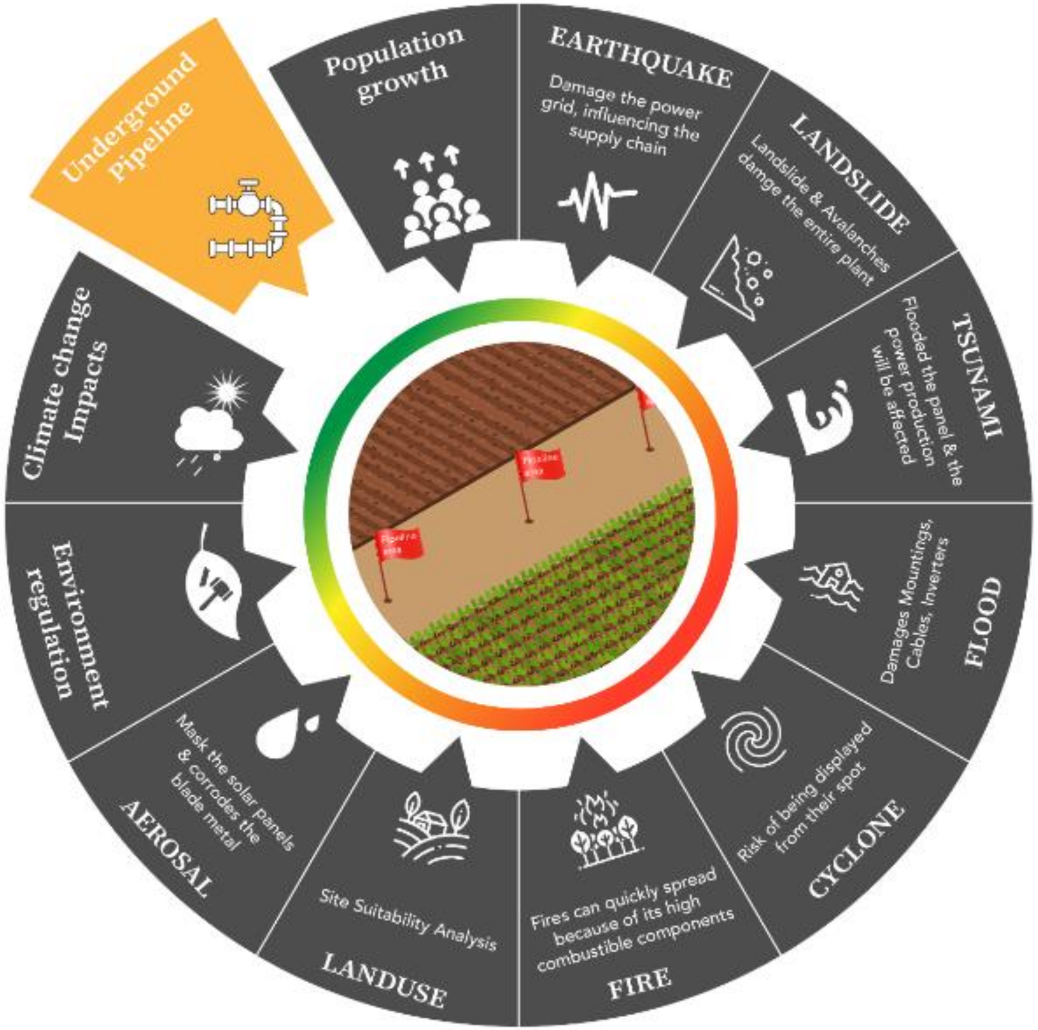


Geo-Hazard Assessment along Hydrocarbon Pipelines

PRESENTED BY

TEAM GCRS & PROF. RAJIV SINHA, IIT KANPUR

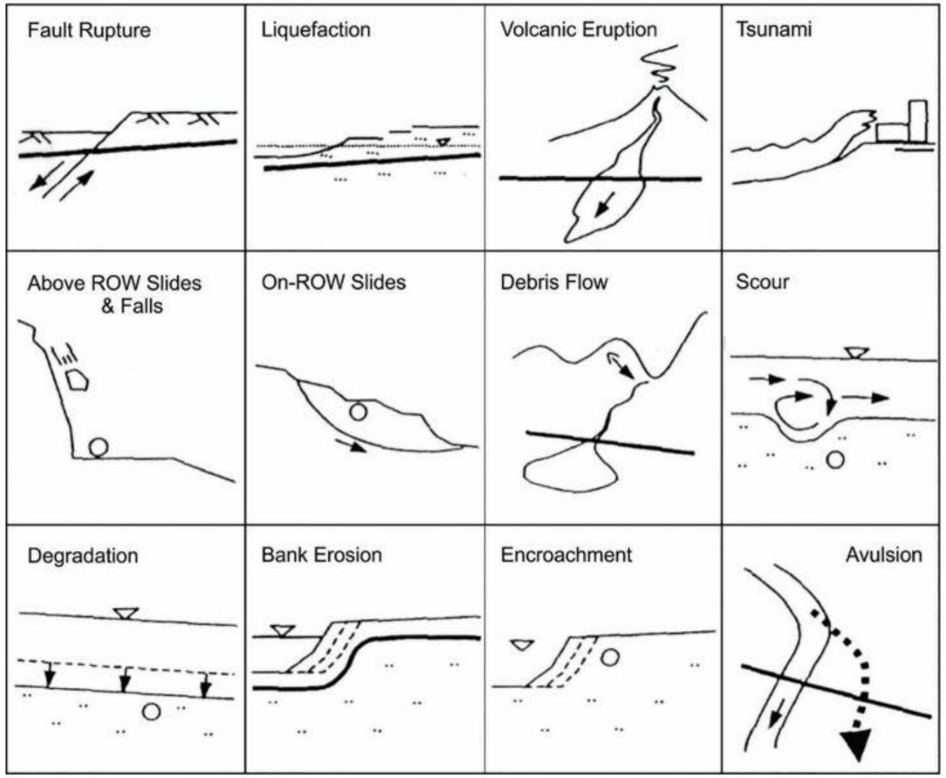
Presentation outline

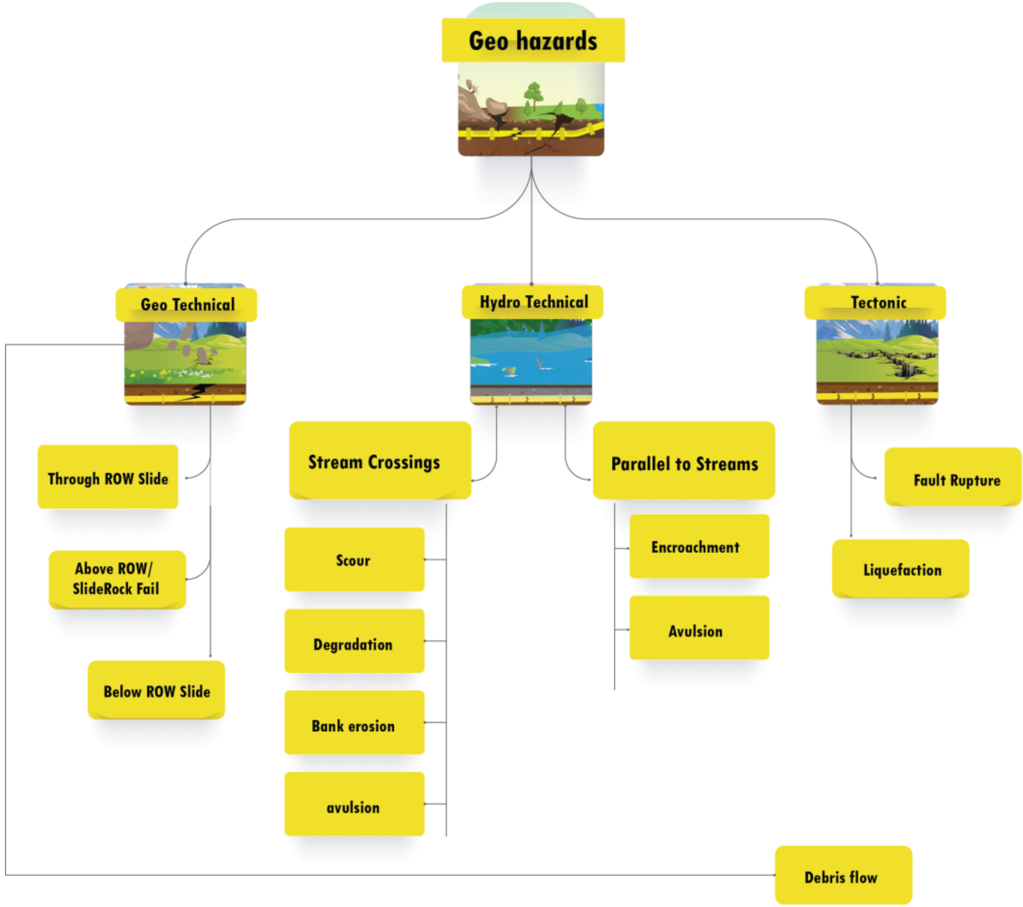
GEOHAZARDS & HYDROCARBON PIPELINE.

