MAHAWELI WATER SECURITY INVESTMENT PROGRAM

WATER BALANCE ASSESSMENT

JUNE 2015

ABBREVIATIONS

ADB	–	Asian Development Bank
CP	–	Concept Paper
ID	–	Irrigation Department
EIA	–	Environment impact assessment
ETo	–	Reference Evapotranspiration
GOSL	–	Government of Sri Lanka
IA	–	implementing agency
ISEWP	–	improving system efficiencies and water productivity
KMTC	–	Kalu Ganga-Moragahakanda Transfer Canal
MASL	–	Mahaweli Authority of Sri Lanka
MCB	–	Mahaweli Consultancy Bureau
MDP	–	Mahaweli Development Program
MRB	–	Mahaweli River Basin
MLBCR	–	Minipe Left Bank Canal Rehabilitation
MFF	–	multitranche financing facility
MMDE	–	Ministry of Mahaweli Development and Environment
NCPC	–	North Central Province Canal
NCPCP	–	North Central Province Canal Program
NWPC	–	North Western Province Canal
PDA	–	project design advance
PMDC	–	program management and design consultant
PPTA	–	project preparatory technical assistance
SIWRM	–	strengthening integrated water resources management
SLPI	–	Sri Lanka Prosperity Index
UEC	–	Upper Elahera Canal
WTP	–	willingness to pay

WEIGHTS AND MEASURES

ACE	–	annual per capita endowment
ha	–	Hectares
km	–	Kilometer
MCM	–	million cubic meters
mm	–	Millimeter
m^3	–	cubic meter
MW	–	Megawatt

CONTENTS

I. OVERVIEW

1. The Mahaweli Water Security Investment Program ("investment program") will contribute to the implementation of major water infrastructure under the Mahaweli Development Program (MDP) for the transfer of water from the water rich central 'wet' zone to the 'dry' zones in the North Central and North Western Provinces for agriculture and domestic water consumption. The investment program includes three projects: (i) the Upper Elahera Canal Project (UECP); (ii) the North Western Province Canal Project (NWPCP); and (iii) the Minipe Left Bank Canal Rehabilitation Project (MLBCRP) with an expected annual water supply of more than 700 MCM from the Mahaweli River to the target systems.[1] The investment program is the first of two phases that will permit the transfer of Mahaweli water northwards to the proposed North Central Province Canal Program (NCPCP). The investment program projects are also part of the larger MDP, with existing consumptive (agriculture and domestic) and non-consumptive (hydropower) water uses and planned further uses.

2. The reliability of water availability from the Mahaweli River Basin for the investment program is essential to assess under both current and future water demand conditions to determine supply reliability and impact of the projects on other existing and planned water uses within the MDP. It is also potentially sensitive to climate change impacts, particularly in terms of impacts on water demand due to predicted temperature increases and changes to rainfall patterns (refer to the Climate Change Vulnerability Assessment[2]). The results of this water balance assessment confirm that the water supply requirements for consumptive and non-consumptive uses are consistent with the planned climate-resilient development of the investment program.

3. This review is based principally on reports prepared by the Mahaweli Consultancy Bureau (MCB) for the Ministry of Mahaweli Development and Environment ("MMDE", formerly the Ministry of Irrigation and Water Resources Management or "MIWRM") on the water balance for the MDP, and results of the Water Balance Model Study[3] for the MDP and NCPCP, which is included herein for reference as Annex 3. The model is the key tool for the planning and management of the NCPCP.

4. This assessment is presented in the following sections:

- Mahaweli Development Program; presents an overview of the MDP and planning for the NCPCP
- Water Balance Model; presents a description of the Water Balance Model, input parameters, simulation scenarios and findings.
- Investment program assessment; presents the assessment of current and future water availability

[1] There are also locally generated (from local recharge) resources supplied to the systems.
[2] See Appendix 5 Climate Risk and Vulnerability Assessment of the PPTA Final Report and the RRP Supplementary Appendix 4 Project Climate Risk Assessment and Management Reporting.
[3] Appendix 1: Water Balance Study of NCP Canal Project, Final Report of Randenigala – Kalu Ganga Project. 2014 Mahaweli Consultancy Bureau for Ministry of Irrigation and Water Resources, Colombo

II. MAHAWELI DEVELOPMENT PROGRAM

5. This section presents an overview of the MDP, its background, current status and plans for completion with the implementation of the investment program as part of the overall NCPCP.

A. Project Background

6. The MDP was formulated by the United Nations Development Program (UNDP) and Sri Lankan experts in 1968 as a multi-purpose agriculture project for development of large-scale irrigation systems, development of hydropower production and other infrastructure facilities in the Mahaweli River Basin and adjacent five river basins in the NCP, Northern Province (NP) and Eastern Province (EP). The project implementation period was conceived to span 30 years.

7. The original scope included twelve distinct systems identified under the Mahaweli Master Plan (1968) for development in the NCP, NP and EP and the corresponding benefit areas are given in

8. Table 1. The plan foresaw the total development of 364,000 ha of which 254,000 ha was to be new area and the balance 110,000 ha supply to existing area. To support this development and the need for power production, the construction of 15 dams was planned of which 12 were to have hydropower plants with a combined installed capacity of 460 MW.

Table 1: Mahaweli Proposed Irrigable Areas

Mahaweli System	Planned Extent of Irrigable Area (ha)			Developed Area (ha)
	Existing	New	Total	
A	5,668	29,636	35,304	7,050
B	2,632	41,741	44,373	18,196
C	1,336	29,798	31,134	22,801
D1	20,729	11,417	32,146	26,520
D2	7,368	3,684	11,052	10,480
E	4,211	4,049	8,260	7,290
F	202	3,320	3,522	
G	1,943	2,510	4,453	5,025
H	16,478	23,036	39,514	32,023
I	21,134	35,547	56,681	4,907
J	2,874	19,919	22,793	
K	13,198	7,854	21,052	
L	8,057	30,972	39,029	19,995
M	4,453	10,081	14,534	4,210
Others*				2,632
Total	**110,283**	**253,564**	**363,847**	**161,129**

Source: MCB, 2014 (*) UW, Mapakada, Dambarawa, Sorabora

9. The existing Systems E and G, and the proposed System K, were to be fed from diversion canals, while all the other systems are fed from augmenting existing reservoirs and from proposed reservoirs.

10. However, the actual area currently developed and augmented from the Mahaweli River is about 161,000 hectares as discussed in the following sections.

B. Mahaweli Development Program Achievements

11. Harnessing the water resources in the Mahaweli River and adjoining basins required a series of regulating reservoirs and an intricate network of conveyance systems incorporating powerhouses to maximize the project benefits.

12. The government commenced project implementation in 1970 with construction of the Polgolla Diversion encompassing the barrage, tunnel, Ukuwela power house, followed by Bowatenna Reservoir across the Amban Ganga including a power house and Lenadora Tunnel to divert water to Kala Oya, part of Malwatu Oya, Yan Oya and Amban Ganga Basins, supplying Systems H, IH, MH, G and D, covering a total benefit area of about 83,000 ha.

13. As a consequence of other developments having taken place during the last three decades, some of the land originally identified for development had been reduced in the service areas of some systems, while the demands in others have increased. The land available for development in System A has reduced considerably due to the demarcation of major portions of it for forest and wildlife reserves.

14. In order to respond to increasing demands for the agriculture and power and to realize project benefits in a shorter period of 6 years, the government decided in 1977 to accelerate the implementation. It set targets of: (i) achieving self-sufficiency in rice by the mid-1980s; (ii) meeting the energy requirements for mid-1990s with hydropower in the Mahaweli cascade; and (iii) promoting employment generation to reduce poverty.

15. The Accelerated Mahaweli Development Program (AMDP) gave priority to: (i) construction of a series of reservoirs along the Mahaweli River comprising Kotmale, Victoria, Randenigala and Rantembe; (ii) completion of Systems H, IH and MH, including construction of Dambulu Oya Reservoir and enlarging Kalawewa Reservoir; (iii) improving irrigation infrastructure in Systems D and G; and (iv) completion of irrigation infrastructure in Systems B, C, and E, including construction of the new reservoirs Ulhitiya, Ratkinda, and Maduru Oya. By the mid-1990s when the AMDP concluded, the benefits achieved included 145,000 ha of irrigated land and the establishment of 660 MW of hydropower generation capacity, contributing substantially to the national gross domestic product.

16. Remaining works in the balance of the systems could not commence due to civil disturbances in the country, especially the northern and eastern provinces from 1983 to 2009. The total benefits realized from the agriculture sector is about 40% of those originally envisaged under MDP.

17. The total irrigated area is currently about 161,000 ha in 14 systems of which 6 are managed by the MASL with 62% of the irrigated area, and the balance of 8 are managed by the Irrigation Department (ID) (refer to

18. Table 2). The total installed hydropower capacity, with the addition of the Upper Kotmale hydropower project (HPP) of 150 MW, was increased to 810 MW as shown in Table 3. In addition, a further three power stations are under construction: Upper Uma Oya (150 MW), Morangakanda (25 MW), and Morogalla (27 MW) for a combined installed capacity of 202 MW.

