Water Resources Evaluation and Management – Terrain Analysis: A Parametric Approach

Dr. Parthasarathi Chakrabarti[1]

Chief Scientist

Introduction

In ancient Indian literature an 'ashirachan' (benediction) –

"Kale Barsatu Parjjanang Prithivi Sashyasalini

Loka Santu Niramaya................."

In time rain may provide adequate/ plentiful crops to the earth and human being would be with satisfaction.

The benediction apparently expresses the inter-linkages between the 'Hydrodynamic Circulation' and use of water resource. However, the main theme specifies the bi-directional relationship between the Human subsystem and Bio-physical environment.

In Yajur-Veda-Samhita (18/36) and Rg-Veda-Samhita (1/23/19) the water resources management is expressed as "conserve, water beneath the ground, water within the plant bodies, water up in the sky and the water in the atmosphere – may all quarters of the earth be full of flowing water for living being".

In present day context, to meet up increasing human needs water resources evaluation and management should be considered in terms of integration of

- 'Water Model' (Basin/ Watershed) and
- 'Response Model' (Socio-economic and Environmental issues) –

to establish dynamic viewing capabilities for identification of acceptable changes between 'Hydrodynamic circulation' and 'Geo-bio-cultural' interactions.

Basically water resources management and development is an attempt towards a redistribution of water ***'in space'*** (i.e. diversion of water) or ***'in time'*** (i.e. storage of water). However, each of these situations means certain change in the 'hydrologic cycle' vis-à-vis watershed (upto micro-watershed level) as the latter is the natural unit of the former on the earth's surface.

Basic Issues

The core business of water resources management may be conceptualized in terms of management of eco-system (i.e. nature's own built system) encompassing human oriented demands with technological development.

[1] Department of Science & Technology, Government of West Bengal, Bikash Bhavan, Salt Lake, Kolkata – 700 091 (West Bengal).

For the purpose, a balanced interrelationship between the hydrological environment and anthropogenic activities is to be maintained. In this respect, essential pre-requisite is integration and analysis of 'proto-type' data (both spatial and aspatial) on hydrogeological/ geomorphological parameters along with societal aspects viz. land use/ land cover, irrigation facilities, drinking and other household consumption etc. to formulate guidelines for rational use of this renewable resources.

Water in hydrologic cycle is a renewable resource and characteristically different from any other natural resources in the context of nature's own built system i.e. continuously circulated by the energy of the sun.

Depending on various climatological and meteorological factors the available amount of water may vary from season to season or year to year. For the reason, long observation period is required to establish the annual variation factor which is fundamentally different from other natural resources e.g. soil survey or geomorphological survey. To foresee the variation after 10/20 years, a network of gauging stations needs to be established.

Precipitation, surface water flow/river flow and ground water are not separate resources; they are parts of the same cycle and interchange many times. For example, infiltrated groundwater may be available further downstream of a river as surface flow (cf. 'effluent stream'); again surface water flow may in turn infiltrate and join the groundwater (cf. 'influent stream').

Therefore, water resources management / development requires a comprehensive evaluation of both surface water and ground water conditions of an area on watershed basis with regional perspective. For example, one watershed/ river basin considered for water resources development could be divided easily into three sectors (Fig-1) viz. upper catchment area (I), middle (II) and lower stretches (III). Now, let us assume potential groundwater resource in the three (3) sectors are evaluated as 2, 5 and 9 units respectively. Apparently, the total groundwater potential in the watershed would be 16 (2 + 5 + 9) units.

It will be a serious mistake, if we proceed with the above figure for development of groundwater resources of the area. For instance, if the 2 units of upper part (i.e. area I) is developed, then the potential groundwater resource in middle stretch will be reduced accordingly to (5 – 2) = 3 units only; and in the lower stretch it would be reduced from 9 units to 7 units (9 – 2) = 7. If both upper and middle sectors are developed then only 4 units [9 – (2 + 3) = 4] would be available in the lower stretch. Therefore, in case of full development of three sectors only 2 + 3 + 4 = 9 units would appear to be available (cf. Bosscher, 1984).

So, water resources development needs very careful analysis of the upper catchments to the lower stretch of a watershed otherwise scattered local level surface/ ground water management in the upstream is likely to affect negatively the recharge in the downstream of a river.

Prime Requisite

A. Generation of spatial database (on scale 1:50,000 and 1:25,000) with morphogenetic approach through terrain evaluation includes —

(a) Creation of primary database on :

- Drainage, watershed (up to micro-watershed level) and surface water bodies
- Hydro-geomorphology and ground water prospect
- Land use/ Land cover pattern
- Slope, aspect and altitude
- Physiographic soil unit
- Settlement location along with administrative boundaries (upto mouza/ village level)

(b) Collection of functional datasets (i.e. non-spatial data) include proto-type physico- chemical attributes e.g. —

- Meteorological data
- Seasonal and annual fluctuation of depth to water level (DWL)
- Porosity and permeability factors of the country rocks/ sediments
- Chemical analysis data of the soil types, water quality etc.
- Demographic composition and usage of water for different purposes etc
- Historical/ traditional data in societal aspects on use of water

B. Integration and analysis of the spatial and aspatial data towards generation of 'pragmatic dataset' (Fig-2) for preservation of ecological system by assessing the capacity of landscape to sustain the present land use or to adopt alternative land use.

