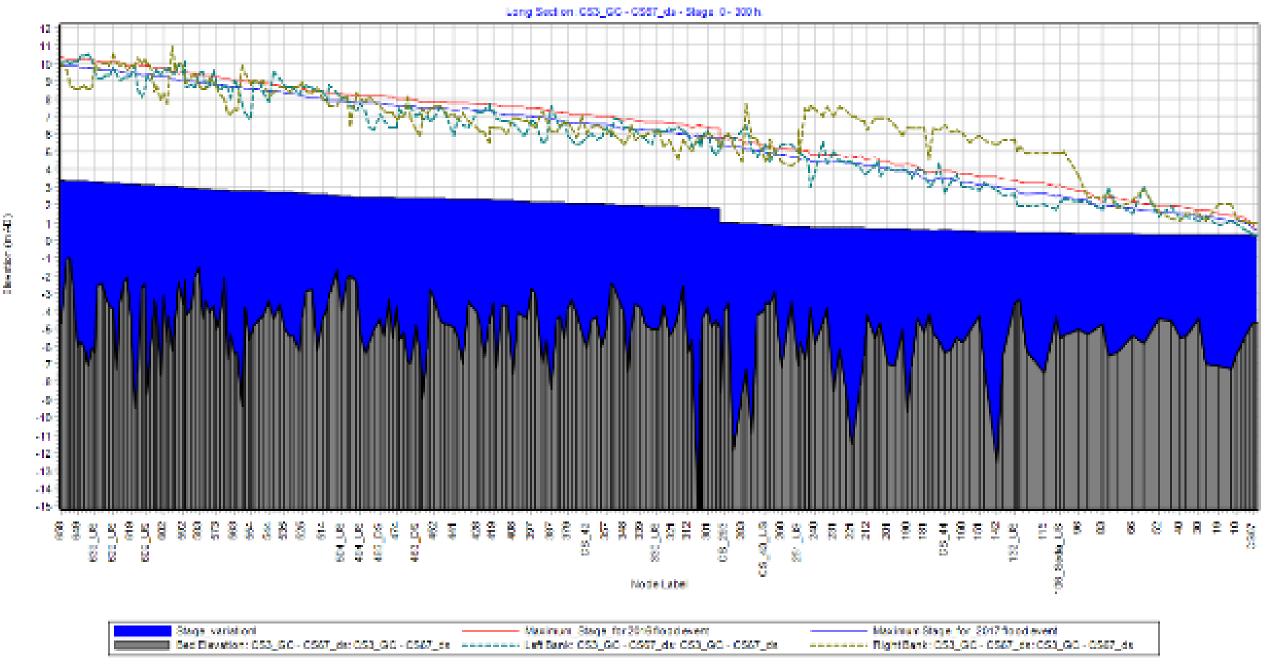


Figure 8 : Longitudinal profile for 2016 and 2017 flood events along Kelani River (Modelled Results of 1D-2D model built in Flood Modeller)

As 2016 event has overbank flow, the significant flood depth differences can be seen in 2D due to the Barrier (Figure 9), but 2017 event has not overbanked, hence it didn't show the significant water depth variations for 2017 event in 2D.

The backwater effect is affected about 10 km upstream from the barrier for 2016 event and it is about 4 km for 2017 event.

3.3 Sensitivity Analysis by increasing and decreasing the barrier different levels

Sensitivity analysis was done to compare the water level rise upstream for the same flow by changing the barrier levels by -1.0 m, -2.0 m, -3.0 m to minimize the back water effect for the respective event.

Table 6, 7 shows the water level rise immediately upstream to the barrier for different levels of the barrier.