ASSESSMENT PROCESS & STANDARDS

WAY FORWARD

Geohazards & hydrocarbon pipelines





Managing System Integrity of Gas Pipelines

ASME B31.8S-2018 identifies weather-related and outside forces as a potential threat to the integrity of the pipeline under section 2.2 Integrity threat classification

The weather-related and outside forces comprise of Excessive hot or cold weather (outside the design range), High wind

Hydrotechnical: water-related threats including, but not limited to, liquefactions, floodings, channeling, scouring, erosions, floatations, breaches, surges, inundations, tsunamis, ice jams, frost heaves, and avalanches

Geotechnical: earth movement threats including, but not limited to, subsidence, extreme surface loads, seismicity, earthquakes, fault movements, mining, and mud and landslides and Lightning

Risk assessment is to identify the most significant risks which aid the operator in prioritizing and developing an effective prevention/detection/mitigation plan to address the risks.

Section 8.3.2 under Plan framework recommends that the risk assessment shall be performed periodically so that new information regarding the changes made to the pipeline system or segment, further assessed using new scientific techniques are included.

The risk assessment is recommended to be performed annually provided substantial changes has been made to the pipeline system and to be performed before the current interval.

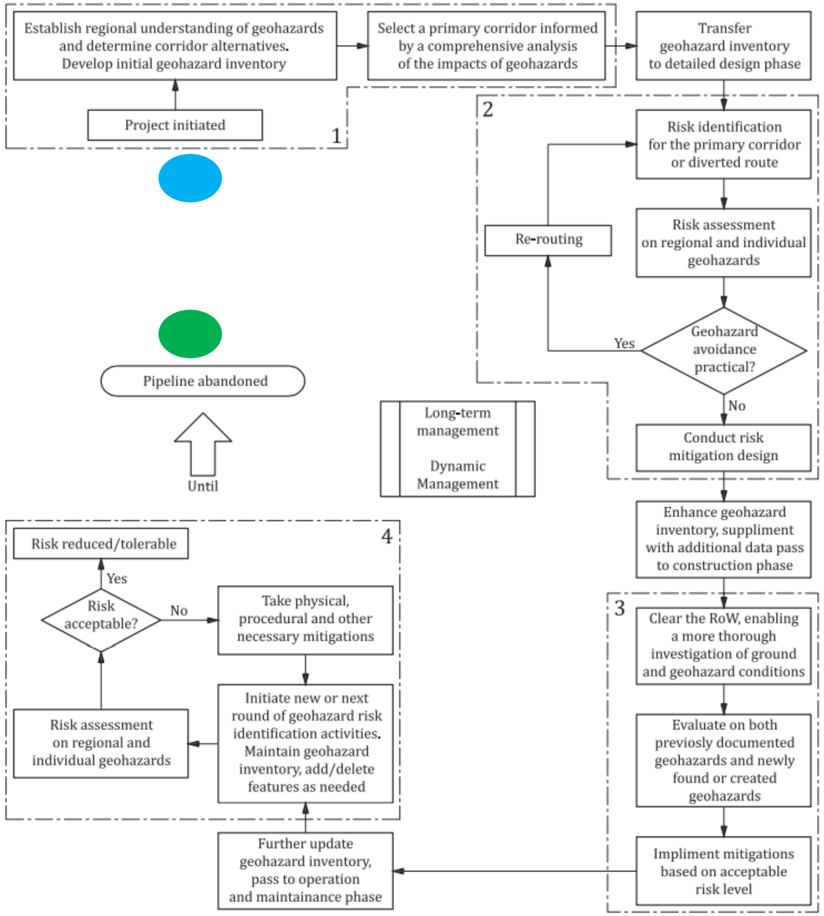
ASME B31.8S-2018

Maintenance of Right of User (RoU)

- Frequent patrolling every once in 30 days for Locations 3 and 4 and every once in every quarter for Locations 1 and 2 is recommended. This investigation is done to detect any surface conditions of RoU, intermediate installations, leakages, encroachments, soil washouts, etc.
- The entire pipeline route should be line walked at least once a year
- Road and railway crossings inspection at least once in three months
- waterbody crossings inspection at least twice a year i.e. prior to and after the monsoon or flash flood for exposure, accumulation of debris, or for any other condition that may affect the safety and security of the crossings.

Petroleum and Natural Gas Regulatory Board (PNGRB)

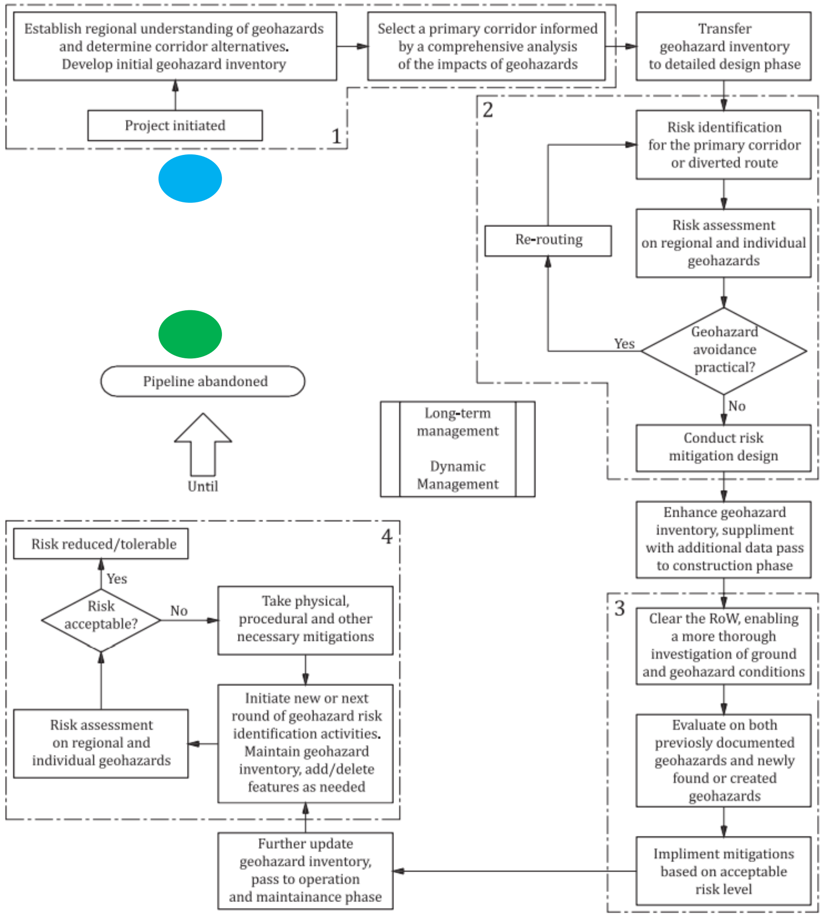
Geohazard Risk Management (stages & processes)



Stages:

1. Preliminary engineering and route selection phase
2. Detailed design phase
3. Construction phase
4. Operation and maintenance phase

Geohazard Risk Management (stages & processes)