C. Social adaptations by stimulating awareness in the society through community preparation towards potential response to land and water resources management in village/ mouza level with regional perspective.

Modern Technology – Geoinformatics

Geoinformatics, operational combination of RS and GIS technologies (Fig-3; Chakrabarti & Nag, 2002) play facilitator role in collection as well as integration and analysis of the up-to-date spatial database and aspatial/ attribute data to generate 'Strategic datasets' for technological adjustment (by structural means) and social adaptations (non-structural means) with future perspective.

In present day context, the state-of-art technology of the high resolution (< 1.0m) 'operational' Earth Observing Satellites (EOS) provide multi-temporal/ time critical up-to-date 'real world' scenario in digital mode or in hard copy format.

Now-a-days, in addition to the high resolution optical and microwave satellite data, Hyperspectral imaging, LiDAR and Airborne multi-spectral digital camera data are also available. In 'Hyperspectral Imaging' system (with more spectral bands and narrow band widths) scope of separability of individual objects / earth cover types is enhanced significantly to get data with "spectral un-mixing". 'Hyperion' is the first hyperspectral imager launched by NASA in December 2000. During this decade airborne hyperspectral images and LiDAR data have gained importance in advanced countries (Table 3 & 4) for site specific detailed information.

However, it is to be mentioned here that the multi-seasonal satellite images with 70 – 20m resolution are more suitable for 'knowledge based' interpretation of geological and geomorphological characteristics of the terrain with regional perspective. Subsequently, 'site-specific' geospatial information could be collected using 'high resolution' images to frame guidelines for generation of specific aspatial attributes through insitu observations/ ground truthing from specific locations.

In response to the 'PIXEL ⇋ RASTER FORMAT' inherent relationship, the RS data are being used readily in GIS environment for integration and analysis of spatial and related non-spatial attribute data as per user choice (Fig 4). However, it is to mention that GIS functionality in hydrological studies requires special attention to design the database accommodating both the physical and anthropogenic variables / factors for answering the questions about the 'real world' – not a simplified model.

Conflicts

It is already mentioned that terrain and water availability are closely related which is again very much influenced by the land use practices i.e. anthropogenic activities. For the reason, in water resources management / development, the most holistic approach is to identify a watershed / river basin (a morpho-hydrological unit) and to analyse the effect of anthropogenic influence on physical system for development accordingly.

This approach has also been accepted in the National Water Policy. However, in this respect the conflicts generally faced are –

- Watershed boundaries versus administrative boundaries (i.e. District / Block / G.P. / Mouza) in implementation of watershed / river basin concept e.g. Dwarkeswar watershed covers parts of Puruliya, Bankura and Hooghly districts, West Bengal from west to east (Fig. 1). So, a comprehensive plan is to be taken up accordingly on watershed basis as discussed earlier.
- Application of micro-watershed concept in relation to physiographic provinces e.g. whether micro-watershed zonation is applicable in the drainage basins with tributaries (as present in Pedimental landscape) or distributaries (present in Alluvial fan/ plains) or anastomatic pattern in Deltaic / Coastal plain.
- Existing land use pattern in response to the present day societal aspects versus acceptance of alternative land use practices e.g. marginal farmers are scared to accept alternative practices considering the risk factor over their assured production / income.

Dynamic groundwater resource can be utilized without endangering the natural hydrologic regime as it gets recharged or replenished periodically or annually by rainfall, irrigation return flow, influent seepage from rivers and other water bodies (Goswami, 2002).

Case History Example : West Bengal Scenario

The state of West Bengal exhibits a wide variation in geology, geomorphology, soil types, climate and distinctive land use/ land cover pattern. The hydrological behaviour at regional level as identified by the Central Ground Water Board (CGWB), Govt. of India and State Water Investigation Directorate (SWID), Govt. of West Bengal (Moullick, 1996), represents a picture of overall satisfaction; however, each and every region is having very specific problems in water resources management considering the hydro-geological/ geomorphological parameters vis-à-vis societal aspects.

Northern hilly/ Mountainous zone

The area constitutes a part of the eastern Himalaya – a mobile belt of active tectonics. This highly sloping landscape receives maximum amount of rainfall. Major portion of the precipitated water finds its way as run-off through streams / rivers and a part infiltrates into the weathered residuum as well as through suitable fissures / joints in the hard rocks to form groundwater which emerges out through fractures in the lower slopes of the hills. Considering the hydrological behaviour of the area, the following measures may be taken up to facilitate the water resources development / management plan –

- in addition to the existing natural lakes, small reservoirs may be constructed in the seepage / spring zones.
- 'roof top' rainwater harvesting programme is to be implemented for both urban and rural areas considering the high rainfall and many cloudy days.

