

Groundwater scenario of Gujarat

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Segments

- **Aquifers in Gujarat**
- **Ground Water level in Gujarat and its trends**
- **Ground water resources in Gujarat**

Hydrogeology of Gujarat State

❖ Groundwater studies in Gujarat state were started by GSI, which later on gained momentum by formation of a separate wing in GSI in 1953. GSI and Exploratory Tubewell Organisation (ETO) carried out extensive hydrogeological studies and exploration. In 1972 Groundwater Division of GSI was merged with Central Groundwater Board (erstwhile ETO) and systematic studies in the field of groundwater exploration and surveys was started in the country.

❖ Due to rapid development of groundwater in the entire state, erratic rainfall and frequent drought conditions has led to over-exploitation of these resources especially in Ahmedabad, Banaskantha, Gandhinagar, Mehsana and Patan districts and degradation of quality due to sea water intrusion in the coastal areas and also due to inland inherent salinity has led to problems forcing water managers to adopt suitable strategies for proper management of available groundwater resources.

STATUS OF HYDROGEOLOGICAL STUDIES

The hydrogeological work in the State was started by the Geological Survey of India (GSI) in the form of short term investigations for domestic water supply.

But later in 1953, groundwater exploration and systematic hydrogeological surveys gained momentum with the establishment of separate Groundwater wing in India.

The Groundwater Division in collaboration with the Exploratory Tubewell Organisation (ETO) launched a massive exploratory programme all over the country, with the technical and financial assistance of Technical Co-operation Mission of USA, in 1953-54.

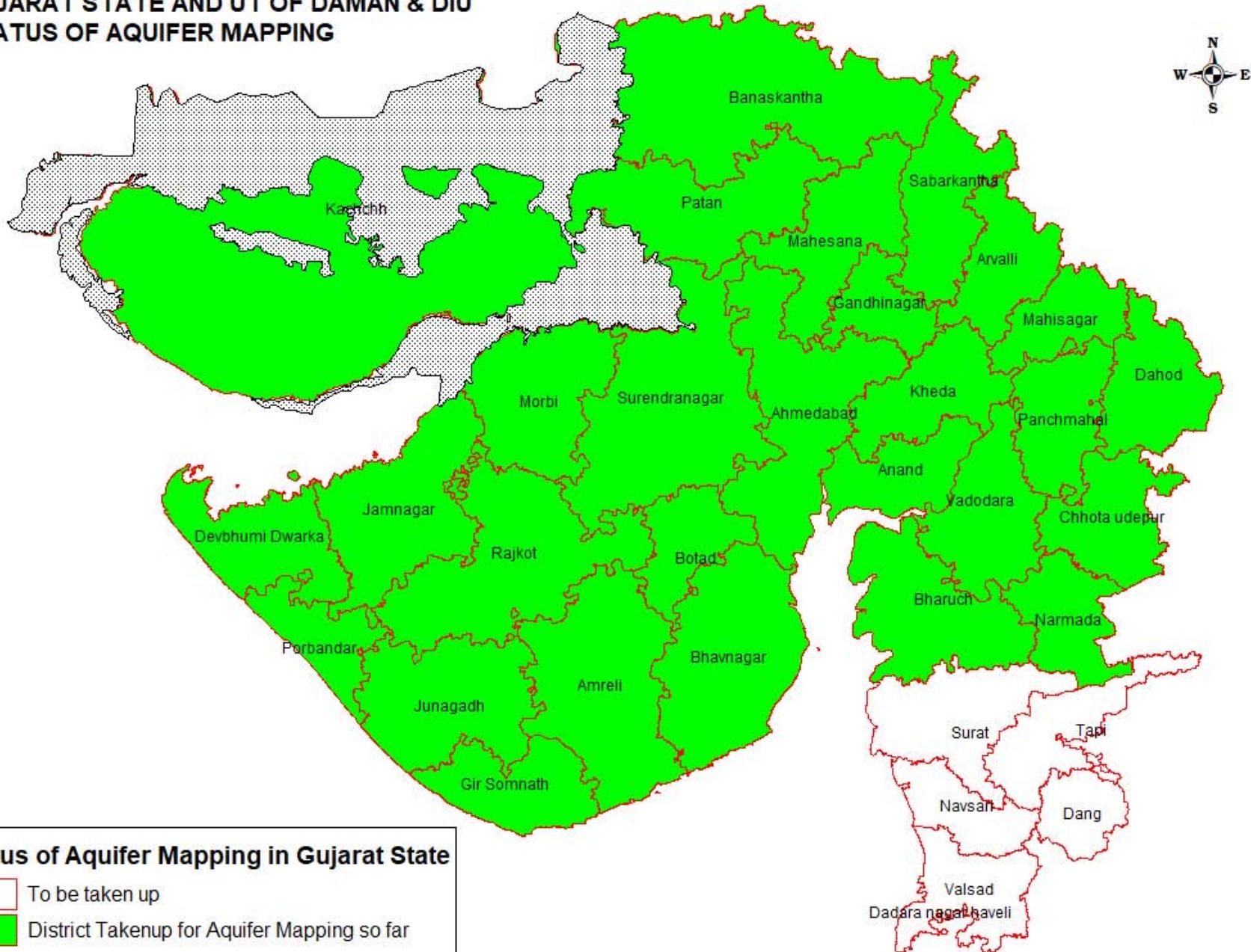
By 1958, large parts of Gujarat were taken up for detailed hydrogeological studies.

In 1972, the Groundwater Division of GSI was merged with the Central Ground Water Board (erstwhile ETO) and with the opening of several regional offices all over the country, very intensive programme of groundwater surveys and exploration was launched.

STATUS OF HYDROGEOLOGICAL STUDIES

- Under the National Aquifer Mapping Program, Central Ground Water Board in the 12th and 13th Plan periods, proposed to generate aquifer maps on 1:50 000 scale for the country as a whole and on 1:10,000 scale in identified problematic areas.
- In AAP 2012-13, CGWB, WCR taken up the Aquifer Mapping work in Gujarat state and UT of Daman and Diu.

GUJARAT STATE AND UT OF DAMAN & DIU STATUS OF AQUIFER MAPPING



Status of Aquifer Mapping in Gujarat State

To be taken up

District Takenup for Aquifer Mapping so far

Total Area :
1,96,000 sq. km

20°06' to 24°42 N Lat &
68°10' to 74°28' E Long.

Location : Gujarat State



BACKGROUND

Location

- Latitude : $20^{\circ} 06' & 24^{\circ} 42'$
- Longitude : $68^{\circ} 10'' & 74^{\circ} 28'$
- Geographical Area : 1,96,024 sq km.
- Coast line : 1600 km
- International Border : Pakistan
- Common State border : Rajasthan, Madhya Pradesh & Maharashtra
- No of Villages : 18,569

BACKGROUND

- Population **6,03,83,628 (2011)**
 - Male **3,14,82,282**
 - Females **2,89,01,346**
- Overall density of population
382 persons per sqkm
- Water Supply Apart from Narmada Water Supply
 - Ground Water is the major source of drinking water
- Irrigation
 - Ground Water sustains > 70% of the irrigated area
- GW Development of the State

CLIMATE

- Climate Region

Humid

: South Gujarat

Sub-humid

: Central Part of Gujarat

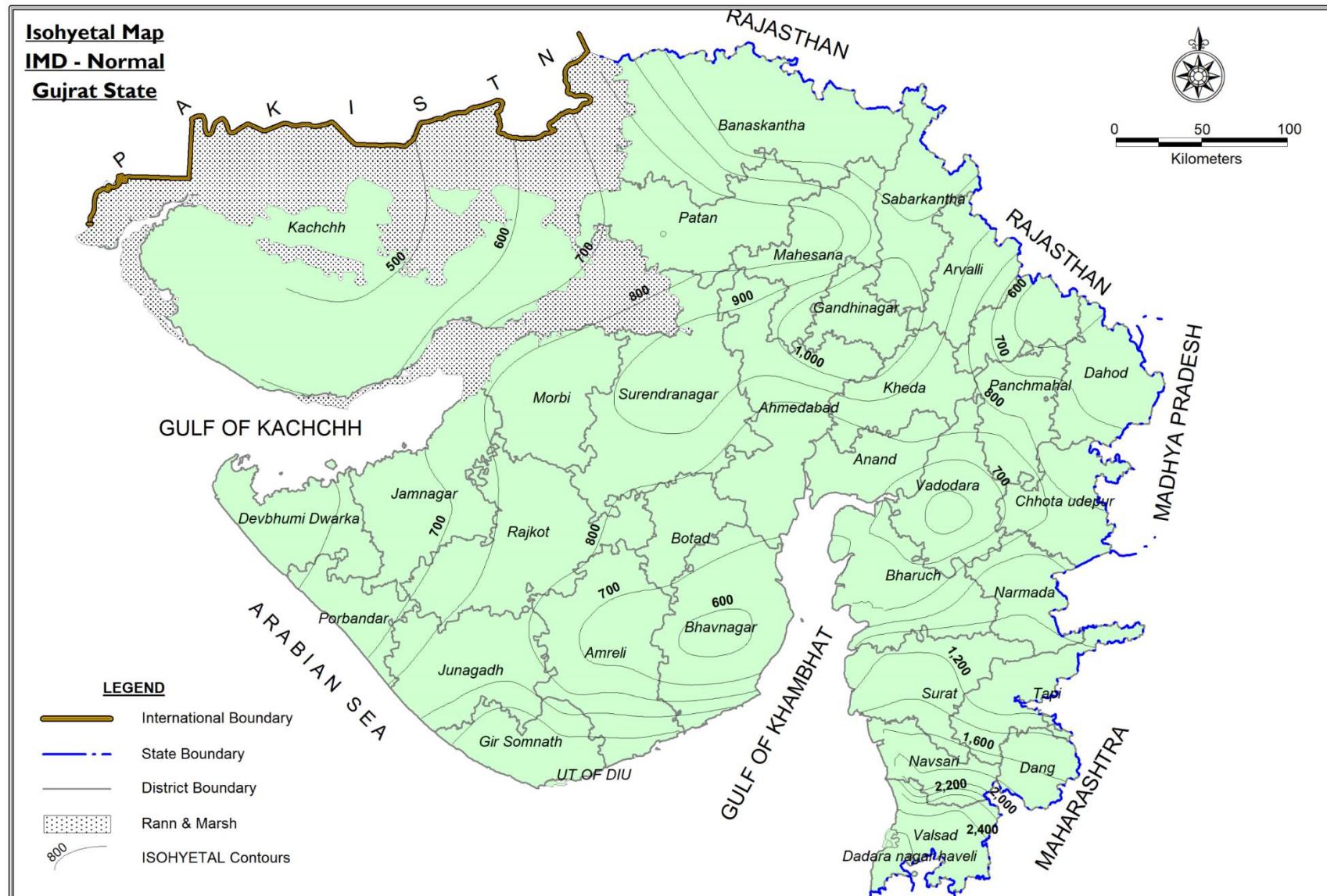
Semi-arid to Arid

: North Gujarat,
Saurashtra & Kachchh

- Rainfall

- South west monsoon is the only wet Season
- Rainfall varies from 2000mm in south to about 300mm in Kachchh
- Rainfall is erratic in north Gujarat, Saurashtra and Kachchh
- Droughts are frequent

ISOHYETAL - NORMAL



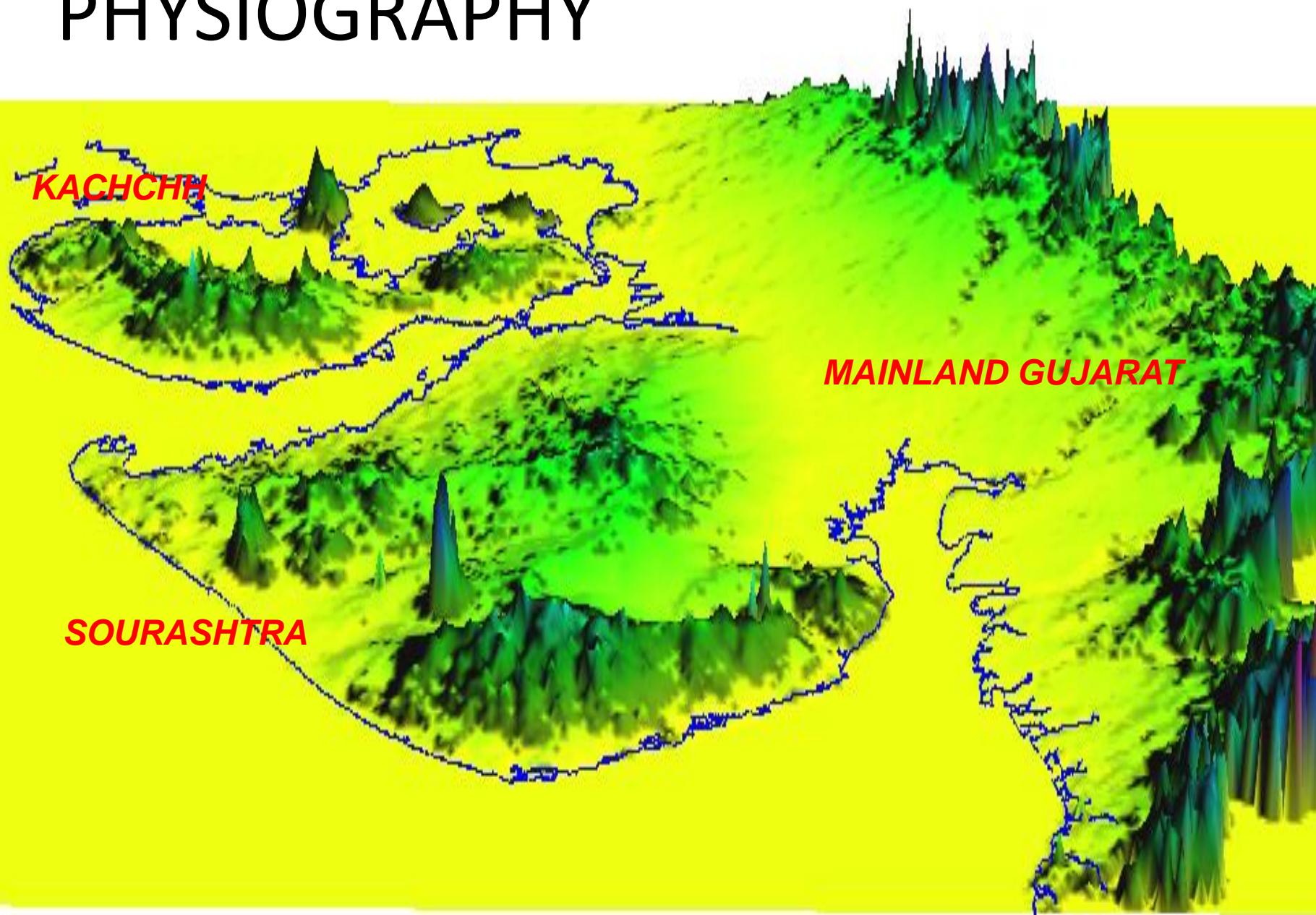
PHYSIOGRAPHY OF GUJARAT STATE

Physiographically, the State has three distinct zones:

- Mainland Gujarat.
- Saurashtra
- Kachchh.

Each zone is marked by its own characteristic coastline.

PHYSIOGRAPHY





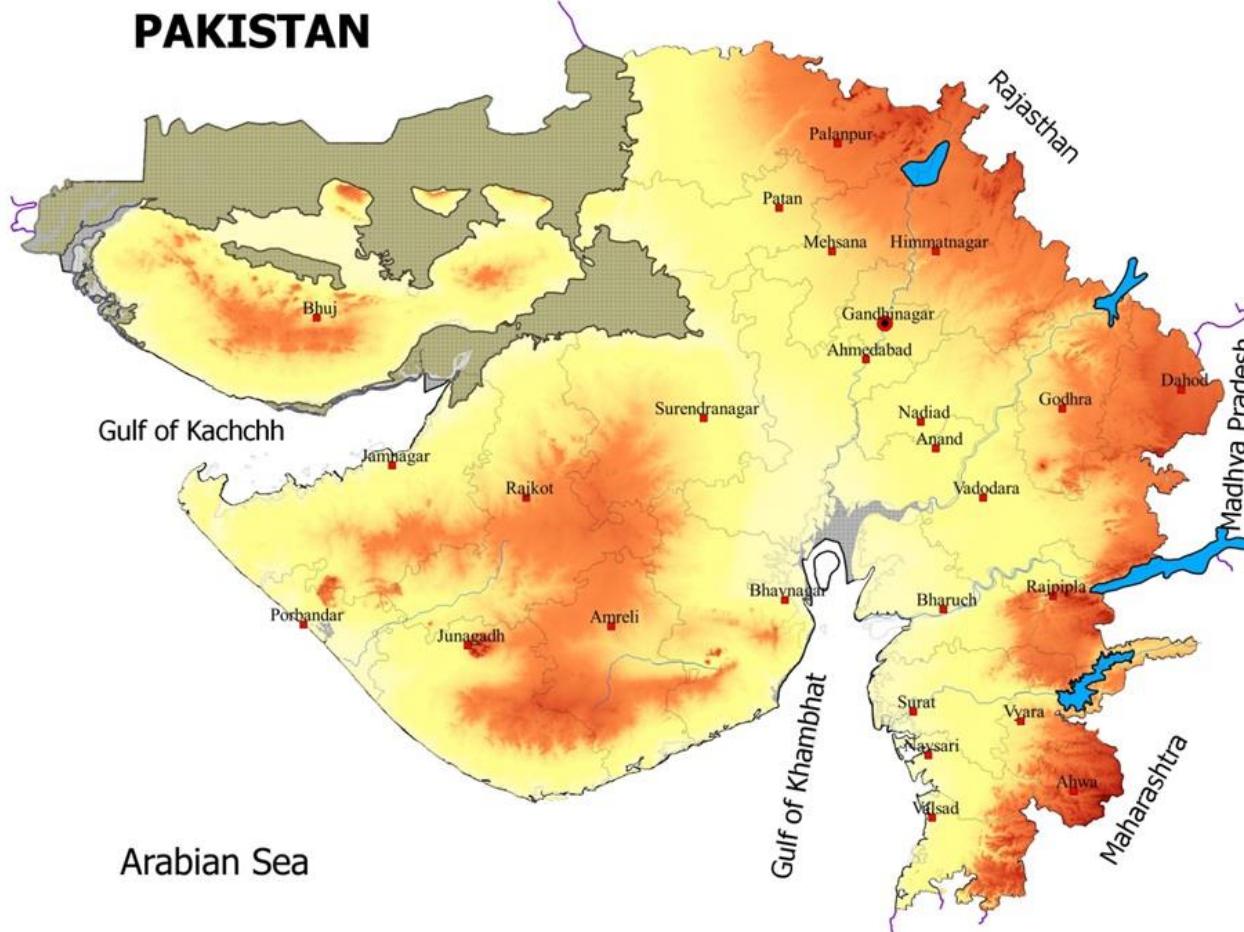
SURFACE ELEVATION

GUJARAT

50 0 50 100 km



PAKISTAN



Legend

Elevation (m amsl)

- < 25 m
 - 25 to 50 m
 - 50 to 100 m
 - 100 to 150 m
 - 150 to 300 m
 - 300 to 450 m
 - 450 to 600 m
 - 600 to 900 m
 - >900 m
- State Capital
 - District Headquarter
 - International / State Boundary
 - District Boundary
 - Rann and Marsh
 - Major Drainage
 - Dams

