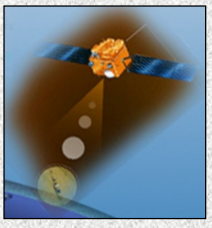
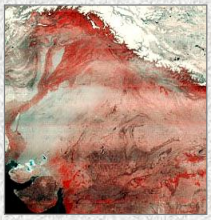
Int. Seminar `Determining Cultural Continuity since Vedic and Epic Eras'
Organised by: I-Serve, New Delhi

Vedic Saraswati River Network in the Late Quaternary Period from Mansarovar to Dwaraka: Perceived through Satellite Remote Sensing



Dr. J. R. Sharma
Chief General Manager, RCs
&
Dr. B. K. Bhadra
Scientist/Engr.`SF', RRSC-W



Regional Remote Sensing Centre – West
NRSC/ISRO, Department of Space, Govt. of India
CAZRI Campus, Jodhpur, Rajasthan

23 February, 2014

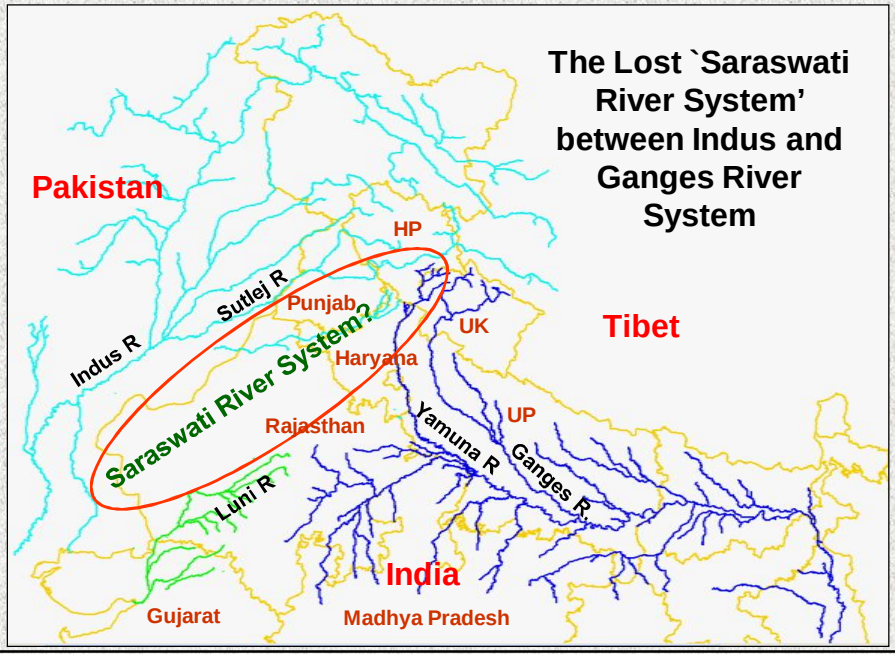
Salient Features of Vedic Saraswati River

- Regarded as one of the Holiest and Mightiest river of Vedic Period 8000-5000 B.P.
- References found in ancient Indian literature like Rigveda, Mahabharata, Ramayana, Upanishad, Saustrasutra & Puranas.
- River Satluj, Yamuna, Drishadvati, Vyas, Chotang, Ghaggar, Markanda, etc. were the tributaries of Saraswati.
- Due to flow of Saraswati and its sub-ordinate rivers, Thar desert region was once a lush green area with full of forests.
- There is Emotional / sentimental / religious attachment of the people of the region.

Geographical Identity of River Saraswati

- Palaeo-drainage systems in NW India have been a topic of research for many decades. Main reason was search for major extinct river system like “Saraswati” whose remnants are present even today.
- Saraswati River originated in the Himalayas and flowed between Indus and Ganges through Punjab, Haryana, western Rajasthan and Gujarat. It finally drained into Arabian Sea.
- It is believed that River Saraswati still flows below the desert sand and its Himalayan connectivity is still alive.

DRAINAGE SYSTEM IN NW INDIA

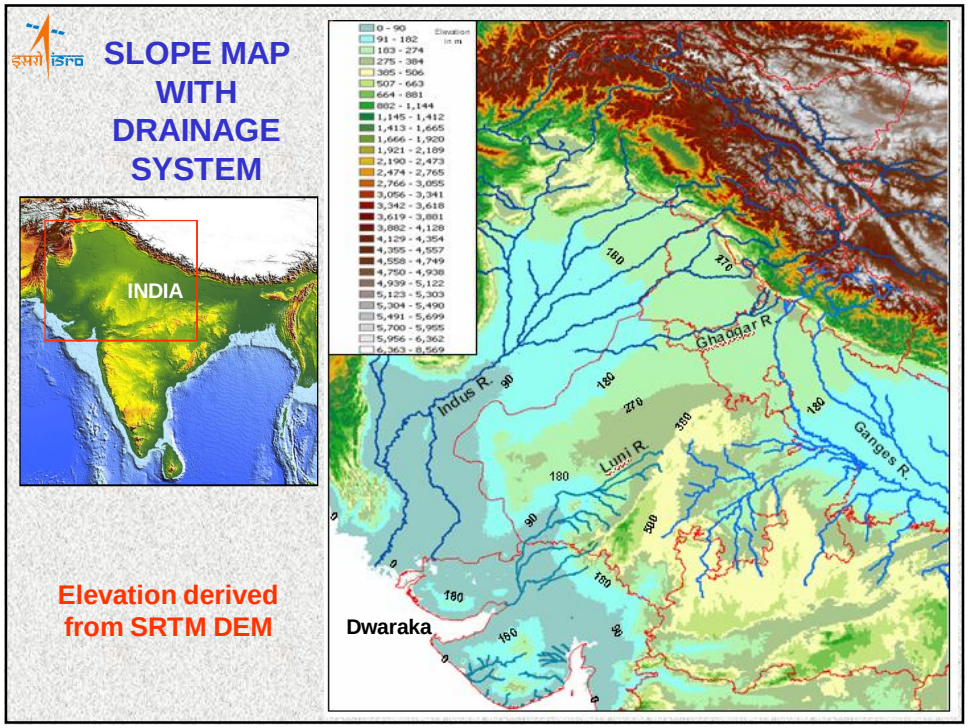


Himalayan Rivers

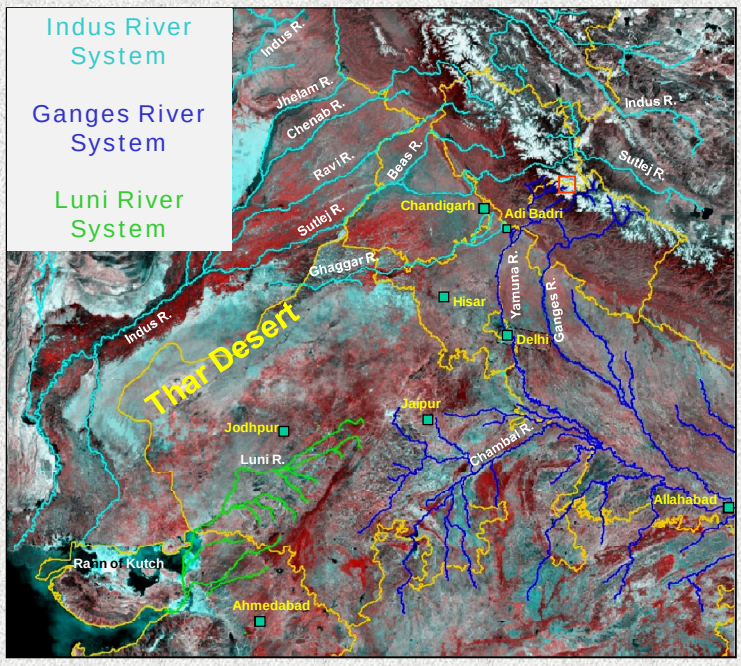
Himalayan Rivers are typical examples of antecedent drainages which formed during Quaternary period. Important Rivers of the NW Himalaya are:

1. **Indus River –** It originates from a glacier near Bokhar Chu in Tibetan region at an altitude of 4164m in Kailash Mountain Range.
2. **Sutlej River** – It originates from Rakas Lake at an altitude of 4555m in Tibet and is connected with Man Sarovar Lake by a stream.
3. **Ganga River** - It originates at Gangotri glacier near Gomukh in Garhwal Himalayas in Uttarakhand at an altitude of 3,900m in the central highlands.
4. **Yamuna River** - It rises at Yamunotri Glacier at an altitude of 3316m on Bandarpunch range and enters the Ganga plain.

The **Saraswati River** was fed by melt from Himalayan glaciers, after the receding of the last ice age during 10,000 BP.