Foot hill zone and Ganga-Bramhaputra Alluvial plain

The foot hill zone is an unique example of coalescing alluvial fans (fan-in-fan morphology) of the Mahananda – Tista – Torsa river systems. In regional context, three geomorphic surfaces have been identified at different altitudes of the fan deposits based on the constituent materials (comprising hill wash / colluvial / alluvial deposits), degree of oxidation etc. (Ghosh & Majumder, 1990; Goswami, 1993; Das & Chattopadhyay 1993) –

- High altitude Samsing – Thalajhor surface (600-280m) - (Proximal Fan)
- Middle altitude Matiali – Chalsa surface (280-80m) - (Intermediate Fan)
- Low altitude Baikunthapur - Saugaon surface (180-30m) - (Distal Fan)

The 'distal' part of the fans are extended further south in the Cooch Behar and Dinajpur districts and terminates at the Barind surface, at places. The high and middle altitude fan deposits are basically recharged with the infiltrating rain water from the higher slopes in addition to the direct seasonal precipitation. However, due to slope factor and nature of constituent materials (unconsolidated/ semi-consolidated assorted boulders, cobbles, pebbles mainly in a sandy matrix) the stored water move further south along the slope. Due to this, in break-in-slopes, seepage zones are present and water flows forming small streams along the slope and ultimately joins the major rivers – as present in Gopalpur, Gayerkata tea estates.

However, all these seepage / autoflow / spring flow zones are becoming dry in the summer months causing acute shortage in surface water availability in the area. In general, all major tea estates of the area are suffering from water scarcity problem in summer time. To ameliorate the problem to a certain extent, tea estates may go for:

- 'roof top' rain water harvesting and store the water in excavated tanks. However, to check the infiltration of the stored water due to high porosity and permeability factors of the ground, the tanks are to be treated properly with some lining e.g. the bottom of the tank may be with lithomerge clay lining and the side walls may be lined with jute geotextile along with lithomerge clay layer instead of cementing.
- construction of 'horse shoe' dykes in the seepage / spring flow zones to store the water in small reservoirs.

In regional level, good water resources availability is reflected from the absence of 'land without scrub' type wasteland as well as presence of 'waterlogged and marshy land (permanent)' in Jalpaiguri and Cooch Behar districts covering 7.81% and 10.77% area respectively with respect to total geographical area of the districts (NRSA, 2005). But in terms of assured 'irrigation supply' for cultivable land and potable water availability, the water resources management invites special attention in respect to changeable depositional / erosional activities of the rivers emerging from the Himalayas. Therefore, water resources management in this terrain should be based on the physical / spatial parameters with identification of individual fan lobes through micro-level terrain analysis rather than overall 'watershed concept'.

It is worth mentioning here that considering the physiographical and lithological factors of the terrain 'locale specific' small reservoirs with canal system interlinking the seasonal streams will be more beneficial for 'irrigation supply' than big dams / reservoirs on the major rivers. In this respect, the adverse effects of the Kosi basin canal system in terms of aggravating the water logging situation due to seepage from the canal system may be taken into consideration.

Central Gangetic Alluvial plain

In general, the Central Gangetic alluvial plain is considered as a repository of groundwater and characterized by the presence of thin and thick aquifers separated by clay beds. However, the main problem of this zone is the occurrence of arsenious groundwater in the intermediate aquifer (20-80 m.b.g.l) of the Younger Alluvial Plain (YAP). Spatially, the YAP is present both in the eastern and western side of the Bhagirathi-Hooghly river. In the east, YAP occupies mainly the interfluve zone of Bhagirathi/ Hooghly and Ganga/ Padma river system, a narrow strip of YAP is present in the west of Bhagirathi-Hooghly river bordering the alluvial upland (Older alluvium / Shelf zone; Ghosh & Majumder, 1990).

The recent study on the role of geomorphic composition and anthropic influences on As-contamination in groundwater of the area of interest by the Deptt. of Science & Technology, Govt. of West Bengal (2006) reveals –

- A distinct relationship prevails between the 'As-high' (i.e. concentration > 0.05mg/l) zones and the geomorphology of the area. The 'As-high' zones are preferentially located close to the existing wetland features of fluvial origin (viz. meander scrolls / scars, ox-bow lakes, abandoned / moribund channels/ rivulets, 'beels'/ 'jhils'/ back swamps etc.).
- Comparative analysis of the As-concentration in the pre-monsoon and post-monsoon / winter season water samples (from same wells) reveals that higher As-concentration is present in the post-monsoon / winter season samples at places where groundwater is being extracted for irrigation of rabi and summer crops. In this context, Nadia district could be cited as an example where surface water bodies are more than other arsenic affected districts. In Nadia district only 26% of the wells showing high As-concentration in post-monsoon / winter season in comparison to 70 – 75% wells in Murshidabad and Malda districts – reflects on use of surface water sources for rabi and summer crops – however, detailed 'site specific' study is required. Similarly, in southern part of 24 Parganas (N) and 24 Parganas (S) as a whole, in general, the ground water are not being used for rabi

and summer crop cultivation as near surface aquifers are saline or brackish in nature – upto 160 m.b.g.l. (Chakrabarti; 1995).

