राष्ट्रीय जल विकास अभिकरण

जल शक्ति मंत्रालय, भारत सरकार

(जल संसाधन, नदी विकास और गंगा संरक्षण विभाग)

National Water Development Agency

Ministry of Jal Shakti, Government of India

(Department of Water Resources, RD and GR)

Minutes of the

Fourteenth Meeting of the "Sub-Committee on System Studies for identification of most appropriate alternative plan"

(Sub-Committee - II)

(Held on 18th February, 2020 at New Dehi)

नई दिल्ली

New Delhi

Minutes of the 14thMeeting of the Sub-Committee on "System Studies for Identification of Most Appropriate Alternative Plan" held on 18.02.2020 at 11.30 A.M in the Committee Room, NWDA, Palika Bhawan, New Delhi.

The 14th Meeting of the "Sub-Committee on System Studies for Identification of Most Appropriate Alternative Plan" was held on 18.02.2020(Tuesday) at 11:30 A.M in the Committee Room, NWDA, Palika Bhawan, New Delhi under the Chairmanship of Prof. P.B.S. Sarma, (Retd.). The list of Members and other participants who attended the meeting is at Annex-I.

At the outset Chairman welcomed all the participants of the meeting. He introduced Shri Bhopal Singh, who has recently assumed the charge of Director General, NWDA.

Prof. Kamta Prasad, Member indicated that the Hon'ble Supreme Court has appointed Special Committee for ILR to expedite interlinking projects and subsequently Sub Committees were appointed to assist Special Committee to implement the direction of Apex court. So far the Sub-Committee has been concentrating to the system study of Mahanadi-Godavari link canal system only. He suggested taking up similar studies of few more ILR projects (at least 4) simultaneously to expedite the progress of work.

Prof. P.B.S. Sarma, (Retd.) Chairman of the Sub-Committee agreed with the suggestions of Prof. Kamta Prasad for taking up more studies simultaneously to expedite the task assigned with the Committee.

Dr. S K Jain, Director, NIH Roorkee indicated that National Perspective Plan (NPP) was conceptualized in the year 1980. Since then many technological advancement took place and many new issues like climate change etc. are being considered now while planning water resources projects as such a Brainstorming Session should be organized where the NPP can be discussed in details.

Thereafter Chairman requested Shri K. P. Gupta, Director (Tech), NWDA and Member Secretary of the Sub-Committee to take up the agenda items for discussion.

Item 14.1: Confirmation of the Minutes of 13thMeeting of the Sub-Committee on System Studies for identification of most appropriate alternative Plan held on 04.02.2019.

The Member Secretary informed that the Minutes of the 13th meeting of Sub-Committee were circulated to all the Members vide letter dated 19.02.2019. As no comments have been received from any of the Members, the Minutes of 13thmeeting of the Sub-Committee were confirmed as circulated.

Item No. 14.2: Draft Consultancy proposal of NIH for the suggested studies related to Mahanadi-Godavari link

Dr. S K Jain, Director, NIH informed that while carrying out System studies NIH is considering the ground water component, issue of climate change, e-flows, change in food habits etc. The experts available with NIH in the respective domain would be associated with the studies.

Shri Bhopal Singh, Director General, NWDA mentioned that to analyse various scenarios and various demand /Supply patterns, System study is necessary and NWDA is working towards setting up a dedicated cell for system studies within NWDA. He requested NIH to provide the technical support to this cell during the System studies of Mahanadi- Godavari Link to develop the capability within NWDA to analyse and generate scenarios of link projects. He was of the opinion that System studies of few more link projects should be simultaneously taken up by NWDA and suggested to consider Godavari-Cauvery link and Manas-Sankosh-Teesta-Ganga-Damodar-Subarnarekha links for the study, which was agreed by the Sub-Committee.

Shri K P Gupta, Member Secretary informed that the consultancy proposal for the studies related to Mahanadi-Godavari link was prepared by NIH and submitted to NWDA. The proposal was circulated to the members of the Sub-Committee and observations received from Prof. PBS Sarma, Chairman and Prof. S. Mohan, member of the Sub-committee were communicated to NIH. NWDA also held a meeting with NIH on 7th February 2020 and reviewed the proposal. The NIH after considering views of the Members of the Sub-Committee and NWDA has modified the proposal which has been circulated to the members (**Annex-14.2.1**)

Dr M K Goel, Scientist-G WRS Division, NIH Roorkee has made Power Point Presentation on modified consultancy proposal of NIH. (**Annex-14.2.2**)

The proposal of NIH Roorkee was evaluated by the Sub-Committee and was approved with following remarks. The Committee also suggested to commence the work at the earliest.

1. The Committee resolved that the broad aim of this study is to develop generic methodology/model for simulation study which will act a model for other links studies also. Accordingly the system study of Mahanadi-Godavari link by NIH shall be carried out scientifically to establish generic model for a solution for complex system which can be replicated in other link/elsewhere comfortably.

2. NIH may involve an expert in Statistic and Sensitivity analysis for the study. Component of economic analysis in terms of Sensitive analysis to be reflected in the study.

3. Available Data with NWDA will be provided to NIH for the study. NWDA will also assist NIH to collect required data from various Organisations.

4. Cropping Pattern data may be obtained from Organisations such as Ministry of Agriculture & Cooperation, GOI; ICAR; State Agriculture Department etc. and from the reports such as State Year Books,

5. NIH Roorkee shall provide dedicated group of scientists for the study. A Note indicating the Functions and Functionaries of each component involved and their time schedule of engagement, responsibility/accountability etc will be prepared by NIH and sent to NWDA.

