NATIONAL WETLAND ATLAS:

MEGHALAYA

Sponsored by

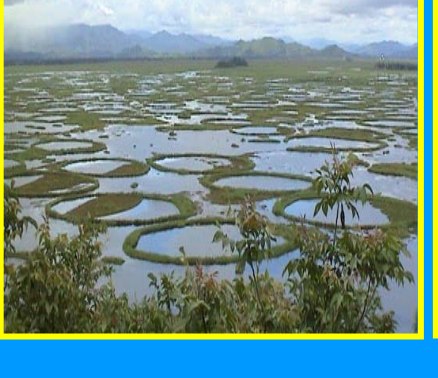
Ministry of Environment and Forests

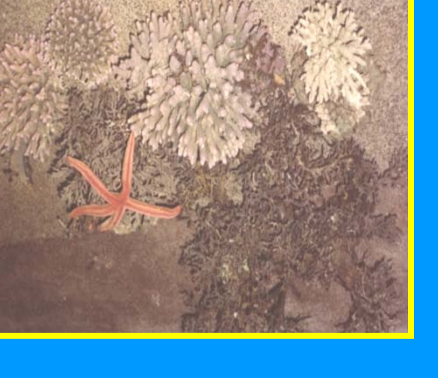
Government of India

Space Applications centre

Indian Space Research Organisation

Ahmedabad – 380 015





This publication deals with the updated database and status of wetlands, compiled in Atlas format. Increasing concern about how our wetlands are being influenced has led to formulation of a project entitled "National Wetland Inventory and Assessment (NWIA)" to create an updated database of the wetlands of India. The wetlands are categorised under 19 classes and mapped using satellite remote sensing data from Indian Remote Sensing Satellite: IRS P6- LISS III sensor. The results are organised at 1: 50, 000 scales at district, state and topographic map sheet (Survey of India reference) level using Geographic Information System (GIS). This publication is a part of this national work and deals with the wetland status of a particular State/Union Territory of India, through text, statistical tables, satellite images, maps and ground photographs.

The atlas comprises wetland information arranged into nine sections. How the NWIA project work has been executed highlighted in the first six sections viz: Introduction, NWIA project, Study area, Data used, Methodology, and Accuracy. This is the first time that high resolution digital remote sensing data has been used to map and decipher the status of the wetlands at national scale. The methodology highlights how the four spectral bands of LISS III data (green, red, near infra red and short wave infra red) have been used to derive various indices and decipher information regarding water spread, turbidity and aquatic vegetation. Since, the aim was to generate a GIS compatible database, details of the standards of database are also highlighted in the methodology.

The results and finding are organised in three sections; viz: Maps and Statistics, Major wetland types, and Important Wetlands of the area. The Maps and Statistics are shown for state and district level. It gives details of what type of wetlands exists in the area, how many numbers in each type, their area estimates in hectare. Since, the hydrology of wetlands are influenced by monsoon performance, extent of water spread and their turbidity (qualitative) in wet and dry season (post-monsoon and pre-monsoon period) are also given. Similarly the status of aquatic vegetation (mainly floating and emergent types) in two seasons is also accounted for. Status of small wetlands are also accounted as numbers and depicted in maps as points. Wetland map also show important ancillary information like roads/rail, relevant habitations. False Colour Composite (FCC) of the satellite image used (any one season) is shown along with the derived wetland map to give a feeling of manifestation of wetlands in remote sensing data and synoptic view of the area. The status of some of the important wetlands like Ramsar sites, National Parks are shown with recent field photographs.

For further details contact:

Director,
Space Applications Centre, ISRO,
Ambawadi Vistar (P.O.)
Ahmedabad – 380 015

director@sac.isro.gov.in

NATIONAL WETLAND ATLAS

Meghalaya

Sponsored by
Ministry of Environment and Forests, Government of India

As a part of the project on National Wetland Inventory and Assessment (NWIA)

Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre, Umiam, Meghalaya

May 2009

First Publication: May 2009, Space Applications Centre (ISRO), Ahmedabad

Citation: National Wetland Atlas: Meghalaya, SAC/RESA/AFEG/NWIA/ATLAS/02/2009, Space Applications Centre(ISRO), Ahmedabad, India, 88p.

Available from: Space Applications Centre, ISRO, Ahmedabad – 380 015, India

Production: SAC carried out the work in collaboration with NESAC, Shillong, Sponsored by Ministry of Environment and Forests, Govt. of India.

जयराम रमेश
JAIRAM RAMESH

राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण एवं वन
भारत सरकार
नई दिल्ली-110003
MINISTER OF STATE (INDEPENDENT CHARGE)
ENVIRONMENT & FORESTS
GOVERNMENT OF INDIA
NEW DELHI - 110 003

सत्यमेव जयते

18TH JANUARY 2010

MESSAGE

It gives me great pleasure to introduce this Atlas, the latest in a series, prepared by Space Applications Centre, Ahmedabad in connection with the National Wetland Inventory and Assessment Project.

This Atlas maps and catalogues information on Wetlands across India using the latest in satellite imaging, one of the first of its kind. Wetlands are areas of land critical ecological significance that support a large variety of plant and animal species adapted to fluctuating water levels. Their identification and protection becomes very important.

Utility-wise, wetlands directly and indirectly support millions of people in providing services such as food, fiber and raw materials. They play important roles in storm and flood control, in supply of clean water, along with other educational and recreational benefits. Despite these benefits, wetlands are the first target of human interference and are among the most threatened of all natural resources. Around 50% of the earth's wetlands are estimated to already have disappeared worldwide over the last hundred years through conversion to industrial, agricultural and residential purposes. Even in current scenario, when the ecosystem services provided by wetlands are better understood - degradation and conversion of wetlands continues.

Aware of their importance, the Government of India has formulated several policies and plans for the conservation and preservation of these crucial ecosystems. Realising the need of an updated geospatial data base of these natural resources as the pre-requisite for management and conservation planning, National Wetland Inventory and Assessment (NWIA) project was formulated as a joint vision of Ministry of Environment & Forestry, Govt. India, and Space Applications Centre (ISRO). I am told that the latest remote sensing data from Indian Remote Sensing satellite (IRS P6) have been used to map the wetlands. The present atlas is part of this project and highlights the results of the study state in terms of statistics of various types of wetlands, extent of water, aquatic vegetation and turbidity in pre and post monsoon period. I also note that special efforts are made to provide detailed information of important wetlands like Ramsar sites, National Parks etc.

I am certain that this Atlas will raise the bar in developing such database and will be of great use for researchers, planners, policy makers, and also members of the general public.

(Jairam Ramesh)

जय हिन्द
डॉ. रंगनाथ आर. नवलगुंद
निदेशक
Dr. Ranganath R. Navalgund
Director

सत्यमेव जयते

भारत सरकार GOVERNMENT OF INDIA
अंतरिक्ष विभाग DEPARTMENT OF SPACE
अंतरिक्ष उपयोग केन्द्र
SPACE APPLICATIONS CENTRE
अहमदाबाद AHMEDABAD - 380 015
(भारत) (INDIA)
दूरभाष PHONE : +91-79-26913344, 26764956
फैक्स/FAX : +91-79-26915843
ई-मेल E-mail : director@sac.isro.gov.in

FOREWORD

Wetlands defined as areas of land that are either temporarily or permanently covered by water exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry. Wetlands are one of the most productive ecosystems and play crucial role in hydrological cycle. Utility wise, wetlands directly and indirectly support millions of people in providing services such as storm and flood control, clean water supply, food, fiber and raw materials, scenic beauty, educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services. However, the very existence of these unique resources is under threat due to developmental activities, and population pressure. This calls for a long term planning for preservation and conservation of these resources. An updated and accurate database that will support research and decision is the first step towards this. Use of advanced techniques like Satellite remote sensing, Geographic Information System (GIS) is now essential for accurate and timely spatial database of large areas. Space Applications Centre (ISRO) took up this challenging task under the project "NWIA" (National Wetland Inventory and Assessment) sponsored by Ministry of Environment & Forests. To account for numerous small yet important wetlands found in the country, mapping at 1:50,000 scales has been taken up. Two date IRS LISS III data acquired during pre and post monsoon season are used for inventory to account for wet and dry season hydrology of wetlands. The map outputs include the status of water spread, aquatic vegetation and turbidity. Ancillary layers like road/rail, habitations are also created. Very small wetlands below the mappable unit are also identified and shown points. The results are complied as Atlases of wetlands for states/Union Territories of India. This Atlas highlights results for a particular state/UT and hopes to improve our understanding of the dynamics and distribution of wetlands and their status in the area.

I congratulate the team for bringing out this informative atlas and sincerely hope that this will serve as a useful source of information to researchers, planners and general public.

January 25, 2010

(Ranganath R. Navalgund)

भारत सरकार
अन्तरिक्ष विभाग
अन्तरिक्ष उपयोग केन्द्र
आंबावाडी विस्तार डाक घर,
अहमदाबाद - 380 015. (भारत)
दूरभाष : +91-79-26912000, 26915000
फ़ैक्स :

Government of India
Department of Space
SPACE APPLICATIONS CENTRE
Ambawadi Vistar P.O.
Ahmedabad - 380 015. (INDIA)
Telephone : +91-79-26912000, 26915000
Fax :

Dr. Sushma Panigrahy
Group Director, AFEG & Project Director, NWIA

Tel. 079-26914020 (O)
Fax : 079-26915823

ACKNOWLEDGEMENTS

The project "National Wetland Inventory & Assessment (NWIA)", is sponsored by Ministry of Environment & Forestry (MoEF), Govt. of India and executed by Space Applications Centre, ISRO, Ahmedabad. We are grateful to Dr. Ranganath R. Navalgund, Director, Space Applications Centre, for his encouragement to take up this challenging task and formulation of the project team for timely implementation. Earnest thanks are also due to Dr. Jai Singh Parihar, Dy. Director, Remote Sensing Applications Area, Space Applications Centre, for providing overall guidance and support to the project. The present Atlas for the state is a part of the "National Wetland Atlas.

This project has benefited from the wisdom of many people**.** It is a pleasure to acknowledge the contributions made by the wetland experts especially to Prof. C.K. Varshney, Former Dean, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, Prof. A.R. Yousuf, The University of Kashmir, Srinagar, Prof. Pradeeep Shrivastava, Head, Wetland Research Centre, Barakatullah University, Bhopal, Dr. Prikshit Gautam, Director, WWF-India, Dr. S. Narendra Prasad, Salim Ali Centre for Ornithology and Nature, Coimbatore and Dr. R.K. Suri, Additional Director, Ministry of Environment and Forests, Govt. of India, New Delhi, to finalise the "Wetland Classification System" followed in this project by their active participation in the Peer Review meeting. We are thankful to the database experts from ISRO who participated in the peer Review meeting to finalise the hierarchical classification system.

We acknowledge the support received from Dr P S Roy, Dy Director, NRSC and Dr S Sudhakar, Head, LRD, NRSC in terms of valuable suggestions and providing the geo-referenced image of NRC-LU&LC project for use as master image in this project.

We acknowledge the positive role played by 16th SC-B (Standing Committee on Bioresources and Environment) of NNRMS (National Natural Resources Management System) meeting in formulating this project. We are extremely thankful to the members of the"Steering Committee" of the project, under the chairmanship of Dr E J James, Director – Water Institute, Karunya University, for their periodical review, critical comments and appreciation of the efforts by the project team. We are thankful to SC-B under the chairmanship of Secretary, MoEF, for periodic review of the progress of the project and guidance towards timely completion of the work. We acknowledge the valuable contributions made by Dr J K Garg, the then scientist of SAC for his active role in formulation of this project, co-authoring the procedure manual document.

We are grateful to Dr G V Subramanyam, Adviser, MoEF, Dr Jag Ram, Director, MoEF for their very active and positive role for implementation of the project. We are thankful to Dr Harendra Kharwal, MoEF for his support for budget related issues. We are thankful to the "Technical Review" team of SAC for critical comments and suggestion of the Atlas. We are thankful to Shri N.M.Suthar Scientist SAC for his valuable contribution for quality checks of RS & GIS Database. We thank Dr R D Shah, Mr Pragnesh Kumar Vaishnav and Ms Yatisha P Vaishnav, Geology Department, M G Science Institute, Ahmedabad for their support in finalization of GIS database.

(Sushma Panigrahy)

PROJECT TEAM

Project Director: Dr. (Mrs.) Sushma Panigrahy

Space Applications Centre, ISRO, Ahmedabad

Shri J. G. Patel
Dr. T. S. Singh
Shri T. V. R Murthy

North Eastern Space Applications Centre, Umiam, Meghalaya

Ms. Kasturi Chakraborty

CONTENTS

List of Plates

1.0 INTRODUCTION

It is increasingly realized that the planet earth is facing grave environmental problems with fast depleting natural resources and threatening the very existence of most of the ecosystems. Serious concerns are voiced among scientists, planners, sociologists, politicians, and economists to conserve and preserve the natural resources of the world. One of the difficulties most frequently faced for decision making is lack of scientific data of our natural resources. Often the data are sparse or unconvincing, rarely in the form of geospatial database (map), thus open to challenges. Thus, the current thrust of every country is to have an appropriate geospatial database of natural resources that is based on unambiguous scientific methods. The wetland atlas of Meghalaya, which is part of the National Wetland Atlas of India, is an attempt in this direction.

1.1 Wetlands

Wetlands are one of the crucial natural resources. Wetlands are areas of land that are either temporarily or permanently covered by water. This means that a wetland is neither truly aquatic nor terrestrial; it is possible that wetlands can be both at the same time depending on seasonal variability. Thus, wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Because of their transitional nature, the boundaries of wetlands are often difficult to define. Wetlands do, however, share a few attributes common to all forms. Of these, hydrological structure (the dynamics of water supply, throughput, storage and loss) is most fundamental to the nature of a wetland system. It is the presence of water for a significant period of time which is principally responsible for the development of a wetland. One of the first widely used classifications systems, devised by Cowardin *et al.,* (1979), was associated to its hydrological, ecological and geological aspects, such as: marine (coastal wetlands including rock shores and coral reefs, estuarine (including deltas, tidal marshes, and mangrove swamps), lacustarine (lakes), riverine (along rivers and streams), palustarine ('marshy'- marshes, swamps and bogs). Given these characteristics, wetlands support a large variety of plant and animal species adapted to fluctuating water levels, making the wetlands of critical ecological significance. Utility wise, wetlands directly and indirectly support millions of people in providing services such as food, fiber and raw materials, storm and flood control, clean water supply, scenic beauty and educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services of which the benefits are estimated at $20 trillion a year (Source : www.MAweb.org). The Millennium Assessment (MA) uses the following typology to categorise ecosystem services:

Provisioning services: The resources or products provided by ecosystems, such as food, raw materials (wood), genetic resources, medicinal resources, ornamental resources (skin, shells, flowers).

Regulating services: Ecosystems maintain the essential ecological processes and life support systems, like gas and climate regulation, water supply and regulation, waste treatment, pollination, etc.

Cultural and Amenity services: Ecosystems are a source of inspiration to human culture and education throughout recreation, cultural, artistic, spiritual and historic information, science and education.

Supporting services: Ecosystems provide habitat for flora and fauna in order to maintain biological and genetic diversity.

Despite these benefits, wetlands are the first target of human interference and are among the most threatened of all natural resources. Around 50% of the earth's wetlands is estimated to already have disappeared worldwide over the last hundred years through conversion to industrial, agricultural and residential developments. Even in current scenario, when the ecosystem services provided by wetlands are better understood - degradation and conversion of wetlands continues. This is largely due to the fact that the 'full value' of ecosystem functions is often ignored in policy-making, plans and corporate evaluations of development projects.

1.2 Mapping and Geospatial technique

To conserve and manage wetland resources, it is important to have inventory of wetlands and their catchments. The ability to store and analyse the data is essential. Digital maps are very powerful tools to achieve this. Maps relate the feature to any given geographical location has a strong visual impact. Maps, thus essential for monitoring and quantifying change over time scale, assist in decision making. The technique used in the preparation of map started with ground survey. The Survey of India (SOI) topographic maps are the earliest true maps of India showing various land use/cover classes including wetlands. Recent years have seen advances in mapping technique to prepare maps with much more information. Of particular importance is the remote sensing and geographic information system (GIS) technique. Remote sensing is now recognized as an essential tool for viewing, analyzing, characterizing, and making decisions about land, water and atmospheric components.

From a general perspective, remote sensing is the science of acquiring and analyzing information about objects or phenomena from a distance (Jensen, 1986; Lillesand and Keifer, 1987). Today, we define satellite remote sensing as the use of satellite borne sensors to observe, measure, and record the electromagnetic radiation (EMR) reflected or emitted by the earth and its environment for subsequent analysis and extraction of information. EMR sensors includes visible light, near-, mid- and far-infrared (thermal), microwave, and long-wave radio energy. The capability of multiple sources of information is unique to remote sensing. Of specific advantage is the spectral, temporal, and spatial resolution. Spectral resolution refers to the width or range of each spectral band being recorded. Since each target affects different wavelengths of incident energy differently, they are absorbed, reflected or transmitted in different proportions. Currently, there are many land resource remote sensing satellites that have sensors operating in the green, red, near infrared and short wave Infra red regions of the electromagnetic spectrum giving a definite spectral signature of various targets due to difference in radiation absorption and reflectance of targets. These sensors are of common use for land cover studies, including wetlands**.** Figure 1 shows typical spectral signature of few targets from green to SWIR region. Converted to image, in a typical false colour composite (FCC) created using NIR, red and green bands assigned as red, green and blue colour, the features become very distinct as shown in Figure 2. In FCC, the vegetation thus appears invariably red (due to high reflection in NIR from green leaves).

Since the early 1960s, numerous satellite sensors have been launched into orbit to observe and monitor the earth and its environment. Most early satellite sensors acquired data for meteorological purposes. The advent of earth resources satellite sensors (those with a primary objective of mapping and monitoring land cover) occurred, when the first Landsat satellite was launched in July 1972. Currently, more than a dozen orbiting satellites of various types provide data crucial to improving our knowledge of the earth's atmosphere, oceans, ice and snow, and land. Of particular interest to India is the indigenous series of satellites called Indian Remote Sensing (IRS) satellites. Since the launch of the first satellite IRS 1A in 1987, India has now a number of satellites providing data in multi-spectral bands with different spatial resolution. IRS P6/RESOURCESAT 1 is the current generation satellite that provides multi-spectral images in spatial resolution of 5.8 m (LISS IV), 23.5 m (LISS III) and 56m (AWiFS). Over the past few decades, Indian remote sensing data has been successfully used in various fields of natural resources (Navalgund et al. 2002).

Development of technologies like Geographic Information System (GIS) has enhanced the use of RS data to obtain accurate geospatial database. GIS specialises in handling related, spatially referenced data, combining mapped information with other data and acts as analytical tool for research and decision making. During the past few decades, technological advances in the field of satellite remote sensing (RS) sensors, computerized mapping techniques, global positioning system (GPS) and geographic information system (GIS) has enhanced the ability to capture more detailed and timely information about the natural resources at various scales catering to local, regional, national and global level study.

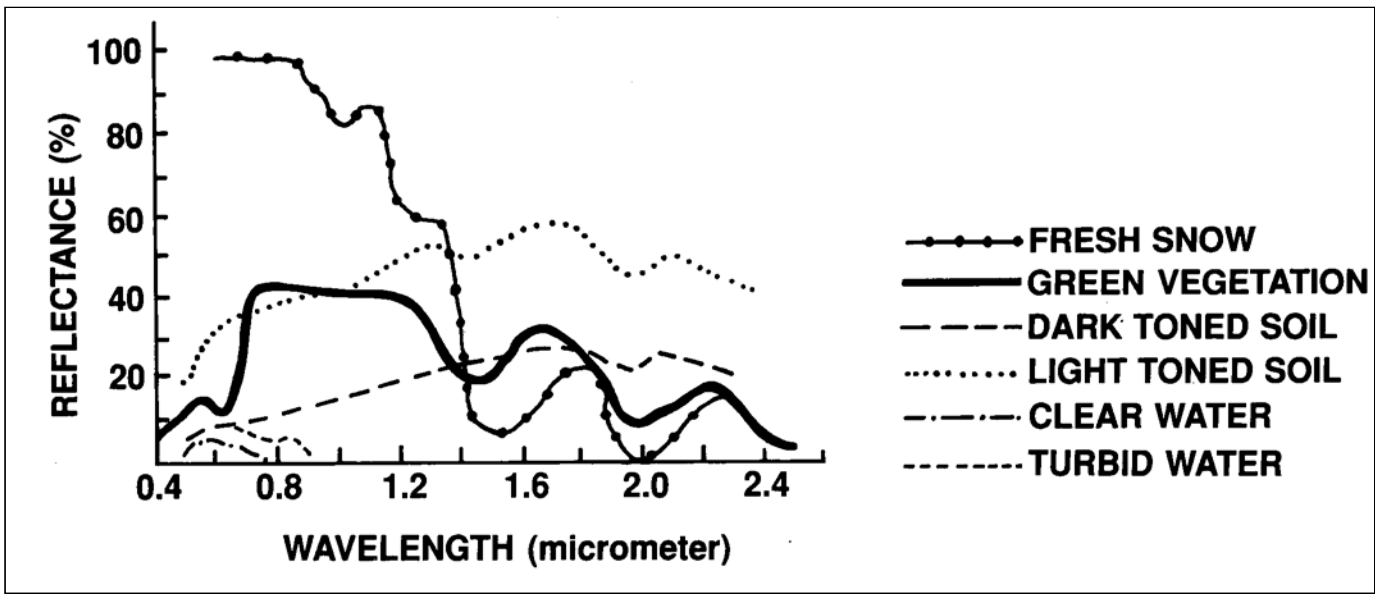


Figure 1: Spectral Signature of various targets

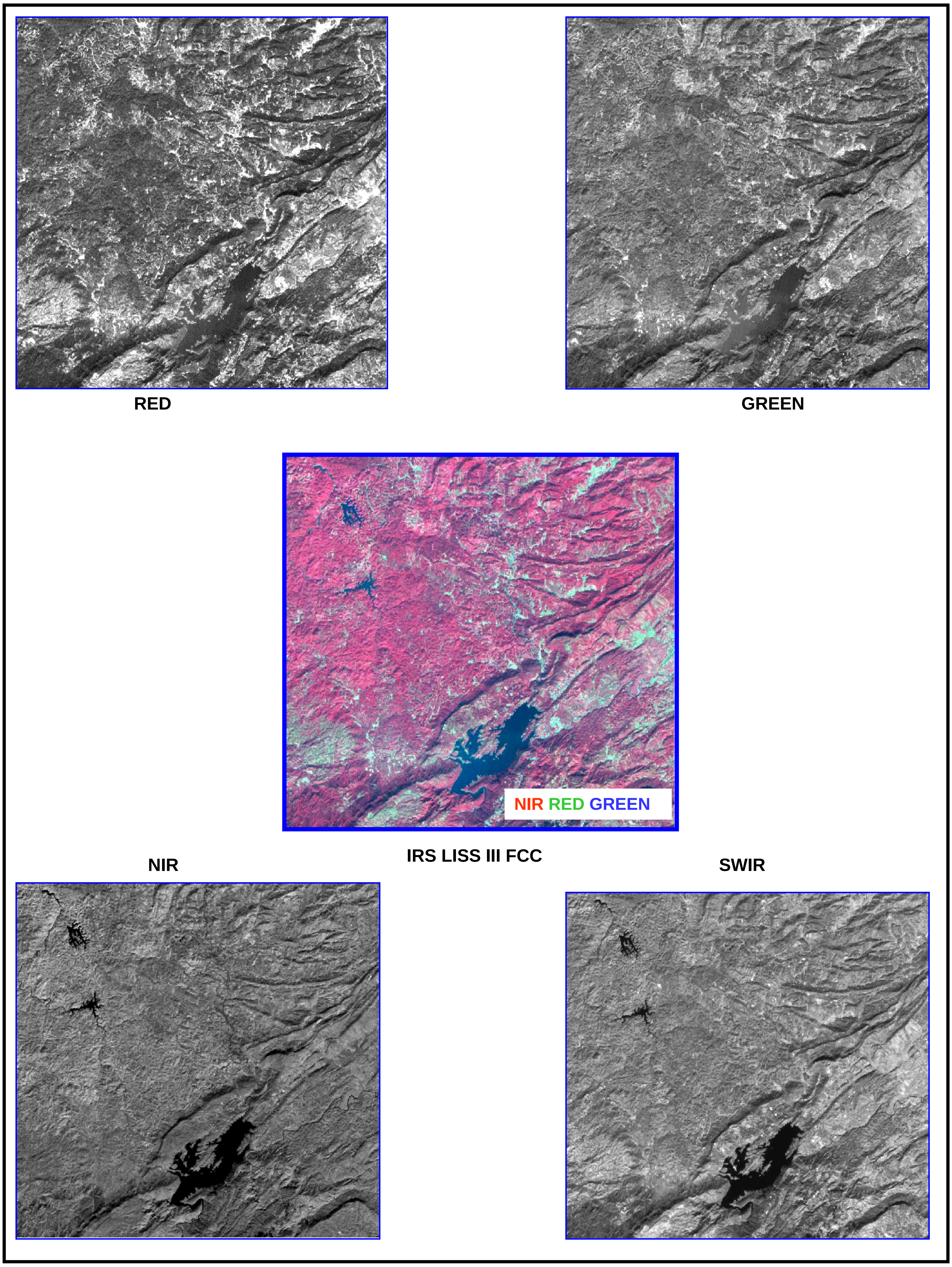


Figure 2: Various land features as they appear in four spectral bands and in a typical three band FCC.

1.3 Wetland Inventory of India

India with its large geographical spread supports large and diverse wetland classes, some of which are unique. Wetlands, variously estimated to be occupying 1-5 per cent of geographical area of the country, support about a fifth of the known biodiversity. Like any other place in the world, there is a looming threat to the aquatic biodiversity of the Indian wetlands as they are often under a regime of unsustainable human pressures. Sustainable management of these assets therefore is highly relevant. Realising this, Govt. of India has initiated many appropriate steps in terms of policies, programmes and plans for the preservation and conservation of these ecosystems. India is a signatory to the Ramsar Convention for management of wetland, for conserving their biodiversity and wise use extending its scope to a wide variety of habitats, including rivers and lakes, coastal lagoons, mangroves, peatlands, coral reefs, and numerous human-made wetland, such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans reservoirs, gravel pits, sewage farms, and canals. The Ministry of Environment and Forests has identified a number of wetlands for conservation and management under the National Wetland Conservation Programme and some financial assistance is being provided to State Governments for various conservation activities through approval of the Management Action Plans. The need to have an updated map database of wetlands that will support such actions has long been realized.

Mapping requires a standard classification system. Though there are many classification systems for wetlands in the world, the Ramsar classification system is the most preferred one. The 1971 Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat is the oldest conservation convention. It owes its name to its place of adoption in Iran. It came into being due to serious decline in populations of waterfowl (mainly ducks) and conservation of habitats of migratory waterfowl. Convention provides framework for the conservation and 'wise use' of wetland biomes. Ramsar convention is the first modern global intergovernmental treaty on conservation and wise use of natural resources (www.ramsar.org). Ramsar convention entered into force in 1975. Under the text of the Convention (Article 1.1) wetlands are defined as:

"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".

In addition, the Convention (Article 2.1) provides that wetlands:

"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".

The first scientific mapping of wetlands of India was carried out during1992-93 by Space Applications Centre (ISRO), Ahmedabad, at the behest of the Ministry of Environment and Forests (MoEF), Govt. of India using remote sensing data from Indian Remote Sensing (IRS) satellite. The mapping was done at 1:250,000 scale using IRS 1A LISS-I/II data of 1992-93 timeframe under the Nation-wide Wetland Mapping Project. Since, no suitable wetland classification existed for comprehensive inventory of wetlands in the country at that time, the project used a classification system based on Ramsar Convention definition of wetlands. The classification considers all parts of a water mass including its ecotonal area as wetland. In addition, fish and shrimp ponds, saltpans, reservoirs, gravel pits were also included as wetlands. This inventory put the wetland extent (inland as well as coastal) at about 8.26 million ha. (Garg et al). These estimates (24 categories) do not include rice/paddy fields, rivers, canals and irrigation channels.

Further updating of wetland maps of India was carried out by SAC using IRS P6/Resourcesat AWiFS data of 2004-05 at 1:250000 scale. In recent years, a conservation atlas has been brought out by Salim Ali Centre for Ornithology and Natural History (SACON, 2004), which provide basic information required by stakeholders in both wetland habitat and species conservation. Space Applications Centre has carried out many pilot projects for development of GIS based wetland information system (Patel et al, 2003) and Lake Information system (Singh et al, 2003).

2.0 NATIONAL WETLAND INVENTORY AND ASSESSMENT (NWIA) PROJECT

Realising the importance of many small wetlands that dot the Indian landscape, it has been unanimously felt that inventory of the wetlands at 1:50,000 scale is essential. The task seemed challenging in view of the vast geographic area of our country enriched with diverse wetland classes. Space Applications Centre with its experience in use of RS and GIS in the field of wetland studies, took up this challenging task. This is further strengthened by the fact that guidelines to create geospatial framework, codification scheme, data base structure etc. for natural resources survey has already been well established by the initiative of ISRO under various national level mapping projects. With this strength, the National Wetland Inventory and Assessment (NWIA) project was formulated by SAC, which was approved and funded by MoEF.

The main objectives of the project are:

- To map the wetlands on 1:50000 scale using two date (pre and post monsoon) IRS LISS III digital data following a standard wetland classification system.
- Integration of ancillary theme layers (road, rail, settlements, drainage, administrative boundaries)
- Creation of a seamless database of the states and country in GIS environment.
- Preparation of State-wise wetland atlases

The project was initiated during 2007. The first task was to have a classification system that can be used by different types of users while amenable to database. An expert/peer group was formed and the peer review was held at SAC in June 2007 where wetland experts and database experts participated and finalized the classification system. It was agreed to follow the classification system that has been used for the earlier project of 1:250,000 scale, with slight modification. Modified National Wetland Classification system for wetland delineation and mapping comprise 19 wetland classes which are organized under a Level III hierarchical system. The definition of each wetland class and its interpretation method was finalized. The technical/procedure manual was prepared as the standard guideline for the project execution across the country (Garg and Patel, 2007). The present atlas is part of the national level data base and deals with the state of Meghalaya.

