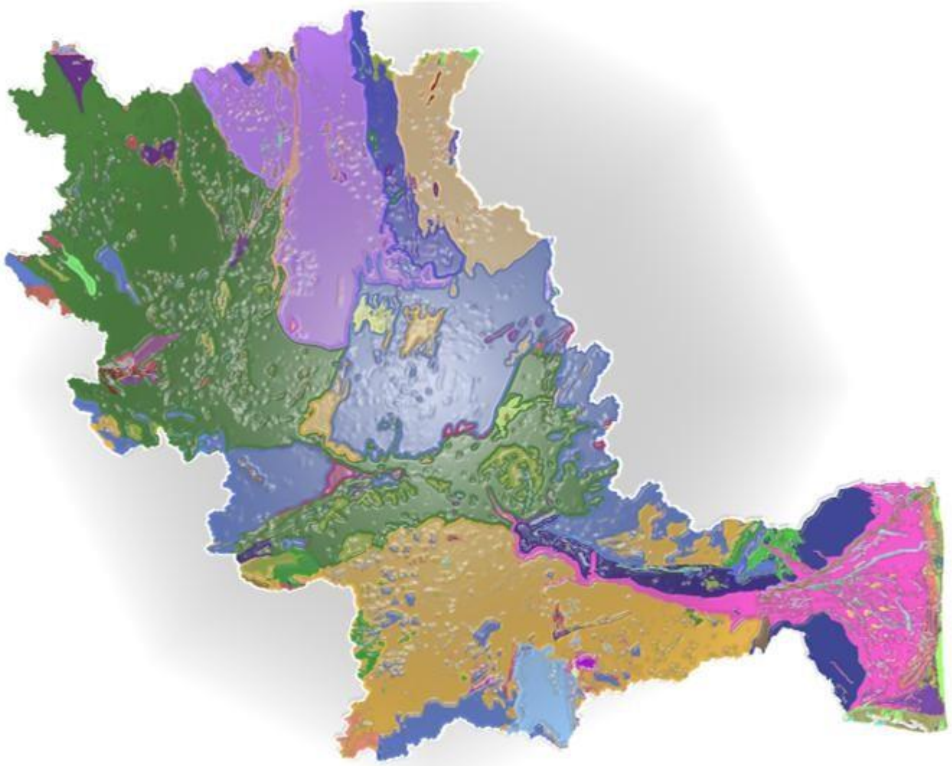
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development and Ganga Rejuvenation
Government of India

Lithological Profile of Cauvery River Basin



December 2024

Lithological Profile

of

Cauvery River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development and Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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The Centre for Cauvery River Basin Management and Studies (cCauvery) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IISc Bengaluru and NIT Tiruchirappalli, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cCauvery is committed to restoring and conserving the Cauvery River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ccauvery.org

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IISc Bengaluru (Lead Institute) and NIT Tiruchirappalli (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Team Members

Praveen C Ramamurthy, cCauvery, IISc Bengaluru
Pradeep P Mujumdar, cCauvery, IISc Bengaluru
Shekhar M, cCauvery, IISc Bengaluru
Nagesh Kumar Dasika, cCauvery, IISc Bengaluru
Srinivas V V, cCauvery, IISc Bengaluru
Lakshminarayana Rao, cCauvery, IISc Bengaluru
Rajarshi Das Bhowmik, cCauvery, IISc Bengaluru
Bramha Dutt Vishwakarma, cCauvery, IISc Bengaluru
Debsunder Dutta, cCauvery, IISc Bengaluru
Nisha Radhakrishnan, cCauvery, NIT Trichy
R Manjula, cCauvery, NIT Trichy
S Saravanan, cCauvery, NIT Trichy
Aneesh Mathew, cCauvery, NIT Trichy
Laveti Satish, cCauvery, NIT Trichy
Prabu P, cCauvery, NIT Trichy
Vinod Tare, cGanga, IIT Kanpur
Rajith K, cGanga, IIT Kanpur

Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Prof. Praveen C Ramamurthy
Centres for Cauvery River Basin
Management and Studies (cCauvery)
IISc Bengaluru (Lead Institute), NIT Tiruchirappalli (Fellow Institute)

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Abbreviations and Acronyms

°	Degree
′	Minute
&	And
km^2	Square kilometre
m^3	Cubic meter
CRB	Cauvery River Basin
CGWB	Central Ground Water Board
ECMI	Eastern Continental Margin of India
EW	East-West
ENE-WSW	East-North-East to West-South-West
ICAR	Indian Council of Agricultural Research
IRS	Indian Remote Sensing
LISS	Linear Imaging Self-Scanning Sensor
km	Kilometre
mbgl	Meters below ground level
m	Meters
Ma	Million years ago
NBSS & LUP	National Bureau of Soil Survey and Land Use Planning
NS	North-South
NNE-SSW	North-North-East to South-South-West
NW-SE	North-West to South-East
SRTM	Shuttle Radar Topography Mission
sq.	Square
WNW-ESE	West-North-West to East-South-East

1. Introduction

1.1. Basin Characteristics

The Cauvery River Basin (CRB) is a peri-cratonic rift basin spanning over 50,000 sq. km, extending both onshore and offshore to depths of up to 2,000 meters. Located in the southern part of the Eastern Continental Margin of India (ECMI), it is classified as a Category I petroliferous basin with established hydrocarbon production (Mukherjee et al., 2025).

The basin contains a sedimentary sequence exceeding 6,000 meters, ranging from the Permian to the present, which has been extensively drilled for hydrocarbon exploration (Raju & Reddy, 2016; Reddy et al., 2013). Aptian-Palaeocene sediments, characterized by major and minor unconformities, are well-exposed along the western margin in the Ariyalur district of Tamil Nadu (Fig. 1) (Nagendra and Reddy, 2017).

The basement geology of the CRB consists predominantly of Archean to late Proterozoic crystalline rocks, covering approximately 80% of the area, while the remaining portion consists of Phanerozoic sedimentary rocks, primarily along the coastal strip and inland river valleys. The hard rock terrain is mainly composed of the Charnockite and Khondalite groups and their migmatitic derivatives, along with supracrustal sequences from the Sathyamangalam and Kolar Groups and the Peninsular Gneiss Complex. These formations have been intruded by ultramafic complexes, basaltic dykes, granites, and syenites (CUTN, 2022).

The major structural elements of the CRB include (DGH India):

- Ariyalur-Pondicherry Depression
- Kumbakonam-Madnam-Portonovo High
- Tranquebar Depression
- Karaikal High
- Nagapattinam Depression
- Vedaranyam High
- Thanjavur Depression
- Pattukottai-Manargudi Ridge
- Mandapam Ridge

- Mannar Depression
- Vedaranyam-Tiruchirapalli Fault

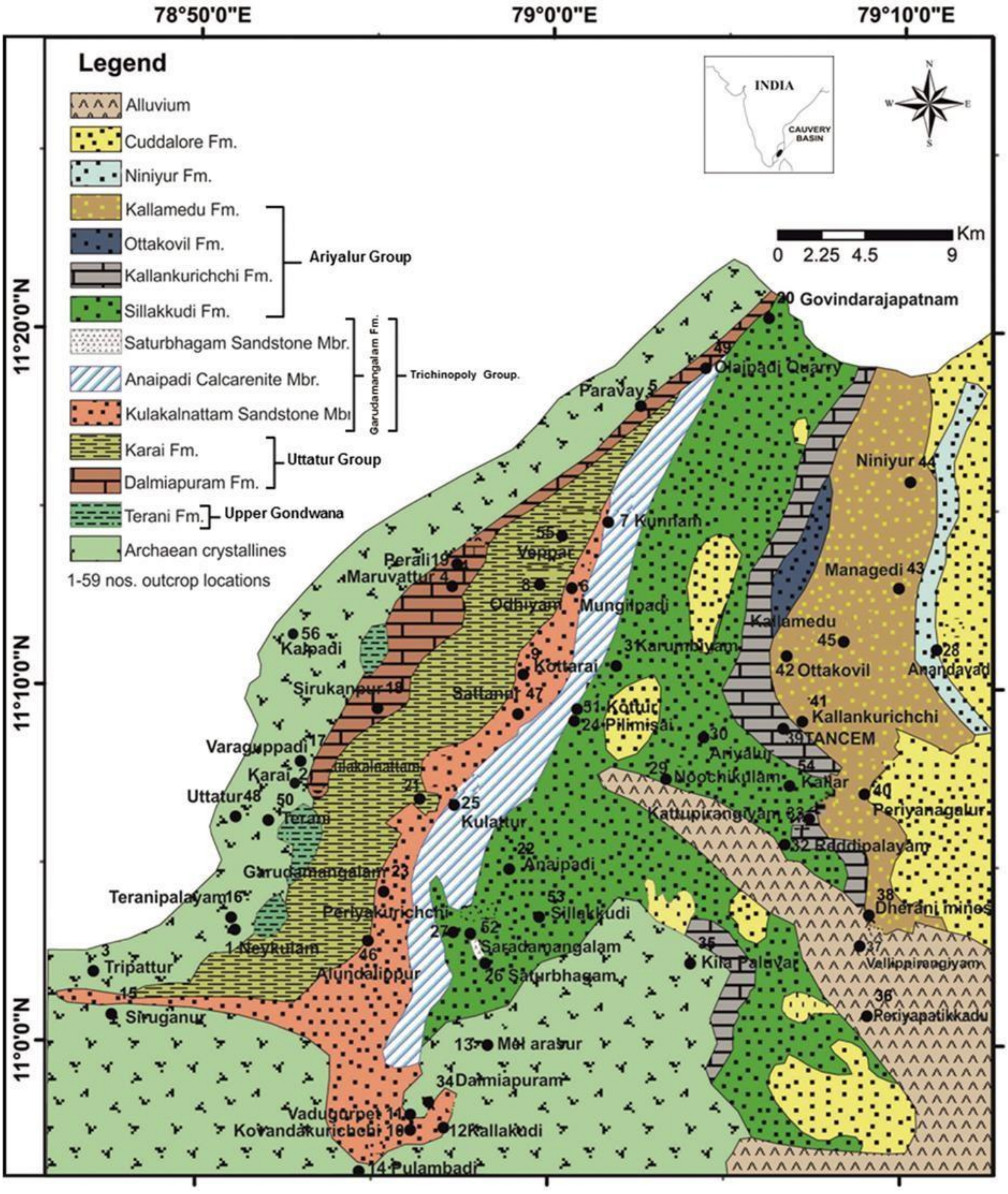

Fig. 1. Lithological formation map of Cretaceous outcrop sediments in the Ariyalur region, CRB
(**Source:** Nagendra and Reddy, 2017)

1.2. Geological Setting

The CRB is predominantly composed of Archean (>2500 Ma) gneissic, charnockitic, and granitic rocks. Geologically, the region is divided into two primary terranes: the Dharwar Craton in the north and the granulite terrane in the south. These terranes are separated by a transition zone in the north, where granitic rocks and supracrustal belts (schist belts) have undergone metamorphism, reaching amphibolite facies or lower grades (Fathima et al., 2023).