DRAINAGE OF GUJARAT STATE

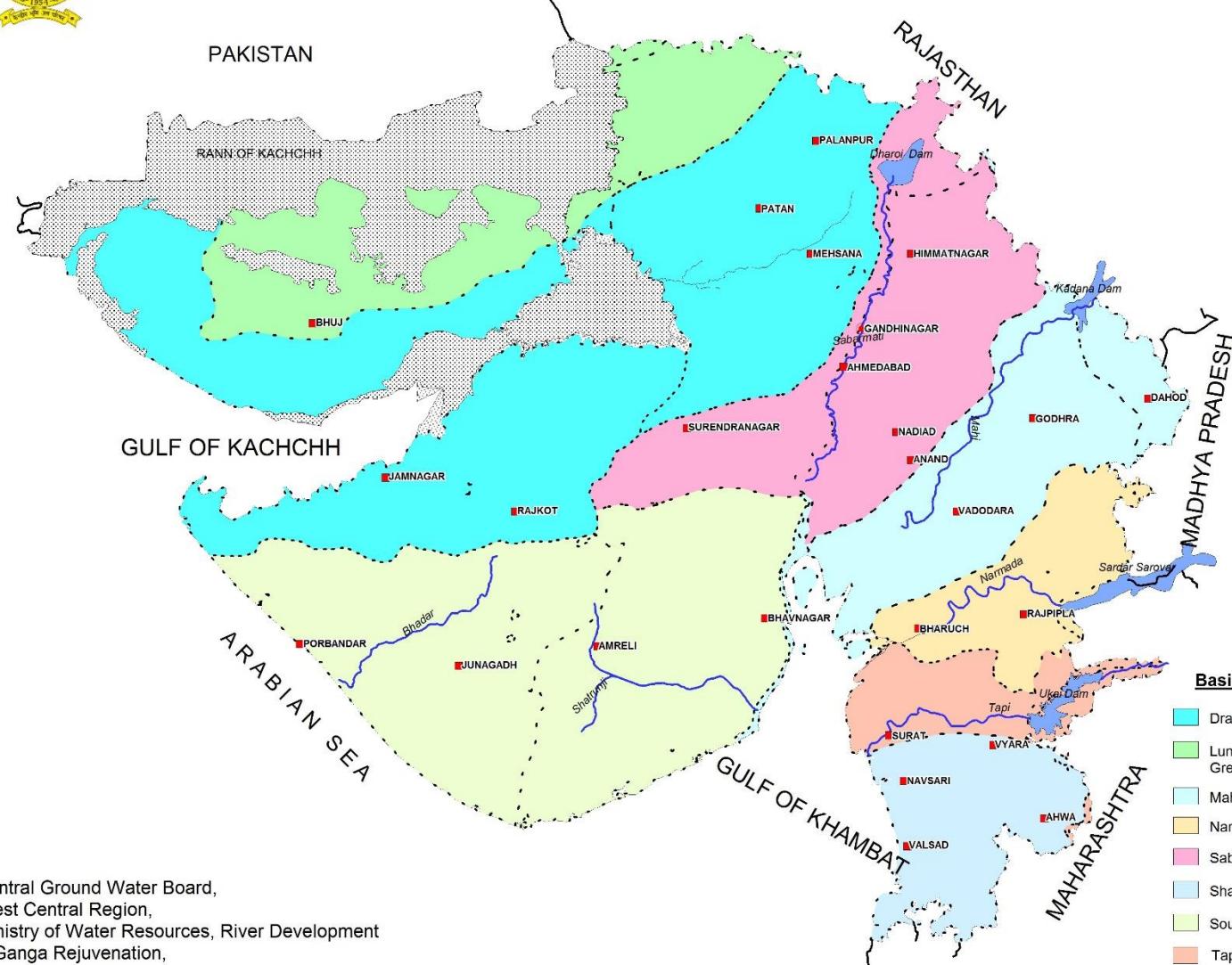
Drainage being a reflection of the terrain characteristics and being controlled by physiography, climate and tectonic framework, rivers in the various physiographic zones behave differently and show striking diversity



RIVER BASINS



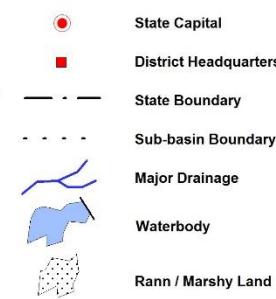
0 50 100
Kilometers



LEGEND

Basins/sub-basins

- Draining into Gulf of Kutch
- Luni and other drainage into Great Rann of Kutch
- Mahi
- Narmada
- Sabarmati
- Sharavati to Tapti
- Southern Kathiawar
- Tapi

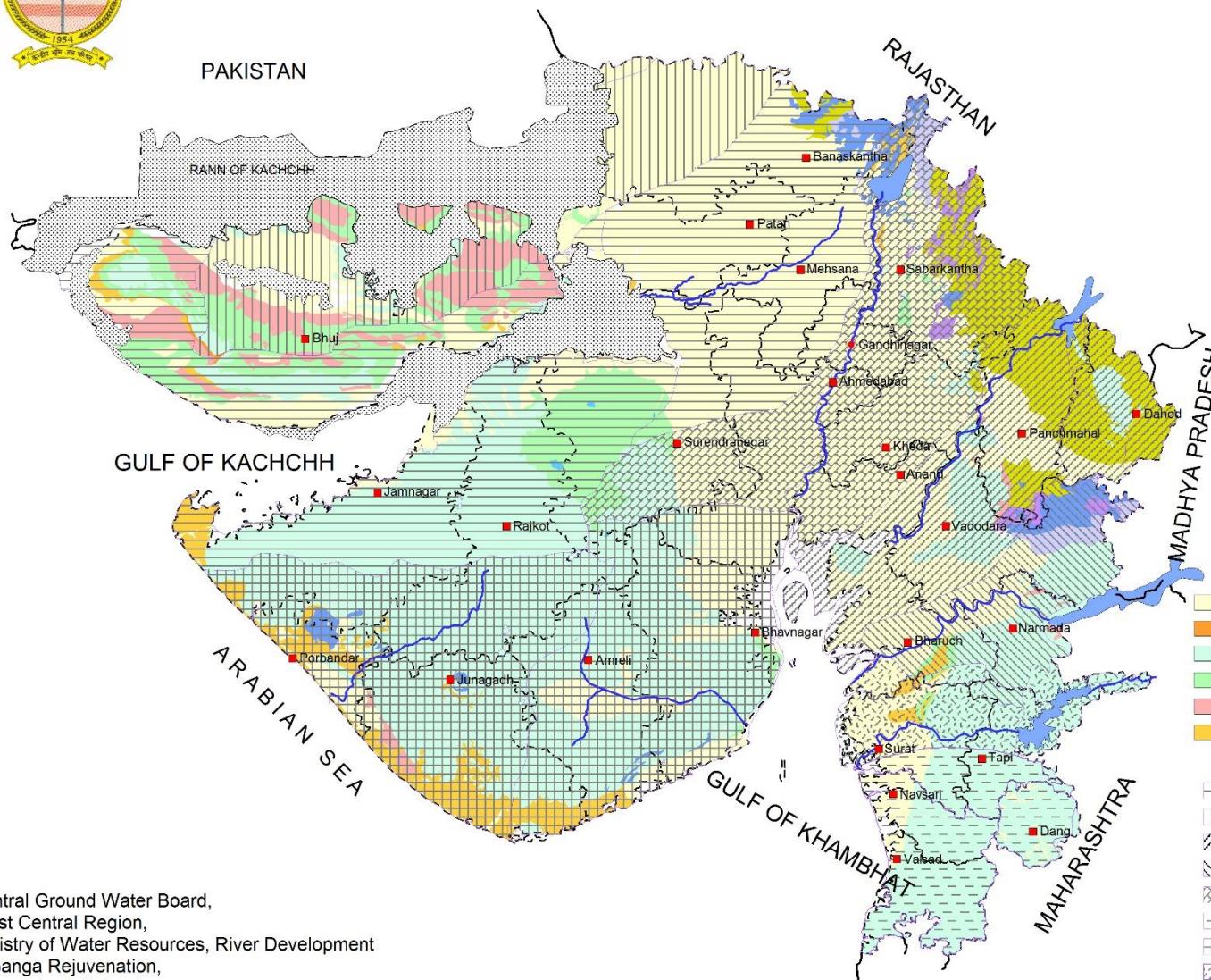




RIVER BASIN WISE AQUIFER DISTRIBUTION



0 50 100 Kilometers



LEGEND

Aquifer

Rann & Marshy Land

Alluvium



Granite



Schist



Basalt



Quartzite



Gneiss



Sandstone



Shale



Limestone



Laterite



Intrusives



Basin/Subbasin

Drainage into Gulf of Kutch



Luni and other drainage into Great Rann of Kutch



Mahi



Narmada



Sabarmati



Sharawati to Tapi



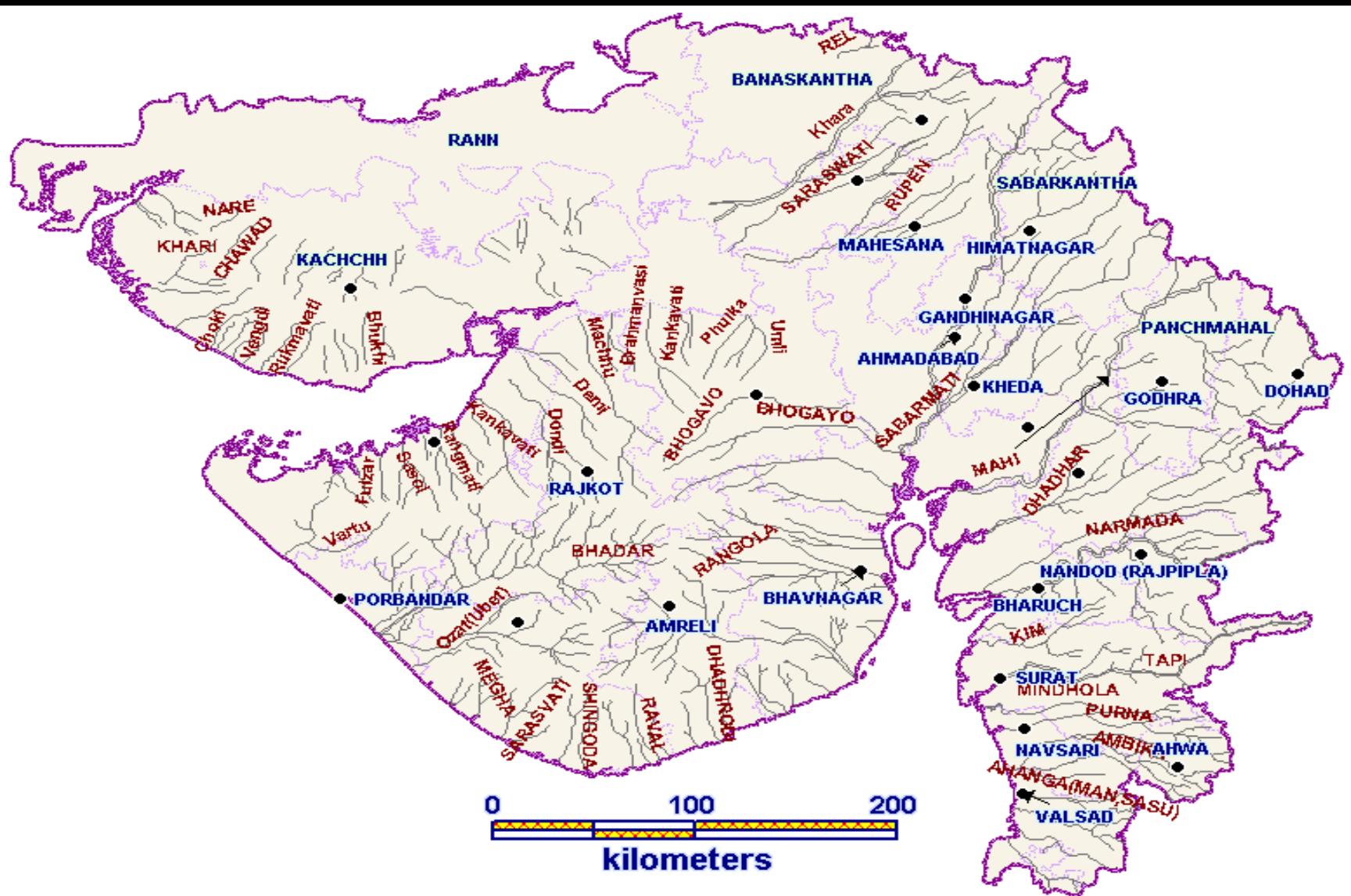
Southern Kathiawar



Tapi



DRAINAGE MAP OF GUJARAT STATE



GEOLOGY OF GUJARAT STATE

Geologically, Gujarat has a wide spectrum of rock types of different ages. Aravalli in the northeast is the oldest in the state with an age of about 2,500 m.y. and on the other hand the unconsolidated alluvial and beach sand in its central and western parts dates back to a few thousand years only.

All the important lithological types, igneous, sedimentary and metamorphic, occur within the state.

The Deccan basalt occupies vast tracts in the Saurashtra and few areas in Kachchh, Vadodara, Panchmahals and Sabarkantha districts and almost entire eastern part of Surat, Valsad and Dangs districts.

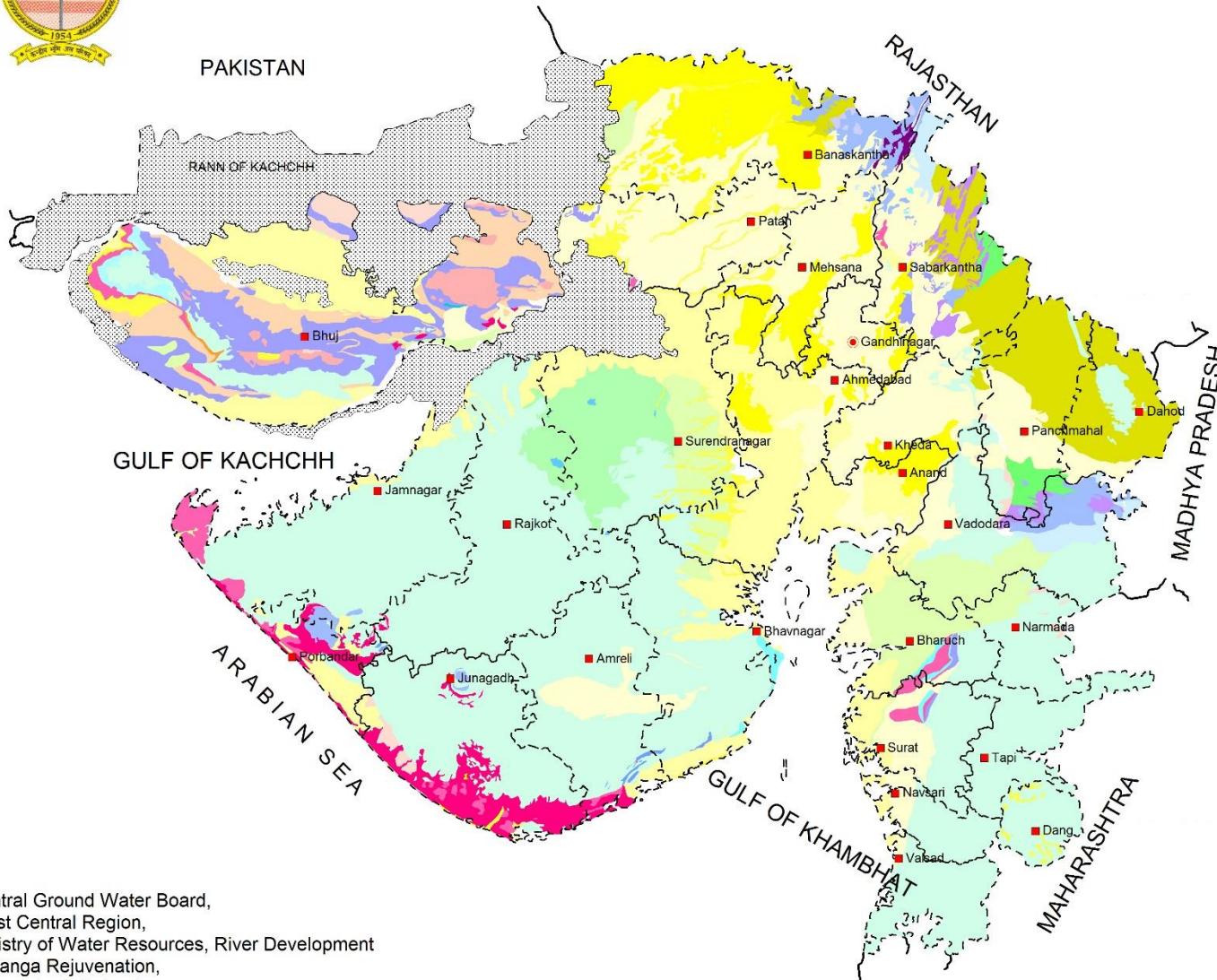
The Jurassic-Cretaceous sedimentary rocks, which occur in Kachchh, Surendranagar, Sabarkantha, Panchmahals and Vadodara districts, occupy same area as occupied by the intrusive igneous rocks and the meta-sedimentaries. Few exposures of Tertiary rocks are found in the alluvial area however in about 70 percent of the alluvial areas these formations are encountered at depths.



MAJOR AQUIFERS SYSTEM



0 50 100 Kilometers



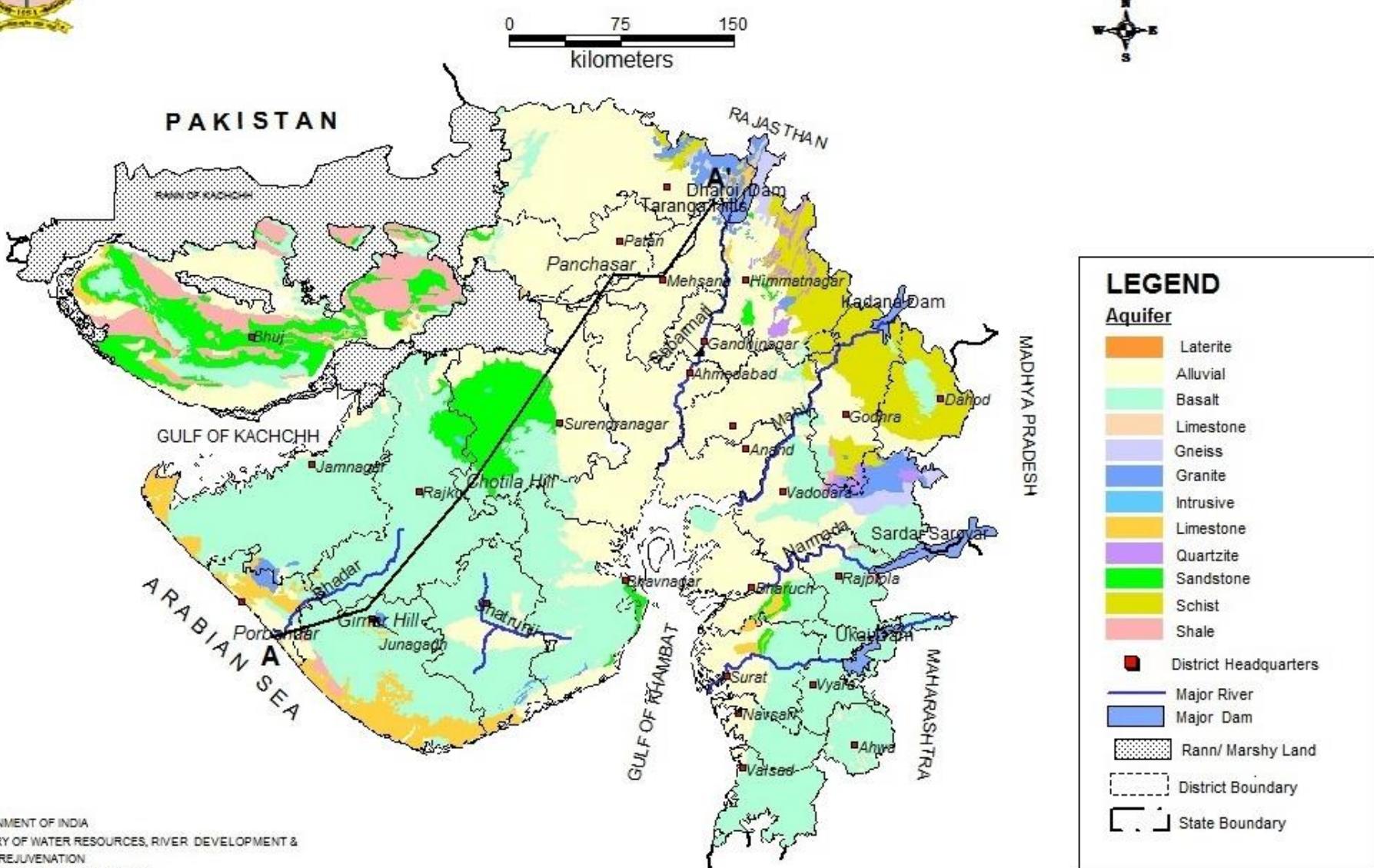
LEGEND

- Rann & Marshy Land
- District Boundary
- State Boundary
- District Headquarters
- State Capital
- Aquifers**
- Younger Alluvium (AL 01)
- Older Alluvium (AL 03)
- Aeolian Sand/Silt (AL 04)
- Coastal Aquifer (AL 05)
- Valley Fill (AL 06)
- Basalt (BS 01)
- Undifferentiated Metamorphics (GN 01)
- Gneiss (GN 02)
- Acidic Rocks (GR 01)
- Acidic Rocks (GR 02)
- Basic Intrusives (IN 01)
- Laterite (LT 01)
- Milliitic Limestone (LS 01)
- Limestone / Dolomite (LS 02) (Semi-Consolidated)
- Limestone / Dolomite (LS 03) (Consolidated)
- Marble (LS 05)
- Sandstone (ST 01)
- Sandstone with Shale (ST 02)
- Sandstone with shale/coalbed (ST 03)
- Sandstone with Clay (ST 04)
- Sandstone with Shale (SH 06)
- Schist (SC 01)
- Phyllite (SC 02)
- Shale with Sandstone (SH 02)
- Shale with Limestone & Sandstone (SH 03)
- Shale (SH 04)
- Quartzite (QZ 02)