Satellite Image showing Three Distinct Drainage Systems in NW India



Remote Sensing Techniques Used for Delineating Palaeochannels

Palaeochannels are basically the old course of river channels which appears on the satellite image as serpentine drainage course with high moisture content (dark tone).

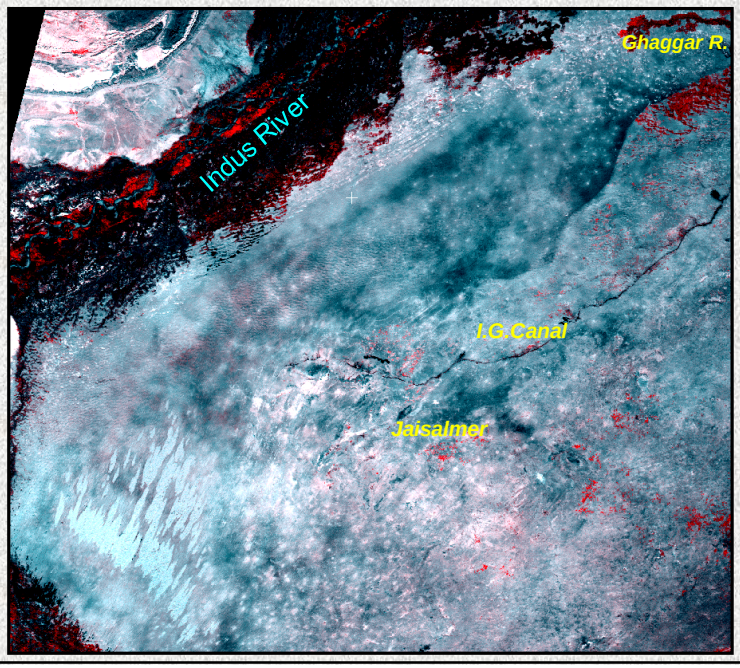
- **"Piece-wise Histogram Stretching"** technique has been used to enhance the palaeochannel signatures on the image. The feature enhancement is carried out by way of loading sub-scenes of 1k x 1k size on computer terminal in full resolution and improving the feature contrast by histogram stretching interactively.

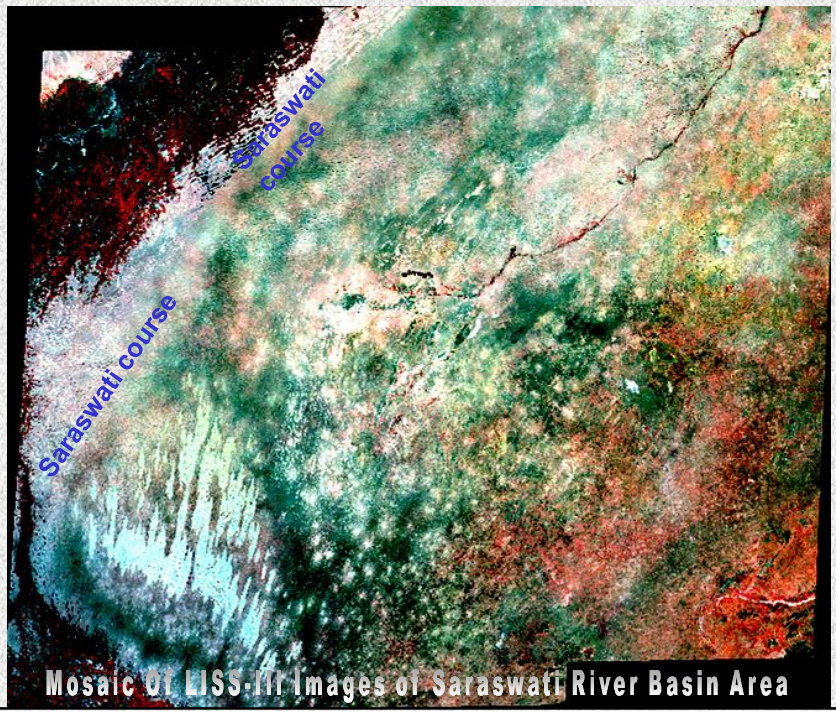
- This **technique has been found unique** in enhancing palaeochannel details in the sandy as well as alluvial and vegetated areas.

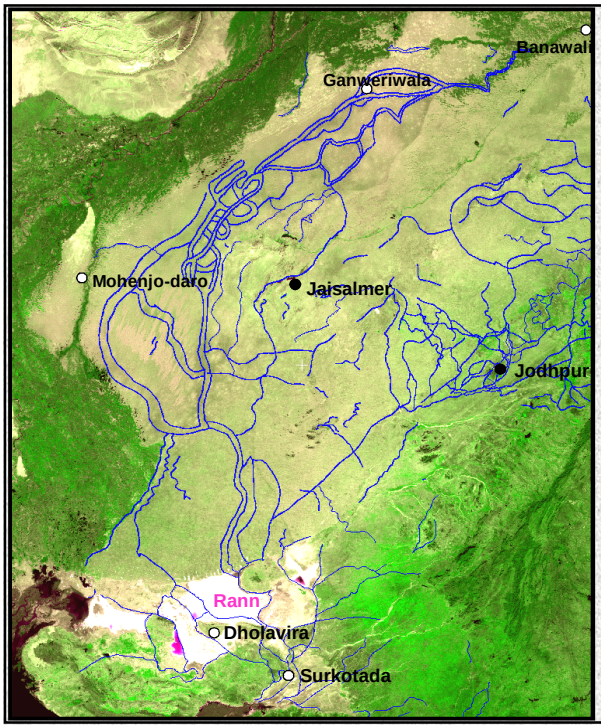
- These palaeochannels also have been **validated through collateral ground data** such as geomorphic anomalies, drilling data (litholog) of tube wells, hydrological parameters (discharge and groundwater quality), age of ground water, archaeological data and published old maps.

Course of Saraswati in Rajasthan

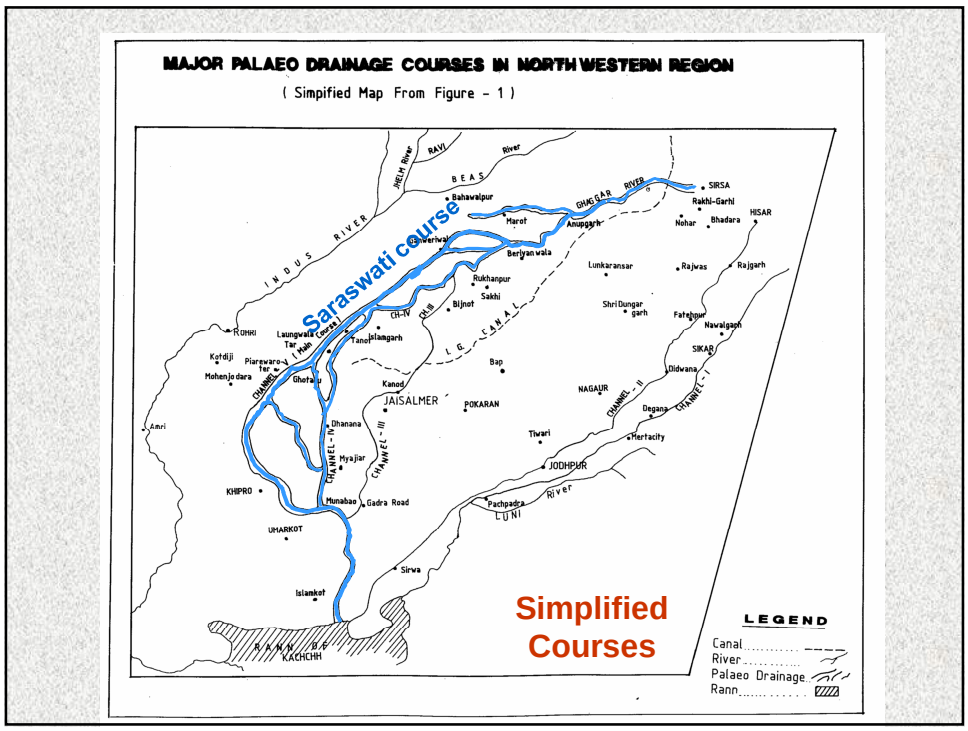
IRS WiFS FCC of Part of Saraswati River Basin







