Geotechnical Appraisal of the River Linking Projects of Sankosh-Tista, Tista-Ganga Link Canal, West Bengal and Bihar

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Abstract

The paper discusses the results of geotechnical investigations on the feasibility of transferring surplus water of the extra-peninsular Ganga-Brahmaputra basin to the peninsular southern India for mitigating the water scarcity. The links envisage diversion of 43,208 MCM of water annually to Ganga. The 349km long Sankosh-Tista and Tista-Ganga (S-T & T-G) link canal is a part of the 457km long Manas-Sankosh-Tista-Ganga (MSTG) link project. The data generated on geology and engineering properties of the fore deep sediments, over which the canal alignment is proposed, is analyzed and relevant conclusions drawn. The proposed canal alignment is passing mostly through the Quaternary surfaces and partly through the Pliocene sediments. The compiled post monsoon water table data surmises a general laminar flow towards south with some local variations. The sudden change of sinuosity index of the few present day river meanders indicate that the river morphology is subjected to neotectonic activity. The satellite imagery indicates that the major tributary rivers follow NW-SE trending mega lineaments and the major fracture system in adjoining West Bengal and Bihar trends ENE-WSW. The relevant aspects of the river linking project, connecting the transboundary rivers have been analyzed with due consideration to the environmental, engineering and neotectonic parameters and their impact on ground water recharge, on which the riparian countries are dependant. Stress has been given on the aspects of ground water recharge in probable basins keeping in view of its depletion through the river linking project.

Introduction

The present work pertains to the geotechnical investigation of Manas-Sankosh Tista-Ganga (MSTG) Link canal (457 km long) project, which belongs to one of the 14 Himalayan river linking components proposed by the National Water Development Agency (NWDA), constituted by the Ministry of Water Resources, Government of India. The MSTG has three parts, Viz. Manas-Sankosh (108 km), Sankosh-Tista (143 km) and Tista Ganga (206 km). The other links related to MSTG link are Ganga-Damodar-Subarnarekha (GDS) Link (294 km), Mahanadi-Godavari (MG) Link (900 km) and the Farrakka-Sunderban link (604 km). The phase of technical feasibility study in river linking project has an immense importance and indispensable which would require multidisciplinary research using remote sensing, GIS, GPS, precision ground survey, soil-subsoil- bedrock sampling and testing (Ghosh et al., 2004).

The geotechnical investigations carried out include, study of engineering properties of the soil samples, geomorphologic and structural studies based on the remote sensing technique followed by geological mapping all along the entire stretch of the canal alignment and large scale mapping on various

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scales to investigate the cross drainage structures, high cutting-filling sections etc. Ground conditions of proposed barrage sites with ponding area and fall points have been studied for proper implementation of the scheme. Ground water data were analyzed to understand the nature of movement of water within the aquifers. As the area is tectonically active, the sinuosity index of major rivers passing through the links has been studied to understand the drainage behavior during Late Holocene period.

The main objective of the mega project is to transfer surplus water of the Ganga-Brahmaputra basin to southern India for mitigating the water scarcity, equitable distribution of water resources, increasing economic viability, ensuring livelihood, food, security, hydropower generation and navigation creating self reliance and employment opportunities for the people. The MSTG Link envisages transferring 43,208 MCM of water to Ganga annually. The transferred water will be required for en route irrigation of command areas through sub-canals. The general bed slope along the canal alignment is 20000:1.The canal will be generally 10-12 cm thick CC lined canal. Bed width of MSTG Link is proposed to vary from 66m to 121m.

Background geology and tectonic setting

The part of West Bengal and Bihar, through which these links are contemplated, comprises Mio-Pliocene to Holocene sediments. So far the Sub-Himalayan terrain is considered, the entire MSTG link is passing through the eastern extension of Bhabar, Terrai and plain zones of West Bengal and Assam. Mishra et al. (1999) suggested many devices for ground water recharge in potential areas. The northwestern part of Bangladesh and the eastern part of adjoining West Bengal comprise parts of Bengal basin, represented as one of the largest geosynclinal basins in the world (Biswas, 2003). The area lying between the Brahmaputra-Tista and Ganga-Mahananda river systems represents a watershed known as Barind (Jahan et al., 1997).