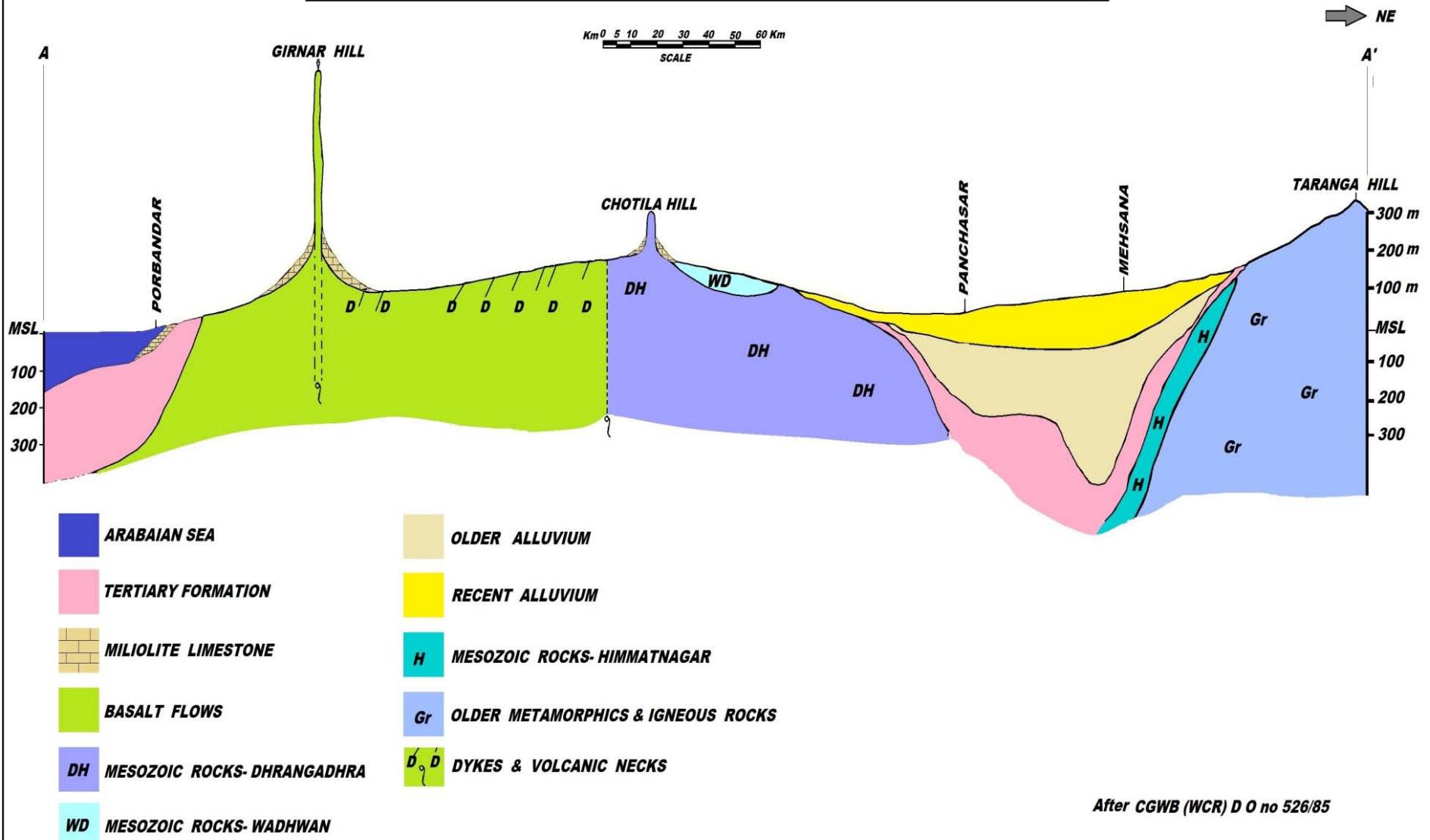
PRINCIPAL AQUIFER SYSTEMS OF GUJARAT

Plate -III



GEOLOGICAL CROSSECTION

Geological section North East - South West (Section Line A-A')



HYDROGEOLOGY OF GUJARAT STATE

- The diverse physiographic, climatic, topographic and geologic conditions have given rise to diversified groundwater situation in different parts of the state.
- The rock formations ranging in age from Archaean to Recent which control occurrence and movement of groundwater are varied in composition and structure.
- Similarly, of equal importance are the variations of the land forms from the hilly tract to the uplands of Kachchh and Saurashtra, the alluvial plains extending from Banaskantha in the north to Valsad in the south, the low lying coastal tract surrounding the Kachchh and Saurashtra uplands and the marshy to saline tracts of the Rann of Kachchh and little Rann of Kachchh.

HYDROGEOLOGY OF GUJARAT STATE

The porosity and permeability of rock types are the two factors, which control the occurrence and movement of groundwater.

Major hydrogeological units of Gujarat State,

- the hard rocks,
- soft rocks and
- semi-consolidated rocks,
occur in equal proportion in the Gujarat State.

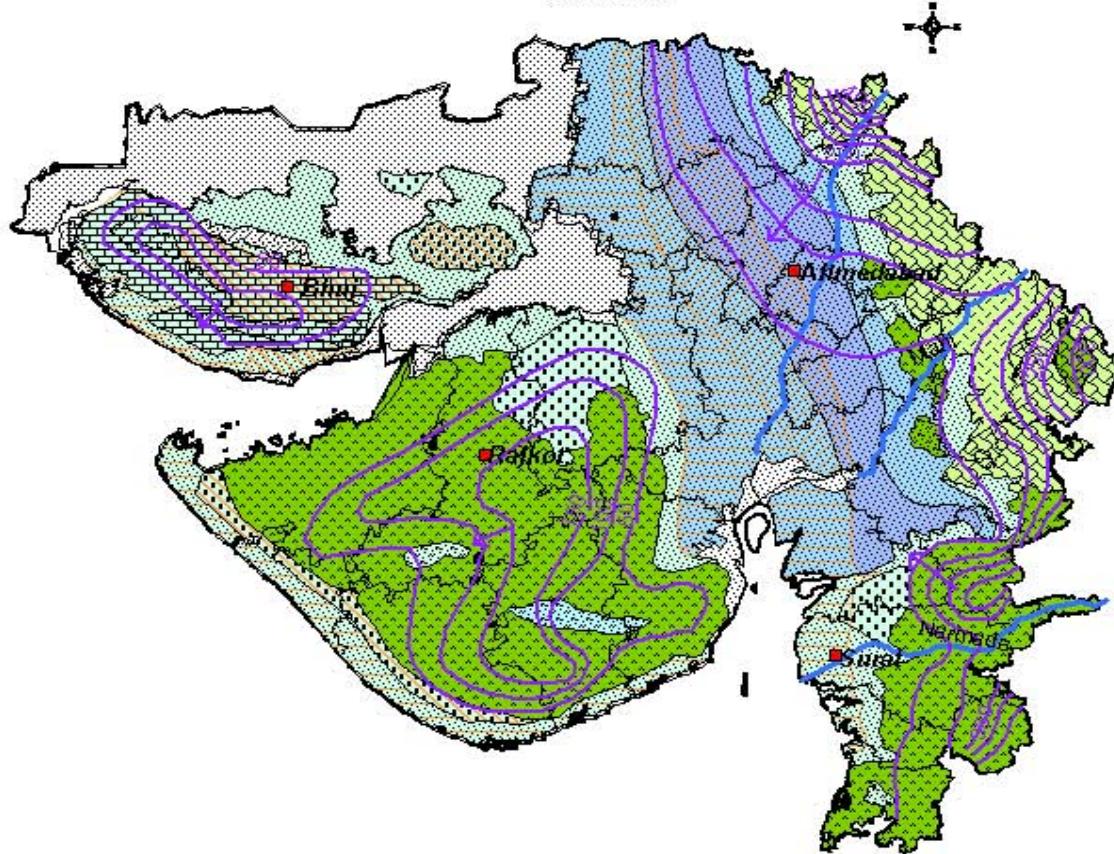
Except for the pre-Cambrian igneous and meta-sedimentary rocks, which form only a small part of the hard rock area, all other hard rocks (basalts) form multi-aquifer systems like the soft rocks .

The semi-consolidated rocks (Mesozoic rocks) also support multi-aquifer system.

HYDROGEOLOGY

HYDROGEOLOGY OF GUJARAT

0 75 150
Kilometers



LEGEND GEOLOGICAL FORMATION

- Basalt with Intertapean Clay
- Phyllite & Gneiss
- Quartzite, Phyllite & Gneiss
- Recent Alluvium (Clay, Sand and Concretion)
- Siltstone, Grit, Sandstone, Limestone etc
- Tertiary & Mesozoic (Sandstone & Conglomerate)

YIELD IN POROUS FORMATION

- Large yield More than 100 m³/hr
- Limited yield Less than 50 m³/hr
- Moderate yield 50 to 100 m³/hr

YIELD IN FISSURED FORMATION

- Low yield less than 5 m³/hr
- Moderate yield 5 to 20 m³/hr

GROUND WATER QUALITY

- Fresh Ground Water Overlain by Saline Ground Water
- Saline Water at all Levels Except Local Pockets
- Saline Ground Water Overlain by Fresh Ground Water
- River
- Water Table Contour (m. amsl.)
- Ground Water Flow Direction
- Rann and Marshy Areas
- State Boundary

OCCURRENCE OF GROUNDWATER

Groundwater occurs under

- water table (phreatic),
- semi-confined and
- confined conditions.

The semi-confined conditions in alluvial or soft formations are due to lenticular disposition of the confining beds and mixed nature of the alluvial material which gives rise to leaky aquitards.

In hard rocks, the major fracture and shear zones connect the phreatic and shallow confined aquifers to give rise to semi-confined conditions.

Pure confined conditions are very rare and are observed only where the alluvial clays are encountered or in the semi-consolidated aquifers as well basaltic aquifers in which the fracture porosity is insignificant in depths.

The water table aquifers show continuity as the weathered material allows passage of water from one rock unit to other in case of hard rocks, as far as a particular basin is considered, but the surface water divides-cum-groundwater divides which comprise massive, compact and non-fractured rocks, break the continuity. In the pre-Cambrian rocks there are no confined aquifers but major shear zones which penetrate deep enough, create conditions similar to confined conditions.

HYDROGEOLOGICAL UNITS OF GUJARAT STATE

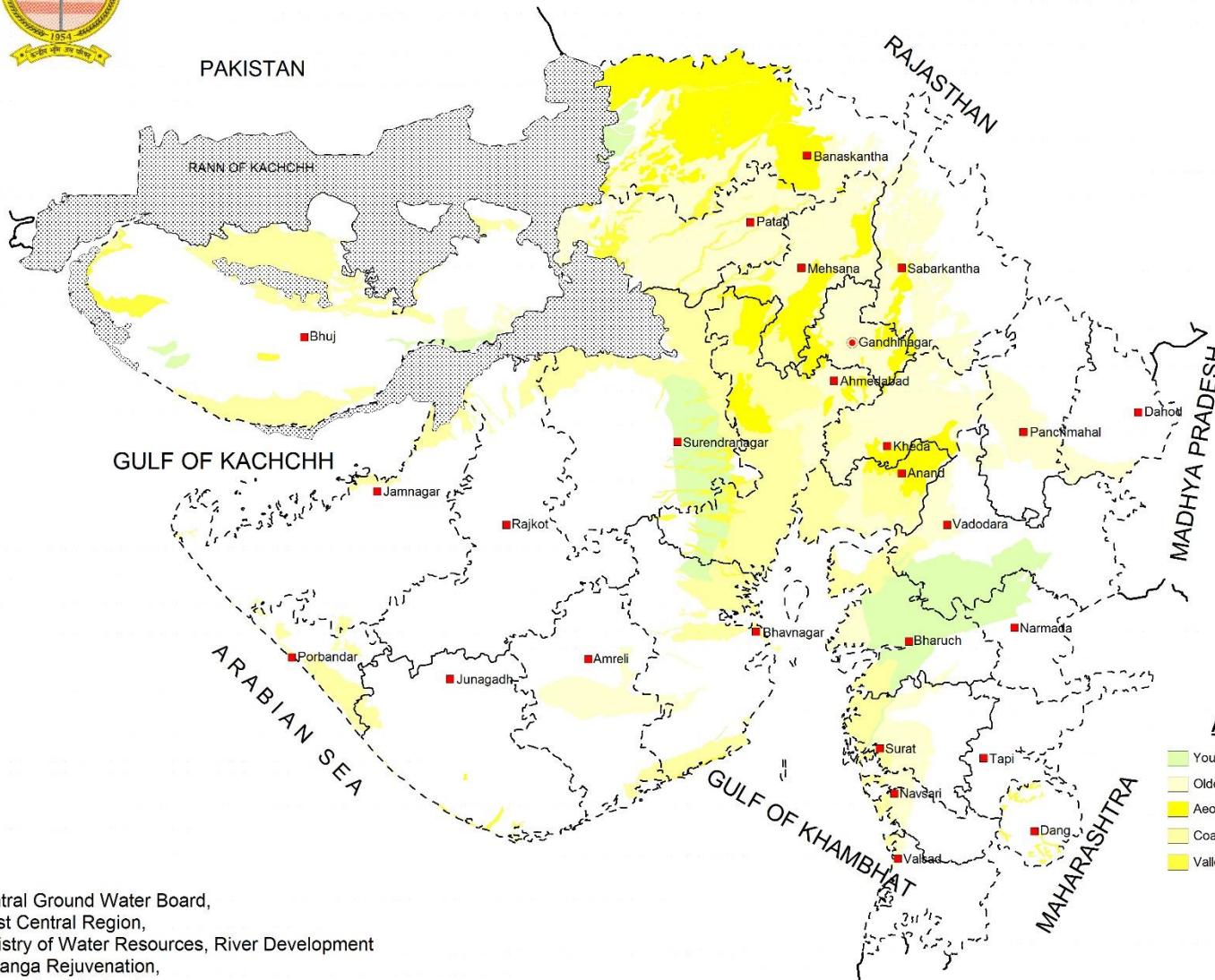
Age	Rock formation	Distribution	Hydrogeological Characteristics
Porous Formation			
Quaternary to Upper Tertiary Conglomerates, pebble	Impure limestones, limestones, sandstones Bharuch, Kachchh, Kheda, beds, silt stones, sands, pebbles, gravels etc.	Ahmedabad, Amreli, Banaskantha, Bhavnagar, Storativity 1.6×10^{-4} to Jamnagar, Junagadh, Rajkot, Mehsana, Surendranagar, Sabarkantha, Vadodara and Valsad districts leaky confined/ confined.	Large to moderate yield prospects - 10 to 40 lps, 7.3×10^{-4} , hydraulic Conductivity 5 to 20 m/day, Transmissivity 50 to 2000 m ² /day. Unconfined shallow aquifer, deeper aquifer.
Mesozoic	Sandstones, shales, limestones & grits.	Kachchh, Surendranagar, Sabarkantha and Vadodara, districts.	Discontinuous aquifers with limited thickness 50 to 300 m. Limited yield prospects less than 15 lps. Hydraulic conductivity 2 to 10 m/day, transmissivity 50 to 1000 m ² /day,
Fissured Formation			
Mesozoic to Palaeozoic	Basalt with inter- trappean clays	Uplands of Saurashtra, Kachchh region, scattered pockets in Panchmahals, Sabarkantha and Vadodara districts, continuous belt in eastern part of Bharuch, Surat and Valsad districts.	Groundwater occurrence restricted to weathered and fractured zones, limited to 200 m. Moderate yield prospects 5 to 15 lps.
Archaean and Precambrian	Granites, gneisses, marbles, schists, phyllites and slates.	Banaskantha, Sabarkantha, Panchmahals, Vadodara and Kheda districts.	Groundwater occurrence restricted to weathered and fractured zones having secondary porosity. Limited yield prospects 2 to 5 lps.



ALLUVIUM AQUIFER SYSTEM



0 50 100 Kilometers



The large alluvial tract extending from Banaskantha district in the north to Surat and Valsad districts in the south constitutes the largest and most potential groundwater reservoir in the state. The aquifers are extensive, thick, hydraulically connected and are moderate to high yielding.

LEGEND

Aquifers

- Younger Alluvium (AL 01)
- Older Alluvium (AL 03)
- Aeolian Sand/Silt (AL 04)
- Coastal Aquifer (AL 05)
- Valley Fill (AL 06)

- Rann & Marshy Land
- District Boundary
- State Boundary
- District Headquarters
- State Capital

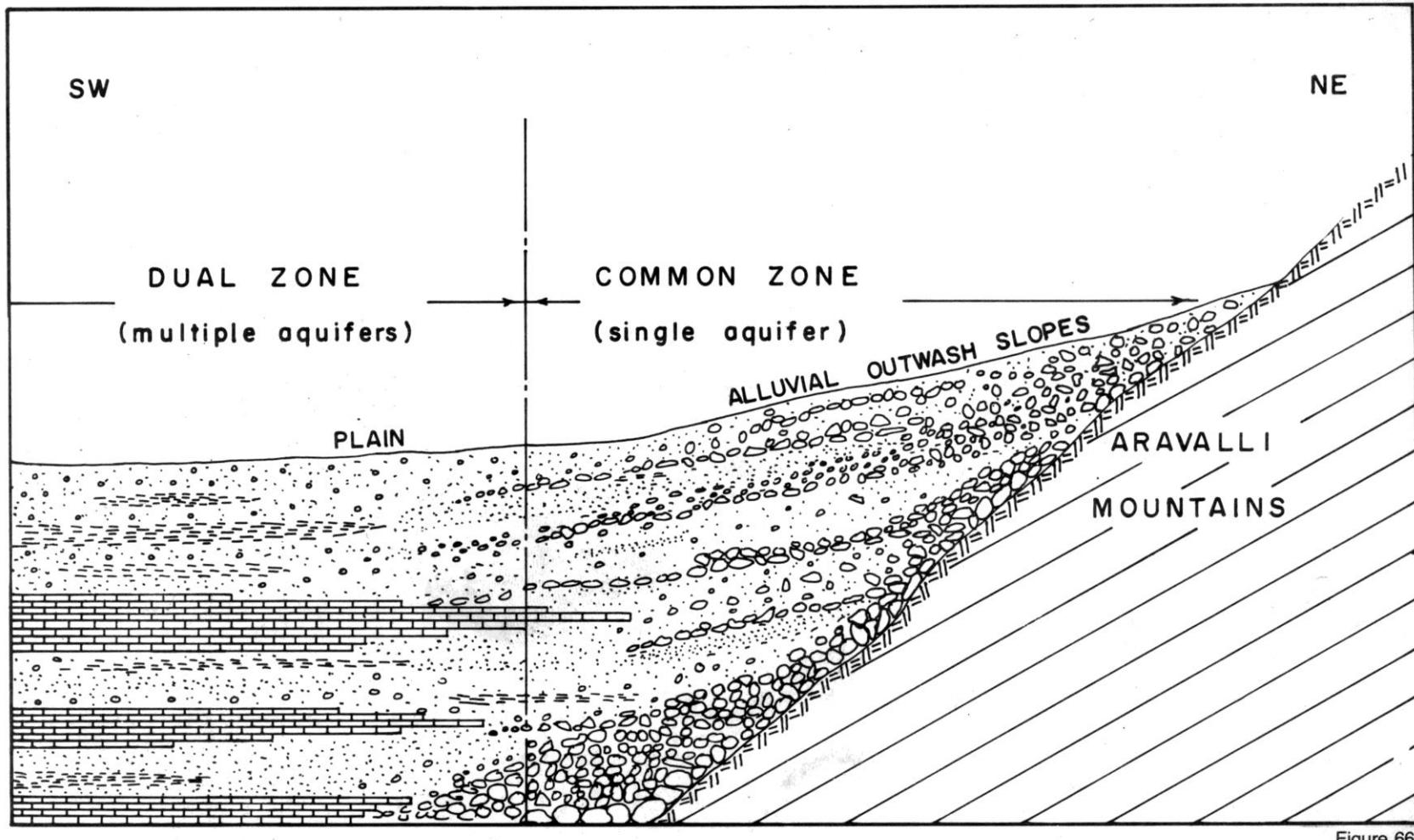
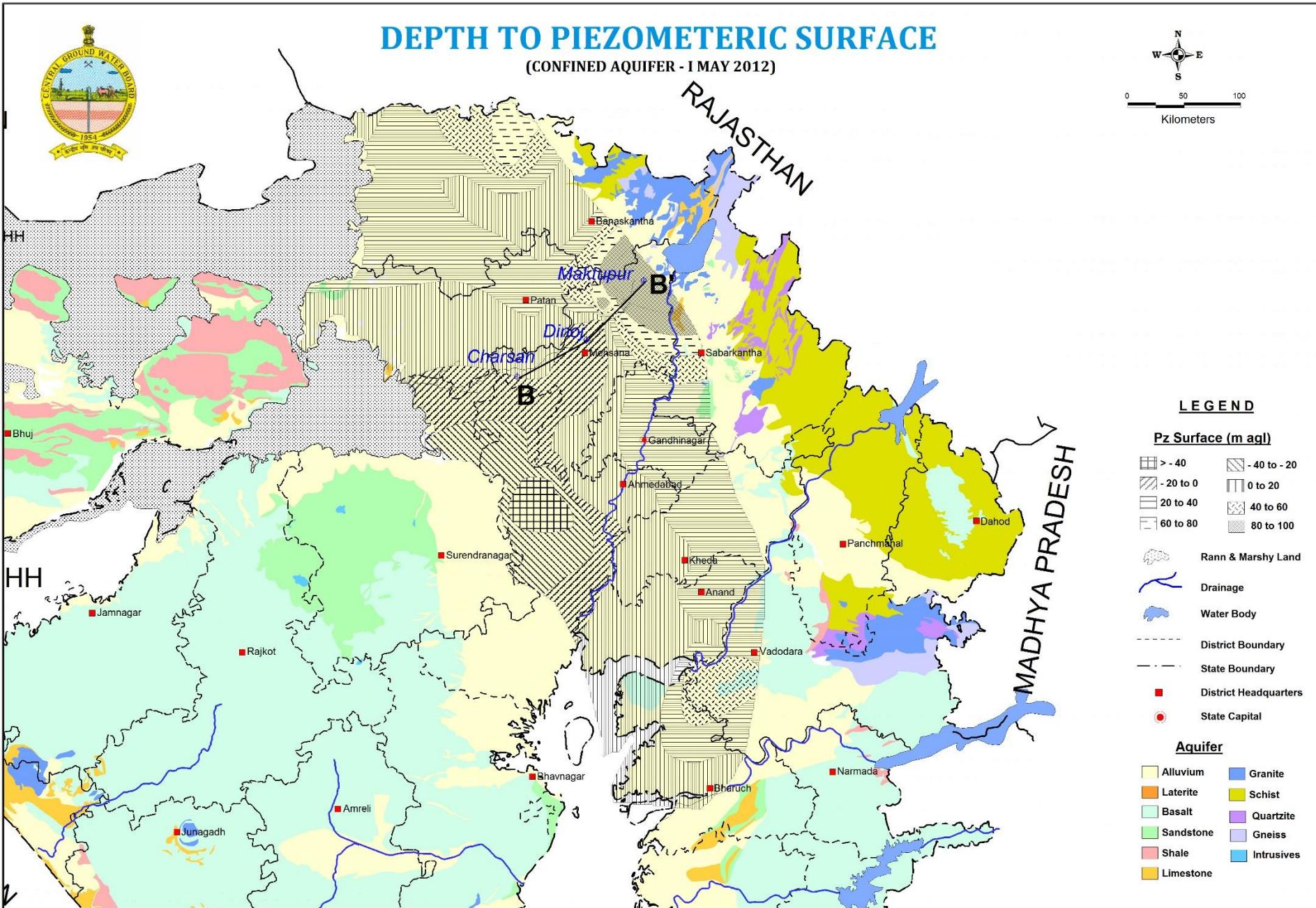
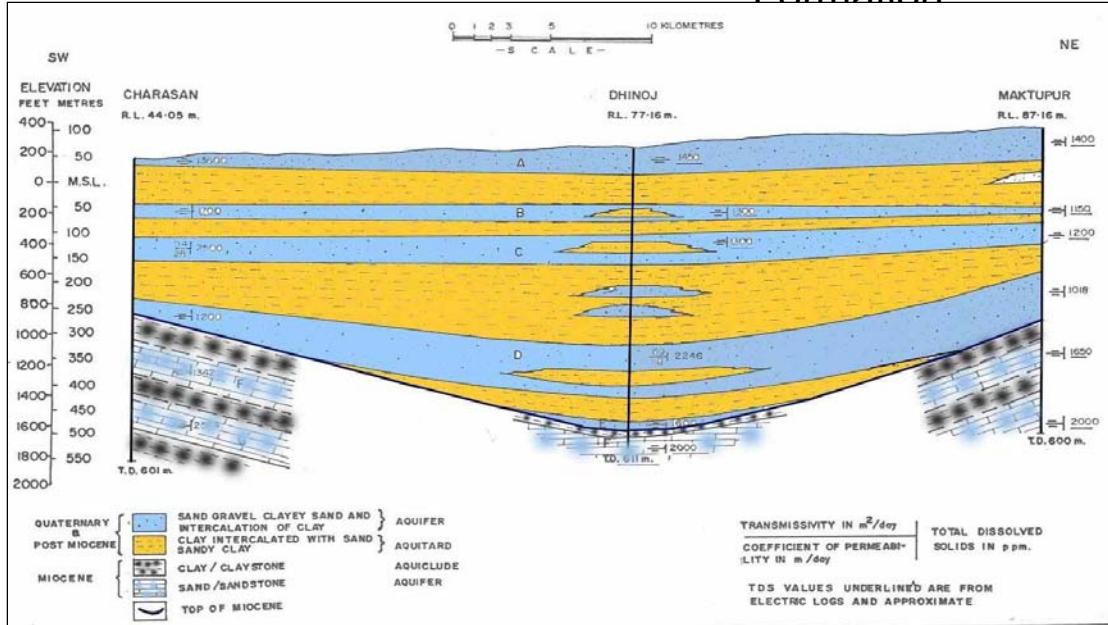