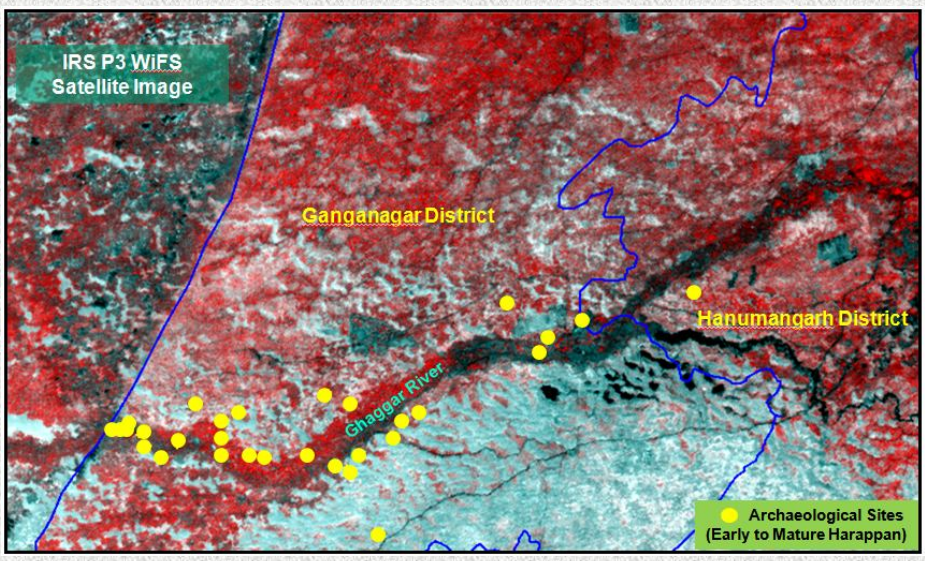
Palaeo Drainage Map of The Indian Desert Region using IRS P3 WiFS Satellite Image



Ground Validation of Palaeochanels

- Through Drilling data: 14 wells drilled by CGWB & GWD.
  - Potable quality water found along the Palaeo Channels
  - Occurrence of Gravel & coarse grained sand reported
  - Channels occur at 20-40 m depth
- Palaeo Geomorphic features - Corn Cob structure
- Archaeological data
- Ground Water Quality & age data
- Palaeo Maps British and Mughal Period

IRS WiFS image showing 81 Harappan Sites along Ghaggar River in Ganganagar and Hanumangarh Districts of Rajasthan



DRILLING SITES ALONG THE PALAEOCHANNELS IN RAJASTHAN

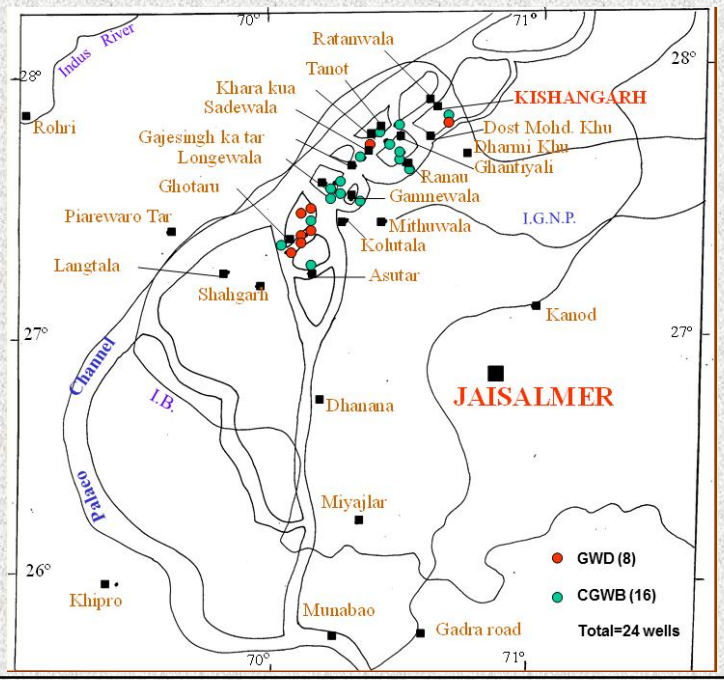


Table – 1 : Data of the tube wells drilled along the palaeo channels in the Jaisalmer district
(Source : Ground Water Department, Government of Rajasthan, Jodhpur)

Sl. No.	Drilled Site	Year Of Construction	Yield (lph)	Quality (EC) TDS figs. in brackets	Depth Drilled (m)	Static Water Level (m)	Structure Installed	Aquifer material as observed in lithologs
1	Tanot 3.5 Km from Ghantiyali to Tanot LHS of Road	1999-2000	11250 by compressor	4400 (2850)	125	33	Tubewell	Mainly fine grained sand, medium grained at some levels.
2	Ghotaru-I 12.5 Kms Ghotaru to Longewala	1999-2000	13500 by compressor	10800 (6506)	151	43	Tubewell	Medium to coarse sand and gravel Out of main channel
3	Ghotaru – II 14.5 Kms Ghotaru to Longewala	1999-2000	Not Developed	-	151	-	-	Fine grained sand –sandstone chips-fine grained S.St.-Kankar . Out of main channel
4	Ghotaru – III 10 Kms from Ghotaru to Longewala, RHS of road	1999-2000	2250 by compressor	7200 (4337)	151	48	Tubewell	Fine grained sand –very coarse grained gravelly sand
5	Ghotaru – IV 3 Kms from Ghotaru to Longewala, RHS of road	1999-2000	32400 by pump	5900 (3554)	151	45	Tubewell	Medium to fine and coarse grained sands
6	Ghotaru – V 150 m NE of Fort	1999-2000	39600 by pump test	2550 (1536)	148	33	Tubewell	Coarse gravelly sands, fine to medium grained sands and occasional clayey sands
7	Ghotaru –VI 1.5 Kms from Ghotaru to Asutar, RHS of road	2000-2001	22500 by pump test	1550 (934)	125	46	Tubewell	Dominantly medium to coarse sands, fine grained and clayey sands at few levels.
8	Dhanni Khu 3 Kms from Kishengarh to Dhanni Khu, RHS of road	2000-2001	36100 by pump test	1700 (1024)	153	40	Tubewell	Fine and medium grained sands
9	Ranau – I * Ranau-Tanot Road, ~2 km from Ranau on LHS of road	1998-1999	9120 by compressor	1676 (1010)	102	42	Tubewell	Fine grained sand and silt with kankar; fine to medium sand
10	Ranau – II* Close to Ranau village RHS of Tanot road	1998-99	18240 by compressor	1660 (1000)	120	58	Pelzometer	N.A.
11	Kanthal* Ranau and Tanot road 9.5 km from Ranau LHS of Road	1998-1999	12312 by compressor	2990 (1800)	125	42	Pelzometer	Mostly Fine sand
12	Nathura Kua* 4.5 Km from Tanot, 250 m RHS of road	1999-2000	12768 by compressor	4410 (2656)	120	36	Pelzometer	Fine grained sand and silt with kankar
13	Kuria Beri*	1998-1999	12768 by compressor	2150 (1295)	131	32	Tubewell	Mostly Fine sand
14	Ghantiyali I* 500 m from Ghantiyali Mandir to Tanot,LHS of Road	1998-1999	11400 by compressor	3650 (2200)	130	62	Pelzometer	Fine grained sand

Note : Yield by pumps are normally higher than the compressor yield by a factor of 1.5 to 2.0 * Wells are drilled by the CGWB

Ages of groundwater samples from Jaisalmer district (Analysed by BARC)

Sample ID	Location	Well Type	Age Uncorrected (Before Past)	Model Age, a (Pearson)-BP
D1	Dharmikua	DW	1900	M
T1	Kishengarh	TW	6190	M
D3	Kuriaberi	DW	4390	1340
D4	Nathurakua	DW	3000	M
T2	Ghantiyali	TW	9630	5550
D5	Ghantiyali	DW	4960	1550
T3	Ranau	TW	5930	1930
T7	Ghotaru I	TW	18700	12400
D12	Ghotaru-II	DW	3860	M
D17	Dost Md.Kua	DW	5780	2000