Key processes

identification of potential geohazards

evaluation of the severity of the geohazards

mitigation of the threat from the geohazards

long-term management of geohazards through monitoring and periodic re-evaluation of threat levels from geohazards

Geohazard Risk Assessment Methods

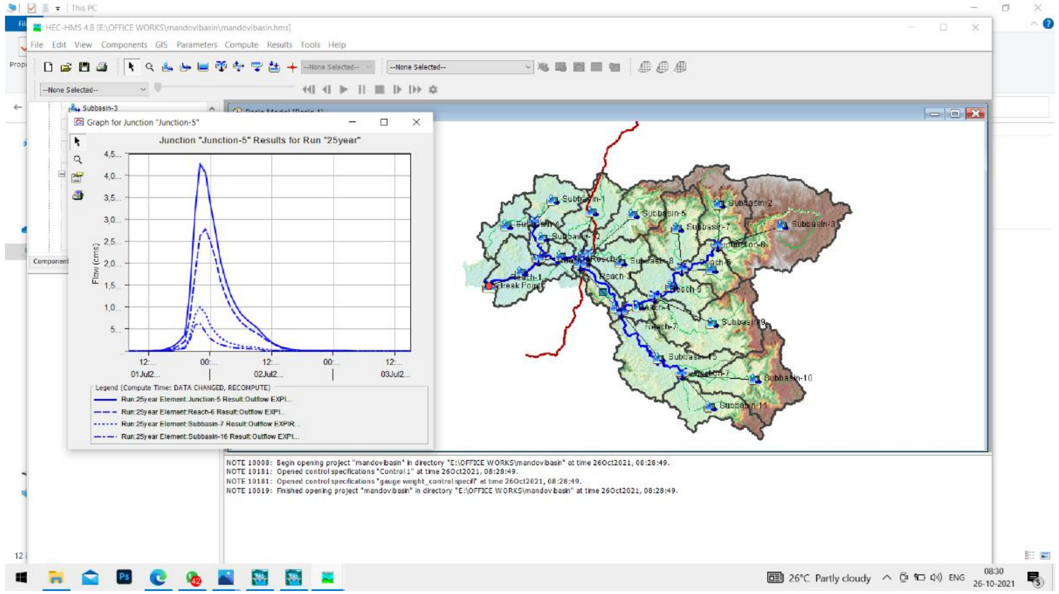


Table 2 — Description of geohazard risk assessment methods

Method	Scope	Advantages	Disadvantages
Qualitative	Hazard probability and consequences expressed in qualitative terms. Risk normally assigned to classes in matrix format.	Based on observation, experience and inference. Enables a basic comparison of different levels of risk.	The method is subjective. Expert judgment is required to execute assessments and reduce inconsistency between comparisons.
Semi-quantitative	Numerical estimates of the relative significance of the key parameters that control the geohazard mechanism and assigning weighting factors. Threat and consequence classes are similar to a qualitative matrix but with numerical ranges.	Less subjective than qualitative methods. Systematic classification of key factors for simple and rapid evaluation of the geohazard. Provides screening and prioritisation of risk. Can be adapted to suit GIS data collection and processing methods.	Typically applies to specific regions and not easily transferrable across diverse geographic or geological environments. Expert judgement is required to ensure consistency between assessments.
Quantitative	Engineering and statistical models are used to quantify the likelihood and consequence of an event.	Perceived as objective and facilitating rigorous comparison of relative risk. Robust approach to reduce uncertainty and increase confidence in assessment results for decision making.	Very demanding in terms of data definition and analysis. The significance or weakness of the assumptions in the mechanism or data might be unclear or concealed within the analysis. Some hazard types cannot be effectively quantified using existing technology/science given the timelines and constraints of pipeline projects.

Geohazard risk Assessment System Components

- Risk assessment purpose
- Risk assessment scope
- Resources and time availability
- Historical data availability
- Projects current stage
- Negative consequences
- Nature of risk
- Risk assessment assumption

ISO 20074 suggests **Techniques and methods for geohazard risk management**

- Risk Identification
- Risk Assessment
- Risk Mitigation

Techniques and methods for geohazard risk management

Phase	Techniques and methods		Design and construction period			Operation period
			Preliminary engineering and route selection phase	Detailed design phase	Construction phase	Operation and maintenance phase
Risk identification	Desktop data analysis (5.3)		●	●	●	●
	LiDAR and remote sensing imagery analysis (5.4)		●	●	●	●
	Field investigation (5.5)	Aerial reconnaissance	●	●	●	●
		Site-specific hazard investigations	◐	●	●	●
		Geophysical surveys	◐	◐	◐	◐
		Intrusive investigations	◐	●	●	●
		Monitoring	◐	◐	◐	◐
	Geotechnical investigation (5.6)		◐	●	●	●
Risk assessment	Qualitative assessment (refer to Annex D)		●	●	●	●
	Semi-quantitative assessment (refer to Annex E)		●	●	●	●
	Quantitative assessment		◐	◐	◐	◐

Phase	Techniques and methods		Design and construction period			Operation period
			Preliminary engineering and route selection phase	Detailed design phase	Construction phase	Operation and maintenance phase
Risk mitigation	Physical risk mitigations (refer to Annex F)	Pipe body strengthening and protection	○	◐	●	●
		Geohazard prevention	○	◐	◐	◐
		Trenchless installation	○	◐	◐	/
		Avoidance or route change	●	●	●	◐
	Procedural risk mitigations (refer to Annex F)	Patrol inspection	/	/	/	●
		Awareness	/	/	/	●
		Earthworks management	/	/	●	●
		Monitoring	●	●	●	●

Key

● means that the item is appropriate

◐ means that the item may be used selectively or if technical and economic conditions permit

○ means that the item is not likely appropriate or is unnecessary

/ means that the item is not applicable

Gathering, Reviewing, and Integrating Data

Gathering, Reviewing, and Integrating Data for risk assessment

(a) joint method (mechanical coupling, acetylene weld,

arc weld)

(b) topography and soil conditions (unstable slopes, water crossings, water proximity, soil liquefactions susceptibility)

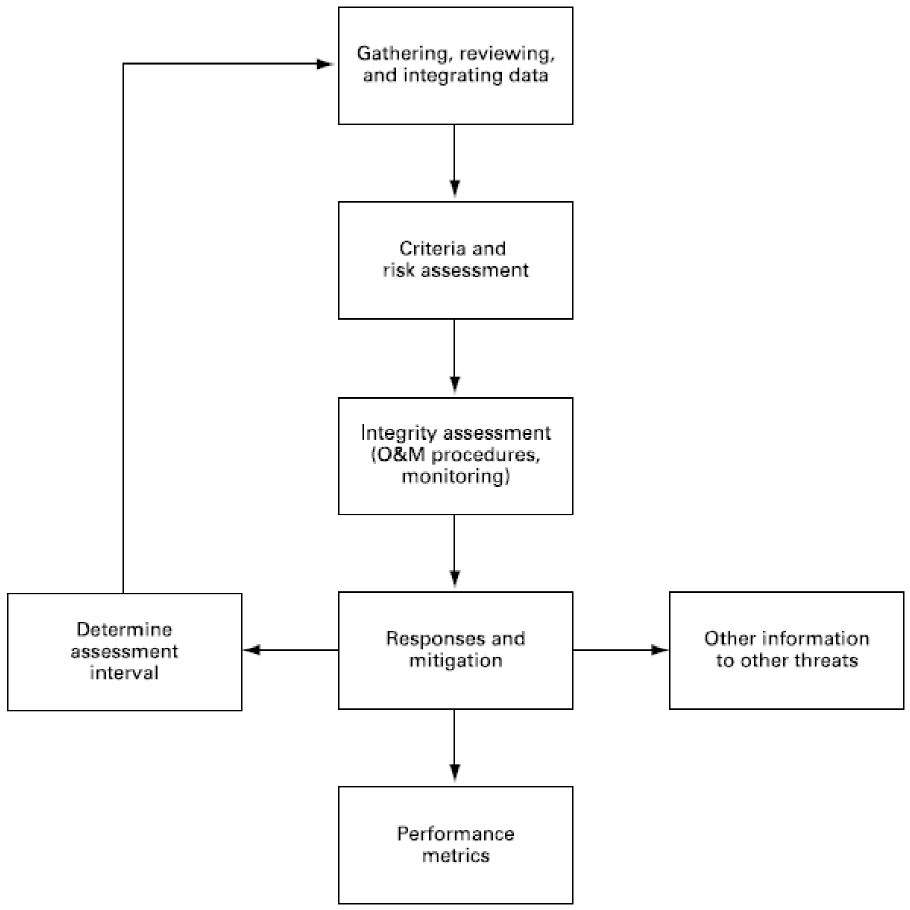
(c) earthquake fault

(d) profile of ground acceleration near fault zones (greater than 0.2*g* acceleration)

(e) depth of frost line

(f) year of installation

(g) pipe grade, diameter, and wall thickness Where the operator is missing data, conservative assumptions shall be used when performing the risk assessment or, alternatively, the segment shall be prioritized in a higher category based on the expected worst case of the missing data.