Table 2: Mahaweli Scheme Summary

System	Area (ha)	Institution
A	7,050	ID
B	18,196	MASL
C	22,801	MASL
D	36,561	ID
E	7,290	ID
G	5,625	MASL
H	32,023	MASL
IH	4,907	ID
MH	4,210	ID

Source: MCB Water Balance Study Report, October 2013

Table 3: Planned and Installed Power Generation Capacities

Hydropower Station	Installed Capacity (MW)	
	Planned	Achieved
1. Ukuwela	34	38
2. Victoria	80	210
3. Kotmale	102	201
4. Randenigala	100	122
5. Rantebe	-	49
6. Bowatenna	11	40
7. Moragahakanda[1]	40	25
8. Upper Uma Oya[1]	25	150
9. Lower Uma Oya[2]	29	
10. Taldena	13	
11. Pallewela	10	
12. Haslaka Oya[2]	11	
13. Heen Ganga[2]	6	
14. Upper Kotmale		150
15. Moragolla[1]		27
Total	**461**	**810**

[1] Under construction
[2] Proposed under NCPCP Phase 2
Source: MIWRM, 2014

C. North Central Province Canal Program

The overall purpose of the NCPCP is to develop and implement the balance of the MDP, principally[4] for the completion of the water transfer to the Northern provinces for irrigation and drinking water supplies. A general overview of the NCPCP is presented below.

[4] There are also plans and projects for water transfer to the south from the Upper Uma Oya to the Karindi Oya, though the volumes and areas are relatively small by comparison with the NCPCP, the average annual volume is approximately 150 MCM.

1. Past Studies

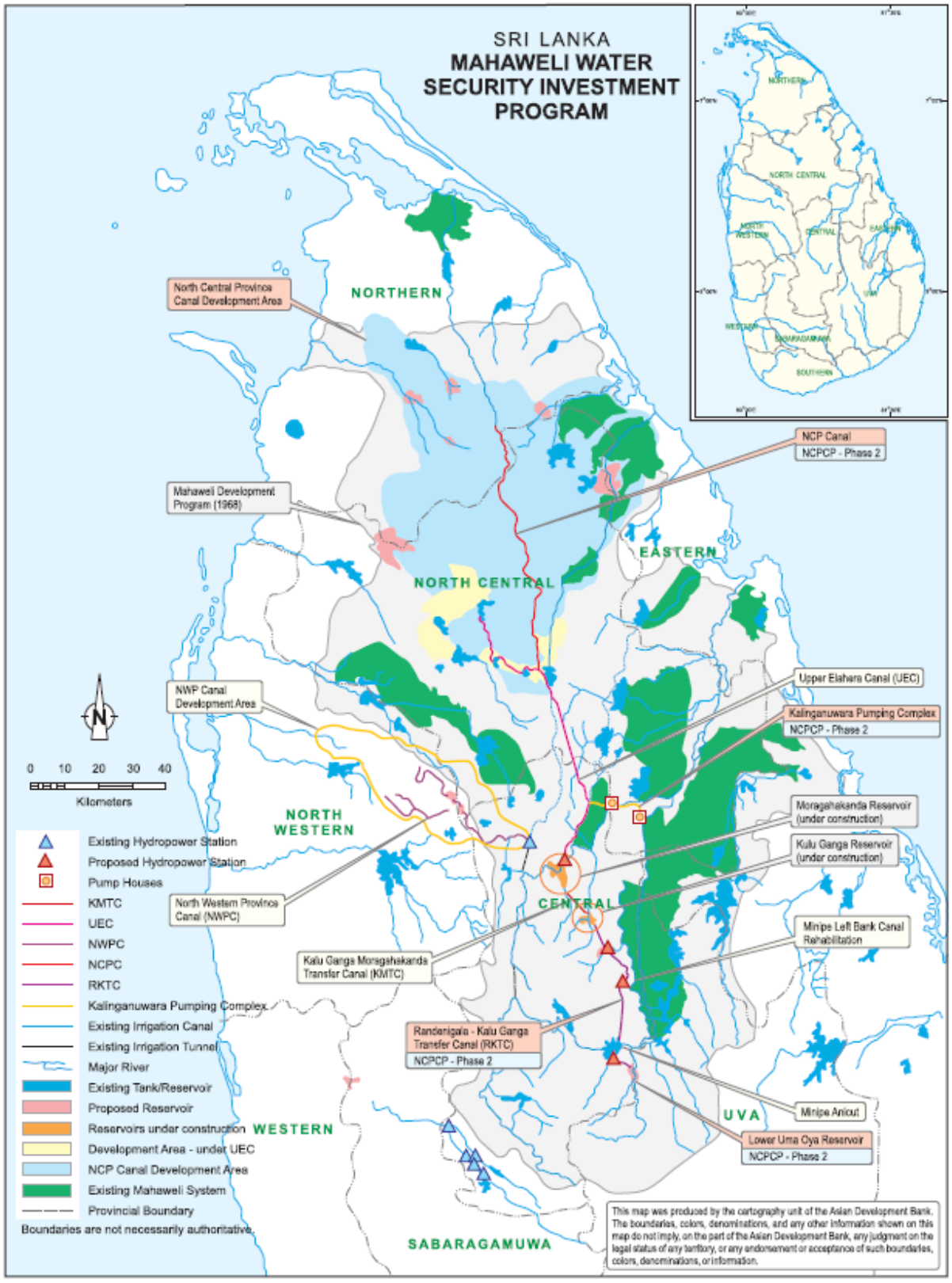
19. The original NCPCP encompassed the transfer of Mahaweli water to the NCP and NP, through a canal taking off from the Moragahakanda Reservoir built across Amban Ganga and augmented from the Bowatenna Reservoir. However, work was suspended in late 1970s due to limitations in financial resources. Subsequently, several consultants conducted studies towards the revival of the NCPCP and proposed alternative solutions, but they had not been considered for implementation due to financial constraints and the civil disturbances that prevailed from 1983 to 2009.

20. The previous studies reviewed the options with a focus on the optimum use of available water resources in the Mahaweli River Basin and the feasible transfer routes from Mahaweli to Amban Ganga basin for augmenting the NCPCP. These studies included:

- UNDP Master Plan Study (1968) proposed works included: works on the Minipe Anicut and Minipe LB Canal, the Angamedilla to Kaudulla and Kantalae Angamedilla pump stations and NCPC and NCP irrigation systems.
- ELECTROWATT – Trans-basin Diversion Study (1980) proposed works included: Minipe Anicut - Minipe LB new parallel canal - Hettipola Pump Station - Kalu Ganga - Elehera - NCPC - NCP Target Area.
- JICA Transbasin Study (1989) proposed works included: Minipe Anicut - Minipe LB New Parallel Canal - Minneriya Tank - Minneriya Pump Station - NCPC - NCP Target Area.

21. Consequently to the above studies a contract for the construction of Moragahakanda Reservoir was awarded in the second quarter of 2012 and presently the work is in progress. The construction of irrigation infrastructure facilities at the Kalu Ganga Reservoir is in progress and the contract for construction of headworks has been scheduled to commence in mid-2014.

Figure 1: General Layout of the NCPCP



2. NCPCP Pre-feasibility Study

22. Under the government policy framework of the "Public Investment Strategy"[5] the NCPCP is a high priority project to be undertaken for development. The NCPCP had been conceived to cater for the increasing water demands in the dry zone areas and to address the urgent need for socio-economic development in the rural sector. In the post-civil disturbance era, the government has given high priority for development of balance water resources of Mahaweli for domestic and agriculture consumption in the NCP, NP, EP and NWP, and identified the development of the NCPCP encompassing Upper Mi Oya and Hakwatuna Oya Basins as the best options to resolve multiple complex socio-economic issues in the above provinces.

23. In 2010, the Secretary of MMDE entrusted the pre-feasibility study of the NCPCP to the Mahaweli Consultancy Bureau (Pvt) Ltd (MCB).[6] The main objective of the study was to assess the availability of water resources in the Mahaweli Basin, Amban Ganga Basin and in the target project areas. And to propose the best diversion routes to optimize diversion quantities for the development of areas in the NWP (Upper Mi Oya Basin), NCP and NP with minimum impacts on the existing systems and environment in conformity with the Public Investment Strategy.

24. The NCPCP Pre-feasibility Study[7] identified the need for further studies to develop seven major irrigation infrastructure facilities listed below as sub-projects to facilitate phased development:

(i) Modification to the configuration of Moragahakanda and Kalu Ganga Reservoirs to accommodate the NCPCP
(ii) Diversion of Mahaweli water through the Randenigala – Kalu Ganga transfer canal including supplementary inflows from Lower Uma Oya, Hasalaka Oya and Heen Ganga Reservoirs
(iii) Development of irrigation infrastructure facilities in System B - Maduru Oya RB
(iv) Heightening of the Minipe Anicut and rehabilitation of the Minipe LB Canal
(v) Provision of water for development of NWP area
(vi) Provision of water to revive the Kantale sugar industry
(vii) Pumping Mahaweli water at Kalinganuwara on the lower Mahaweli Ganga.

25. The study proposed staged implementation of the NCPCP with due consideration to the magnitude of the infrastructure development involved, socio-economic constraints, required investments, and achieving benefits during project implementation. Table 4 provides a summary of the proposed stages and the timeframes for sequential implementation of the development program.