Geology of the study area

In the present study area, the canal alignment of Sankosh-Tista (ST) and Tista Ganga (TG) Links start through Mio-Pliocene represented by Siwalik Group and continuing over Pleistocene and Holocene formations comprising matrix-supported gravels and pebbles with white fine sand, silt and clay [space for Fig. 1] Geological mapping reveals that the recent sandy alluvium, distributed over the present day flood plain, is separated by a sand-silt-clay layer of Holocene period forming an aquitard all along the link canal site. Thus, while passing through the parts of West Bengal, MSTG Link will be cutting across three separate ground water provinces viz. I.) Ground water of confined condition within unsorted boulders, pebbles and minor clay, ii.) Ground water of semi confined condition within the gravel, sand and pebbly to silty strata and iii.) Ground water of unconfined condition in fine to medium sand, gravel, silt and clay. The basal Quaternary, as encountered here, is Chalsa/Rohini Formation, which is well developed in piedmont zone of West Bengal (Fig-1). The Baikunthapur/Islampur Formation (Mid-Holocene) is most extensively developed, represented by the younger fan projected above the present day flood plain (Chattopadhay et al. 1987). The present day flood plain comprising recent sandy alluvium is not shown in Fig-1.

The major fracture system in adjoining West Bengal and Bihar trends ENE-WSW and NW-SE, the former being more akin to the Bogra strike (ENE-WSW trend). The study of lineaments in the study area indicates that NW-SE trending fractures and lineaments cut across the ENE-WSW trend (Bogra strike) at steep angle. It appears that these deep seated fracture systems following the main drainages are continuous in the deep-seated Precambrians of south east influencing the movement of water in deep aquifers.

Analysis and Interpretation

Contour map of post-monsoon water table (January-March, 2004, field data) is prepared showing distribution of water table elevation of TG link from MSL [space for Fig-2]. The uniformity in contour pattern in the eastern part indicates that laminar flow occurs mostly towards south and southwest. In the middle part the water table contour map over the Balasone River valley shows a reversal of flow, this appears to be due to the presence a fault. A similar reversal is noticed in the eastern part, likely to be due to local warping in the strata. Test on irrigation tube wells of the younger formations show that the transmissivity of the sand layers vary from 795 m^2 to 3796 m^2/day and the coefficient of field permeability from 13.71 to 85.30 m/day. Groundwater of the area is alkaline with pH varying between 7.1 and 8.3, bicarbonate content from 12 to 360 ppm and chloride content from 7 to 113 ppm as per CGWB data (Chattopadhyay, 1987). Thus the chemical constituents are all in permissible limits. As per the local well study and borehole data the groundwater level of S-T link varies from 2.5m to 7.50 m from NSL except the very high cutting reaches. A 24m variation of water table from highest contour 128m to lowest contour 104m has been observed [space for Fig-3]. The uniform contour in the northern and southern part of the link indicates that the laminar flow is mostly towards the south i.e. entering the canal section from its right bank. However, there are reversals of directions in two places. Where there is a reversal of water table, the possibility of water logging is suspected in such stretches. The field data indicates down buckling of some sectors along the reach showing shallow water table. In such sectors, care has to be taken against gushing out of confined water at the time of actual excavation. Thus it can be concluded that in S-T link laminar flow towards south is prevalent with a few reversals of ground water flow direction due to tectonic control and in the rest of the stretch, canalling is likely to be feasible without ground water problem.

The analytical results of ground water of CWC in parts of Jalpaiguri indicates its pH values around 8 or more. Thus ground water in the entire stretch is alkaline and potable and its admixtures with river water does not create any extra concentration of H^+ ions per litre of solution. Generally groundwater occurs in unconfined condition in shallow aquifers requiring constant recharge.

The sinuosity index of Mahananda, Balasone, Chenga, Mechi and Kankai Rivers of TG link has been studied [space for Fig-4] to get an idea of neotectonic activity changing the river regime during the Late Holocene period. Based on the morphology of each meander sinuosity has been calculated dividing the present day meander length (W) on 1: 50,000 Toposheet by the geometrical distance (S or Cartesian distance) between the end points of meander (Fig-4) (Ouchi, 1985). Generally high to low and low to high sinuosity change indicate that river crosses subsidence or uplift axes respectively. Along the course of Balasone River sinuosity increases abruptly upto 3 over a stretch where the river is subsequent to NE-SW trending fault. The increase in sinuosity up to 2 is observed along Mahananda and Mechi Rivers also where they are found to be in association with lineament interpreted from satellite imagery. This indicates that the change in sediment discharge, stream flow pattern and ground water hydrology are all influenced / controlled by neotectonic activity along the proposed canal alignment.