6. The Committee suggested NIH to arrange the field visits of experts involved in the study for better understanding of the study area.

7. Futuristic assumptions considered for the study should be logical and well defined and justified in the report.

The Sub-Committee continued its deliberation further and following decisions were taken

I. The meeting of the Sub-Committee may be held frequently for the effective monitoring of System study. NIH may request NWDA to convene the Meeting of Sub-Committee at any point of time if they feel necessary for getting the guidance of Sub-Committee.

II. Manas-Sankosh-Teesta-Ganga-Damodar-Subarnarekha-Mahanadi link system and Godavari-Cauvery link are identified by the Sub Committee for taking up System studies. A draft Expression of Interest (EOI) involving the scope of the study may be prepared by NWDA for carrying out the study and the same may be circulated among the members of the Committee by 3rd week of March 2020.

III. NWDA may identify an expert(s) from premier National Institutes like IITsfor Review Consultant of System studies being carried out by NIH.

Item No.14.3: Extension of Tenure of the Sub-Committee

The Committee noted the contents of the Agenda that the subcommittee-II will be functioning coterminous with the Special Committee for Inter-Linking of Rivers along with the Subcommittee-I.

Item No.14.4: Any other item with the permission of the Chair.

The Member-Secretary informed that Shri Sriram Vedire, Member of the Sub-Committee and Advisor for Ministry of Jal Shakti has been appointed as Chairman of Task Force and he has expressed his inability to continue in the Sub-Committee.

Dr. Sharad Kumar Jain, Director, NIH and Member of the Sub-Committee is superannuating from service on 29th February 2020. The Sub-Committee decided to reconstitute the Sub-Committee considering the above and inclusion of new suitable experts as members and requested NWDA to prepare the proposal in this regard and send to Ministry for approval of the competent authority.

The meeting ended with a vote of thanks to the chair

Annex-I

List of participants of the 14th Meeting of the "Sub-Committee on System Studies for identification of most appropriate alternative plan" held on 18.02.2020, New Delhi.

1.	Prof. P.B.S. Sarma, (Retd.), CED, IIT Delhi, New Delhi	In Chair
2.	Prof. Kamta Prasad, Chairman, IRMED, New Delhi	Member
3.	Dr. Sharad K. Jain, Director, NIH Roorkee	Member
4.	Shri M. K. Sinha, Assessor, K WD T, New Delhi	Member
5.	Shri K.P. Gupta, Director (Tech.),NWDA, New Delhi	Member- Secretary

Special Invitees

6. Shri Bhopal Singh
   Director General, NWDA, New Delhi
7. Shri Muzaffar Ahmad,
   Superintending Engineer, NWDA, New Delhi

Officers from NIH Roorkee

8. Dr. M. K. Goel,
   Scientist - 'G', WRS Division, N.I.H., Roorkee
9. Shri Surjeet Singh
   Scientist -F , WRS Division, N.I.H., Roorkee

Other Officers from NWDA

10. Shri Anil Kumar Jain,
    Deputy Director (SCILR),New Delhi
11. Shri P. V. Baiju,
    Consultant, New Delhi

Memorandum of Understanding
(MOU)

Between

National Water Development Agency (NWDA), New Delhi

And

National Institute of Hydrology (NIH), Roorkee

NAME OF WORK

Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed Mahanadi-Godavari Link

February, 2020

Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed Mahanadi-Godavari Link

1.0 Background

River interlinking is a long term plan, aims to effectively manage water resources in India by linking Indian rivers by a network of reservoirs and canals. This programme is considered to face dual challenge of persistent floods in some parts and water shortages in others. Under the National Perspective Plan (NPP) prepared by Ministry of Water Resources (now Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation), NWDA has identified 14 links under Himalayan Rivers Component and 16 links under Peninsular Rivers Component for inter-basin transfer of water based on field surveys, investigation and detailed studies. Out of these, feasibility reports (FR) of 14 links under Peninsular Component and 2 links (Indian portion) under Himalayan Component have been prepared. Draft FR of 7 link projects (Indian portion) of Himalayan Component have also been completed.

The Mahanadi-Godavari link (M-G link) is the first and the critical link of nine link systems of Mahanadi-Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar under Peninsular Component of NPP. The Sub-Committee-II under Special Committee on Interlinking of Rivers in its 7th meeting held on 29.09.2015 decided that system simulation studies of Mahanadi-Godavari link including the water balance studies to ascertain surplus water should be carried out by National Institute of Hydrology, Roorkee. The report on the hydrological studies and multi reservoir simulation prepared by NIH, Roorkee, for the proposed Mahanadi-Godavari link was considered by the Sub-Committee for System Studies in the tenth meeting held on 03.03.2017 and the report was accepted.

The FR of Mahanadi-Godavari link with proposed Manibhadra dam completed earlier and now with Barmul dam (in place of Manibhadra dam) is under preparation. However, some additional studies, as per the directions given during the 12th Meeting of the "Sub-Committee on System Studies for identification of most appropriate alternative Plan" held on 27.07.2018 are required. The committee recommends that impact of issues of Climate change, change in irrigation application methods, shifting of cropping pattern, crop water requirement and the recharge of ground water in the area surrounding the M-G link needs to be investigated.

In this regard, NWDA vide its letter no. NWDA/CE(N)/LKO/T-122(A)/1987-88 dated 06/08/2019, as per the decisions taken during the 13th meeting of the "Sub-Committee on System Studies for identification of most appropriate alternative plan" held on 04.02.2019, requested NIH to prepare consultancy proposal for *" Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed Mahanadi-Godavari Link"* based on the modified ToRs. This proposal has been prepared in response to the NWDA call.