[5] Government of Sri Lanka, Ministry of Finance and Planning. 2013. *Public Investment Strategy, 2014–2016*. Colombo.
[6] Through a contract signed (Contract No TS/NCP/P-FS/88 December 2010) between MCB and the Mahaweli Authority of Sri Lanka (MASL)
[7] MCB. 2012. *Pre-feasibility Study for the Implementation of North Central Province (NCP) Canal*. Colombo.

Table 4: Study Development Stages[8]

Timeframe	Stage No.	Proposed Development
2014 – 2017	Stage I	• Kalu Ganga – Moragahakanda Transfer Canal • Upper Elahera Canal • Lower Uma Oya Hydro Power Project • 9,000 ha in NWP • 10,500 ha in NCP • 5,120 ha in Kantale • Heen Ganga hydro power project
2018 – 2022	Stage II	• Hasalaka Oya hydro power project • Angamedilla Pump Station • 24,500 ha in NCP
2023 – 2027	Stage III	• Randenigala - Kalu Ganga Diversion Canal • Kalinganuwara Pump station • 18,000 ha in NCP • 2,000 ha NWP • 1,456 ha Kantale

Source: MIWRM, 2014

3. Randenigala – Kalu Ganga Diversion Study

26. In 2012 MMDE assigned the finalization of the water balance study for the NCPCP and project layout for the Randenigala- Kalu Ganga transfer route to the MCB.[9]

27. Having considered the ongoing work, magnitude, complexity and time allocation for the project, the MCB submitted to the MMDE a revised work program with detailed clarifications and an amended scope of work.[10] The MMDE concurred the amended scope of work and the extension of the period of the assignment as given below (along with current status of relevant elements):

- Finalize the Water Balance Study; finalized and published in October 2013.
- Conduct a geophysical survey along the transfer route and dam sites; on-going and partially completed as part of the detailed design for the NCPCP.
- Submit water quality reports at the following locations: Kalinganuwara and Minipe Anicut in the Mahaweli River Basin, and Parakramasamudra, Minneriya Tank and Angamedilla Anicut in Amban Ganga Basin; completed.
- Prepare a report on sediment management of the Lower Uma Oya, Randenigala, Rantambe, and Minipe Complex; completed.
- Conduct a socio-economic and inundation surveys for the project components; completed for Kalu Ganga and Moragahakanda reservoirs.
- Prepare and submit required documents to the client for initiating EIA and archeological impact assessments.
- Update the recommendations given in the NCPCP Pre-feasibility Study and establish an optimum layout for the configuration for the Randenigala – Kalu Ganga Transfer Canal route and associated hydropower reservoirs.
- Update the financial and economic analysis conducted for Pre-feasibility Study of the NCPCP.

[8] It should be noted that the definition of stages and phases discussed in the Pre-feasibility study differs from that subsequently adopted for the proposed ADB funded project which is presented as two phases.
[9] By the letter 02/02/87/RKTC, dated 26 December 2012
[10] By the letter MCB/ENG/FS/Randenigala/93, dated 15 November 2012

- Prepare TORs to undertake detail designs relevant to project components for feasibility stage designs.

28. This recent study for the Randenigala – Kalu Ganga Transfer Canal Project represents the most recent and comprehensive updating of the NCPCP, particularly in terms of the projects proposed for Phase 2 (refer to Annex 3).

III. WATER BALANCE ASSESSMENT

A. 2013 Water Balance Study

29. The study approach and results[11] are presented in the Water Balance Study Report of October 2013.[12] The purpose of the study was to assess water availability within the Mahaweli River Basin, including the Amban Ganga, and to formulate an agricultural development plan for the adjacent water scare areas in the northern and eastern provinces.

30. The investment program forms part of the NCPCP and its projects are covered in the Water Balance Study as listed in

31. Table 5. The 2013 study included an assessment of estimated water demands for all command areas (current and future) and water availability in the system to reliably meet this demand. Therefore, the study findings provide the basis for assessment of project water availability and impact on future planned development in the Mahaweli scheme.

32. The 2013 study utilized the Mahaweli Water Balance Model to evaluate a number of scenarios for incrementally expanding scheme development over a number of stages. The Mahaweli scheme is a complex system with multiple water sources, storage sites and transfer routes for water supply. In terms of water demand there are a large number of command areas with varying levels of internally-generated water resources. The numerical model was used to optimise supply and demand scenarios, within a set of operating rules for hydropower generation, and irrigation and drinking water supply allocation rules.

33. The overall MDP development envisioned an expansion in irrigated area from about 146,000 to 230,000 ha, an increase in cropping intensity from about 140% to 180%,[13] and diversification to cash crops (from paddy) in the Yala season in major and minor tanks.

34. As presented in the previous section, the initial proposal for the full development of the MDP included additional reservoirs, hydropower stations, transfer canals, as well as pumping stations at Kalinga Nuwara and Angamedilla on the Mahaweli and Amban Ganga, respectively. The proposed development plan was for implementation in three stages with; Stage 1 (2018-2022), Stage 2 (2023-2027) and Stage 3 (2028-2032); however, this has now been superseded by the planned two-phase approach as discussed in Section IV.

[11] The model was subsequently applied for assessment of water availability for the proposed ADB funded projects.
[12] MCB. 2013. *Water Balance Study Report*. Contract No. MIWRM/AGR/Consult/2011/22. Colombo.
[13] However cropping intensities vary between individual systems.

B. 2013 Water Balance Models

35. The water balance model Acres Reservoir Simulation Program (ARSP) was developed by the Canadian consulting firm Acres International in the 1980s as part of the original scheme development and is commonly referred to as the 'Acres model.' It is a custom-built mass balance mathematical model for simulating the scheme's operation over a 40 year timeframe (1971-2010), which integrates reservoir operations, hydropower generation and water issues for optimisation of water management.

36. The irrigation demand series for the irrigation systems included in NCPCP have been computed using Acres' Irrigation Demand Model (AIDM) for the cropping patterns selected; the irrigation demand time series computed are an input to ARSP. The paddy-paddy cropping pattern has generally been used in computing the irrigation demand series, as the basis for determining infrastructure design duties, but with the understanding that this is the likely upper limit of demand and with crop diversification water demand will be lower. The feasibility studies prepared by the MCB assumed a gradual increase in other field crops once irrigation water supplies were more secure. For example, a likely cropping pattern for such a future scenario would be bananas 20%, green gram 22%, groundnut, and chillies 17% each, and vegetable and onions 12% each in 20% of the irrigated lands in Yala[14] crop under major to medium reservoirs,[15] and that of 80% under minor reservoirs.

37. The Water Management Secretariat (WMS) of the MASL utilizes the model for planning and management of the scheme including in the preparation of Seasonal Operational Plans (SOPs) and in day-to-day management of reservoirs and water issues (allocations) for hydropower and irrigation. It was utilized by the MCB for the 2013 Water Balance Study, and the present assessment of the investment program, to evaluate various development options, corresponding water supply and demand issues, and to test development scenarios, according to operational rules and supply reliability constraints as outlined in the following sections.

1. Methodology

38. The purpose of the modelling is to optimise water distribution within the Mahaweli Scheme, both for in basin and transfer basins, for hydropower production and for irrigation and drinking water supplies. The optimisation objectives are to sustain hydropower generation at predetermined levels, based on long-term production levels, reliably meet prescribed drinking water supply levels, and to maximise the irrigable area within supply reliability criteria.

39. The approach is based on a volumetric water balance between water demand, for both consumptive and non-consumptive uses, and water supply, both from the Mahaweli River Basin and within the irrigation command areas (tank cascades). The modelled period is based on climatic and hydrological information for the 40 year period 1970 to 2010. The analysis is based on monthly values over this period, with a results matrix of 12 by 40.

40. Irrigation demand is calculated for each cascade system within the scheme's present and planned system areas based on crop water requirements, both pre-season and during the

[14] In Sri Lanka there are two principal cultivation seasons; Yala from May to September and Maha from December to February which coincide with the South West and North East Monsoons, respectively.

[15] Reservoir systems are referred to as cascade irrigation systems, with either major, medium and or minor reservoirs (referred to as tanks). The cascade refers to the hydraulic inter-linkage of a sequence of tanks and irrigation command areas, which in effect recycle water within the system from tank to farm to tank down the system in essence forming a hydraulic cascade.

season, system efficiency, and effective rainfall. Drinking water supplies were calculated for a number of communities within the extended scheme area based on current and projected demands to 2030. Hydropower requirements are based on the minimum impact on current production levels, which are on average 1,874 GWh per annum, and taking into consideration the planned change in operation mode from base to peak production.

41. For the purpose of analysis the Scheme is organised hydraulically with key features assigned as input and output parameters. The key hydraulic features are: river and canal reaches with inflow and outflow nodes, storage reservoirs with inflows and outflows (releases and spills), power plant points, irrigation demand points and pumping stations.

