A Geo-spatial prelude of water prospect and their sustainable utilisation in drought prone region of West Bengal: A case study of Raghunathpur-I Block, Purulia District

Dr. Bhaskar Das
Cartographer, Department of Geography, Visva-Bharati (A Central University), West Bengal-731235

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ABSTRACT *An intensive research work has been carried out to assess and report elaboration of the sub-surface and surface water resource potential and management in drought prone Region of West Bengal,i.e Purulia District, which is regionally a part of the western upland, constitutes the eastern fringe of the Chhotanagpur plateau with erosional isolated hills exhibiting highly dissected pediment landscape and lateritic upland with skeletal soil. The drought prone parameter creates a deep adverse effect and affect in Raghunathpur-I block (one of the drought prone block of Purulia District) environment and resultant changes in socio-economic attribute and aspect in space with time. An effort has been made of surface and sub-surface water potential mapping through application of geo-spatial technology with applied geo-scientific approach for water sustainability.*

Keywords: *Water Balance, Potential, Hydrogeomorphology, Geo-spatial technology*

Introduction

Water Resources Management implies rational utilisation of land and water resources for optimal and sustained production with the minimum hazard to natural resources and environment. Use of an integrated water resources perspective ensures that social, economic, environmental, and technical dimensions are taken into account in the management and development of surface waters (rivers, lakes, and wetlands) and groundwater (UNESCO ,2009). Identification of surface and sub-surface water potentials zone and their conservation strategy of selected blocks will examines the present institutional arrangements for water resources management and assesses the requirement for institutional development, strengthening and necessary reform measures to support the development of sustainable water resource management.

Issues and Problems at Raghunathpur-I Block

- ✓ Acute scarcity of surface water and potable drinking water
- ✓ Poor surface and sub-surface water recharge
- ✓ Fluctuation of water table within short distance
- ✓ Depletion of water quality i.e. Fluoride contamination of water
- ✓ Inadequate and insufficient irrigation system
- ✓ Increase of wasteland (i.e. Gully /Sheet erosion etc).
- ✓ Soil erosion
- ✓ Unscientific and improper surface water utilisation & management system
- ✓ Siltation of existing pond, tank and gully head bund
- ✓ Unawareness of socio-cultural issues

For the purpose of proper environmental management, therefore a balanced interrelationship is to be maintained between the hydrological condition and anthropogenic activities. It is essential to integrate and analyses field-based data (both spatial and non-spatial)on hydro-geological/ geomorphic-parameters along with societal aspects vis. land use/ land cover, irrigation facilities, drinking and other household consumption etc. to formulate a guidelines of rational use of this renewable resources.

Objectives

The research work will cover the some acute diagnosis and exploration of suitable techniques for terrain based water resource management system and identification of sub-surface and surface water prospect zoning in Raghunathpur-I block, a drought prone block of Purulia district. There are several objective of this assessment can be justified as follows:

a) Find out the surface and sub-surface water scenario of this block
b) To make root assessment of surface and sub-sub-surface water recharge and potentiality.
c) To assess, both the spatial and non-spatial data sets for generation of 'geo-information', micro-level

orientation and 'water potential zones' for sub-surface and surface water availability through RS & GIS

d) Assessment of surface and sub-surface hydrology and adopt terrain specific water manage strategies.

Methodology

The micro level interpretation through integration and analysis of the various thematic information provided by the IRS LISS-III and LISS-IV satellite image (precision geocoded images), Quickbird satellite data has been used as the input for preparation of thematic maps or layer. In order to prepare the maps with attributes as stated in methodology, will be three phases for carrying out the whole work – i) Pre-field information and study, ii) Field verification, iii) post field data generation and thematic layers integration

Location and area of study

The geographical location of Raghunathpur-I block is 86° 34' 50'' E to 86° 47' 30'' E and 23° 37' 30'' to 23° 23°27'55'' N under Purulia District (22°42'35''- 23°42'0''N, 85°54'37'' - 86°48'25''E) is the westernmost District of West Bengal). Total Geographical Area of this block is 201.82 sq.km. (https://ipfs.io/ipfs/wiki/Raghunathpur_I.html)