Geohazard risk assessment data management

The database(s) should, at a minimum, contain the following elements for each identified geohazard:

— the geohazard inventory information listed in code
— the classification or risk score resulting from the application of the assessment system;
— the dates of identification and evaluation;
— the types of mitigation and monitoring conducted for the hazard (if applicable);
— the intervals at which hazard-specific monitoring is conducted (if applicable);
— links to or summaries of the details of mitigation conducted for the hazard (if applicable);
— links to or summaries of monitoring conducted for the hazard (if applicable);
— links to photographs, emails, reports, and other pertinent information concerning the hazard.

The database(s) should also contain the following information for each area managed by the PGMP (not hazard specific):

a) the date of prior assessments (i.e. identification and evaluation processes);
b) the area covered by these assessments (length along pipeline system and corridor width);
c) hazards considered under these assessments;
d) the intervals at which non-hazard specific monitoring is conducted (such as ILI or remote sensing);
e) if the operator has multiple assessment systems for a given hazard type, the assessment system(s) utilized;
f) the scheduled date of the next reassessment.

Data sourcing from public domain

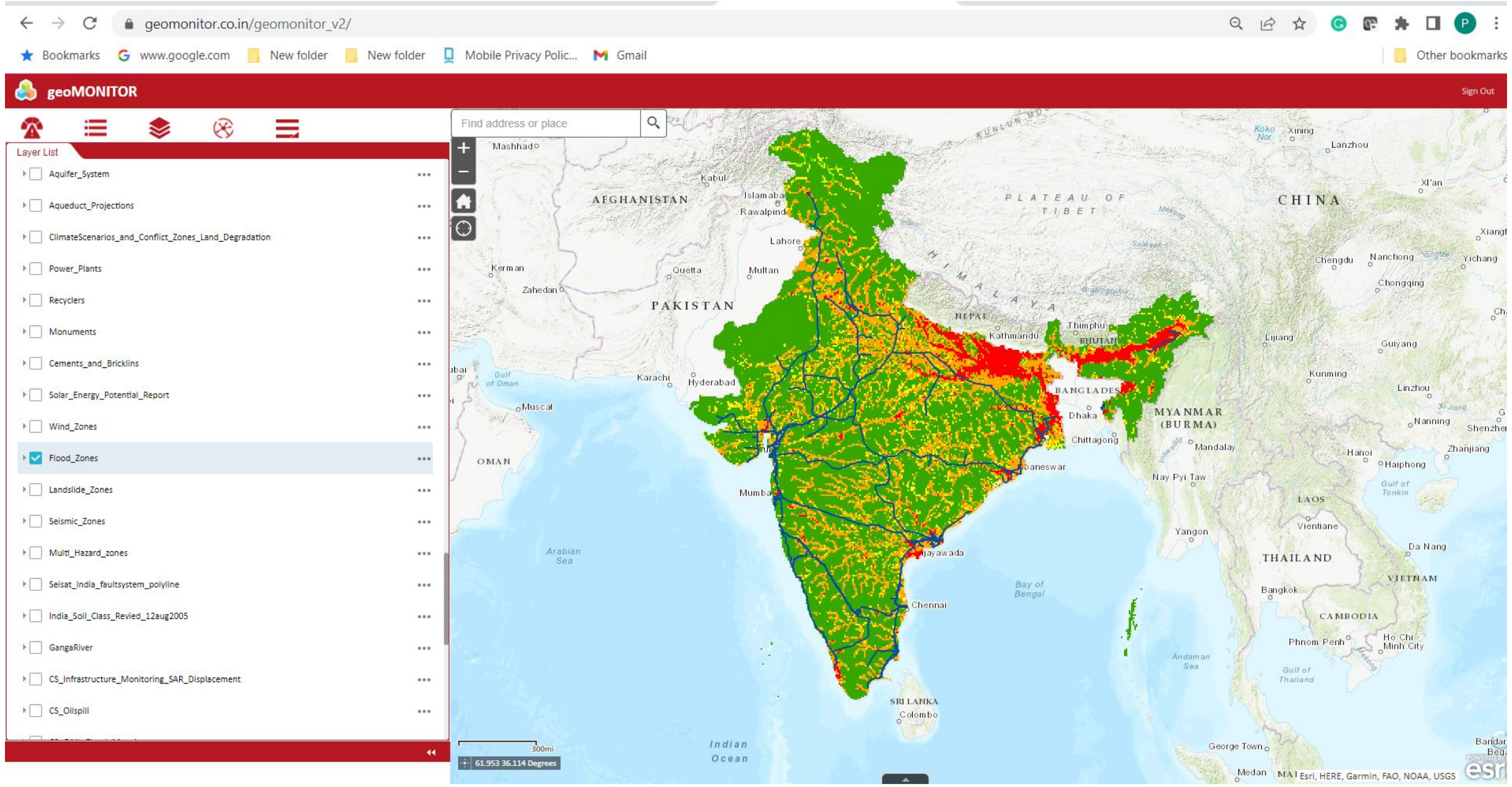
1. Land use land cover • Standard level 2 classification (NRSC LULC standards) for Sentinel Data of 10 meter resolutions • Standard level 3 classification for High resolution data sets (0.5 to 3 meters) 2. Population Density • Population density 3. Vegetation Index • Vegetation intensity index using Sentinel data 4. Social Risk zones • Conflict zones • Terrorism and War Zones 5. Network • Road network • Rail network • Water/river network /canal network • Power network • Solar power plants/Nuclear power plants/Thermal power plants 6. Heritage sites • Geo-heritage • Cultural heritage 7. Major and minor industry • Major industry • Minor industry clusters • Special economic zones 8. Biodiversity zones • Protected Area • Eco sensitive zones	9. Geo hazards • Flood zones • Waterlogging zones • Soil Liquefaction • Seismic zones • Tectonic fault zones • Landslides/massmovement/soil erosion • Land degradation zones • Cyclone zones • Wild fire zones • River avulsions 10. Mining and related activities • Mining (large); active and abandoned mines • Mining (small scale) o Brick kiln o Sand mining o Gravel mining 11. Geology, geohydrology, and hydrology • Geological formations • Soil type • Aquifer information • Groundwater levels and quality • Surface water bodies 12. Land displacement • Land displacement measures using Synthetic Aperture Radar • Karst movements

Key sources for data collection

- Google Earth
- Bhukosh (Geological Survey of India)
- BMPTC (Building Materials and Technology Promotion Council)
- USGS
- Bhuvan
- Sentinel Satellite data
- IMD
- FSI
- IBAT
- IBM
- MOEF &CC, Ministry of Jal Shakti