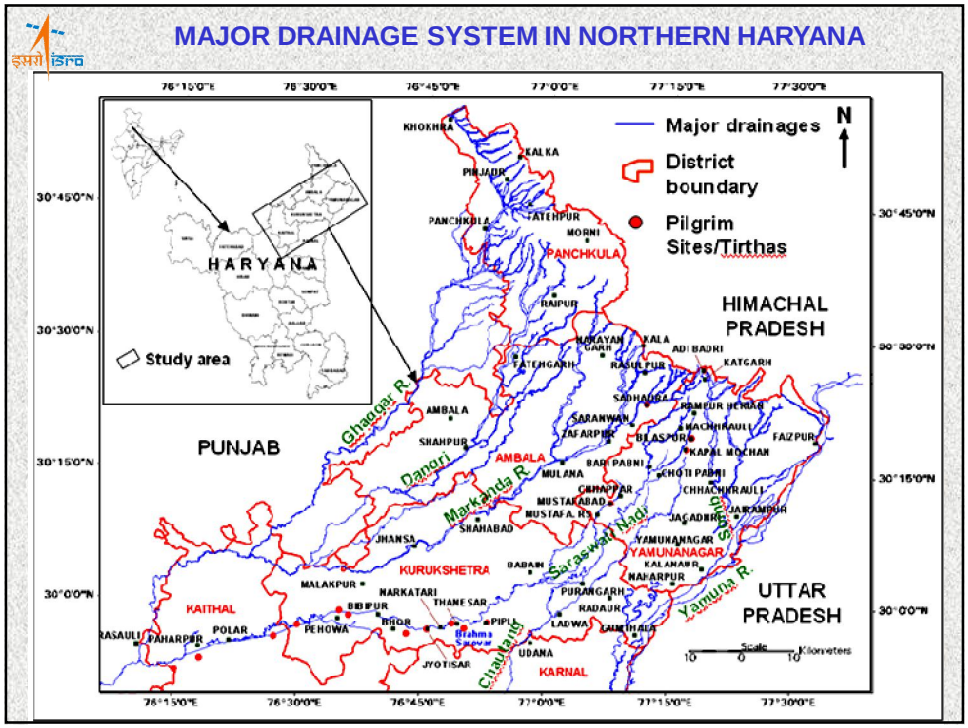
Age of Saraswati ground water ~ 1340 to 12400 BP

Hydrogeological Characters of the aquifer Zones delineated along Palaeochannels in Jaisalmer District (GWD, 2003)			
	Zone-A1	Zone-A2	Zone-A3
Formation Material	Alluvial	Alluvial	Alluvial
Area (sq.km)	547	1100	150
Dir. Location	NE part	SW part	SW part
Water Levels(m)	31-62	45-63	39-60
WL fluctuation (m)	0.14	0.02	0.69
Av. Yield (m3ph)		136	22.6
EC (omh m)	1100-4000	2960-4000	1100-4000
Aquif. Thickness(m)	18	14	9
Static GW Reserves (mcm)	590	92	81
Recharge due to RF	Negligible	Negligible	Negligible

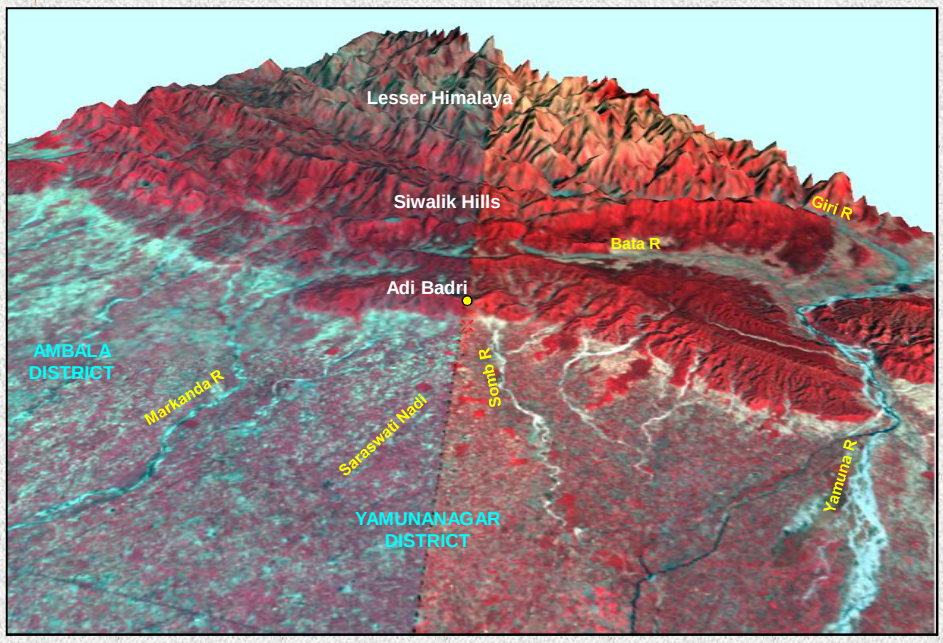
Drilling Site of ONGC at Saraswati-1 near Dabla village, 6 km S of Jaisalmer Town

VES Survey by WAPCOS – Presence of fresh water in a confined aquifer (450-530m)
Year of drilling – June, 2006; Well depth = 554 m; Water level = 90 m; Yield = 76000 liters/hr
TDS = 5500 mg/l to 3700 mg/l to 3050 mg/l

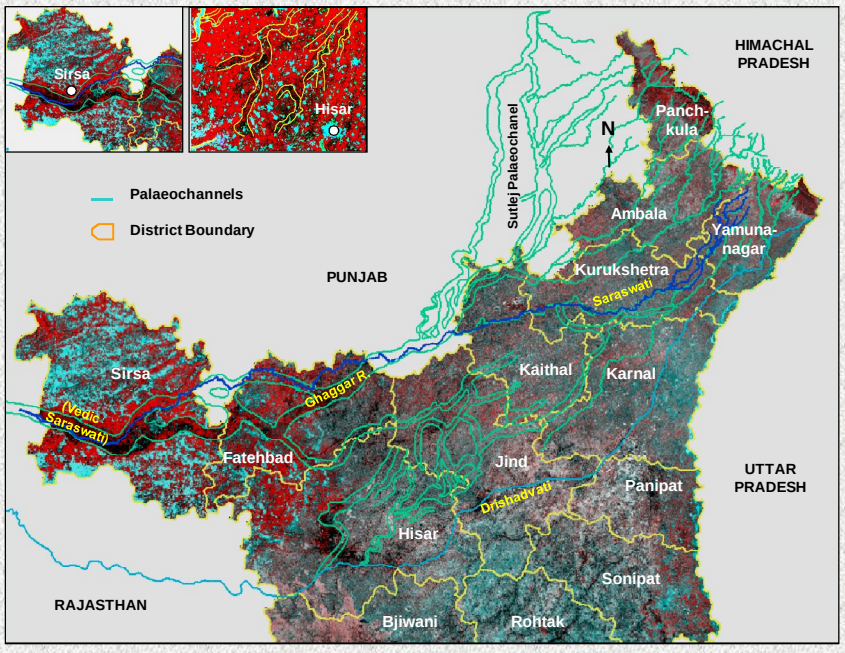
Course of Vedic Saraswati in Haryana



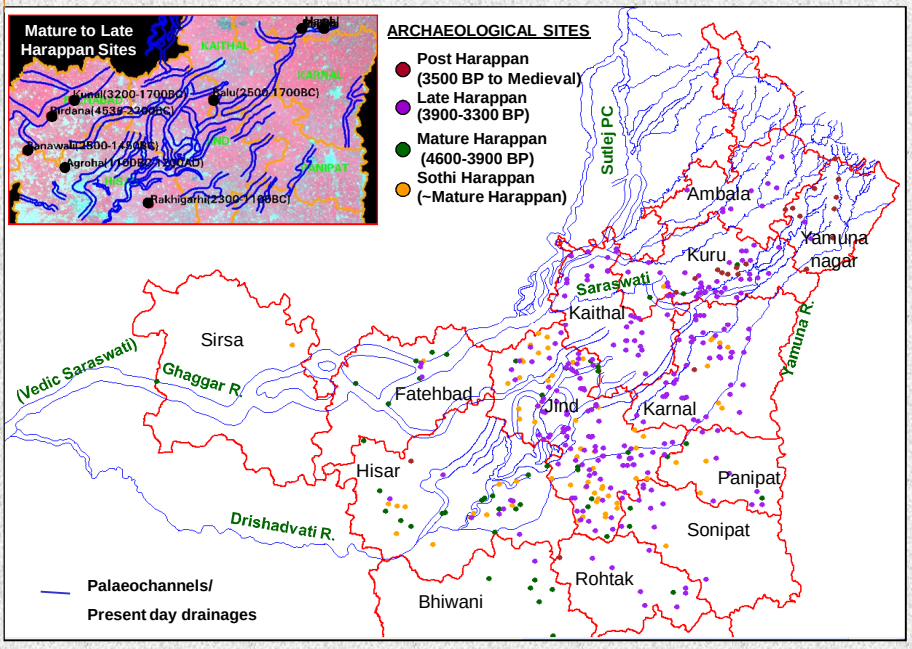
3-D View of Adi Badri Area by SRTM DEM & Landsat ETM image