It is worth mentioning here that very recently presence of high fluoride concentration has been reported from Malda, Uttar & Daksin Dinajpur and 24 Parganas (South) districts. However, further detailed study is required to find out whether the areas are within the younger Alluvial Plain (YAP) or not as As-concentration is mainly present in the YAP.

Considering, the interdependence of various physico-chemical parameters, sediment types and anthropogenic influences, it will be wise to make good use of the surface water. In this respect, necessary 'site-specific' surface water conservation practices may be adopted in village level using numerous 'beels'/ oxbow lakes etc. In long term perspective, the 'Nadia group of rivers' may be rejuvenated through river interlinking (Chakrabarti, 2004) to get all season flow in the rivers and use of the river water both for irrigation and drinking water supply.

It may be added that the Bhagirathi / Hooghly river, in general, is taken as the western limit of the Ganga delta. However, studies on palaeo-geographic development of the Ganga delta (Niyogi, 1975; Umitsu, 1993, Acharya et.al., 1999, 2000) indicate that the Bhagirathi / Hooghly river has shifted towards east through space and time since 22,000 YBP with the development of the deltas of the east flowing right bank tributaries (viz. Mayurakshi, Ajay, Damodar etc.) coupled with neotectonic activities. All these inland deltas / fans are good repository of ground water, however, subject to flood inundation during rainy season.

Western upland

The western upland, regionally, constitutes the eastern fringe of the Chhotanagpur plateau with erosional remnants (in the form of isolated hills) exhibiting highly dissected pedimental landscape and lateritic upland with skeletal soil covering Puruliya district and parts of Bankura, Paschim Medinipur and Birbhum districts. It is an established fact that the surface runoff of seasonal rainfall (1300-1350 mm) is more in the area due to its terrain characteristics which is also accelerated by the existing landuse practices.

In this type of terrain, surface water management through micro-watershed planning in sub-watershed orientation in conjunction with adaptation of alternative landuse practice may be considered as the best form of landscape ecology vis-à-vis biological diversity – where a compromise is sought between the upstream (catchment area) and downstream bio-physical environment of a river for wise use of natural resources through analysis of traditional and existing landuse pattern. To do so, multi-theme information regarding drainage / surface water bodies, hydro-geology/ geomorphology, land use / land cover are to be generated for identification of –

Abandoned channel courses Areas of 'geomorphic anomalies' Inland delta/ fan	Geomorphological aspects
Areas of lineament intersections Autoflow/ spring flow zones	Geological perspective

In this respect, multi-seasonal / time critical RS data provide immense help in identification of the above referred features subject to ground verification for collection of related aspatial ground / insitu data using conventional methods. Subsequently, under GIS environment, both the spatial and aspatial datasets should be analyzed to generate pragmatic 'geo-information' for site specific 'Rain water harvesting structure' in micro-watershed orientation and 'potential zones' for groundwater targeting or artificial recharge.

In this context, some examples are being furnished below from the database generated under various national / state level programmes by the Geoinformatics & RS Cell, DST, Govt. of West Bengal –

- Bordering the lateritic upland, in Kotalpur block, Bankura district, an impression of moisture saturated zone connecting the older meander scrolls of Damodar river in the north and Dwarkeswar river in the south has been identified in the satellite images. Existing literature reveal that this particular zone is the impression of the *Dakshin Saraswati* river. This link river was present in the 8th (eighth) century and was abandoned in the 14th century (Chakrabarti, 1999; Roy 1952).
- Analysis of lineaments and depth to water level fluctuation (pre and post-monsoon/ winter season) in pediment zone of Puruliya, Bankura, Paschim Medinipur, Barddhaman and Birbhum districts reveal –
  - E – W trending lineament is not favourable for ground water localization
  - N – S, NW – SE and NE – SW lineaments, singly or intersecting are more or less characterized by the presence of shallow (3.0 – 5.0 m.b.g.l.) to moderate (5.0 – 7.0 m.b.g.l.) depth to water level in pre-monsoon period
- In Dwarkeswar Watershed areas of 'geomorphic anomalies' and intersecting lineaments are indicative of good ground water condition e.g. 'zero' fluctuation zone in Tilaboni hill area, Puruliya district; small ground water 'highs'/ 'mounds' around Kharbana – Chanpasol – Bindna villages, Chhatna block, Bankura district etc.
- In Damodar watershed, the ENE – WSW / E –W trending major lineament (North Puruliya Shear Zone) act as a conduit for surface water movement. The reservoir at Dubrajpur village, Puruliya I block is unable to support the beneficiaries of Para block in the downstream (i.e. northern side of the reservoir) as the water while passing over the shear zone with highly fractured and crushed CGC (Chhatonagpur Granite Gneiss Complex) rocks, percolates beneath the surface.
- In the adjoining parts of the Dwarkeswar and Kangsabati watershed, in Hura block, Puruliya district, the identified lineament in the satellite image is actually a dolerite dyke and acts as a barrier for movement of groundwater as exemplified by the depth to water level (DWL) data from dug well on both sides of the dyke around Amlator – Chatumudar villages.
- The presence of 'autoflows'/ 'flowing tube wells' at places in the lower fringe of the lateritic upland draw special attention in terms of existence of 'shallow confined aquifer' between lateritised gravel bed and the underlying lithomerge clay/ clay stone member (cf. 'Shantiniketan formation' – Deb, 1995). In micro-watershed development programme such 'flowing tube wells' may play facilitator role to increase local irrigation potential for winter crops in the surrounding plots. For