South of this transition zone, both granitic and supracrustal rocks experience high-grade metamorphism, giving rise to granulite-facies rocks such as charnockite, pyroxene granulite, and high-grade amphibolite assemblages. The gneisses and charnockites within the transition zone have been dated to approximately 3000-2500 Ma (Friend and Nutman, 1991).

The boundary between the Dharwar Craton and the southern granulite belt is defined by a major fault and thrust zone, where the charnockite terrane has been uplifted and overthrust onto the craton (Radhakrishna, 1968). According to Radhakrishna (1993), the Himalayan orogeny played a crucial role in reactivating shear and fault systems, leading to the uplift and formation of several block mountains (Sharma and Rajamani, 2001).

1.3. Tectonic Evolution

The CRB shares evolutionary, stratigraphic, and sea-level fluctuation patterns with several central European basins, including the Danish Basin, North Sea Basin, North German Basin, and the Northern Gulf of Mexico Basin (Nagendra et al., 2011a, 2011b). During the Archean and Proterozoic epochs, the crystalline rocks of the basin experienced a complex geological history marked by multiple deformations, anatexis (partial melting of pre-existing rocks), intrusions, and multiphase metamorphic events. In the northern and central regions, the Precambrian terrain of Tamil Nadu is highly fractured and deeply faulted, whereas the Phanerozoic sedimentary rocks remain relatively undisturbed, preserving well-defined bedding planes with dips ranging from horizontal to 100°. The crystalline basement, however, exhibits clear evidence of multiphase deformation and metamorphism, resulting in well-developed foliation that aligns with lithological contacts. Subsequent tectonic events led to the local development of new S-fabrics, further contributing to the basin's structural complexity.

The regional structural trends of the CRB vary across different sectors. The predominant trend follows an NNE-SSW orientation, characterized by long, linear, canoe-shaped folds. In the northwest, the structural trend shifts closer to NS, displaying evidence of multiphase folding, though distinct regional structures remain undefined. The central region exhibits a diverse structural pattern, with trends varying from EW to ENE-WSW and WNW-ESE. South of the Tambaraparani River, a pronounced NW-SE structural grain is observed, reflecting the influence of tectonic forces that have shaped the basin's evolution over geological time.

Several Precambrian shear zones have been identified, including:

- Moyyar Shear Zone
- Bhavani Shear Zone
- Salem Shear Zone
- Attur Shear Zone
- Cauvery Shear Zone
- Dharmapuri Shear Zone
- Gangavalli Shear Zone
- Achankovil Shear Zone

These shear zones played a crucial role in shaping the basin's structural complexity and controlling its hydrocarbon potential (CUTN, 2022).

1.4. Climate

Karnataka has a diverse climate influenced by both its geographical features and the monsoons. The state experiences three major climatic zones: tropical monsoon, tropical savanna, and semi-arid. The coastal and Malnad regions receive heavy rainfall, while the northern interior is much drier. Summer temperatures typically range between 95°F (35°C) and 104°F (40°C), with April and May being the hottest months. Winters are mild, with temperatures dropping to around 60°F (15°C) in some parts. Karnataka receives an average annual rainfall of about 1,248 mm, with significant variation across regions. The coastal belt, particularly the Western Ghats, receives over 3,500 mm of rainfall annually, while the northern interior districts receive less than 600 mm, making them prone to frequent droughts. The Southwest Monsoon (June to September) contributes most of the rainfall, whereas the Northeast Monsoon (October to December) provides additional but lesser precipitation. Karnataka's varied topography results in distinct climatic regions, supporting diverse agriculture and ecosystems, from the coffee plantations of Coorg to the arid zones of North Karnataka. The climate of Tamil Nadu is predominantly tropical, ranging from dry sub-humid to semi-arid, with rainfall primarily dependent on the monsoon seasons. The state experiences high temperatures, with May and June being the hottest months, where daily maximum temperatures in Chennai average around 100°F (38°C), while minimum temperatures hover around 80°F (27°C). During December and January, the coldest months, temperatures range from 70°F (21°C) in the morning to around 30°C (mid-80s°F) in the afternoon. Tamil Nadu receives an average annual rainfall of approximately 945 mm (37.2 in), with 48% of precipitation occurring during the Northeast Monsoon (October-December) and 32% from the Southwest Monsoon (June-September). The state has two distinct rainy periods, with the Northeast Monsoon bringing significant rainfall, while the Southwest Monsoon has less impact. The extreme western part of the state, particularly the Nilgiri Hills, receives the highest precipitation, while the southeastern and southern regions receive the least. Given its heavy reliance on monsoon rains, Tamil Nadu is prone to water shortages and droughts during monsoon failures. The state is divided into seven agroclimatic zones: northeast, northwest, west, south, high rainfall, high altitude hills, and the Cauvery delta, which is the most fertile agricultural region.

1.5. Generalized Stratigraphy

The stratigraphy of the CRB has been established through outcrop geology and subsurface data from seismic and drilling studies. The Precambrian basement consists of granites and gneisses exposed along the western margin of the basin. Overlying these are Late Jurassic to Early Cretaceous Gondwanic sedimentary rocks, including the Shivganga Beds and Therani Formation, the latter containing index fossils (Ptilophyllum acutifolium). The Early Cretaceous Uttatur Group comprises formations such as Kalakundi, Karai Shale, and Maruvathur Clay in outcrops, while in the subsurface, the Andimadam, Sattapadi, and Bhuvanagiri formations dominate. The Andimadam Formation, found in the Ramnad, Tanjore, Tranquebar, and Ariyalur-Pondicherry grabens, consists of micaceous sandstones and silty shales. The Sattapadi Shale, a key hydrocarbon source rock, is marine in origin, while the Bhuvanagiri Formation, primarily sandstone, was deposited in middle shelf to upper bathyal environments. The Palk Bay Formation, restricted to the Palk Bay area, consists of calcareous sandstones and sandy claystones deposited in a fan delta setting. The Late Cretaceous sediments are classified into the Trichinopoly and Ariyalur Groups, composed of sandstones and limestone. Notable formations include the Kudavasal Shale, Nannilam Formation, Porto-Novo Shale, and Komarakshi Shale, each with distinct lithologies and depositional settings, ranging from marine shales to argillaceous deposits. The Tertiary sequence, well-developed in both outcrop and subsurface, includes the Niniyur Formation (Paleocene) and Cuddalore Sandstone (Mio-Pliocene). In the subsurface, it is divided into the Nagore Group and Narimanam Group, both marked by unconformities. The Nagore Group comprises formations such as Kamalapuram, Karaikal Shale, Pandanallur, and Tiruppundi, spanning the Paleocene to Eocene. The Narimanam Group, the youngest sequence, includes formations such as Niravi, Kovilkalappal, Shiyali Claystone, Vanjiyur Sandstone, Tirutaraipundi Sandstone, Madanam Limestone, Vedaranniyam Limestone, and Tittacheri Formation, deposited in a range of environments from shallow marine to deltaic settings. The Tittacheri Formation, grading into the Cuddalore Sandstone, represents the Miocene to Pliocene transition (DGH, India).

2. Lithological Framework and Groundwater Dynamics of the CRB

2.1. Rock Formations in the CRB

As per the geological data from Bhukosh, the CRB contains the following distinct rock formations (Fig. 2):

2.1.1. Igneous Rocks

Description: Formed from solidification of magma or lava, includes intrusive (granite, gabbro) and extrusive (basalt, rhyolite) types and cover approximately 19,574.01 sq. km of the CRB.
Organic Content: None; these are non-organic, crystalline rocks.
Reservoir Properties: Typically, poor due to low porosity and permeability; however, fractured volcanic or intrusive rocks can act as reservoirs.
Geotechnical Properties: Generally strong and stable; high compressive strength; low weathering potential.

Hydrocarbon Potential: Very low as source rocks, but fractured igneous bodies (e.g., granite wash) can sometimes serve as unconventional reservoirs or tight gas plays.

2.1.2. Metamorphic Rocks

Description: Metamorphic rocks, formed through intense heat, pressure, and chemical alterations, include schists, gneisses, quartzites, and marbles. They cover approximately 54,729.55 sq. km of the CRB.

Organic Content: Very low to none; metamorphism destroys original organic matter.

Reservoir Properties: Generally poor, but fractured quartzites and certain gneisses may store hydrocarbons.

Geotechnical Properties: Often strong, but foliated rocks may have directional weaknesses.

Hydrocarbon Potential: Negligible for source potential; minor potential in structurally trapped fractured units.

2.1.3. Sedimentary Rocks

Description: Formed through the accumulation and lithification of sediments, this group includes sandstone, shale, limestone, and conglomerate. In the CRB, sedimentary rocks occupy a relatively smaller area, covering approximately 2,706.16 sq. km.

Organic Content: High in shales and carbonates; major source rocks.

Reservoir Properties: Excellent in sandstones and some limestones (high porosity and permeability); shales have low permeability but may be rich in organics (source rocks).

Geotechnical Properties: Variable; shales are weak and swell-prone, sandstones are more stable.

Hydrocarbon Potential: High-these are the primary source, reservoir, and seal rocks in petroleum systems.

2.1.4. Unconsolidated Sediments

Description: Unconsolidated deposits, including sand, clay, and silt, cover an area of approximately 8,085.74 sq. km within the basin.

Organic Content: Can be high in coastal and floodplain clays.

Reservoir Properties: Potentially high in clean sands but low in fine clays.

Geotechnical Properties: Generally weak; compressible and prone to settlement; poor stability in construction.

Hydrocarbon Potential: Low in current form but may become future reservoirs or source rocks after burial and maturation.

2.1.5. Weathered Rocks

Description: Rocks modified by intense surface weathering, primarily laterites and saprolites, cover approximately 124.67 sq. km within the CRB.

Organic Content: Low to moderate; may accumulate organics in weathering profile.

Reservoir Properties: Generally poor; low porosity due to secondary mineralization.

Geotechnical Properties: Highly variable; can be soft and weak depending on degree of weathering.

Hydrocarbon Potential: Very low.

2.1.6. Significance of Lithology Map

These results are significant for understanding the resource potential and geotechnical properties of the CRB. Igneous and metamorphic rocks have low hydrocarbon potential but offer groundwater storage and construction stability due to their fractured nature and strength. Sedimentary rocks, especially sandstones and shales, are key for hydrocarbon exploration, serving as source and reservoir rocks. Unconsolidated sediments influence groundwater dynamics and agricultural planning due to their variable porosity, while weathered rocks impact soil fertility and construction in certain areas. Overall, these findings guide resource management, land use, and sustainable development in the basin.