2.0 The Mahanadi-Godavari Link Project

Water balance studies done by NWDA reveal that Mahanadi and Godavari basins are water surplus basins. The combined surpluses of these basins after accounting for in-basin uses in the ultimate stage of development can be diverted to meet the water requirement of deficit basins in South up to Gundar river through Mahanadi-Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar links (9 link system). The proposed Mahanadi-Godavari link will originate from Barmul dam with all the design features of conveyance system as proposed in the FR of Mahanadi-Godavari link. It is proposed to have a dam at Barmul 14 km upstream of Manibhadra on River Mahanadi. After meeting the en-route needs, 4682 MCM water is proposed to be transferred to Godavari. The total length of the link canal would be 844 km. Six dam projects at Saiki and Ong in Ong sub-basin and Uttei Roul Integrated Project, Khadago, Upper Udanti and Tel Integrated Project in Tel sub-basin in Mahanadi basin will be integrated in the Mahanadi - Godavari scheme. These six dam projects will utilize about 1376 MCM of water within Odisha State. The submergence from Barmul dam will be 21262 ha and from six dam projects will be 10222 ha. Thus, total submergence shall be about 31484 ha. These projects are in the planning stage and hence the design features may change later on.

The Mahanadi - Godavari link project shall provide irrigation (CCA) to the tune of 2.57 lakh ha in Odisha through link canal and 1.82 lakh ha through six dam projects. Thus, total irrigation in Odisha State shall be 4.39 lakh ha. It is proposed to provide 125 MCM water for drinking water supply. The six dam projects have a potential of generating 240 MW of hydropower. There will also be flood moderation in Mahanadi river basin. The proposal prepared is preliminary based on remote sensing studies and will be firmed up by detailed studies. Layout of the proposed M-G Link is shown in Figure – 1.

Figure – 1: Layout of proposed M-G Link

3.0 Scope of Work

The scope of work will be as follows:

(i) Analysis of present ground water scenario in en-route command of M-G link.

(ii) Quantification of recharge to ground water due to M-G link canal irrigation.

(iii) Evaluation of impact of en-route utilization of system of M-G link canal and its distributaries on the groundwater levels in the command area over next 50 years.

(iv) Estimation of additional irrigation potential that may be created by recharged water while maintaining ground water at the safe level.

(v) Scope of conjunctive use of surface and groundwater in en-route command area so as to avoid water logging due to increased GW recharge.

(vi) Study of impact of different possible scenarios arising out of:

a) Climate change in the long term, say 25 to 50 years

b) Changes in food consumption and consequent changes in cropping pattern during next 50 years

c) Improved water application such as adoption of modern irrigation methods and other foreseeable factors, affecting water use efficiency

d) Higher intensity of irrigation

(vii) Analysis of following alternatives of water availability at source, i.e., off take point (Mahanadi at Barmul):

a) Contribution of Mahanadi only, as being envisaged in the aforesaid study
b) Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is considered as per PFR/FR
c) Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is dropped

4.0 Basic Data Requirement

Following data are required for addressing different components of this study:

4.1 Data requirements for addressing the ground water component:

- Study area/ en-route command area of M-G link shape files
- Ground water levels along with reduced levels and location details
- DEM/ surface topography
- Meteorological data (rainfall, temperature, etc.)
- Soil map
- River network shape file
- Existing ground water usage/ withdrawal patterns

- Litho logs
- Link canal and its distribution system details, like full supply level, supply schedule, planned intermediate releases, canal network in the study area
- Land use land cover (LULC) map
- Existing cropping pattern in the study area and likely changes in future after implementation of the project

4.2 Data requirements for addressing climate change and irrigation components

- Long term meteorological station data, viz. rainfall, temperature (T_{min} & T_{max}), evapo-transpiration (ET), relative humidity (RH), Wind speed, Sunshine hour etc. for validation of satellite derived meteorological data
- Existing Food consumption pattern and lifestyles
- Irrigation Master Plan
  - Existing irrigation projects
  - Under-construction irrigation projects
  - Proposed irrigation projects including LI schemes, Hi-tech irrigation measures, etc.
- Existing command area under Sprinkler/Drip/Micro-irrigation systems

4.3 Data requirement for addressing water availability at Source:

- Planned releases from the Barmul project to the M-G Link
- Inflows from Manas and Sankosh rivers, if Farakka- Sunderbans link is to be considered
- Inflows from Manas and Sankosh rivers, if Farakka- Sunderbans link is not to be considered

4.4 Data requirement for the System Study of MG Link Network:

- Shapefile of the MG Link network of canals and distribution system
- Inflows at various nodes in the canal network
- Water releases, diversions, etc. in the network system
- Future proposed network details

5.0 Study Area

The study area covers the area under Mahanadi-Godavari Link, which off-takes from the right flank of the proposed Barmul Dam on river Mahanadi in Odisha and after traversing 828 km, outfalls in the Godavari River at 15 km upstream of the existing Dowlaiswaram barrage in Andhra Pradesh. However, simulation studies may also be included with the water contribution from Manas and Sankosh river in different scenario.

6.0 Broad Methodology

Broad methodology to be adopted in the study (scope-wise) is given below:

(i) System Study of MG Link Canal Network

The MG link canal network will be prepared in the GIS environment comprising of MG main link, branch canals, etc. All these network will be integrated and imported in an allocation model (say, Mike Hydro Basin/ WEAP/ e-Water etc.). System network will comprise of reaches and nodes. The flow series at various nodes in the system and will be assigned. The system will be modelled for computing evaporation and seepage losses in various reaches under different water availability scenarios at Barmul and under different climatic conditions.