Hydrotechnical Hazards

Hydrotechnical hazard



Flood Risk

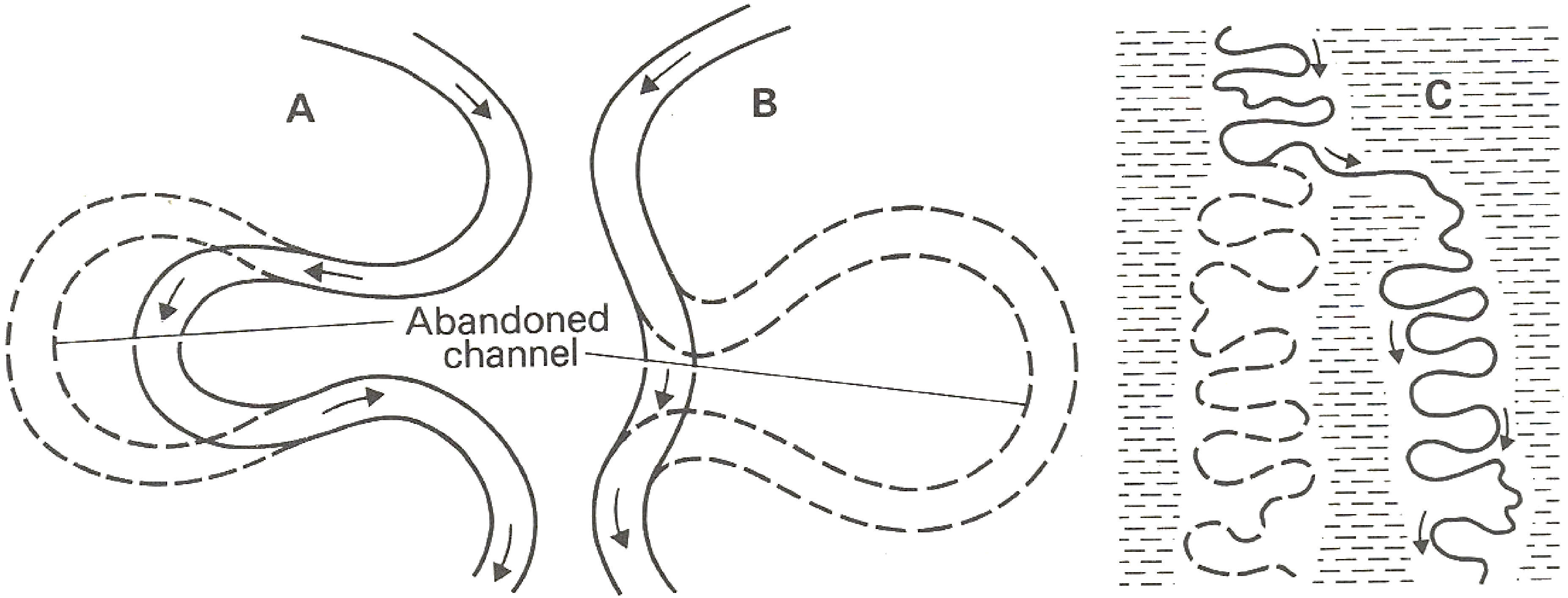
River scouring (vertical and lateral)

River avulsion

Buoyancy effects

River bank erosion

River Dynamics: Mechanisms



Chute cut-off **Neck cut-off** **Avulsion**

Controlling factors of River Dynamics

River dynamics: changes of channel courses/characteristics to maintain the dynamic equilibrium

Controlling factors:

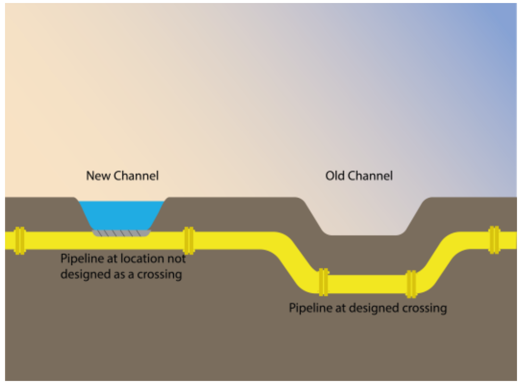
- Independent controls: Discharge, Sediment flux, Valley slope
- Dependent variables: Geology, Vegetation, Human effects

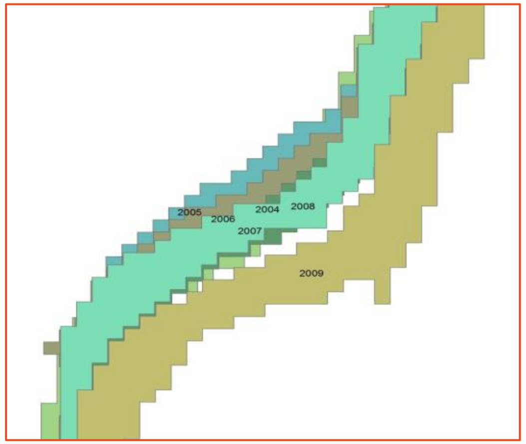
Three main allogenic drivers : Climate, Tectonics, Base level

Governing variables for analytical purposes

- Space-time distribution of run-off
- Rate & size distribution of sediment supply
- Space-time distribution of crustal deformation

River Avulsion





Description of Phenomenon

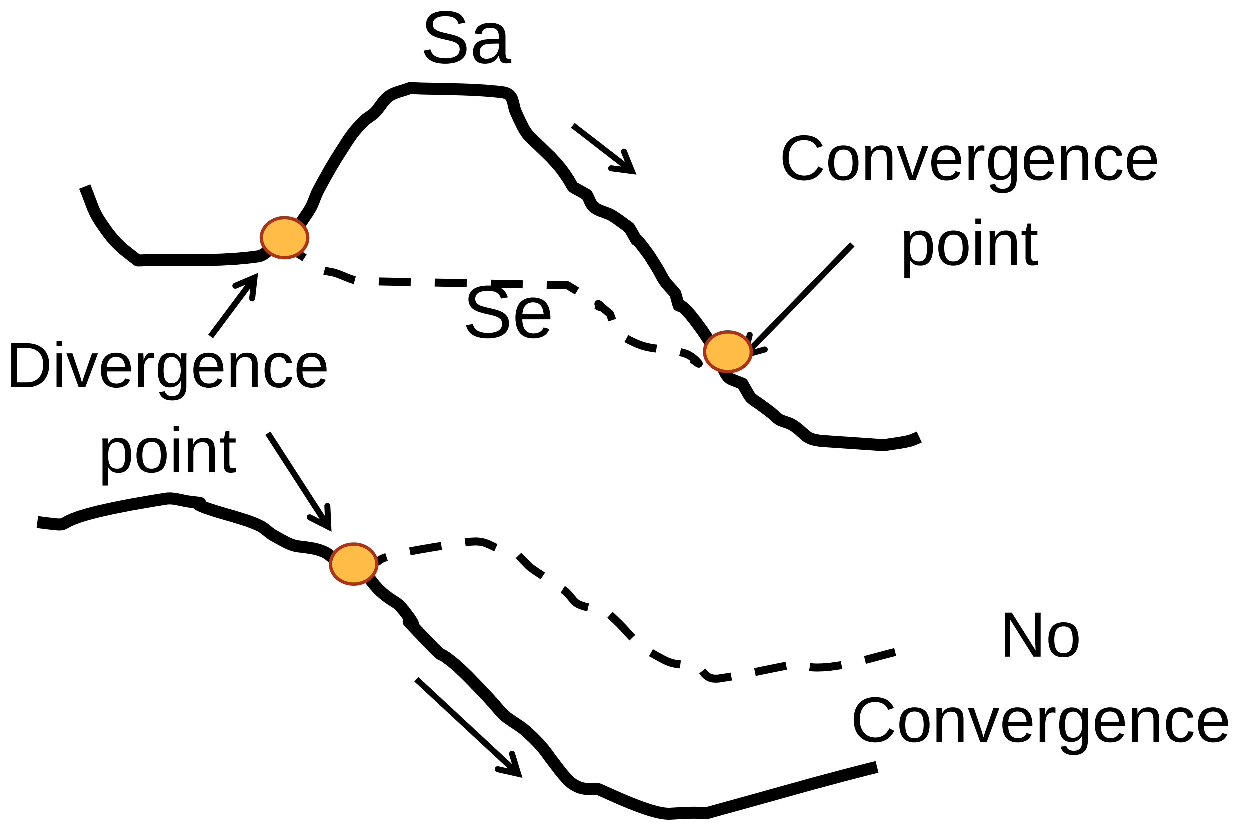
Ø Sudden migration of watercourse channel on an alluvial fan or floodplain due to rapid accumulation of debris in original channel.