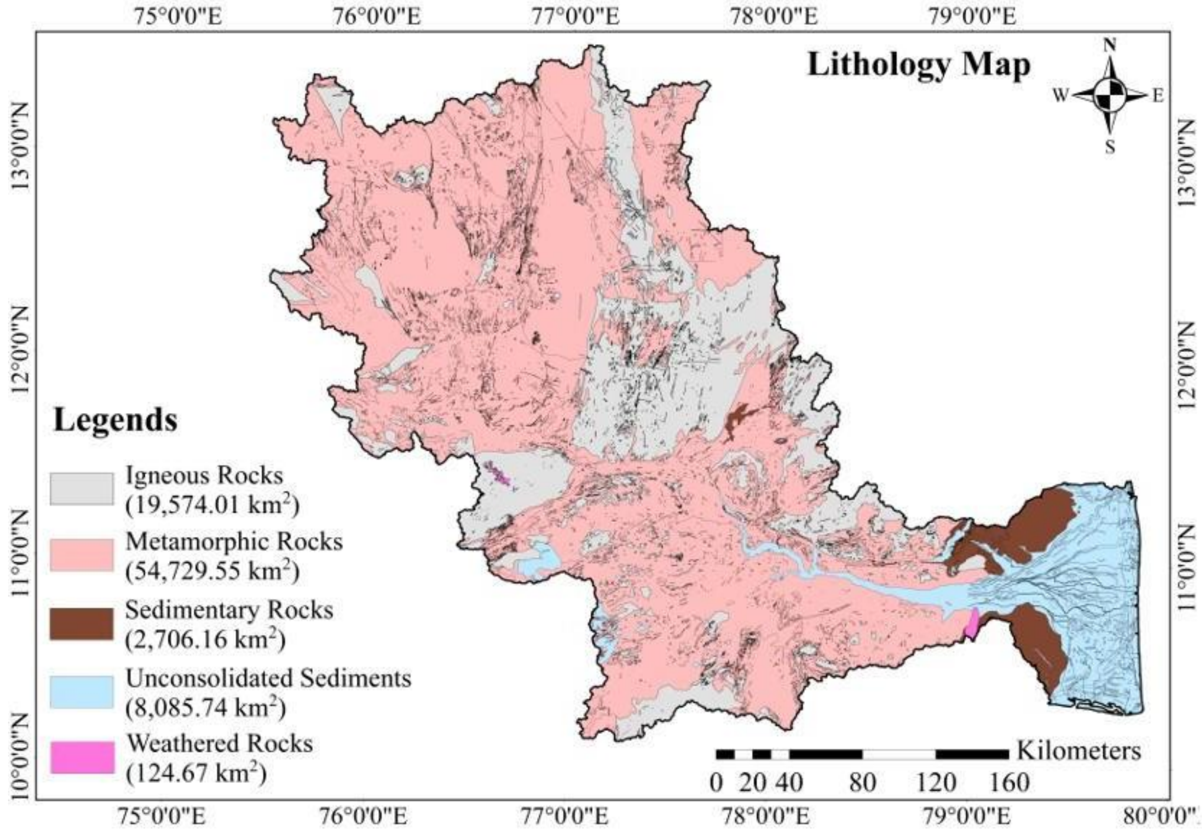

Fig. 2. Major rock types in the CRB
(**Source:** Bhukosh)

Table 1 presents the major rock types, their areal extent (in sq. km), and the corresponding lithological units of the CRB.

Table 1. Major rock types, their areal extent, and corresponding lithological units

Rock Type	Area (sq. km)	Lithological Units
Igneous rock	19,574.01 sq. km	Acid to Intermediate Charnockite
		Anorthosite
		Anorthosite Gabbro
		Aplite
		Birbirite
		Diorite
		Diorite Porphyry
		Dolerite
		Dunite
		Felsite
		Gabbro
		Gabbroic Anorthosite
		Granite
		Granitoid
		Granodiorite
		Grey Biotite Granite

		Grey Granite
		Grey Hornblende Biotite Granite
		Hornblende Granite
		Leuco Granite
		Leucosyenite
		Nepheline Syenite
		Norite
		Orbicular Granite
		Pegmatite
		Pegmatoidal Granite
		Pegmatoidal Syenite
		Peridotite
		Pink Biotite Granite
		Pink Granite
		Pink Porphyritic Granite
		Pink Syenite
		Porphyritic Granite
		Pyroxenite
		Ultramafite
		Agglomerate
Metamorphic rock	54,729.55 sq. km	Amphibolite
		Banded Ferruginous Quartzite
		Banded Magnetite Quartzite
		Biotite Gneiss
		Biotite Hornblende Gneiss
		Biotite Schist
		Calc Gneiss
		Calc Granulite
		Calc Granulite with Limestone
		Calc Silicate Rock
		Carbonaceous Phyllite
		Carbonate Schist
		Cordierite-Sillimanite Gneiss
		Epidiorite
		Epidote-Hornblende Gneiss
		Fenite
		Ferruginous Phyllite
		Ferruginous Quartzite
		Fuchsite-Kyanite Quartzite
		Fuchsite-Sericite Quartzite
		Fuchsite Quartzite
		Gar-Bio-Sill Gneiss Graphite Kyanite
		Garnet-Biotite Gneiss
		Garnet-Cordierite Gneiss

	Garnet-Grunerite Schist
	Garnet-Hornblende Gneiss
	Garnet-Mica Schist
	Garnet-Pyroxene Granulite
	Garnet-Sillimanite-Cordierite Schist
	Garnet-Sillimanite-Gneiss Graphite Cordierite
	Garnet-Sillimanite-Kyanite Gneiss
	Garnet-Sillimanite Schist
	Garnet-Staurolite-Kyanite-Muscovite Quartzite
	Garnet Gneiss
	Garnet Quartzite
	Gneiss
	Granite Gneiss
	Granodiorite Gneiss
	Graphite-Biotite Schist
	Graphite-Kyanite Schist
	Grey Hornblende Biotite Gneiss
	Grey Hornblende Gneiss
	Grunerite-Magnetite Schist
	Hornblende-Biotite Gneiss
	Hornblende-Biotite Schist
	Hornblende-Diopside Gneiss
	Hornblende Biotite Granite Gneiss
	Hornblende Gneiss
	Hornblende Granulite
	Kyanite-Mica Schist
	Kyanite-Staurolite-Mica Schist
	Leuco Gneiss
	Magnetite Quartzite
	Manganiferous Phyllite
	Marble
	Meta-Basalt
	Meta-Dolerite
	Meta-Gabbro
	Meta-Pyroxenite
	Meta-Ultramafite
	Mica Schist / Schist
	Migmatite Gneiss
	Paragneiss
	Pegmatoidal Gneiss
	Phyllite
	Pink Gneiss
	Pink Granite Gneiss

		Pink Granulite
		Pink Migmatite
		Porphyritic Gneiss
		Pyroxene Granulite
		Quartz-Feldspar-Garnet Granulite
		Quartz-Garnet-Sericite Schist
		Quartz Vein/Reef
		Quartzite
		Sericite Schist
		Serpentinite
		Sill-Serici-Bio-Gar Graph Schist
		Sillimanite-Kyanite-Corundum-Mica Schist
		Sillimanite-Kyanite-Quartz Schist
		Sillimanite-Staurolite-Kyanite Schist
		Sillimanite Fuchsite Quartzite
		Talc Tremolite Actinolite Schist
		Talc Tremolite Schist
		Tremolite-Actinolite-Talc-Chlorite Schist
Sedimentary Rocks	2,706.16 sq. km	Argillaceous Sandstone
		Argillite
		Banded Iron Formation
		Calcrete
		Conglomerate
		Dolomite
		Dolomitic Limestone
		Limestone
		Mottled Sandstone
		Oligomictic Conglomerate
		Sandstone
		Shale
		Shell Limestone
		Syenite
Unconsolidated Sediments	8,085.74 sq. km	Black Clay (Active Tidal Flat)
		Black Clay Underlain by Coarse Sand (Palaeo)
		Black Clayey Sand (Tidal Channel Bar)
		Black Silty Clay (Active Flood Plain)
		Brown Fine Sand (Palaeo Beach Ridge)
		Brown Silt (Active Levee)
		Brown Silty Clay (Lagoonal Island)

		Brown Silty Clay (Palaeo Floodplain)
		Brown Silty Clay (Palaeo Lagoon)
		Brown Silty Clay (Palaeo Tidal Flat)
		Clay
		Coarse Sand with Rock Fragments (Active Channel)
		Grey Fine Sand (Active Beach Ridge & Spit)
		Gypseous Clay
		Mud (Mud Flat)
		Red Clayee Sand (Mangrove Swamp)
		Sand (Active Tidal Flat)
		Sand (Channel Bar/ Point Bar)
		Sand (Inland Dune)
		Sand (Palaeo Dune)
		Sand (Paleo Lagoon)
		Silty Clay (Tidal Channel)
		Silty Sand with Salt (Salt Marsh)
Weathered Rocks	124.67 sq. km	Laterite

2.2. Litho-logs

The CRB exhibits a rich and diverse geological framework, encompassing a wide array of lithologic formations that narrate its complex tectonic and depositional history. The sedimentary layers are interspersed with igneous and metamorphic rocks, reflecting multiple phases of sedimentation, erosion, and tectonic activity (Fig. 3).

2.2.1. Sedimentary Formations

Dominating the stratigraphy of the basin are calcareous and carbonate-rich sediments, characterized by sandstones interbedded with clay, shale, and occasionally lignite deposits. These lithologies often reveal calcareous cementation and include fossil-bearing limestone and shell fragments, indicating episodes of marine influence or shallow marine environments. The Cuddalore Sandstone, a recurring unit, is frequently observed in association with clay and limestone, marking a significant sedimentary phase in the region's geologic evolution.

Clastic sedimentary rocks are widespread, comprising sand-clay-gravel mixtures and fine to coarse-grained sandstones. These often present in stratified sequences, indicating fluvial to deltaic depositional settings. Additionally, formations bearing kankar nodules signify semi-arid pedogenic processes that affected the alluvial plains during certain geological periods.

Fossiliferous strata, comprising sandstones and limestones embedded with organic remnants, hint at biologically active depositional environments. These are crucial markers for paleoenvironmental reconstruction and are often interlayered with shale and clay-rich deposits.

2.2.2. Metamorphic and Igneous Bedrock

Beneath and sometimes intruding into the sedimentary layers are expansive exposures of crystalline basement rocks. The metamorphic suite includes various forms of gneisses-biotite, hornblende, and sillimanite-bearing varieties-as well as schists and granulites. These are frequently fractured or weathered, contributing to secondary porosity, which is significant for groundwater storage.

Notably, the region also hosts charnockites, banded gneissic complexes, and pegmatite intrusions, signifying high-grade metamorphic conditions and magmatic events that have shaped the subsurface lithology. Pink granites and nepheline syenites further attest to intrusive igneous activity, particularly in the western and southern segments of the basin.

2.2.3. Unconsolidated and Mixed Sediments

In the alluvial stretches of the basin, especially in the deltaic plains, unconsolidated deposits dominate. These include alternations of sand, silt, clay, and gravel, forming layered sequences with varying degrees of compaction. The presence of these sediments supports active hydrological processes and fertile soil development in the basin's lowland areas.