The Atterberg limit (Casagrande, 1932) determined in the study area for a few UDS samples in Geotechnical laboratory, GSI, ER indicate plasticity index varying from 3 to 7 falling in ML and MI group. The liquid limit ranges from 18-32. Liquid limit below 50 indicates low swelling potential and stable characters of clay minerals. This nature of soil is due to presence of gravel with inorganic clays (CH group). The Atterberg limit shows high plasticity index having clay to silty clay composition as per the CSMRS data. The Plasticity Index (PI) or range of moisture content in these samples is up to 33% falling in low to medium compressibility type. In the section towards the Sankosh river side the soil is coarser in grain size. In such soil, with further desiccation, higher shearing stress may be obtained. The plot of plasticity chart indicates the soil to be inorganic gravel, sand, silt, clay having GC-GP group (within Siwalik Group), GM-GC, SC-SP group in Chalsa Formation and varying range of GM-GC, SW-SP and SM-SC in Baikunthapur formation. Under normal condition such strata will have higher compressibility when loaded. SM-SC group indicates somewhat peaty or organic in nature of such soil. Such soil is problematic as construction medium. Natural moisture content varies from 7-41% and the sand fraction in these samples varies from 16 to 80%, the rest is silt and clay. Average permeability is 2.9 x 10^{-5} cm/sec in T-G section and 7.90 x 10^{-4} cm/sec to 1.33 x 10^{-6} in S-T section. This indicates heavy pore pressure between the canal lining creating seepage in S-T link, for which proper care below the CC lining should be taken. Thus the permeability of the T-G link is less and requires toe drainage and that of S-T section is more (7.90 X 10^{-4} cm/sec) in particular area due to presence of sand and gravel. Shear parameters in T-G section show average C (Cohesion) and j (Angle of shearing resistance) values as 0.45 kgf/cm^2 and 24^0 respectively. The UCS of S-T section varies from 1.063 to 1.447 kgf/cm^2 This comes within the category of fine to stiff clay of grade S_3 to S_4 (IS: 11315, part-5, 1987). The shear strength indicates that the soil in general posses reasonably good shear strength sheared under confining pressure of 1, 2, 3 and 4 kgf/ cm^2 respectively after achieving full saturation. SPT has been carried out in sandy to pebbly sections, but generally it shows refusal due to presence of pebbly strata at shallow depth. The ultimate bearing capacity is 8 to 10 kgf/cm^2 (about 800 to 1000 kN/m^2) with an estimated amount of settlement of 8 to 10mm would indicate that there is no weaker stratum in those sections [Method of load test on soils, BIS 1988 (1971)]. Or Unconfined Compressive Strength (UCS) of 388 kN/m^2 or more can be compared to SPT value of 30 or more for laying normal canalling structures like syphons etc. if it is less than 388 kN/m^2 suitable safety factor of 3 may be incorporated in laying canal structures. In the proposed two barrage sites of S-T link raft foundation is suggested as sheet piling in such pebbly strata is not possible. The test results of T-G link indicate non-plastic behaviour of the sandy to silty soil having good porosity. The construction of canal in this medium is not problematic. SM (Boundary classification within the gravel and sand groups) class indicates sandy to silty nature of the soil having poor to fair drainage. The unit dry density of 1.76-2.00 indicates poor to good bearing capacity.

Discussions and Conclusions

The geotechnical investigation carried out in the stretch of the link canal shows that the non plastic sandy to silty soil is having good inter-granular porosity. SM-SC group indicate peaty soil in some section, which may create settlement. It is suggested to remove such soil as far as practicable before laying foundation. The soil generally possesses good shear strength under normal pressure. The LL value indicates low swelling potential and stable characters of clay minerals. Permeability of soils varies from strata to strata. In some sections of S-T link where permeability is more, suggestions have been given to take adequate care in CC lining to combat heavy pore pressure below such lining. To maintain non-scouring velocity of 20000:1 of the canal lining 7 fall points have been proposed by the project in TG link, which have been studied in detail. The maximum fall is 17m. Slight shifting of one such fall points have been suggested from Baikunthapur Formation to adjacent Chalsa Formation which is having comparatively better compaction and better oxidized soil. One fault is located at the proposed Torsa river barrage site, where proper exploration is suggested as surface manifestation of such features is minimum in alluvial tract. At the beginning of the S-T link, a 20 to 25m cutting is involved, where ground water lowering has to be done before actual excavation. From the study of ground water contour, laminar flow towards the south has been seen. However, reversal of flow is located at places, where, there may be water logging. The shallow water table occurring due to the down buckling of some sectors (field data) may result in gushing out of confined water at the time of excavation in those sectors.