2.1 Wetland Classification System

In the present project, Modified National Wetland Classification system is used for wetland delineation and mapping comprising 19 wetland classes which are organized under a Level III hierarchical system (Table 1). Level one has two classes: inland and coastal, these are further bifurcated into two categories as: natural and man-made under which the 19 wetland classes are suitably placed. Two date data pertaining to pre-monsoon and post monsoon was used to confirm the classes. Wetlands put to agriculture use in any of the two dates are not included as wetland class. Definitions of wetland categories used in the project is given in Annexure-I.

2.2.1 Spatial Framework and GIS Database

The National Spatial Framework) (NSF) has been used as the spatial framework to create the database (Anon. 2007). The database design and creation standard suggested by NRDB/NNRMS guidelines is followed. Feature codification scheme for every input element has been worked out keeping in view the nationwide administrative as well as natural hierarchy (State-district- within the feature class for each of the theme. All data elements are given a unique name, which are self explanatory with short forms.

Following wetland layers are generated for each inland wetland:

- Wetland extent: As wetlands encompass open water, aquatic vegetation (submerged, floating and emergent), the wetland boundary should ideally include all these. Satellite image gives a clear signature of the wetland extent from the imprint of water spread over the years.

- Water spread: There are two layers representing post-monsoon and pre-monsoon water spread during the year of data acquisition.

- Aquatic vegetation spread: The presence of vegetation in wetlands provides information about its trophic condition. As is known, aquatic vegetation is of four types, viz. benthic, submerged, floating, and emergent. It is possible to delineate last two types of vegetation using optical remote sensing data. A qualitative layer pertaining to presence of vegetation is generated for each season (as manifested on pre-monsoon and post-monsoon imagery).

- Turbidity level of open water: A layer pertaining to a qualitative turbidity rating is generated. Three qualitative turbidity ratings (low, medium and high) is followed for pre and post-monsoon turbidity of lakes, reservoirs, barrages and other large wetlands.

- Small wetlands (smaller than minimum mappable unit) are mapped as point features.

- Base layers like major road network, railway, settlements, and surface drainage are created (either from the current image or taken from other project data base).

  In the case of coastal wetlands only wetland extent is given.

Table 1: Wetland Classification System and coding (Annexure I for more details)

Wettcode*	Level I	Level II	Level III
1000	Inland Wetlands		
1100		Natural	
1101			Lakes
1102			Ox-Bow Lakes/ Cut-Off Meanders
1103			High altitude Wetlands
1104			Riverine Wetlands
1105			Waterlogged
1106			River/stream
1200		Man-made	
1201			Reservoirs/ Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
2000	Coastal Wetlands		
2100		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt Marsh
2106			Mangroves
2107			Coral Reefs
2200		Man-made	
2201			Salt pans
2202			Aquaculture ponds

* Wetland type code

3.0 STUDY AREA

Meghalaya occupies the western position of the North eastern region. The North Eastern state of Meghalaya- the abode of clouds is predominantly a land of hills and valley. Owing to its natural beauty and grace it has been also named as ‘Scotland of the East’. Geographical location of the state is between 89^{o} 45’ to 92^{o} 48’ and 25^{o} 02’ to 26^{o} 05’. The total geographical area of the state is 22, 429 Sq Km, extending 300 km west to east and 100 km from north to south.

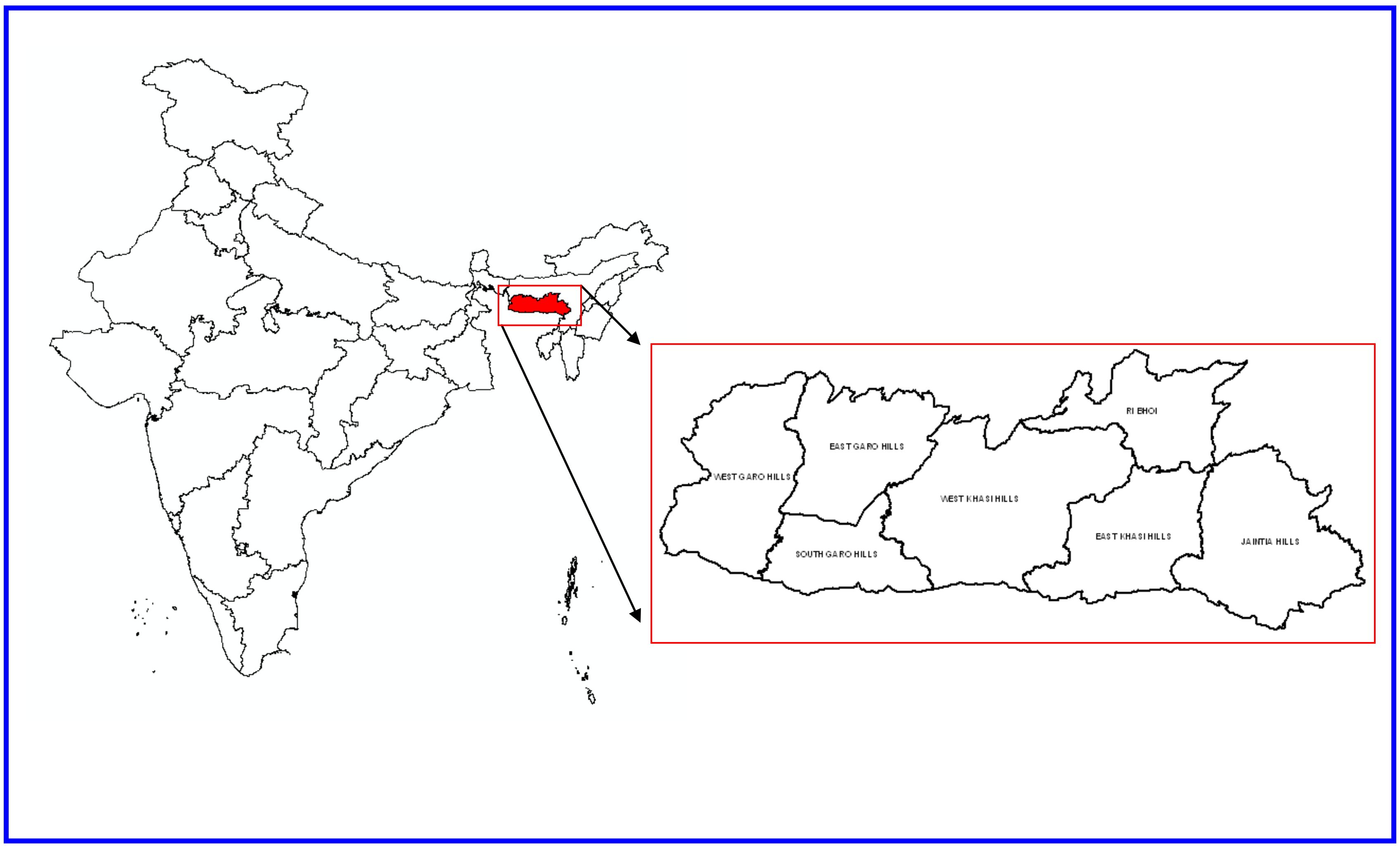
It is bounded on the north by Goalpara and Kamrup district of Assam, on the east by North Cachar and Karbi Anglong, the Western and Southern boundary is the International border between India and Bangladesh. The prevailing climate in the state is characterized by heavy rainfall, which favors the action of streams to a considerable extent.

The geological formations, its resultant topography and tendency of headword erosion by rain water have lead to the creation of drainage network in Meghalaya. The state is blessed with number of perennial rivers. The principal rivers of the state run either a Northerly or Southerly direction. Satellite imagery identifies the adaptation of streams along major and minor lineaments. The rivers flowing towards the north to meet mighty Brahmaputra river of Assam plain have gentle gradient of longitudinal profiles and thereby do not form any major waterfalls and deep gorges. The rivers flowing towards the south are characterized by steepest gradient and abruptly falls to the Bangladesh plain.

The capital of Meghalaya state is in Shillong. There are total seven districts of Meghalaya state. The districts derive their names from that of the tribes inhabiting the region. The seven districts are: East Khasi hills, East garo hills, Jaintia hills, Ri Bhoi, South Garo hills,West Garo hills and West Khasi hills (Statistical hand book of Meghalaya, 2007) . There are about 5,782 villages in the state. The total population of the state is 2,318, 822 (Manorama year book 2009).

The major rivers of the state are Ganol, Ringgi, Krishnai, Manda, Darong, Bhogai, simsang, Dareng, Umkhri, Umtrew, Umiam, Kopili, Kynshiang,Shella, Umngot, Myntdu, Lubha, etc. One of the marked features of River Kynshi in West Khasi Hills is the formation of River Island called Nongkhnum. Nongkhnum is not only India’s but Asia’s second largest river island. Ranikor situated in the West Khasi Hills district in the confluence of Kynshi and Rilang rivers is one of the best fishing spots. Meghalaya has the highest hydro – electric potential in the north-eastern region second only to Auranachal Pradesh. Hydel projects such as Umiam and Umtrew have caused construction of artificial lakes for the generation of electricity. Umiam Lake commonly called Barapani is formed by the damming of the Umiam river under the Umiam Hydro-Electric Project is a place of major tourist attraction and has great potentialities of recreation, aquatic sports, fishing etc. Meghalaya is also noted for a number of river cataracts and waterfall of great beauty located at different heights and scenic setting.

The state is covered by 54 Survey of India topographical maps on 1:50,000 scale that spatial framework for mapping (Figure 4). The spatial framework was prepared using 15’x15’ grid.



Figutr 3: Location map

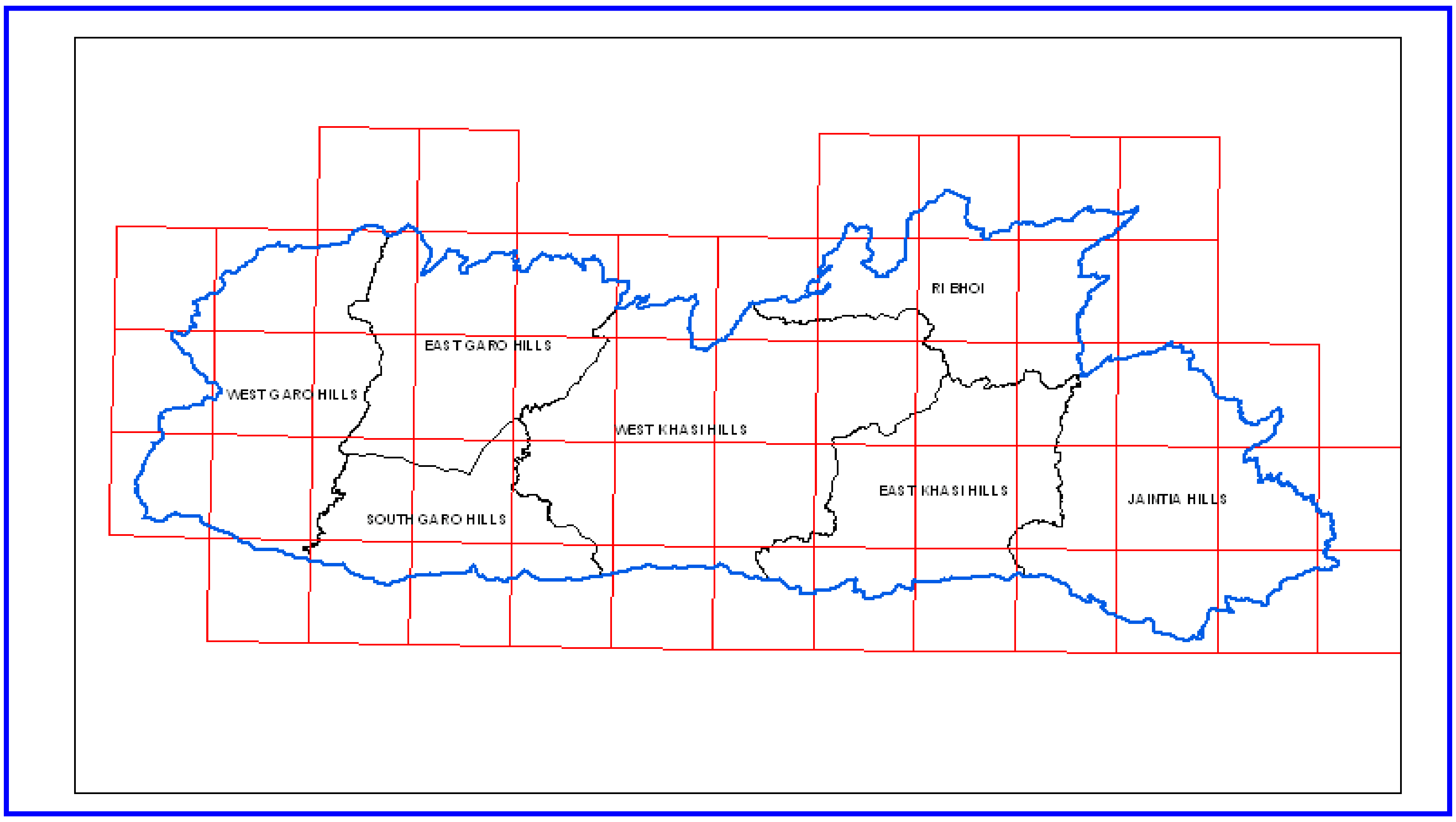


Figure 4: Spatial Framework of Meghalaya

4.0 DATA USED

Remote sensing data

IRS P6 LISS III data was used to map the wetlands. IRS P6 LISS III provide data in 4 spectral bands; green, red, Near Infra Red (NIR) and Short wave Infra Red (SWIR), with 23 m spatial resolution and 24 day repeat cycle. The spatial resolution is suitable for 1:50,000 scale mapping. The state of Meghalaya is covered in 6 IRS LISS III scene (Figure 5). Two date data, one acquired during March and another during January were used to capture the pre-monsoon and post-monsoon hydrological variability of the wetlands respectively (Table-2). Figure 6 shows part of Meghalaya as seen in the LISS III FCC of post- monsoon pre-monsoon data respectively.

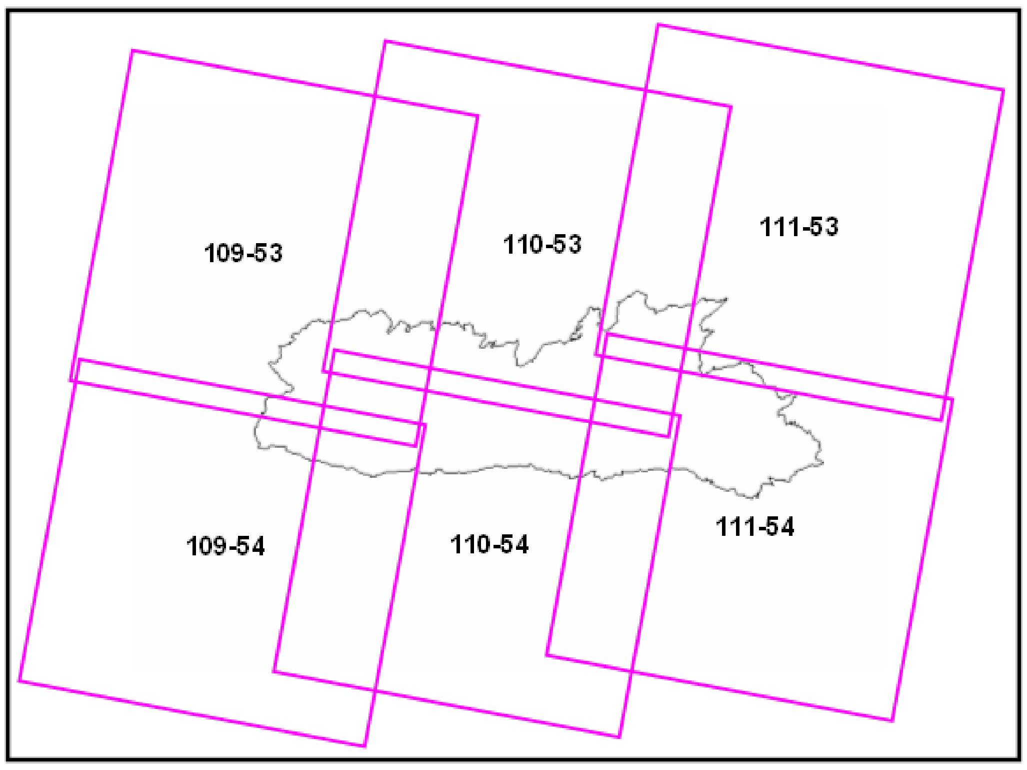


Figure 5: IRS P6 LISS-III coverage (path-row) of Meghalaya

Table-2: Satellite data used

Sl. No	Resourcesat LISS III Path/ Row	Post-Monsoon	Pre-Monsoon
1	109/53	Oct 27, 2006	Mar 20, 2007
2	109/54	Oct 27, 2006	Mar 20, 2007
3	110/53	Dec 14, 2007	Mar 25, 2007
4	110/54	Dec 19, 2006	Feb 10,2006
5	111/53	Nov 25, 2007	Jan 22, 2006
6	111/54	Nov 30, 2006	Mar 30, 2007

Ground truth data

Remote sensing techniques require certain amount of field observation called "ground truth" in order to convert into meaningful information. Such work involves visiting a number of test sites, usually taking the satellite data. The location of the features is recorded using the GPS. The standard proforma as per the NWIA manual was used to record the field data. Field photographs are also taken to record the water quality (subjective), status of aquatic vegetation and water spread. All field verification work has been done during October and November 2008.

Other data

Survey of India topographical maps (SOI) were used for reference purpose. Lineage data of National Wetland Maps at 1:50,000 scale was used for reference.

5.0 METHODOLOGY

The methodology to create the state level atlas of wetlands is adhered to NWIA technical guidelines and procedure manual (Garg and Patel, 2007). The overview of the steps used is shown in Figure 7. Salient features of methodology adopted are

- Generation of spatial framework in GIS environment for database creation and organisation.
- Geo-referencing of satellite data
- Identification of wetland classes as per the classification system given in NWIA Manual and mapping of the classes using a knowledge based digital classification and onscreen interpretation
- Generation of base layers (rail, road network, settlements, drainage, administrative boundaries) from satellite image and ancillary data.
- Mosaicing/edge matching to create district and state level database.
- Coding of the wetlands following the standard classification system and codification as per NWIA manual.
- Preparation of map compositions and generation of statistics
- Outputs on A3 size prints and charts for atlas.

Work was carried out using ERDAS Imagine, Arc/Info and ArcGIS softwares.

5.1 Creation of spatial framework

This is the most important task as the state forms a part of the national frame work and is covered in multiple map sheets. To create NWIA database, NNRMS/NRDB standards is followed and four corners of the 1:50,000 (15' x 15') grid is taken as the tics or registration points to create each map taking master grid as the reference. Spatial framework details are given in NWIA manual (Garg and Patel, 2007). The spatial framework for Meghalaya state is shown in Figure 4.

5.2 Geo-referencing of satellite data

In this step the raw satellite images were converted to specific map projection using geometric correction. This is done using archived geometrically corrected LISS III data (ISRO-NRC-land use / land cover project). Standard image processing software was used for geo-referencing. First one date data was registered with the archived image. The second date data was then registered with the first date data.

5.3 Mapping of wetlands

The delineation of wetlands through image analysis forms the foundation for deriving all wetland classes and results. Consequently, a great deal of emphasis has been placed on the quality of the image Interpretation. In the present study, the mapping of wetlands was done following digital classification and onscreen visual interpretation. Wetlands were identified based on vegetation, visible hydrology and geography. There are various methods for extraction of water information from remote sensing imagery, which according to the number of bands used, are generally divided into two categories, i.e. Single-band and multi-band methods. Single-band method usually involves choosing a band from multi-spectral image to distinguish water from land by subjective threshold values. It may lead to over- or under-estimation of open water area. Multi-band method takes advantage of reflective differences of each band. In this project, five indices known in literature that enhances various wetland characteristics were used (McFeetres, 1986; Xu Hanqiu, 2006; Lacaux *et al*, 2007; Townshend and Justice, 1986; Tucker and Sellers, 1986) as given below:

i) Normalised Difference Water Index (NDWI) = (Green-NIR) / (Green + NIR)

ii) Modified Normalised Difference Water Index (MNDWI) = (Green-MIR) / (Green + MIR)

iii) Normalised Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red)

iv) Normalised Difference Pond Index (NDPI) = (MIR – Green / MIR + Green)

v) Normalised Difference Turbidity Index (NDTI) = (Red – Green) / (Red + Green)

The indices were generated using standard image processing software, stacked as layers. (Figure 8). Various combinations of the indices/spectral bands were used to identify the wetland features as shown in Figure 9.

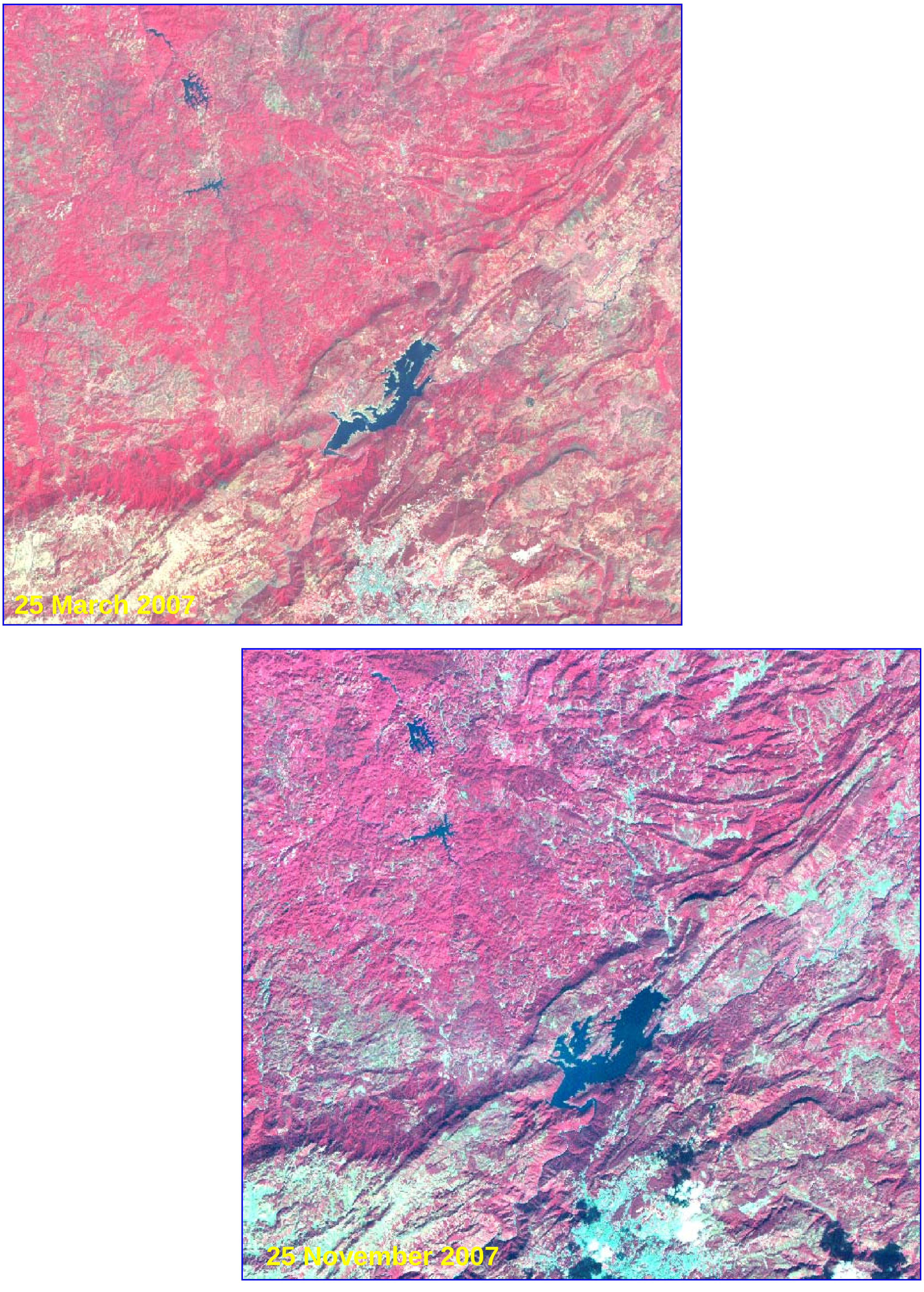


Figure 6: IRS LISS-III FCC showing part of Meghalaya (pre-monsoon and post-monsoon satellite images)

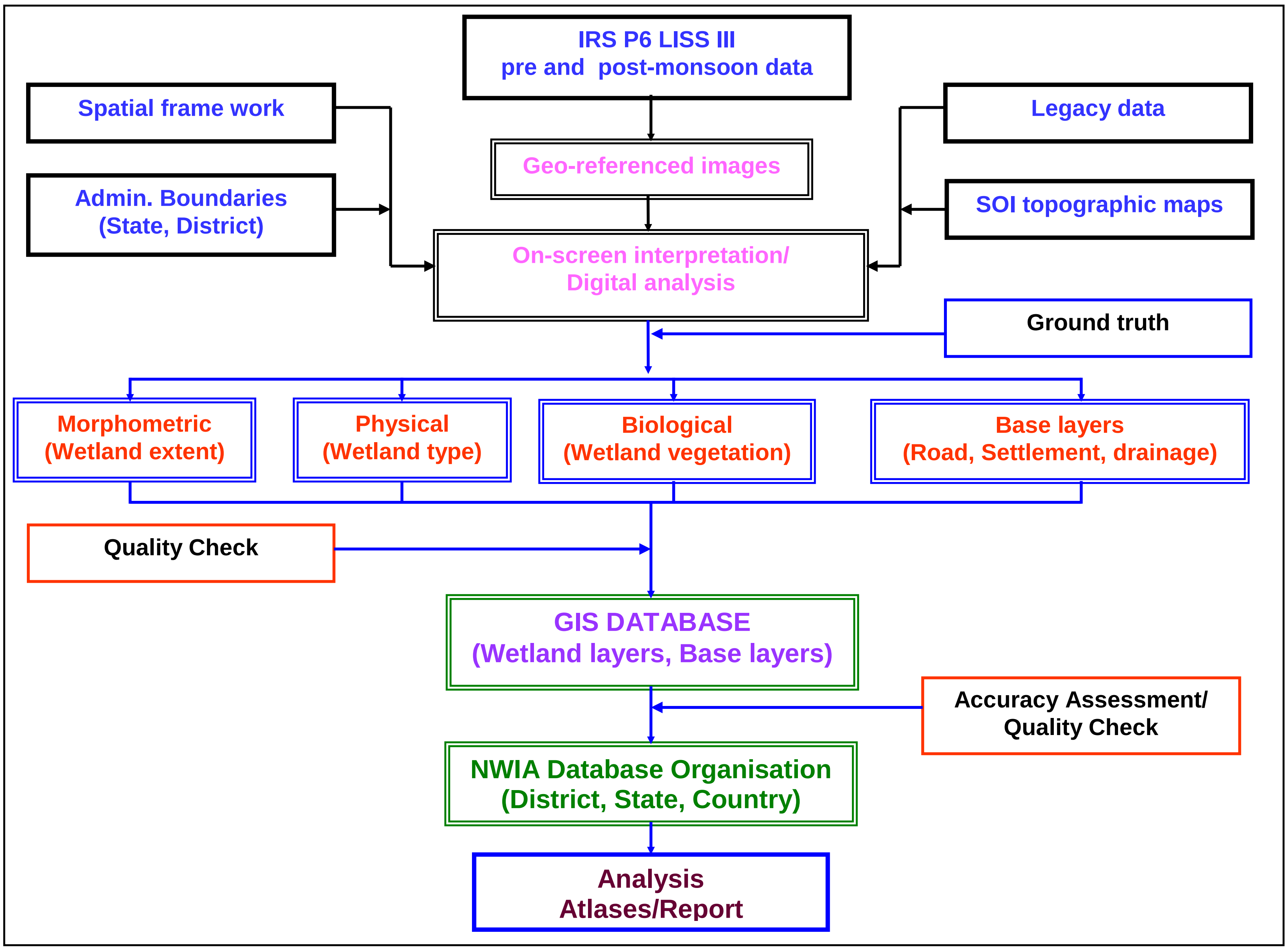


Figure 7: Flow chart of the methodology used

The following indices were used for various layer extractions:

- Extraction of wetland extent :
  MNDWI, NDPI and NDVI image was used to extract the wetland boundary through suitable hierarchical thresholds.

- Extraction of open water :
  MNDWI was used within the wetland mask to delineate the water and no-water areas.

- Extraction of wetland vegetation :
  NDPI and NDVI image was used to generate the vegetation and no-vegetation areas within a wetland using a suitable threshold.

- Turbidity information extraction :
  NDTI and MNDWI image was used to generate qualitative turbidity level (high, moderate and low) based on signature statistics and standard deviations. In the False Colour Composite (FCC) these generally appear in different hues as given in Table-3.