Figure 66

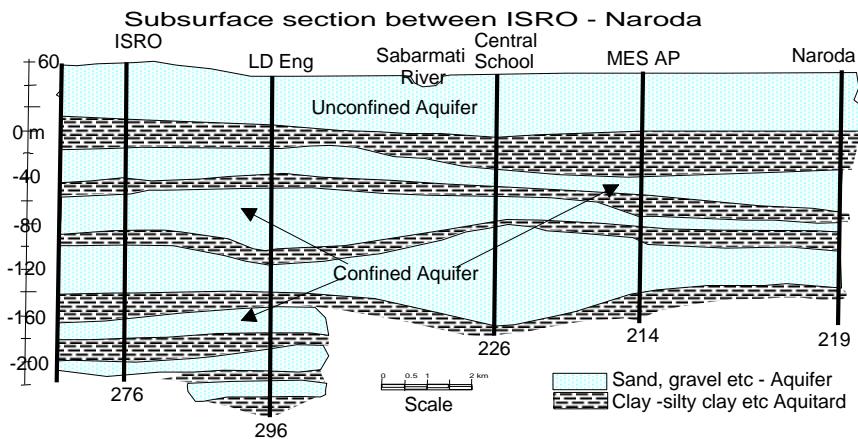
SCHEMATIC SECTION SHOWING DUAL-AQUIFER SYSTEM CONCEPT

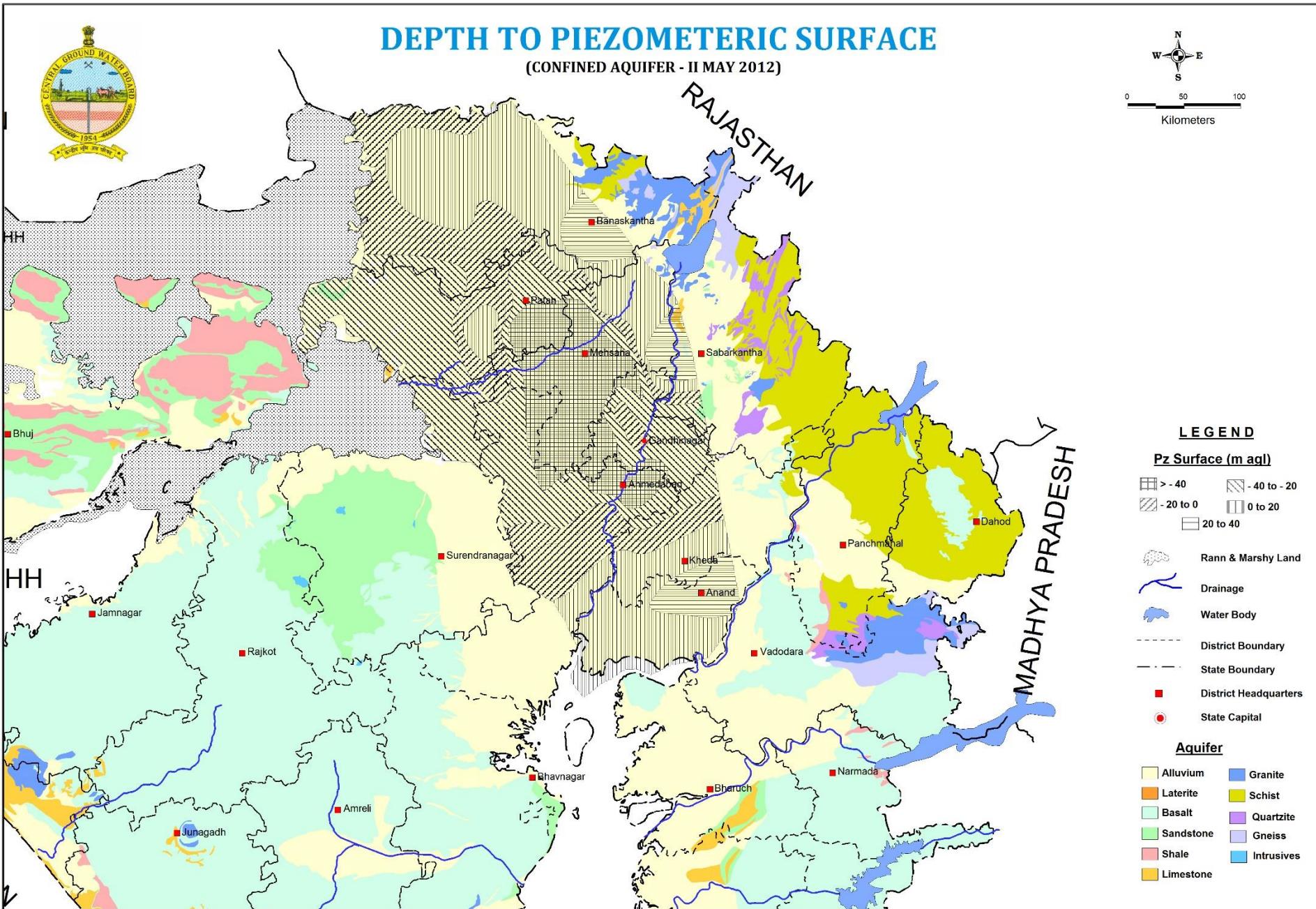


Common features of Multilayered hydrogeology units - Alluvium Unconsolidated Formation



- Multilayered aquifer system
 - Very large storage –
variable flow
 - Extensive Regionally
extention –lateral
continuity
 - Vary high rate of
recharge capacity –
comapre to hard rock
aquifer sytem



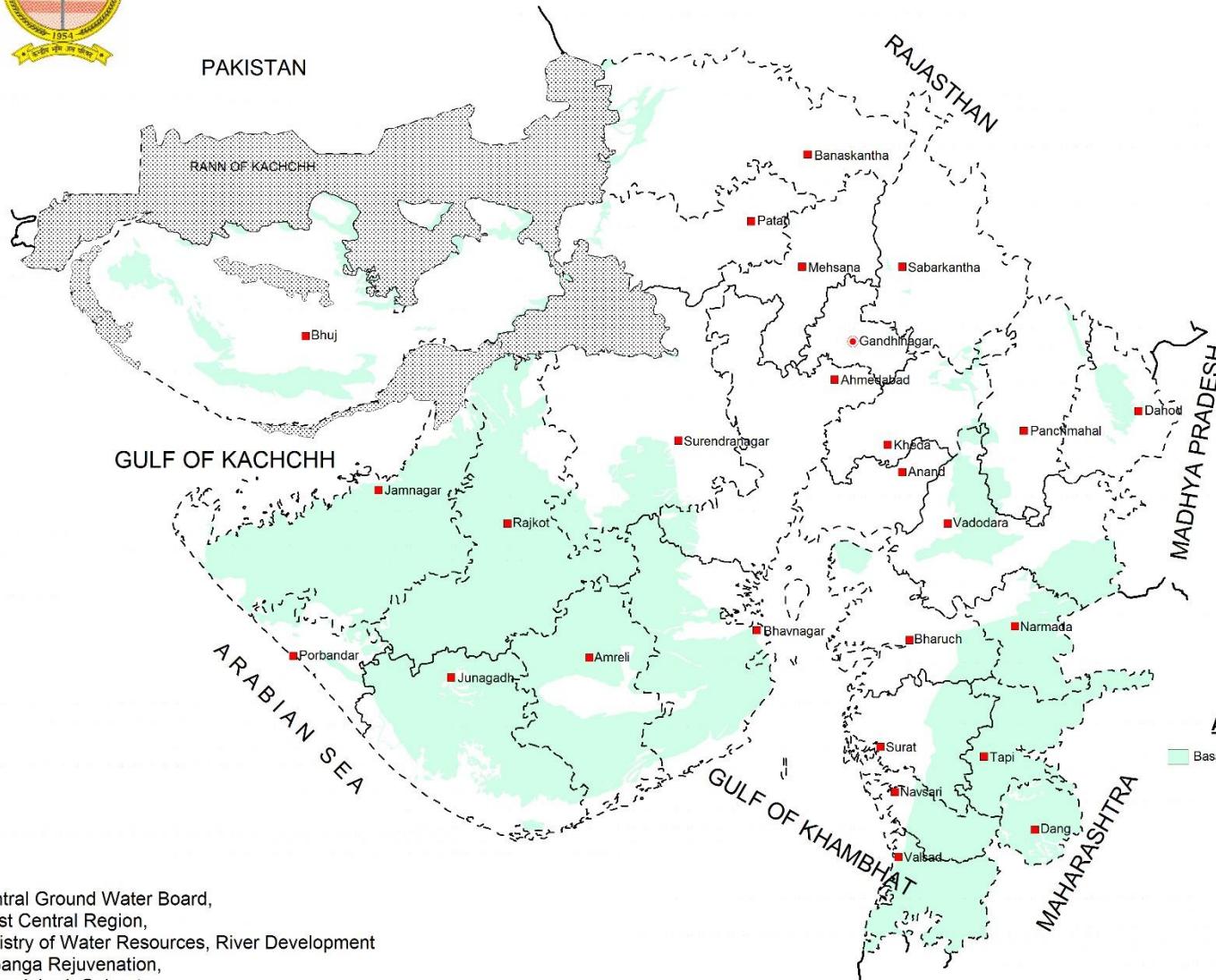




BASALT AQUIFER SYSTEM



0 50 100
Kilometers



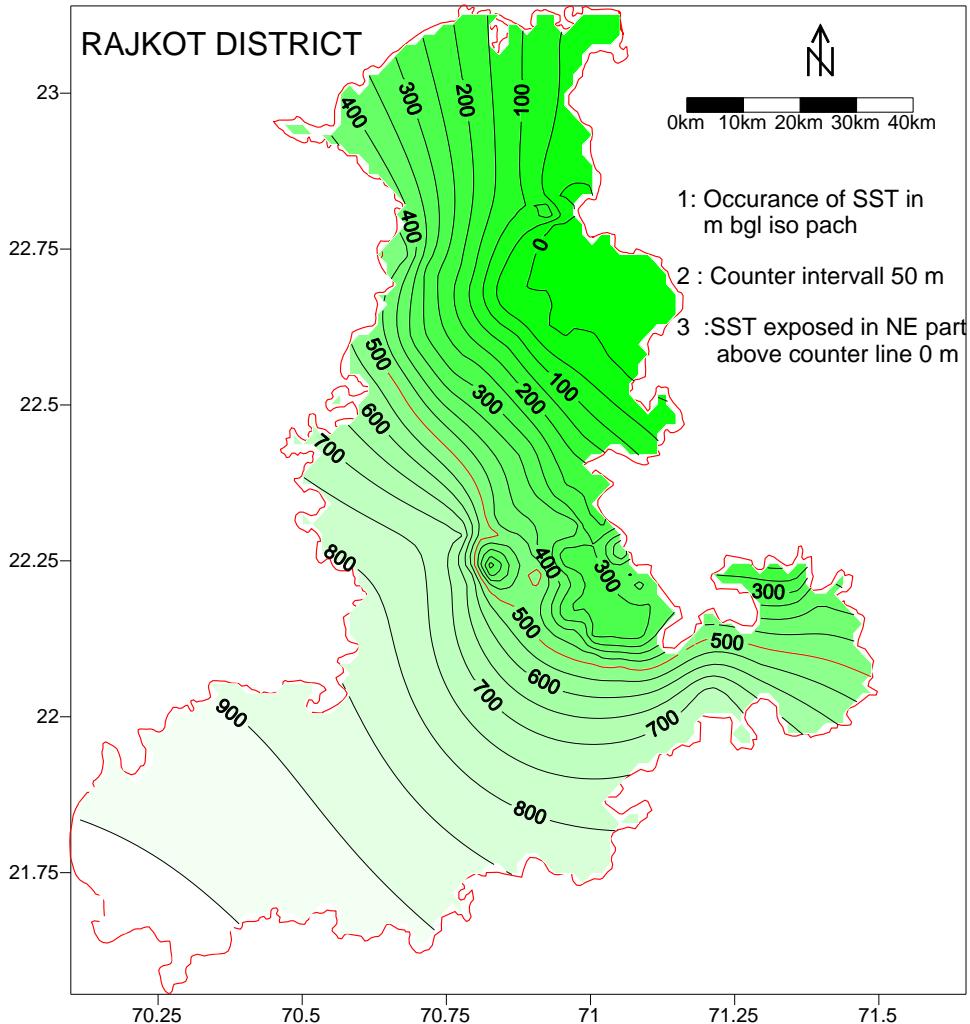
LEGEND

Aquifers

Basalt (BS 01)

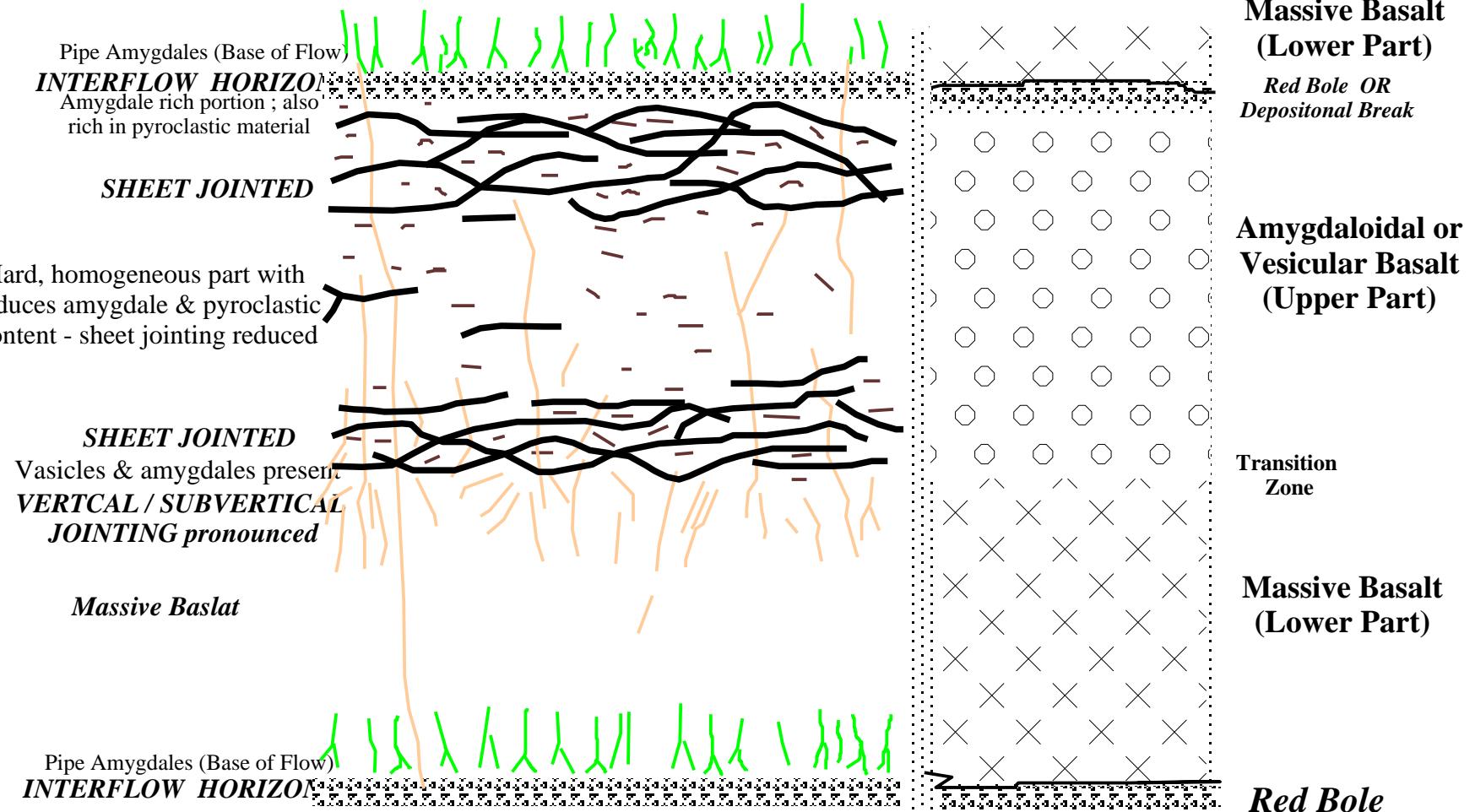
- Rann & Marshy Land
- District Boundary
- State Boundary
- District Headquarters
- State Capital