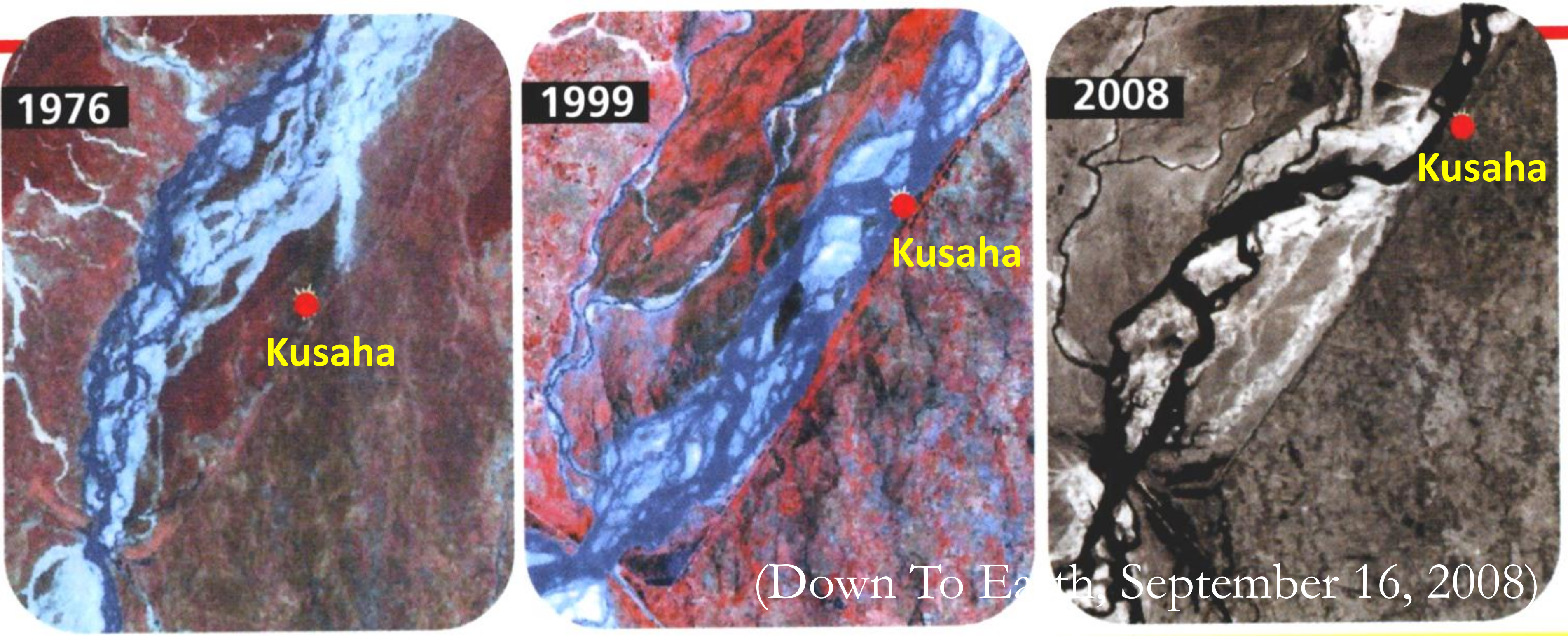
Potential Effects on Pipeline

ØReduction of cover or pipe exposure outside of original channel crossing section of pipeline; possible unsupported span leading to pipe strain aggravated by debris caught on pipe.

Anatomy of Avulsion

- Sudden movement around a nodal point (divergence point)
- Occurs when an event of sufficient magnitude (usually a flood) occurs along a river that is at or near **avulsion threshold**
- Mechanisms/Style
  - Channel reoccupation (rapid)
  - Crevasse splay (gradual)





(Down To Earth, September 16, 2008)

River avulsions can be predicted through continuous monitoring

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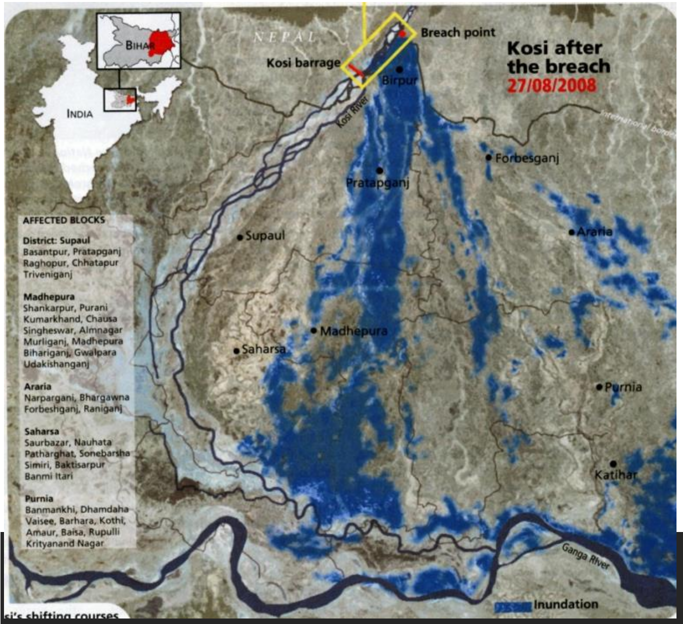
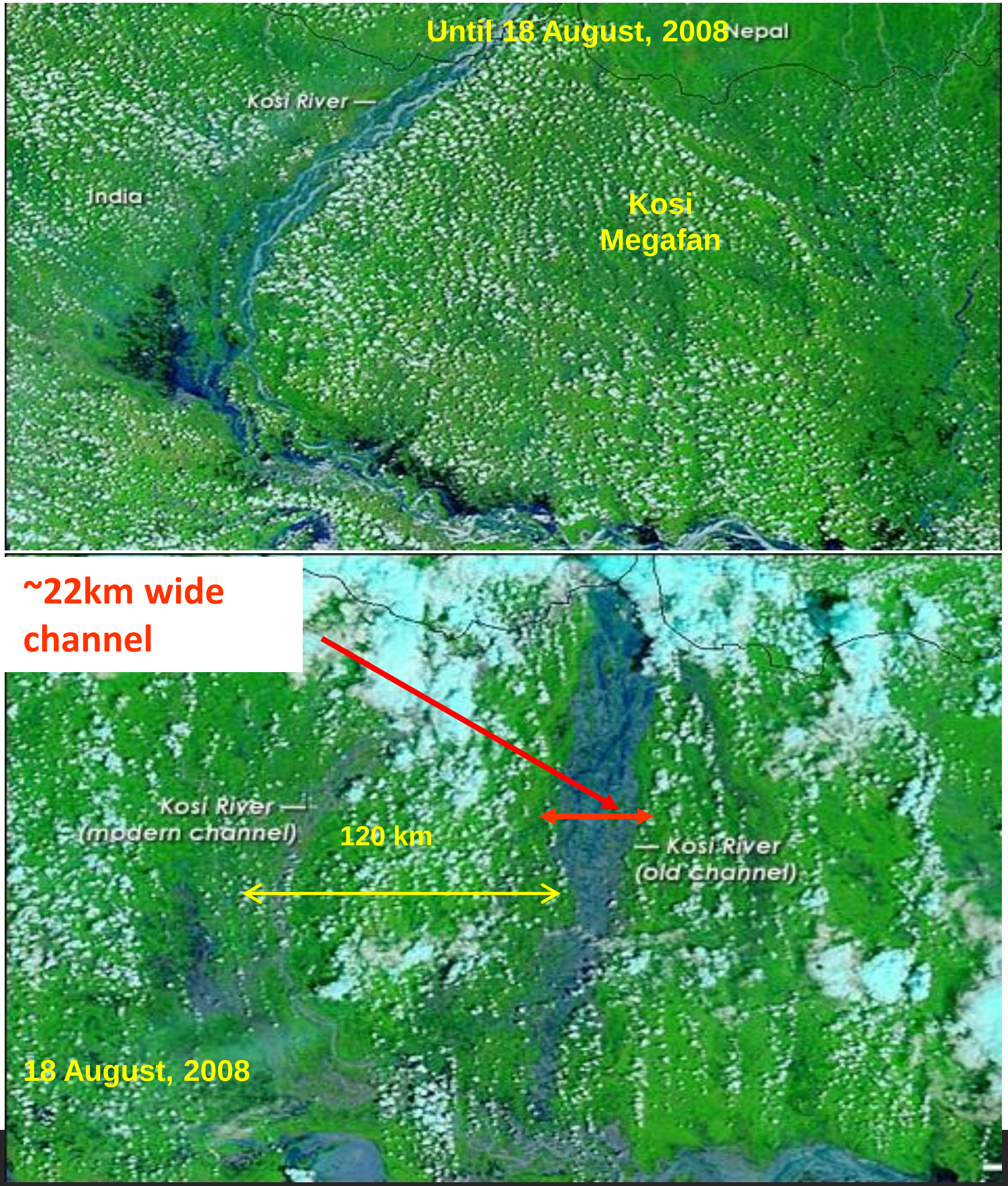
The Kosi avulsion of 2008