Table 3: Qualitative turbidity ratings

Sr. No.	Qualitative Turbidity	Conditional criteria	Hue on False Colour Composite (FCC)
1.	Low	$> +1\sigma$	Dark blue/blackish
2.	Moderate	$> -1\sigma$ to $<= +1\sigma$	Medium blue
3.	High/Bottom reflectance	$<= \mu - 1\sigma$	Light blue/whitish blue

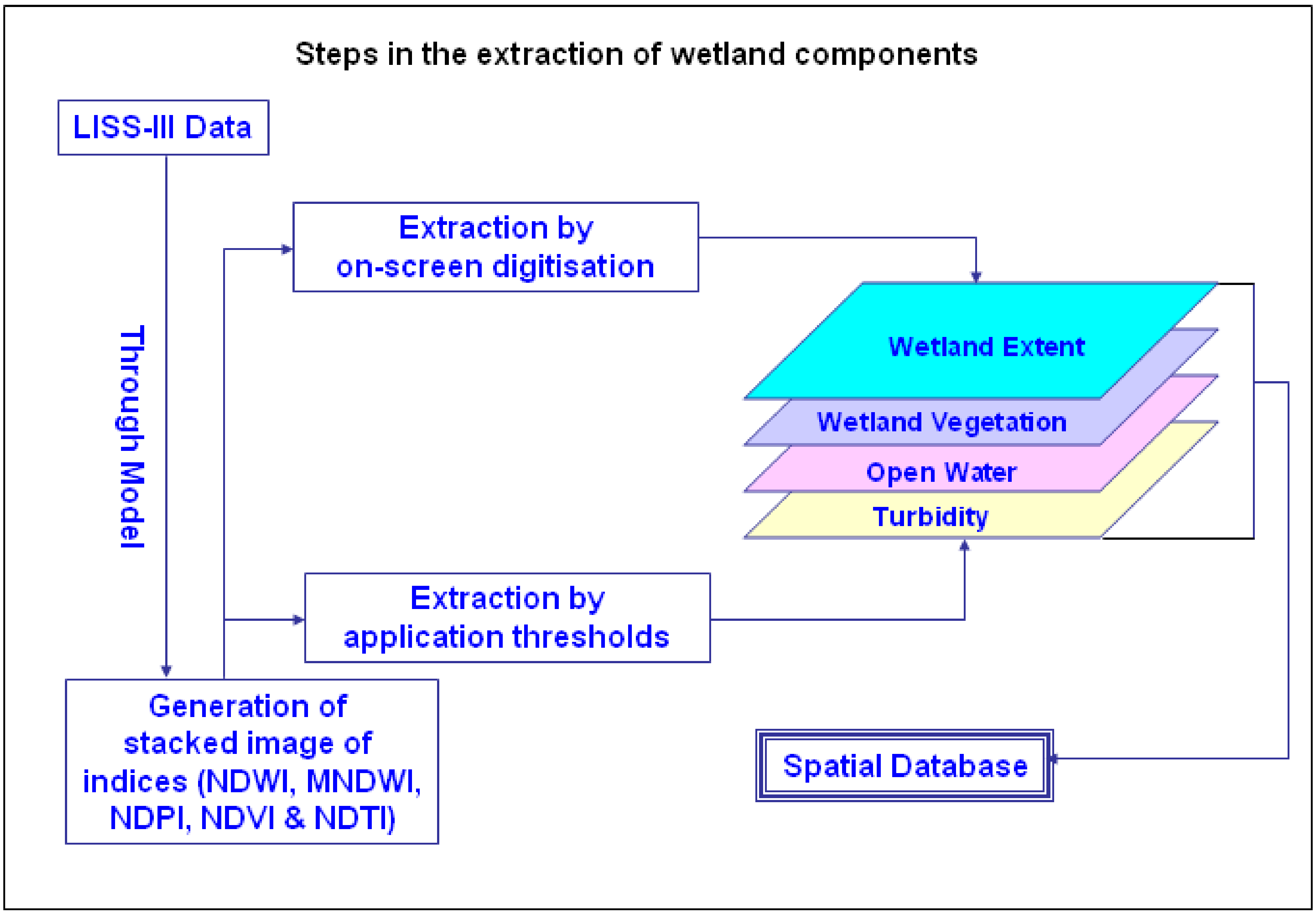


Figure 8: Steps in the extraction of wetland components

5.4 Conversion of the raster (indices) into a vector layer

The information on wetland extent, open water extent, vegetation extent and turbidity information was converted into vector layers using region growing properties or on-screen digitisation.

5.5 *Generation of reference layers*

Base layers like major rail, road network, settlements, drainage are interpreted from the current image or taken from other project database. The administrative boundaries (district, state) are taken from the known reference data.

5.6 *Coding and attribute scheme*

Feature codification scheme for every input element has been worked out keeping in view the nationwide administrative as well as natural hierarchy (State-district-taluka) within the feature class for each of the theme. All data elements are given a unique name/code, which are self explanatory with short forms.

5.7 Map composition and output

Map composition for atlas has been done at district and state level. A standard color scheme has been used for the wetland classes and other layers. The digital files are made at 1:50,000 scale. The hard copy outputs are taken on A3 size.

6.0 ACCURACY ASSESSMENT

A comprehensive accuracy assessment protocol has been followed for determining the quality of information derived from remotely sensed data. Accuracy assessment involves determination of thematic (classification) as well as locational accuracy. In addition, GIS database(s) contents have been also evaluated for accuracy. To ensure the reliability of wetland status data, the project adhered to established quality assurance and quality control measures for data collection, analysis, verification and reporting.

This study used well established, time-tested, fully documented data collection conventions. It employed skilled and trained personnel for image interpretation, processing and digital database creation. All interpreted imageries were reviewed by technical expert team for accuracy and code. The reviewing analyst adhered to all standards, quality requirements and technical specifications and reviewed 100 percent of the work. The various stages of quality check include:

1. Image-to-Image Geo-referencing/Data generation
2. Reference layer preparation using NWIA post monsoon and pre-monsoon LISS-III data.
3. Wetland mapping using visual/digital interpretation techniques.
4. Geo-data base creation and organization
5. Output products.

6.1 Data verification and quality assurance of output digital data files

All digital data files were subjected to rigorous quality control inspections. Digital data verification included quality control checks that addressed the geospatial correctness, digital integrity and some cartographic aspects of the data. Implementation of quality checks ensured that the data conformed to the specified criteria, thus achieving the project objectives. There were tremendous advantages in using newer technologies to store and analyze the geographic data. The geospatial analysis capability built into this study provided a complete digital database to better assist analysis of wetland change information. All digital data files were subjected to rigorous quality control inspections. Automated checking modules incorporated in the geographic information system (Arc/GIS) were used to correct digital artifacts including polygon topology. Additional customized data inspections were made to ensure that the changes indicated at the image interpretation stage were properly executed.

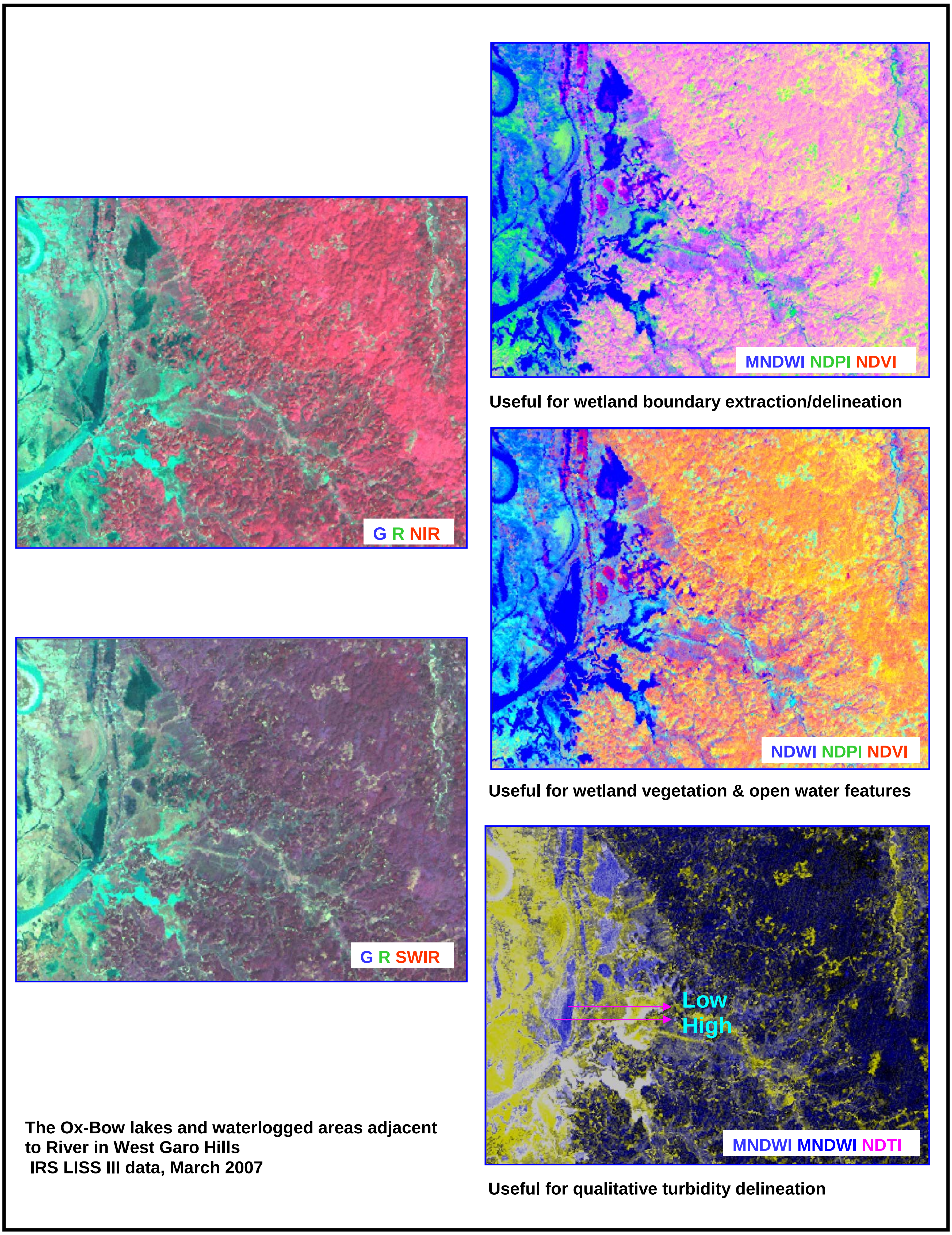


Figure 9: Various combinations of the indices/spectral bands used to identify wetland components

MAPS AND STATISTICS

7.0 WETLANDS OF MEGHALAYA: MAPS AND STATISTICS

Area estimates of various wetland categories for Meghalaya have been carried out using GIS layers of wetland boundary, water-spread, aquatic vegetation and turbidity. In the state of Meghalaya, 259 (wetlands have been delineated. Total wetland area estimated is 29987 ha. (Table 4). Small wetlands, which are less than minimum mapable units (MMU), are 167 in the district. The major wetland types are River/Stream (24841 ha) and Reservoirs (1562 ha). Graphical distribution of wetland type is shown in Figure 10.

Table 4 : Area estimates of wetlands in Meghalaya

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	15	501	1.67	337	175
2	1102	Ox-bow lakes/ Cut-off meanders	1	461	1.54	316	107
3	1104	Riverine wetlands	4	1272	4.24	836	1271
4	1105	Waterlogged	77	1028	3.43	678	280
5	1106	River/Stream	124	24841	82.84	24112	24051
	1200	**Inland Wetlands -Man-made**					
6	1201	Reservoirs/Barrages	8	1562	5.21	1520	1415
7	1202	Tanks/Ponds	29	150	0.50	113	121
8	1203	Waterlogged	1	5	0.02	-	-
		Sub-Total	**259**	**29820**	**99.44**	**27912**	**27420**
		Wetlands (<2.25 ha), mainly Tanks	167	167	0.56	-	-
		Total	**426**	**29987**	**100.00**	**27912**	**27420**

Area under Aquatic Vegetation	819	852

Area under turbidity levels		
Low	24919	24692
Moderate	1928	1168
High	1065	1560

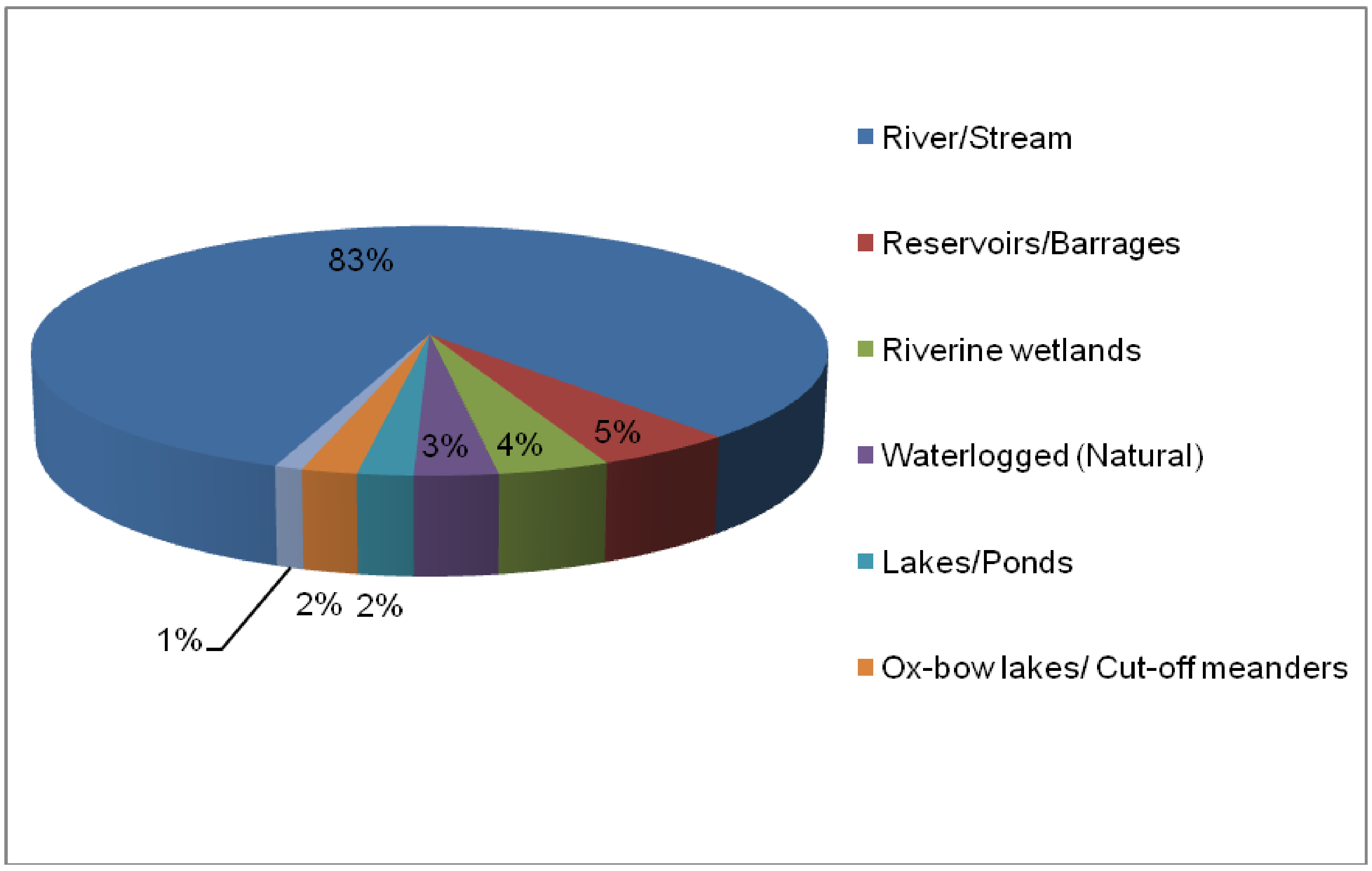


Figure 10: Type-wise wetland distribution in Meghalaya

7.1 DISTRICT-WISE WETLAND MAPS AND STATISTICS

The state has seven districts. District-wise wetland area estimates is given in Table-5.

Wetland statistics followed by wetland map and corresponding satellite data for each district is given to have a fairly good idea about the distribution pattern and density of wetlands in the district.

Table – 5: District-wise wetland area

Sr. No.	District	Geographic Area (sq. km)	Wetland Area (ha)	% of total wetland area	% of district geographic area
1	West Garo Hills	343890	7196	24.01	0.021
2	East Garo Hills	286869	2649	8.84	0.009
3	South Garo Hills	187083	3169	10.57	0.017
4	West Khasi Hills	522543	5920	19.75	0.011
5	Ri Bhoi	237005	1945	6.49	0.008
6	East Khasi Hills	285216	4796	16.00	0.017
7	Jaintia Hills	379347	4302	14.35	0.011
	Total	**2241953**	**29977**	**100.00**	

(* Source: Census 2001)

West Garo Hills district of Meghalaya covers the maximum wetland area (24 %). A major portion of wetland areas are observed in West khasi Hills, East Khasi Hills and in Jaintia Hills. East Garo Hills and Ribhoi district covers small portion of wetland area. The graphical distribution of district-wise wetland area is shown in Figure 11.

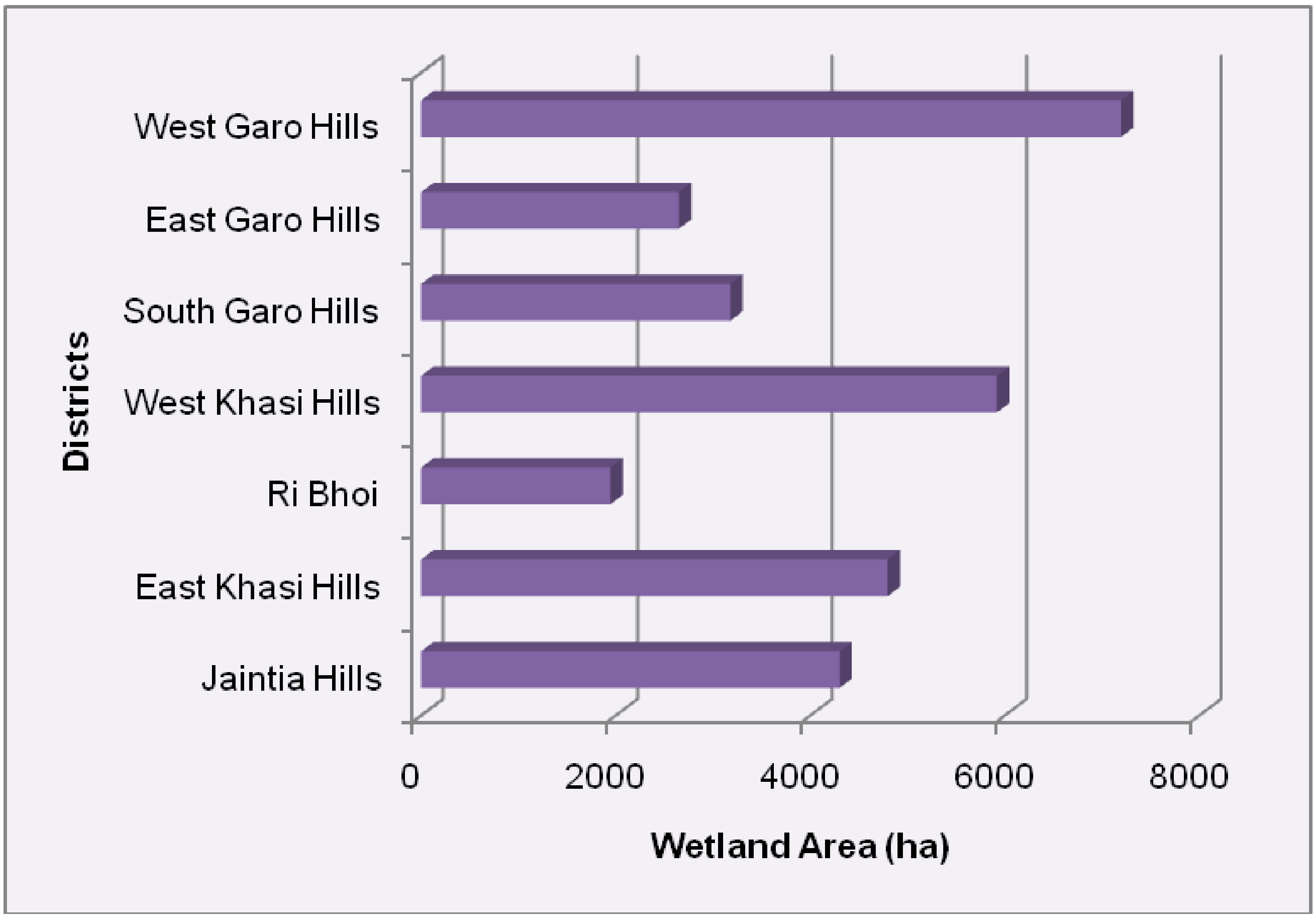
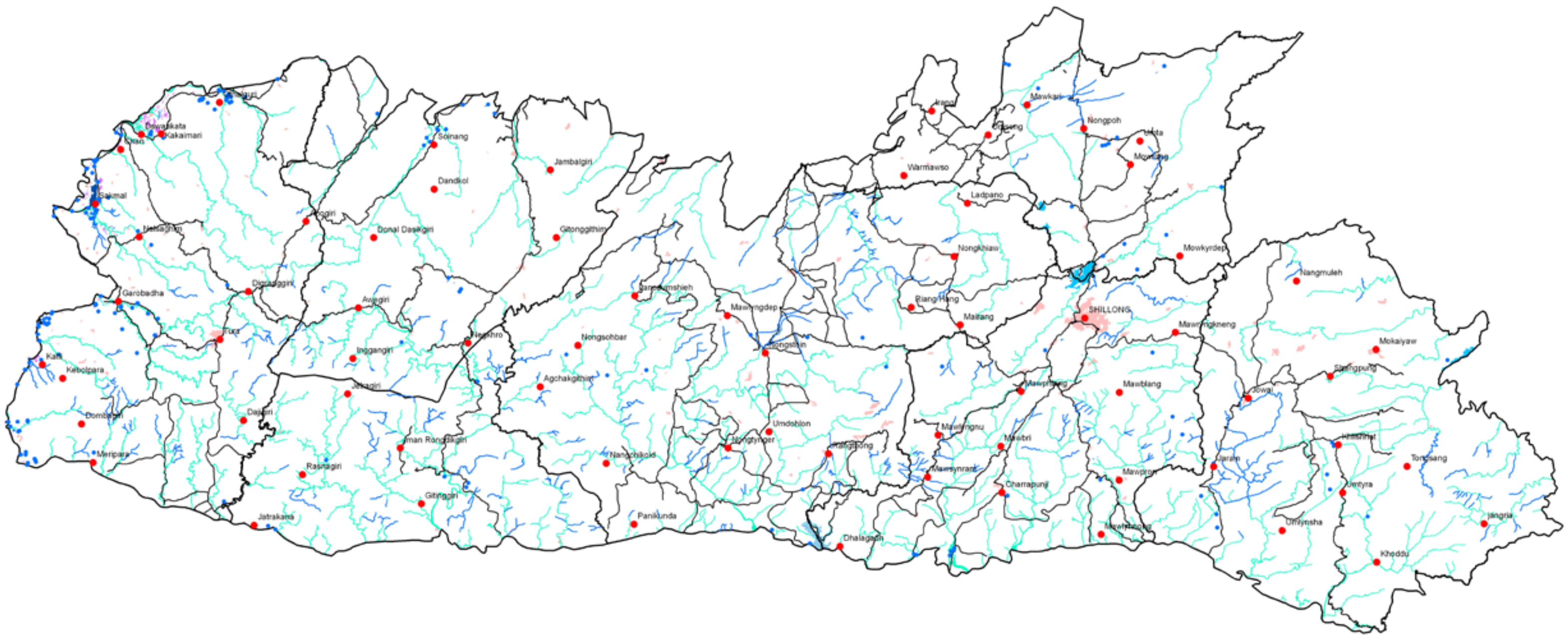


Figure 11: District-wise wetland distribution

State : Meghalaya

WETLAND MAP

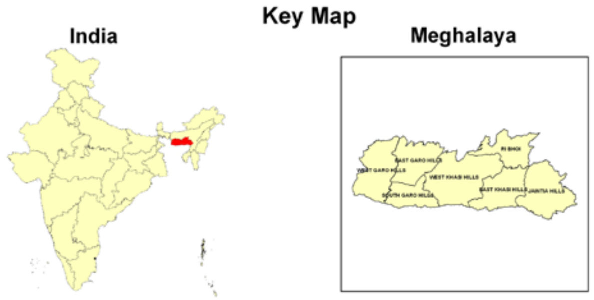


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements

Key Map



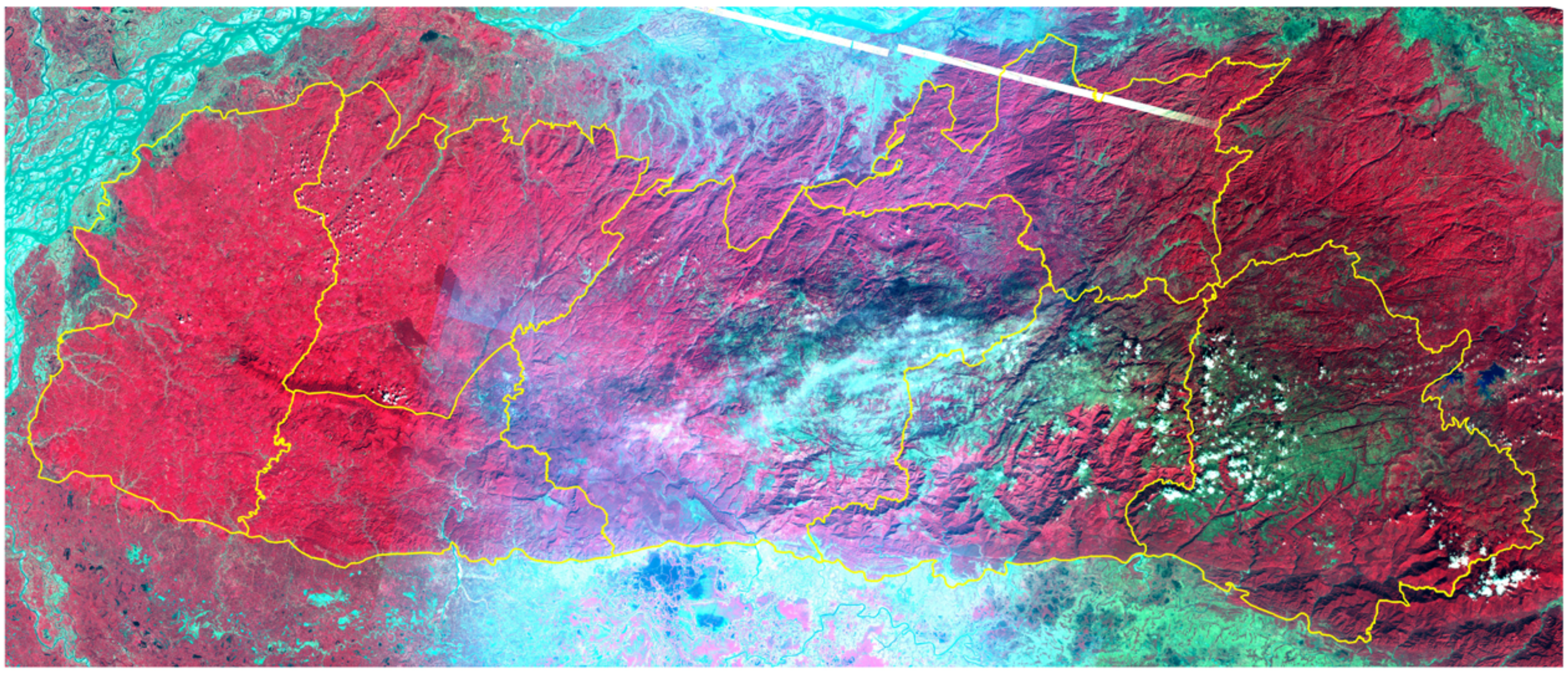
20 10 0 20 40 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya



IRS P6 LISS III post monsoon data (2006)

7.1.1 Wetland Distribution in West Garo Hills

West Garo Hills is one of the largest districts of Meghalaya located in the western part of the State. The Garo Hills district was divided into two districts, viz. the West Garo Hills district and the East Garo Hills district in October 1976. The erstwhile West Garo Hills district was further divided into two administrative districts of West and South Garo Hills on June 1992. The district headquarters of West Garo Hills is Tura, which is the second largest town in the State after Shillong. The West Garo Hills district is bounded by the East Garo Hills district on the east, the South Garo Hills on the south-east, the Goalpara district of Assam on the north and north-west and Bangladesh on the south. The total geographic area of West Garo Hills district of Meghalaya is 343890 ha. The wetland area estimated is 7196 ha. Small wetlands, which are less than minimum mapable units (MMU), are 99 in the district. Details are given in Table 6. The major wetland types are River/Stream, waterlogged areas, Lakes/Ponds and Ox-bow lakes.