**Isopach Map of Deccan Trap
Depth to Cretaceous Formation - Sandstone**



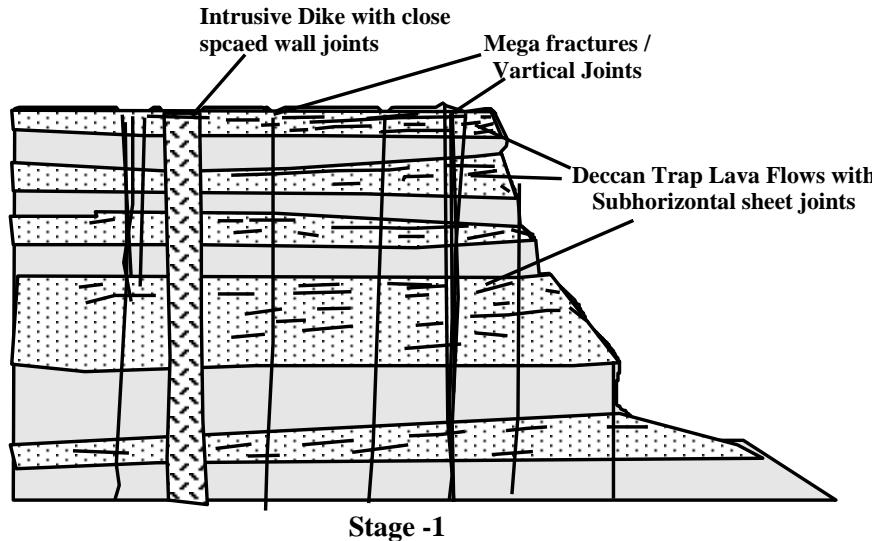
**Isopach of Deccan
Trap Rocks Above
Underlying
Cretaceous
Sandstone
Formation**

Schematic diagram of vertical cross section of a typical Deccan Trap Basalt Flow

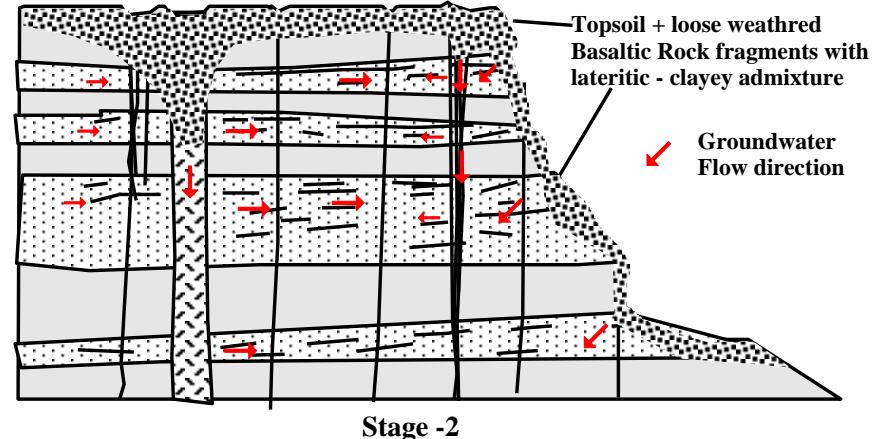


(compiled and reproduced from original concept – Kale VS & Kulkarni
H – CSIR Study Report & Singhal BBS(1997))

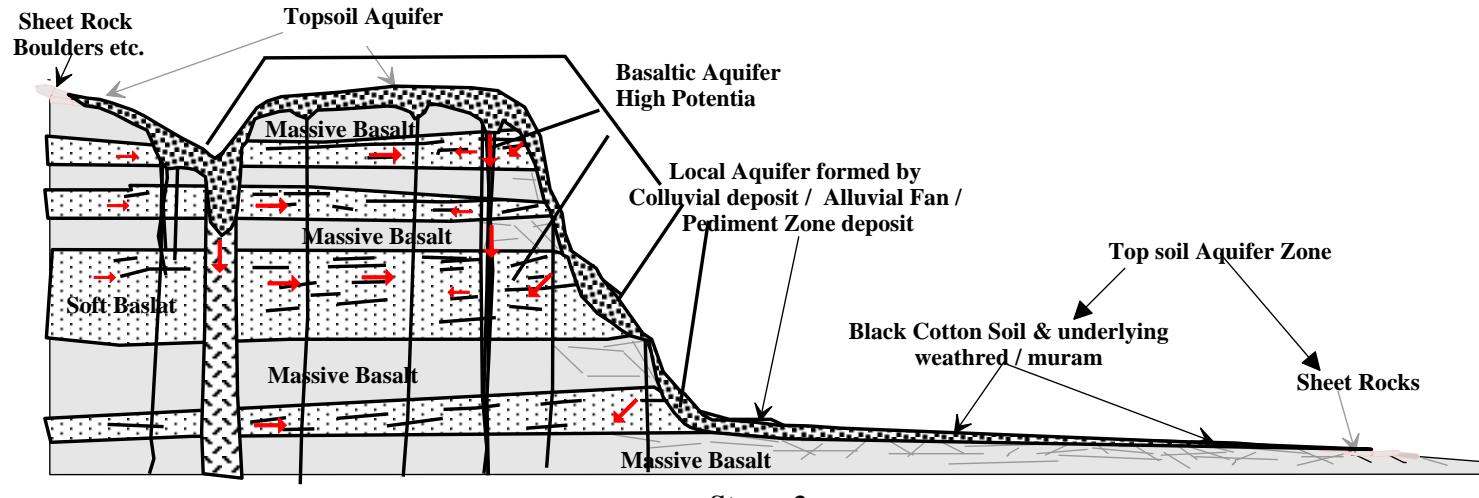
Schematic sequence of geomorphic evolution of Deccan Trap Flows into Aquifer System



Stage -1

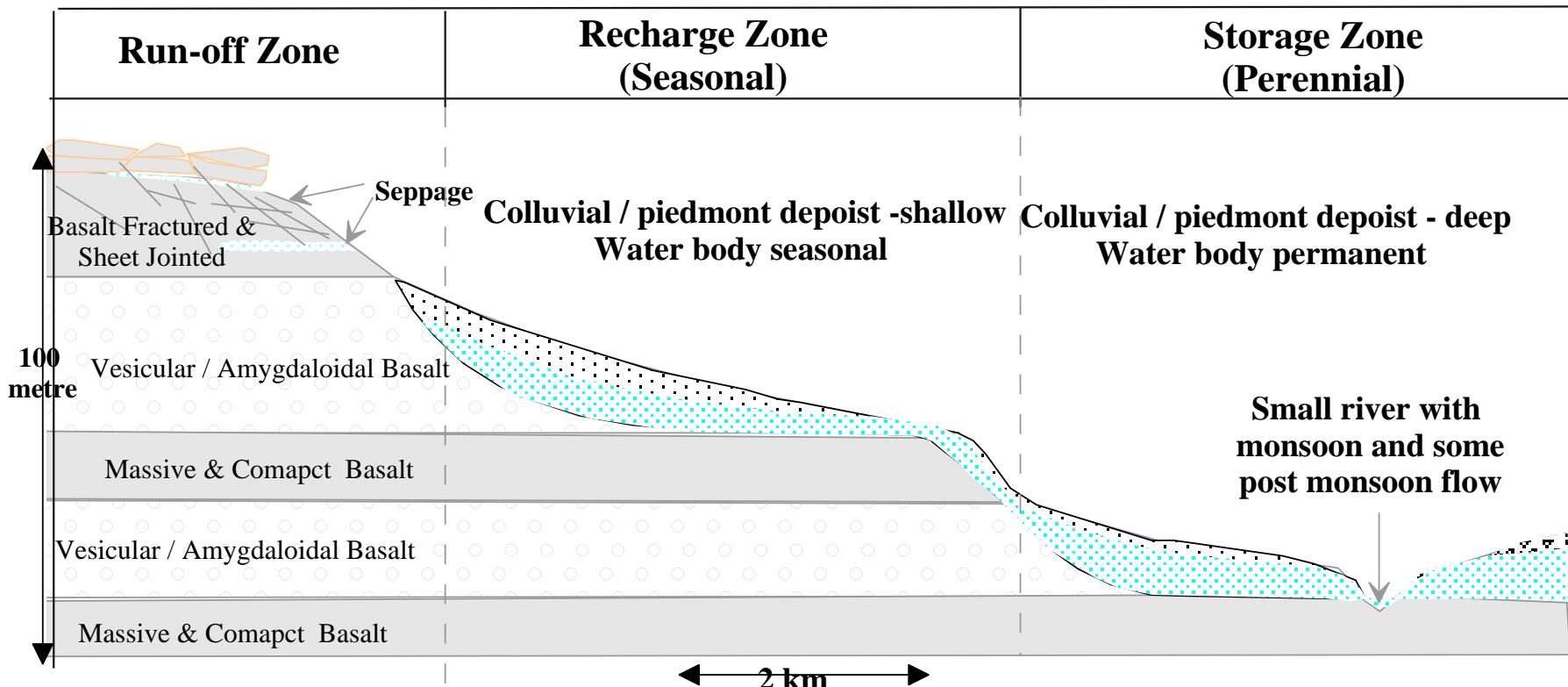


Stage -2



Stage -3

Compiled & redrawn – original concept Kale VS & et al, CSIR Study report)



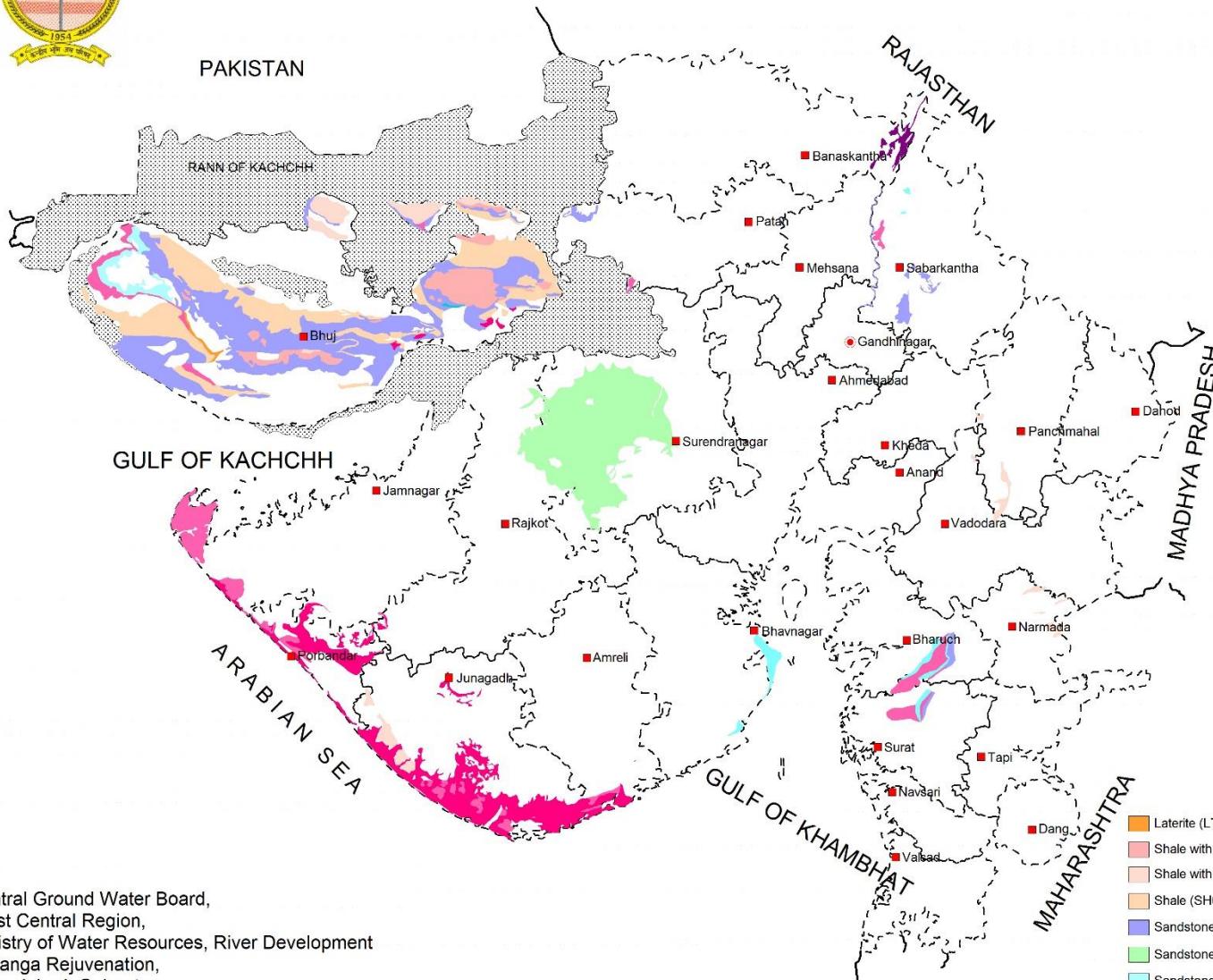
(Compiled & redrawn – original concept by Foster S. – 2006 –GMATE Briefing Note Series)



SEMI-CONSOLIDATED AQUIFERS SYSTEM



0 50 100 Kilometers



LEGEND

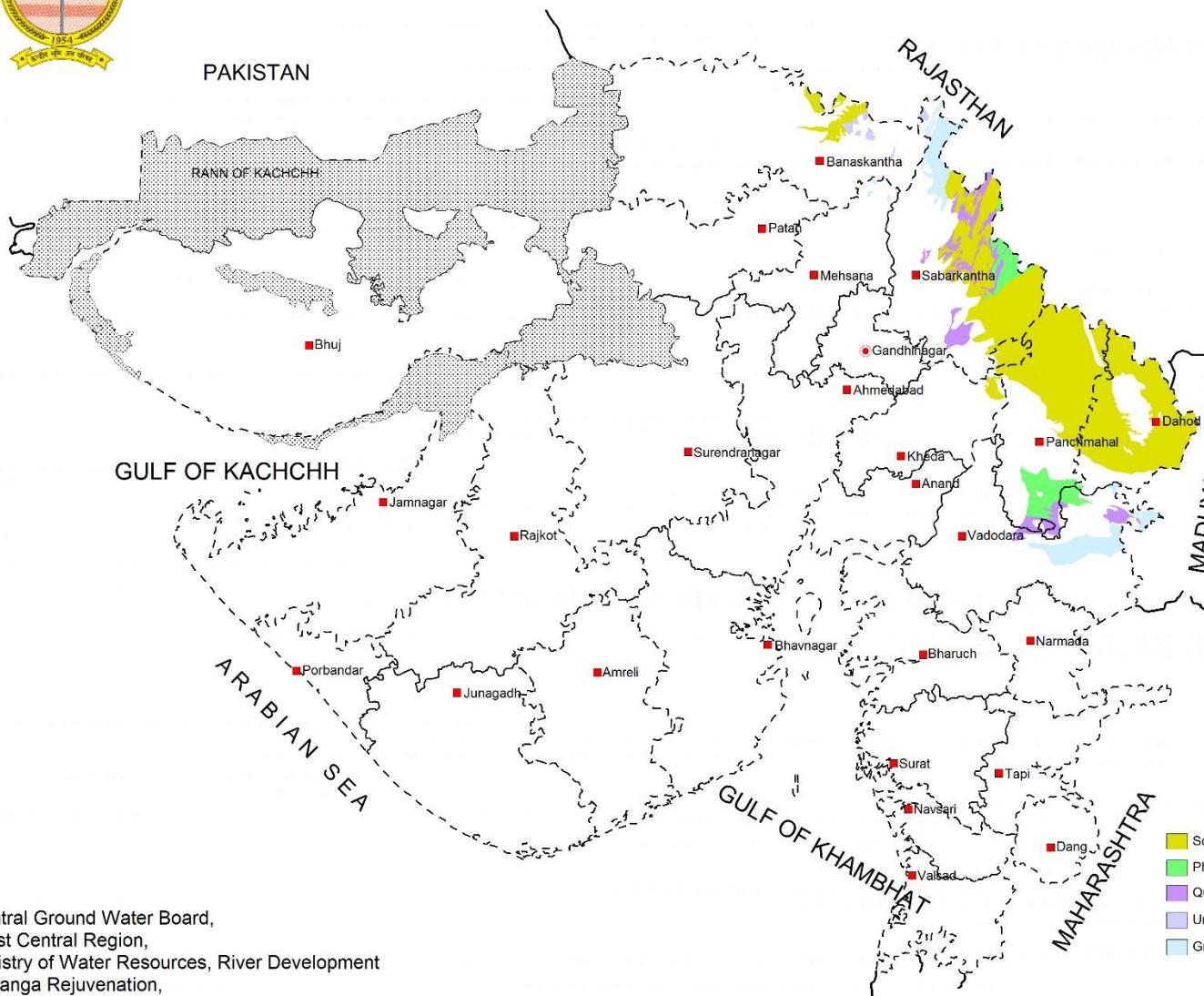
	Rann & Marshy Land
	District Boundary
	State Boundary
	District Headquarters
	State Capital
Aquifers	
	Sandstone with Clay (ST04)
	Sandstone with Shale (SH06)
	Shale with Limestone & Sandstone (SH03)
	Miliolitic Limestone (LS01)
	Limestone / Dolomite (LS02) (Semi-Consolidated)
	Limestone / Dolomite (LS 03) (Consolidated)
	Sandstone with Shale (ST02)
	Sandstone with shale/coalbed (ST03)
	Marble (LS05)



METAMORPHIC AQUIFERS SYSTEM



0 50 100 Kilometers



The high relief areas in the eastern and north-eastern parts of the state occupied by the Deccan Traps and the Archeans respectively have steep topographic gradients resulting in high run-off, and therefore, provide little scope for groundwater recharge. The groundwater potential in this terrain is limited.

LEGEND

Aquifers

- Schist (SC 01)
- Phyllite (SC 02)
- Quartzite (QZ 02)
- Undifferentiated Metamorphics (GN01)
- Gneiss (GN 02)

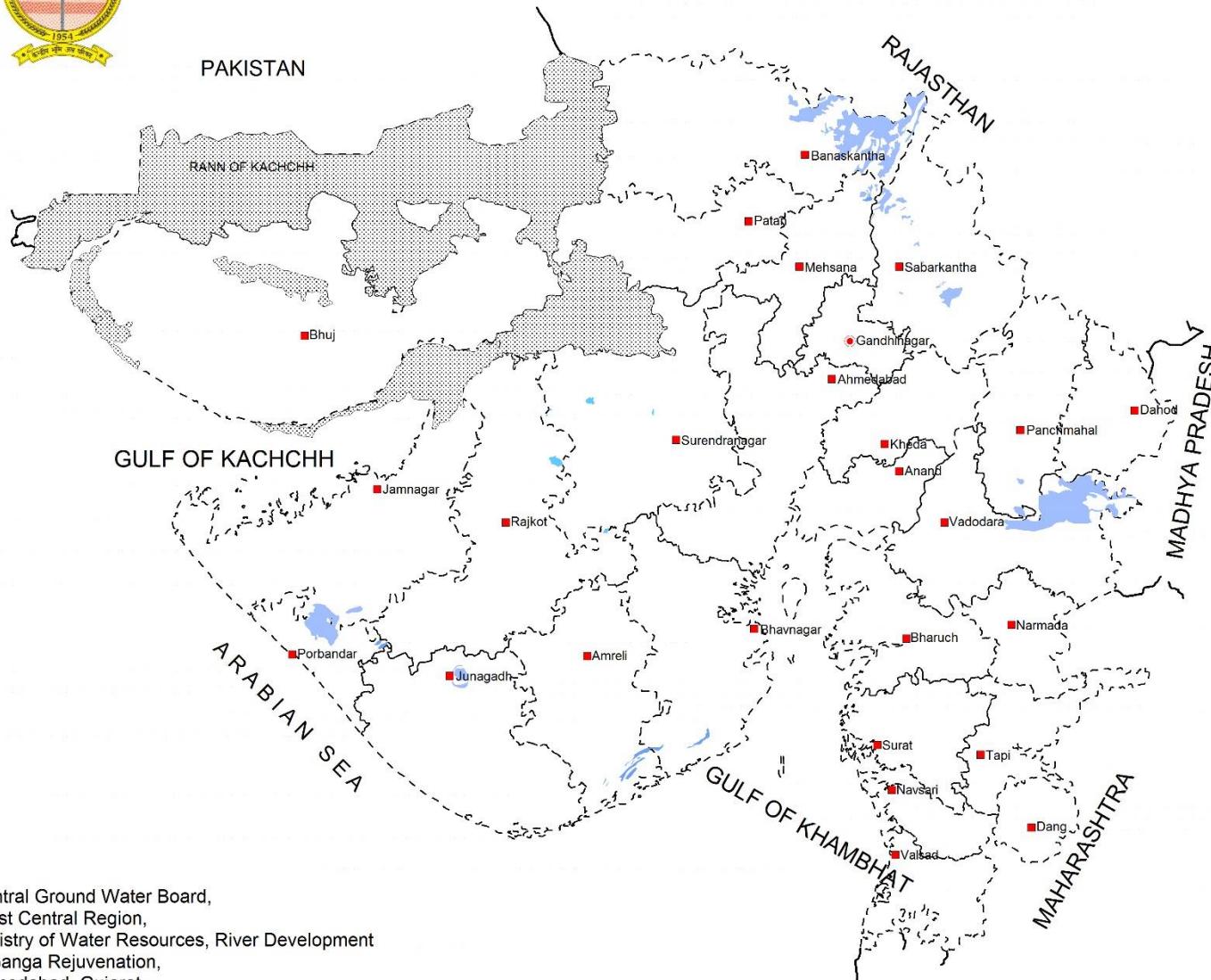
- Rann & Marshy Land
- District Boundary
- — — State Boundary
- District Headquarters
- State Capital