example, in the middle stretch of the Kunur watershed around Saraswatiganj,

- Kanksa block, Barddhaman district, a ring canal has been constructed along the fringe zone of the Dissected Lateritic Upland to collect the run off during monsoon as well as the seepage water as stated above. In Jambani block, Paschim Medinipur district, Beliya, Burihandi – Asanboni, Balibhasa areas (Dulung Watershed) extensive winter crops (wheat, mustard & vegetables) and at places early 'Boro' paddy are being cultivated using such flowing water.

In view of the above in micro-watershed development programme one should be aware about the terrain condition / geoinformation to achieve the best result (Chakrabarti, 2004) for example —

i) Construction of 'Rain water harvesting structures' (e.g. check dam, nalabundh etc.) within micro / mini watershed requires very specific detailed ground / insitu survey for identification of suitable sites for such structures e.g. the nalabundh at Kajalpahari Ghat on Kulia Nadi, Abdarpur village, Birbhum district, became useless as the river bypassed the structure. However, suitable site for such structure with rocky basement and side wall, is present about 100m upstream of the river (Chakrabarti, P. et.al. 2006).

   It is worth mentioning here that based on 'locale specific' geo-information about one hundred (100) check dam sites have been identified by this department in Puruliya district. It may be added also that desiltation in the upstream side of the check dam should be considered as a routine work and that could be done in the pre-monsoon period engaging local people under any income generating programme of Government.

ii) In the Ayodhya hill surroundings (parts of Baghmundi, Balarampur, Arsa and Jhalda blocks, Puruliya district), the hill wash deposits (especially 'Accumulation glacis') play an important role in recharging the groundwater table in accordance with the master slope. The hill wash deposits constitute unconsolidated to semi-consolidated materials with varying texture and thickness, which retains a major portion of normal precipitation and has locale-specific significance in surface and ground-water movements. Due to such geomorphic configuration, construction of low height 'horseshoe dyke' is likely to arrest surface run-off for subsequent recharge of groundwater as well as partial utilisation as surface flow.

   On the other hand, in coal field area (Andal, Raniganj blocks, Barddhaman district), the areas of subsidence could easily be identified from the 'geomorphic anomalies' and 'drainage deflection' – those areas are not favourable for micro-watershed development approach as well as groundwater targeting as the terrain condition is obliterated to a great extent by mining activities (Chakrabarti, 2001).

iii) In this pedimental landscape with lateritic cover, the tanks are to be excavated to touch the impervious lithomerge clay layer (i.e. around 15' — 25'). Wherever, such layer is not present, a layer of 1'-2' thick lithomerge clay may be provided at the base. In the side walls of the tank, 'Jute Geo-textile' may be used along with a lining of 'lithomerge' clay. It may be mentioned that lithomerge clay is available in the lateritic parts of the districts as well as waste material of the china clay quarries in the districts. In this aspect, the tank excavated at Amjhor village, Puruliya II block by Ramakrishna Mission Vidyapith, Puruliya and the tank in Ramkrishna Mission Vidyapith, Puruliya may be cited as examples where this Department has provided S & T input as well as fund support. Recently, this department has also identified around one hundred (100) tanks in Puruliya district for re-excavation to attain the above specified depth or treatment.

iv) Already existing large gully head tanks may be desilted to increase the storage capacity of the tanks as suggested for Babubandh, Sadar block; Jahanabad tank, Gangpur G.P. Rajnagar block, Birbhum district, Dulmi and Raja bandhs, Puruliya outskirts. Best example is the Chharra gully head tank, Puruliya II Block, where desiltation has been done by R.K. Mission with fund support of this department. It may be mentioned that there are about fifteen (15) such bundhs/ tanks are present in Puruliya district which needs desiltation to increase the water holding capacity.

v) Regarding 'rooftop rainwater harvesting' structures, the Primary, Secondary and Higher Secondary Schools may be targeted. In this regard, this Deptt. has already provided funds to the Puruliya Zilla School and Balakdih School, Manbazar for the purpose. However, it has been suggested that 'Jute Geo-textile' and lithomerge clay may be used for the 'Storage tanks' instead of brick lying to maintain the BOD level.

'Site Specific' alternative land use practices in accordance with the terrain characteristics in drought prone area often increases moisture content of the skeletal soil as well as prevents land degradation processes. For example –

- 'Tnar' and 'Baid' lands with skeletal soil may preferably be used for Agro-horticulture/ Agro forestry instead of low productive kharif crop.
- 'Kanali' and 'Bahal' areas are, in general, with good soil profile with high moisture content. In the 'Bahal' (geomorphologically-Infilled Valley) summer rice ('Boro') cultivation is very common and life-saving irrigation is being provided using the available water from the adjacent water bodies making them dry during the summer season – causing societal problem.
- Wastelands (with/ without scrub / stony waste areas) could be used for plantation of bamboos, Acacia etc. and at places agro-horticulture (e.g. Guava, Papaya etc.) may be introduced with rainwater harvesting.