Moreover, zones where sedimentary deposits transition into crystalline basement often features mixed lithologies-combinations of sandstone, shale, claystone, and weathered gneiss. Such interfaces are key hydrogeological zones and frequently act as aquifers.

2.2.4. Significance of Litho-log Map

The significance of the described geological framework of the CRB lies in its intricate lithological diversity, which plays a crucial role in shaping the region's hydrogeological characteristics, agricultural potential, and resource management strategies. The sedimentary formations, particularly calcareous and fossil-rich deposits, provide important insights into past marine and fluvial environments, crucial for reconstructing paleoenvironmental conditions. This understanding aids in identifying areas of potential hydrocarbon deposits and evaluating soil fertility for agricultural purposes.

The metamorphic and igneous bedrock beneath the sedimentary layers, especially the fractured gneisses and charnockites, significantly contribute to groundwater storage through secondary porosity, making them important for sustainable water management in the region. These formations also offer potential for mineral exploration, with the presence of high-grade metamorphic rocks indicating tectonic activity that has shaped the region's geological history.

The unconsolidated and mixed sediments in the deltaic and alluvial plains are vital for hydrological processes, supporting fertile soils and providing crucial aquifers for groundwater extraction. These areas are key for agriculture and water supply, making the basin's lowlands highly productive and essential for the region's socio-economic well-being.

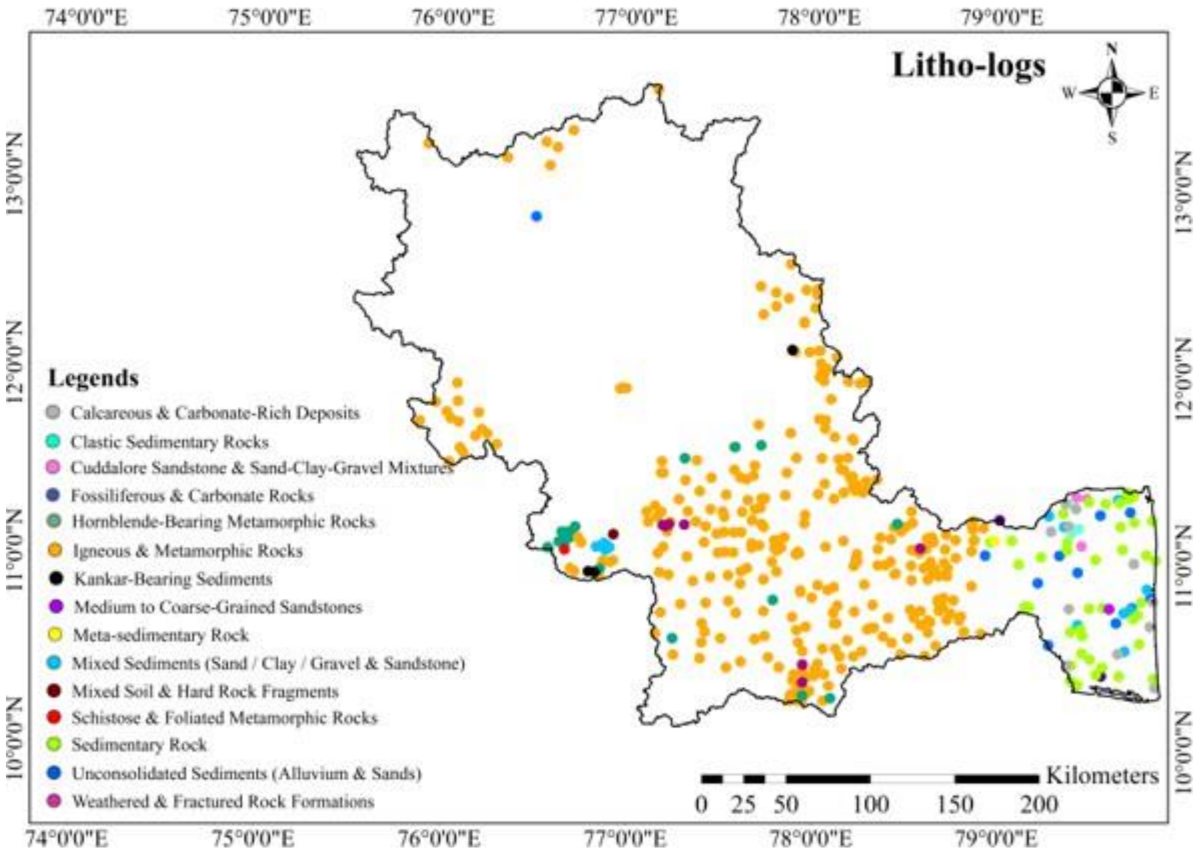

Fig. 3. Litho-logs in the CRB
(**Source:** Bhukosh)

Table 2 provides a detailed overview of the major litho-logs and their description.

Table 2. Detailed overview of the major litho-logs and their description

Major Litho-logs	Lithologic Description
Calcareous & Carbonate-Rich Deposits	Cuddalore Sandstone with Clay Intercalations
	Cuddalore Sandstone Wity Clay, Shale & Lignite
	Sand with Clay & Sandstone Stone & Limestone
	Sand with Clay and Calcareious Sandstone
	Sand with Clay Sandstone & Limestone
	Sand, Alternate Layers of Clay & Sandstone. Calcareous Sandstone with Shell Fragments, Limestone
	Sandstone, Clay, Carbonaceous with Lignite
	Sandstone, Claystone & Limestone Wity Sand and Clay
Clastic Sedimentary Rocks	Cuddalore Sandstone Clay & Gravels
	Cuddalore Sandstone with Carbona- Ceous Matter at Depths
	Cuddalore Sandstone with Mottled Clay
Cuddalore Sandstone & Sand-Clay-Gravel Mixtures	Sand, Clay, Cuddalore Sandstone
	Sand, Clay, Gravel & Sandstone
	Sand, Gravel & Clay, Cuddalore Sandstone
Fossiliferous & Carbonate Rocks	Fossiliferous Limestone with Sand & Clay
	Fossiliferous Sandstone Limestone
Hornblende-Bearing Metamorphic Rocks	Hornblende Biotite Gneiss
	Hornblende Gneiss
	Hornblende Gneiss with Quartz Feldspathic Gneiss
	Horneblende Biotite Gneiss
	Horneblende Granite Fractured
Igneous & Metamorphic Rocks	Archaean Crystallines
	Banded Gneissic Complex
	Biotite & Garnetiferrous Sillimanite Gneiss
	Biotite Gneiss
	Biotite Gneiss & Charnockite
	Biotite Gneiss & Pink Granite
	Biotite Gneiss with Pegmatite
	Biotite Gneiss with Pegmatite Intrusions
	Biotite Granite Gneiss
	Biotite Hornblende Gneiss
	Calc Granulite & Biotite Gneiss
	Charnockite
	Charnockite & Granite Gneiss
	Charnockite & Gneiss

	Charnockite Biotite Gneiss
	Charnockite Biotite Gneiss & Crystalline Limestone
	Charnockite with Intrusive Pink Granite
	Charnockite, Fractured
	Charnockites Followed by Gneiss
	Fractured Biotite Gneiss
	Fractured Biotite Gneiss with Pegmatite & Quartz Veins
	Fractured Gneiss
	Gabbro, Diorite
	Ganetiferous Biotite Gneiss with Pegmatite Intrusions
	Gneiss
	Gneiss & Granite
	Gneiss Charnockite
	Gneiss Fractured
	Gneiss Hard Massive
	Granite
	Granite Biotite Gneiss
	Granite Charnockite
	Granite Gneiss & Biotite Gneiss
	Granite Gneiss & Charnockite
	Granite Gneiss & Nephelene Syenite
	Granite Gneiss & Charnockite
	Granite Gneiss Fractured
	Granite Gneiss Highly Fractured
	Granite Gneiss Rich in Biotite
	Granite Gneiss with Biotite Gneiss
	Granite Gneiss with Pegmatite
	Horneblende Gneiss
	Quartz Feldspar Biotite Schist
	Schist
	Pink Granite
	Fractured Granite Gneiss
	Pink Granite Gneiss
Kankar-Bearing Sediments	Sand with Kankar Followed by Fractured Biotite Gneiss & Calc Granulite
	Sand with Kankar, Granite Gneiss
Medium to Coarse-Grained Sandstones	Sand, Medium Grained, Sandstone
	Sand, Medium Grained, Sandy Clay
	Sand, Medium to Coarse Grained, Sandstone
Meta-sedimentary Rock	Sandstones Shales, Biotite Gneiss
Mixed Sediments (Sand / Clay / Gravel & Sandstone)	Clay, Cuddalore Sandstone, Sands
	Clay, Sand, Gravel
	Clay, Sands, Cuddalore Sandstone

	Clay, Sands, Gravels, Laterite
	Clay, Sands, Sandstone & Gravels
	Clay, Sands, Sandstones, Limestone
	Sand & Clay Followed by Fractured Biotite Gneiss
	Sand & Clay with Gravel Followed by Fractured Biotite Gneiss
	Sand & Clay, Cuddalore Sandstones, Shales & Claystones
	Sand with Clay, Sandstone
	Sand, Clay Cuddalore Sandstone with Calcareous Nature at Bottom
	Sand, Clay with Gravel Followed by Fractured Biotite Gneiss
	Sand, Clay with Gravel Followed by Fractured Biotite Gneiss & Pegmatite
Mixed Soil & Hard Rock Fragments	Soil with Kankar, Biotite Gneiss
Sedimentary Rock	Sandstone & Limestone with Clay
	Sand and Clay, Sandstones with Shales
	Sand with Clay & Sandstone
	Sand with Clay & Carbonaceous Shale & Tertiary Sandstones
	Sand, Clay Sandstones & Shale
	Sand, Clay Sandstones Calcareous Sandstones
	Fossiliferrous Sandstone Claystone & Shale
	Sandstone
	Cuddalore Sandstone
	Sandstone & Limestone with Sand Clay & Lignite
	Sandstone & Shale with Sand & Clay
	Sandstone with Clay
	Sandstone with Clay & Charnockite
	Sandstone with Clay & Shale
	Sandstone, Clay & Limestone
	Sand with Clay
	Alternate Layers of Sand & Clay Limestone
	Alternate Layers of Sand, Sand- Stone, Clay
Schistose & Foliated Metamorphic Rocks	Quartz Biotite Schist
Unconsolidated Sediments (Alluvium & Sands)	Alluvium & Sandstone
	Clay, Sands
	Clay, Sands & Gravels
	Clay, Sands, Clayey Sands
Weathered & Fractured Rock Formations	Fractured Biotite Gneiss with Pegmatites
	Weathered &Fractured Gneiss
	Weathered & Fractured Granite Gneiss
	Weathered Granite Gneiss

2.3. Litho-logs of Wells

2.3.1. Observation Network and Monitoring Period

Groundwater monitoring in the CRB has been systematically carried out by the Central Ground Water Board (CGWB) through a dense network of 1,018 observation wells. These wells are strategically distributed across different geological settings and physiographic zones of the basin to provide a comprehensive understanding of groundwater behaviour. Monitoring has been conducted four times annually-during January, April/May, August, and November-over a span of 24 years (1996-2020).