(ii) The present ground water scenario in command area of M-G link

The present ground water scenario in the command area will be assessed by analyzing and mapping the spatial variation of ground water based on the historical ground water level data. The variation of ground water will be assessed spatially as well as temporally considering rainfall variation as well as local ground water withdrawal patterns. For this purpose, historical ground water level data will be utilized. The same can be obtained from Central Ground Water Board (CGWB) and State Ground Water Department.

(iii) Quantification of GW recharge due to M-G link canal irrigation

The recharge to ground water will be quantified using different approaches depending on the availability of data. However, in normal course, the recharge in the command area will be estimated using the Rainfall Infiltration Factor (RIF), Water Table Fluctuation (WTF) method considering the GEC-2015 norms. The recharge from canal will be estimated using methodology suggested by GEC-2015 as well as empirical equations like Chaturvedi (1973), UP Irrigation Research Institute formula etc. using rainfall, and alternatively, can also be estimated from canal geometry based empirical formula as well as with data on soil and underground formations. GEC also suggests methods for estimation of recharge from surface water as well as ground water irrigation.

(iv) Impact on groundwater table in the command area over next 50 years

Ground water modelling will be carried out using MODFLOW for the en-route command area by applying stresses on pumping and recharge. The model will be calibrated and validated on the historical data. The calibrated model will be used to further assess the impact of canal seepage on the ground water regime considering rise in ground water levels and changed cropping pattern in the command area over the next 50 years. Various input data requirements in consolidated form have been discussed as above in sub-section 4.1 under basic data requirements for groundwater component.

(v) Additional irrigation potential that may be created by recharged water while maintaining ground water at the safe level

Additional irrigation potential created will be estimated on the basis of average annual recharge in en-route command considering changed cropping pattern.

(vi) Scope of conjunctive use of surface and groundwater in the en-route command area so as to avoid water logging.

Seepage/recharge taking place from the canal network will be estimated and examined through modelling. If the recharge is excessive and results in rise of ground water levels, then scope of conjunctive use of water shall be explored.

(vii) Study of impact of different possible scenarios arising out of:

(a) Climate change in the long term, say 25 to 50 years

The CMIP6 GCMs are considered as more accurate climate models than earlier versions and will be used in this study. The CMIP6 models include two types of experiment, (1) long term and (2) near-term scenarios (10-30 years).

1) The CMIP6 GCM models will be used for generation of future projections for precipitation and temperature during 2011-2040 (denoted by 2020s), 2041-2070 (denoted by 2050s) and 2071-2099 (denoted by 2080s) for the study area.
2) Bias correction (BC) approach using “quantile mapping” will be utilised to minimise uncertainties in GCM based outputs, which adjusts (corrects) the modelled output with reference to observed datasets in post-processing step.

(b) Climate change impact in long term on ground water levels

Impact of climate change on ground water levels will be quantified using the downscaled time series in response to future climate change. The future climate series would be used in the estimation of ground water recharge for future to be utilized by the ground water flow model. The calibrated and validated ground water flow model will be run again for developing scenarios to show the variation of ground water levels in future.

(c) Change in food consumption and consequent changes in cropping pattern during next 50 years

There has been a clear shift in recent decades from the grain consumption to non-grain food and animal products consumption (Chatterjee et al., 2006, Bansil 1999, and Rao 1999). This decline is due to various reasons, including income growth and urbanization and associated changes in life styles, changes in relative prices and the availability of non-grain food etc. Several studies in

the past have also projected India's food grain demand for 2020 (Bhalla et al. 1999; IWMI 2000; Kumar 1998; Rosegrant et al. 1995; Radhakrishna and Reddy 2004). It is planned to assess the level of consumption of different crops or animal products that provide the projected calorie supply in the study area and Indian context.

A diet with a high intake of meat has resulted in higher water requirement. Change in food consumption has a direct effect on the water requirement vis-à-vis the agriculture demand for a particular crop. Based on the secondary data and suitable assumptions, the effect of change in food consumption and its likely impact on the cropping pattern and overall water requirement will be assessed in the study.

(d) Improved water application such as adoption of modern irrigation methods and other foreseeable factors, affecting water use efficiency

Government initiatives such as More Crop Per Drop have long repercussions in making available more water which can be utilized in producing more grains in a command. Increasing water productivity (WP) now is a national priority in India (Economic Survey, 2018-19). Water Accounting Plus (WA+) technique will be used for assessing the water productivity (WP) (Kg/m3) and land productivity (kg/ha) in the study area. Various engineering measures and socio-economic factors will be assessed affecting the Water Productivity in the study area. The study will gather information from different sources, adopt suitable assumptions, and assess the overall impact of modern irrigation methods.

(e) Different scenario of intensity of irrigation

Intensity of irrigation is defined as the percentage of culturable command area proposed to be irrigated annually. Usually the areas irrigated during each crop season (Rabi, Kharif, etc.) is expressed as a percentage of the Culturable Command Area (CCA) which represents the intensity of irrigation for the crop season. Once the amount of water to be taken as seasonally available for design purposes is determined, the key question is then the area to be supplied. This involves consideration of cropping pattern, water requirements of individual crops, land availability, and the socio-economic question of intensity of irrigation. Suitable assumptions (percentages) on intensity of irrigation will be considered to estimate the likely irrigated area increased (or decreased) in the study area.