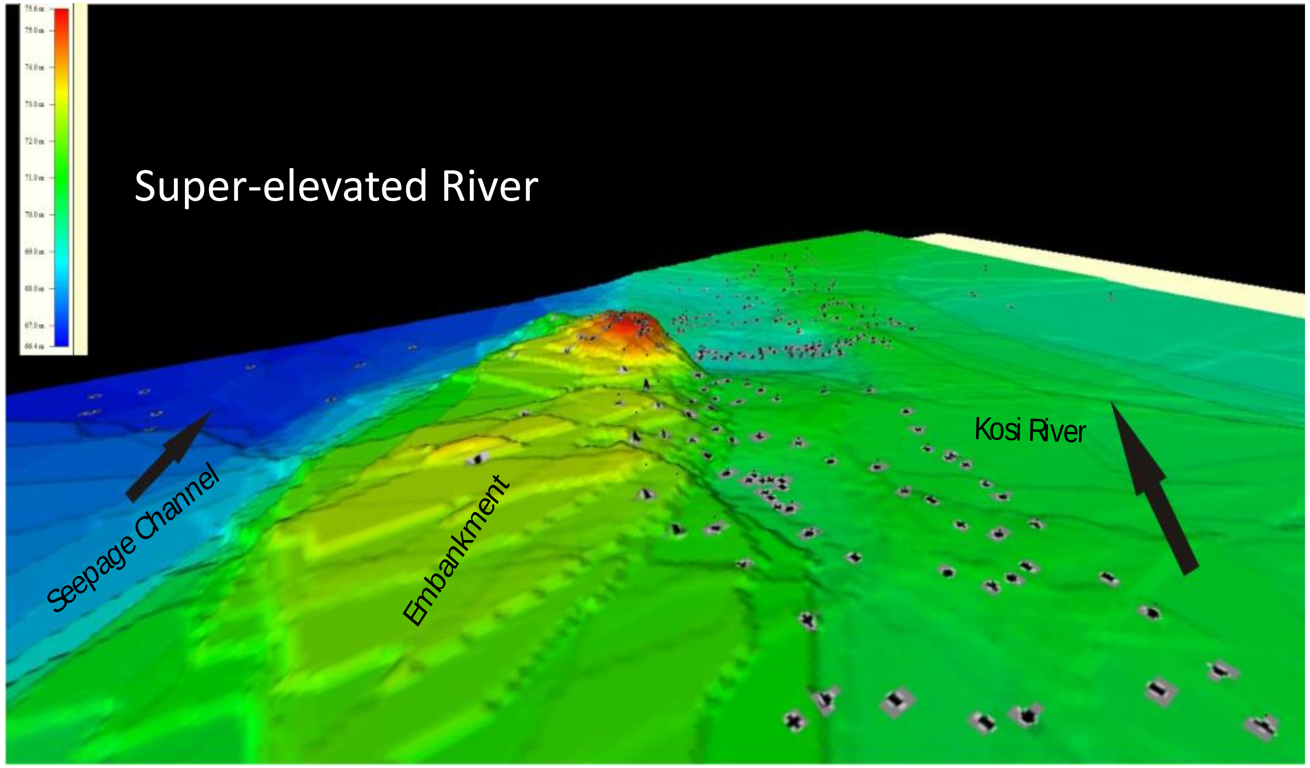


- Continuous eastward shift since 1976
- History of breaches in 1963, 1968, 1971, 1980, 1984, 1991 at several points (Successively upstream)
- Embankments more than 45 yrs old – poor maintenance
- But created a 'false sense of security'