The multi-decadal nature of this dataset allows for the identification of both seasonal and long-term trends in groundwater fluctuations, offering critical insights into the health and sustainability of aquifers across the region.

2.3.2. Distribution of Groundwater Levels

An analysis of the long-term average groundwater depths across the basin reveals significant spatial variability, suggesting complex interactions between geology, recharge rates, land use, and groundwater extraction pressures:

- 47 wells showed water levels shallower than 2 meters below ground level (mbgl), indicative of excellent recharge conditions or low extraction pressures (Fig. 4).
- 293 wells reported water levels between 2.1 and 5 mbgl, also representing areas of good groundwater availability.
- 372 wells had water levels in the range of 5.1 to 10 mbgl, reflecting moderate accessibility to groundwater resources.
- 248 wells registered between 10.1 and 20 mbgl, suggesting deeper water tables that may be the result of increased pumping or lower recharge.
- 58 wells recorded depths exceeding 20.1 mbgl, pointing toward regions under severe groundwater stress or located in naturally less permeable geological formations.

This distribution highlights how groundwater availability is not uniform but varies widely across the CRB, emphasizing the need for localized groundwater management strategies.

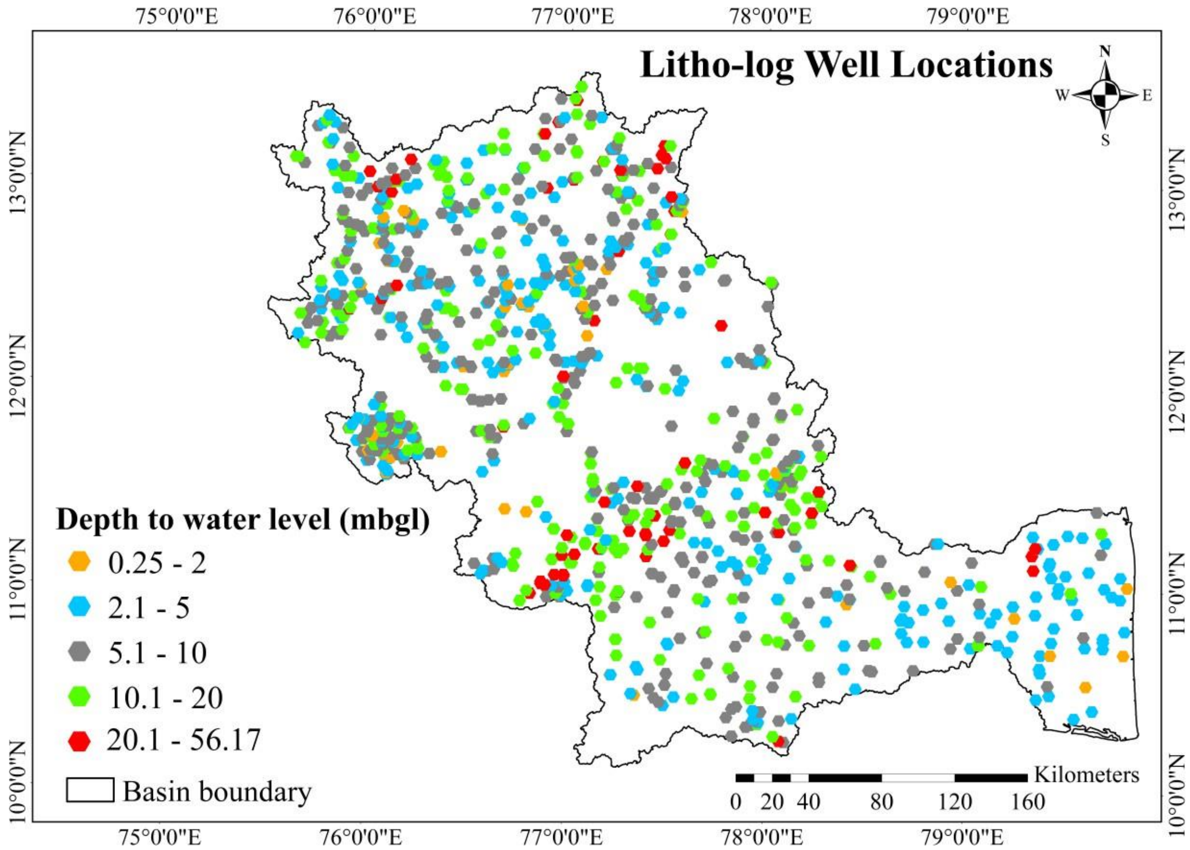

Fig. 4. Litho-log well locations and their depths to water level (mbgl)
(**Source:** CGWB, India-WRIS)

2.3.3. Temporal Trends in Groundwater Levels (1996-2020)

Fig. 5 depicts the annual minimum and maximum groundwater levels averaged across all observation wells, illustrating both seasonal behaviour and long-term changes:

- The minimum groundwater levels (deepest water table readings) showed significant inter-annual fluctuations, with the most critical depletion phases occurring around 2004-2005. During this period, the average minimum depth approached nearly 12 mbgl, a clear indication of over-extraction exceeding natural recharge.
- Following 2005, a moderate recovery trend was observed; however, the water levels never returned to the shallower conditions of the late 1990s. This incomplete recovery suggests that while climatic variability (rainfall patterns) and management interventions might have helped, persistent extraction pressures have prevented full aquifer replenishment.

Overall, the long-term trends point to a gradual deepening of groundwater levels over the decades, a concerning signal for future groundwater security.

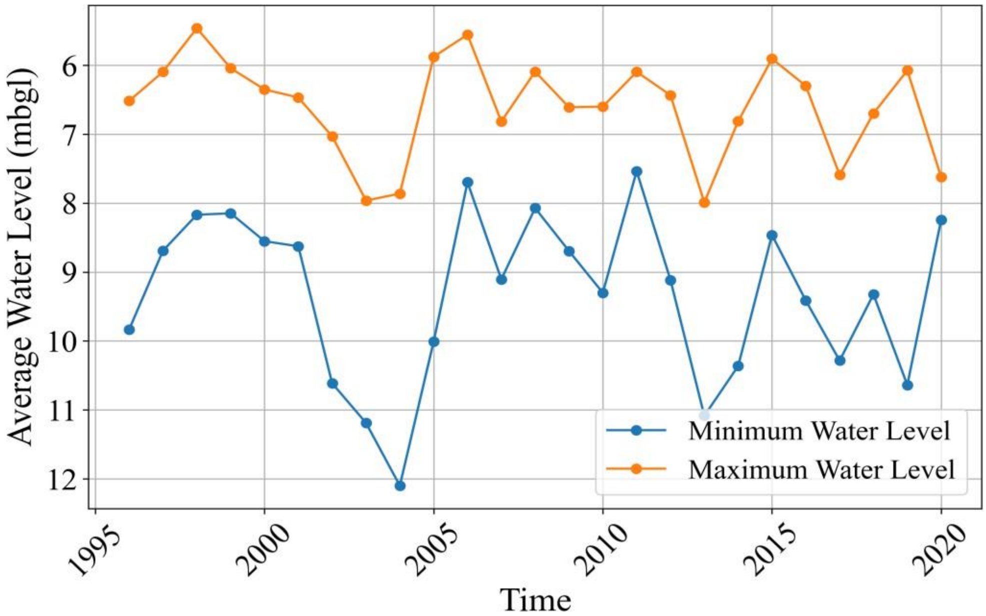

Fig. 5. Minimum and maximum ground water level values for the period 1996-2020, derived from seasonal averages across all 1,018 observation wells
(**Source:** CGWB, India-WRIS)

2.3.4. Stability of Maximum Water Levels

In contrast to the behaviour of minimum levels, maximum groundwater levels (representing the shallowest observed points across the network) have remained relatively stable over the 24-year monitoring period:

- Most maximum levels consistently stayed between 6 and 8 mbgl, with only minor annual fluctuations.

This stability suggests that in some parts of the basin, particularly areas with higher natural recharge or limited groundwater development, aquifer conditions remain relatively resilient.
It also indicates that recharge mechanisms-whether natural through rainfall or artificial via recharge structures-have been somewhat successful in maintaining shallow water tables in localized pockets.
However, the contrast between stable maximum levels and deepening minimum levels hints at growing disparities: while some wells continue to yield easily accessible groundwater, others are facing progressive drawdown, exacerbating spatial inequality in groundwater access.

2.3.5. Implications for Groundwater Management

The observed patterns raise serious concerns about the sustainability of groundwater resources across the CRB:

- Deepening minimum levels signal that aquifer depletion is occurring faster than replenishment in many areas, especially during dry periods or drought years.
- The relative stability of maximum levels provides some hope but also emphasizes that localized interventions alone are insufficient; basin-wide, integrated management is necessary.

To address these challenges, there is an urgent need to:

- Implement artificial recharge projects (check dams, percolation ponds, recharge wells).
- Promote water conservation and demand-side management strategies in agriculture (e.g., micro-irrigation techniques like drip and sprinkler systems).
- Enforce groundwater regulation policies in overexploited zones.
- Enhance community participation in groundwater governance to encourage sustainable practices.
- Improve aquifer mapping and monitoring programs for better prediction and management.

3. Soil Characteristics of the CRB

3.1. Soil Texture

3.1.1. Source and Methodology of Soil Texture Data

The soil texture dataset for the CRB was developed by the Indian Council of Agricultural Research – National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS & LUP). This dataset combines both satellite-based observations and field survey information to ensure high spatial accuracy. It was created using satellite imagery from the Indian Remote Sensing (IRS) Linear Imaging Self-Scanning (LISS)-III sensors and Shuttle Radar Topography Mission (SRTM) data, with resolutions of 66 meters and 30 meters respectively. Mapped at a detailed scale of 1:50,000, the soil dataset provides a valuable resource for regional planning and land management. Data collection took place during 2004-2005, involving careful ground-truthing and classification based on the proportions of sand, silt, and clay present in the soil. This systematic approach enables a nuanced understanding of soil behaviour across the CRB, making it a critical foundation for studying agricultural suitability, water resource dynamics, and environmental planning.

3.1.2. Soil Texture Classification

The soils in the CRB are classified into four major categories based on their textural characteristics, which are critical determinants of their agricultural and hydrological behavior. Sandy soils, dominated by sand particles, are characterized by high permeability and low water-holding capacity, making them more prone to drought without regular irrigation. Coarse-textured soils, similarly rich in larger sand fractions, have very high drainage rates and low nutrient retention, posing challenges for sustainable farming unless carefully managed. Loamy or medium-textured soils offer a balanced composition of sand, silt, and clay, providing ideal conditions for crop cultivation due to good aeration, moisture retention, and nutrient availability. Fine-textured soils, which are rich in clay, exhibit low permeability and high water-holding capacity, making them especially suitable for water-retentive crops like paddy. Each category not only influences agricultural productivity but also governs soil-water interactions, runoff, infiltration, and groundwater recharge characteristics.