(viii) Water availability at Source, i.e., off takes point (Mahanadi at Barmul)

The water availability at source, i.e., off takes point at Barmul (Mahanadi river) will be considered as suggested in the modified approved ToR considering following three alternatives:

- Contribution of Mahanadi only, as being envisaged in the aforesaid study
- Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is considered as per PFR/FR
- Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is dropped

Though the broad methodology is given above, the exact methodology would depend on the time and data provided for the study.

7.0 Time Schedule

NIH shall provide the inception report within one month from the date of receipt of data from NWDA or signing of agreement or receipt of first instalment, whichever is later. The draft report along with findings and recommendations shall be submitted within next twelve months. Consolidated comments from NWDA on the draft report would be expected within a month and final report shall be submitted in subsequent two months' duration. It is to submit that the consolidated comments would be considered only once.

8.0 Deliverables

NIH shall submit one copy of the inception report in one month as per above time schedule. The draft report in one hard copy along with a soft copy will be submitted. Five copies of the final report will be submitted along with soft copy.

9.0 Cost

The estimated cost of the consultancy work is Rs.85.00 Lakh (Rs. Eighty five lakh only) inclusive of GST. Major head-wise details are presented in table below. Any tax to be paid on account of this consultancy work (e.g. GST etc.), including those to be paid under statutory rules, would be fully reimbursable to NIH with each instalment.

S. No.	Head	Amount (Rs. in Lakh)
1.	Institute charges for salary of NIH scientists and intellectual fee	58.10
2.	Project staff	7.50
3.	Consumables & Services/utilities, Equipment uses and Contingency (including overhead)	3.44
4.	TA/DA	3.00
	Total	72.04
5.	GST (@ present rate of 18%)	12.96
Grand Total		85.00
Grand Total - Rs. Eighty five Lakh only inclusive of GST		

Note:

1. Taxes applicable from time to time shall be payable by NWDA. NIH has been exempted from income tax deduction at source.
2. In case some additional data for the study is required, NIH will request the NWDA to procure it and make available to NIH.
3. After submission of final report, if any subsequent work is to be carried out, it will be charged as per actual basis.
4. All the payments are to be made by A/C payee bank draft or by e-transfer in the name of "**NATIONAL INSTITUTE OF HYDROLOGY**" payable at Roorkee. For online transfer, the account details are as below:

   A/C Name: NIH Consultancy Project; Bank A/C SBI- IIT, ROORKEE;

   A/C No. 31125916862; IFSC CODE: SBIN0001069; MICR CODE: 247002094; SWIFT NO. SBININBB559.

10.0 Payment Schedule

The payment schedule will be as follows:

S. No.	Schedule	Percentage
1	First instalment at the time of signing agreement	20% + tax
2	Within one week after submission of inception report	20% + tax
3	Within one week after submission of draft report	40% + tax
4	Within one week after submission of final report	20% + tax
Total		**100% + tax**

11.0 Monitoring of Progress

As the work is to be completed in a time bound manner, the progress of the work will be monitored by NWDA at 3-monthly interval. The general conditions of consultancy are given at **Annexure - I**.

12.0 Arbitration

Differences/ disputes if any, arising during project period, will be mutually settled through reconciliation between NIH & NWDA.

13.0 Force Majeure

For the purpose of and within the scope of the contract by way of indication and not of limitation, the term `Force Majeure' shall mean acts of nature, strikes, Lockouts,

or other industrial disturbances, act of public/enemy, wars, blockades, insurrection, riots, epidemics, landslides, earthquakes, storms, lightening, flood, washouts, civil disturbances, explosions and any other similar event not within the control of either party and which by exercises of due care and diligence neither party is able to prevent or overcome. Should the occurrence of force majeure last more than 15 days, extension of time will be given with the mutual consent of NIH, Roorkee and NWDA, New Delhi.

Signed on behalf of NIH, Roorkee On this day, Name: Dr. M. K. Goel Designation: Scientist “G” WRS Division, N.I.H., Roorkee– 247667 (Uttarakhand)	Signed on behalf of NWDA, New Delhi On this day, Name: Designation: NWDA, New Delhi

Annexure - I

GENERAL CONDITIONS OF CONSULTANCY

1. General Obligations

1.1 The consultant shall commence the study after the signing of agreement, receipt of first instalment and receipt of all required data from NWDA.

1.2 During the course of study and as a result of detailing, observation and analysis, any proposal for change in scope/agreement/price shall not be accepted. However, if any change in scope of the study is contemplated, NWDA and NIH may jointly consider such a change in conditions/agreement /price. In such a case, the necessary changes shall be introduced with mutual consent of both sides.

1.3 Under circumstances developing beyond the control of consultant, which he could not reasonably foresee and is not responsible and is unable to conduct the study, the agreement is liable to be terminated. In the event of termination of contract under circumstances beyond the control of consultant, the entire or part of the amount paid by NWDA, as decided by mutual consent, shall be refunded by the consultant.

1.4 All documents, drawings, data and information received or required during the course of the study and relating directly or indirectly to the study shall be used solely for the purpose of the study. Any confidential data/information received from the NWDA will not be published or disclosed to any other party without prior written permission from NWDA.

1.5 The consultant shall not communicate or use in advertising/publicity, or in any other medium, photograph or other reproduction of the study or any other information concerning the study without prior written permission of NWDA. However, NIH will be free to present summary information to its various technical committees, Annual Reports, web-site, technical papers etc.