Table 6: Area estimates of wetlands in West Garo Hills

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1101	Lakes/Ponds	15	501	6.96	337	175
2	1102	Ox-bow lakes/ Cut-off meanders	1	461	6.41	316	107
3	1105	Waterlogged	74	1010	14.04	665	268
4	1106	River/Stream	61	5083	70.64	5149	5087
	1200	**Inland Wetlands -Man-made**					
5	1202	Tanks/Ponds	5	37	0.51	26	32
6	1203	Waterlogged	1	5	0.07	3	3
		Sub-Total	**157**	**7097**	**98.62**	**6496**	**5672**
		Wetlands (<2.25 ha), mainly Tanks	99	99	1.38	-	-
		Total	**256**	**7196**	**100.00**	**6496**	**5672**

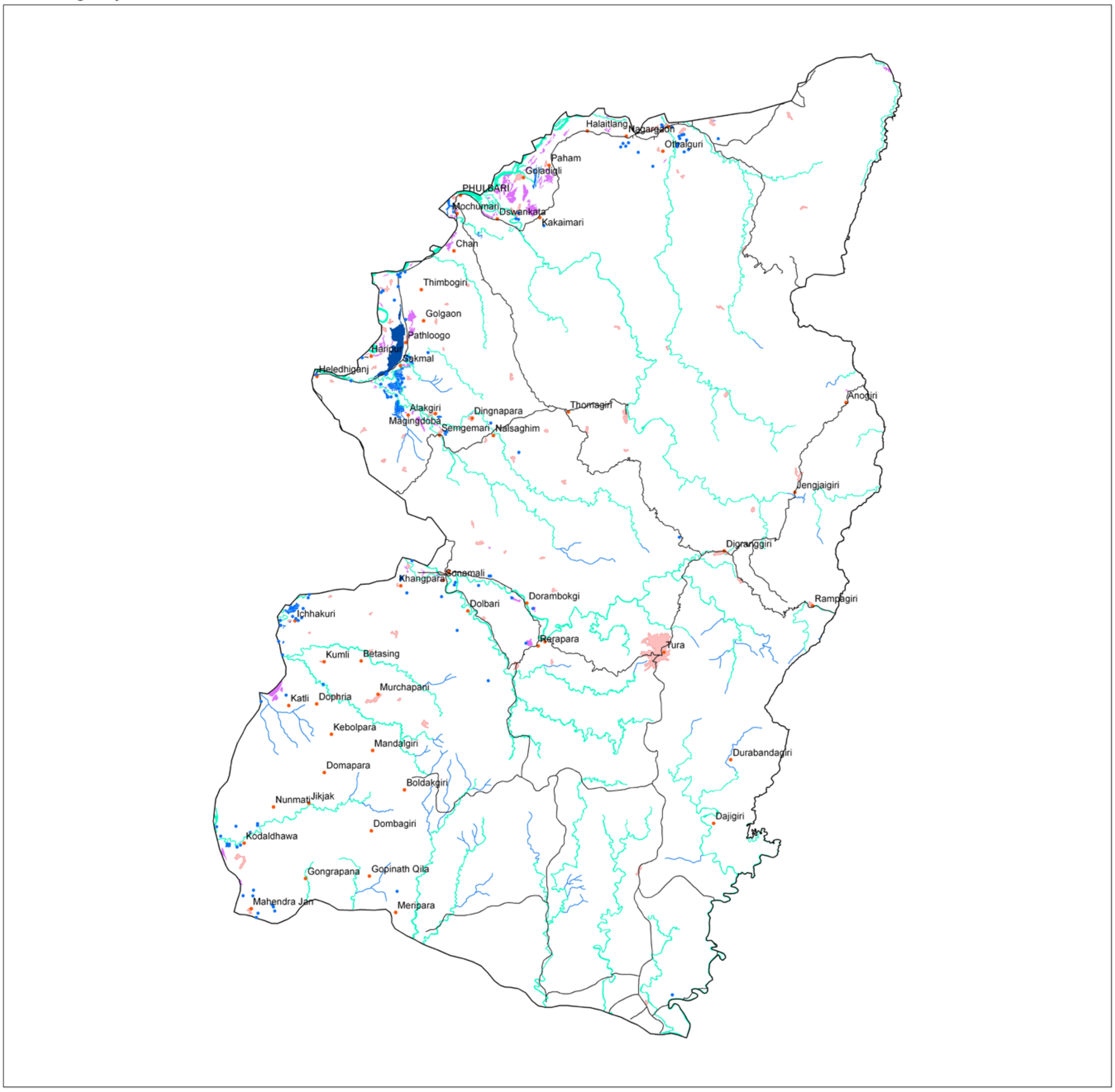
Area under Aquatic Vegetation	630	778

Area under turbidity levels		
Low	5664	5297
Moderate	716	302
High	114	70

State : Meghalaya

WETLAND MAP

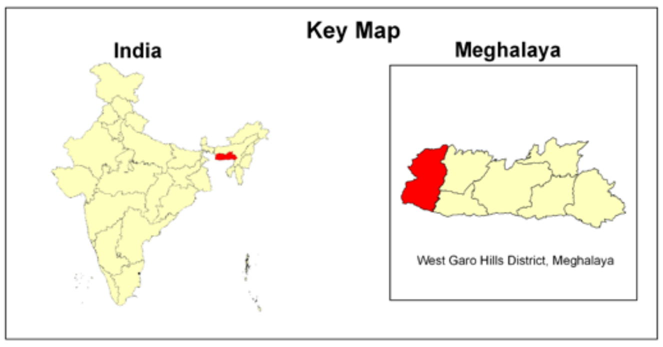
District : West Garo Hills



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



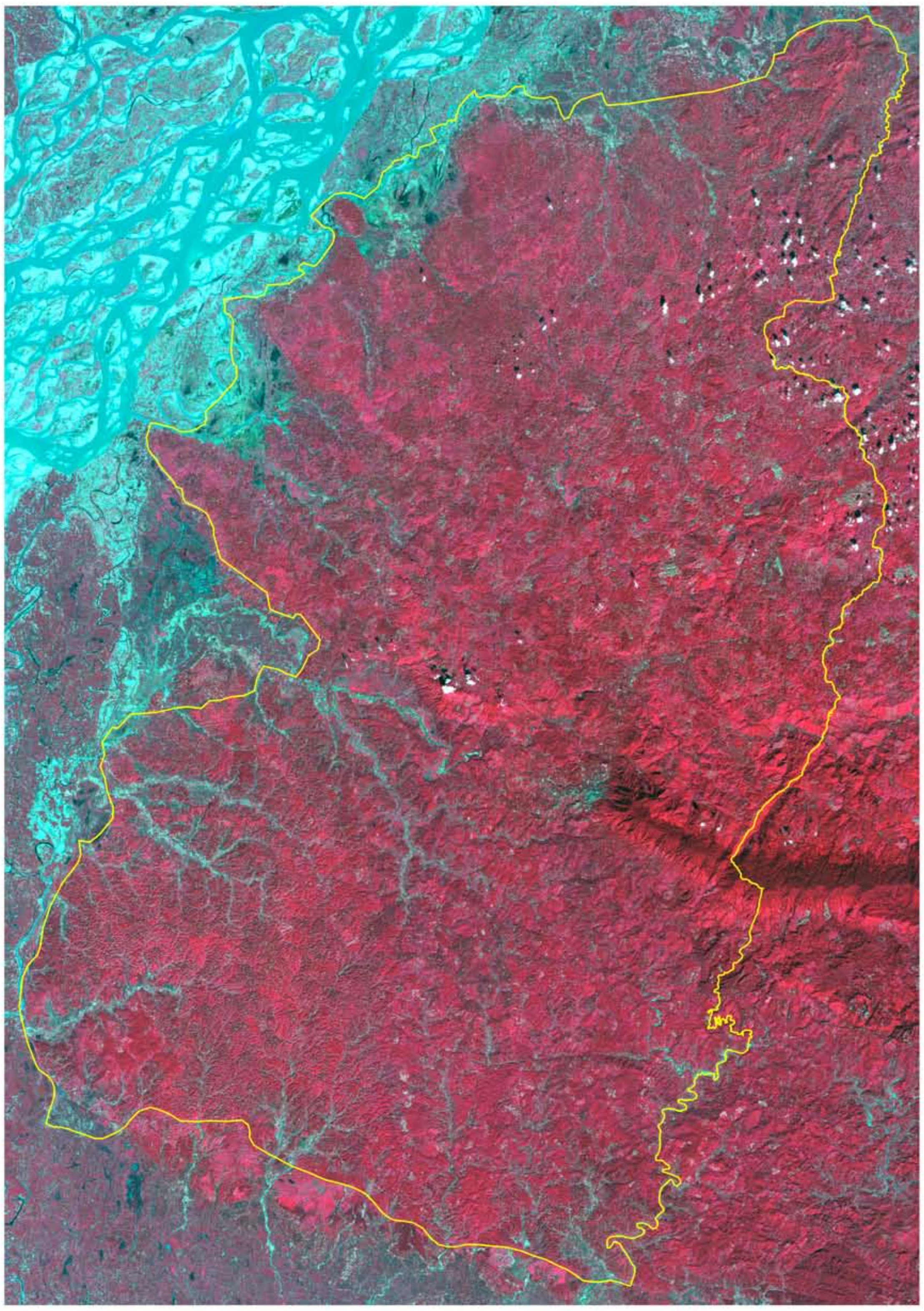
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : West Garo Hills



IRS P6 LISS-III post-monsoon data(2006)

7.1.7 Wetland Distribution in East Garo Hills

The East Garo Hills district was formed in 1976. The district was carved out from the Garo Hills District. The district headquarter is located at Williamnagar. As per 2001 census, the district is home to 2,50,582 people. Agriculture, horticulture, fisheries, textile, pottery, handicrafts, sericulture, cottage industries constitute the economic scenario of East Garo Hills. The topography of the district is undulating low hills, with altitude ranging from 150 to 600 metres above sea level. The total geographic area of East Khasi Hills district of Meghalaya is 286869 ha. The wetland area estimated is 2649 ha. Details are given in Table 7. Small wetlands, which are less than minimum mapable units (MMU), are 14 in the district. The major wetland types are River/Stream, tanks/ponds and areas under water logging. Other than the Simsang river which drains southeastwards, all other rivers run north or northwest towards the Brahmaputra.

Table 7: Area estimates of wetlands in East Garo Hills

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1105	Waterlogged	3	18	0.68	12	12
2	1106	River/Stream	19	2563	96.75	2563	2563
	1200	**Inland Wetlands -Man-made**					
3	1202	Tanks/Ponds	9	54	2.04	32	32
		Sub-Total	**31**	**2635**	**99.47**	**2607**	**2607**
		Wetlands (<2.25 ha), mainly Tanks	14	14	0.53	-	-
		Total	**45**	**2649**	**100.00**	**2607**	**2607**

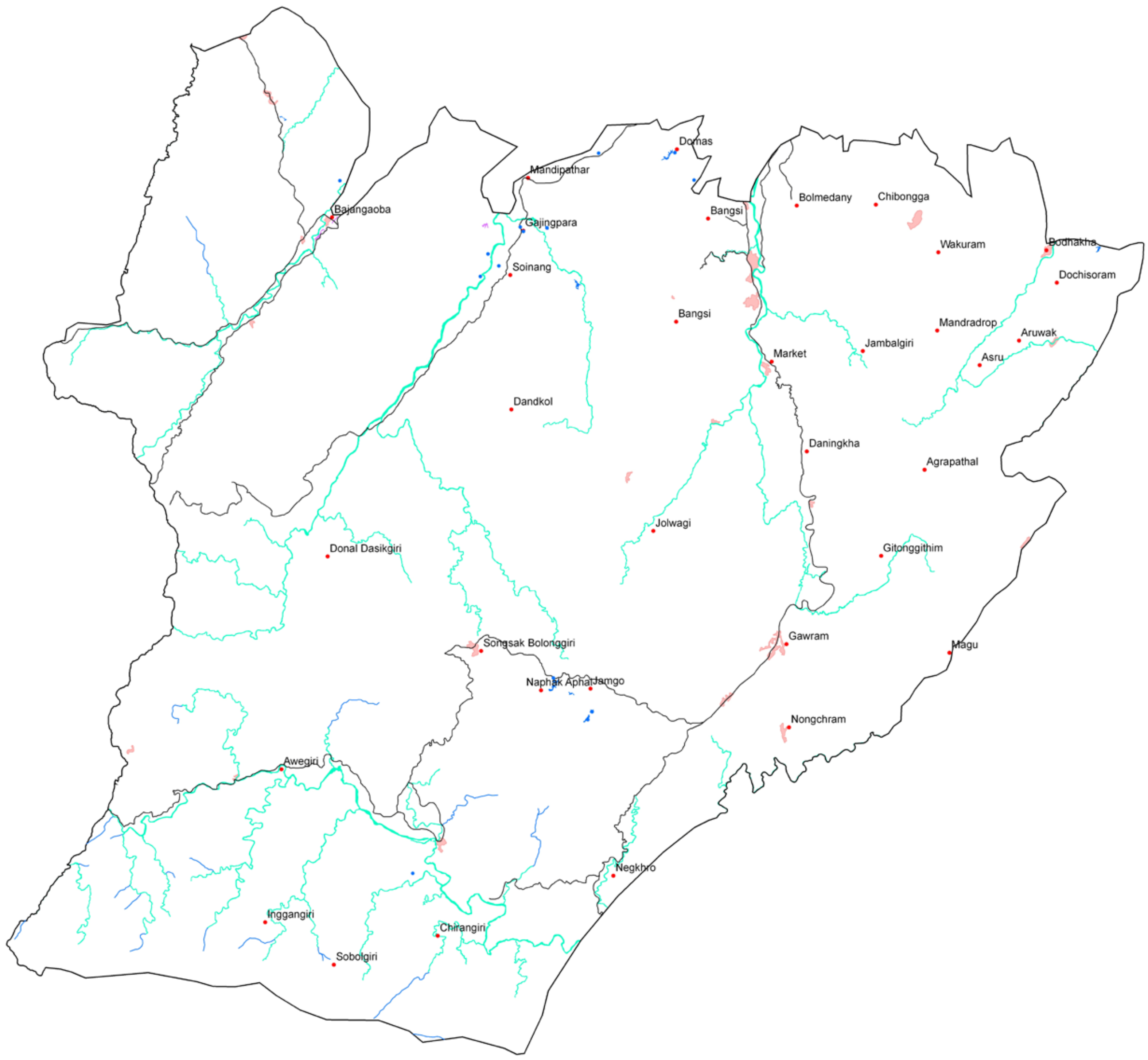
Area under Aquatic Vegetation	28	10

Area under turbidity levels		
Low	2564	2565
Moderate	45	41
High	-	2

State : Meghalaya

WETLAND MAP

District : East Garo Hills

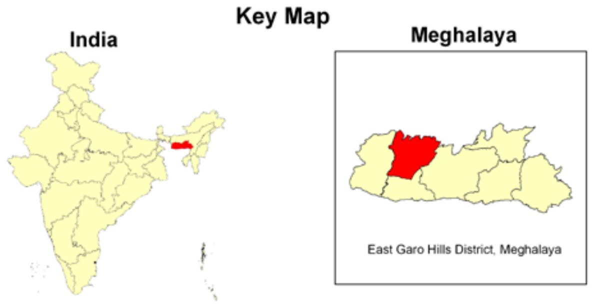


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements

Key Map



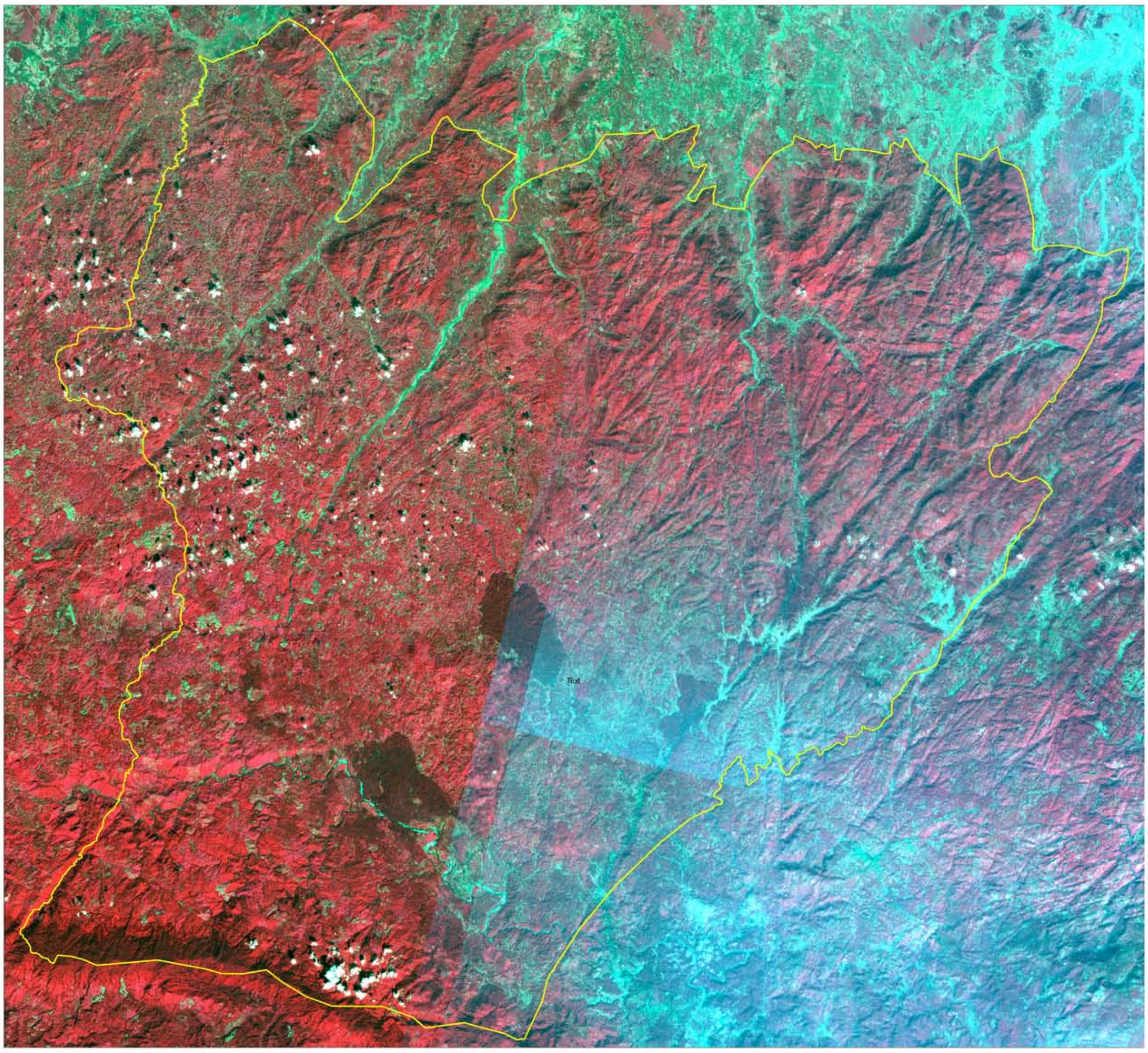
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : East Garo Hills



IRS P6 LISS-III post-monsoon data (2006)

7.1.3 Wetland Distribution in South Garo Hills

The South Garo Hills district came into existence on 18th June 1992 after the division of the West Garo Hills district. The district headquarter is Baghmara. The district is located in the southern part of the state and bounded by West Garo Hills district in the west, East Garo Hills in the north, West Khasi Hills in the East and Bangladesh in the South. The district is hilly with difficult terrain. The total geographic area of South Garo Hills district of Meghalaya is 187083 ha. The wetland area estimated is 3179 ha. Small wetlands, which are less than minimum mapable units (MMU), are 7 in the district. The major wetland types are River/Stream.

Table 8: Area estimates of wetlands in South Garo Hills

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1106	River/Stream	127	3172	99.78	3168	3168
		Sub-Total	**127**	**3172**	**99.78**	**3168**	**3168**
		Wetlands (<2.25 ha), mainly Tanks	7	7	0.22	-	-
		Total	**134**	**3179**	**100.00**	**3168**	**3168**

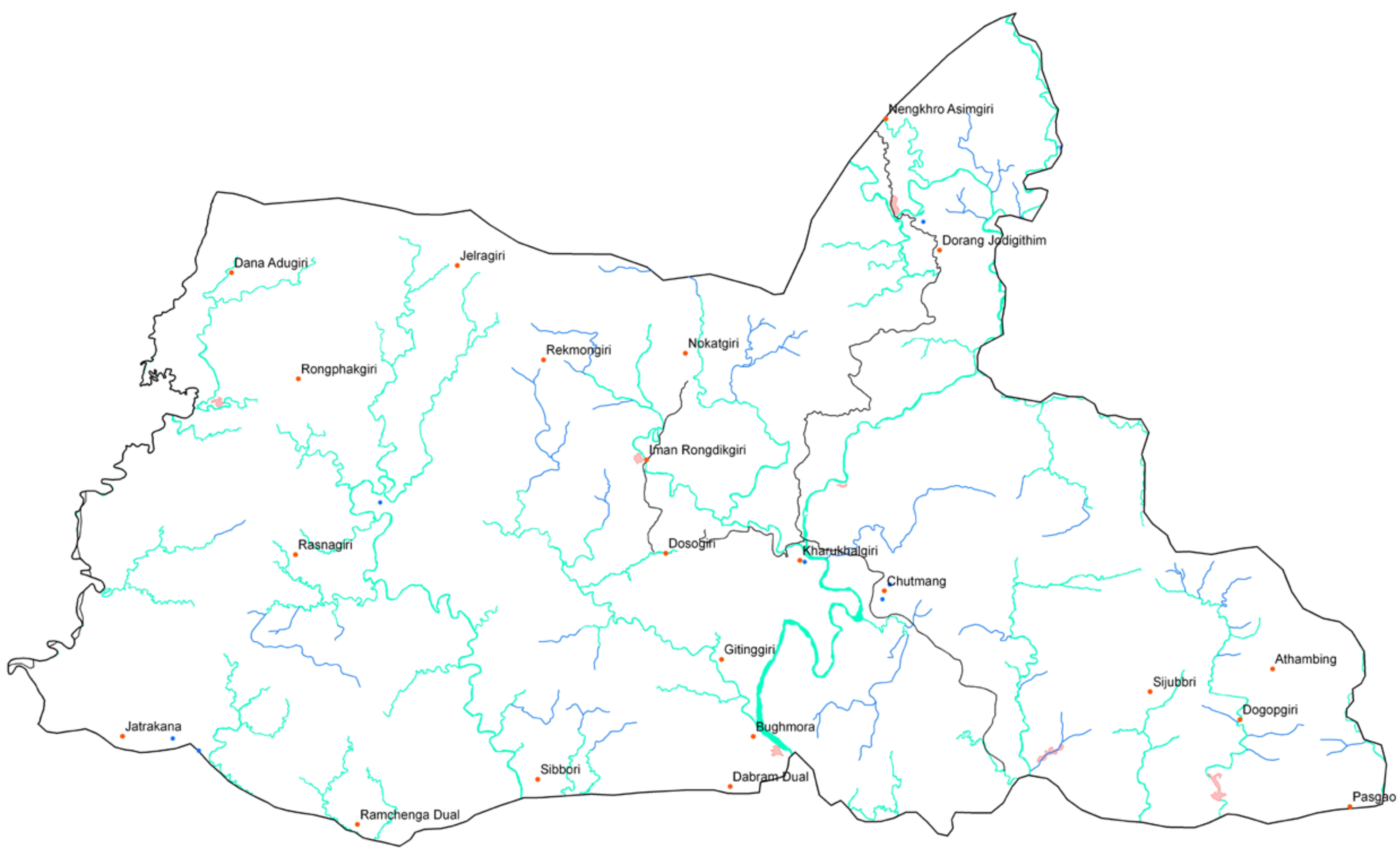
Area under Aquatic Vegetation	-	-

Area under turbidity levels		
Low	3169	3169
Moderate	-	-
High	-	-

State : Meghalaya

WETLAND MAP

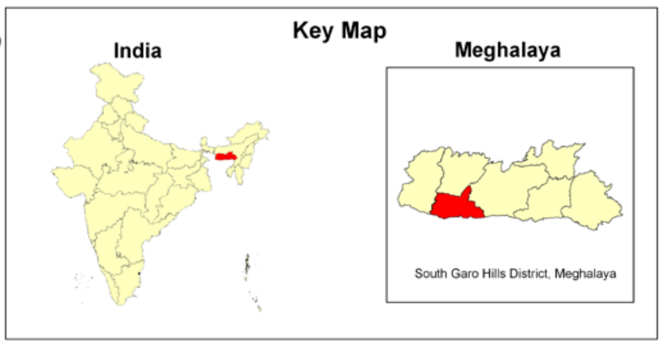
District : South Garo Hills



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



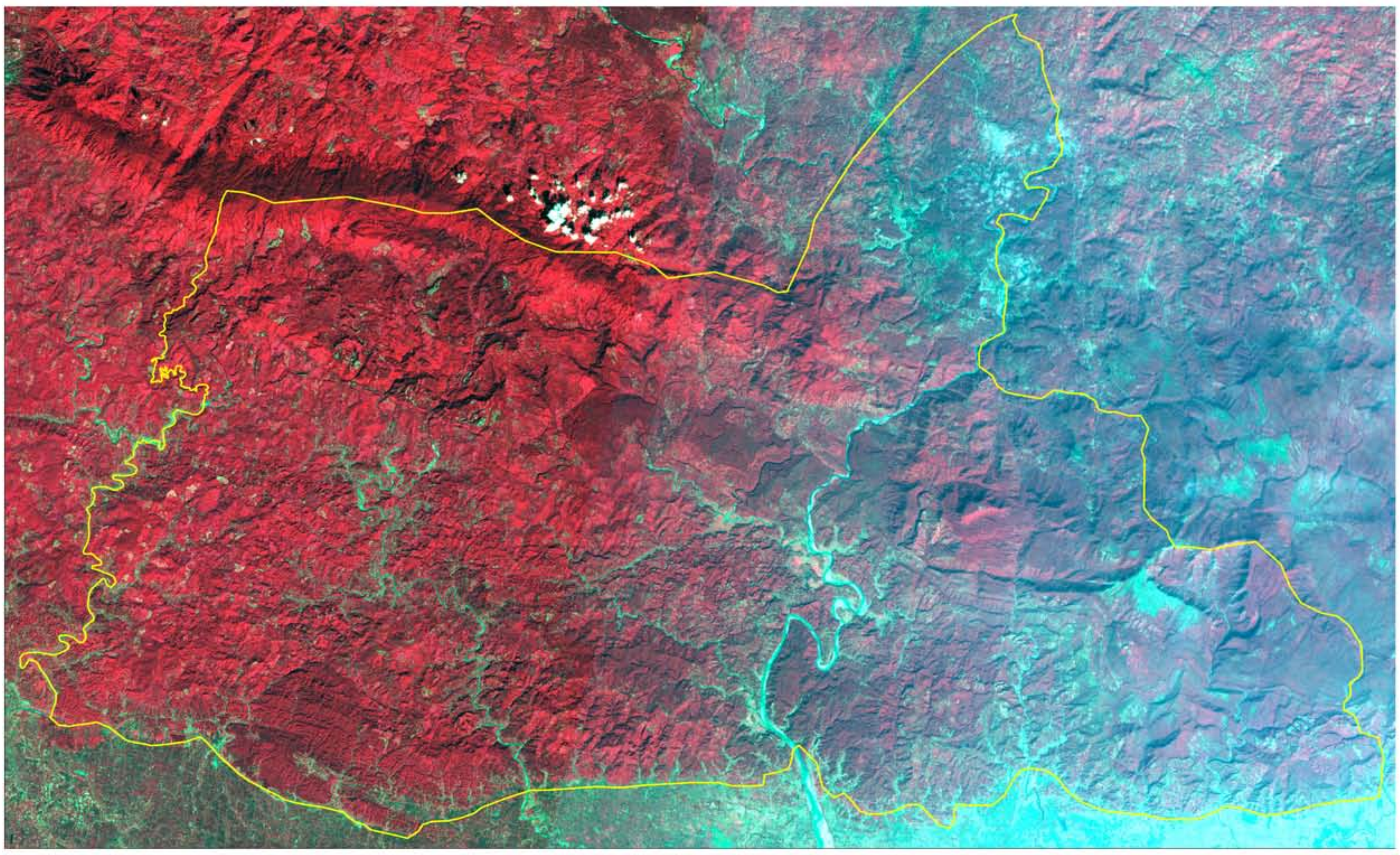
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : South Garo Hills



IRS P6 LISS-III post-monsoon data (2006)

7.1.4 Wetland Distribution in West Khasi Hills

The West Khasi Hills district is presently the largest district of Meghalaya. It was carved out from the Khasi Hills District on the 28th October, 1976. It is bounded on the north-west by Kamrup district of Assam, on the north-east by Ri-Bhoi district, on the east by East Khasi Hills district, on the south by Bangladesh, on the west by East Garo and South Garo Hills districts. Nongstoin, is the Headquarters of the District. Ranikor, Mawlangkhar, Mawthadraishan, Nongkhnum River Island, Thum Falls, Weinia Falls, Langshiang Falls, Jakrem Hot Spring, Kyllang rock are the major attractions of the region. The total geographic area of West Khasi Hills district of Meghalaya is 522543 ha. The wetland area estimated is 5920 ha. Small wetlands, which are less than minimum mapable units (MMU), are 10 in the district. Details are given in Table 9. The major wetland types are River/Stream and Riverine wetlands.