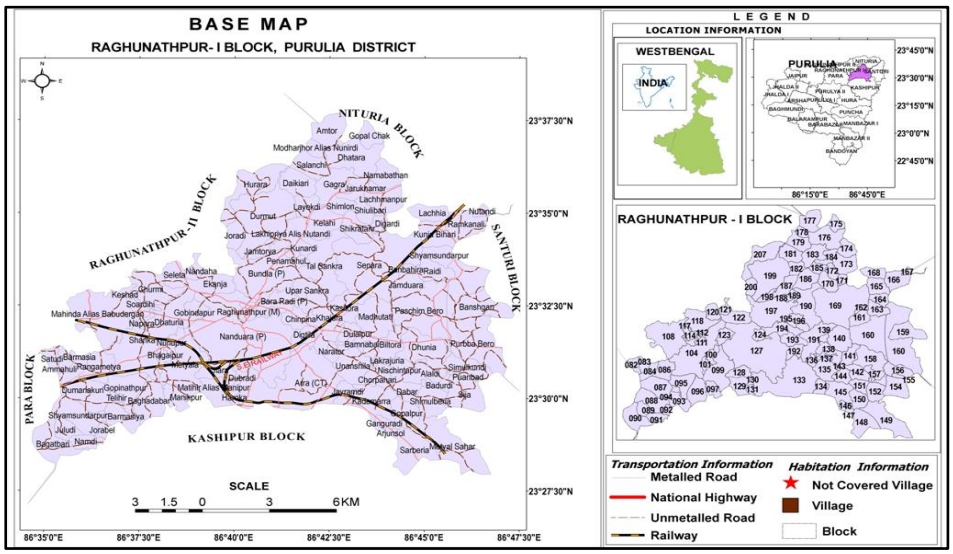

Fig 1: Location map (Source –Author)

Creation of various thematic layers with geodatabase

The input satellite image in digital format (IRS-P6, LISS-III and LISS-IV Precision geocoded, FCC-2005-06 and 2014-15 with scale of 1:50000) and quickbird satellite data and georeferenced SOI toposheet has been used for detailed on screen mapping and digitization to generate the theme (layers) like geology, lithology, lineament, structural controlling feature and the various geomorphological features as well as hydrological parameter drainage, soil, land use/ land cover, transport and settlement with attribute information and extraction techniques also has been stepwise followed. To compare and interpret all these theme maps overlay analysis has been done. After that final theme maps have been prepared of the present study for surface water potentiality zone.

The advantage with on screen interpretation and mapping is that the smaller objects such as valley fill, sill, dyke, hill, ridge etc. can be easily detect and identified with classification by zooming (1:20000) the image. Some of the features were also identified and discriminated easily by individual band data. The errors which normally creep-in during the creation of vector data from tracing film drawing by digitization can be avoided.

Identifications of sub-surface and surface water potential zone at Raghunathpur-I Block

The District of Purulia forms the last two steps in the descent from the hills of central India& Chhotanagpur plateau to the Damodar plains of West Bengal. According to the structure and landform, Purulia is a part of the Ranchi peneplains and displays typical old-age characteristics of a moderate absolute altitude and moderately low relative relief. The rest part of this District has a gently undulating topography with occasional hillocks (ex. Panchet Hill) of hard rocks. (Bengal District Gazetteers ,1911). Towards the east the undulatios are less pronounced and the country presents the appearance of rolling downs with isolated conical hills here and there. In the south, the Baghmundi or Ajodhya Hills reaches an elevation of over 2,000

feet at places. The district generally slopes down from the west to the east (Bengal District Gazetteers,1911) Important rivers in the district are: Damodar, Kangsabati, Kumari, Dwarakeswar and Subarnarekha (MSMI Report.2016). The whole region including Raghunathpur-I block are characterised by undulating topography with rugged hilly terrain in the western and southern part. The general elevation of the surface landscape ranges between 150m to 300m.The master slope of the land surface being towards the east and south east.

Keeping in mind all these parameter of geo-physical parameter like geology, lithology, fractural information, topography, climate and rainfall, the surface water resource potential at this block vary terrain specific. Surface water resources potential are here main issue and have to essential phenomena to find out the prospect zone in this village. A systematic water management both the surface and sub surface at this block is built upon long-term hydrological and meteorological monitoring networks that provide robust, accurate, timely, and consistent data that can be used to develop and access decision making tools needed to quantify water fluctuation, water movement information and pre-monsoon, monsoon and post -monsoon climate scenarios providing reasonable and relevant supply of usable as well as drinking water resources. The groundwater quality and availability, is unsatisfactory surface water sources need to be developed. Restoration and building of tanks and other water bodies along with rainwater harvesting structures for recharge and for direct collection at community and household levels constitute an attractive option.