IRS P6 LISS-III IMAGE WITH DELINEATED PALAEOCHANNELS IN HARYANA

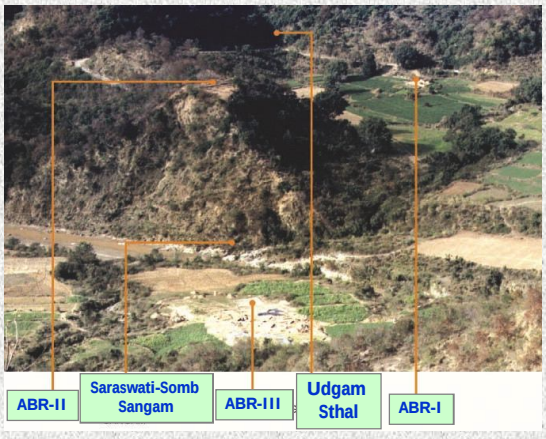


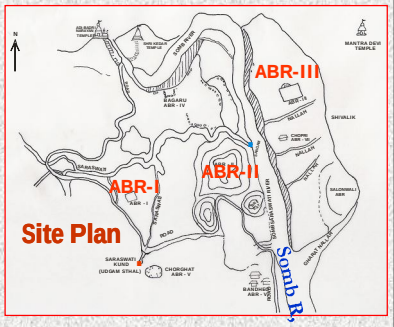
Archaeological Sites and the Palaeochannels in Northern Haryana



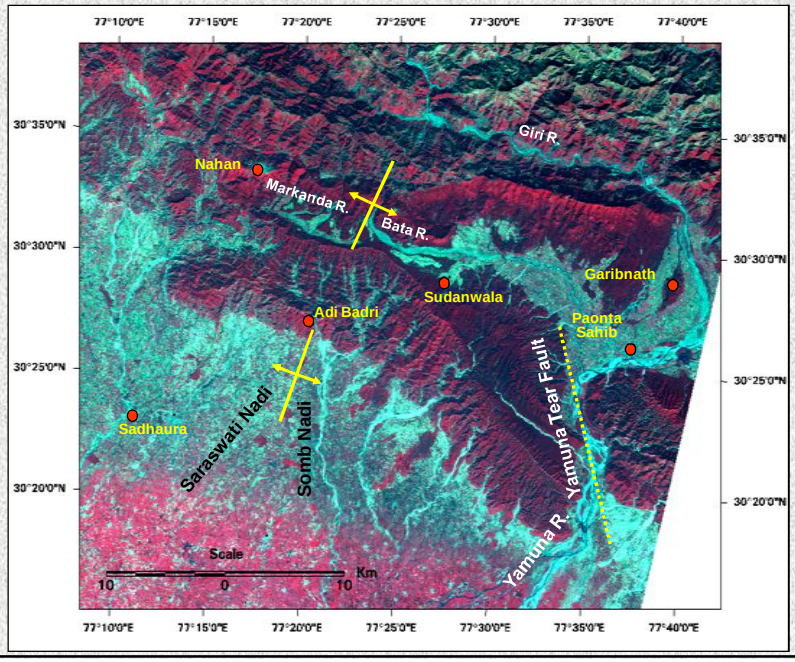
Archaeological Excavation site at Adi Badri (40 km NNE of Yamunanagar)

- The excavations were carried out at the mounds ABR-I, ABR-II and ABR-III.
- ABR-I and ABR-II are located on the western side of the *Sarasvati-Somb* confluence and ABR-III is situated on the eastern side of the confluence



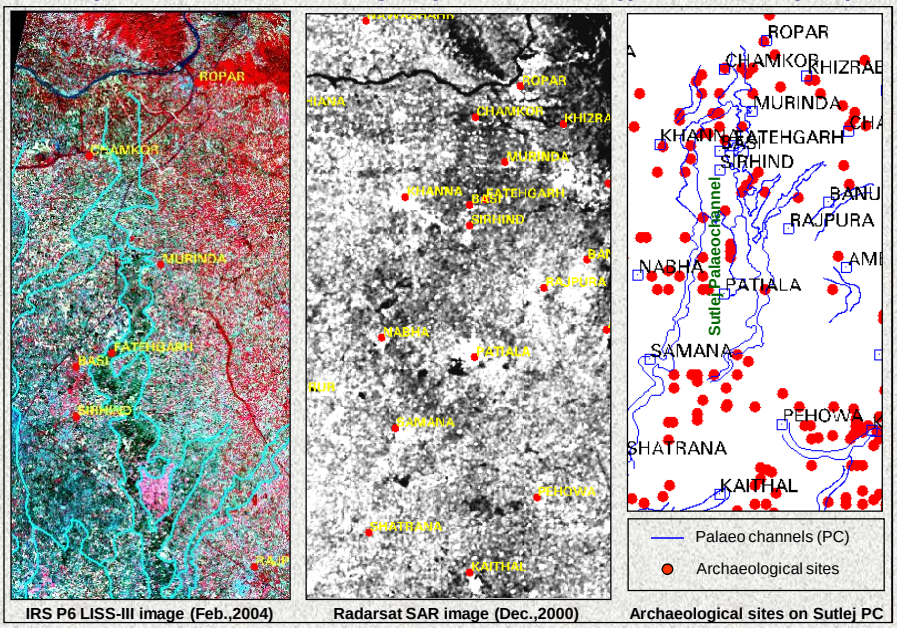


TECTONIC FEATURES AROUND ADI BADRI AREA



Course of Vedic Saraswati in Punjab

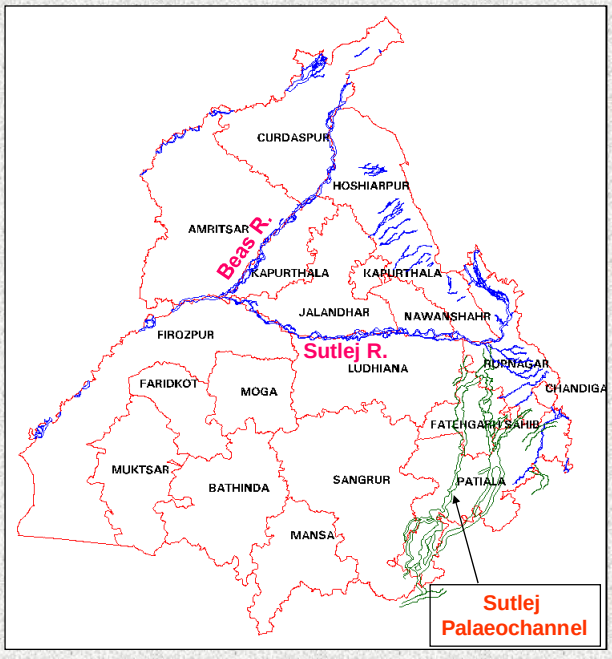
Sutlej Palaeochannels along Ropar-Sirhind-Rajpura section (N-S)

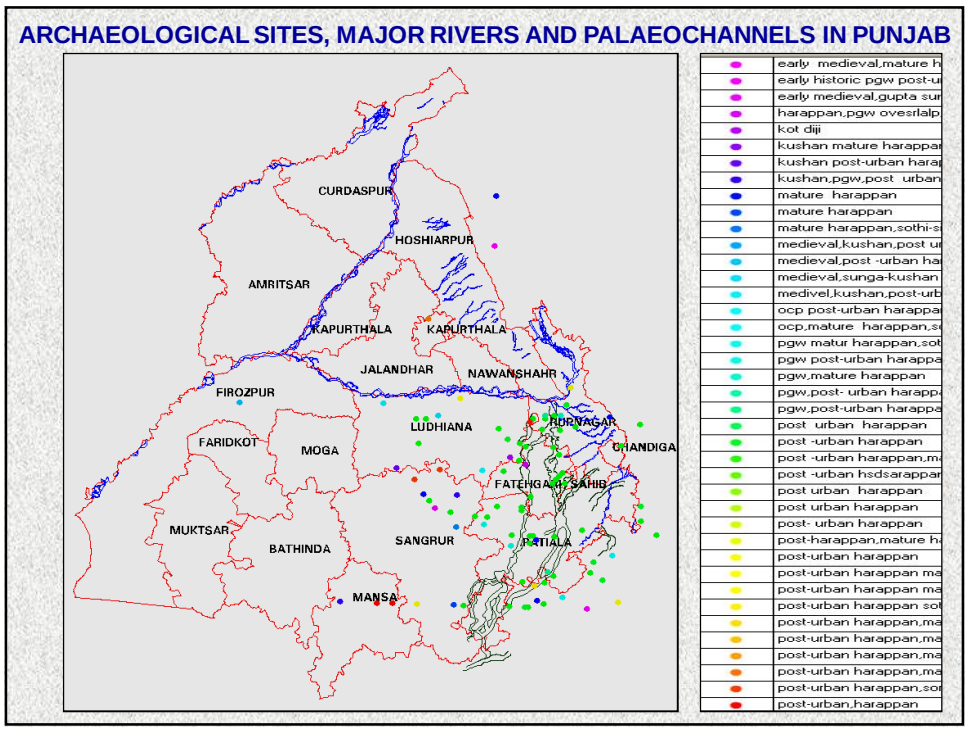


IRS P6 LISS-III image (Feb.,2004) | Radarsat SAR image (Dec.,2000) | Archaeological sites on Sutlej PC

Optical (IRS P6) and SAR (Radarsat) images showing the delineated Sutlej palaeochannels between Ropar and Shatrana in Punjab. Note a large number of archaeological sites lie along the palaeochannels.