3.1.3. Spatial Distribution of Soil Textures in the CRB

The spatial distribution of soil textures across the CRB shows distinct regional patterns that reflect the basin's geomorphology and hydrology (Fig. 6). Fine-textured soils dominate large parts of the basin, covering approximately 58,259.4 sq. km, and are primarily found in the upper reaches and lower alluvial plains, where fine sediments accumulate in low-energy environments. These clay-rich soils contribute significantly to agricultural activities, particularly paddy cultivation. Medium-textured or loamy soils, extending over around 15,257.9 sq. km, are generally distributed across transitional zones between uplands and lowlands. Their favourable balance of drainage and water retention makes them highly versatile for diverse agricultural practices. Coarse-textured soils, occupying about 9,203.55 sq. km, are found mainly in the more dissected middle reaches of the basin, where higher slope gradients and energetic rivers dominate the landscape. These soils often require intensive irrigation and soil management practices to maintain agricultural productivity. Non-soil areas, such as rocky outcrops and water bodies, represent landscapes where soil development is limited or absent, thus being unsuitable for cultivation. These areas collectively cover approximately 2,846.79 sq. km within the CRB.

3.1.4. Geomorphological and Sedimentological Interpretation

The observed spatial patterns of soil textures in the CRB are a direct outcome of long-term geomorphological and sediment transport processes. Fine-textured soils are predominantly located in low-energy fluvial environments such as floodplains and deltaic regions, where fine-grained materials like clay and silt are deposited by slow-moving rivers. In contrast, coarse-textured soils are found in high-energy, dissected terrains where the erosional forces of rivers are stronger, resulting in the deposition of coarser particles like sand and gravel. Medium-textured soils typically occupy transitional landscapes where the balance between erosion and deposition creates loamy sediments. This distribution reflects the dynamic interactions between tectonic uplift, climatic variations, and fluvial processes that have shaped the CRB landscape over geological timescales, influencing not only the present-day soil characteristics but also water availability and land use patterns.

3.1.5. Significance of Soil Texture Map

The soil texture map plays a vital role in a wide range of applications across agriculture, water resource management, and environmental planning in CRB. It aids in assessing soil suitability for agriculture, as soil texture directly influences key factors such as water retention capacity, drainage characteristics, nutrient availability, and selection of appropriate crops. Moreover, the map is instrumental in irrigation planning and groundwater recharge assessments, given that infiltration rates vary significantly with soil texture, affecting water movement and availability. It also supports land use planning, erosion control, and the development of conservation strategies, ensuring that land management practices are aligned with the physical characteristics of the soil. In the field of water resources, the map provides a foundational dataset for hydrological and hydrogeological modelling, especially in evaluating aquifer recharge potential and understanding surface-water-groundwater interactions. Additionally, it serves as a valuable tool for policymakers, planners, and researchers by enabling targeted interventions, promoting sustainable land use practices, and guiding agricultural zoning based on the spatial variability of soil properties within the region.

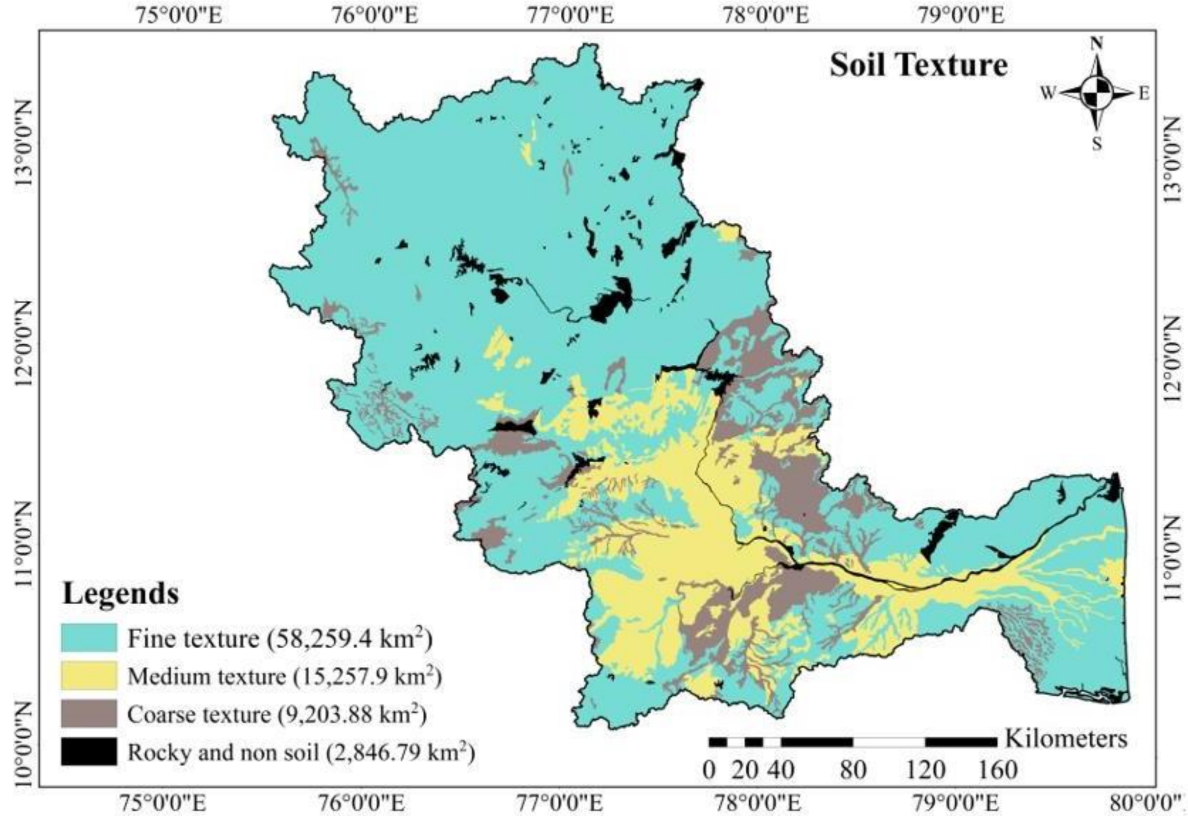

Fig. 6. Soil texture map
(**Source:** ICAR-NBSS & LUP, India WRIS)

3.2. Soil Erosion

3.2.1. Source and Methodology of Soil Erosion Data

The soil erosion dataset, developed by the ICAR-NBSS & LUP, offers valuable insights into the spatial distribution of erosion intensity across the Cauvery Basin. With a spatial resolution of 66 meters, the dataset is based on soil texture classifications- Sandy, Coarse, Loamy, and Fine- determined by the relative proportions of sand, silt, and clay. The data was derived from high-resolution satellite imagery, including IRS LISS-III, SRTM (30 m), and Sentinel-2, and mapped at a detailed 1:50,000 scale using observations from 2004-2005. Together, this robust dataset enables a detailed understanding of erosion processes and their impact on land stability and productivity.

3.2.2. Spatial Distribution of Soil Erosion in the CRB

Covering a total basin area of 85,220.39 sq. km, the soil erosion dataset reveals a highly variable erosion pattern across the CRB (Fig. 7). Moderate erosion is the most widespread category, affecting approximately 43,157.3 sq. km of the basin. Slight erosion, which indicates relatively stable land conditions with minimal soil loss, covers about 24,898 sq. km. Severe erosion, a serious concern for land degradation and loss of agricultural potential, is recorded over 15,336.6 sq. km. Very severe to gullied erosion-representing extreme degradation, deep gully formation, and major disruption of land surfaces-is confined to 2,176.26 sq. km. This classification provides a clear picture of where soil conservation efforts need to be prioritized.

3.2.3. Characteristics of Soil Erosion Categories

Slight Erosion: Areas experiencing slight erosion are relatively stable, with minimal soil loss under current land use and climatic conditions. These regions require maintenance of existing conservation practices to prevent future degradation.

Moderate Erosion: Moderate erosion dominates the CRB landscape. It typically involves noticeable topsoil loss, which can gradually reduce soil fertility and water retention if left unchecked. Implementing soil conservation methods such as contour farming and vegetative barriers is crucial in these areas.

Severe Erosion: Severe erosion zones suffer from significant soil loss, resulting in lower agricultural productivity and heightened vulnerability to further degradation. These areas need active intervention, such as reforestation, terracing, and check dam construction, to arrest soil movement.

Very Severe and Gullied Erosion: These are the most critical zones where deep gullies and extensive rill formations are evident. The land here is often unsuitable for conventional agriculture without significant rehabilitation efforts like gully plugging, watershed management, and land reclamation programs.

3.2.4. Factors Influencing Soil Erosion Patterns

The spatial variation in soil erosion across the basin is closely tied to multiple natural and anthropogenic factors. Soil texture plays a major role: sandy and coarse-textured soils are generally more prone to erosion due to their loose structure, whereas fine-textured soils offer greater resistance but can be severely affected once disturbed. Topography is another major factor-steeper slope in the middle reaches of the basin facilitate faster water runoff, accelerating soil erosion. Land use practices, such as intensive agriculture, deforestation, and poor grazing management, further exacerbate the severity and extent of erosion. Climate, particularly the intensity and duration of rainfall events during the monsoon, also drives seasonal variations in erosion rates.

3.2.5. Significance of Soil Erosion Map

This distribution indicates that soil erosion is a significant concern across the Cauvery Basin, with moderate to severe erosion affecting most of the landscape. The prevalence of moderate erosion suggests widespread but manageable land degradation, while the notable extent of severe and very severe (gullied) erosion highlights critical hotspots where urgent soil conservation and land management interventions are needed. The spatial heterogeneity in erosion severity underscores the importance of targeted erosion control measures tailored to the local terrain, land use, and soil characteristics, to ensure sustainable land productivity, reduce sediment load in rivers, and maintain long-term ecological balance in the basin.