GRANITE / INTRUSIVES AQUIFERS SYSTEM



0 50 100 Kilometers



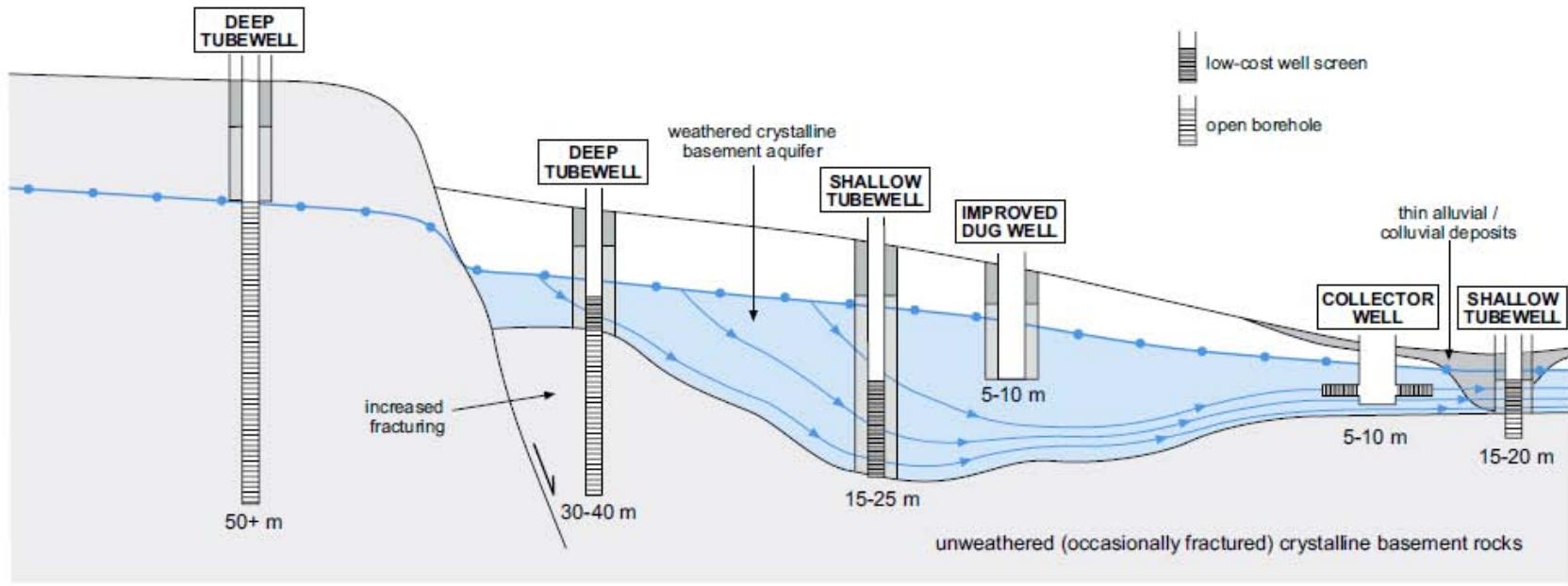
LEGEND

- Rann & Marshy Land
- District Boundary
- State Boundary
- District Headquarters
- State Capital

Aquifers

- Acidic Rocks (GR01)
- Acidic Rocks (GR 02)
- Basic Intrusives (IN 01)

Common features of hard rock hydrogeology units - Metasediment – Granite / Gneiss etc.



YIELD PROSPECTS	very variable	very good	good	moderate (drought reductions)	good	good
RELATIVE COST	high	moderate	low	very low	moderate	low

VARIATION OF WATERWELL CHARACTERISTICS WITH TERRAIN

Varied features depending extent of weathering and climatic vagaries they have undergone in geological past.

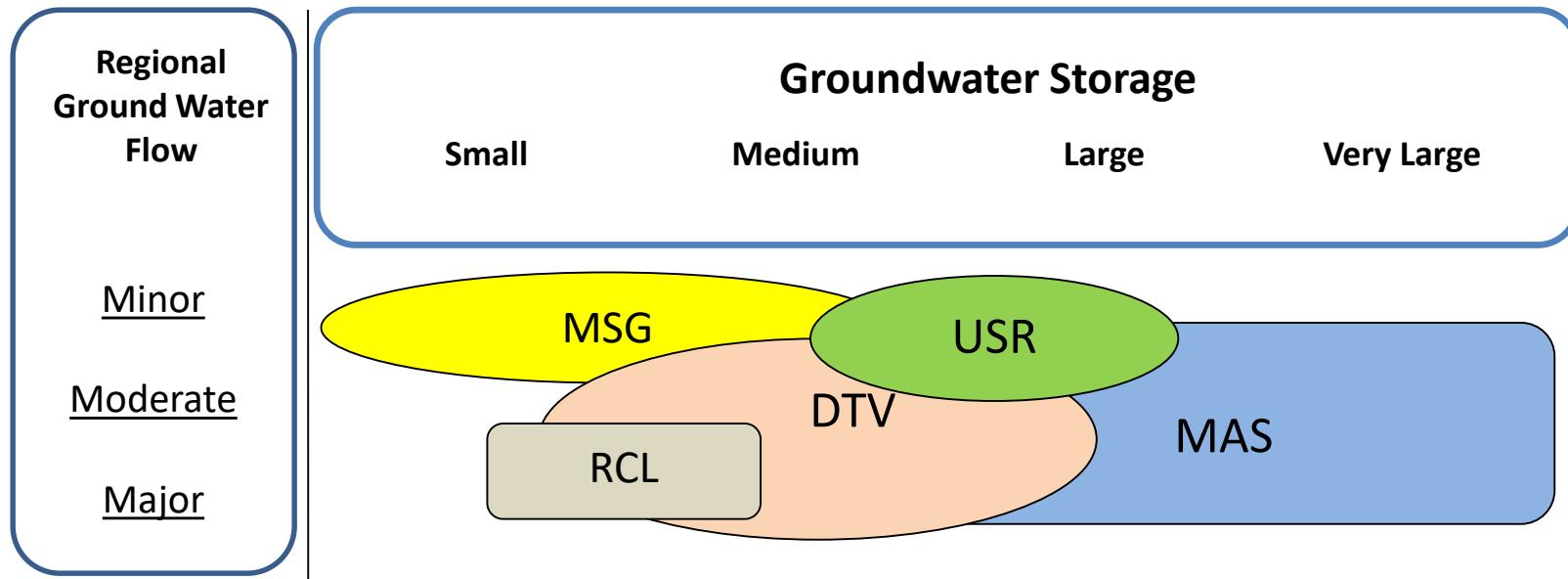
Main three geomorphic units

- Hill front (piedmont) zones with colluvial outwash deposits, and bedrock faulting or lineaments
- Extensive upland plains with bedrock (pediment) locally at surface and more normally under a variable depth of in-situ weathering products
- Minor alluvial tracts across the latter with some surficial alluvial re-deposition.

The groundwater, in such unit is mainly confined to the weathered mantle, with more localized flow in fractures, joints and lineaments of the underlying bedrock.

[Continue next](#)

Summary of key properties of most widely occurring aquifer system – Gujarat State



Meta sediments & Granite / Gneiss
Shallow depth weathered rocks producing a thin mantle of low permeability; very extensive low but low storage & minor to medium yielding aquifer

Recent Coastal Limestone
Coral limestone and detritus Limited extent; medium to high potential fringing coastline or islands

Deccan Trap - Volcanic
Variable weathering profile; medium to large storage and minor to moderate yield prospects ; Layered flow – variable storage & uniform flow along individual lava floe

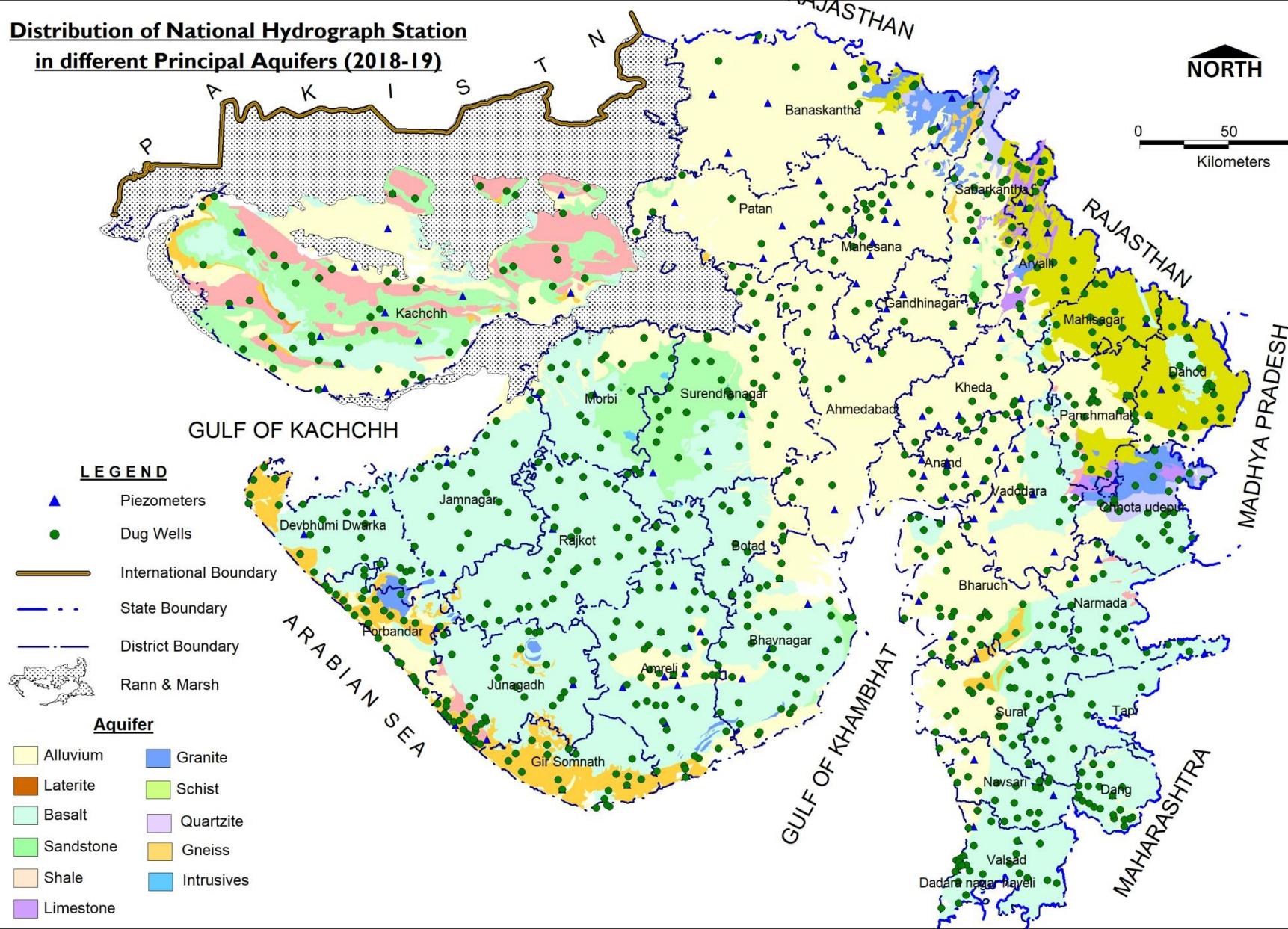
Unconsolidated Soft Rock – Mesozoic – Tertiary SST / LST / MarL etc.
Sandstone or limestone with consolidation and fracturing small to medium storage & moderate flow

Mulilayered Aquifer System
Unconsolidated alluvium formation , medium to very large storage, extensive ; varied flow regime (gravels, sands silts) extensive and of large thickness

**Distribution of National Hydrograph Station
in different Principal Aquifers (2018-19)**

NORTH

0 50 100
Kilometers

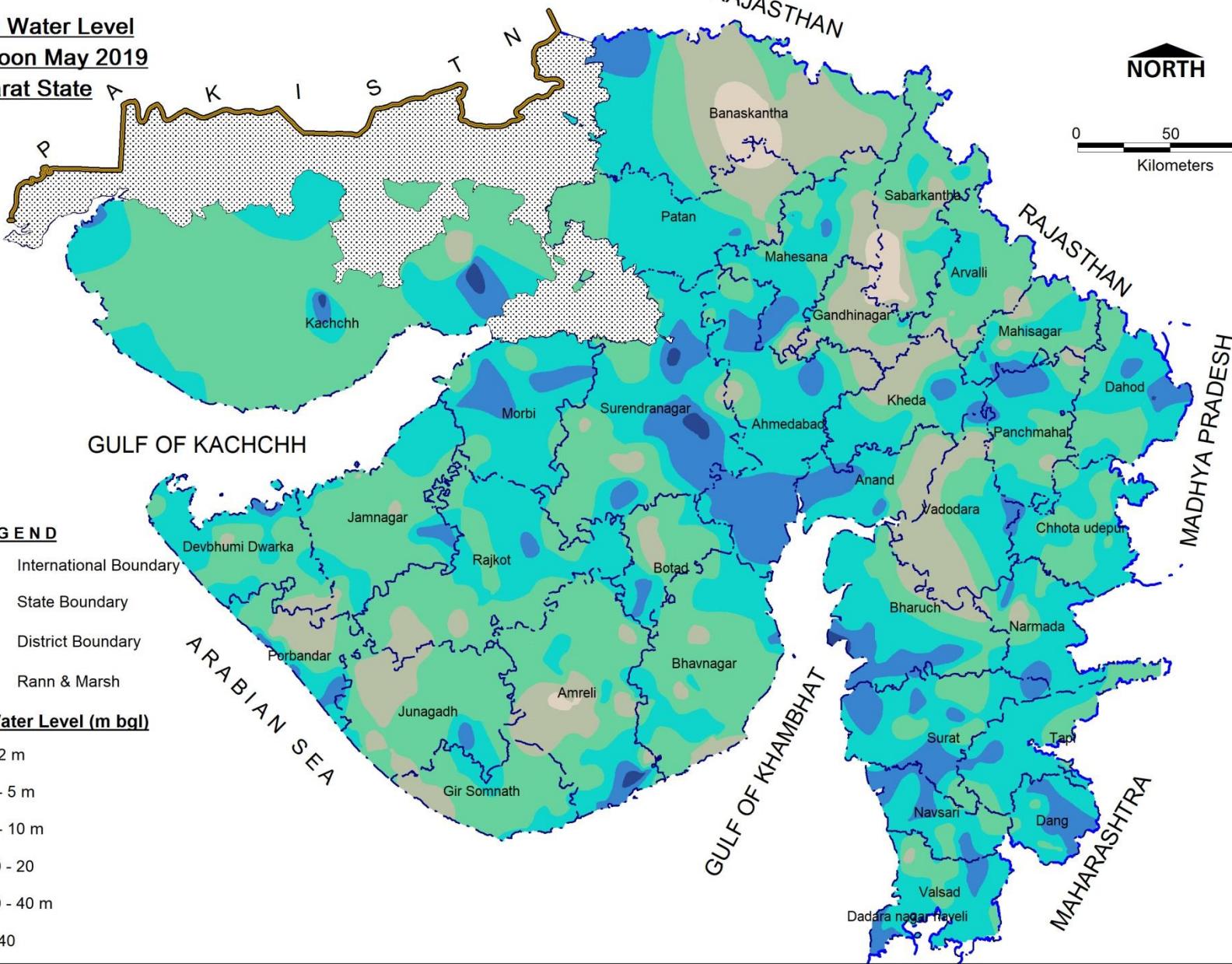


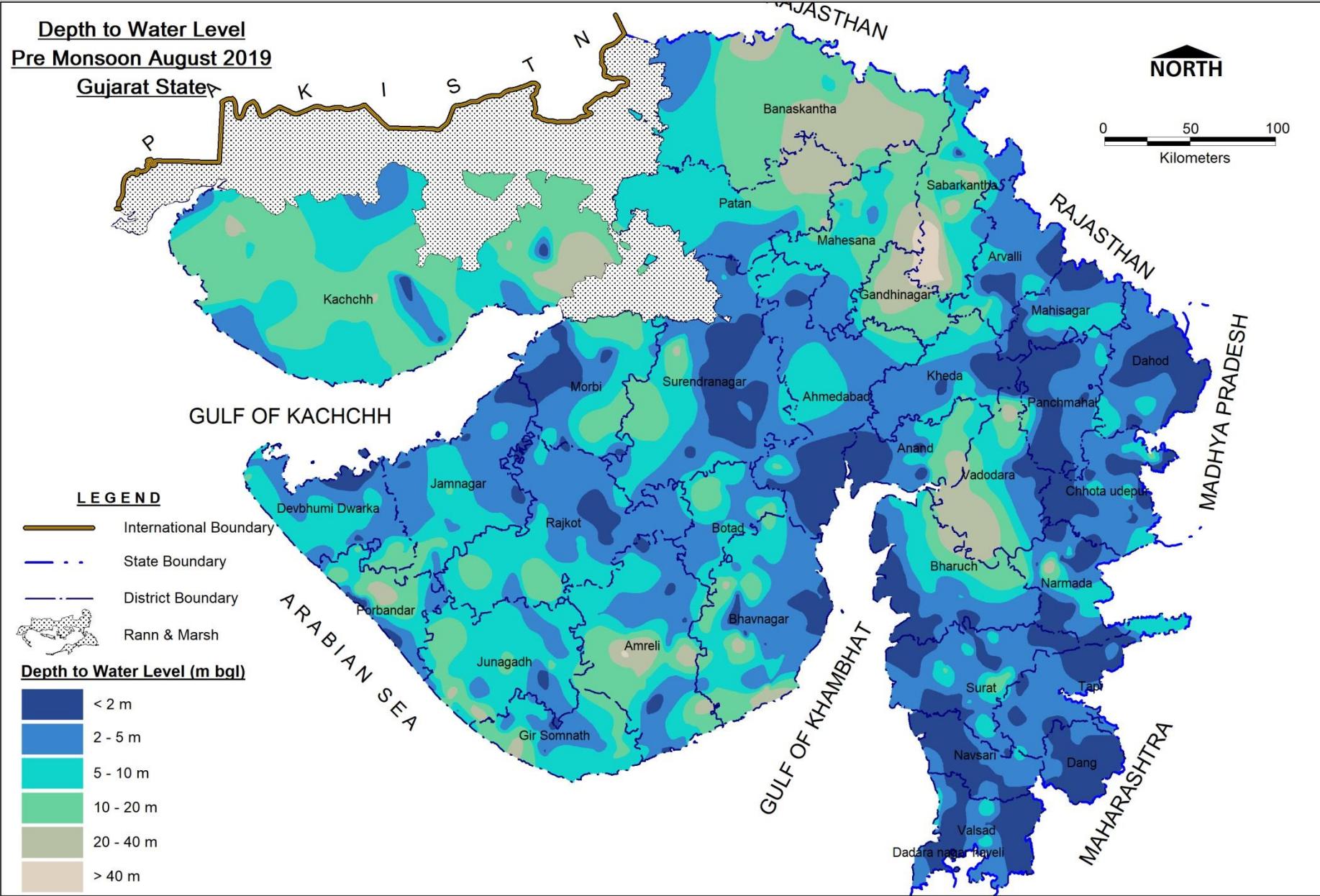
Depth to Water Level
Pre Monsoon May 2019