Remote sensing studies contribute appropriately in better observation and more systematic analysis of various hydro geomorphic units / landforms, lineaments, features with synoptic, multispectral repetitive coverage of the terrain (Horton*, 1945; Kumar and Srivastava, 1991*;). The main focus of the remote sensing and integration of GIS application under investigation study of surface water potential zone has been adapted both remotely sensed digital satellite images, supervised classification process with digital interpretation through extraction of spatial information related to topographic feature patterns, geohydrological, geo-morphological, structural features and drainage pattern at this block. Some significant tasks that have been performed are as follows:

- Identification Hydro-geomorphological unit
- Identification Geomorphological unit
- Identification of the fracture controlled zone or lineament (i.e. joints/fracture/faults etc. from the satellite imagery).
- Collection of well inventory data for depth of water level (both pre and post-monsoon).
- Seasonal and annual fluctuation of depth to water level (DWL)
- Mapping and plotting of terrain wise surface water yield range
- Integration of themes and analysis of surface and sub-surface water potential zone.
- Finally prepared the template of surface water potential zone Raghunathpur-I block
- Prepared also the legend with scientific symbols of different theme with their attribute for proper map unit reading and identification of surface water potential zone.

The above thematic vector layers has been derived and mapped in conjunction with limited field observation, checked scientifically with existing database into desirable map format using raster calculator in spatial analysis module of Arc GIS and Erdas imagine software to delineate the village level surface water potential zoning, sustainable water utilisation with planning of suggestive measures.

The second part deals with the evaluation of hydro geomorphic unit based on hydrogeological features present at this block. Such as,

(i) Estimation of surface and sub-surface water scenario by taking into account the observed well inventory data.
(ii) Identification and make some suggestions of suitable terrain wise and best fit location for constructing artificial recharge structure along with prioritization of socio-economic references.

On the basis of Geology and lithology the entire the district is underlain by Precambrian metamorphic rocks barring a small patch in the north-eastern part, where sediments of Gondwana group occur. Unconsolidated sediments of Recent to sub-recent age are confined to narrow river channels and to the valleys. The majorities of the exposed weathered rocks are granitoid in nature and shows the characteristics of gneissic banding with presence of some patches of amphibolites, metabasic etc., (Dunn, J. A. 1937). Few alluvium patches have been found near northern part of this block due to presence of Damodar river belt. Quartz vein also observed east-central part in this block. The main geology in this block is granite gneiss and amphibolites and hornblende schist intrusion under Singhbhum group (Dunn, J. A., & Dey, A. K. 1942) creates the main hindrance of ground water availability.

Geomorphologically the whole region is characterised by undulating topography with rugged hilly in isolated form. The relative height is 100m to 300m and sometime the general elevation has been found around 300-450 m. Raghunathpur hill is important hill in this block. The master slope of the landscape has been observed from the south to northern direction (IMSD Report, 1996) which is also creates the main encumbrance of surface and sub-surface water potentiality and accessibility.