2. Inputs

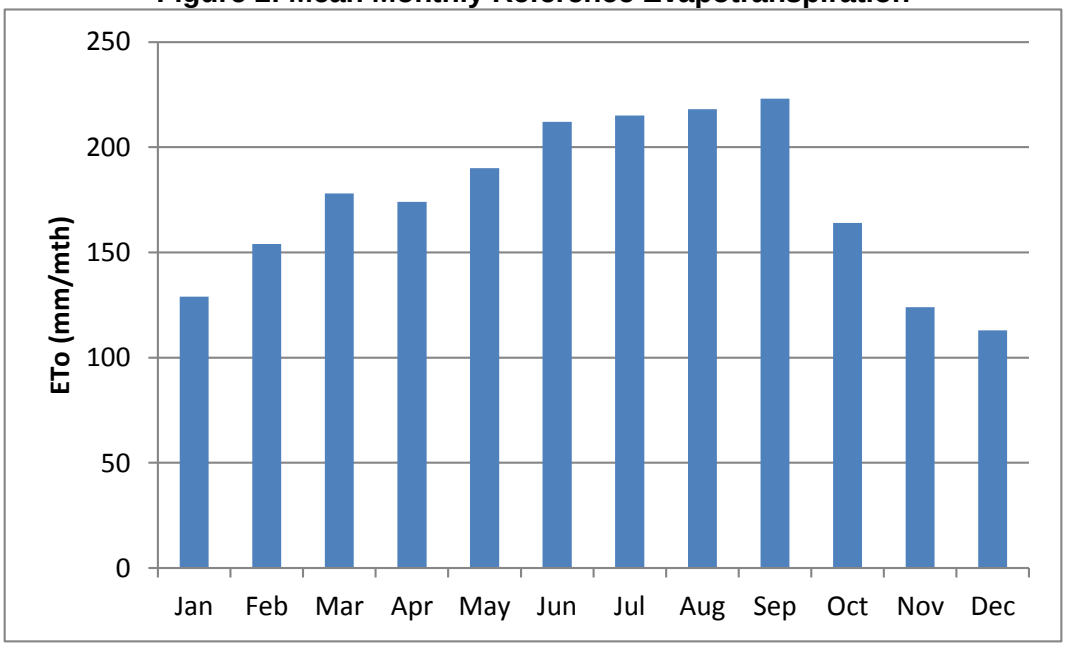
42. The inputs parameters include those for determination of irrigation water demand and water supply from river flows and storage reservoirs.

43. The irrigation water demand parameters are:

- Reference evapotranspiration (ETo): mean monthly value over the model period for two stations representative of the system areas (both located within the dry zone). Average annual ETo is 2,094 mm, with a peak during the Yala season of about 215 mm per month and low of about 110 mm per month during the Maha season (refer to
- Figure 2).
- Crop information: crop type (paddy (for both short and long-term varieties rotation), sugarcane, chillies, soya beans/cow pea and field crops), stages and coefficients.
- Rainfall: monthly rainfall over the model period from more than 100 stations.
- Pre-season irrigation: for paddy the pre-season irrigation depth is 100 mm
- Irrigation efficiency: the irrigation efficiency was determined as the cascade system efficiency, which is the overall efficiency from the point of issue to the last point with the system and is inclusive of recycling within the system. For existing systems this was determined from previous season records of water issues. Efficiency values differ between the two growing seasons, Maha and Yala, due to differences in cropping intensity (efficiency increases with intensity due to greater recycling) and effective rainfall. Figure 3 shows the average seasonal efficiency for the Mahaweli systems, which vary widely between systems from less than 40% to 90%.[16]

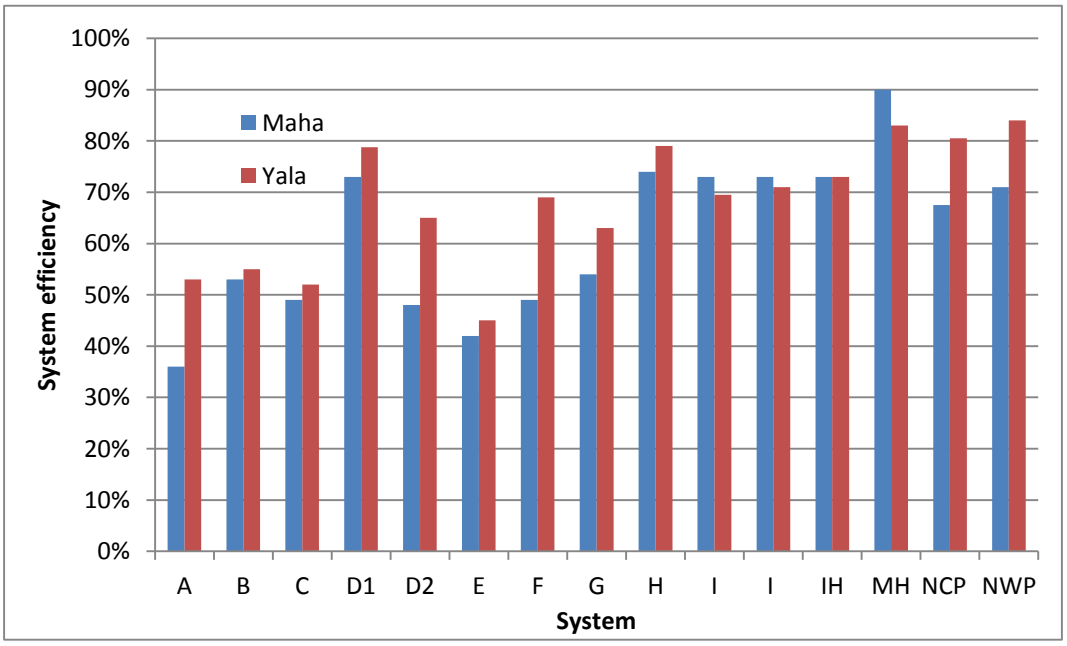
[16] The irrigation efficiencies for the NWP are 71% and 84% for Maha and Yala seasons, respectively, Irrigation efficiencies are predicted to increase as a result of the investment program, by 5% in Maha and 10% in Yala season, as per Cases B and C in the Water Balance Study Table 3.5.

Figure 2: Mean Monthly Reference Evapotranspiration



Source: MCB, 2014

Figure 3: System Irrigation Efficiencies



Source: MCB, 2014

44. Water availability from the Mahaweli River Basin (inclusive the Amban Ganga) is based on historical flow records over the model period as measured at a number of gauging stations and from dam reservoir records.

3. Optimization Criteria

45. As mentioned above the objective was to optimize options for the development of the balance of the available water resources within the Mahaweli River Basin. This was achieved within three development stages and supply criteria.

46. To cater for changes in irrigation efficiency and crops, the water balance study adopted three 'cases' (A to C) over the three development stages (2012-17, 2018-22 and 2023-32, respectively). The cases assume that water demand per unit area will decline over time due to improved system efficiencies (due to improved; conveyance efficiency, field application efficiencies and irrigation management) and lower crop water demand due to changes in paddy and crop varieties, and planting times (in the case of paddy resulting in shorter duration crops and hence lower water demand). The study also acknowledged that total water demand could also be reduced with diversifying to field crops with lower water demands than paddy. The three cases were:

- Case A; is the 'present case' (without project) that is, current irrigation efficiencies and cropping patterns including ratio of long-term, medium-term and short-term[17] paddy (ratio of 1/3 long-term to 2/3 medium-term in Maha season and ratio of 2/3 medium-term to 1/3 short term in Yala season).
- Case B; improved irrigation efficiencies (with increases of 5% and 10% in the Maha and Yala seasons respectively) and bringing forward planting dates due to improved water supply reliability.[18] (This is the "with- project" alternative.)
- Case C; in addition to (above) improved irrigation efficiency, the ratio of paddy varieties are changed to further reduce water demand (ratio of 1/3 short-term to 2/3 medium-term in Maha season and ratio of 1/3 medium-term to 2/3 short term in Yala season).

47. **Supply Reliability.** In the preparation of the Seasonal Operational Plans (SOP) for the Maha and Yala seasons, the WMS uses a Reliability Criterion in assessing the irrigation deficits of individual systems in the simulated system performance. The water balance study adopted the same three criterion, which are:

- *Irrigation failure* occurs when the supply deficit exceeds 5% of Yala seasonal demand. It should not exceed 20% occurrence (over the modelled period).
- *Significant failure* occurs when the supply deficit exceeds 10% of Yala seasonal demand. It should not exceed 10% occurrence (over the modelled period).
- *Total failure* occurs when the supply deficit exceeds 20% of Yala seasonal demand. It should not exceed 5% occurrence (over the modelled period).

48. An *irrigation failure* is assumed to be effectively managed by 'tightening up' on water deliveries with no significant losses. While managing *significant and total failures* requires water supply restrictions and restricting serviced areas, and would adversely impact on overall agricultural production.

49. The reliability criteria are in essence multiple supply criteria, with the respective levels being at the 95, 90 and 80 percentile levels respectively. Typically, irrigation schemes are designed for supply reliabilities of greater than 80%, so the criteria are within accepted design and economic norms.

[17] Short, medium and long terms are crops of 90, 105 and 135 days duration respectively.
[18] In Maha season shifting start of planting from 01 Nov to 15 Oct, and in Yala season from 15 May to 01 May.