1.6 The consultant shall extend full cooperation for inspection of progress of study at various stages.

1.7 Where there is a conflict as regards to the interpretation of clauses, scope of work etc., the matter will be mutually settled between the consultants & NWDA.

1.8 All the studies, data generated during study and the final study shall be submitted to NWDA in editable soft copies.

1.9 It is to submit that consolidated comments on the draft report by the sub-committee and various related experts would be compiled by NWDA and provided to NIH for revision/modification of the draft report. No subsequent comments would be entertained as it becomes a never-ending process.

2. Responsibilities of Consultant (NIH)

2.1 The consultant shall exercise all responsible skill, care and diligence in carrying out the study and shall carry out all his responsibilities in accordance with recognized professional standards/ethics.

2.2 The copyright of all documents prepared by the consultant in connection with the study shall rest with the NWDA.

2.3 NIH will not involve/engage/be responsible/answerable for any disagreement or any legal issues arising out of the results of the present study.

3. Responsibilities of Client (NWDA)

3.1 NWDA shall supply all available data and documents for the studies to the consultant in softcopy form and shall provide all such technical information as is required for comprehensive scientific analysis.

3.2 NWDA will nominate a nodal official (conversant with the study area) or a team of officials for the study for continuous interaction with NIH for providing any additional information or for any clarification.

3.3 NWDA will nominate the team of officials for regular monitoring and progress review of the study at 3-monthly interval.

* * *

Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed Mahanadi-Godavari Link

18 February, 2020

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Background

- ✓ Water balance studies done by NWDA reveal that Mahanadi and Godavari are water surplus basins.
- ✓ The combined surpluses of these basins after accounting for in-basin uses in the ultimate stage of development can be diverted to meet the water requirement of deficit basins in South up to Gundar through Mahanadi-Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar links (9 link system).
- ✓ The proposed M-G link will originate from **Barmul dam**, 14 km upstream of Manibhadra on River Mahanadi.
- ✓ After meeting the en-route needs, **4682 MCM water is proposed to be transferred to Godavari**. Total length of the **link canal would be 844 km**.

Mahanadi-Godavari Link Project

- ✓ The Mahanadi-Godavari link (M-G link) is **the first and the critical link** of Mahanadi-Godavari-Krishna-Pennar-Cauvery-Vaigai-Gundar under Peninsular Component of National Perspective Plan.
- ✓ The Sub-Committee-II (**7th meeting held on 29.09.2015**) allotted System simulation studies of M-G link to NIH, Roorkee and **Report on hydrological studies and multi reservoir simulation** up to Barmul was prepared.
- ✓ The Sub-Committee (**12th meeting held on 27.07.2018**) wants investigation on impact of issues of Climate change, change in irrigation application methods, shifting of cropping pattern, crop water requirement and the recharge of ground water in the area surrounding the M-G link.
- ✓ The Sub-Committee (**13th meeting held on 04.02.2019**) seeks proposal for *"Study of Various Possible Scenarios for Understanding the Long-term Effect of en-route Canal Irrigation for Proposed M-G Link"* based on the modified ToRs.

Layout of proposed M-G Link

Mahanadi-Godavari Link Project contd…

- ✓ The Mahanadi-Godavari link project shall provide irrigation (CCA) to the tune of 2.57 lakh ha in Odisha through the link canal.
- ✓ It is proposed to provide **125 MCM water for drinking water supply**.
- ✓ There will also be flood moderation in Mahanadi river basin.

Scope of Work

- **Analysis of present ground water scenario** in en-route command of M-G link.
- **Quantification of recharge** to ground water due to M-G link canal irrigation.
- **Evaluation of impact** of M-G link canal and its en-route utilization on the groundwater levels in the command area **over next 50 years**.
- **Estimation of additional irrigation potential** that may be created by recharged water while maintaining ground water at the safe level.
- Scope of **conjunctive use of surface and groundwater** in en-route command area so as to avoid water logging due to increased GW recharge.
- **Study of impact of different possible scenarios arising out of**:
  - ✓ Climate change in the long term, say 25 to 50 years
  - ✓ Changes in cropping pattern during next 50 years
  - ✓ Improved water use efficiency
  - ✓ Higher intensity of irrigation
- **Analysis of alternatives of water availability at source, i.e. Mahanadi at Barmul:**
  - ✓ Contribution of Mahanadi only, as being envisaged in the aforesaid study
  - ✓ Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is considered
  - ✓ Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is dropped

Study Area

- The study area covers the command area en-route Mahanadi-Godavari Link, which off-takes from the right flank of the proposed Barmul Dam on river Mahanadi in Odisha and after traversing 844 km, outfalls in the Godavari River at 15 km upstream of the existing Dowlaiswaram barrage in Andhra Pradesh.

Data Requirements

Data requirements for addressing the ground water component:

- Study area/ en-route command area of M-G link shape files.
- Historical groundwater levels and location details.
- DEM/ surface topography.
- Meteorological data (rainfall, temperature, etc.).
- Soil map.
- River network shape file.
- Existing ground water usage/ withdrawal patterns.
- Lithologs and aquifer characteristcs.
- Link canal details, like full supply level, supply schedule, canal network in the study area.
- Land use land cover (LULC) map.
- Existing cropping pattern in the study area and likely changes in future after implementation of the project.

Data Requirements contd…

Data requirement for addressing climate change & irrigation components

- Long term meteorological station data, viz. rainfall, temperature (T_{min} & T_{max}), evapo-transpiration (ET), relative humidity (RH), Wind speed, Sunshine hour etc.
- Irrigation Master Plan
- Existing irrigation practices and proposed irrigation systems.