In the western upland areas, occurrence of high concentration of fluoride in ground water has been reported recently from 10 (ten) blocks of Bankura district, 7 (seven) blocks of Birbhum and 17 (seventeen) blocks of Puruliya district. On this aspect, Central Ground Water Board, Govt. of India, SWID, PHED and Deptt. of Science & Technology, Govt. of West Bengal are engaged in database generation to ameliorate the problem as far as possible. It is worth mentioning here that the "Task Force Committee on Fluoride Mitigation Programme" has also suggested to take up "Rainwater Harvesting Programme" in Puruliya district as short term measure to provide safe drinking water after necessary treatment.

Coastal zone

The Coastal Quaternaries, West Bengal is characterized by a broad expanse of fluvio-tidal and marine-coastal sediments (viz. sand, silt and clay) resulting from Flandrian transgression (around 6000 YBP) – the 'on-lapping' sequence and subsequent delta pro-gradation (the 'off-lapping' sequence) upto the stabilization of the sea level, around 3000 YBP to present (Chakrabarti, 1995a).

The coastal tract of West Bengal is characterized by the presence of two contrasting coastal environs :

- Macro-tidal (tidal range : > 4.0 m) Hooghly estuary (covering Sagar-Namkhana islands including 'Sunderban')
- Meso-tidal (tidal range : 2.0 – 4.0 m) Digha – Junput (Medinipur) coastal plain in the west of Hooghly river

A comparative analysis of the existing database of CGWB on Hooghly estuary and Medinipur Coastal plain reveals that the potential fresh water aquifers occur at great depth between 160.00 – 330.00 m.b.g.l. in Hooghly estuary (e.g. at Kakdwip, Namkhana, Sagar islands) than the Digha-Junput area (Medinipur coastal plain) where it varies from 91.44 to 140.20 m.b.g.l. and 167.64 to 198.12 m.b.g.l. (Chakrabarti, 1995b; Goswami, 1997). This variation in depth range may be the reflection of the increased thickness of Quaternary sediments in the Hooghly estuary in comparison to Medinipur coastal plain due to 'structural lowering' or 'geosynclinal downwarping' (Chakrabarti, 1995a). According to CGWB (Mishra, 1996), the brackish water aquifer occurring at 150 – 180 m.b.g.l. in the east of Hooghly river increases to 320.00 m.b.g.l. in the extreme south -eastern part of the coastal stretch.

In the coastal tract, occurrence of saline and brackish water aquifers at shallow depth is the main problem. The generalized hydro-chemical profile as revealed from the electrical log of the boreholes (CGWB reports, 1979, 82 & Das 1991) in Kakdwip, Namkhana and Sagar islands is furnished below :

- Saline water (0.00 – 84.0 m.b.g.l.)
- Brackish water (84.0 – 160.0 m.b.g.l.)
- Fresh water (160.0 – 330.0 m.b.g.l.)
- Saline water (330.0 – 530.0 m.b.g.l.)

The deeper aquifers between 180.0 to 330.0 m.b.g.l. are the potential source of fresh water with an important water saturated granular zone in the depth span of 250.0 – 280.0 m.b.g.l.

In view of the above, the following points emerge for water resources development and management in the coastal belt of West Bengal :

- in the context of prevailing erosional activities and shifting of high water line (HWL) both in the Hooghly estuary and western part of the Medinipur coastal plain (i.e. Digha – Chandpur / Shankarpur Sector), freshwater – saline water interface study should be carried out. It may be mentioned that the CGWB has indicated extension of saline tract inland for about 9.0 to 12.8 km in the area (Das, 1996)
- rain water harvesting through large lined tanks, small dams and derelict canals/ tidal creeks for irrigation of Rabi crops in local level

Conclusion

Water is a renewable natural resource, however, availability is influenced by the physical (e.g. hydro-geology / geomorphology, climate etc.) and anthropogenic factors (e.g. land use pattern, irrigation, industrial use etc.).

Water resources development and management should be carried out on watershed / river basin wise, being a distinct hydrological unit, integrating both the surface and sub-surface water availability, closely in turn tied with land use practices. In this respect, water may be considered as an economic resource and may not be perceived as a free and indefinite supply. Therefore, emphasis should be given on social awareness programme.

Remote Sensing and GIS technologies may be used as a supportive tool for updation of the existing prototype data and subsequent integration with the present day land use practices to frame future directives in tune with human needs, options and constrains.

Evaluation of the S & T oriented suggestive measures vis-à-vis use of the same by 'Implementing sectors' – in this respect, the Central Ground Water Authority (CGWA) and State Ground Water Authority (SGWA) may play important role.