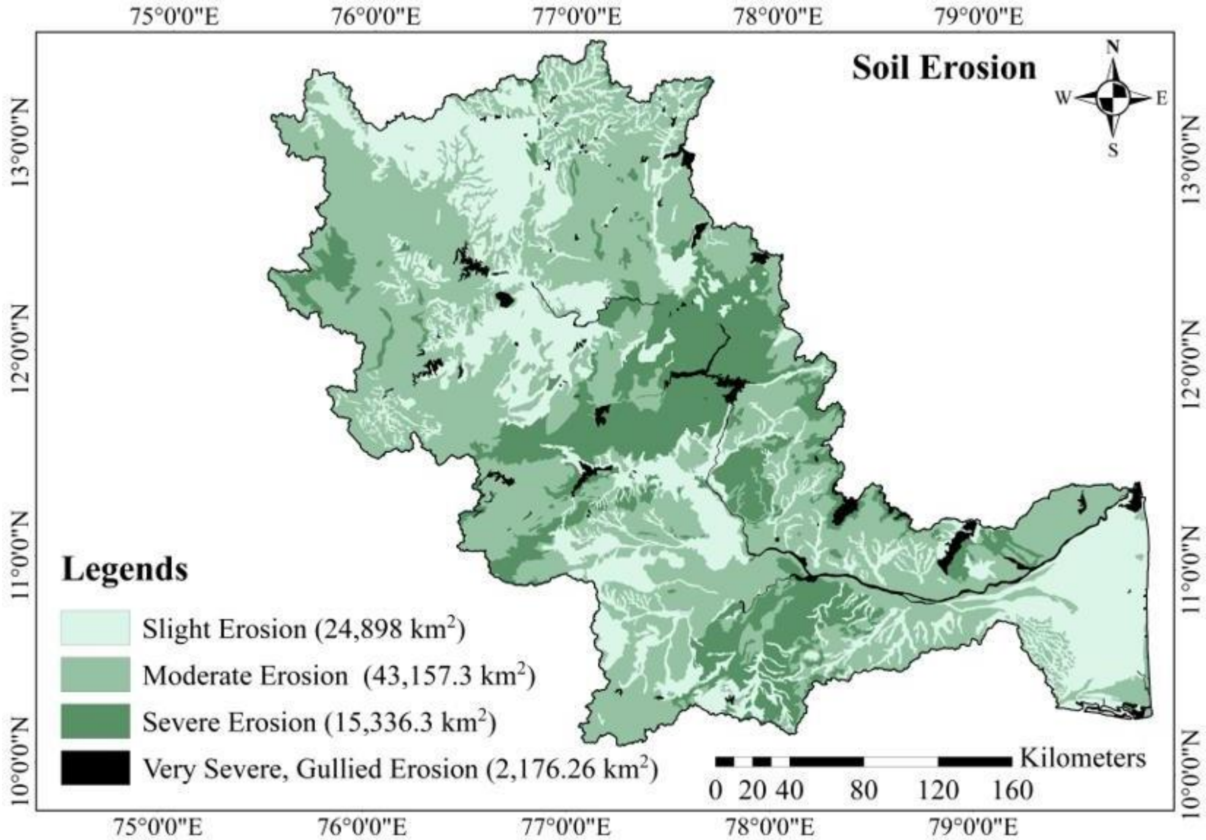

Fig. 7. Soil erosion map
(**Source:** ICAR-NBSS & LUP, India WRIS)

3.3. Soil Depth

3.3.1. Source and Methodology of Soil Depth Data

The Soil Depth Dataset, developed by the ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), provides crucial insights into the vertical extent of soil across the study region. Available at a high spatial resolution of 66 m, the dataset is generated using integrated inputs from multiple satellite sources, namely IRS LISS-III, SRTM (30 m), and Sentinel-2 imagery.

Mapping was conducted at a detailed scale of 1:50,000 during 2004-2005, supported by extensive field observations, ensuring high accuracy. The classification of soils into different depth categories- extremely shallow (<10 cm), very shallow (10–25 cm), shallow (25–50 cm), and deep (>50 cm)- offers a robust framework for evaluating soil suitability for agriculture, water management, and ecological restoration. This layer serves as a baseline for decision-making in sectors like agriculture, groundwater development, and land conservation, which are vital in regions where land and water resources are under increasing pressure.

3.3.2. Classification and Distribution of Soil Depth

The dataset reveals a distinct distribution pattern in soil depth across the region (Fig. 8):

- Deep soils (>50 cm) dominate the landscape, covering approximately 70,856 sq. km.
- Shallow soils (25-50 cm) are found over about 10,076.6 sq. km, typically located on uplands and old alluvial terraces.
- Very shallow soils (10-25 cm) extend across 2,063.71 sq. km, often associated with rocky outcrops and eroded slopes.
- Extremely shallow soils (<10 cm) are the least extensive, occupying 2,571.63 sq. km, generally corresponding to exposed bedrock and barren lands.

This spatial arrangement suggests that most of the area is underlain by deeper soil profiles, favoring agricultural practices and vegetation growth, while regions with shallower soils point to landscape fragility and lower agricultural potential.

3.3.3. Landscape Interpretation Based on Soil Depth

Soil depth serves as a key indicator of the landscape's developmental history and geomorphic stability. Areas with deeper soils typically reflect:

- Stable geomorphic environments, such as floodplains and broad valleys, where sediment accumulation over time fosters deeper soil development.
- Climatic conditions conducive to intensive chemical weathering and organic matter buildup, promoting thicker soil horizons.

Conversely, shallow soil formations are characteristic of:

- Erosion-prone zones like sloping terrains and undulating landscapes.
- Regions subject to mechanical weathering, influenced by seasonal climatic variations.
- Human-induced land degradation, such as deforestation and overgrazing.

Understanding this relationship is critical for land use planning:

- Deep soils offer opportunities for sustainable agriculture and diverse cropping systems.
- Shallow soils are more suited to rangeland, horticulture, or forest restoration.
- Extremely shallow soils necessitate strict conservation strategies to preserve the delicate ecosystems.

3.3.4. Significance of Soi Depth Map

Soil depth plays a vital role in determining the basin's capacity to retain moisture, support crop roots, and sustain plant growth. Deeper soils, which dominate large parts of the CRB, are generally more fertile and capable of storing more water, making them well-suited for water-intensive crops such as paddy and sugarcane that are common in the region. These areas offer greater resilience against drought and enable better groundwater recharge. On the other hand, areas with shallow or very shallow soils may indicate rocky terrain, degraded lands, or regions prone to erosion, which are less suitable for conventional farming. Understanding the spatial distribution of soil depth helps in targeted agricultural planning, optimizing irrigation practices, and implementing soil conservation measures-especially crucial in a basin where water availability is highly contested among states.

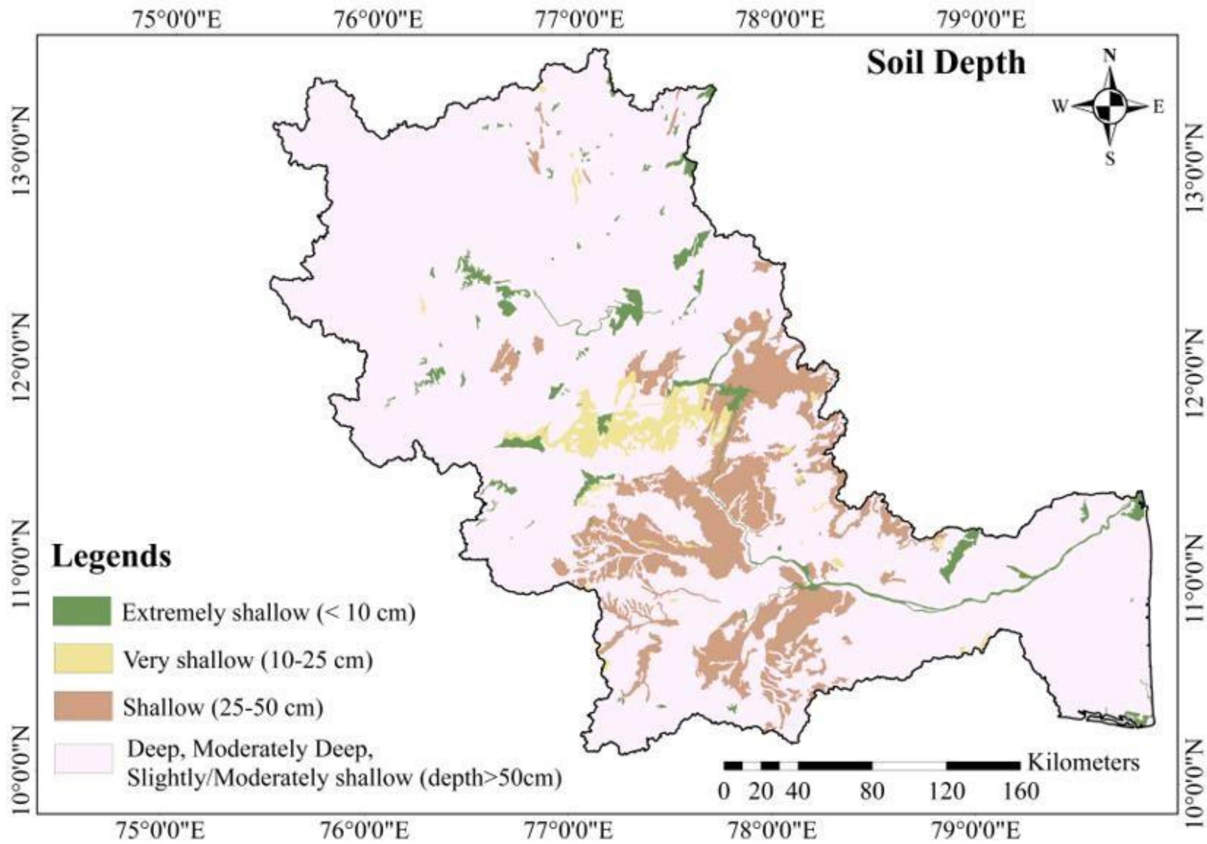

Fig. 8. Soil depth map
(**Source:** ICAR-NBSS & LUP, India WRIS)

4. Aquifers of the CRB

An aquifer is an underground layer of permeable rock or unconsolidated materials, such as sand, gravel, or silt, that holds groundwater and allows it to be extracted through dug wells or borewells. Related concepts include aquitard, which is a layer of low permeability that occurs alongside an aquifer, and aquiclude (or aquifuge), a solid, impermeable layer either above or below the aquifer. If an impermeable layer is located above the aquifer, it can create a confined aquifer, where groundwater is under pressure. Aquifers exist at varying depths, with those closer to the surface being more accessible for water extraction and more likely to be replenished by local rainfall. Alluvial deposits, sandstone, and loose sand or gravel are considered excellent materials for aquifers due to their high permeability. In hard rock areas, the presence of fractures or lineaments is crucial for identifying regions with good groundwater potential, as these fractures allow for better water flow and storage within the rock layers. The aquifers in CRB range from hard crystalline rocks to sedimentary layers and unconsolidated alluvial deposits, each with distinct hydrogeological characteristics (Fig. 9), as described below.

4.1. Aquifers in Hard Crystalline Rocks

Crystalline formations such as gneiss, granite, charnockite, schist, and khondalites dominate large parts of the basin. These rock units generally support unconfined to semi-confined aquifers, where groundwater occurs in fractures, joints, and weathered zones. Water-bearing depths typically range between 3 to 35 m, and yields are highly variable, often depending on the extent of fracturing. In well-developed zones, water output can range from 12 to 3000 m^3/day, sufficient for localized water supply.