Gujarat State

NORTH

0 50 100
Kilometers





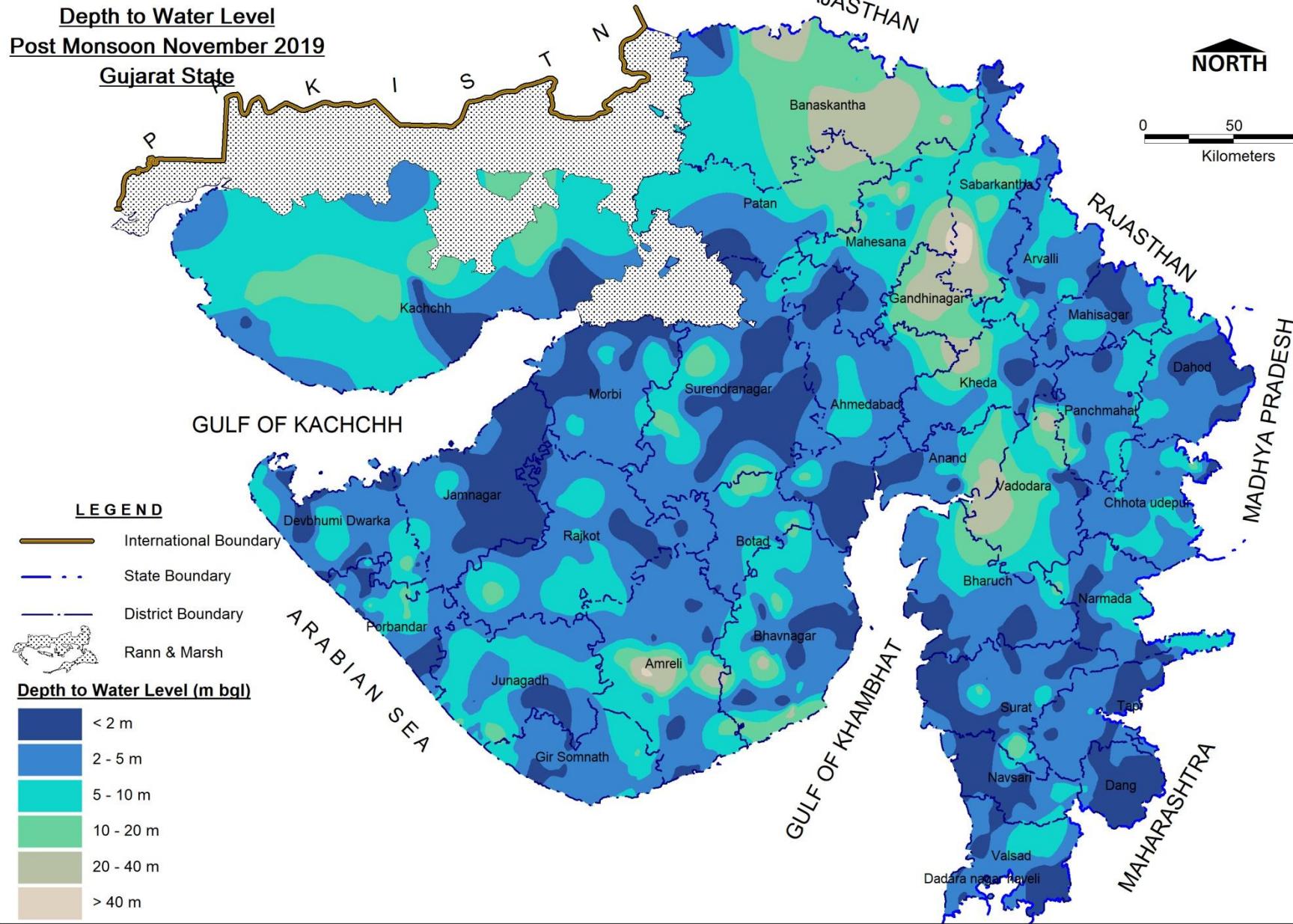
Depth to Water Level

Post Monsoon November 2019

Gujarat State

NORTH

0 50 100
Kilometers



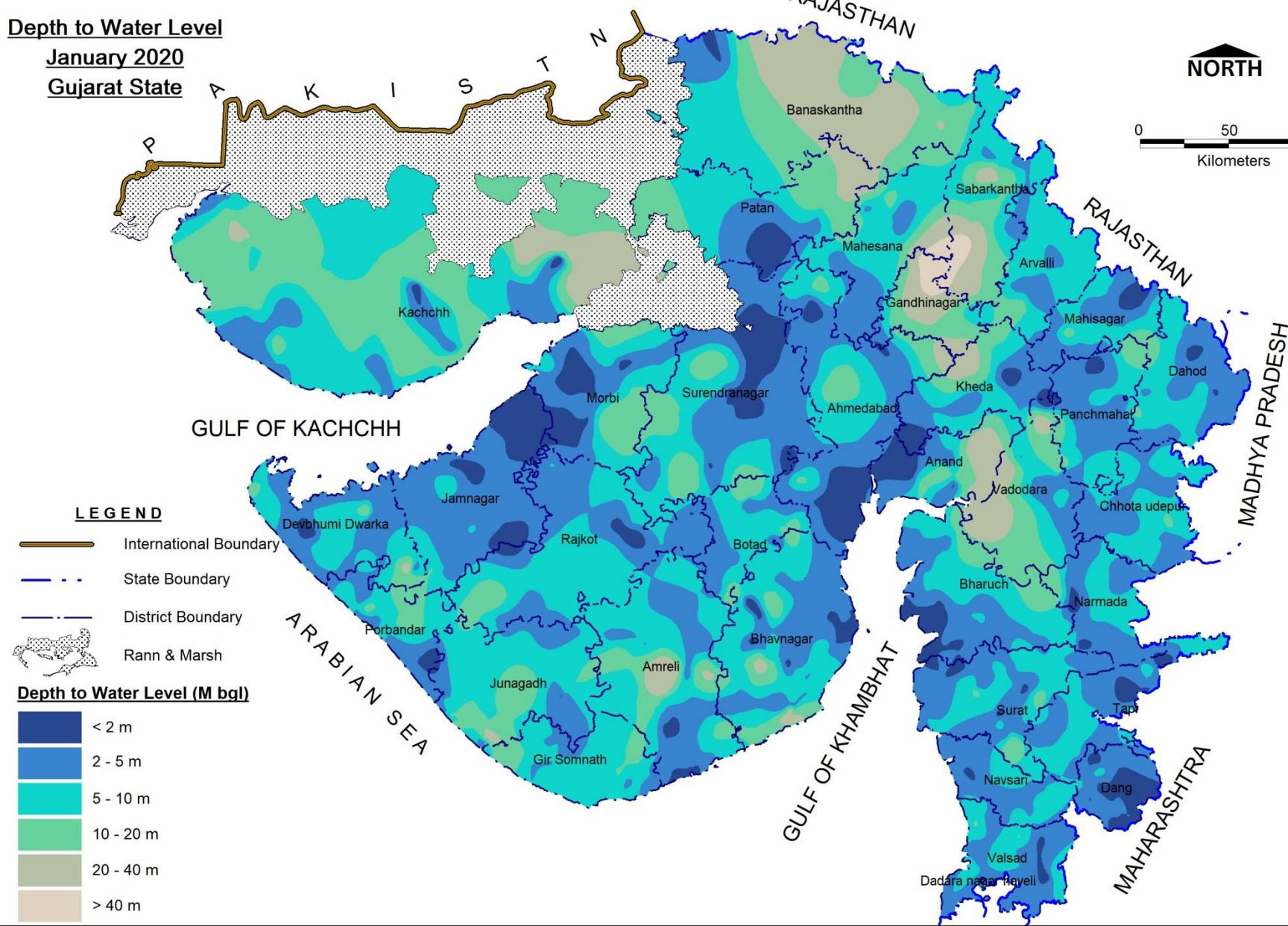
Depth to Water Level

January 2020

Gujarat State

NORTH

0 50 100
Kilometers



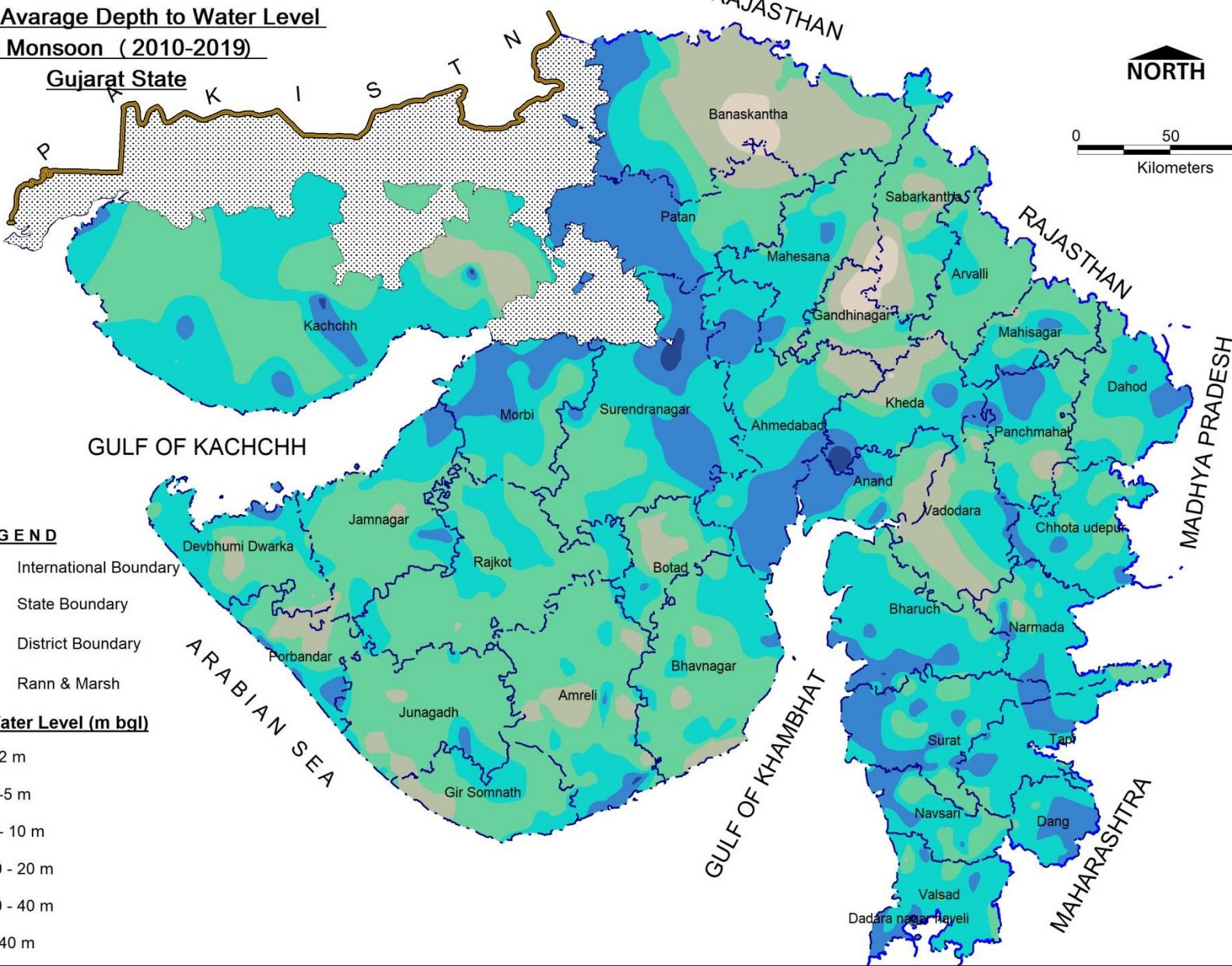
Decadal Average Depth to Water Level

Pre Monsoon (2010-2019)

Gujarat State

NORTH

0 50 100
Kilometers



Decadal Average Depth to Water Level

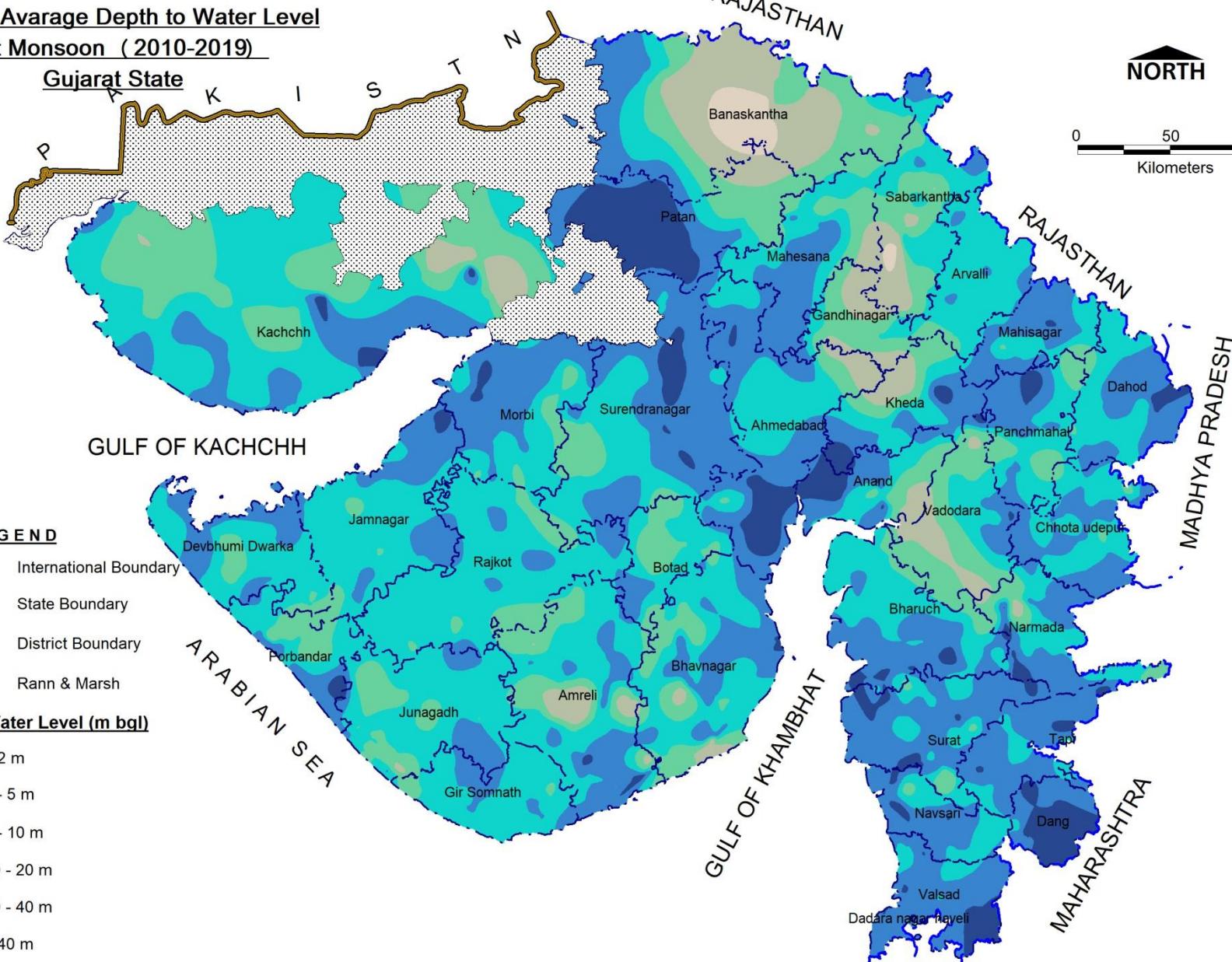
Post Monsoon (2010-2019)