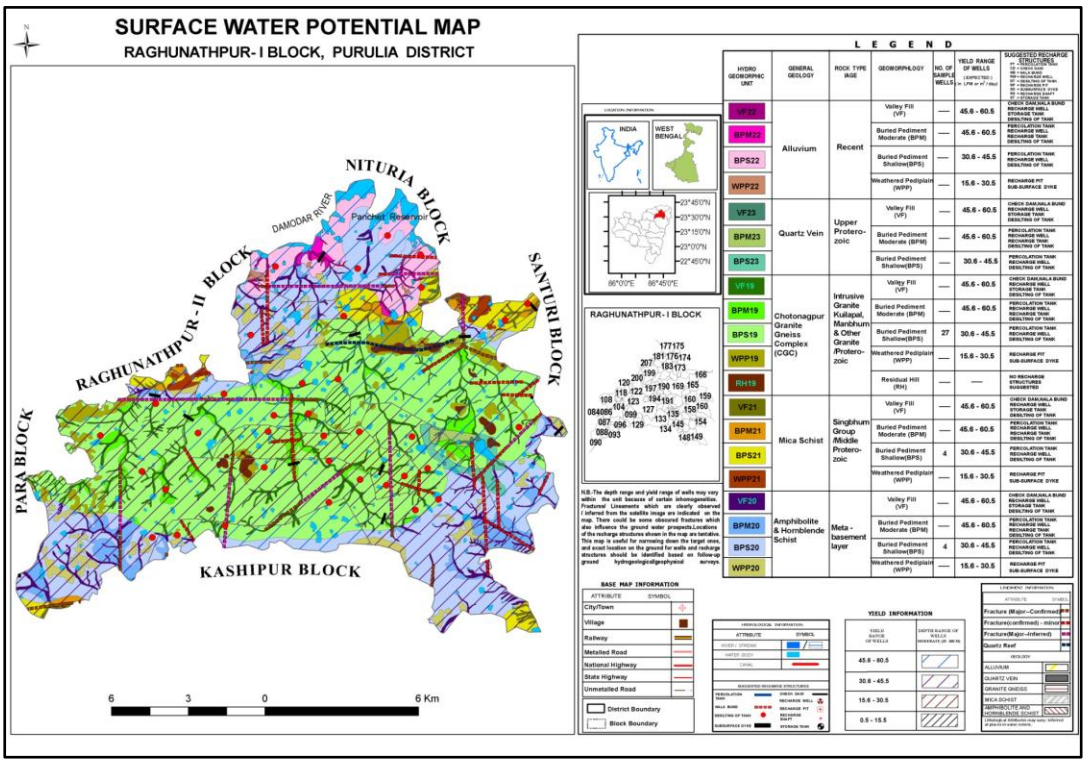

Fig 2: Water Potentiality map (Source- Author)

The atmospheric temperature during the summer ranges between 33° to 49° Celsius. Humidity in the area varies between 56 to 87%.Dry hot winds during summer blows across the District with velocity ranging between 17-30km/hr. Average annual rainfall varies between 1200 and 1450 mm. (IMD, Kolkata, 2015). The relative humidity is high in monsoon season, being 75% to 85%. But in hot summer it comes down to 22% to 32%. Temperature varies over a wide range from 11 degrees Celsius in winter to 49.3 degrees Celsius in the summer. Record highest temperature is 51°Celsius.This block is suffering from frequent heat wave in the summer months when the maximum temperature goes up to 43°C or even beyond.(IMD, Kolkata, 2015) which has deep impact upon the creation of climatic draught in this area.

The salient features of surface hydrology in this block as per in Raghunathpur-I block are:-

- **Surface weathered residuum part** which comprises of weathered material of granitic rock underlain by existing hard rocky structure. Here the expected yield range of dug well is 20.23 liter per hour (lph).(SWID report, 2002)
- **Fracture Regions i.e** faults and fracture lines in the underlying rock strata controls the permeability and base flow of water in terrain to a great extent. Rain groundwater base flow through this fractured zones (*Goswami, A.B. 2002*). The shallow fractures at the depth of 46-73m in this block are accessed mainly by borrow wells fitted with hand pump and the yield varies from <0.5 to 1.11 Liter per second (lps).The deeper fractures are occurring at the depth of 96m-118m where the expected yield is 2.87 Liter per second. (SWID report, 2002)
- **In-filled valley portion** (Zone of 1st order stream) is a zone of accumulation of weathered materials of upland/hill and unconsolidated sediment deposition along the 'jor' (1st order stream). The in-filled valley (zone of 1st order stream) portion is regarded as best surface water prospect zone (cf.*Horton, R.E. 1945*). The expected yield range in this unit is 65 to 120 liter per hour (lph) for a considerable period of pumping in this block (CGWB,2009) .
- **Weathered Pediplain (WPP)/ 'Tanr'** is few stretches of multi-concave type of rock-cut erosion surfaces formed by the coalescence of two or more adjacent pediments and domes (locally termed as 'Tanr')

(*Chakraborty, P. et al,1999*).