Data requirement for addressing water availability (off-take at Barmul)

- Planned releases from the Barmul project to the M-G Link.
- Inflows from Manas-Sankosh rivers, if Farakka-Sunderbans link is considered.
- Inflows from Manas and Sankosh rivers, if Farakka-Sunderbans link is not to be considered.

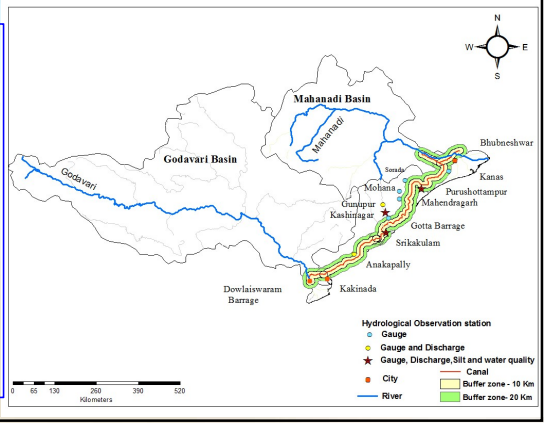
Data Requirements contd…

Data requirement for the MG Link Canal System

- Shape file of the MG Link network of canals and distribution system
- Inflows at various nodes in the canal network
- Water releases, diversions, etc. in the network system

APPROACH & METHODOLOGY

- ✓Baseline data (GIS layers) preparation
- ✓Resources estimation
- ✓Analysis for a **Buffer zone** (say) 10 km or actual command area of the M-G Link
- ✓ Major G&D sites
  - Purushottampur
  - Kashinagar
  - Srikakulam



METHODOLOGY contd…

The present ground water scenario in command area of M-G link

- The present ground water scenario in the command area will be assessed by analyzing and mapping the spatial variation of ground water based on the historical ground water level data.
- The variation of ground water will be assessed spatially as well as temporally considering rainfall variation as well as local ground water withdrawal patterns.

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METHODOLOGY contd…

Quantification of GW recharge due to M-G link canal irrigation

- Ground water recharge will be quantified using different approaches depending on the availability of data.
- Recharge in the command area will be estimated using the Rainfall Infiltration Factor (RIF), Water Table Fluctuation (WTF) method considering the GEC-2015 norms.
- The recharge from canal will be estimated using methodology suggested by GEC-2015 as well as canal geometry based empirical formula considering underlying soil and rock formations..
- GEC also suggests methods for estimation of recharge from surface water as well as ground water irrigation.

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METHODOLOGY contd…

Impact on groundwater table in command area over next 50 years

- Ground water modelling will be carried out using MODFLOW, developed by USGS, for the en-route command area by applying stresses on pumping and recharge. The model will be calibrated and validated based on the historical records.
- The calibrated and validated model will be used to further assess the impact of canal seepage on the ground water regime considering rise in ground water levels and changed cropping pattern in the command area over next 50 years.

Additional irrigation potential that may be created by recharged water while maintaining ground water at the safe level

- Additional irrigation potential, that will be created, will be estimated on the basis of average annual recharge in en-route command considering changed cropping pattern.

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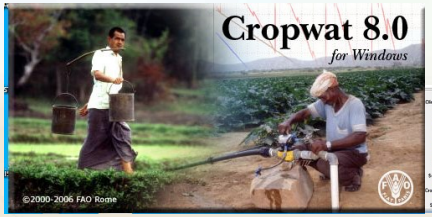
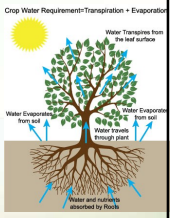
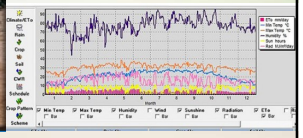
METHODOLOGY contd…

Crop water requirement

CROPWAT 8.0 will be used for calculation of crop water requirements and irrigation requirements based on soil, climate and different cropping pattern data







METHODOLOGY contd…

Scope of conjunctive use of surface and groundwater in the en-route command area so as to avoid water logging

- Seepage/recharge that will take place from the canal network, will be estimated and examined through modelling.
- If the recharge is excessive and results rise in ground water levels, then scope of conjunctive use of water shall be explored and suggested.

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METHODOLOGY contd…

Impact of different possible scenarios of Climate change in long term, say 25 to 50 years

- The **CMIP6 GCM** models will be utilized for the generation of future projections under different scenarios in the M-G Link canal en-route region.
- The future projections will be developed for precipitation and temperature during **2011-2040 (denoted by 2020s), 2041-2070 (denoted by 2050s) and 2071-2099 (denoted by 2080s)** for the study basin.
- Bias correction (BC) approach using **"quantile mapping" will be utilised to minimise uncertainties in GCM based outputs**, which adjusts (corrects) the modelled output with reference to observed datasets in post-processing step.

METHODOLOGY contd…

Climate change impact in long term on groundwater levels

- Impact of climate change on groundwater levels will be quantified using the downscaled rainfall-recharge time series in response to future climate change.

Table 1. Description of selected CMIP6 GCM models in this study.