The MSTG Link is contemplating to divert 43,208MCM of water to Farakka annually as per National Water Development Agency (NWDA) proposal. The Brahmaputra has an annual flow of 585.60 BCM or 585600 MCM (Sinha Roy, 2004). So, the transferable water by MSTG Link comes to about 7%. But presently there are infrastructure problems of transferring the Manas river water for wild life sanctuaries in Assam. Therefore, proposal for transfer of water only from the Sankosh and the Tista rivers has been made at present. Thus the figure of 7% transfer will be further reduced. The estimated flow of Brahmaputra during monsoon is around 30,000 CM/sec. and the possible diversion comes to about 1500CM/sec indicating a 5% transfer of water during the peak monsoon period (Sinha Roy, 2004). The other apprehension from the scheme is that the continued supply of diverted river water may decrease the fertility of the soil due to increased salinity. There is a speculation that further increase of salinity will be there in Sunderban and South West part of Bangladesh when river linking project will be implemented. Already the mangrove economy of these areas is affected due to incursion of sea water (Azad et el., 2004). Therefore, provision of releasing additional water in Ganga should be kept while implementing the project to mitigate this problem.

So far as positive aspects are concerned, river linking would help improve flood control measures through transferring surplus water to other deficient basins forming water grid across the regional domains. This project is expected to help Assam, Bihar and West Bengal in respect of flood control measures. Besides it would help irrigating dry lands. Soil erosion would also be checked to improve siltation problem downstream. Irrigation in the command areas will help recharging ground water aquifers particularly in weathered and fractured rock profiles or in sand/silt layers connected to shallow or medium aquifers in the sub soil. Thus in specified rechargeable areas continuous supply of water may make influent rivers temporarily effluent.

This plain zone comprises well stratified, fine to medium sand, gravel silt and clay. Here ground water occurs in unconfined condition in shallow aquifers requiring constant recharge. The actual rechargeable zones will be identified first and water harvesting structures would be located there. The recharge will be carried out through out the year by sub canals making irrigation a success even in dry season. This type of recharge is urgently needed for the depleting water table of unconfined shallow aquifers located in parts of West Bengal and Bihar.

The ground water province of the sandy alluvium, which is occurring as an over-bank type of deposit adjacent to the rivers but separated from the underlying Holocene aquifer by silt-clay aquitard, can yield large quantities of ground water that can be used for potable purposes. One of the aims of the river linking project is to provide canal water to the vadose or porous zones, permeable and unsaturated geological horizons making it as subsurface ware house. The flood plains of West Bengal and adjoining Bangladesh are having porous zones with intergranular porosity more than 50%. The present day river system is draining this porous zone making it unsaturated. The river-linking project is contemplating to recharge such unsaturated zones capturing the free flow water of

Sankosh, Tista etc. in their upper reaches. As the movement of ground water is due south in the Tista-Ganga reach, canal water is expected to recharge a large area further south where the permeable zone is having continuity. Thus the withdrawal of water in these links should not deplete the ground water level appreciably in Bangladesh jeopardizing the saturated zones of Dupitilas in Table land, which was a speculation for this neighboring country. The Dupitilas in Bangladesh, which is the main aquifer in the table lands (Khan, 1991) has a variable recharge potential depending upon the thickness of the strata and dip direction. As it is already discussed that the diverted water will be used in potential command areas and after the recharge of such areas, water will be diverted back to the main river system.

From the study it is revealed that the river linking projects as contemplated is viable through a consideration of geoscientific aspects. The negative aspects of the scheme are however, minor depletion of water in major rivers as well as shallow and deep aquifers. The geotechnical study of the Links indicates that canalling through the detrital sediments of the area is feasible. Only high cutting sections have to be carefully tackled as all the strata are not well oxidized and bonding is not uniform throughout. Two barrage sites studied at the Torsa and Jaldhaka rivers indicate that natural geographic and terrain condition favours for such structures and ponding area is located well within the topographic boundary. Geotechnical parameters of the soil samples indicate favourable canalling conditions excepting few places where permeability character of the soil is more, to create pore pressure in the canal lining.

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