- **Weathered Pediplain (shallow type-WPS)/ 'Baid'** type of landscape unit, occurring in lower part of upland zone, which is characterised by gentle sloping topography with skeletal soil reworked under rill and gully erosion (*Chakraborty, P.et al, 1999*) can be considered as poor to moderate surface water potentiality.
- **Weathered Pediplain (moderate type-WPM) / 'Canali'** type of landscape unit has been characterised by gentle sloping topography with shallow to moderately thick soil profile occurring adjacent to the cultivable land area where soil moisture content is reasonably high hence considered as moderate to good surface water potential zones (IMSD Report, 1997).
- **Shallow Bazada** is broad, continuous hill wash depositional zone or gently inclined weathered surface extending from the foot hill of the Raghunathpur Hill area and formed by the lateral coalescence of a series of weathered washed out material where water potentiality is quite high. (IMSD Report, 1997).

Sl No	Geomorphology	Geology	Merged Unit	Avg. Depth of water table (Pre Monsoon)	Avg. Depth to water table (Post Monsoon)	Highest Avg. Depth to water table (Post-Monsoon)	Avg Yield Range (m^3/ Day)
				(Unit in m^3)			
1	Bazada Shallow (BJ)	Granite Gneiss (19)	BPS19	7.64	16.1	62.76	22.94
2	Buried Pediplain Shallow (BPS)	Granite Gneiss (19)	BPM19	2.54	4.34	4.34	20.09
3	Weathered Pediplain (WPP)	Granite Gneiss (19)	WPP19	2.33	3.22	2.43	13.21
4	Buried Pediplain Shallow (BPS)	Unclassified Metamorphi (Mica Schiest) (21)	BPS21	3.21	7.82	9.31	13.76

Table 1: Terrain-specific water level scenario of Raghunathpur-I Block (Source- SWID, 2013)

Water table scenario

Sub-surface water level fluctuation between the pre and post monsoon periods water level has been measured in the months of May and November (2008-10) respectively In this block out of 67 wells water level of 42 wells shows rising and 25 wells shows sinking conditions of water table with poor aquifer condition during the post and pre monsoon periods (*SWID decadal change - 2000-09report*).

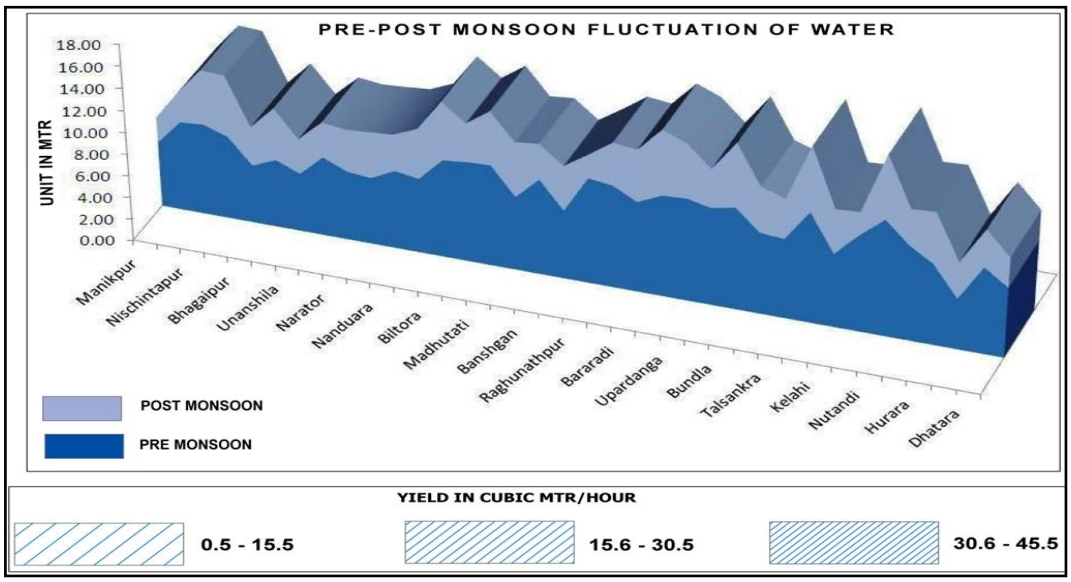

Fig 3: Pre-monsoon and post-monsoon fluctuation of sub-surface water table (Graph prepared based on IRS LISS-III image, 2016 and SWID data)