Sr.	Model	Organization	Nominal Resolution	Run
M1	GFDL-ESM4	Geophysical Fluid Dynamics Laboratory, USA	100km	r1i1p1f1
M2	IPSL-CM6A	Institut Pierre Simon Laplace, France	250km	r1i1p1f1
M3	MIROC6	Center for Climate System Research; University of Tokyo; Japan Agency for Marine-Earth Science and Technology (JAMSTEC); National Institute for Environmental Studies, Japan	250km	r1i1p1f1
M4	MRI-ESM2	Meteorological Research Institute (MRI), Japan	100km	r1i1p1f1

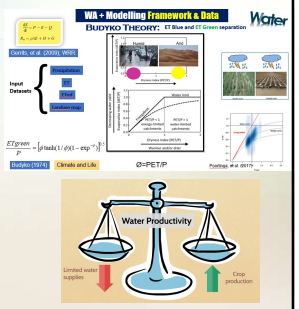
Note: The GCMs models given in the above table can be changed (+ or -) as per their availability.

- The future climate series will be used in the estimation of groundwater recharge for future to be utilized by the ground water flow model.
- The calibrated and validated groundwater flow model will be run again for developing scenarios to study the variation of groundwater levels in future.

METHODOLOGY contd…

Improved water application such as adoption of modern irrigation methods and other foreseeable factors, affecting water use efficiency

- Economic Survey- 2019-20: shifting the focus in agriculture to 'irrigation water productivity' from land productivity.
- Water Accounting Plus (WA+): technique will be used for assessing the water productivity (WP) (Kg/m3) and land productivity (kg/ha) in the M-G Link canal en-route.
- Various engineering measures and socio-economic factors will be assessed affecting the WP in the M-G Link canal en-route.
- The study will gather information from different sources, adopt suitable assumptions, and assess the overall impact of modern irrigation methods in M-G Link canal en-route.



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METHODOLOGY contd…

Different scenario of intensity of irrigation

- It is the percentage of culturable command area proposed to be irrigated annually. Usually the areas irrigated during each crop season (Rabi, Kharif, etc.) is expressed as a percentage of the Culturable Command Area (CCA) which represents the intensity of irrigation for the crop season.
- Once the amount of water to be taken as seasonally available for design purposes is determined, the key question is then the area to be supplied.
- This involves consideration of cropping pattern, water requirements of individual crops, land availability, and the socio-economic question of intensity of irrigation. Suitable assumptions (percentages) on intensity of irrigation will be considered to estimate the likely irrigated area increased (or decreased) in the study area.

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METHODOLOGY contd…

Water availability at Source, i.e., off take point (Mahanadi at Barmul)

- The water availability at source, i.e., off takes point at Barmul (Mahanadi river) will be considered considering following three alternatives:
  - ✓ Contribution of Mahanadi only, as being envisaged in the aforesaid study.
  - ✓ Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is considered as per PFR/FR.
  - ✓ Contribution of Manas and Sankosh rivers, if Farakka-Sunderbans link is dropped.

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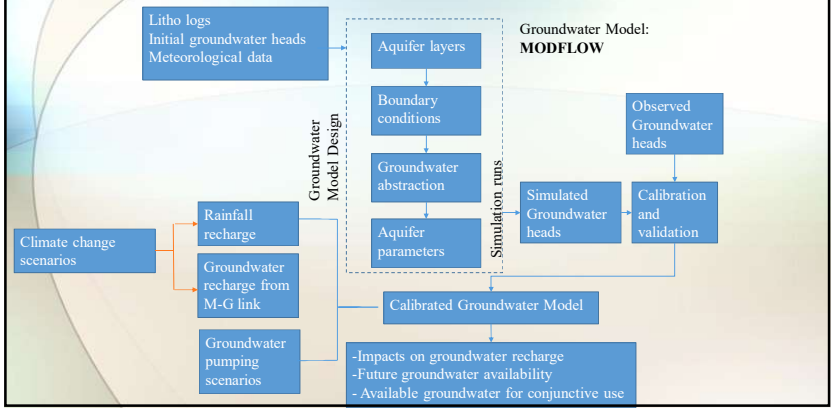
Schematic of groundwater modelling



List of Experts with Specialization

NAME	DESIGNATION	QUALIFICATION	SPECIALIZATION
Dr. Sanjay K. Jain	Scientist 'G'	M.E. (Soil Dynamics), Ph.D (Civil Engg.)	Remote Sensing & GIS Applications in Water Resources , Climate Change Studies
Dr. M. K. Goel	Scientist 'G'	M.E. (Irrigation & Hydraulics), Ph.D (WRD)	Operation of Reservoir Systems, Irrigation Water Management, Conjunctive Use.
Dr. Surjeet Singh	Scientist 'F'	M.E. (Irrigation & Drainage), Ph.D (Irrigation and Drainage Engg.)	Ground Water Modelling & Assessment, Irrigation Water Management.
Dr. P K Singh	Scientist 'D'	M.Tech (Soil & Water Conservation Engg), Ph.D (WRD)	Irrigation Water Management, Water Accounting.
Dr. P K Mishra	Scientist 'C'	M.Tech (WRDM), Ph.D (WRD)	Irrigation Water Management, Hydrological Modelling.
Dr. Vishal Singh	Scientist 'C'	M.Tech (Remote Sensing & GIS specialization in Water Resources), Ph.D (Civil Engg.)	Climate Change Modelling, Remote Sensing & GIS Applications in Water Resources Management, Hydrological & Hydrodynamic Modelling, Python Programming for Data analysis.
Dr. Nitesh Patidar	Scientist 'B'	M.Tech (Water Management), Ph.D (Civil Engg.)	Ground Water Recharge Estimation, Remote Sensing & GIS Applications, Surface & Sub Surface Hydrological Modelling.
Mr. P K Agarwal	Scientist 'B'	Dilpoma in Civil Engg, B.Tech (Civil)	Hydrology & Water Resources Systems, Environmental flow Assessment, Reservoir Operation.

Thank You