MAJOR RIVERS AND PALAEOCHANNELS IN PUNJAB



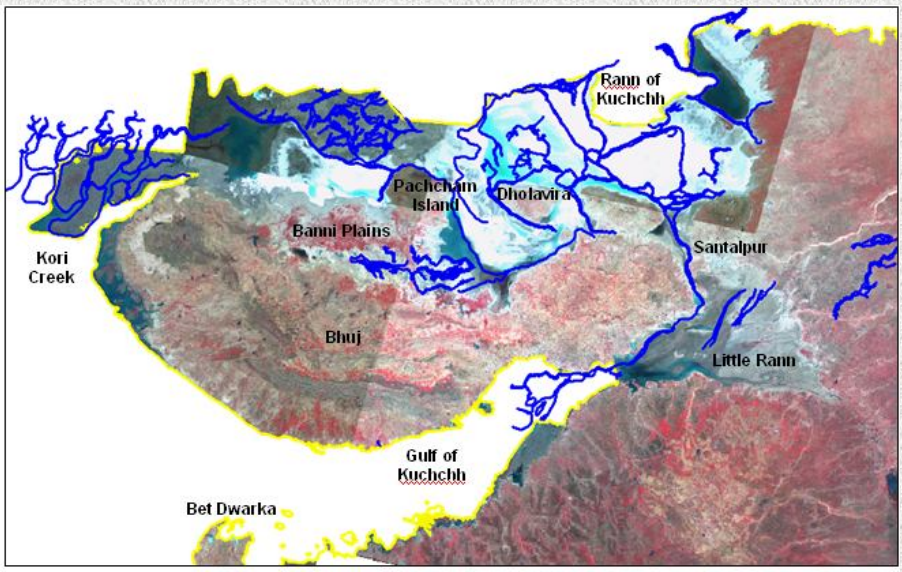


Course of Vedic Saraswati in Gujarat

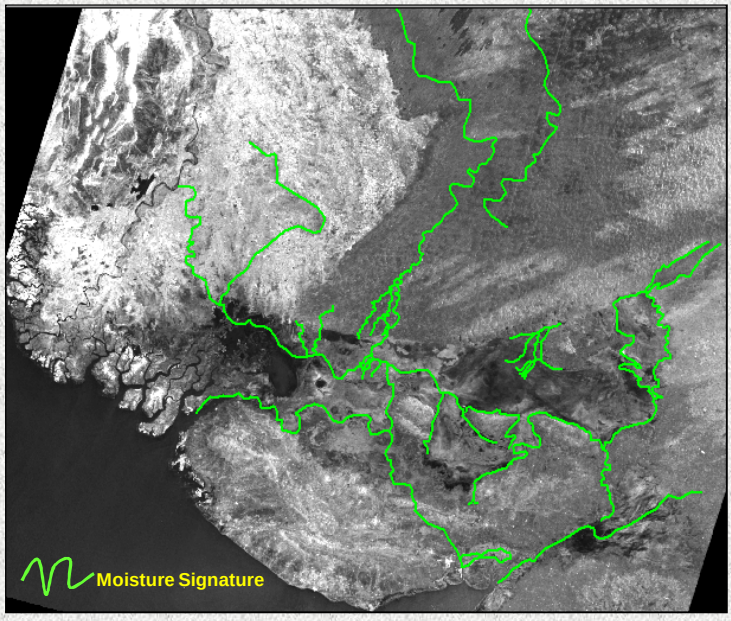
Saraswati Delta Structure at Rann of Kachchh (Gujarat)

- Digital image processing of IRS-P6 AWiFS and Radarsat SAR images reveals deltaic drainage pattern (Bird's Foot type) which is made up of complex intertwined channels.
- The delta structure was formed in the past by huge sediment discharge of Saraswati River within marshy land of Great Rann of Kachchh.
- These palaeochannels can be traced upto the Gulf of Kachchh which might have a link to the submerged Dwarka of Mahabharata times.

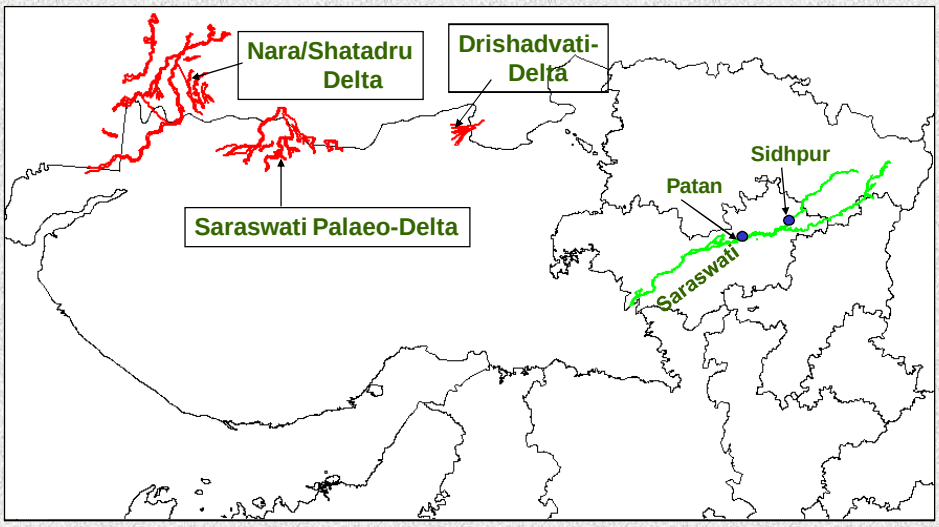
Satellite Image showing the Saraswati palaeo-drainage network (blue lines) in Rann of Kachchh area, Gujarat



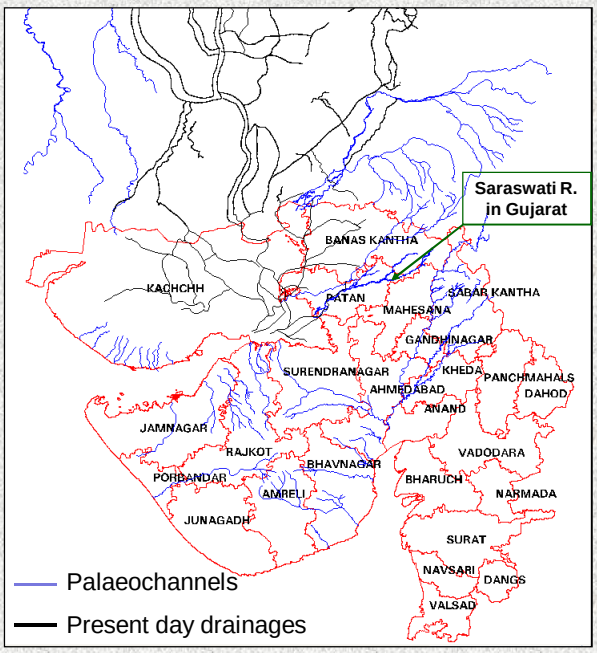
RADARSAT-SAR Image showing Moisture Signature of Palaeo-Drainages in northern Gujarat



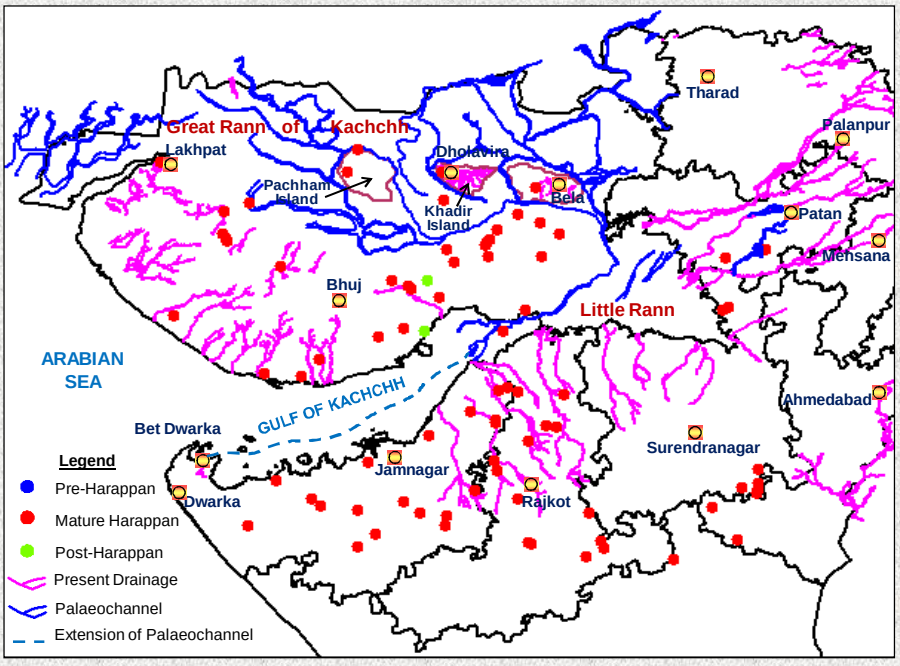
Saraswati River and its Palaeo-Delta Complex in Rann of Kachch, Gujarat