50. **Rationing rules.** The model analysis is based on the existing allocation rules under rationing conditions (low flow periods) between system based on priority uses, with the ancient riparian systems on the Mahaweli and Amban Ganga assigned highest priority (Systems E, C, D1 and D2), and the newer systems assigned lower priority. Within this rule the full scheme (all systems and cascades) has to meet the above supply reliability levels. The results are presented in **Annex 1**, for the two relevant modelled scenarios:

(i) **A2A** equivalent to Phase 1 of the NCPCP
(ii) **A10A** equivalent to Phase 2 (as described in this report)

51. **Rule curves.** The scheme reservoirs and irrigation tanks are operated according to pre-defined rule curves for monthly water levels, anticipated rainfall, and storage volumes which were adopted in the water balance study. As mentioned above, maintenance of current hydropower generation was one of the optimization conditions.[19]

4. Outputs

52. The model results formed the basis of the determination of water availability for development of the NCPCP including for the proposed increases in cropping intensities and irrigated areas. The results are presented for the series of development scenarios (12)[20] and development stages (3).[21] The outputs include withdrawals and spill volumes for key diversion points, all irrigation systems, and energy generation for hydropower stations.

53. The results helped provide a basis for the selection the investment program projects based on logical water management and financial constraints, referred to below as Phase 1 and subsequent developments in Phase 2. As indicated below, at full development the irrigated area both fully and partially supplied from the Mahaweli Scheme will be in the order of 233,000 ha with an average cropping intensity of 1.9 and annual diversion of 4,300 MCM (up from 3,200 MCM).

54. The modelling approach is based on maintaining current hydropower production levels and supply reliability to existing systems and proposed extensions to the north (NCP and NWP) and east (System B Right Bank). The approach provides a sound quantitative analysis of water demand and supply to determine the reliably allocable water resources for multipurpose use (hydropower, irrigation and drinking water supply) to support full scheme development. From the review of the Water Balance Study and Water Model, the approach appears to be well founded on existing water availability and demand, and robust in terms of determining water availability for future development, for not only the proposed investment program but also for other proposed developments including the NCP, System B Right Bank, System D1 Kantale and increased cropping intensities within existing systems, as well as drinking water supplies.

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[19] One of the principal objectives, (for the model) is to maintain or at least minimize impacts of the NCPC allocation on annual power generation. Whether the power production is peaking or base, does not significantly impact on the model (which is based on month time steps).

[20] The 12 scenarios include the base case (scenario A1A), Stage 1 scenarios (A2A to A5A), Stage II scenario (A6A) and Stage III scenarios (A7A to A11A and A14A). The scenarios are based on the progressive development of water infrastructure, and improvements in irrigation efficiency and changes in crops (Cases A to C). The results for the scenarios are presented in Table 4-1 of the Water Balance Study (Simulations) of the Appendix 1: Water Balance Study of NCP Canal Project (October 2013).

[21] The Water Balance model assumed three development stages based on progressive of water storage and transfer infrastructure with; Stage 1 including construction of KMTC and UEC, Stage II including construction of the Hasalaka and Heen Ganga stretch of the Randenigala Kalu Ganga Transfer Canal (RKTC) and diversion of Hasalaka power flows to the Kalu Ganga, pump station at Angamedilla and NCPC to Kahatagasdigiliya, and Stage III including completion of the RKTC and NCPC.

IV. MAHAWELI WATER SECURITY INVESTMENT PROGRAM

55. This section presents an overview of the MDP as proposed under the NCPCP and NWPCP, and secondly those elements to be developed under the investment program.

A. Scheme Summary

56. The proposed development program entails the construction of additional storage and conveyance canals for the transfer of water from the Mahaweli River and Amban Ganga to irrigation systems and for drinking water supply to the Northern provinces. This will be initially achieved through water transfer at Pologolla and via the UEC, extended with transfer via the Randenigala – Kalu Ganga Transfer Canal (RKTC) and pumping of water at Kalinga Nuwara (to compensate for diversion in the upper Amban Ganga). It is a complex system and a large development program which requires sequenced implementation to ensure sustained water supply for hydropower generation and to existing systems.

57. Table 5 lists the proposed implementation schedule in two phases, with Phase 1 development financed under the investment program, and Phase 2 under future funding.

58. In addition to the implementation of Phases 1 and 2 for development of the scheme, the 'balance' of systems including Systems A, C, D2 G and H will have minor changes in water supply levels due to changes in cropping intensities and improvements in WUE.

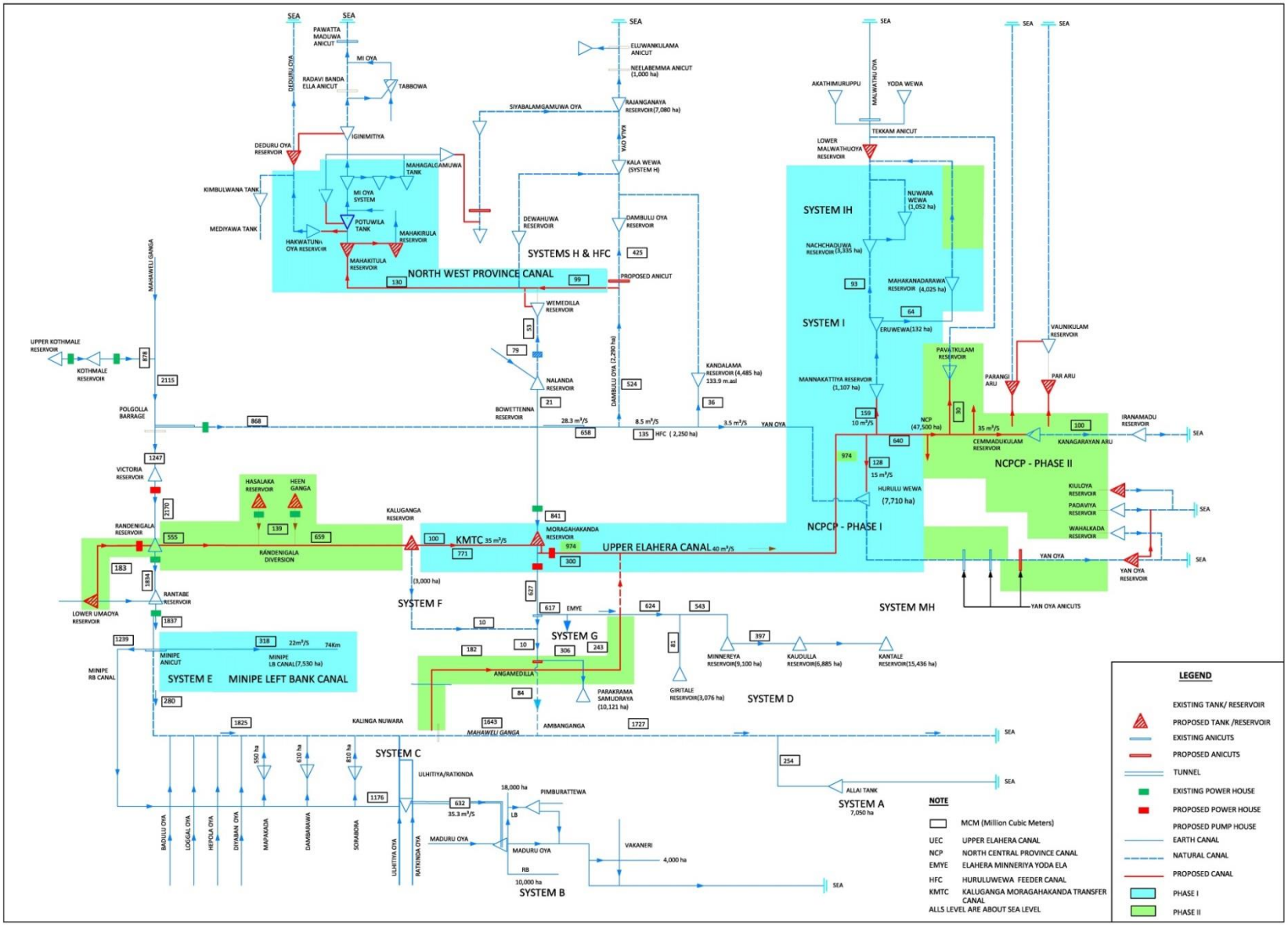
59. Figure 4 presents the schematic layout of the Mahaweli Scheme at full development with the completion of proposed works under the NCPCP and NWPC. It shows those the two phases shaded by principal works and systems in which addition scheme water is to be delivered.