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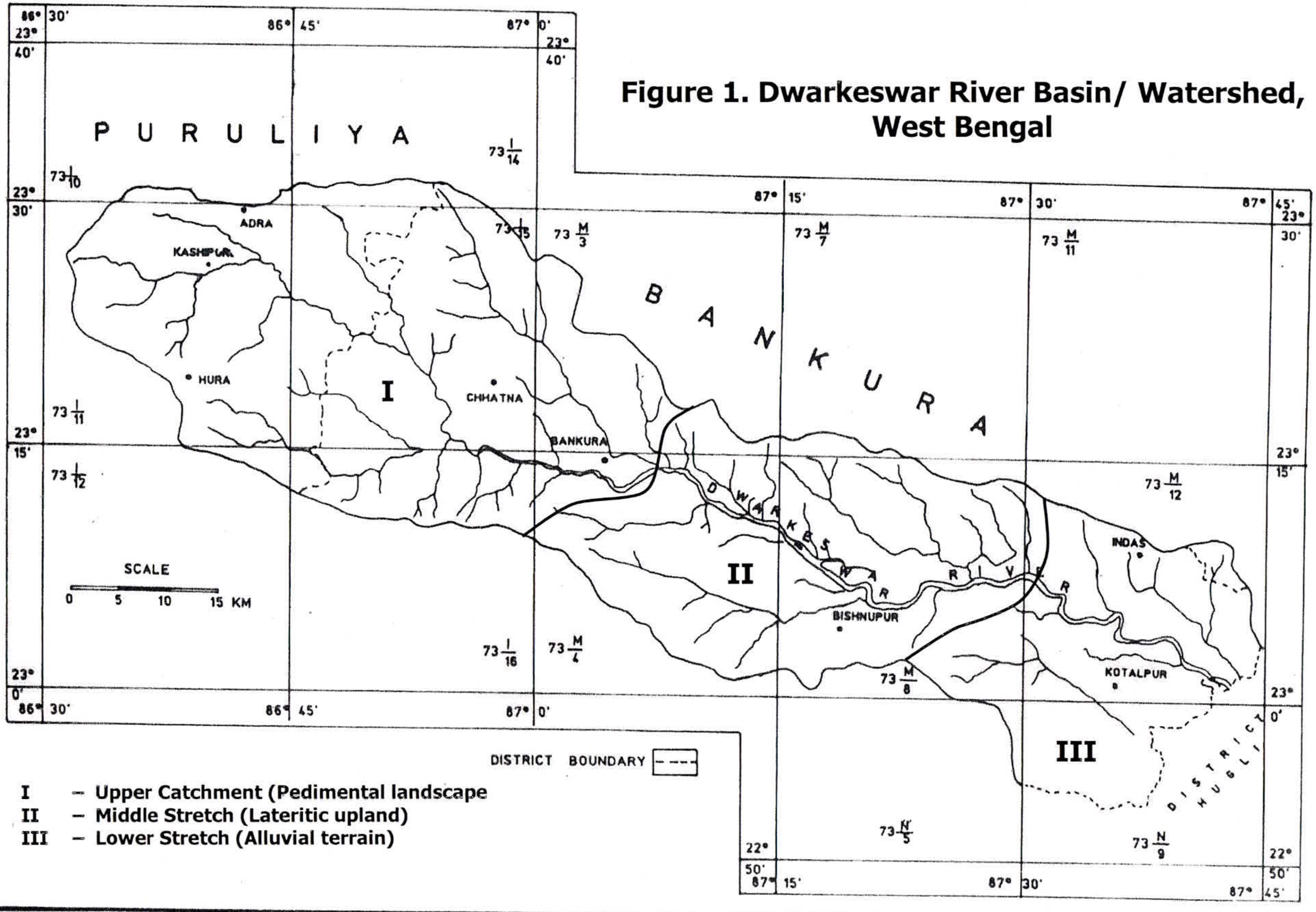
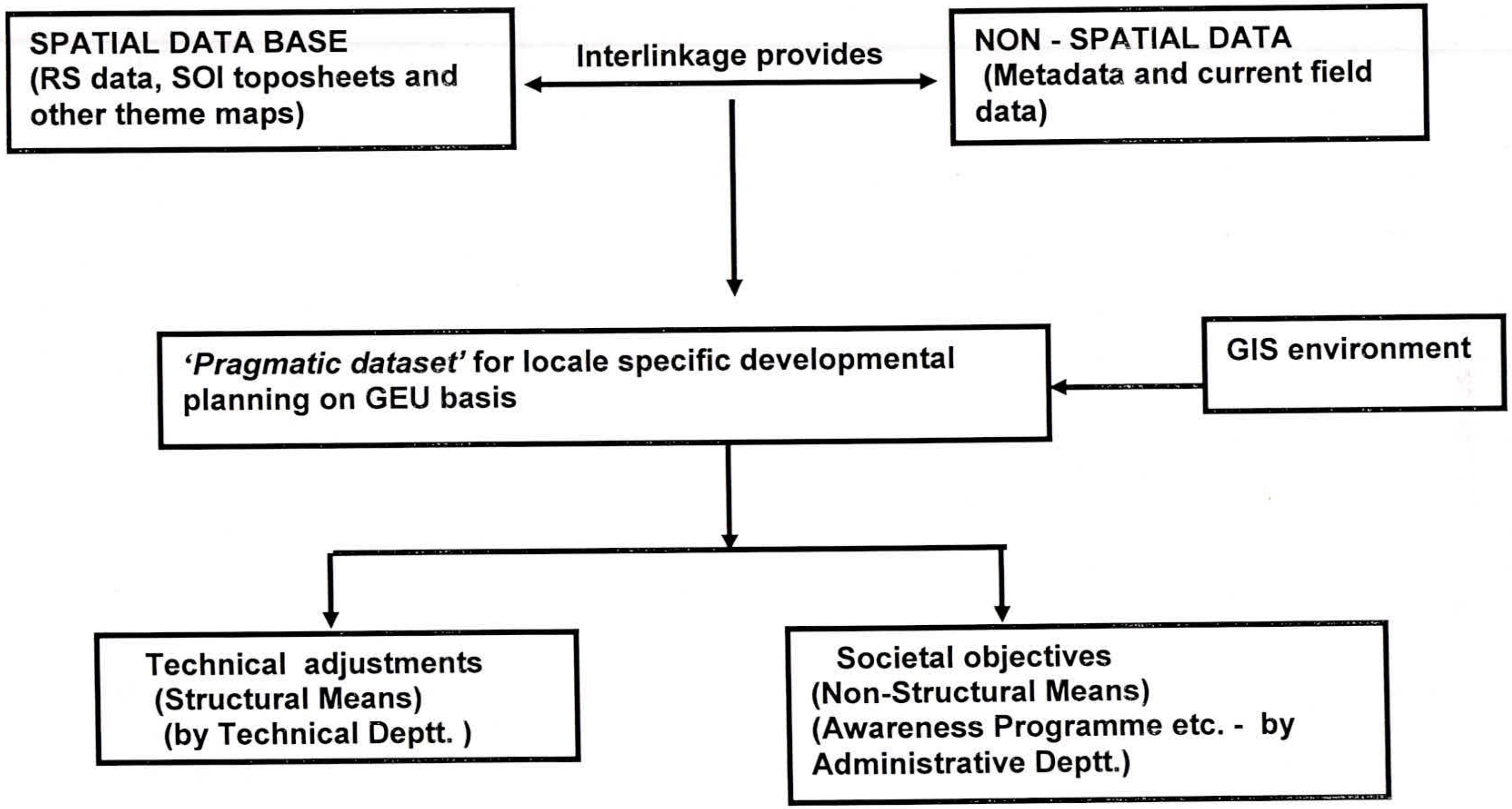
Figure 1. Dwarkeswar River Basin/ Watershed, West Bengal