PRESENT DAY DRAINAGES AND SARASWATI PALAEOCHANNELS IN N. GUJARAT

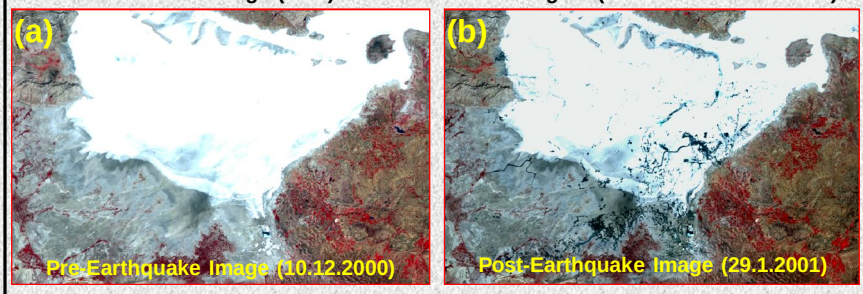


ARCHAEOLOGICAL SITES WITH PALAEOCHANNELS IN NORTHERN GUJARAT

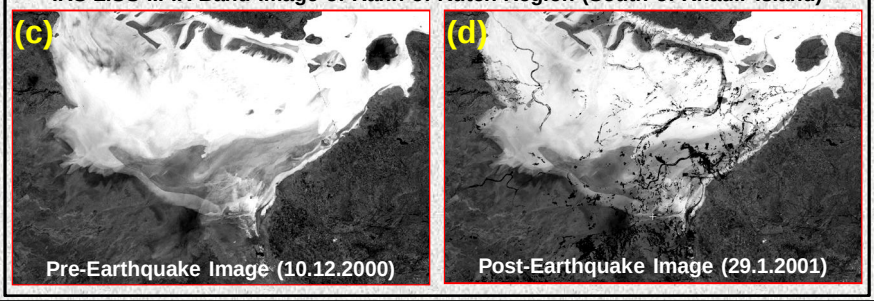


REJUVENATION OF SUB-SURFACE DRAINAGES IN RANN OF KACHCHH AREA AFTER BHUJ EARTHQUAKE IN 2001

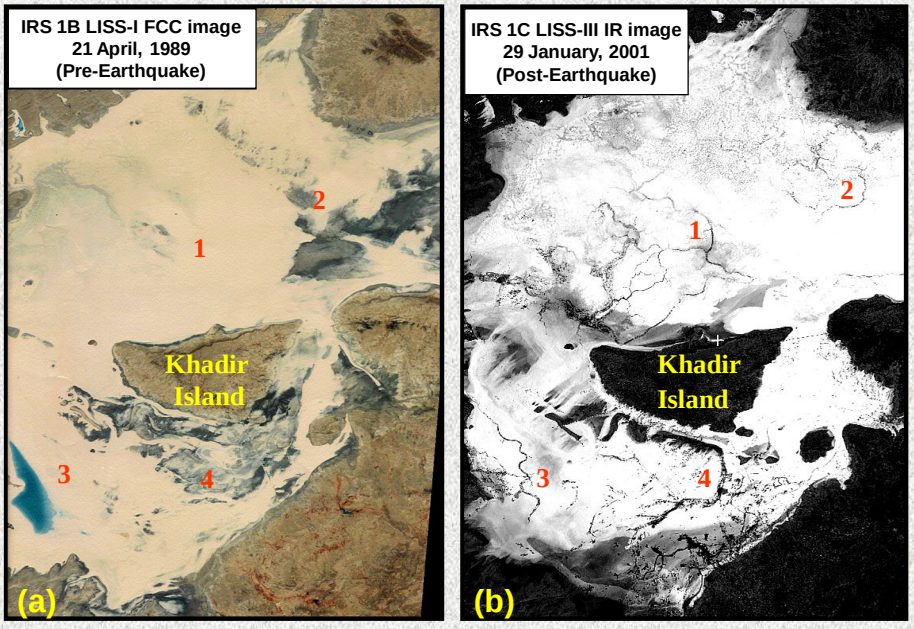
IRS LISS-III RGB Image (FCC) of Rann of Kutch Region (South of Khadir Island)



IRS LISS-III IR Band Image of Rann of Kutch Region (South of Khadir Island)



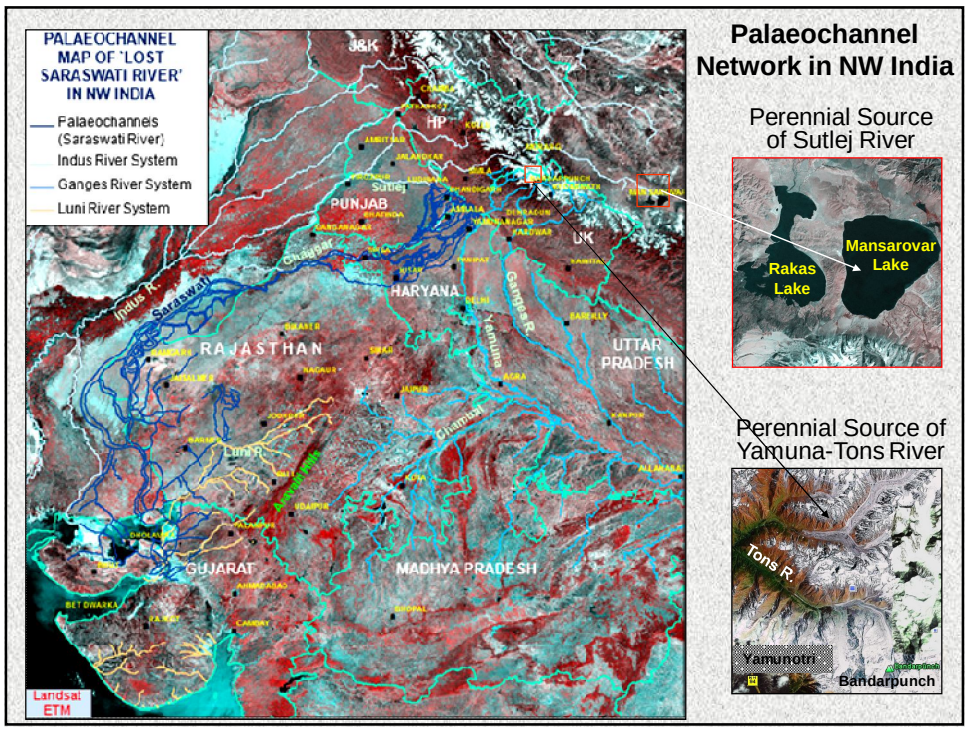
EMERGENCE OF SUB-SURFACE DRAINAGES AROUND DHOLAVIRA (KHADIR) ISLAND AFTER BHUJ EARTHQUAKE IN 2001