Table 9: Area estimates of wetlands in West Khasi Hills

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1104	Riverine wetlands	4	679	11.47	427	628
2	1106	River/Stream	135	5192	87.70	5067	5067
	1200	**Inland Wetlands -Man-made**					
3	1201	Reservoirs/Barrages	8	39	0.66	35	36
		Sub-Total	**147**	**5910**	**99.83**	**5529**	**5731**
		Wetlands (<2.25 ha), mainly Tanks	10	10	0.17	-	-
		Total	**157**	**5920**	**100.00**	**5529**	**5731**

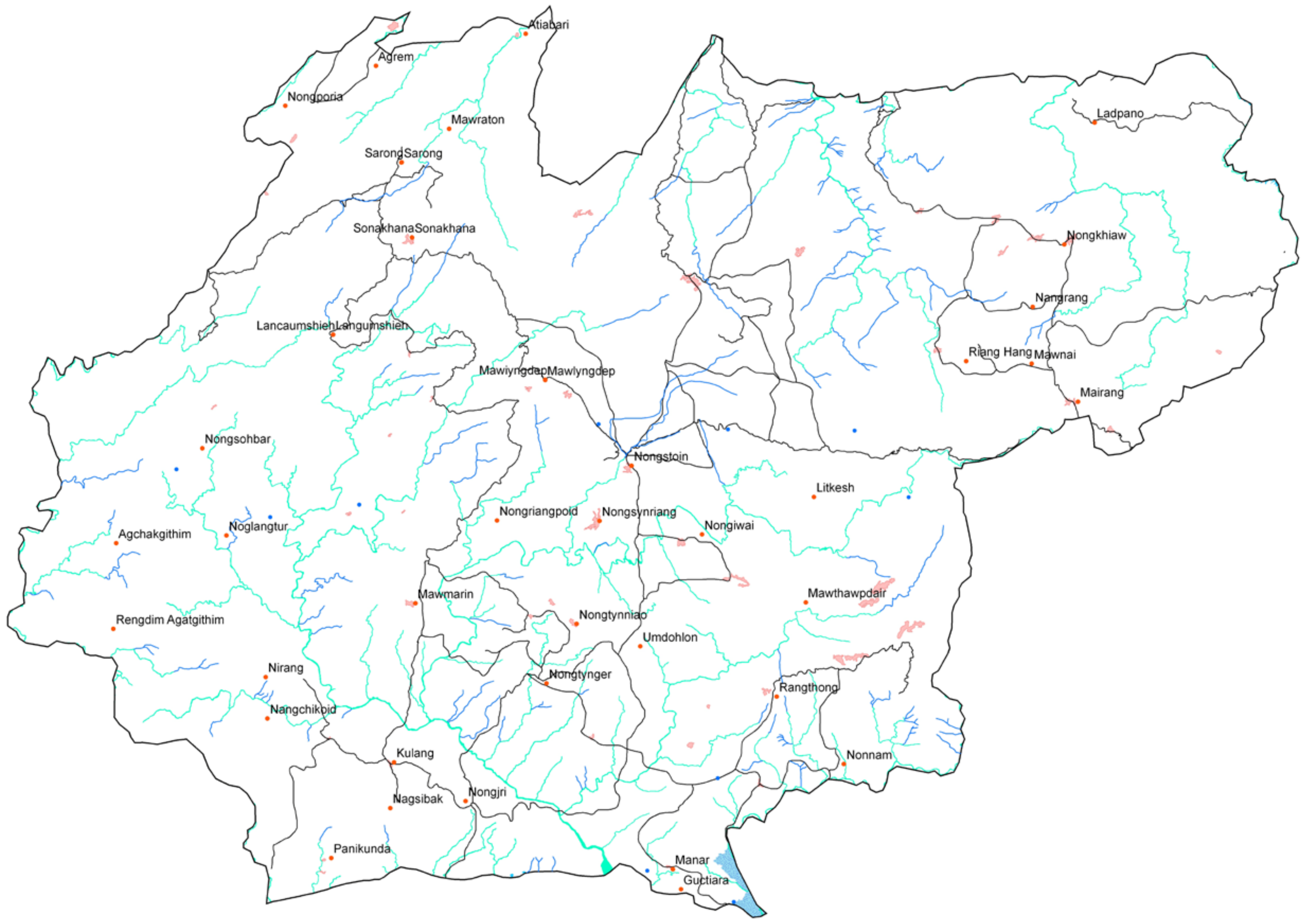
Area under Aquatic Vegetation	60	4

Area under turbidity levels		
Low	5074	5078
Moderate	29	25
High	423	628

State : Meghalaya

WETLAND MAP

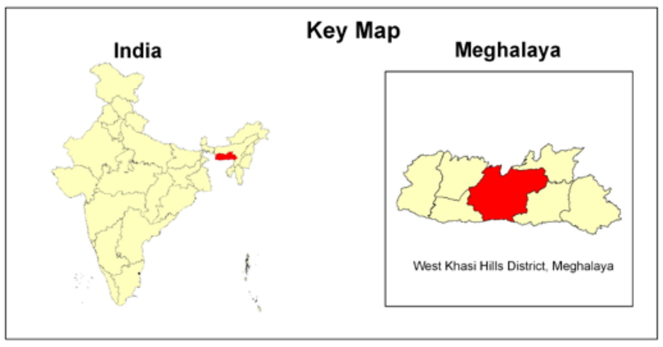
District : West Khasi Hills



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



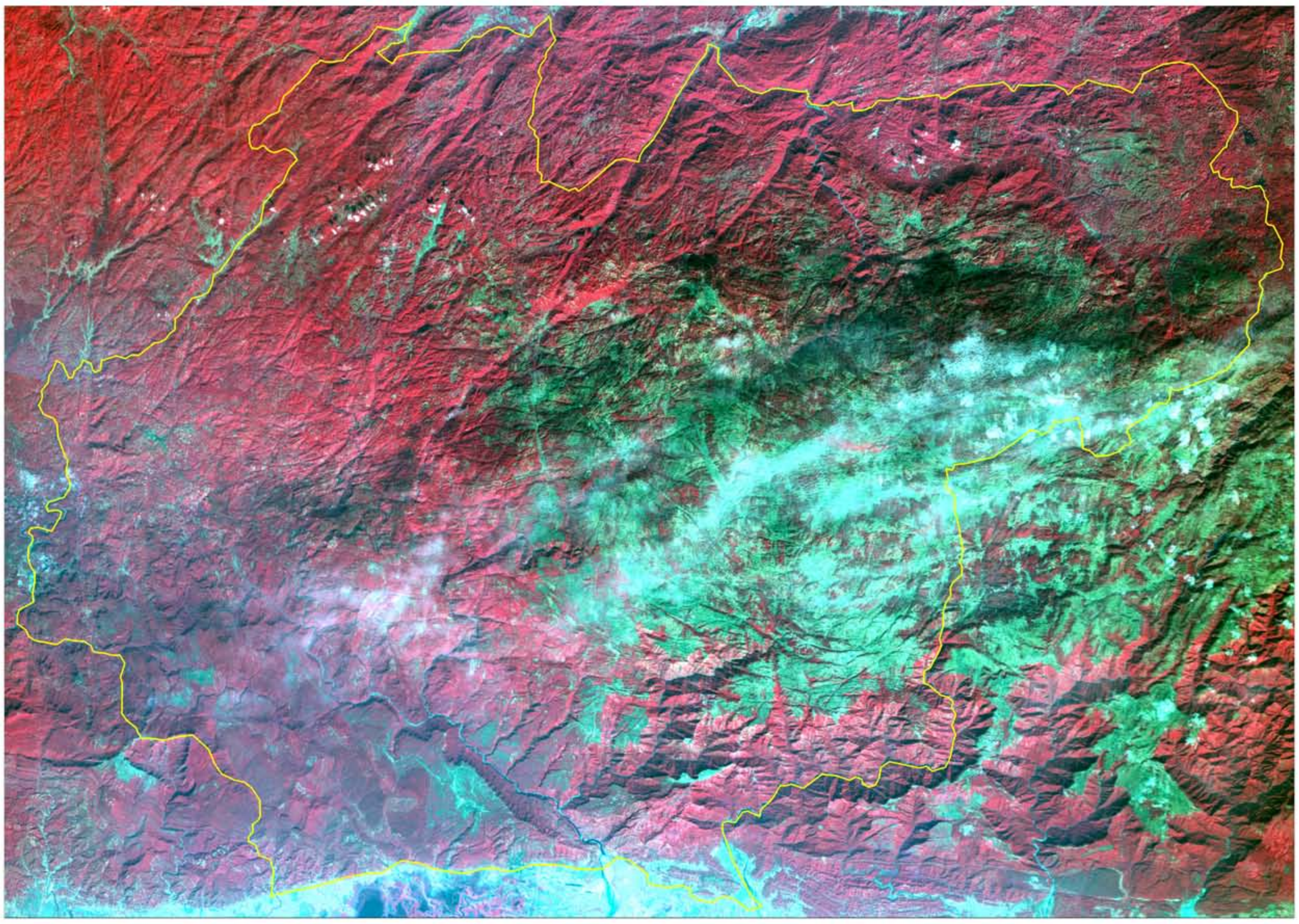
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : West Khasi Hills



IRS P6 LISS-III post-monsoon data (2006)

7.1.5 Wetland Distribution in Ri Bhoi

Ri Bhoi District was upgraded from Sub Divisional level to a full fledged district on 4th June, 1992. The new district, was carved out from the erstwhile East Khasi Hills. Its headquarter is at Nongpoh, which is about 53 Kms from the State Capital, Shillong. It is bounded on the north by Kamrup District and on the East by Jaintia Hills and Karbi Anglong District of Assam and on the West by West Khasi Hills district. This district is characterized by rugged and irregular land surface. It includes a series of hill ranges which gradually sloped towards the north and finally joins the Brahmaputra Valley. The important rivers flowing through this region includes the Umtrew, Umsiang, Umran and Umiam rivers. The total geographic area of Ri Bhoi district of Meghalaya is 237005ha. The wetland area estimated is 1945 ha. Small wetlands, which are less than minimum mapable units (MMU), are 13 in the district. Details are given in Table 10. The major wetland types are River/Stream and Reservoirs/Barrages.

Table 10: Area estimates of wetlands in Ri Bhoi

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1106	River/Stream	96	1156	59.43	1222	1222
	1200	**Inland Wetlands -Man-made**					
2	1201	Reservoirs/Barrages	10	754	38.77	731	705
3	1202	Tanks/Ponds	7	22	1.13	18	21
		Sub-Total	**113**	**1932**	**99.33**	**1971**	**1948**
		Wetlands (<2.25 ha), mainly Tanks	13	13	0.67	-	-
		Total	**126**	**1945**	**100.00**	**1971**	**1948**

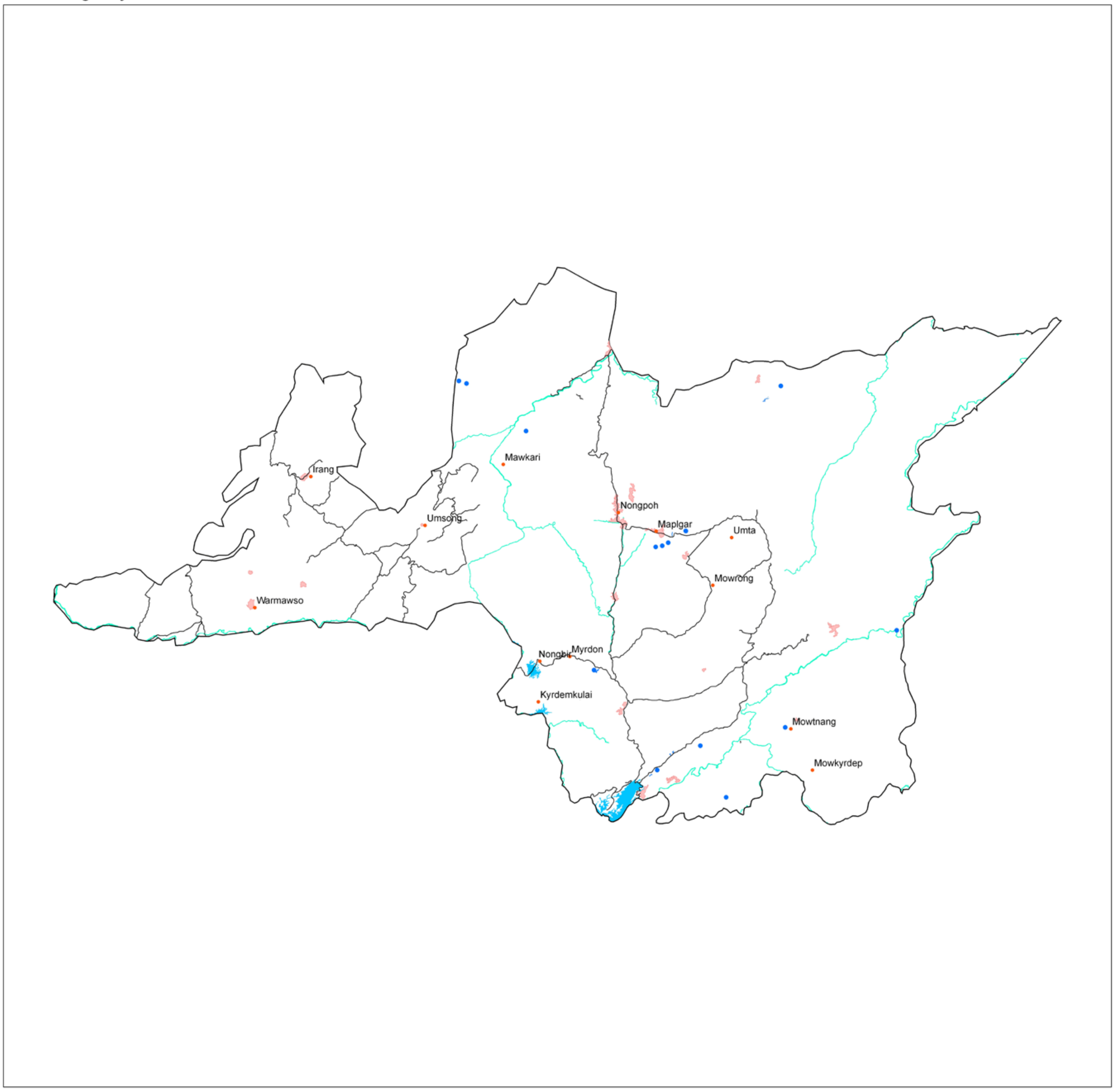
Area under Aquatic Vegetation	8	30

Area under turbidity levels		
Low	1401	1437
Moderate	512	347
High	58	164

State : Meghalaya

WETLAND MAP

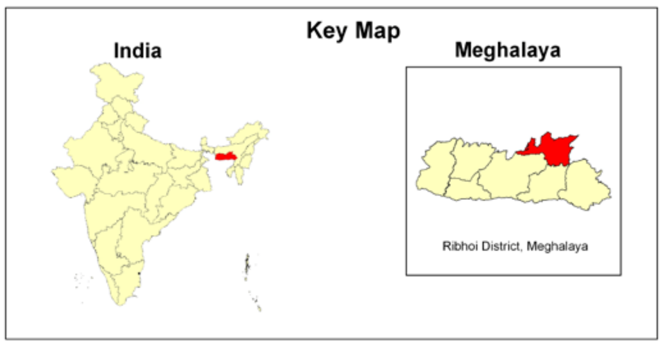
District : Ri Bhoi



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



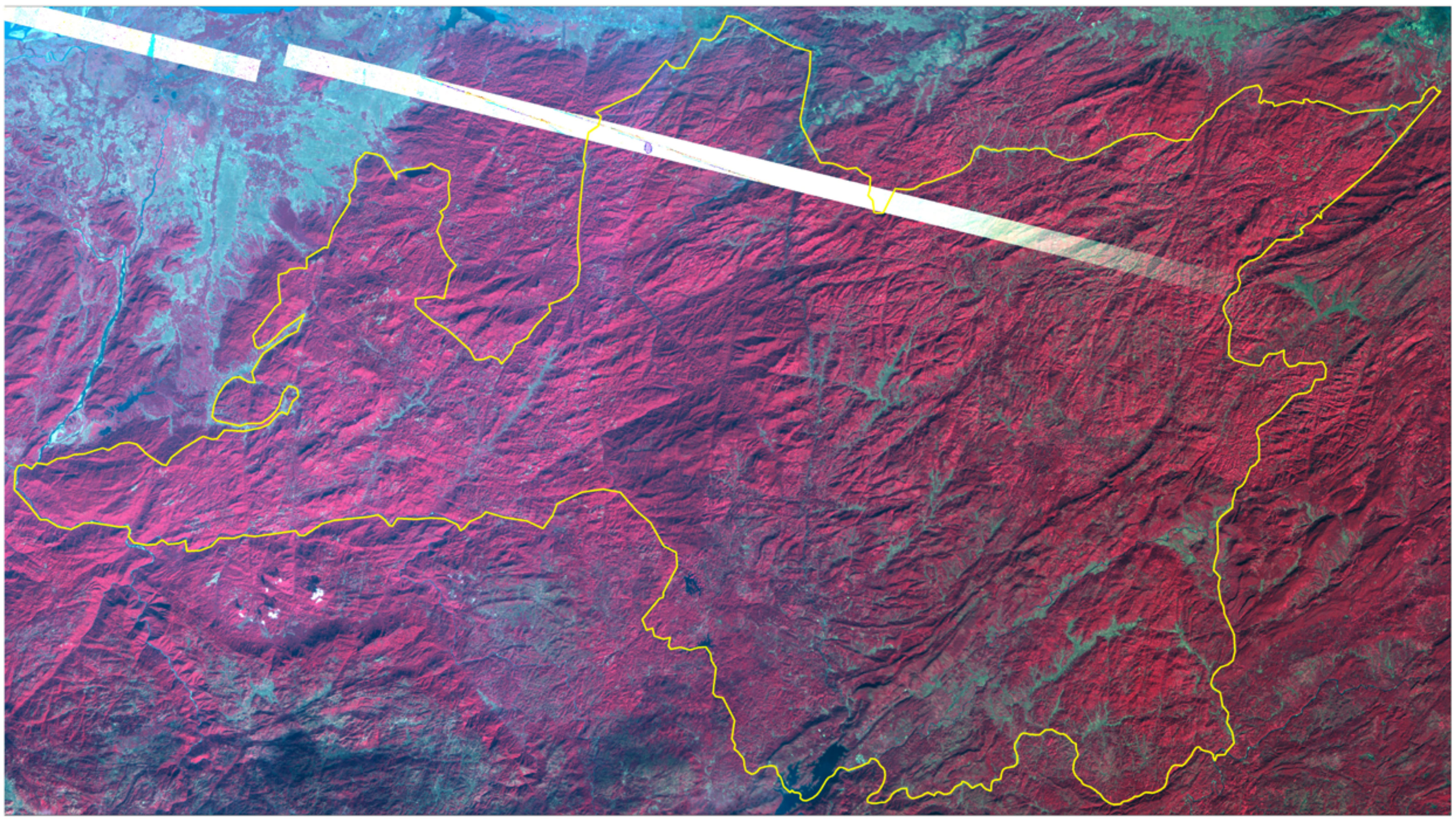
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : Ri Bhoi



IRS P6 LISS-III post-monsoon data (2006)

7.1.7 Wetland Distribution in East Khasi Hills

East Khasi Hills district forms central part of Meghalaya. The headquarter of the district is Shillong which is also the capital city of State. The district is bounded by Ri-Bhoi district in the north, Bangladesh in the south, Jaintia Hills district in the east and the West Khasi Hills district in the west. Agriculture, horticulture, fisheries, weaving, handicrafts, sericulture and cottage industries makes up the economic scenario of East Khasi Hills. The East Khasi Hills District is mostly hilly with deep gorges and ravines on the southern portion. The most important physiographic features of the district is the Shillong Plateau interspersed with river valley, then fall sharply in the southern portion forming deep gorges and ravine in Mawsynram and Shella-Bholaganj bordering Bangladesh. The total geographic area of East Khasi Hills district of Meghalaya is 285216 ha. The wetland area estimated is 4796 ha. Small wetlands, which are less than minimum mapable units (MMU), are 13 in the district. Details are given in Table 11. The major wetland types are River/Stream, riverine wetlands and Reservoirs/Barrages.

Table 11: Area estimates of wetlands in East Khasi Hills

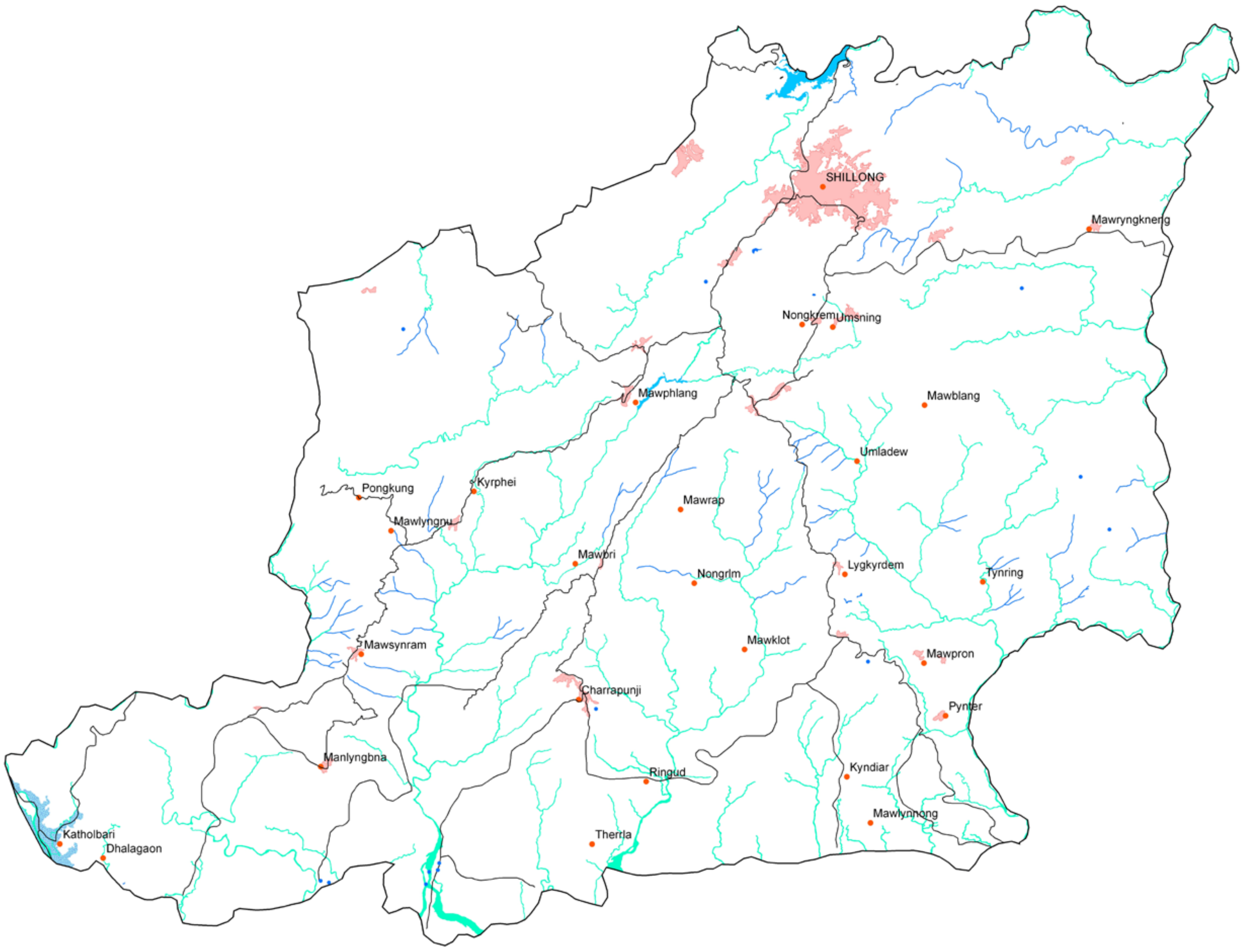
Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1104	Riverine wetlands	6	593	12.36	409	643
2	1106	River/Stream	107	3656	76.23	3758	3758
	1200	**Inland Wetlands -Man-made**					
3	1201	Reservoirs/Barrages	5	509	10.61	493	474
4	1202	Tanks/Ponds	6	25	0.52	25	23
		Sub-Total	**124**	**4783**	**99.73**	**4685**	**4898**
		Wetlands (<2.25 ha), mainly Tanks	13	13	0.27	-	-
		Total	**137**	**4796**	**100.00**	**4685**	**4898**

Area under Aquatic Vegetation	93	30

Area under turbidity levels		
Low	3862	3962
Moderate	392	241
High	432	696

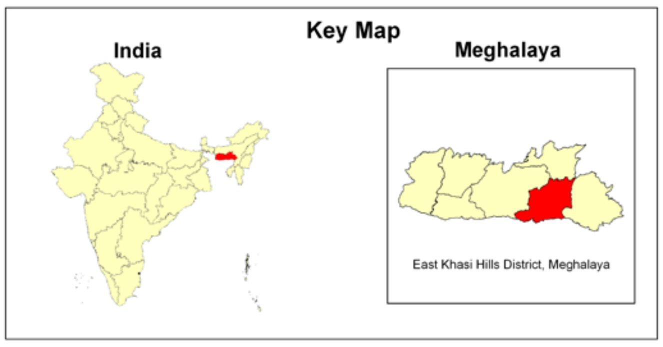
State : Meghalaya | **WETLAND MAP** | **District : East Khasi Hills**



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



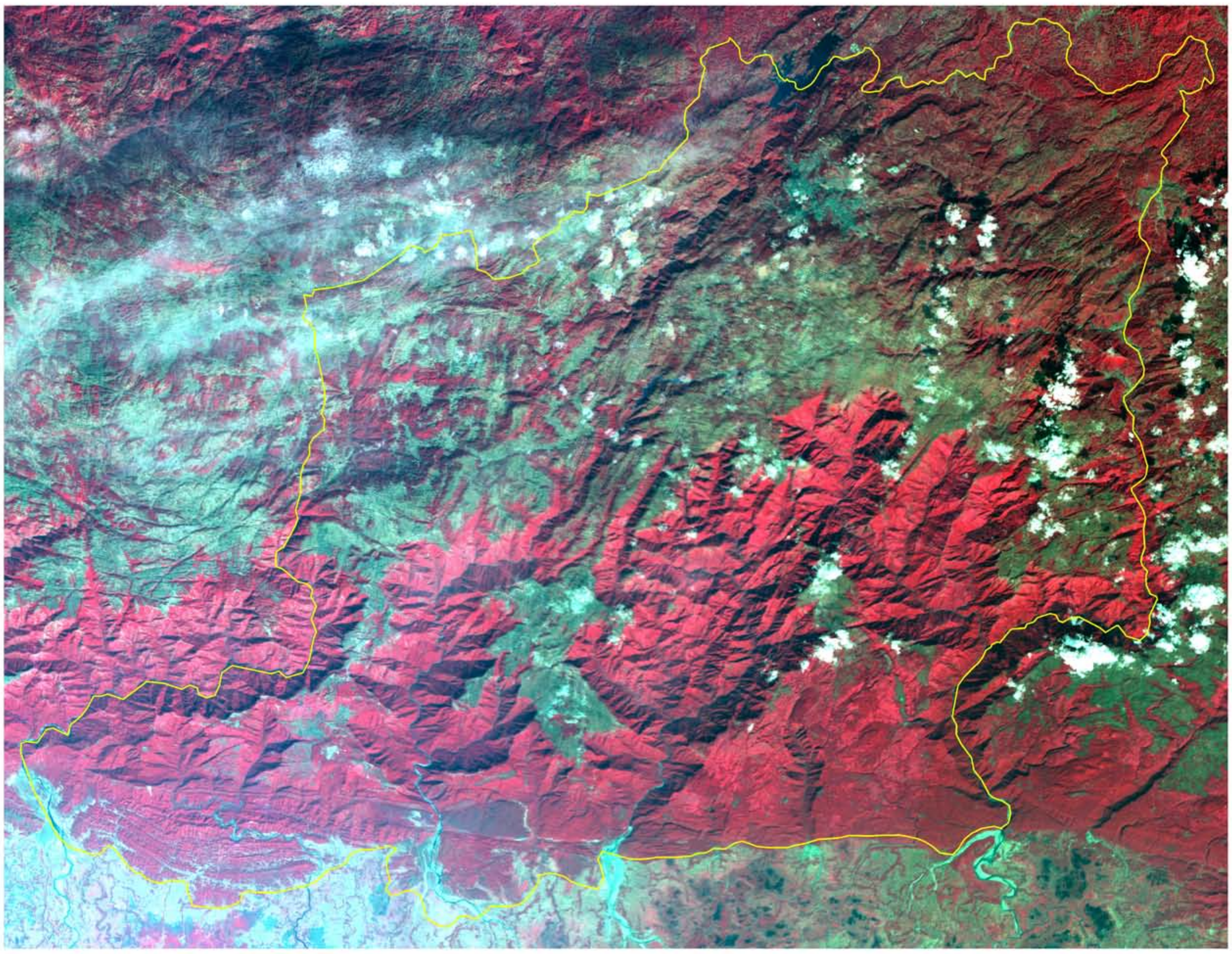
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : East Khasi Hills



IRS P6 LISS-III post-monsoon data (2006)

7.1.7 Wetland Distribution in Jaintia Hills

Jaintia Hills being a component of the Meghalaya Plateau has its physiographical features almost similar to that of Khasi Hills. The only difference is that Jaintia Hills has comparably more flat topography with a mild gradient. The Hills gently slope towards Brahmaputra valley of Assam in the North and meet up the gentle plains of Bangladesh in the South. The Marangksih peak on the Eastern plateau of Jaintia Hills stands majestically at the elevation of 1631 meters from the mean sea level of Karachi and is the highest peak in the entire district. The main elevation of the district ranges between 1050m to 1350m with Jowai which was established in the year 1972 as its Headquarter lies on the central plateau. In general, the whole district is full of rugged and undulating terrains with the exception of the deep gorges and narrow valleys carved out by the rivers. The Jaintia Hills is richly endowed with natural resources. Jaintia Hills have large deposits of coal and rich deposits of other mineral resources. Cement factory, coffee plantations, handloom, fisheries and by-products of fruit are other means of income for the people of Jaintia. The total geographic area of Jaintia Hills district of Meghalaya is 379347 ha. The wetland area estimated is 4302 ha. Small wetlands, which are less than minimum mapable units (MMU), are 11 in the district. Details are given in Table 12. The major wetland types are River/Stream and Reservoirs/Barrages.