Assessment unit/ Block	Command/ Non-Command total	Net ground water avail-ability	Existing gross ground water draft for irrigation (in ha m)	Existing gross ground water draft for domestic and industrial water supply (in ha m)	Existing gross ground water draft for all use (in ha/m)	Association for domestic and industrial requirement supply up to next 25 yrs (in ha m)	Net ground water availability for future irrigation development (in ha m)	Stage of ground water development (%)
Raghunathpur-I	--	2675	176	145	321	212	2231	13.43

Table 2: Surface water utilisation and requirement in Raghunathpur-I Block (Source BDO Office, 2014)

Surface Water Development

The other inputs to measure the ground water condition includes seepage from water bodies, canals etc. The piezometric head has been found to exist at deeper level for the dug wells tapping the unconfined aquifer (Sheng,T.C. 1990). Rainfall is the principal source of recharging and storing the surface and sub-surface water in this block. The other sources of surface water are existing drainage, some artificial recharge structure and return flow of irrigation practices. The surface and subsurface water resources in Raghunathpur-I block are essentially a dynamic resource which is replenished annually or periodically by inadequate precipitation, irrigation return flow, seepage from existing water bodies, artificial water recharge structure, influent seepage from water bodies. This surface water utilisation balance can be framed as –

- *Change in recharge and storage of surface and sub-surface → surface and sub-surface water inflow → sub-surface water outflow.*

The Rainfall recharge estimations as per surface hydrology in this block are as follows:

Surface and sub-surface water Inflow	Surface and sub-surface water Outflow
Rainfall recharge to the phreatic aquifers	Evaporation from the capillary fringe in shallow water table areas and transpiration by phreatophytes
Natural recharge from existing stream (Jor), Nala, Pond, Tank	Natural discharge by effluent seepage spring flow and base flow to existing stream(Jor), Nala, Pond, Tank
Surface and sub surface water inflow, artificial recharge from dam, check dam, weir, reservoir, surface irrigation, recharge well, irrigation well etc	Surface and sub surface water outflow, artificial discharge by over ground water extracting, artesian flow from fracture or through drains etc.

Table 3: Surface water and subsurface water balance information (Source –Field Survey, 2015)

Sl No	Hydrological situation	Rainfall Infiltration Factors	Prospect of Surface water availability
1	Semi fractured, friable and highly porous Granitic terrain with weathered and low clay content	10- to 12 % of normal rainfall	Poor to low
2	Semi fractured, friable and highly porous Granitic terrain with un-weathered or less weathered or with significant amount of clay content	05- to 09 % of normal rainfall	Good to moderate
3	Consolidated to semi-consolidated quartzite	05- to 07 % of normal rainfall	moderate
4	Massive and quite poorly fractured rock	01- to 03 % of normal rainfall	low

Table 4: Expected recharge estimation (Source: Data compiled and prepared using CGWB data & IMD-2014)

Some other aspects regarding surface water development in this block are as follows:

- **Return seepage from irrigated field**: It is observed during the field survey that 63 % of cultivable area is under rain fed farming and only 33% of the area *(CGWB data and field investigation, 2014)* is under river lifting irrigation, open dug wells irrigation and deep tube well irrigation. The recharge due to return flow from irrigation may be estimated as follows:
- **Seepage from existing gully head bunds, tanks and ponds:** There is 1.23 mm / day (45%) of the maximum water spread area in which gully head bunds, tanks and ponds has water throughout the year and seepage process is relatively going on. *(CGWB data and field investigation, 2014)*

- **Seepage from check dam, weir, nala bunds and percolation tanks:** There is 2.03 mm / day (35%) *(CGWB data and field investigation, 2014)* of gross storage of surface water in which check dam, weir, nala bunds and percolation tank has water throughout the year and seepage process is relatively going on.

Conclusion

Water resource planners, engineers and officials of three-tier government system are to be advised to undertake an intensive exercise to identify the water prospect zones with site specific local strategies that are appropriate for their specific situations. Long term strategies should be adopted to meet the local surface water management. They are as follows:

- ✓ Double cropping to be practiced by improving irrigation facilities
- ✓ Improvement in agriculture system
- ✓ Horticulture and Floriculture to be given priority as present context
- ✓ Better market facility for better agriculture and allied products be created in the District Cooperative sector should give incentive to the mechanized farming and related practices

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