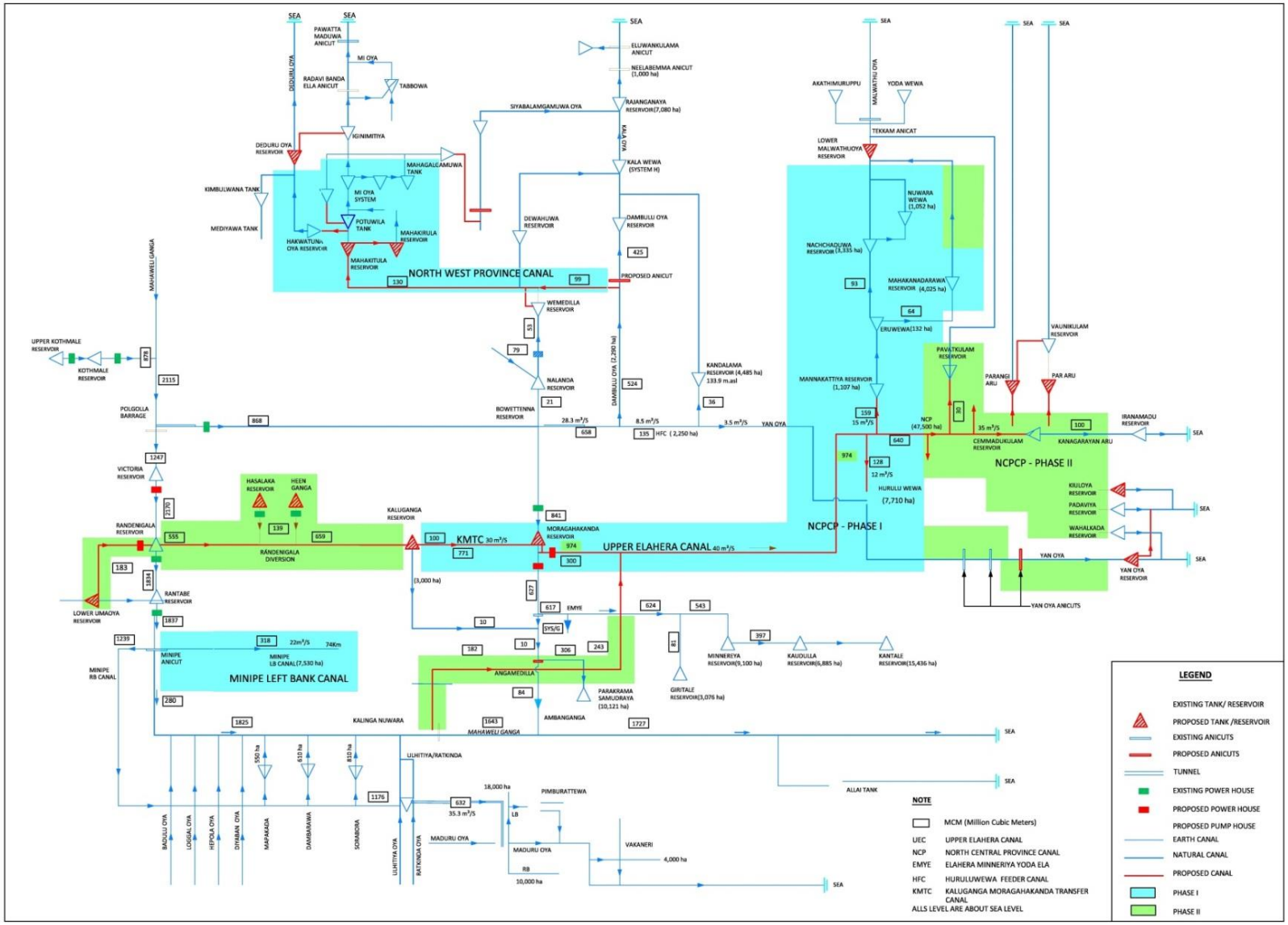
Table 5: Development Sequence for Phases 1 and 2

Phase	Infrastructure	Systems Area (added)
Phase 1	• Upper Elahera Canal and Kalu Ganga-Moragahakanda Transfer Canal. • NWPC Stage 1 Canal and Reservoirs • Minipe Left Bank Canal Rehabilitation	• D1: 1,420 ha Kaudulla • MH: 4,210 ha • IH: 4,907 ha • I: 3,264 ha • NWPC: 11,420 ha
Phase 2	• Lower Uma Oya Dam and Canal • Randenigala – Kalu Ganga Transfer Canal • Kalinganuwara Pump Station • North Central Province Canal	• B: Maduru Oya RB 10,000 ha • D1: Kantale sugar 6,576 ha • I: expanded to 5,264 ha • MH: expanded to 7,710 ha • NCP: added at 47,500 ha • NWP: expanded to12,420 ha

Source: MIWRM 2014

Figure 4: Mahaweli Development Program Schematic showing Phases 1 and 2





Source: MCB, 2014

60.

Table 6 presents a summary of the system areas supplied, fully and partially, from the Mahaweli Scheme currently and in the future, as well as the current and planned cropping intensities (CI, %). The total scheme irrigated area is currently approximately 146,000 ha, and with Phase 1 this will be extended out to 162,000 ha with the addition of areas in NWPC, the compensation area (1,420 ha) to be developed downstream of the Moragahakanda Reservoir (System D1), and addition of System I (3,264 ha). With the completion of Phase 2 the scheme area will increase to 232,500 ha, with the addition of the NCP minor and major tank cascades (47,500 ha), extension of the NWPC (1,000 ha), extension of System I (to 5,264 ha), addition of System B Right Bank Canal (10,000 ha), addition of the Kantale sugar estate in System D1 (6,576 ha), and expansion of System MH by 3,500 ha.

Table 6: Irrigation Systems by Phase

Irrigation System	Current		Phase 1		Phase 2	
	Area (ha)	CI (%)	Area (ha)	CI (%)	Area (ha)	CI (%)
A	7,050	2.00	7,050	2.00	7,050	2.00
B	18,500	1.78	18,500	1.80	28,500	1.80
C	22,800	1.88	22,800	2.00	22,800	2.00
D1	26,520	1.91	27,940	1.91	34,516	2.00
D2	10,480	1.99	10,480	2.00	10,480	2.00
E	7,530	1.95	7,530	2.00	7,530	2.00
F	3,000	2.00	3,000	2.00	3,000	2.00
G	6,210	1.85	6,210	2.00	6,210	2.00
H	34,545	1.89	34,545	1.89	34,545	1.89
I			3,264	1.80	5,264	1.80
IH	4,907	1.67	4,907	1.83	4,907	1.83
MH	4,210	1.53	4,210	1.80	7,710	1.80
NCP					47,500	1.80
NWP			11,492	1.80	12,492	1.80
Total	**145,752**	**1.88***	**161,928**	**1.91***	**232,504**	**1.89***

Source: MCB, 2013 (derived from Water Balance Study Report) (*) Cropping intensities for the area under direct scheme command, that is as supplied with water (partially or fully) from the Mahaweli Ganga (which differs from that reported below, which include areas not under command for the purpose of determination of project benefits).

61. It should be noted that Table 6 refers to the MDP as a whole, current and future, inclusive of all systems (including those not part of the investment program). The subsequent tables (7, 8 and 9) refer only to systems within the MDP which are part of the investment program. For the investment program, the determination of benefits the approach looks at the current CIs (with and without MDP supply) and the change in CI in the future under Phase 1 and Phase 2. The systems of interest for the investment program are systems E, I, IH, MH, NWP and D1 Kadulla for Phase 1, as per Tables 7 and 8, and NCP plus increase in areas systems I, and MH for Phase 2 as per Table 9.

62. The other systems within the MDP do not directly benefit from the investment program; any changes in CIs for these systems are a result of general trends in crop and water management which are not directly attributable to the investment program.
63. Annex 2 presents a more comprehensive summary of the systems and sub-systems (cascades) for both the current situation and future Phase 2 of the NCPCP. In addition to the above information, it also shows current cropping intensities for the system areas not currently supplied from the Mahaweli Scheme. The current cropping intensity inclusive of these areas is about 1.42, and will increase to 1.51 and 1.89 under the investment program and NCPCP Phase 2, respectively.

64. Current scheme annual water diversions for irrigation are about 3,200 MCM (for an irrigated area of 146,000 ha). At final development this will increase to 4,300 MCM to meet an annual irrigation demand of about 5,300 MCM, and 160 MCM for drinking water supplies. It should be noted that the balance between diversions from the Mahaweli Ganga (and associated reservoirs) and demand of 1,200 MCM (5,500 – 4,300 MCM) is to be met from local recharge and storage (within major and minor tanks).

B. Investment Program Summary

65. Table 7 presents a summary of the current system cascade irrigated areas, cropping intensities, duties and water issues (irrigation demand) for the Phase 1 projects (those funded under the investment program).

66. The total irrigated area is 32,823 ha of which 12,381 ha is within the command of the proposed UEC in the Systems of IH, I and MH, which have a combined cropping intensity of about 1.37, though it varies significantly between cascade tanks. Annual water issues are of the order of 206 MCM, most of which is generated from local tank recharge as annual diversion form the Mahaweli Scheme are about 60 MCM.

67. The proposed NWPC has an irrigated areas of 11,492 ha and cropping intensity of 1.11. Annual water issues on average are about 155 MCM, again most of which is generated from local recharge, with a minor contribution (about 20 MCM) releases from the Nalanda Reservoir. The MLBC, in System E, with an irrigated area of 7,530 ha has an annual water demand of about 343 MCM, most of which is supplied from the Mahaweli River.

68. The project area also includes D1 Kadulla which is the area (1,420 ha) to be developed downstream of the Moragahakanda Reservoir as compensation for lands inundated by the new reservoir.

69. Table 8 lists a summary for the investment program areas on completion of the infrastructure works. While the irrigated area remains the same with additional water, the system cropping intensities increase and overall intensity rises to 1.86 from 1.35. The total irrigation demand increases to 892 MCM from 704 MCM.