Table 12: Area estimates of wetlands in Jaintia Hills

Area in ha

Sr. No.	Wettcode	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
						Post-monsoon Area	Pre-monsoon Area
	1100	**Inland Wetlands - Natural**					
1	1106	River/Stream	133	4019	93.42	3186	3185
	1200	**Inland Wetlands -Man-made**					
2	1201	Reservoirs/Barrages	1	260	6.04	259	199
3	1202	Tanks/Ponds	2	12	0.28	11	12
		Sub-Total	**136**	**4291**	**99.74**	**3456**	**3396**
		Wetlands (<2.25 ha), mainly Tanks	11	11	0.26	-	-
		Total	**147**	**4302**	**100.00**	**3456**	**3396**

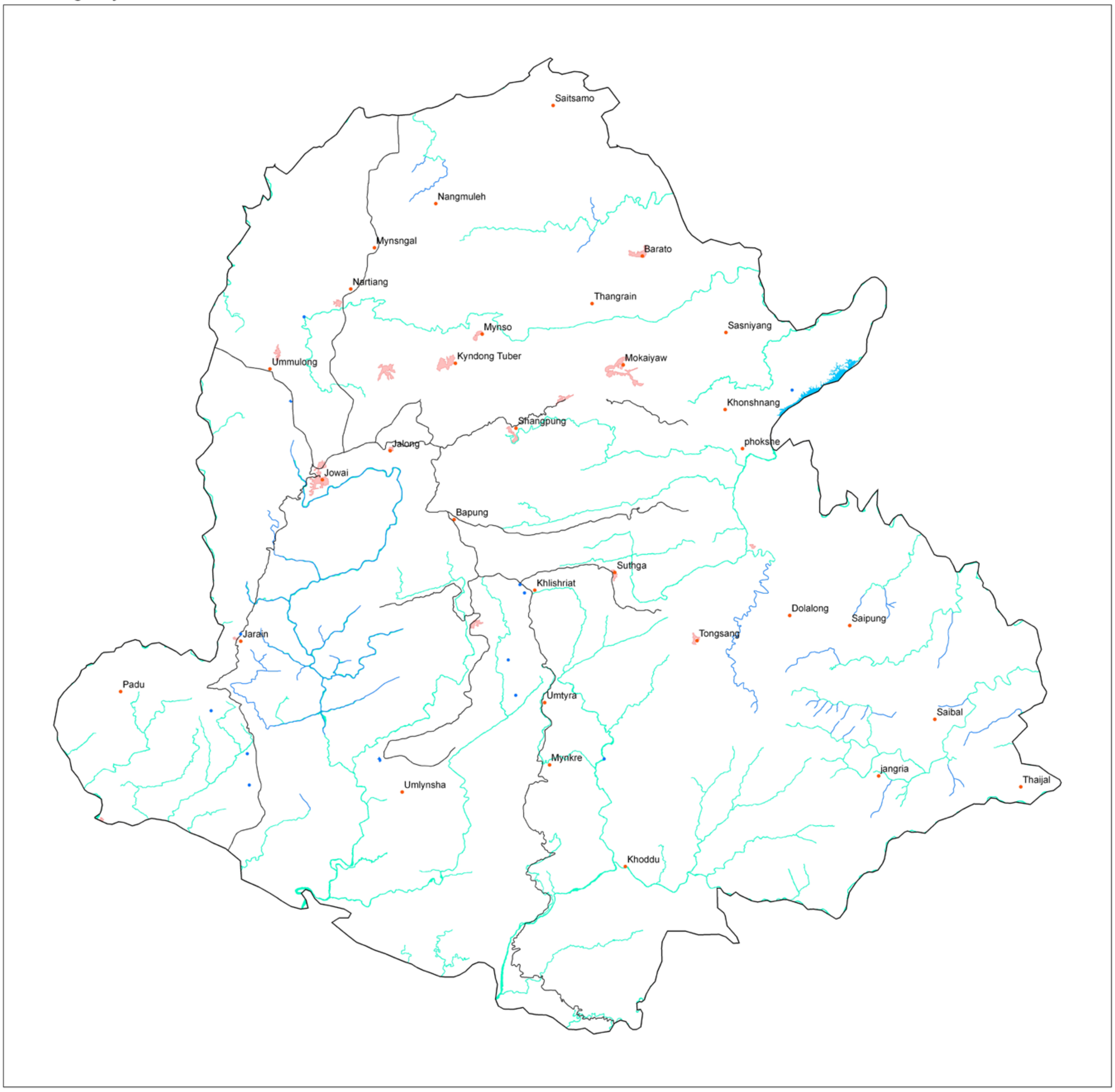
Area under Aquatic Vegetation	-	-

Area under turbidity levels		
Low	3185	3184
Moderate	234	212
High	38	-

State : Meghalaya

WETLAND MAP

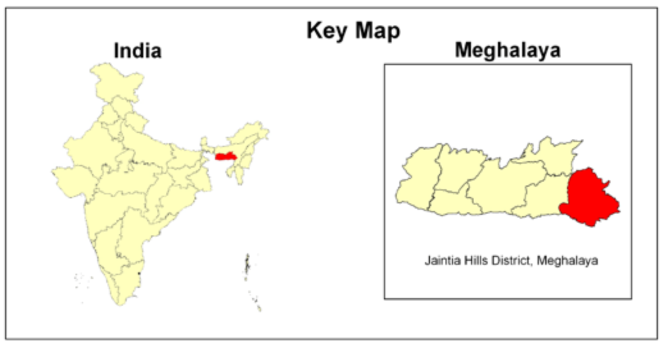
District : Jaintia Hills



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements



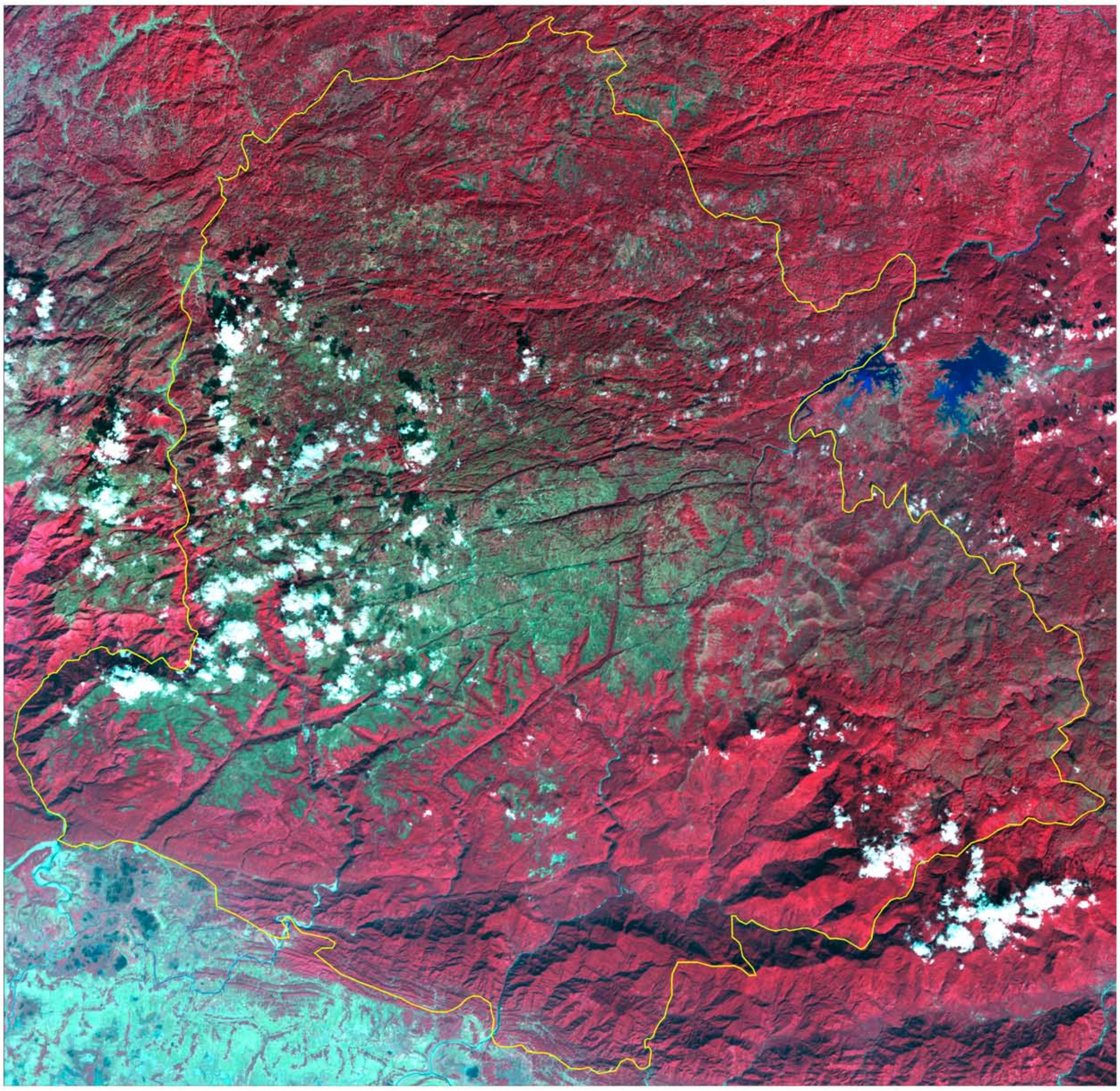
8 4 0 8 16 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

District : Jaintia Hills



IRS P6 LISS-III post-monsoon data (2006)

MAJOR WETLAND TYPES

8.0 MAJOR WETLAND TYPES OF MEGHALAYA

Major wetland types observed in the state are rivers, reservoirs and few lakes. Details are given in Plate-1. Ground truth data was collected for selected wetland sites. The standard proforma was used to record the field data. Field photographs are also taken to record the water quality (subjective), status of aquatic vegetation and water spread. The location of the features was recorded using GPS. Field photographs and ground truth data of different wetland types are shown in Plates 2a,2b and 2c.

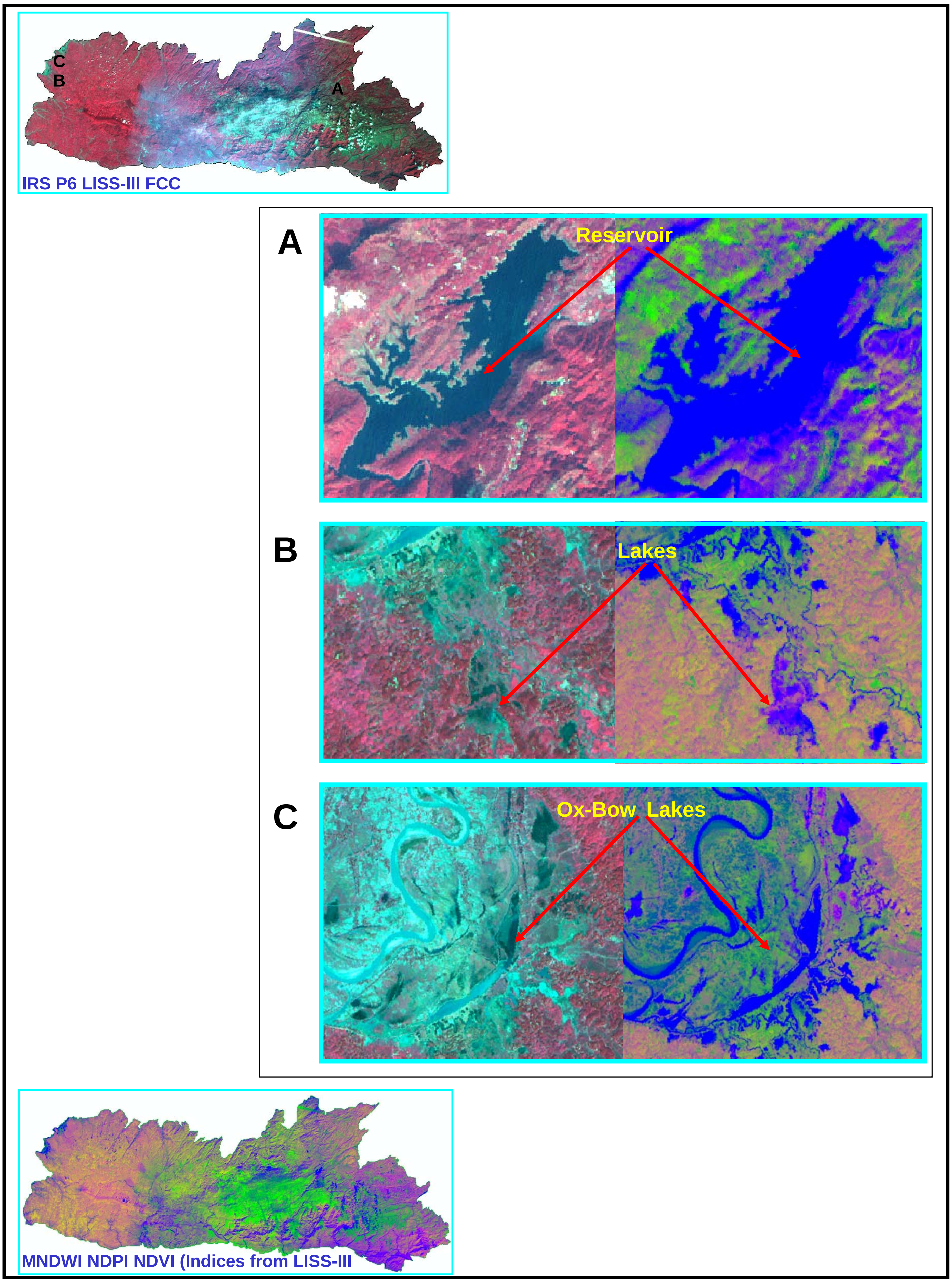


Plate - 1: Major wetland types of Meghalaya

Sr. No.	Description	Field photograph
1.	Wetland Type : Man-made Reservoir Name: Umiam/Barapani Location : longitude: 91^0 51' E latitude : 25^0 37' N Aquatic Vegetation : Absent Turbidity : Low	
2.	Wetland Type : River Name:River Island – Nongkhnum Location : longitude: 91^0 14' E latitude : 25^0 25' N Turbidity : Moderate	
3.	Wetland Type : River Name: Ranikor Location : longitude: 91^0 14' E latitude : 25^0 13' N Turbidity : Low	
4.	Wetland Type : River Santuksiar Location : longitude: 92^0 12' E latitude : 25^0 26' N Turbidity : Low	

Plate 2a: Field photographs and ground truth data of different wetland types in Meghalaya

Sr. No.	Description	Field photograph
5.	Wetland Type : Lakes Name: Pamphyrnai lake Location : longitude: 91^0 20' E latitude : 25^0 32' N Aquatic Vegetation : Absent Turbidity : Low	
6.	Wetland Type : Lakes Name: Thadlaskein lake Location : longitude: 92^0 10' E latitude : 25^0 19' N Aquatic Vegetation : Absent Turbidity : Moderate	
7.	Wetland Type : Lake- Name: Barabil Location: longitude: 89^0 58' E latitude : 25^0 45' N Aquatic Vegetation : Present Turbidity : Low	
8.	Wetland Type : Reservoir/Barrages Name: Kyredemkhulai Location : longitude: 91^0 48' E latitude : 25^0 44' N Aquatic Vegetation : Absent Turbidity : Moderate	

Plate 2b: Field photographs and ground truth data of different wetland types in Meghalaya

IMPORTANT WETLANDS OF MEGHALAYA

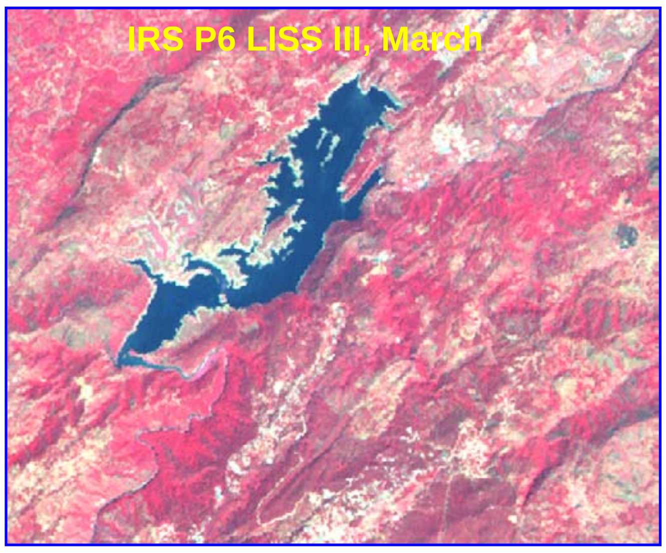
9.0 IMPORTANT WETLANDS OF MEGHALAYA

Umiam lake, Nongkhnum Island and Ranikor riverine area are important wetland sites of Meghalaya. Extensive ground truth data was collected for these selected wetland sites. Wetland maps of 5 km buffer area and image map of corresponding LISS-III images have been prepared. Details are given in subsequent sections.

9.1 Umiam Lake

Umiam lake, also known as Barapani is located at a distance of 14 Kms from Shillong town on the Shillong-Guwahati road. The place is formed by damming of the Umiam river under the Umiam-Hydro-Electric project. It is one of the places of major tourist attraction in Meghalaya.

	Name : Umiam/Barapani Reservoir
1.	**Location**: 91^o 51' to 91^o 54' 25^o 37' to 25^o 40'
2.	**Area**: 10.24 Sq Km
3.	**Wetland type**: Man-made - Reservoir
4.	Umiam reservoir shows change in the wetland waterspread in premonsoon and post monsoon boundary. Pre-monsoon image shows marked shrinkage of wetland boundary in parts of the lake boundary. No significant growth of aquatic vegetation seen in the waterbody. The lake shows low turbidity level.
5.	Umiam Lake, also known as Barapani is a spot around 15 Km from Shillong where a massive hydro-electric dam has been constructed across the Umiam river stream.The Lake is popular for the Water Sport and adventure facilities that it offers. Kayaking, Water cycling/scooting and boating are a few of the facilities available at the Umiam Lake. The Lake has been developed as a tourist spot by the State authorities and the Meghalaya Tourism Department. The water spread of the reservoir is about 10.24 Sq.km. The climate of the area is sub-tropical montane characterized by mild summer and cold winters. The annual rainfall in the area is about 2400mm. The amount of rainfall increases in the southern parts, coming Under the Mawsynram- Cherrapunji rain belt.



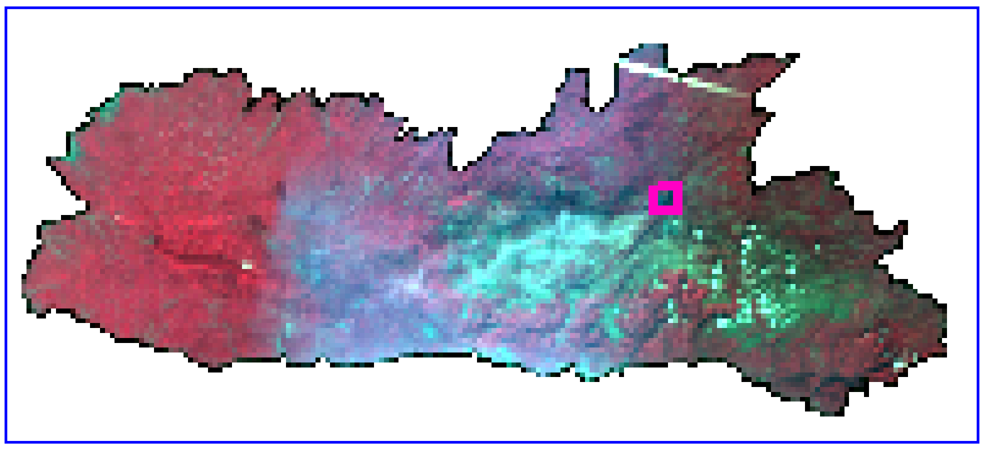
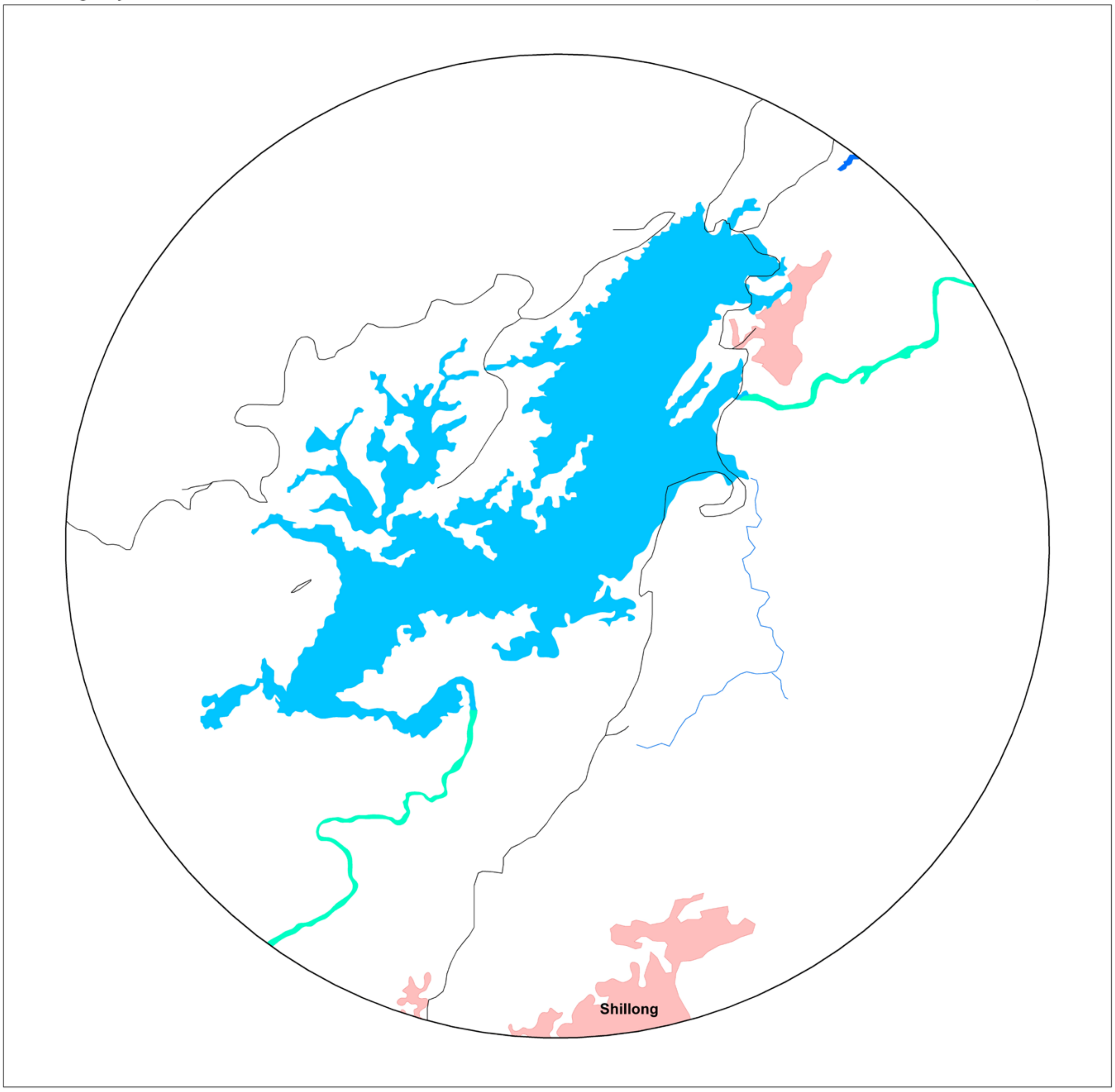


Plate 3: Umiam lake

State : Meghalaya **WETLAND MAP** **Umiam/Barapani Reserv**

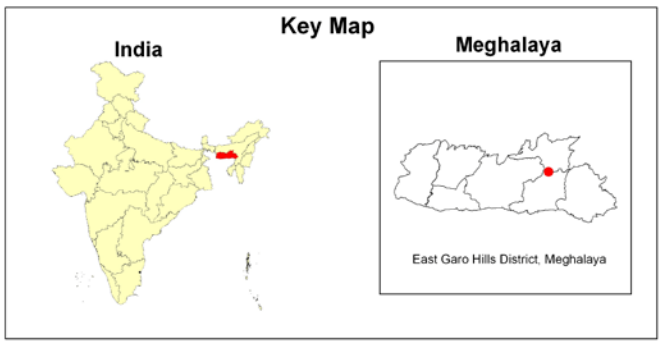


Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25ha)
- Drainage (line)
- Major Roads
- Settlements
- District Boundary
- Towns/Settlements
- 5 Km buffer area

Key Map



1 0.5 0 1 2 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :
Space Applications Centre (ISRO), Ahmedabad
and
North Eastern Space Applications Centre (NESAC)
Dept. of Space, Umiam, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

Plate 4: Wetland map - 5 km buffer area of Umiam lake

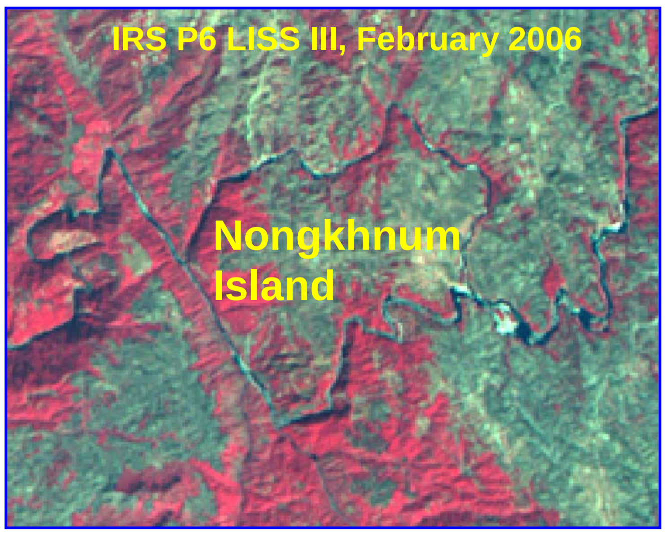
Umiam/Barapani Reservoir

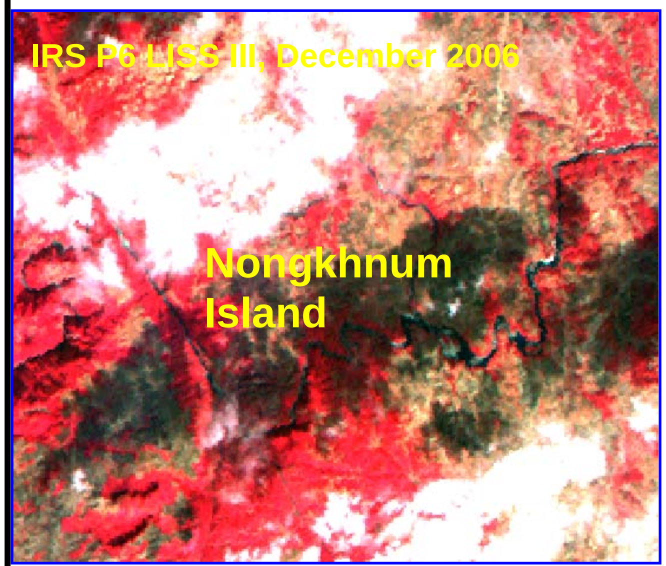
IRS P6 LISS III post-monsoon data 2006

9.2 Nongkhnum River Island

Nongkhnum Island is the biggest River Island in Meghalaya and the second biggest island in Asia, after Majuli Island in Assam. Located about 14 Kms from Nongstoin, the district hqs. of West Khasi Hills, it is 20 to 25 sq. kms in area. The area surrounded by the two Rivers, i.e. Phanliang and Namliang forms the Nongkhnum Island. Within the Island, there are big trees and areas of grassland and natural playground. There are plenty of fishing pools, especially near the sandy shore, called Wei-Phanliang.

	Name : Nongkhnum River Island
1.	**Location** : 91^{0} 14' to 91^{0} 16' 25^{0} 25' to 25^{0} 27'
2.	**Area** : 25 Sq. Kms
3.	**Wetland type** : Natural- Island formed by rivers
4.	Nongkhnum river island formed by the three rivers is a prominent feature appearing in the satellite image. The Island consists of forests, open scrubs and sand deposits along the river. No significant change observed in the wetland boundary and turbidity in the pre- monsoon and post-monsoon seasons.
5.	The climate of the West Khasi Hills is mildly tropical in the northern and southern foothills, while in the central upland zone; the climate is temperate and places at medium altitude in the northern, western and southern parts of the district experience sub-tropical climate. Nongkhnum Island is the biggest River Island in Meghalaya and the second biggest island in Asia, after Majuli Island in Assam covering an area of 25 Sq.Kms located about 14 Kms from Nongstoin, the district hqs. of West Khasi Hills. The Island is formed by the bifurcation of Kynshi River into the Phanliang River and the Namliang River. At the point of divergence, there is a beautiful sandy shore. The Phanliang River forms a beautiful lake adjacent to the sandy beach. The River then moves along and before reaching a deep gorge, forms a pretty fall about 60 meters high, called Shadthum Fall. At the bottom of the fall, there is a beautiful pool where a variety of fishes can be found. It then continues its journey and finally reunites with the Namliang River, near a place called Thongrin. There are plenty of fishing pools, especially near the sandy shore, called Wei- Phanliang.





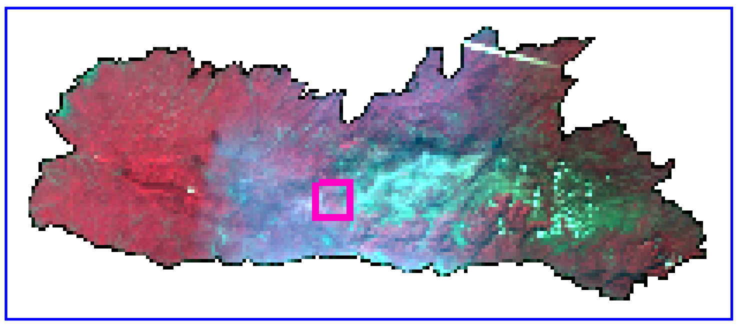


Plate 5: Nongkhnum River Island

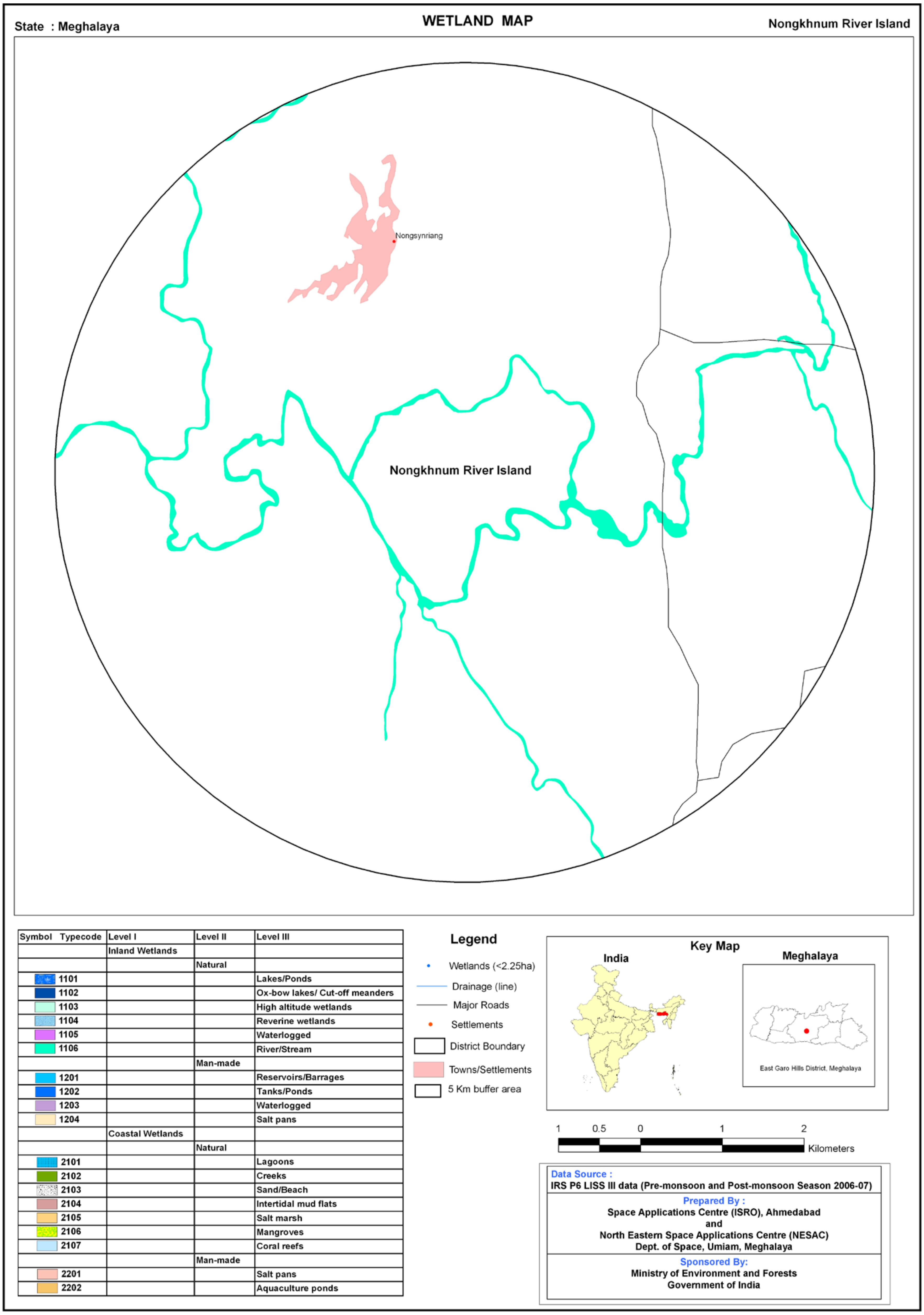
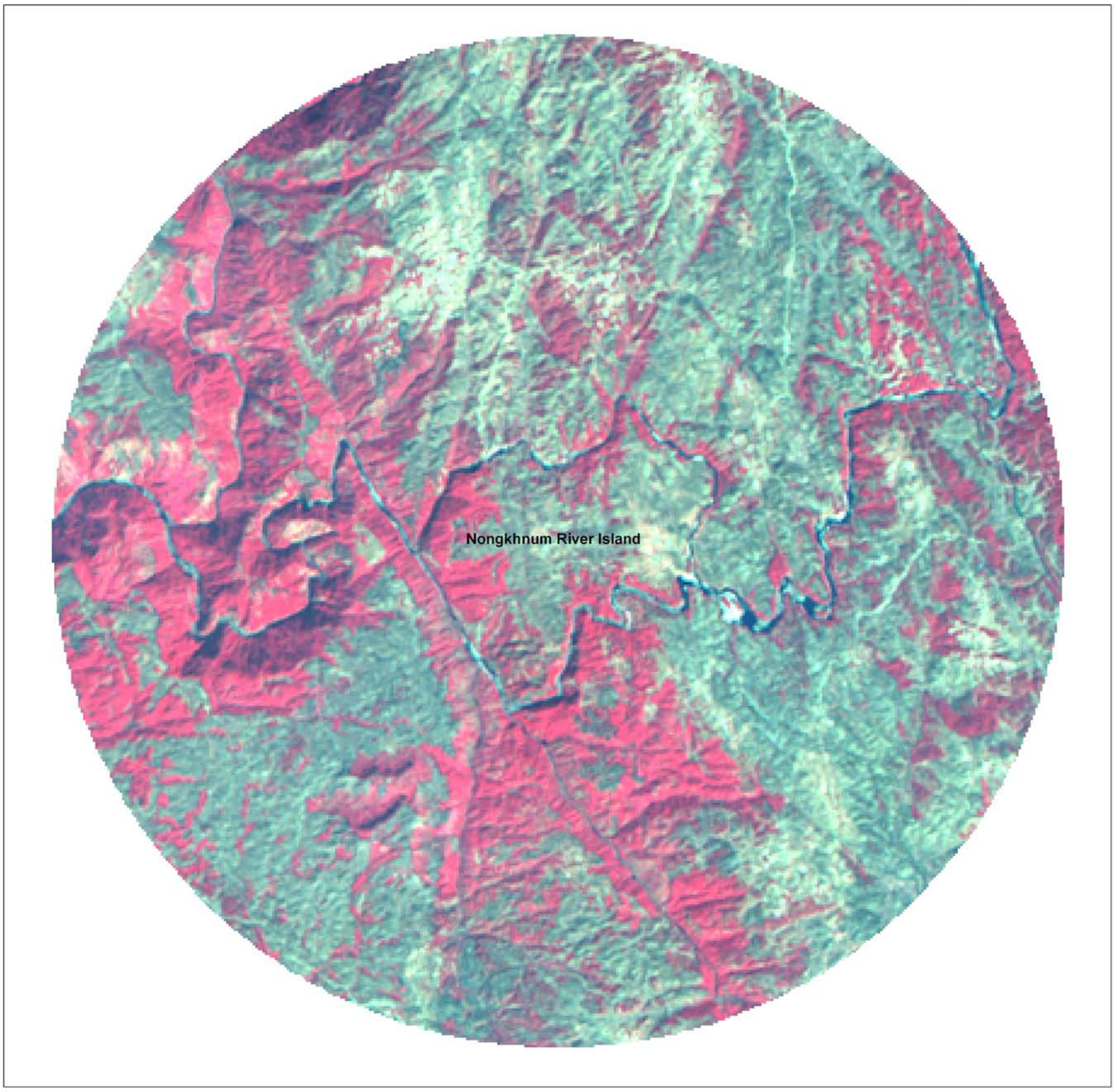


Plate 6: Wetland map - 5 km buffer area of Nongkhnum lake

Nongkhnum River Island

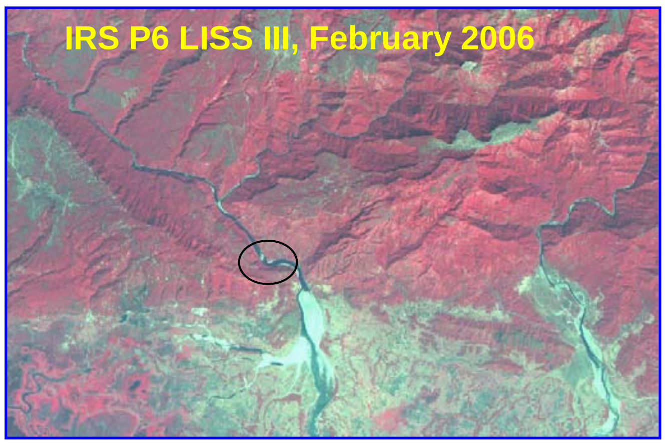


IRS P6 LISS III Pre-monsoon 2006

9.3 Ranikor

Ranikor is an isolated place located around 140 Kms from Shillong in the India- Bangladesh border. It is one of the largest wild fishing spot left in the state of Meghalaya. This river also offers great birding experience. One can also see tribal anglers using modern as well as traditional means of angling/fishing. It is also a place of great scenic beauty and tourist attraction.