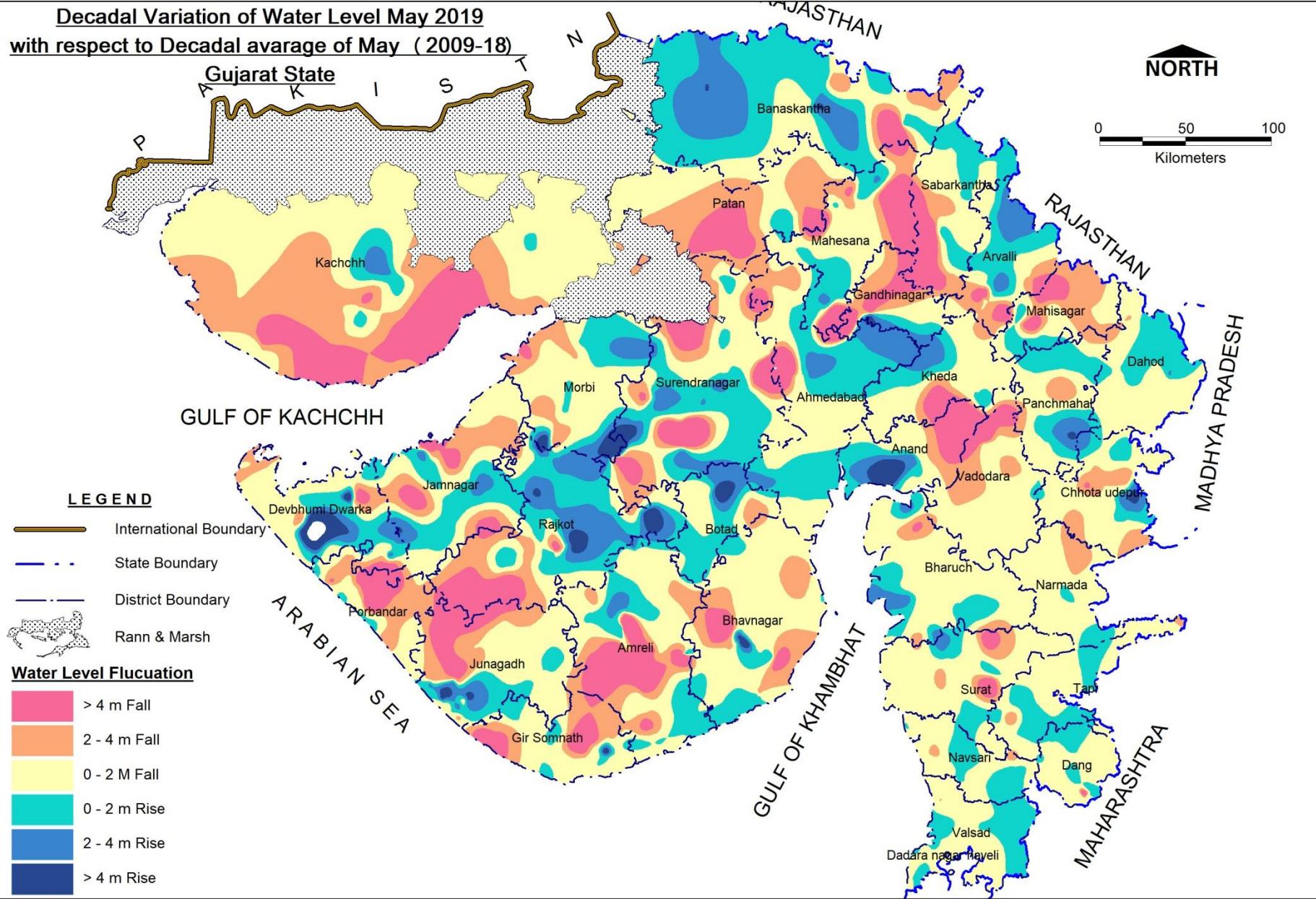
Gujarat State

K I S T N

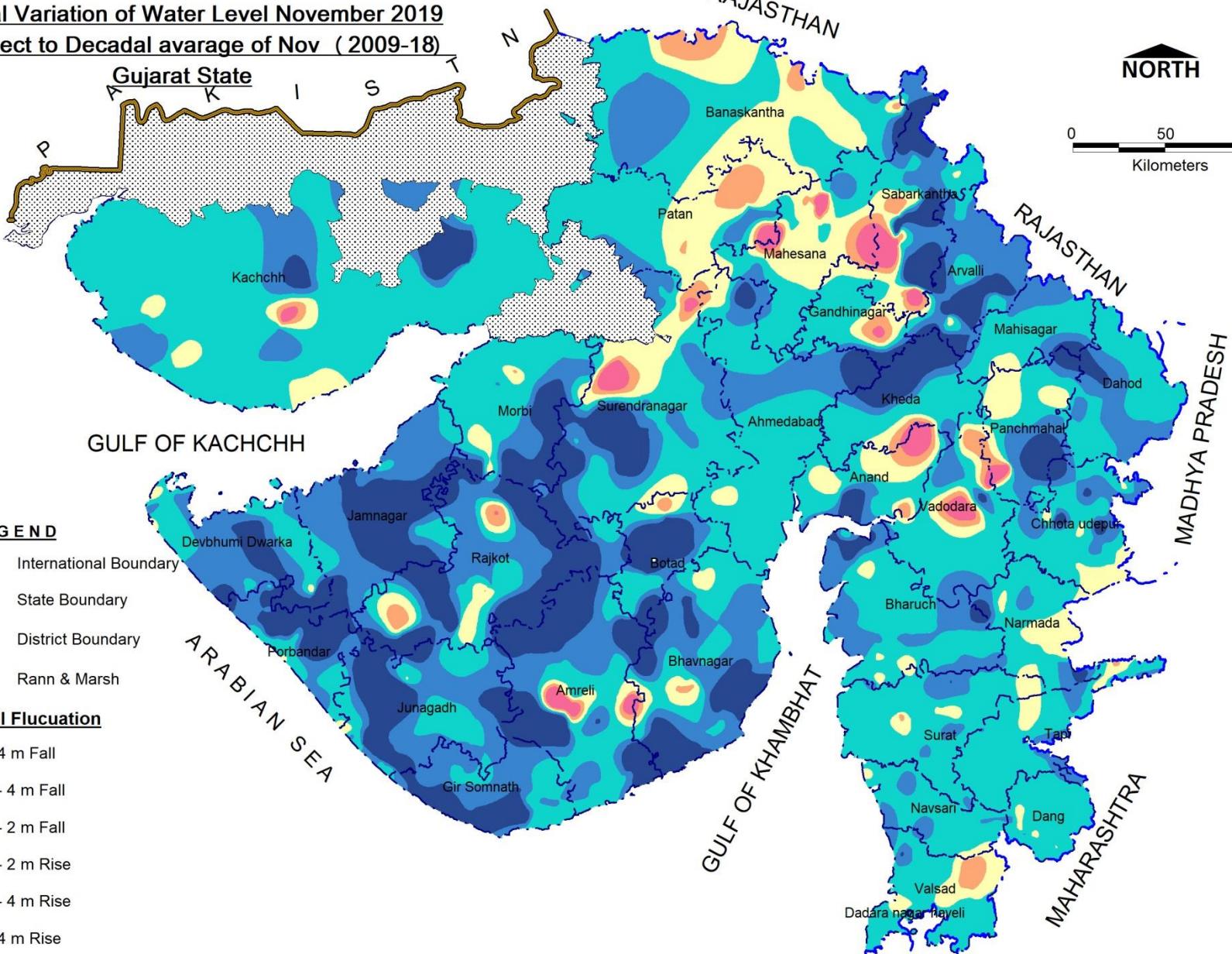
NORTH

0 50 100
Kilometers





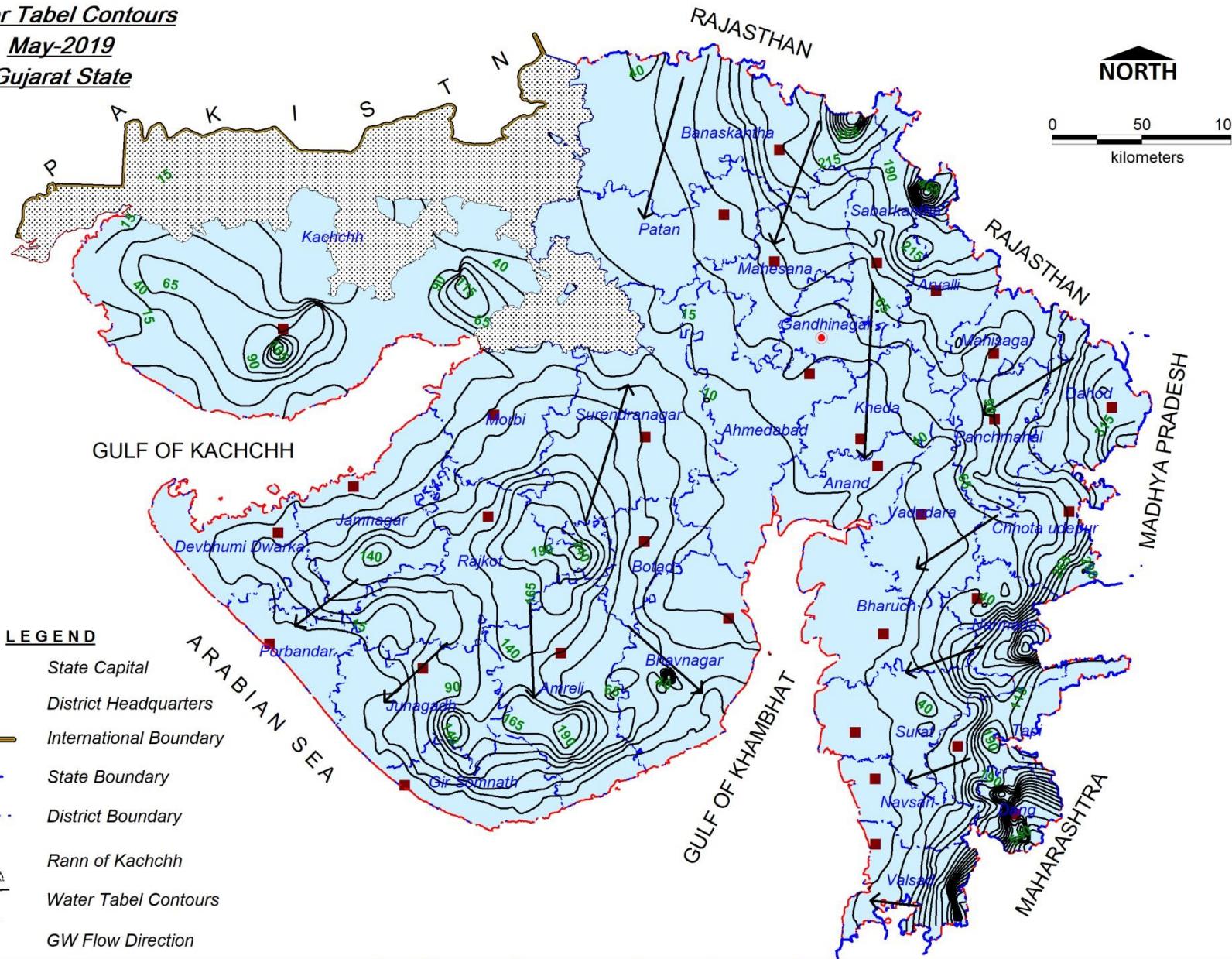
**Decadal Variation of Water Level November 2019
with respect to Decadal average of Nov (2009-18)**



Water Table Contours

May-2019

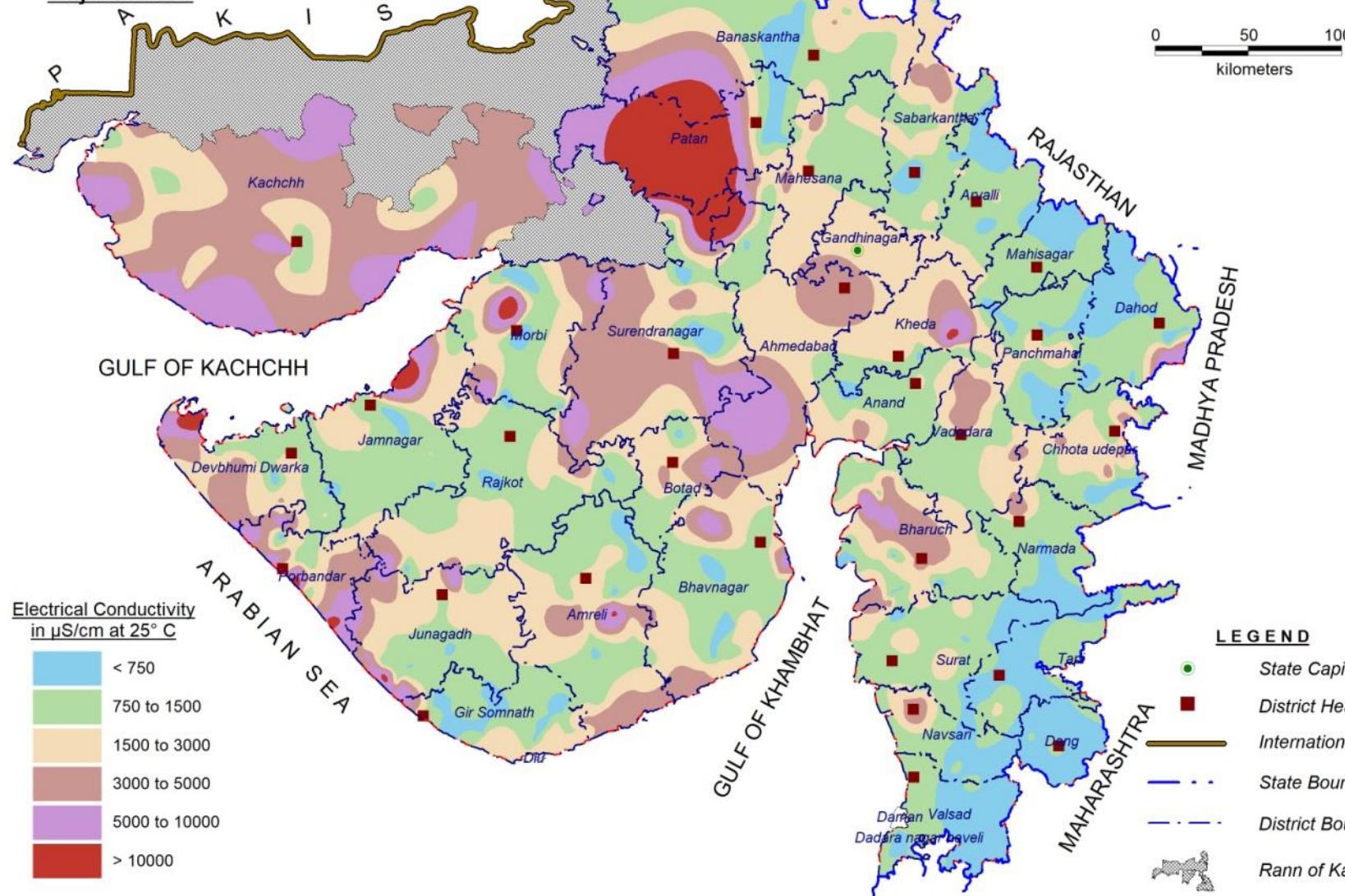
Gujarat State



Electrical Conductivity

Pre-monsoon 2019

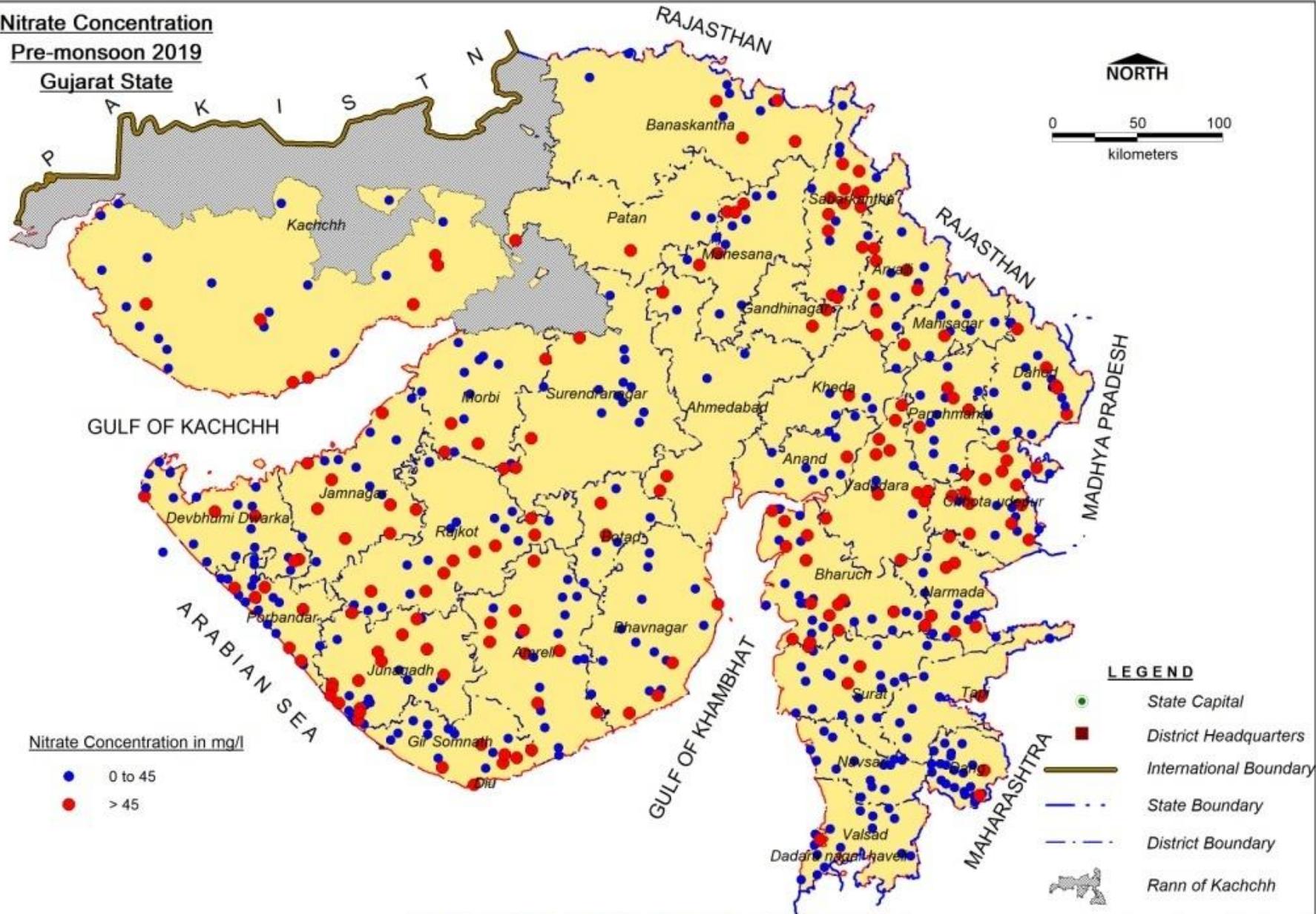
Gujarat State



Nitrate Concentration

Pre-monsoon 2019

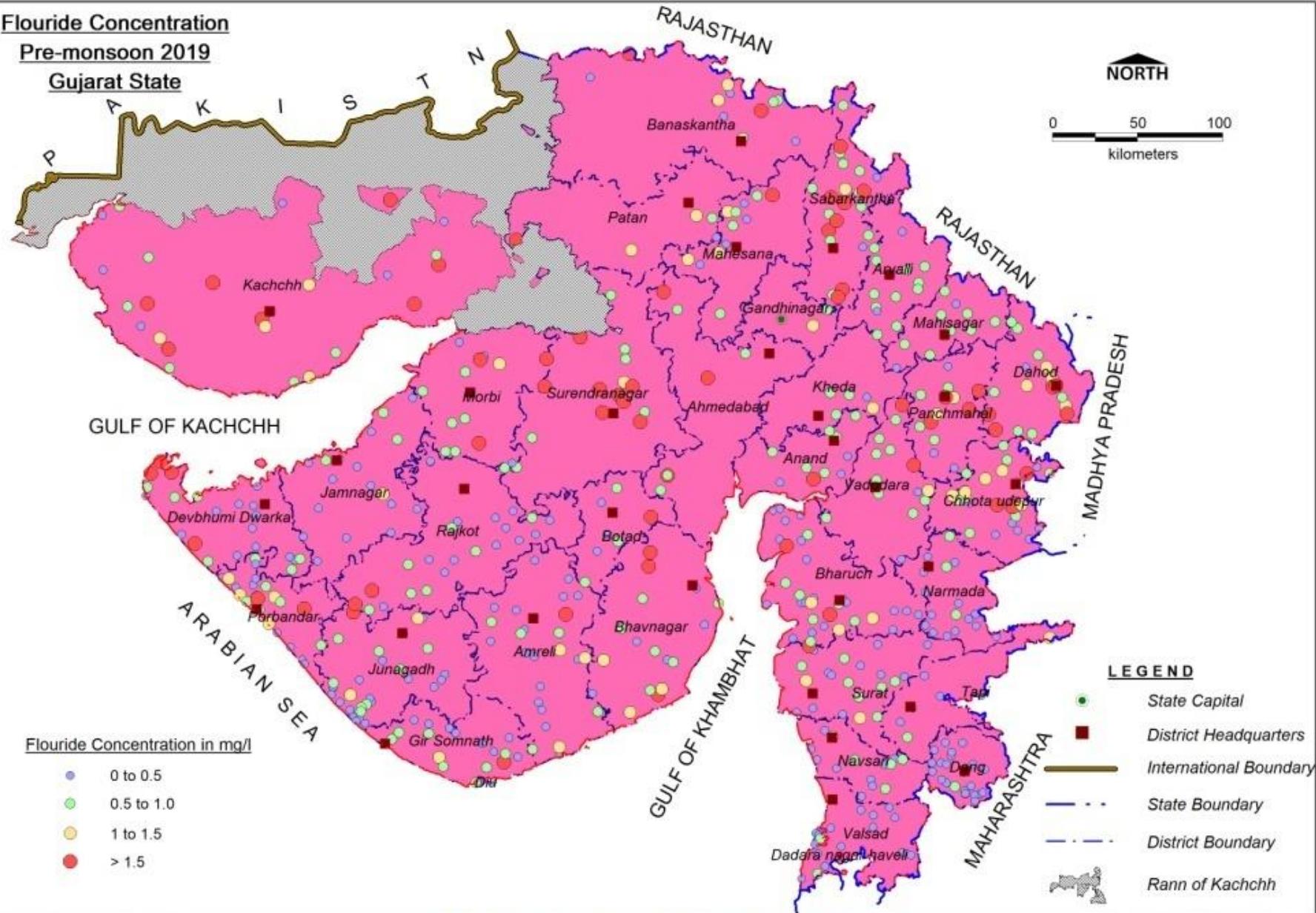
Gujarat State



Fluoride Concentration

Pre-monsoon 2019

Gujarat State

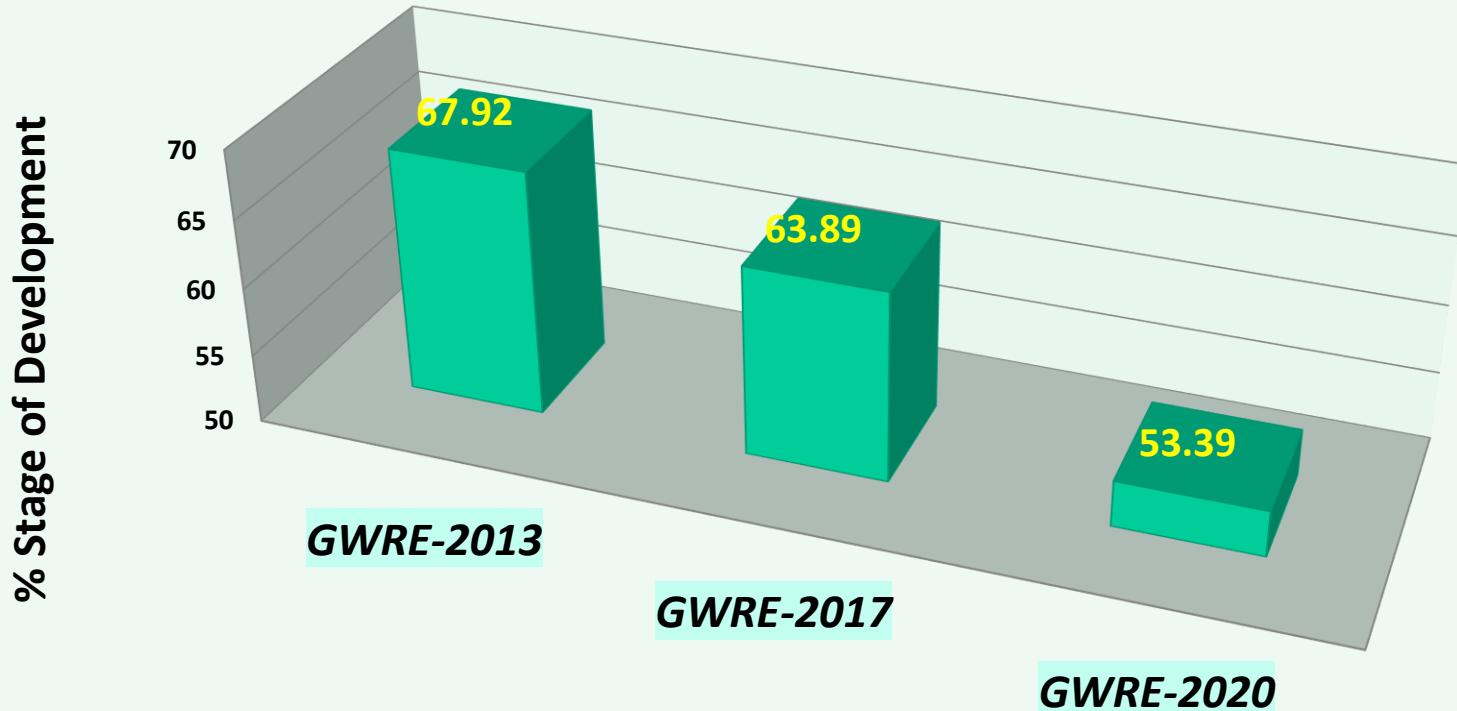


Ground water Resources 2020 for Gujarat			(Bcm)
Ground Water Recharge	Monsoon Season	Recharge from rainfall	19.59
		Recharge from other sources	2.89
	Non-monsoon Season	Recharge from rainfall	0
		Recharge from other sources	4.32
	Total Annual Ground Water Recharge		26.81
	Total Natural Discharges		
Annual Extractable Ground Water Resource			24.91
Current Annual Ground Water Extraction	Irrigation		12.65
	Industrial		0.03
	Domestic		0.62
	Total		13.3
Annual GW Allocation for Domestic Use as on 2025			0.78
Net Ground Water Availability for future use			12.52
Stage of Ground Water Extraction (%)			53.39

Dynamic Ground Water Resources of Gujarat

A comparison 2013 vs 2017

SI No		GWRE 2013 (values in MCM)	GWRE 2017 (values in MCM)	GWRE 2020 (values in MCM)
1.	Annual Replenishable Ground Water Resources	20853.98	22368.58	26808.84
2.	Natural Discharge During non-monsoon Season	1066.51	1118.44	1903.58.2
3.	Annual Extractable Ground Water Recharge	19787.47	21250.14	24905.26
4.	Current Annual Ground Water Extraction	13440.13	13577.24	13296.3
5.	Stage of Ground Water Extraction (%)	67.92	63.89	53.39
Total no of Assessment Units		223	248	248
Categorization		OE- 23 Critical-06 Semi Critical-09 Safe-175 Saline-10	OE- 25 Critical-05 Semi Critical-11 Safe-194 Saline-13	OE- 25 Critical-04 Semi Critical-24 Safe-182 Saline-13



■ Stage of Ground Water Extraction (%)

	GWRE-2013	GWRE-2017	GWRE-2020
■ Stage of Ground Water Extraction (%)	67.92	63.89	53.39

Thank You!!