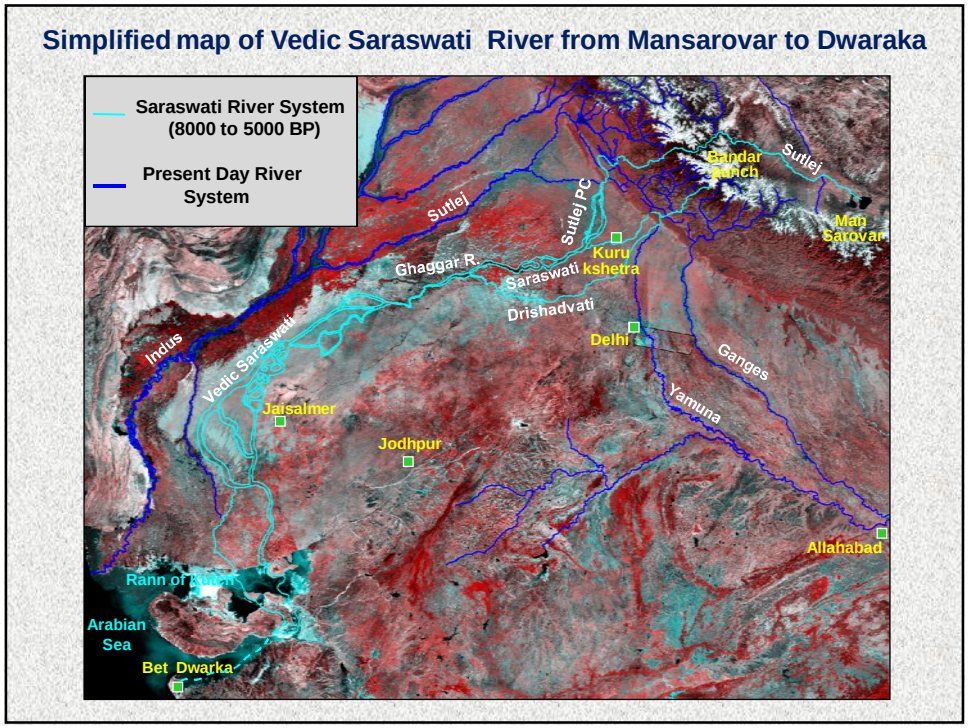


SARASWATI CONFLUENCE AT DWARAKA

- Dwaraka was the capital of the Yadavas which is mentioned in Indian epic Mahabharata. It is believed that Lord Krishna has founded this town by reclaiming 12 yojana land from the Sea at about 3,600 years ago.
- Mahabharata describes that Balaram travelled along the dry banks of Saraswati River from Dwaraka to Mathura. It is possible that Saraswati River might have continued beyond Little Rann upto Dwaraka along the Gulf of Kachchh.
- Archaeological excavation revealed the existence of Harappan settlements in Dwaraka as well as port city of Lothal. Rise in sea level caused submergence of Dwarka in 3443 BP.

Integrated Study of Vedic Saraswati in NW India


PALAEOCHANNEL MAP OF 'LOST SARASWATI RIVER' IN NW INDIA
Palaeochannels (Saraswati River)
Indus River System
Ganges River System
Luni River System
J&K
HP
PUNJAB
Sutlej
Chenab
Indus R.
Saraswati
HARYANA
Ganges R.
Yamuna
UTTAR PRADESH
RAJASTHAN
Luni R.
Chambal
GUJARAT
MADHYA PRADESH
Landsat ETM
Palaeochannel Network in NW India
Perennial Source of Sutlej River
Mansarovar Lake
Rakas Lake
Perennial Source of Yamuna-Tons River
Tons R.
Yamunotri
Bandarpunch


Simplified map of Vedic Saraswati River from Mansarovar to Dwaraka
Saraswati River System (8000 to 5000 BP)
Present Day River System
Bandar Punch
Sutlej
Sutlej
Sutlej PC
Man Sarovar
Kuru kshetra
Ghaggar R.
Saraswati
Drishadvati
Indus
Vedic Saraswati
Delhi
Ganges
Yamuna
Jaisalmer
Jodhpur
Allahabad
Rann of Kutch
Arabian Sea
Bet Dwarka

Radiometric Dating of Saraswati River Basin

Geochronological Events Related to Saraswati Drainage Evolution in NW India during Quaternary Period (Quaternary Period = Pleistocene in 10000 to 2 million years BP and Holocene in 0-10000 years BP)		
Duration (BP)	**Events**	**References**
1,500 – 3,500	Sea level rise (4-5m). Dwaraka submerged.	Nigam (2012)
< 2,900	Ghaggar-Saraswati drainage system become weak with the beginning of semi-arid climate	OSL dating by Saini et al. (2009)
2,900 - 4,300	Desiccation of the Saraswati channel	OSL dating by Saini et al. (2009)
2,900 - 5,900	Vedic Saraswati Channel buried with relict landform in sub-humid climate. Existence as Saraswati palaeochannels.	OSL dating by Saini et al. (2009)
3,000 - 4,000	Sea level was lower (4-5m). Lothal port dissociated from sea. Land reclamation by Lord Krishna to build Dwaraka city	Nigam (2012)
3,500	Major river diversion of Sutlej and Yamuna	Sinha et al. (2013)
3,500 - 5,000	Major phases of aeolian activities after Holocene Climatic Optimum	TL/OSL dating Singvi & Kar (2004)
3,792	Astronomical dating for Mahabharata War (1792BC)	Ashok Bhatnagar (2014)
< 4,000	Saraswati dwindled and dried up due to river shifting, river piracy.	Sankaran (1999)
4,000 - 7,000	Sea level rise (4-5m). Submergence of Neolithic settlement in Gulf of Khambat	Nigam (2012)
5,000	Continuous flow of Saraswati upto Little Rann	Sankaran (1999)
6,000 - 8,000	Saraswati was in full majesty.	Radhakrishna(1999),Valdiya(2002)
7,000 - 10,000	Sea level was lower (0-30m). Establishment of first Neolithic settlement near Surat in Gujarat coast.	Nigam (2012)
8,670 - 17,000	Groundwater in Jaisalmer region: Medium aquifer (170m) = 9000-17000years	C^{14} dating by Reddy et al. (2011)
10,000	Mighty Himalayan rivers were flowing in western Rajasthan. Sea level was lower (60-80m) than today	Sankaran (1999); Nigam (2012)
10,000 - 18,000	Reduced fluvial activity. Major aeolian activities took place. Aeolian deposition started after LGM.	TL and OSL dating by Singvi and Kar (2004)
1,340 - 18,880	Isotopic age (^3H, ^{18}O and C^{14}) by BARC. Groundwater in the palaeochannels in Jaisalmer region, Rajasthan	Rao and Kulkarni (1997) Nair et al. (1999).
26,000 - 28,000	Existence of Himalayan-fed channel network/older palaeochannels	OSL dating by Saini et al. (2009)
40,000	Himalayan Rivers originated by melting of glaciers due to warming. Groundwater in deeper aquifer (480m) in Jaisalmer >40,000 years	Sankaran (1999); C^{14} dating by Reddy et al. (2011)
40000BP-1.7m.y (Pleistocene)	Himalayan mountains under glacial cover. Climate was fluctuating between glacial and interglacial phases.	Sankaran (1999), Mitra and Bhadu (2012)

GEOCHRONOLOGICAL EVENTS OF SARASWATI DRAINAGE EVOLUTION

- Sediments analysis and Optical Stimulated Luminance (OSL) dating of sand (quartz), Saini et al. (2009) suggested a much older palaeochannels (~26000 to 28000 BP) than the Saraswati palaeochannels (2900 to 5900 BP).
- Thermo Luminescence (TL) and Optically Stimulated Luminescence (OSL) dating of sands, Singvi and Kar (2004) interpreted that major aeolian activities took place with reduced fluvial activity during 10,000 - 18,000 BP.
- Isotopic analysis (H^3, O^{18} and C^{14}) of groundwater samples along the palaeochannels in Jaisalmer district of Rajasthan by BARC, Mumbai indicates that age of trapped groundwater varies from 1340 to 18880 BP (Rao and Kulkarni, 1997; Nair et al., 1999).

- Recently, groundwater samples were analysed by Reddy et al. (2011) in Jaisalmer district shows
  (a) Groundwater of deeper aquifer > 40,000 years
  (b) Groundwater in medium aquifer = 9000 to 17,000 years.
- Based on foraminifera study, Nigam (2012) advocates that
  (a) Lowering of sea level in 7,000-10,000 & 3,000-4,000 years which causes dissociation of Lothal dockyard.
  (b) Rise in sea level in 4,000-7,000 & 1,500-3,500 years which causes submergence of Neolithic settlement in Gulf of Khambat and Dwaraka in Gulf of Kachchh.
- Himalayan drainage in northwest India was existing more than 40,000 years ago i.e. before the Saraswati civilization.
- Vedic Saraswati River was in full majesty during 6,000-8,000 years.

CONCLUSIONS

- The entire course of Vedic Saraswati River has been delineated using latest satellite images and validated with archaeological, drilling and hydrogeological data.
- Radiometric ages of river sediments suggests that the age of Saraswati River (older palaeochannels) may be as old as 28,000 years and flourished during 8000 to 5000 years ago (younger palaeochannels).
- Age of trapped groundwater in the palaeochannels in Rajasthan shows contemporary age of Saraswati (1340-8910 BP) and as old as 18800BP.
- Present day perennial sources of Sutlej and Yamuna/Tons rivers have been considered as part of Vedic Saraswati River.
- Saraswati River network might have been in existence as old as 28,000 years BP and ceased to be a dry channel during 3792 years BP.

Thank You for your Patience...

RESTORE THE CULTURAL HERITAGE OF THE COUNTRY...