	Name : Ranikor
1.	**Location** : 91^{o} 14' 12.2'' 25^{o} 13 6.22''
2.	**Area** : Part of river
3.	**Wetland type** : River
4.	The river with clear water is the ideal habitat for the fishes. The river flows along the steep hills in Meghalaya and joins in Bangladesh. The hills along the river stretch is covered by dense forests. It is very important that proper care is taken for carrying out sustainable fishing practice in the region.
5.	Located 140 kms from Shillong, Meghalaya,Ranikor is a small town on the border of India and Bangladesh. It is one of the last wild fishing spots left in the state of Meghalaya. In the past few years, this place has become famous amongst the local anglers for fish spieces like- Golden mahseer, Chocolate mahseer, Goonch (Catfish), eels, etc. Fishing area on the river Kynshi at Ranikor is approximately 15 to 16 kilometers. The river orginates from a small town called Rilang.It is also a place of great scenic beauty, and makes for an ideal camping spot. The climate of the area is sub-tropical montane characterized by mild summer and cold winters. The annual rainfall in the area is about 2400mm.



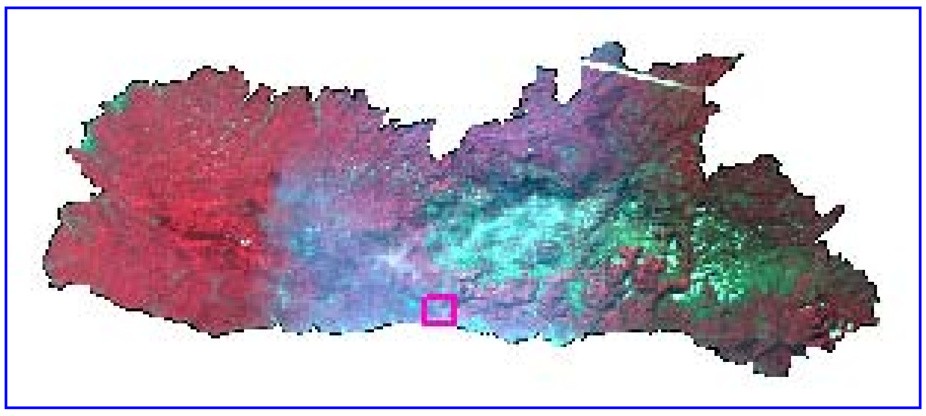


Plate 7: Ranikor

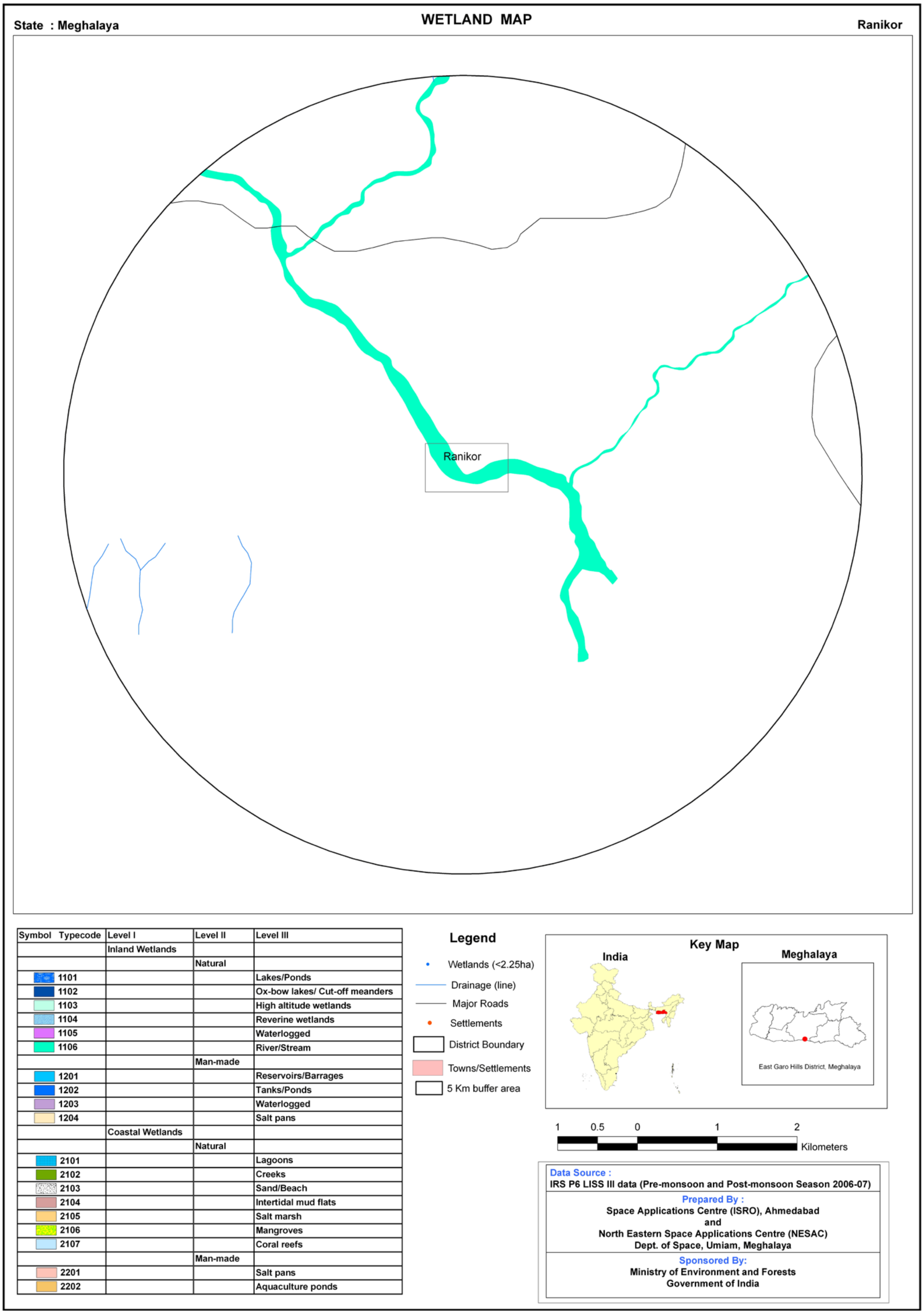


Plate 8: Wetland map - 5 km buffer area of Ranikor

Ranikor

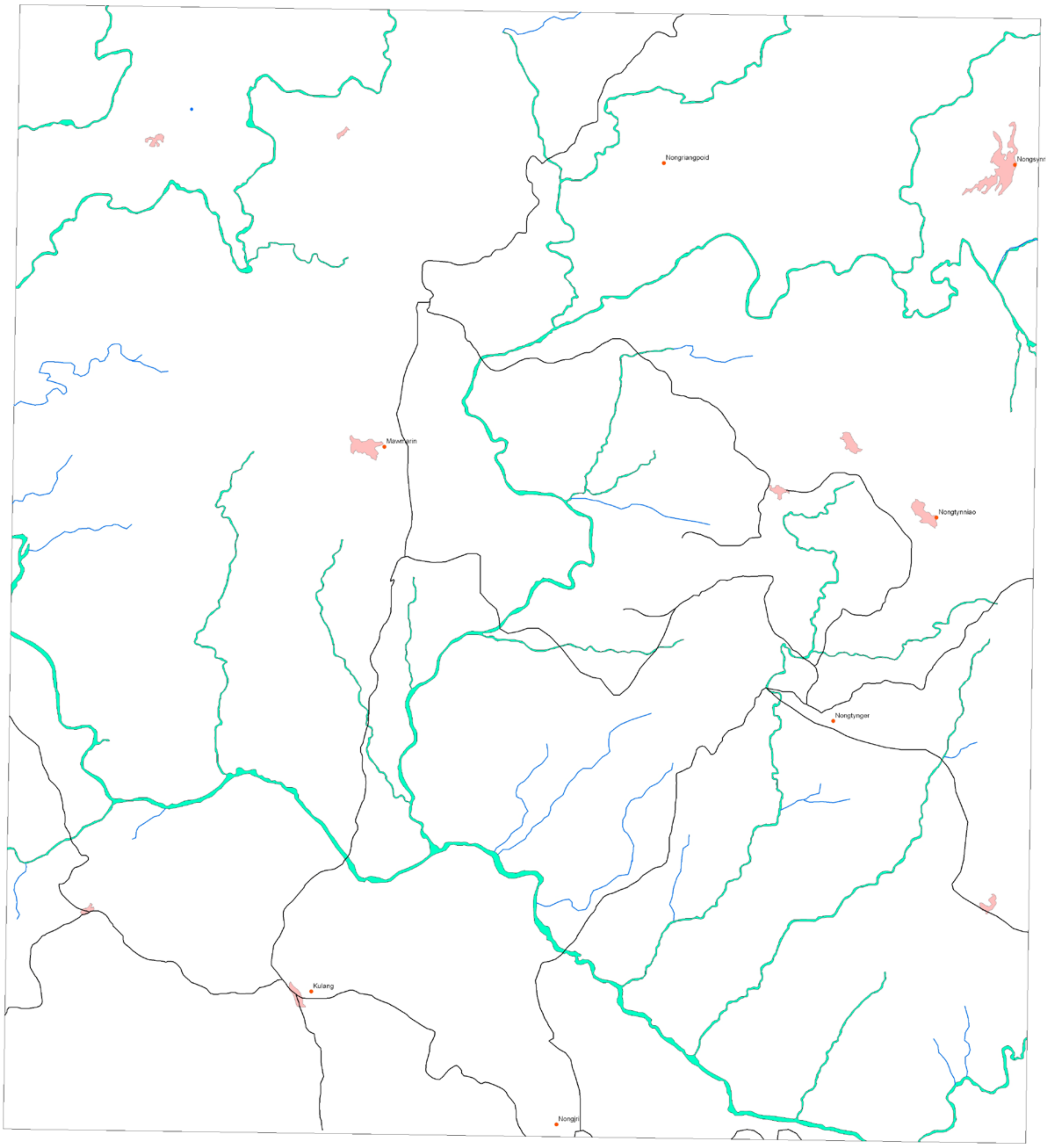
IRS P6 LISS III Pre-monsoon data 2006

SOI MAP SHEET-WISE WETLAND MAPS (selected)

State : Meghalaya

WETLAND MAP

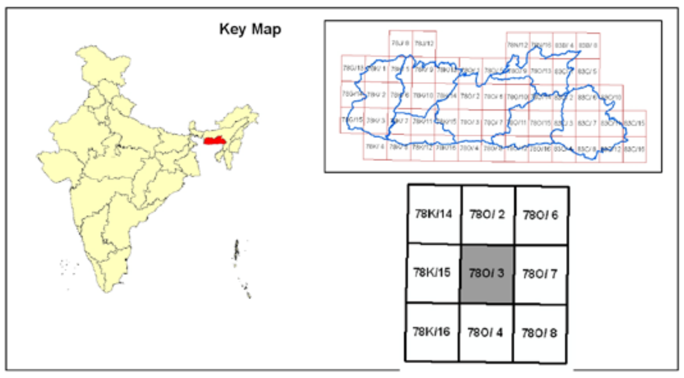
Map No.: 78O/3



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- wetpnt point
- drainl arc
- settlep point
- settlea polygon



0 1 2 4 6 8 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

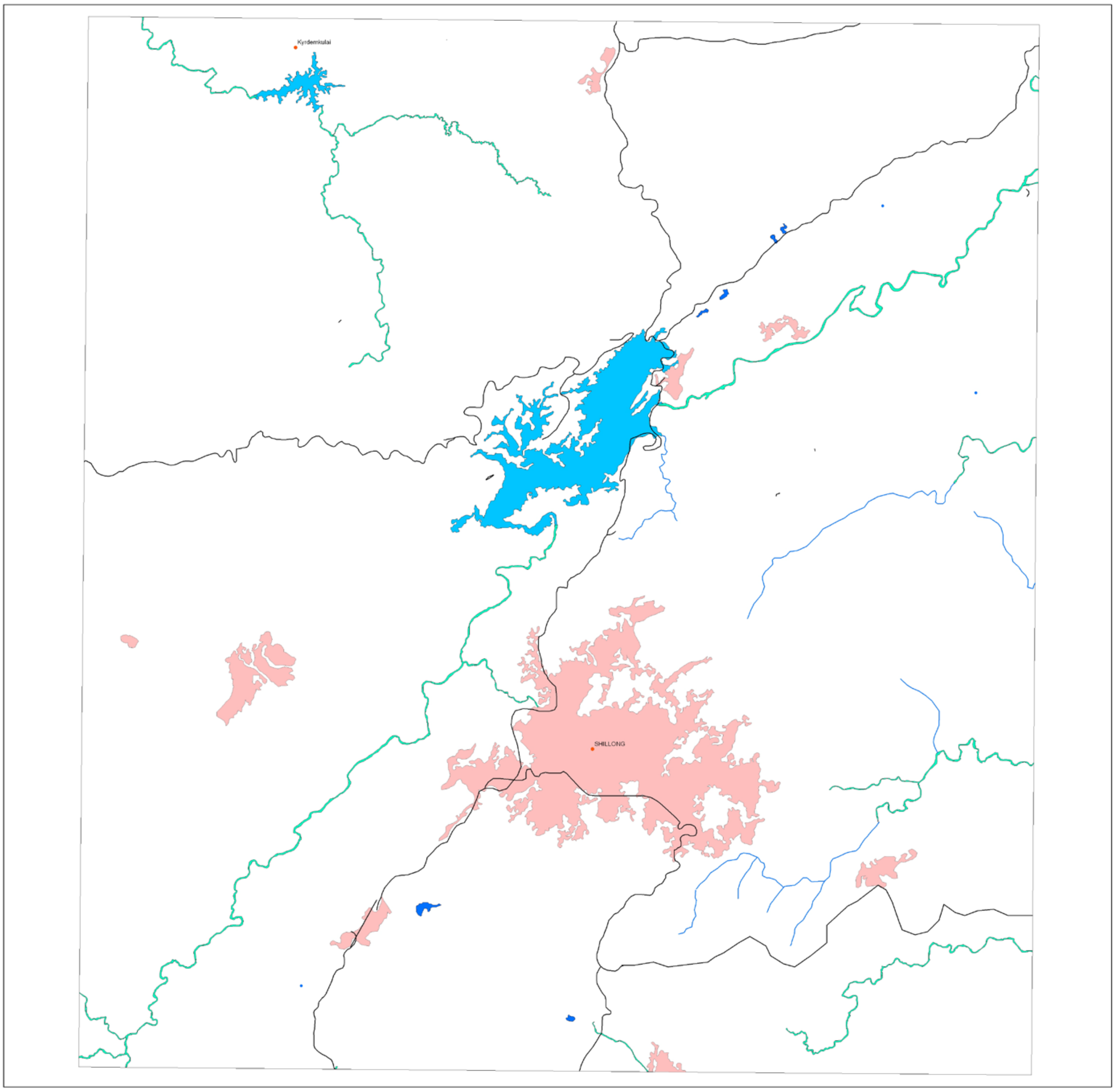
Prepared By :
North Eastern Space Applications Centre, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya

WETLAND MAP

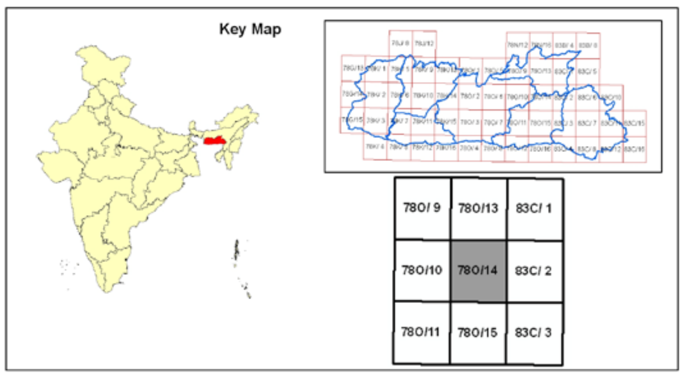
Map No.: 78O/14



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- wetpnt point
- drainl arc
- settlep point
- settlea polygon



Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

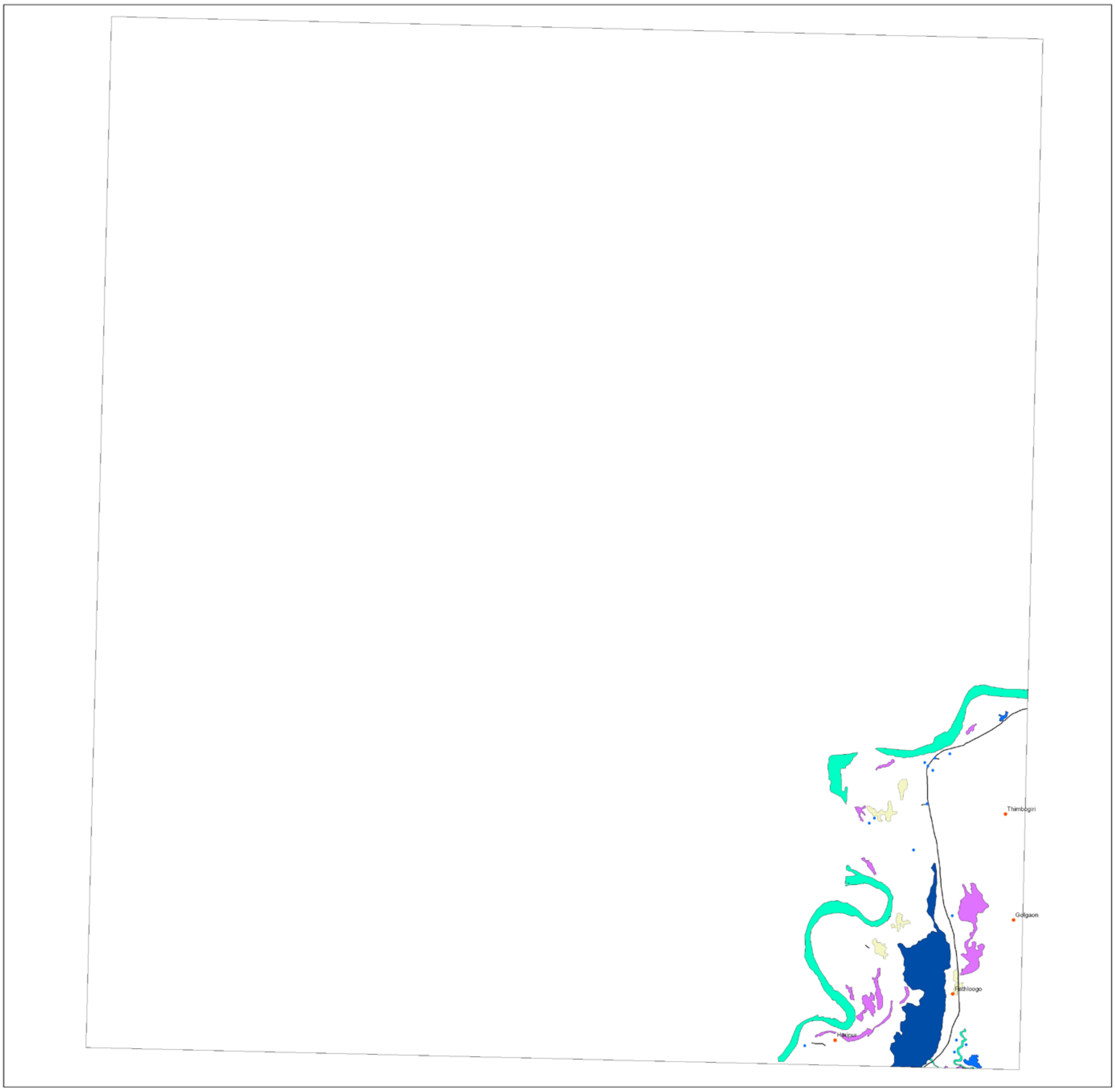
Prepared By :
North Eastern Space Applications Centre, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya

WETLAND MAP

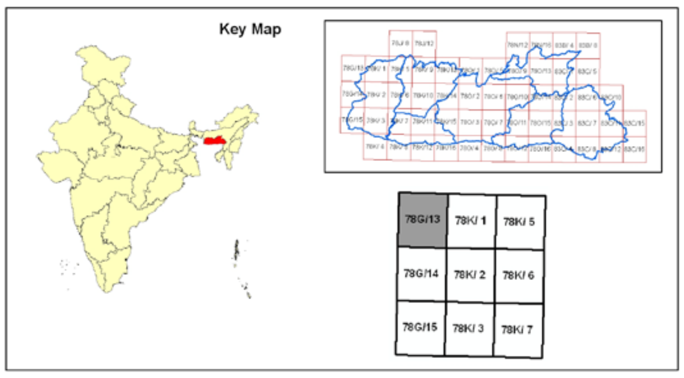
Map No.: 78G/13



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- wetpnt point
- drainl arc
- settlep point
- settlea polygon



0 1 2 4 6 8 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

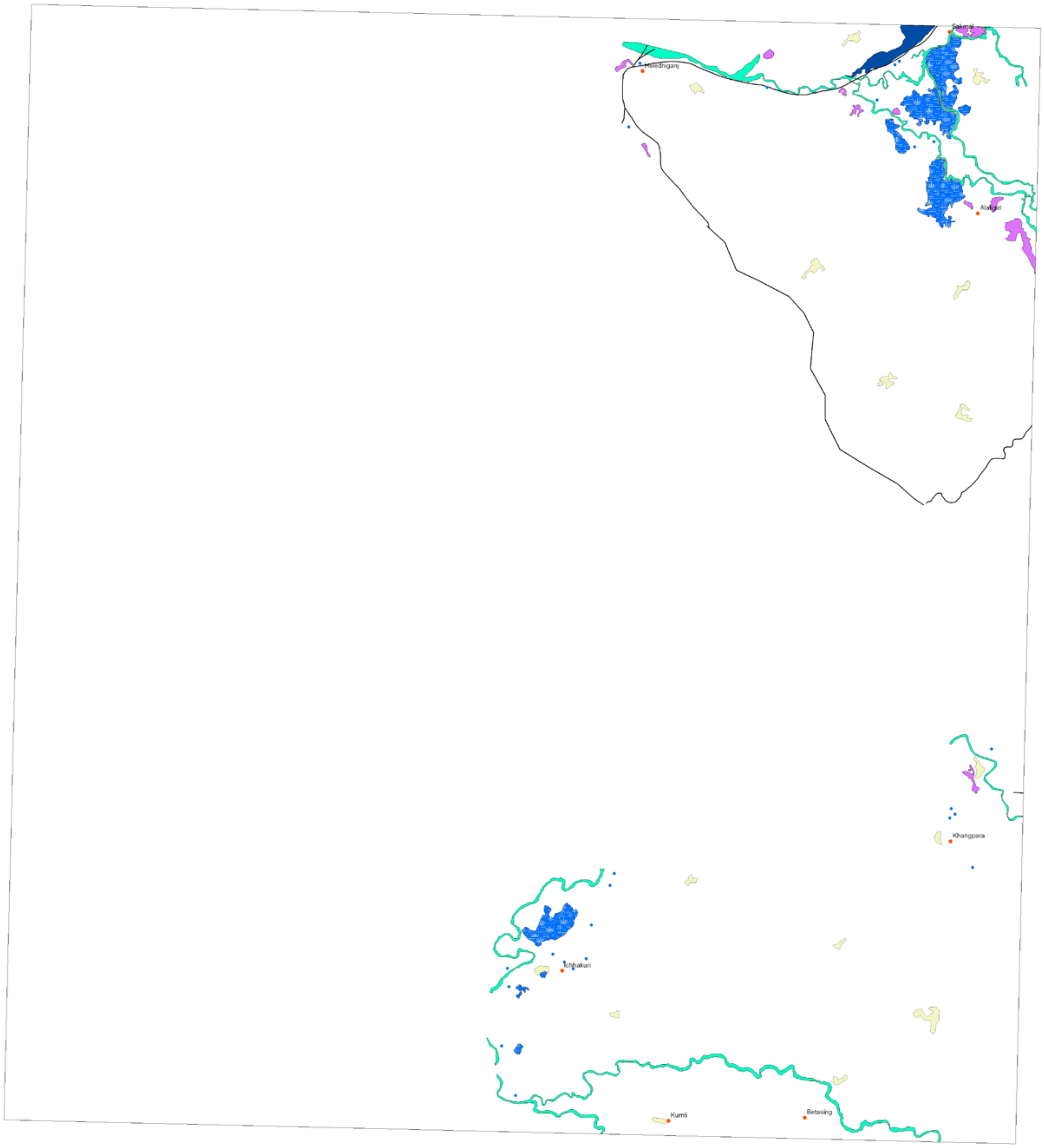
Prepared By :
North Eastern Space Applications Centre, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya

WETLAND MAP

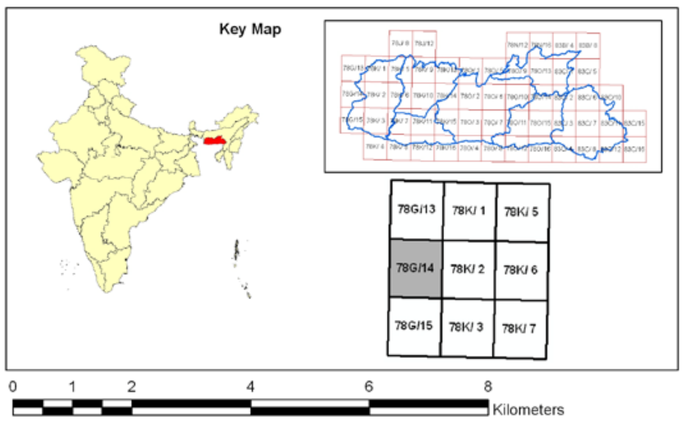
Map No.: 78G/14



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- wetpnt point
- drainl arc
- settlep point
- settlea polygon



Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

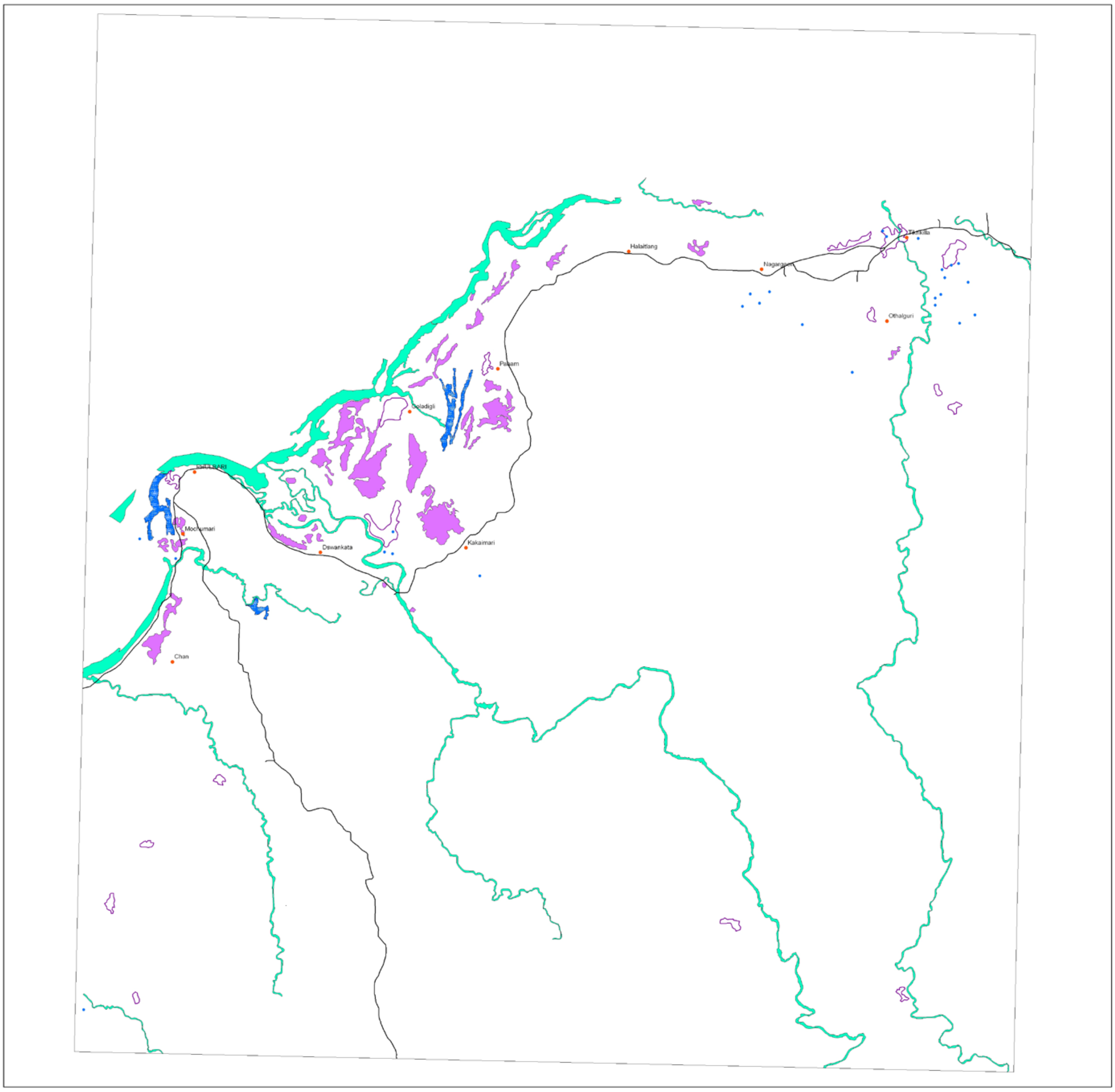
Prepared By :
North Eastern Space Applications Centre, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya

WETLAND MAP

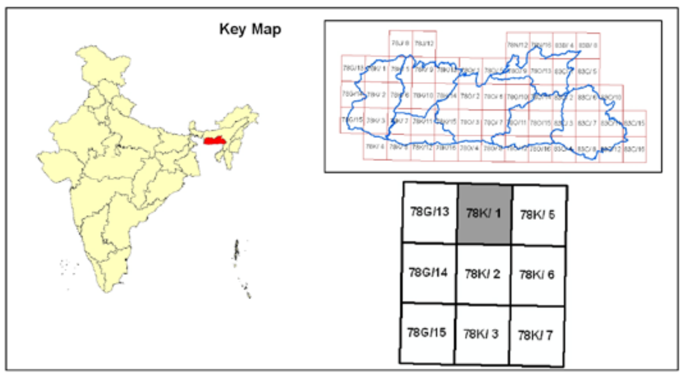
Map No.: 78K/1



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

wetpnt point
drainl arc
settlep point
settlea polygon



0 1 2 4 6 8 Kilometers

Data Source :
IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

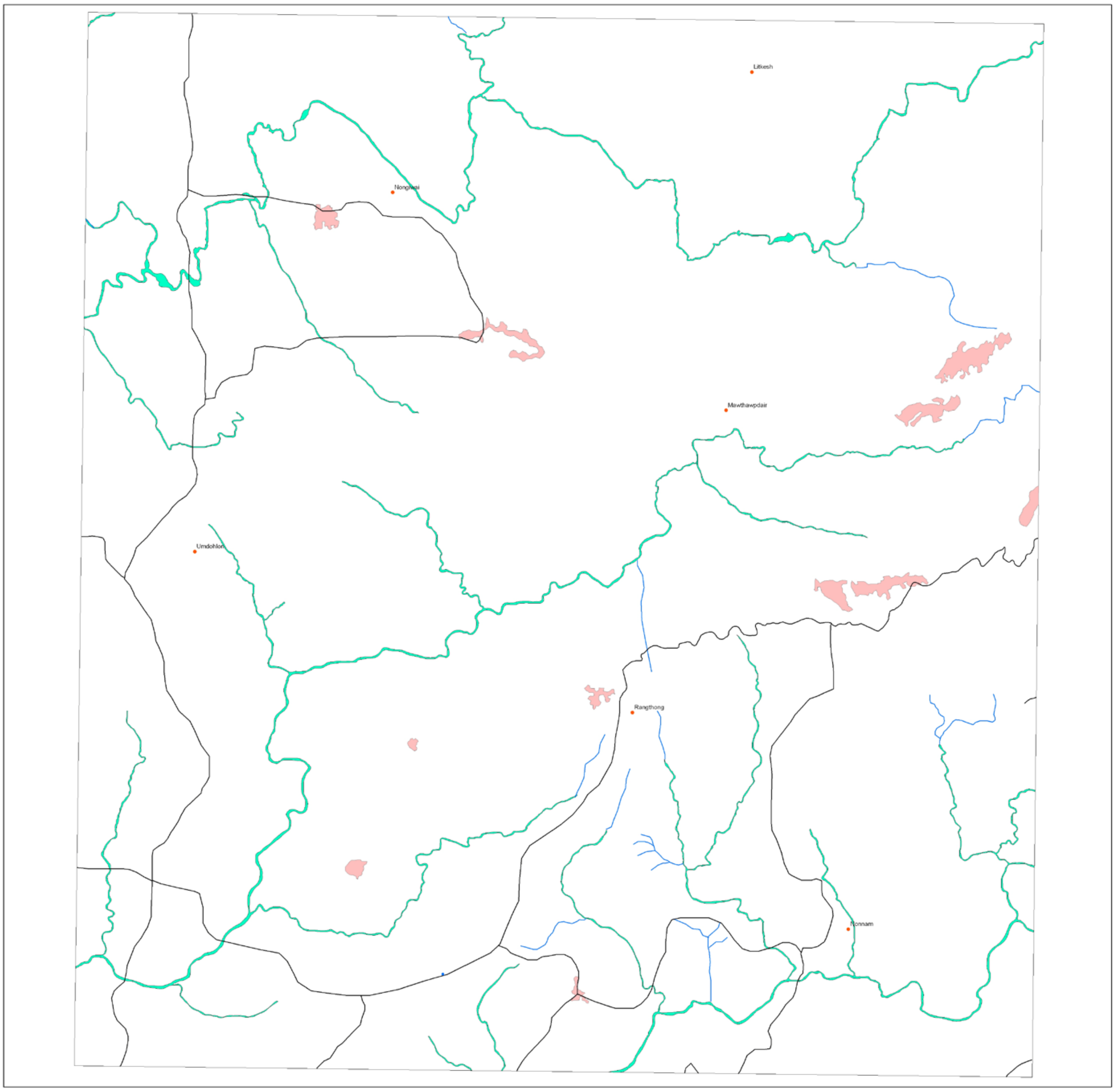
Prepared By :
North Eastern Space Applications Centre, Meghalaya

Sponsored By:
Ministry of Environment and Forests
Government of India

State : Meghalaya

WETLAND MAP

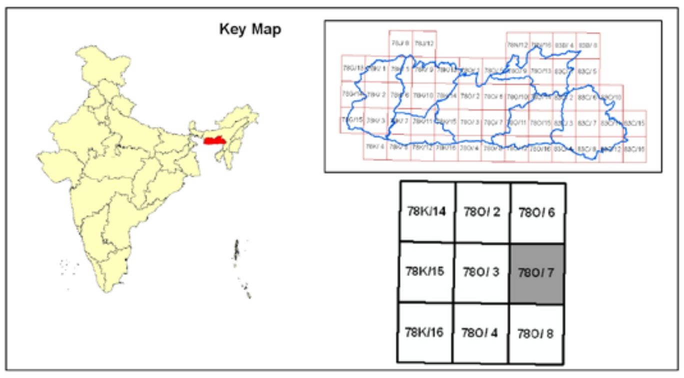
Map No.: 78O/7



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- wetpnt point
- drainl arc
- settlep point
- settlea polygon



0 1 2 4 6 8 Kilometers

Data Source :

IRS P6 LISS III data (Pre-monsoon and Post-monsoon Season 2006-07)

Prepared By :

North Eastern Space Applications Centre, Meghalaya

Sponsored By:

Ministry of Environment and Forests
Government of India

REFERENCES

1. Anon. 2005, NNRMS Standards. A National Standards for EO images, thematic & cartographic maps, GIS databases and spatial outputs. ISRO:NNRMS: TR:112:2005. A Committee Report: National Natural Resources Management System, Bangalore
2. Anon. 1993. Directory of Indian Wetlands, 1993. WWF India, New Delhi and AWB Kuala Limpur, xvi+264pp., 32 maps.
3. Clark, John R. (1977). *Coastal Ecosystem Management,* A Wiley Interscience Publication, John Wiley & Sons, New York,.
4. Cowardin, L.M., Carter, V., Golet, E.C. and La Roe (1979). *Classification of wetlands and deep water habitats*. USFWS/085-79/31, Office of the Biological Services, U.S. Fish and Wildlife Service, Washington, D.C.
5. *Encyclopaedic Directory of Environment (1*988). (Ed. By G.R. Chatwal, D.K. Pandey, and K.K. Nanda). Vol. I-IV, Anmol Publications, New Delhi.
6. Garg, J.K., Singh, T.S. and Murthy, T.V.R. (1998). *Wetlands of India*. Project Report: RSAM/sac/resa/pr/01/98, June 1998, 240 p. Space Applications Centre, Ahmedabad,
7. Garg J.K. and Patel J. G., 2007. National Wetland Inventory and Assessment, Technical Guidelines and Procedure Manual, Technical Report, SAC/EOAM/AFEG/NWIA/TR/01/2007, June 2007, Space Applications Centre, Ahmedabad,
8. *Glossary of Geology* (1974). (Ed. By Margarate G., Robbert, M. Jr. and Wolf, C.L), American Geological Institute, Washington, D.C..
9. Jensen, J.R. (1986). *Introductory Digital Image Processing: A Remote Sensing Perspective,* Prentice Hall, Englewoods Cliff, NJ.
10. Lacaux, J.P., Tourre, Y.M., Vignolles, C., Ndione, J.A. and Lafaye, M. 2007. Classification of ponds from high-spatial resolution remote sensing: Application to Rift valley fever epidemics in Senegal. *Remote Sensing of Environment*, 106, pp. 66-74
11. Lillesand, T.M. and Keifer, R.W. 1987. Remote Sensing and Image Interpretation. John Wliey and Sons, New York.
12. *Manorama Yearbook 2007*
13. *McGraw - Hill Encyclopaedia of Environmental Science* (1974). (Ed. Sybil P. Parkar), McGraw-Hill Book Company, New York.
14. McFeeters, S.K. 1996. The use of Normalised Difference Water Index (NDWI) in the delineation of open water features. *International Journal of remote Sensing*, 7, pp. 1425-1432.
15. Millennium Ecosystem Assessment. 2005, Ecosystems and Human Well-being: A Framework for Assessment, http://www.MAweb.org
16. Mitsch, William J. and Gosselink, James G. (1986). *Wetlands*, Van Nostrand Reinhold Company, New York.
17. Navalgund, R.R., Nayak, S.R., Sudarshana, R., Nagaraja, R. and Ravindran, S. 2002. Proceedings of the ISPRS Commission VII. Symposium on Resource and Environmental Monitoring, IAPRS & SIS, Vol.35, Part-7, NRSA, Hyderabad.
18. Patel J.G., Singh T.S., Garg J.K. et al, Wetland Information System, West Bengal, SAC/RSAM/RESA/FLPG/WIS/01/2003, A Technical report: Space Applications Centre, Ahmedabad
19. Ramsar Convention (2007). www.ramsar.org
20. Reid, George K and Wood, Richard D. (1976). *Ecology of Inland Waters and Estuaries*. D. Van Nostrand Company, New York.
21. SACON, 2004, Inland Wetlands of India : Conservation Atlas. Coimbatore, Salim Ali Centre for Ornithology and Natural History, 2004, ISBN 81-902136-1-X. ,Vedams eBooks (P) Ltd. Vardhaman Charve Plaza IV, Building # 9, K.P Block, Pitampura,
22. Singh T.S., Patel J.G., Garg J.K. et al. Loktak Lake Resources Information System (LRIS), SAC/RSAM/RESIPA/FLPG/WIS/02/2003, A Technical report: Space Applications Centre, Ahmedabad
23. Statistical hand book of Meghalaya, Directorate of economics and statistics, Govt. of Meghalaya, 2007
24. Townshend, J.R., and Justice, C.O. 1986. Analysis of dynamics of African vegetation using the Normalised difference Vegetation Index. *International Journal of Remote Sensing, 7, pp. 1435-1445.*
25. Tucker, C.J. and Sellers, P.J. 1986. Satellite remote sensing of primary productivity. *International Journal of Remote Sensing, 7, pp. 1395-1416.*
26. Xu Hanqiu, 2006. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International Journal of Remote Sensing, 7, pp. 3025-3033.*
27. http://eastkhasihills.gov.in/district.htm
28. http://meghalayaonline.in/profile/districts/East_Garo.asp
29. http://westgarohills.gov.in/profile.htm
30. http://meghalayaonline.in/profile/districts/West_Khasi.asp
31. http://meghalayaonline.in/profile/districts/South_Garo.asp
32. http://ribhoi.gov.in/districtprofile_old.htm
33. http://jaintia.nic.in/Profile.htm

Annexure I
Definitions of wetland categories used in the project

For ease of understanding, definitions of wetland categories and their typical appearance on satellite imagery is given below:

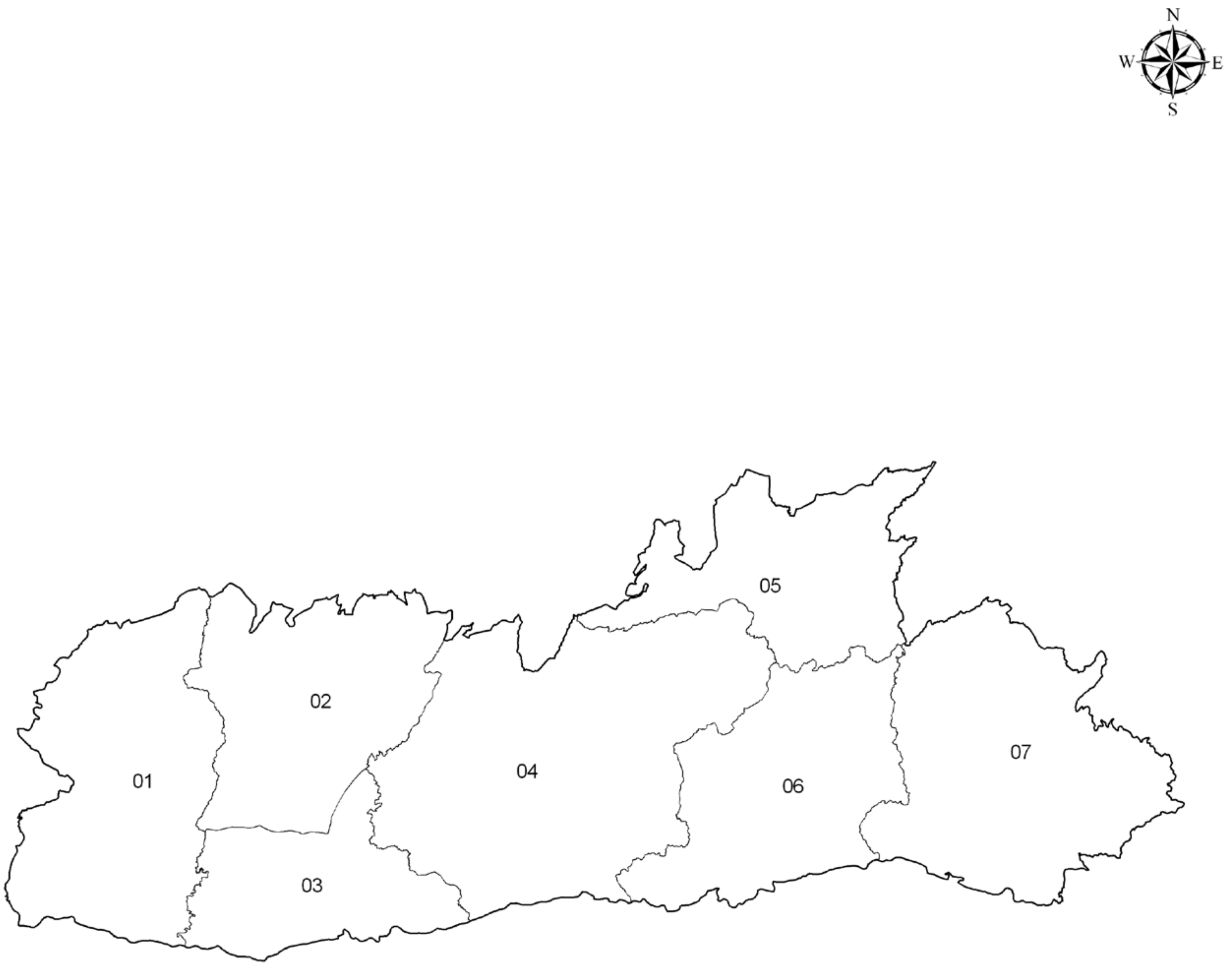
Wetland type code	Definition and description
1000	**Inland Wetlands**
1100	**Natural**
1101	**Lakes**: Larger bodies of standing water occupying distinct basins (Reid *et al*, 1976). These wetlands occur in natural depressions and normally fed by streams/rivers. On satellite images lakes appear in different hues of blue interspersed with pink (aquatic vegetation), islands (white if unvegetated, red in case of terrestrial vegetation). Vegetation if scattered make texture rough.
1102	**Ox-bow lakes/ Cut off meanders**: A meandering stream may erode the outside shores of its broad bends, and in time the loops may become cut-off, leaving basins. The resulting shallow crescent-shaped lakes are called oxbow lakes (Reid *et al*, 1976). On the satellite image Ox-bow lakes occur near the rivers in plain areas. Some part of the lake normally has aquatic vegetation (red/pink in colour) during pre-monsoon season.
1103	**High Altitude lakes:** These lakes occur in the Himalayan region. Landscapes around high lakes are characterized by hilly topography. Otherwise they resemble lakes in the plain areas. For keeping uniformity in the delineation of these lakes contour line of 3000 m above msl will be taken as reference and all lakes above this contour line will be classified as high altitude lakes.
1104	**Riverine Wetlands**: Along the major rivers, especially in plains water accumulates leading to formation of marshes and swamp. **Swamps** are 'Wetland dominated by trees or shrubs' (U.S. Definition). In Europe, a forested fen (a peat accumulating wetland that has no significant inflows or outflows and supports acidophilic mosses, particularly *Sphagnum*) could be called a swamp. In some areas reed grass - dominated wetlands are also called swamps). (Mitsch and Gosselink, 1986). **Marsh**: A frequently or continually inundated wetland characterised by emergent herbaceous vegetation adapted to saturated soil conditions. In European terminology a marsh has a mineral soil substrate and does not accumulate peat (Mitsch and Gosselink, 1986). Tone is grey blue and texture is smooth. **Comment**: Using satellite data it is difficult to differentiate between swamp and marsh. Hence, both have been clubbed together.
1105	**Waterlogged:** Said of an area in which water stands near, at, or above the land surface, so that the roots of all plants except hydrophytes are drowned and the plants die (Margarate *et al*, 1974). Floods or unlined canal seepage and other irrigation network may cause waterlogging. Spectrally, during the period when surface water exists, waterlogged areas appear more or less similar to lakes/ponds. However, during dry season large or all parts of such areas dry up and give the appearance of mud/salt flats (grey bluish).
1106	**River/stream:** Rivers are linear water features of the landscape. Rivers that are wider than the mapping unit will be mapped as polygons. Its importance arises from the fact that many stretches of the rivers in Indo-Gangetic Plains and peninsular India are declared important national and international wetlands (Ex. The river Ganga between Brajghat and Garh Mukteshwar, is a Ramsar site, Ranganthattu on the Cavery river is a bird sanctuary etc.). Wherever, rivers are wide and features like sand bars etc. are visible, they will be mapped.
1200	**Man-made**
1201	***Reservoir**: A pond or lake built for the storage of water, usually by the construction of a dam across a river (Margarate et al, 1974). On RS images, reservoirs have irregular boundary behind a prominent dyke. Wetland boundary in case of reservoir incorporates water, aquatic vegetation and footprint of water as well. In the accompanying images aquatic vegetation in the reservoir is seen in bright pink tone. Tone is dark blue in deep reservoirs while it is ink blue in case of shallow reservoirs or reservoirs with high silt load. These will be annotated as Reservoirs/Dam.* **Barrage:** Dykes are constructed in the plain areas over rivers for creating Irrigation/water facilities. Such water storage areas develop into wetlands (Harike Barrage on Satluj – a Ramsar site, Okhla barrage on the Yamuna etc. – a bird sanctuary). Water appears in dark blue tone with a smooth texture. Aquatic vegetation appears in pink colour, which is scattered, or contiguous depending on the density. Reservoirs formed by barrages will be annotated as reservoir/barrage.

1202	**Tanks/Ponds:** A term used in Ceylon and the drier parts of Peninsular India for an artificial pond, pool or lake formed by building a mud wall across the valley of a small stream to retain the monsoon (Margarate *et al*, 1974). **Ponds** Generally, suggest a small, quiet body of standing water, usually shallow enough to permit the growth of rooted plants from one shore to another (Reid *et al*, 1976). Tanks appear in light blue colour showing bottom reflectance. In this category **Industrial ponds/mining pools mainly comprising Abandoned Quarries are also included (**Quarry is defined as "An open or surface working or excavation for the extraction of stone, ore, coal, gravel or minerals." In such pits water accumulate (McGraw Hill Encyclopaedia of Environmental Sciences, 1974), **Ash pond/Cooling pond** (The water body created for discharging effluents in industry, especially in thermal power plants (Encyclopaedic Directory of Environment, 1988) and **Cooling pond**: An artificial lake used for the natural cooling of condenser-cooling water serving a conventional power station (Encyclopaedic Directory of Environment, 1988). These ponds can be of any shape and size. Texture is rough and tonal appearance light (quarry) to blue shade (cooling pond).
1203	**Waterlogged :** Man-made activities like canals cause waterlogging in adjacent areas due to seepage especially when canals are unlined. Such areas can be identified on the images along canal network. Tonal appearance is in various hues of blue. Sometimes, such waterlogged areas dry up and leave white scars on the land. Texture is smooth.
1204	**Salt pans:** Inland salt pans in India occur in Rajasthan (Sambhar lake). These are shallow rectangular man-made depressions in which saline water is accumulated for drying in the sun for making salt.
2000	**Coastal Wetlands**
2100	**Natural**
2101	**Lagoons/Backwaters:** Such coastal bodies of water, partly separated from the sea by barrier beaches or bass of marine origin, are more properly termed lagoons. As a rule, lagoons are elongate and lie parallel to the shoreline. They are usually characteristic of, but not restricted to, shores of emergence. Lagoons are generally shallower and more saline than typical estuaries (Reid *et al*, 1976). **Backwater**: A creek, arm of the sea or series of connected lagoons, usually parallel to the coast, separated from the sea by a narrow strip of land but communicating with it through barred outlets (Margarate *et al*, 1974).
2102	**Creek:** A notable physiographic feature of salt marshes, especially low marshes. These creeks develop as do rivers "with minor irregularities sooner or later causing the water to be deflected into definite channels" (Mitsch and Gosselink, 1986). Creeks will be delineated, however, their area will not be estimated.
2103	**Sand/Beach:** Beach is an unvegetated part of the shoreline formed of loose material, usually sand that extends from the upper berm (a ridge or ridges on the backshore of the beach, formed by the deposit of material by wave action, that marks the upper limit of ordinary high tides and wave wash to low water mark(Clark,1977).Beach comprising rocky material is called rocky beach.
2104	**Intertidal mudflats**: Most unvegetated areas that are alternately exposed and inundated by the falling and rising of the tide. They may be mudflats or sand flats depending on the coarseness of the material of which they are made (Clark, 1977).
2105	**Salt Marsh**: Natural or semi-natural halophytic grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water level fluctuates either tidally or non- tidally (Mitsch and Gosselink, 1986). Salt marshes look in grey blue shade when wet.
2106	**Mangroves**: The mangrove swamp is an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical coastlines (Mitsch and Gosselink, 1986). On the satellite images mangroves occur in red colour if in contiguous patch. When mangrove associations are scattered or are degraded then instead of red colour, brick red colour may be seen.
2107	**Coral reefs:** Consolidated living colonies of microscopic organisms found in warm tropical waters. The term coral reef, or organic reef is applied to the rock- like reefs built-up of living things, principally corals. They consist of accumulations of calcareous deposits of corals and corraline algae with the intervening space connected with sand, which consists largely of shells of foraminefera. Present reefs are living associations growing on this accumulation of past (Clark, 1977). Reefs appear in light blue shade.
2200	**Man-made**
2201	**Salt pans**: An undrained usually small and shallow rectangular, man-made depression or hollow in which saline water accumulates and evaporates leaving a salt deposit (Margarate *et al*, 1974). Salt pans are square or rectangular in shape. When water is there appearance is blue while salt is formed tone is white.
2202	**Aquaculture ponds**: Aquaculture is defined as "The breeding and rearing of fresh-water or marine fish in captivity. Fish farming or ranching". The water bodies used for the above are called aquaculture ponds (Encyclopaedic Directory of Environment, 1988). Aquaculture ponds are geometrical in shape usually square or rectangular. Tone is blue.

Annexure – II
Details of District information followed in the atlas

State : Meghalaya

District Boundary Map



List of Districts

District Code	District Name
01	West Garo Hills
02	East Garo Hills
03	South Garo Hills
04	West Khasi Hills
05	Ri Bhoi
06	East Khasi Hills
07	Jaintia Hills

Legend

State Boundary

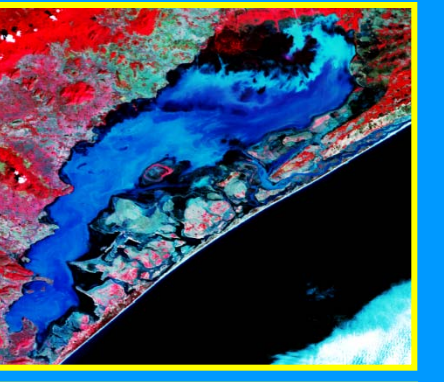
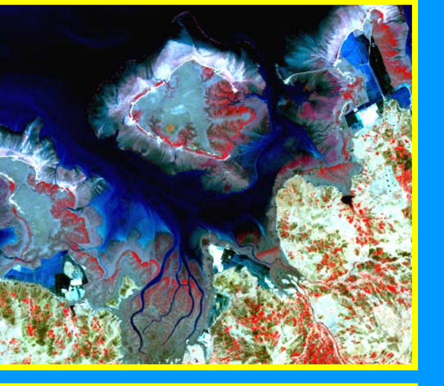
District Boundary

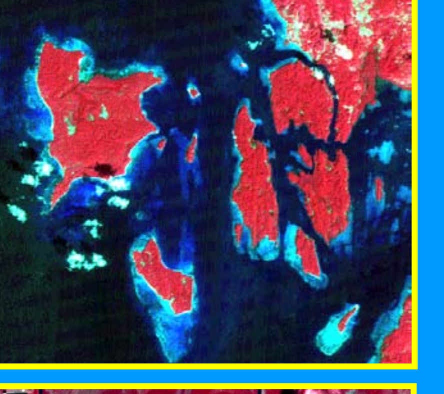
Source : Survey of India (Surveyed in 2004 and published in 2005)

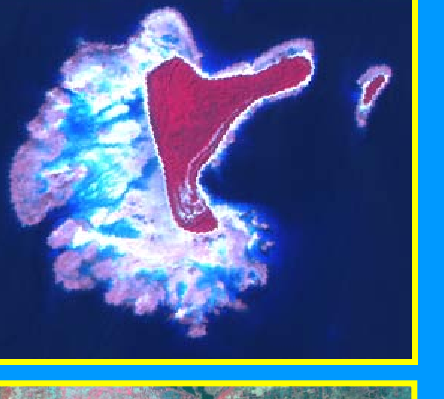
Space Applications Centre (SAC) is one of the major centres of the Indian Space Research Organisation (ISRO). It is a unique centre dealing with a wide variety of disciplines comprising design and development of payloads, societal applications, capacity building and space sciences, thereby creating a synergy of technology, science and applications. The Centre is responsible for the development, realisation and qualification of communication, navigation, earth & planetary observation, meteorological payloads and related data processing and ground systems. Several national level application programmes in the area of natural resources, weather and environmental studies, disaster monitoring/mitigation, etc are also carried out. It is playing an important role in harnessing space technology for a wide variety of applications for societal benefits.

SAC is a host institution for the training programmes related to Satellite Communication, Satellite Meteorology and global change under the Centre for Space Science & Technology Education in Asia and the Pacific (CSSTEAP) affiliated to the United Nations (UN).

http://www.isro.org





Space Applications centre
Indian Space Research Organisation
Ahmedabad – 380 015