I – Upper Catchment (Pedimental landscape
II – Middle Stretch (Lateritic upland)
III – Lower Stretch (Alluvial terrain)

Figure 2. Interlinkages between Spatial & Aspatial data



GIS allows people to analyze problems in different way with geographical representation of reality/ real world scenario.

Figure 3. The Directed Eye: RS + GIS – Spatio – thematic operational approach – the IT

Geo-informatics include : Acquisition, Transformation, Management & Dissemination.

The Aided Eye

Remote Sensing (RS) data (i.e. Aerial photos & Satellite Imagery) analysis	**Provide site specific up-to-date geo-spatial information with regional perspective through synoptic viewing**
+	
Survey and Geodesy	**For ground truthing**
+	
Map and Cartography	**Enhance creative sensibility through 'private visual thinking' towards conceptualization and analytical approaches.**

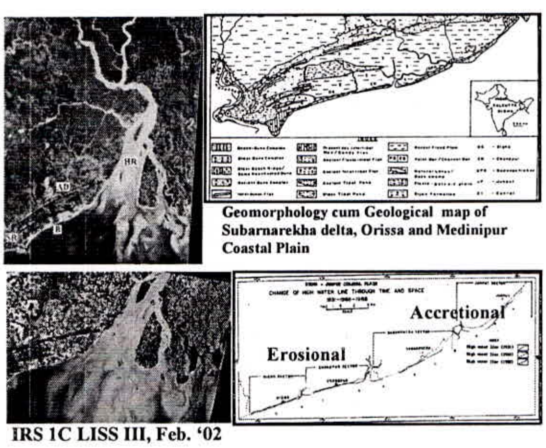
The Educated Eye

Spatial Decision Support System (SDSS) – Geographical Information System (GIS) Environment	**Harmonization and Standardization of spatial and aspatial data to frame decision rules with specific perspective based on criterion weights.**

Figure 4. Relationship between RS and GIS Technologies

RS provide real world spatial information(pixel based) in Raster Format

Input ⟶



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GIS platform with Raster/Vector FDS (formal data structure) ----- Harmonisation and standardization of spatial and aspatial data to frame decision rules with specific perspective

Output in user's orientation e.g. demarcation of areas of interactions of basic natural resources (i.e. land and water) with anthropogenic influences or Environmental Impact Assessment or site selection for archaeological interest etc.

Error sources:

- **Fuzziness of data**
- **Determination of cell size**