Table 7: Phase 1 Projects – Existing Status

System	Cascade	Area (ha)	Cropping Intensity Maha	Yala	Annual	Duty (ha/mcm) Maha	Yala	Water Issues (MCM)[22] Maha	Yala	Total
Upper Elahera Canal										
IH	Nuwarawewa	1,052	0.98	0.96	1.94	97	65	11	16	26
	Nachchaduwa	3,335	0.94	0.66	1.60	94	50	33	44	77
	Tis'wa/Basa'ma	520	1.00	0.63	1.63	83	86	6	4	10
I	Manankattiya	607	0.86	0.64	1.50	100	60	5	6	12
	Eruwewa	132	0.70	0.00	0.70	100	60	1	0	1
	Mahakandarawa	2,525	0.41	0.10	0.51	100	60	10	4	15
MH	Huruluwewa	4,210	1.00	0.53	1.53	126	70	33	32	65
	Subtotal	**12,381**	**0.85**	**0.52**	**1.37**			**100**	**106**	**206**
NWP	Stage I	6,505	0.75	0.45	1.20	90	70	54	42	96
	Stage II	4,987	0.80	0.20	1.00	90	70	44	14	59
	Sub Total	**11,492**	**0.77**	**0.34**	**1.11**			**99**	**56**	**155**
E	Minipe LB	7,530	0.98	0.97	1.95	55	35	134	209	343
D1	Kaudulla	1,420	0.00	0.00	0.00					
	Total	**32,823**	**0.82**	**0.54**	**1.35**			**333**	**371**	**704**

Source: PPTA Consultant based on Water Balance Study Report (MCB, 2013)

Table 8: Phase 1 Projects – Developed

System	Cascade	Area (ha)	Cropping Intensity Maha	Yala	Annual	Duty (ha/mcm) Maha	Yala	Water Issues (MCM) Maha	Yala	Total
Upper Elahera Canal										
IH	Nuwarawewa	1,052	1.00	0.96	1.96	105	70	10	14	24
	Nachchaduwa	3,335	1.00	0.80	1.80	100	55	33	49	82
	Tis'wa/Basa'ma	520	1.00	0.80	1.80	85	86	6	5	11
I	Manankattiya	607	1.00	0.80	1.80	100	70	6	7	13
	Eruwewa	132	1.00	0.80	1.80	100	70	1	2	3
	Mahakandarawa	2,525	1.00	0.80	1.80	100	70	25	29	54
MH	Huruluwewa	4,210	1.00	0.80	1.80	126	80	33	42	76
	Subtotal	**12,381**	**1.00**	**0.81**	**1.81**			**116**	**147**	**263**
NWP	Stage I	6,505	1.00	0.80	1.80	100	80	65	65	130
	Stage II	4,987	1.00	0.80	1.80	90	70	55	57	112
	Sub Total	**11,492**	**1.00**	**0.80**	**1.80**			**120**	**122**	**243**
E	Minipe LB	7,530	1.00	1.00	2.00	55	35	137	215	352
D1	Kaudulla	1,420	1.00	1.00	2.00	100	70	14	20	34
	Total	**32,823**	**1.00**	**0.86**	**1.86**			**387**	**505**	**892**

Source: PPTA Consultant based on Water Balance Study Report (MCB, 2013)

[22] In Sri Lanka the term 'Issue' refers to water deliveries

70. The UECP will initially deliver water to the IH, I and MH Systems at the equivalent average annual rate of about 240 MCM (though it is designed to meet the ultimate duty for the NCPCP of 974 MCM as discussed below). Diversion from the Mahaweli Scheme to the NWPCP will be from the Nalanda Reservoir to the Wemedilla Reservoir (53 MCM) and from the Dambulu Oya via the Bowettana Reservoir (100 MCM). The MLBC (System E) will initially maintain similar diversion rates at around 350 MCM.

71. The UECP is designed to meet the ultimate duty of the NCPCP, and, therefore, a substantial proportion of the costs are attributable to Phase 2 development (alternatively a substantial proportion of the benefits from the NCPCP are attributable to the conveyance works developed in Phase 1).

72. Table 9 lists a summary of the areas, cropping intensities and irrigation demand with the addition of the NCPCP (i.e. Phases 1 and 2). In addition to the 47,500 ha under the NCPCP command, there will also be (due to higher water availability) an increase in the irrigated areas in the other UECP serviced systems (I and MH) and the NWPCP (due to improved WUE) with an increase in total irrigated area to 86,823 ha. The final (weighted average) final cropping intensity (at full development) is 1.82.

73. With the increase in irrigated area in Phase 2 the irrigation water demand on the UECP supplied systems increases to nearly 1,200 MCM per annum of which 900 MCM will be transferred from the Mahaweli River (it should be noted that the UECP is designed for an average annual duty of 974 MCM of which 70 MCM are assigned for drinking water supplies in the NCPCP) (in addition to 92 MCM within the command of the UECP).

74. Annual irrigation water supply in the NWPCP remains at about 250 MCM[23] (but with the addition of 1,000 ha in Yapahuwa due to improved water management), and annual supply marginally declines in the MLBCRP to 327 MCM (from 352 MCM) of which 318 MCM will be supplied from Mahaweli diversions.

[23] This is anticipated to due to increases in irrigation efficiency and reduction in crop water demand due to changes in cropping patterns (shorter duration paddy, and increased in lower water demand cash crops)

Table 9: Phase 1 Projects – Developed with NCP

		Area	Cropping Intensity			Duty (ha/mcm)		Water Issues (MCM)		
System	Cascade	(ha)	Maha	Yala	Annual	Maha	Yala	Maha	Yala	MCM
Upper Elahera Canal										
IH	Nuwarawewa	1,052	1.00	0.96	1.96	123	73	9	14	22
	Nachchaduwa	3,335	1.00	0.80	1.80	118	57	28	47	75
	Tis'wa/Basa'ma	520	1.00	0.80	1.80	100	89	5	5	10
I	Manankattiya	1,107	1.00	0.80	1.80	117	74	9	12	21
	Eruwewa	132	1.00	0.80	1.80	128	70	1	2	3
	Mahakandarawa	4,025	1.00	0.80	1.80	113	73	36	44	80
MH	Huruluwewa	7,710	1.00	0.80	1.80	150	84	51	73	125
	Subtotal	**17,881**	**1.00**	**0.81**	**1.81**			**140**	**196**	**336**
NCP	Minor Tanks	33,000	1.00	0.80	1.80	119	84	277	314	592
	Major Tanks	14,500	1.00	0.80	1.80	127	84	114	138	252
	NCP Subtotal	**47,500**	**1.00**	**0.80**	**1.80**			**391**	**452**	**844**
	UEC Total	**65,381**	**1.00**	**0.80**	**1.80**			**531**	**649**	**1,180**
NWP	Stage I	6,505	1.00	0.80	1.80	100	80	65	65	130
	Stage II	5,987	1.00	0.80	1.80	100	80	60	60	120
	NWP Subtotal	12,492	**1.00**	**0.80**	**1.80**			125	125	250
E	Minipe LB	7,530	1.00	1.00	2.00	64	36	118	209	327
D1	Kaudulla	1,420	1.00	1.00	2.00	100	70	14	20	34
	Total	**86,823**	**1.00**	**0.82**	**1.82**	**85**	**63**	**774**	**983**	**1,756**

Source: PPTA Consultant based on Water Balance Study Report (MCB, 2013)

75. It should be noted that the total areas in the above tables differ from those for the entire Mahaweli Scheme (Annex 2) as they are confined to those systems directly benefiting from the investment program. While those systems listed above (IH, I, MH, NWPC, D1 Kadulla) and the future development of the NCPCP all directly benefit from increase in water availability.

76. **Climate Change.** Simulations to assess the impact of climate change on the ultimately developed Mahaweli Scheme have also been carried out. The assessment considered both increases in crop water demand and reductions in water availability, and their impact on reliability of water availability for each of the individual Mahaweli systems.The methodology, results and proposed adaptation measures are documented in the Climate Risk and Vulnerability Assessment Report.

77. **Conclusions.** The main purpose of this report was to assess the reliability of water availability to meet the investment program requirements, and verify that these requirements would not impact on future development within the existing Mahaweli Scheme. As presented in the preceding sections, the planned scheme development, inclusive of the investment program, has been comprehensively assessed within the context of the existing scheme and proposed future developments. The outcome of this assessment confirms the reliability of water availability, within acceptable levels of supply reliability to meet the program requirements, and without impacting on other existing water uses and planned water resource development projects and uses within the Mahaweli Scheme.

ANNEX 1

WATER BALANCE MODEL RESULTS

1. The table below lists the relevant (to the investment program) results of the water balance model study. It presents the two scenarios for Phases 1 and 2 of the NCPCP (A2A and A10A, respectively) for the Yala and Maha seasons.