Flood Depth differences in m for 2016 flood event with and without Barrier in 2D

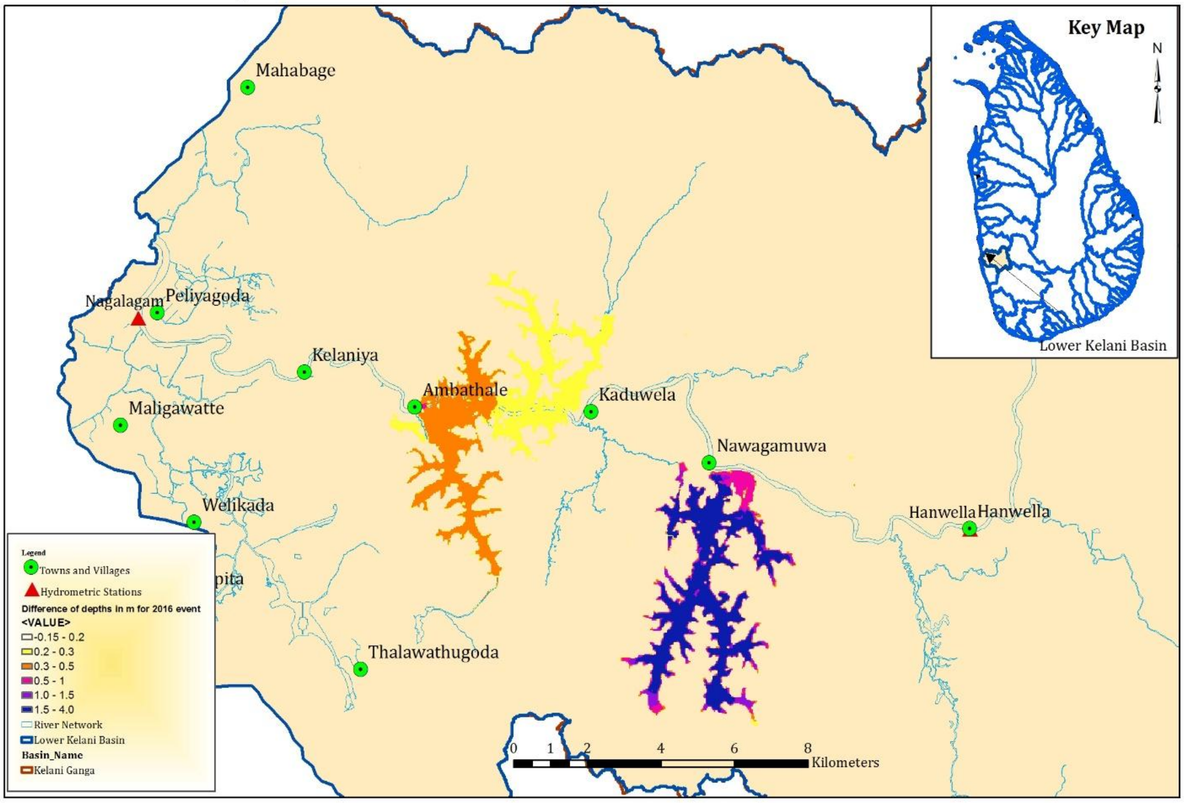


Figure 9 : Flood depth differences due to Salinity Barrier at Ambathale for 2016 flood event

Table 6 : Water level rise immediately upstream of the barrier for different levels of the barrier for 2016 flood event

Description	During 2016 event (0.4m AMSL)	Reduced the Spill level upto 0.0m AMSL	Reduced the Spill level upto -0.5m AMSL	Reduced the Spill level upto -1.5m AMSL	Reduced the Spill level upto -2.5m AMSL	Reduced the Spill level upto -3.5m AMSL
Maximum water level with Barrier	6.22	5.85	5.8	5.72	5.65	5.6
Maximum water level without Barrier	5.73	5.37	5.37	5.37	5.37	5.37
Level difference due to the Barrier	0.49	0.48	0.43	0.35	0.28	0.23

Table 7 : Water level rise immediately upstream of the barrier for different levels of the barrier for 2017 flood event

Description	During 2017 event (-0.2m AMSL)	Reduced the Spill level upto -0.5m AMSL	Reduced the Spill level upto -1.5m AMSL	Reduced the Spill level upto -2.5m AMSL	Reduced the Spill level upto -3.5m AMSL
Maximum water level with Barrier	5.82	5.79	5.67	5.63	5.45
Maximum water level without Barrier	5.36	5.35	5.35	5.35	5.35
Level difference due to the Barrier	0.46	0.44	0.32	0.28	0.10

4. Conclusion and Recommendations

This study concluded that there's an impact to flood due to the Barrier during recent floods. Though the barrier is the most feasible solution for the salinity intrusion, the alternative methods are to be studied to minimize the backwater effect of the upstream of Barrier.

It is concluded that the head loss and backwater effect is minimum at about -3.5 m AMSL, according to the model results. Hence it is recommended to move the water intake to the upstream or find the suitable alternative structural measures to minimize the impact to the public, as it acts as a barrier to the flow during the flooding.

5. References

1. https://en.wikipedia.org/wiki/Kelani_River

2. WS Atkins International Ltd, June 2018, 'Consultancy Services for Basin Investment Plans (DBIP) for Selected Basins, Volume 2: Computational Framework Specific to Kelani Ganga Basin' –Final Report prepared for CRIP.

3. Danish Hydraulic Institute in association with Lanka Hydraulic Institute, March 1992,'Kelani Ganga Flood Protection Study' – Final Report prepared for Irrigation Department

4. Danish Hydraulic Institute in association with Lanka Hydraulic Institute, Febuary 1993, 'Kelani Ganga Water Quality Study' – Final Report prepared for National Water Supply and Drainage Board.