4.2. Groundwater in Sedimentary Formations

Regions with sandstone, limestone, and shale offer relatively better aquifer conditions due to higher porosity and permeability. These units often show semi-confined to confined behaviour, with depths reaching up to 500 m in certain zones. Yields can be substantial, ranging from 20 to 4800 m^3/day, particularly in the sandstone-dominated areas where aquifer thickness and saturation are high.

4.3. Alluvial Deposits

Along the river floodplains and coastal tracts, alluvial aquifers are formed by layers of sand, silt, clay, and calcareous material. These are typically multi-layered confined systems that can extend to depths of 400 m. Known for their high porosity (sometimes exceeding 6%), these aquifers can deliver substantial groundwater volumes, with discharge rates reaching up to 690 m^3/day-making them vital for agriculture and drinking water needs.

4.4. Intrusive and Volcanic Rock Aquifers

Aquifers developed in basalt and other intrusive rocks like dolerite, anorthosite, and granophyre is present in limited areas. These systems are often unconfined, and though not extensive, they can provide moderate groundwater yields ranging from 20 to 180 m^3/day, especially in zones with intense fracturing or weathering.

4.5. Lateritic Formations

Laterites and ferruginous concretion-rich zones act as shallow aquifers in elevated terrains, especially in Tamil Nadu and Karnataka. These typically lie within 5 to 30 m depth and are unconfined in nature. Depending on the local conditions, they can yield from 15 to 150 m^3/day, supporting both domestic and agricultural use in hilly regions.

4.6. Basement Complex Aquifers

The Basement Gneissic Complex is among the most tapped aquifer systems in the region. These aquifers are usually shallow to moderately deep (5-60 m) and range from unconfined to semi-confined or even confined types in certain locations. While the groundwater yield varies, it can be quite dependable in weathered and fractured segments, producing up to 400 m^3/day.

4.7. Significance of Aquifer Map

The detailed characterization of aquifer types across the CRB is highly significant for managing the region's water resources, particularly considering increasing demand and recurrent water scarcity. The basin encompasses a variety of geological formations, each influencing groundwater availability differently. Crystalline rocks like granite and gneiss, which dominate large parts of the basin, support unconfined to semi-confined aquifers with variable yields that depend on the degree of fracturing and weathering. In contrast, sedimentary formations such as sandstone and limestone offer better aquifer conditions due to higher porosity and permeability, with yields reaching up to 4800 m^3/day in some zones. Alluvial deposits along river floodplains provide highly productive, multi-layered confined aquifers crucial for agriculture and drinking water. Though less extensive, intrusive volcanic rocks and lateritic formations contribute to localized water supply, especially in hilly or elevated regions. The Basement Gneissic Complex, a widely tapped aquifer system, supports dependable yields in weathered and fractured zones. Understanding the depth, yield potential, and behaviour of these diverse aquifers is essential for groundwater management, well-siting, irrigation planning, and implementing recharge strategies. This information forms a critical foundation for sustainable water use, helping balance agricultural needs with long-term water security across the CRB.

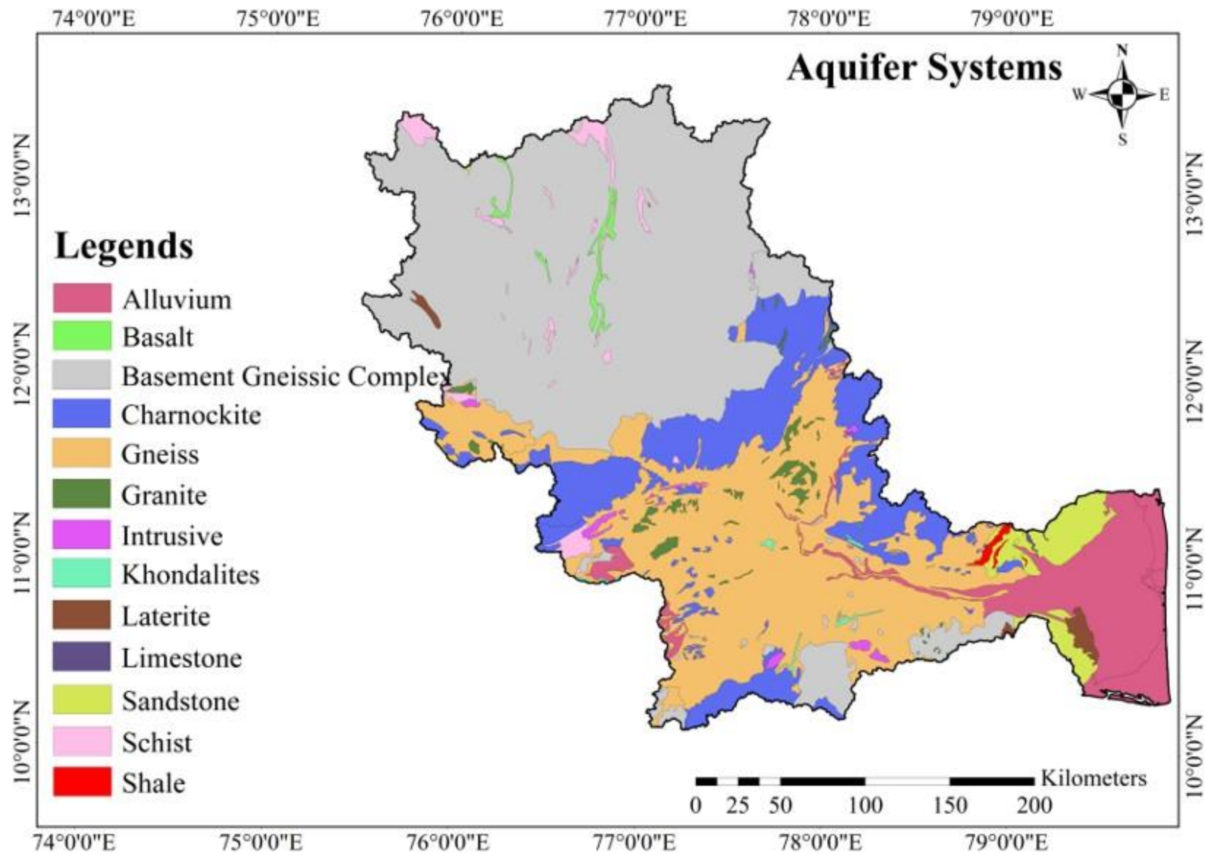

Fig. 9. Major aquifer systems
(**Source:** CGWB)

5. Findings and Summary

The CRB presents a diverse and complex lithological framework, shaped by its intricate geological history. It encompasses five major lithological groups: igneous, metamorphic, and sedimentary rocks, along with unconsolidated sediments and weathered rocks. Igneous rocks, covering approximately 19,574 sq. km, are predominantly non-organic and generally exhibit poor reservoir quality, although fractured variants may serve as unconventional hydrocarbon reservoirs. Metamorphic rocks, the most extensive at about 54,730 sq. km, are similarly non-organic, marked by strong geotechnical properties and limited hydrocarbon potential, mainly within fractured zones. In contrast, sedimentary rocks, though occupying a smaller area of around 2,706 sq. km, are of high significance for hydrocarbon systems, offering rich organic content and excellent reservoir properties, especially within sandstones and shales. Unconsolidated sediments (around 8,086 sq. km) and weathered rocks (125 sq. km) display variable reservoir characteristics and generally low hydrocarbon potential, yet they play an essential role in groundwater dynamics.

The CRB's lithological stratigraphy reveals a complex layering, with sedimentary sequences interspersed among crystalline metamorphic and igneous bedrock. The sedimentary formations, primarily calcareous, comprise sandstone, clay, shale, and occasional lignite, deposited largely under fluvial to deltaic conditions. Fossiliferous strata indicate past biologically rich environments, crucial for reconstructing the paleoenvironment of the basin. Beneath these layers lie widespread exposures of metamorphic rocks such as gneisses, schists, and charnockites, where significant fracturing enhances groundwater storage. In the alluvial and deltaic plains, thick deposits of unconsolidated sands, silts, clays, and gravels form extensive and productive aquifers.

Groundwater monitoring data from 1,018 wells, recorded between 1996 and 2020, reveal substantial spatial and temporal variability. Water levels range from less than 2 m to over 20 m below ground level, highlighting areas of excellent recharge. Temporal trends indicate a deepening of minimum groundwater levels, particularly noticeable around 2004-2005, largely due to over-extraction. Although partial recovery has occurred, groundwater levels have not returned to pre-depletion conditions, signalling persistent aquifer stress. Meanwhile, maximum water levels have remained relatively stable, suggesting localized resilience where recharge mechanisms are effective. However, the widening gap between maximum and minimum levels underscores growing spatial disparities in groundwater access, emphasizing the urgent need for integrated, basin-wide groundwater management strategies.

Soil texture mapping, utilizing satellite and field data, classifies CRB soils into sandy, coarse, loamy, and fine-textured categories. Fine-textured (clay-rich) soils dominate the lowland and floodplain regions, providing an excellent foundation for extensive paddy cultivation. Loamy soils are widespread across transitional zones and support diverse agricultural practices, while coarse and sandy soils, largely confined to uplands, require careful management due to their low water-holding capacity. These patterns reflect the basin's sedimentological evolution, shaped by dynamic fluvial processes, tectonic activity, and climatic fluctuations.

Soil erosion studies indicate that moderate erosion is the most widespread process, affecting about half of the basin's area, while slight erosion is also prevalent. Severe and very severe erosion, although confined to smaller pockets, poses serious risks to land productivity and agricultural sustainability. These findings highlight the critical importance of targeted soil conservation measures, including contour farming, afforestation, and watershed management, to maintain the CRB's agricultural productivity and ecological health.

Soil depth analysis emphasizes the predominance of deep soils (>50 cm), which cover approximately 70,856 sq. km of the basin. These deeper soils are vital for supporting agriculture and vegetation growth. Shallower soils are primarily restricted to uplands, rocky outcrops, and degraded landscapes, identifying zones more susceptible to erosion and limited agricultural potential. The distribution of soil depth mirrors the region's geomorphic and climatic history, where deeper profiles correspond to stable floodplains and valleys, while shallow profiles mark erosion-prone or degraded areas. Understanding these variations is crucial for targeted land-use planning, agricultural optimization, and conservation efforts.

Parallelly, the aquifer study across the CRB reveals a complex hydrogeological framework influenced by diverse geological formations. Crystalline rocks dominate vast regions, hosting unconfined to semi-confined aquifers with yields heavily dependent on the degree of fracturing. Sedimentary rocks, particularly sandstone and limestone, offer more favourable conditions for groundwater storage, with high yield potentials. Highly productive alluvial aquifers along floodplains serve as critical sources for both agriculture and domestic use. Although less extensive, aquifers within intrusive volcanic rocks, lateritic formations, and the Basement Gneissic Complex contribute significantly to groundwater availability, particularly in hilly terrains. A detailed understanding of soil depth, lithology, and aquifer characteristics forms the foundation for sustainable agricultural planning, groundwater management, and long-term water security strategies, all of which are increasingly vital for a basin under growing resource pressure.

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