System	Scheme	Yala			Maha			Yala			Maha		
	Model scenario	A2A			A2A			A10A			A10A		
	% exceedance	5%	10%	20%	5%	10%	20%	5%	10%	20%	5%	10%	20%
	no. fail years	8	4	2	8	4	2	8	4	2	8	4	2
A	Allai												
B	System B	2											
C	System C							1	1	1			
D1	Minneriya												
D1	Giritale							1	1	1			
D1	Kaudulla	3	2	2	1								
D1	Kantale	1											
E	Minipe LB												
G	System G							1	1				
H	KalawewaRB	3	3					6	3	1			
H	DambuluOya												
H	Kandalama	6	3	1				2	2				
H	KHF							1	1				
I	Eruwewa												
I	Mahakandarawa	1	1					2	1	1			
I	Manankattiya												
IH	Nachchaduwa												
IH	Nuwarawewa												
IH	Tisawewa												
MH	Huruluwewa							1	1				
NCP	NCP2(major)								0				
NCP	NCP1(minor)							5	3		2	2	
NWP	NWP(minor)							2	2	1	1	1	
	Kalu Ganga	4	3	2	2	1							

Source: MCB, 2013

Notes:

- % exceedance = threshold of percent of seasons (for the 40 year modeled period); with 5% being 'irrigation failure', 10% being 'significant irrigation failure' and 15% being 'total irrigation failure'.
- No. fail year = the threshold number of years (over the 40 year period) for the above levels of exceedance.
- The number of seasons per system (modelled period) the above exceedance thresholds are exceeded.

ANNEX 2

MAHAWELI SCHEME SUMMARY - CURRENT AND DEVELOPMENT PHASES (2)

1. The tables (3) below present summaries of the areas, cropping intensities and issues for the without project and with project (Stages 1 and 2).

System Areas	CURRENT				
	Area	CI	Duty	Issue	MDP DVN
	ha		ha/MCM	MCM calc	MCM
Phase 1	32,823	1.35	80	679	408
Phase 2	70,576	0.62	86	436	0
Subtotal	**103,399**	**0.85**	**84**	**1,115**	**408**
Balance	129,105	1.88	77	3,364	2,833
Total	**232,504**	**1.42**	**80**	**4,326**	**3,241**

System Areas	PHASE 1				
	Area	CI	Duty	Issue	MDP DVN
	ha		ha/MCM	MCM calc	MCM
Phase 1	32,823	1.86	82	849	641
Phase 2	70,576	0.62	86	435	0
Subtotal	**103,399**	**1.01**	**85**	**1,255**	**641**
Balance	129,105	1.92	78	3,334	2,752
Total	**232,504**	**1.51**	**81**	**4,401**	**3,337**

System Areas	PHASE 2				
	Area	CI	Duty	Issue	MDP DVN
	ha		ha/MCM	MCM calc	MCM
Phase 1	32,823	1.86	85	802	1,345
Phase 2	70,576	1.82	98	1,343	0
Subtotal	**103,399**	**1.83**	**94**	**2,119**	**1,345**
Balance	129,105	1.93	84	3,144	3,002
Total	**232,504**	**1.89**	**89**	**5,064**	**4,294**

Notes:

- The System Areas by phase refers to the total area current and potentially under command of the phase works.
- Phase 1 refers to those systems directly under the command and benefiting from the investment program, these include; NWPC, System E (Minipe Left Bank Canal), D1 Kaudulla and those under the command of the UEC canal including MH, IH and I.
- Phase 2 refers to the those systems under the command of the Phase 2 future investment and benefit from the pre-requisite Phase 1 investments, including NCPC (NCP major and NCP minor), System B Maduru Right Bank, D1 Kantale and extensions to the NWP, MH and I Systems.
- The 'Balance' are those system which do not directly benefit from the Phase 1 and 2 investment, that is no significant change in scheme water supply though cropping intensities improve through increased water use efficiency and paddy variety changes and planting dates.

2. The tables below (3) present details of the above by irrigation system.

Mahaweli Scheme Summary – Current

	Basin	CURRENT				
Anicut/OT	**Mahaweli Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
System	**Cascade**	**ha**		**ha/MCM**	**MCM calc**	**MCM**
Minipe	E	7,530	1.95	44	336	347
	C	22,800	1.88	63	678	1,062
	B-LEFT BANK	18,500	1.78	57	582	
	B-RIGHT BANK	10,000	0.00			
	A	7,050	2.00	50	282	
	Sub Total	**65,880**			**1,878**	**1,409**
Anicut/OT	**Amban Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
Nalanda	NWP-1	11,492	1.11	90	153	0
	NWP-2	1,000	1.00	90	11	
Bowatenna	H	32,180	1.85	88	678	725
	HFC	2,365	1.92	47	97	
Kaula Ganga	F	3,000	2.00	72	83	
Elahera	M/H-1	4,210	1.53	102	63	61
	M/H-2	3,500	1.00	100	35	
	I/H	4,907	1.68	72	114	
	I-1	3,264	0.70	100	23	
	I-2	2,000	0.70	100	14	
	NCP1(Minor)	33,000	0.70	100	231	
	NCP2(Major)	14,500	1.00	100	145	
EMYE	D1	26,520	1.91	103	492	705
	D1 Kaudulla	1,420	0.00	100	0	
	D1-KANTALE	6,576	0.00	100	0	
	G	6,210	1.85	57	202	
Angamedilla	D2	10,480	1.99	77	271	341
	Sub Total	**166,624**			**2,612**	**1,832**
	DRINKING WATER				**0**	**0**
	TOTAL	**232,504**			**4,490**	**3,241**

Notes:

- Without Project: current scheme areas, ie. for which water is currently supplied from the Mahaweli River Basin plus future areas
- With Project Phase 1; the scheme with development of the UECP
- With Project Phase 2; the scheme with the development of the NCPCP and Madura Oya Right Bank Canal
- Anicut/OT; the systems are organised hydraulically upstream to downstream, by Anicut or offtake location
- Area; areas as per the Water Balance Study (Oct 2013)
- CI: annual cropping intensity per annum, as per the Water Balance Study
- Duty; average duty per season (Maha and Yala) expressed as irrigated area per MCM
- Issue; calculated gross irrigation demand (as issued from the tank) as MCM per annum
- MDP DVN; Diversion from the Mahaweli River Basin, including Amban Ganga as per Water Balance model scenario results and drinking water diversions are inclusive in diversions to transfer canals.

Mahaweli Scheme Summary – Phase 1

	Basin	PHASE I				
Anicut/OT	**Mahaweli Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
System	**Cascade**	**ha**		**ha/MCM**	**MCM calc**	**MCM**
Minipe	E	7,530	2.00	43	350	349
	C	22,800	2.00	65	702	1,062
	B-LEFT BANK	18,500	1.80	62	537	
	B-RIGHT BANK	10,000	0.00			
	A	7,050	2.00	50	282	
	Sub Total	**65,880**			**1,871**	**1,411**
Anicut/OT	**Amban Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
Nalanda	NWP-1	11,492	1.80	100	207	56
	NWP-2	1,000	1.00	100	10	
Bowatenna	H	32,180	1.86	88	680	644
	HFC	2,365	1.92	53	86	
Kaula Ganga	F	3,000	2.00	75	80	
Elahera	M/H-1	4,210	1.80	101	75	236
	M/H-2	3,500	1.00	100	35	
	I/H	4,907	1.83	76	118	
	I-1	3,264	1.80	84	70	
	I-2	2,000	0.70	100	14	
	NCP1(Minor)	33,000	0.70	100	231	
	NCP2(Major)	14,500	1.00	100	145	
EMYE	D1	26,520	1.91	103	492	718
	D1 Kaudulla	1,420	2.00	100	28	
	D1-KANTALE	6,576	0.00	100	0	
	G	6,210	2.00	60	207	
Angamedilla	D2	10,480	2.00	78	269	328
	Sub Total	**166,624**			**2,747**	**1,982**
	DRINKING WATER				**92**	
	TOTAL	**232,504**			**4,710**	**3,393**

Notes as above

Mahaweli Scheme Summary – Phase 2

	Basin	PHASE 2				
Anicut/OT	**Mahaweli Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
System	**Cascade**	**ha**		**ha/MCM**	**MCM calc**	**MCM**
Minipe	E	7,530	2.00	46	327	318
	C	22,800	2.00	66	691	1,239
	B-LEFT BANK	18,500	1.80	66	505	
	B-RIGHT BANK	10,000	1.80	66	273	
	A	7,050	2.00	55	256	
	Sub Total	**65,880**			**2,052**	1,557
Anicut/OT	**Amban Ganga**	**Area**	**CI**	**Duty**	**Issue**	**MDP DVN**
Nalanda	NWP-1	11,492	1.80	99	209	53
	NWP-2	1,000	1.80	99	18	
Bowatenna	H	32,180	1.86	97	617	658
	HFC	2,365	1.92	53	86	
Kaula Ganga	F	3,000	2.00	83	72	
Elahera	M/H-1	4,210	1.80	111	68	974
	M/H-2	3,500	1.80	111	57	
	I/H	4,907	1.83	84	107	
	I-1	3,264	1.80	92	64	
	I-2	2,000	1.80	92	39	
	NCP1(Minor)	33,000	1.80	101	588	
	NCP2(Major)	14,500	1.80	104	251	
EMYE	D1	26,520	2.00	112	474	799
	D1 Kaudulla	1,420	2.00	100	28	
	D1-KANTALE	6,576	2.00	112	117	
	G	6,210	2.00	62	200	
Angamedilla	D2	10,480	2.00	86	244	306
	Sub Total	**166,624**			**3,240**	2,790
	DRINKING WATER SUPPLY				**162**	
	TOTAL	**232,504**			**5,454**	**4,347**

Notes as above