The furious Kosi: August 2008

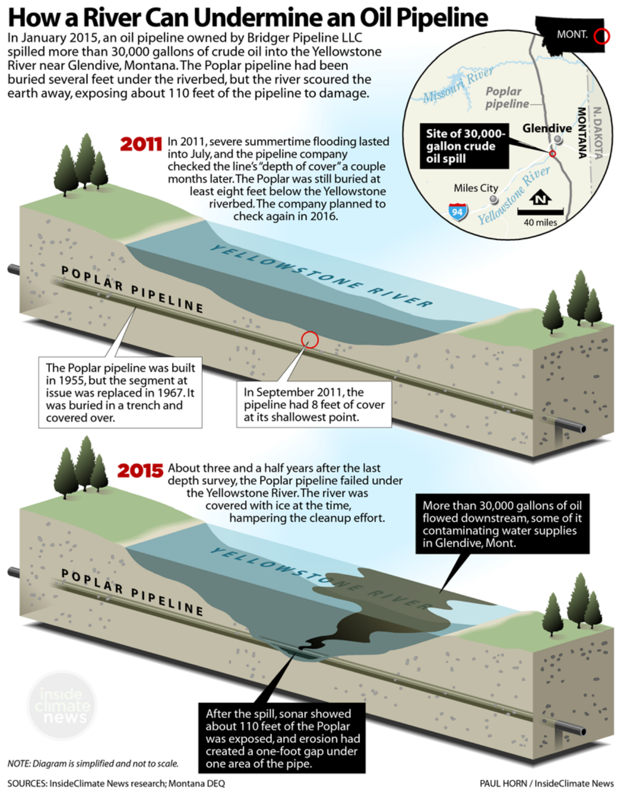


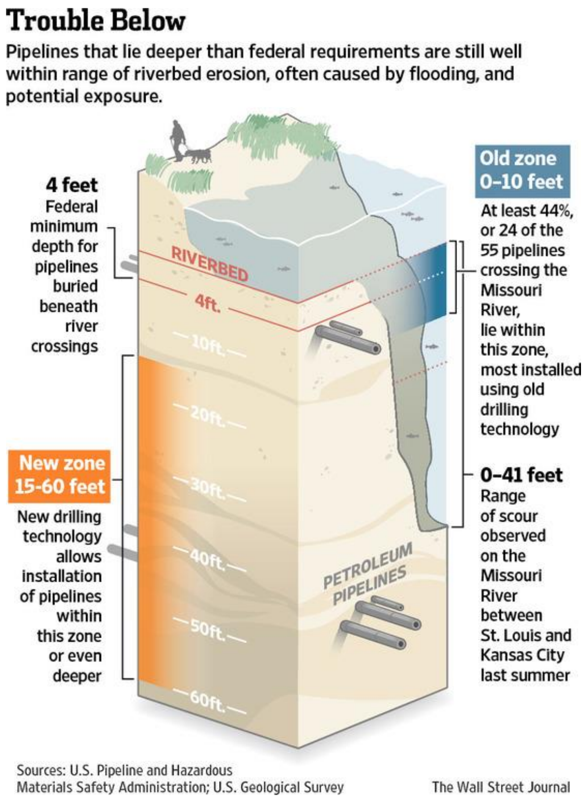
Raging Waters



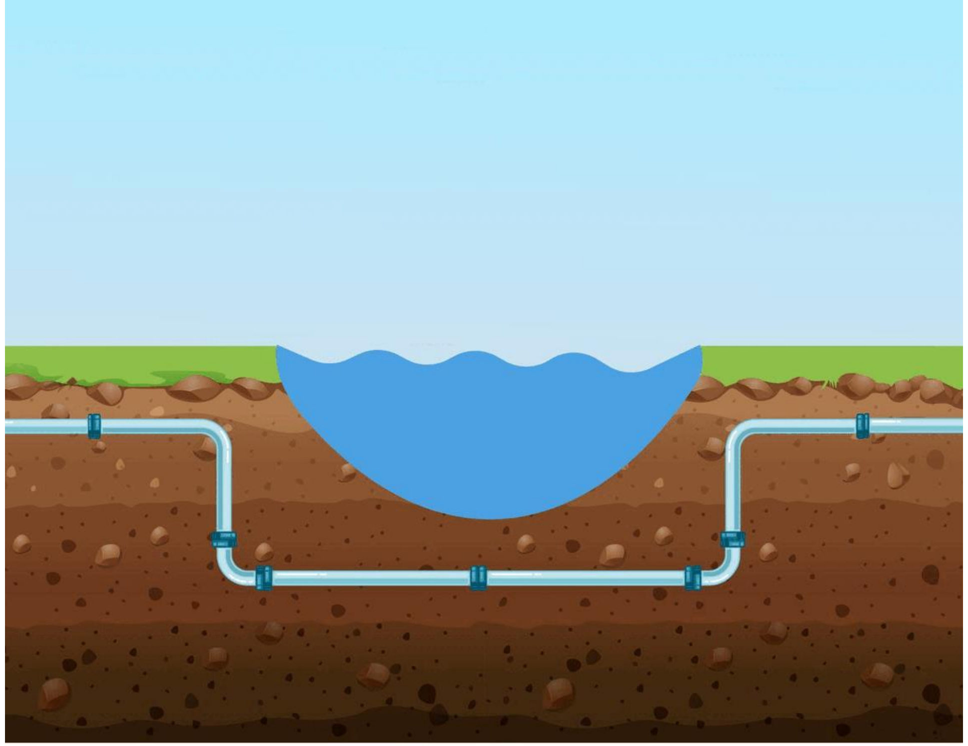
- Excessive sediment flux and embankments caused excessive aggradation of river bed, breaching and extensive flooding
- Breach at 1,44,000 cusecs - much below the designed capacity of the embankments (9,50,000 cusecs)
- Diverted >70% of flow to the new channel
- Unprecedented eastward migration ('avulsion') and inundation
- 5 districts, 2528 villages and 48.04 lakhs people affected in Nepal and north Bihar

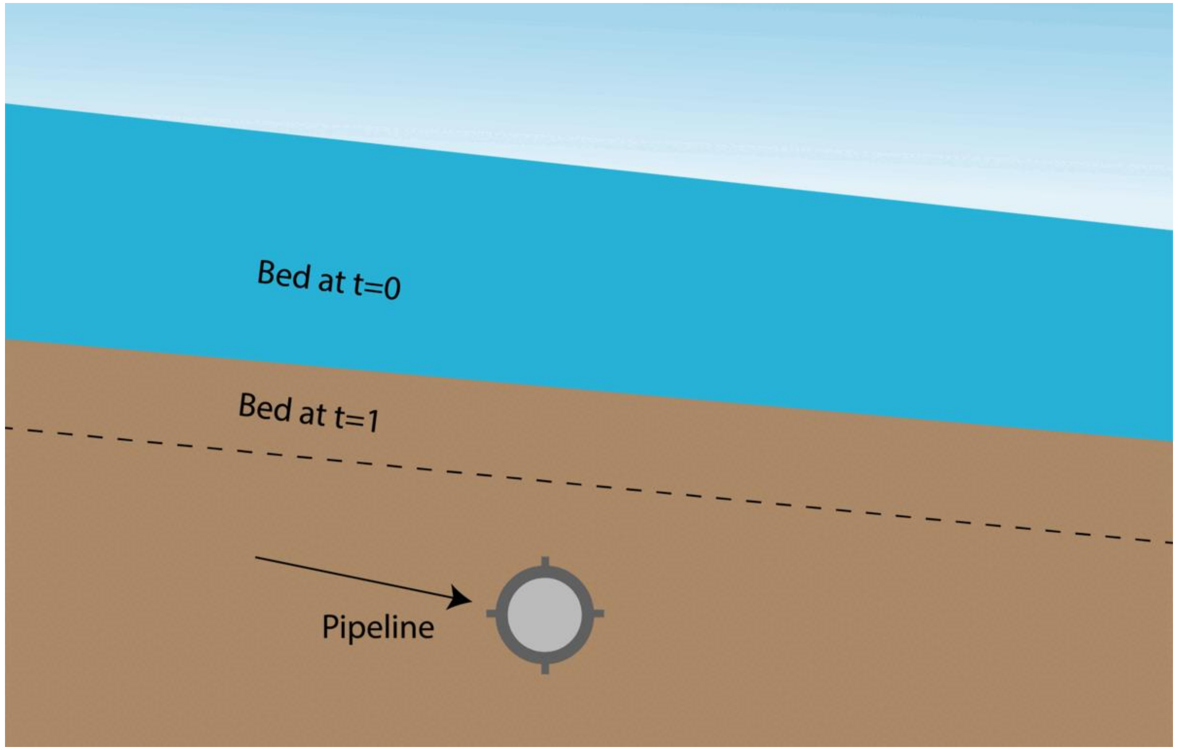
River scouring



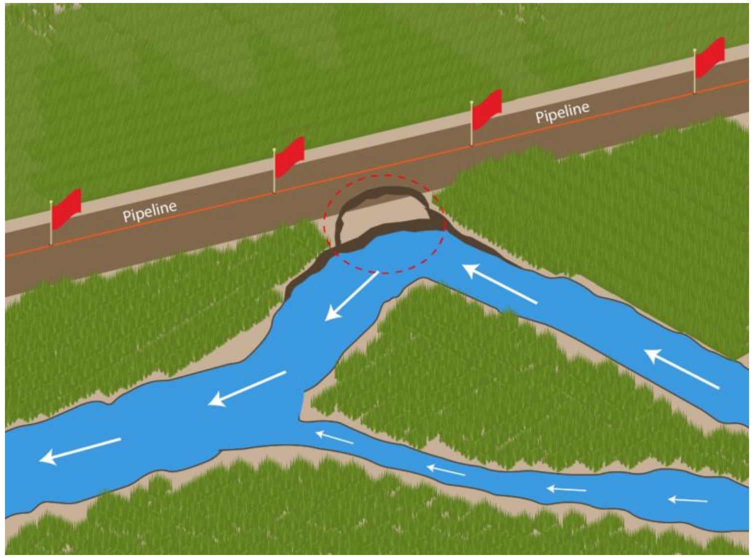


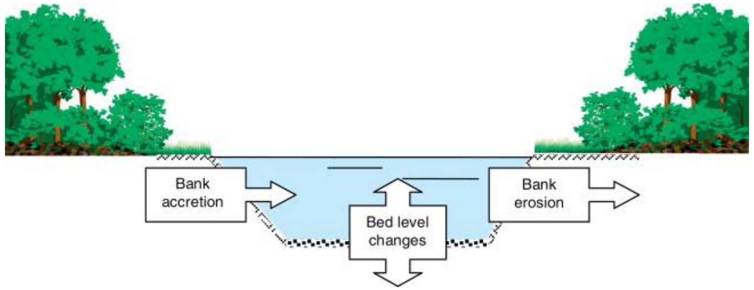
River scouring





Bank Erosion





Description of Phenomenon

- Lateral migration of watercourse channel into a floodplain by hydraulic removal of material from channel banks; accretion results from deposition of hydraulically transported material, generally on inside bends of channels

Potential Effects on Pipeline

- Reduction of cover or pipe exposure; possible pipe strain from unsupported pipe span with vortex shedding aggravated by debris caught on pipe in extreme case; possible toe erosion of slopes; accretion may result in increased pipe cover and vertical loading.

Geohazard susceptibility grade (qualitative assessment method)

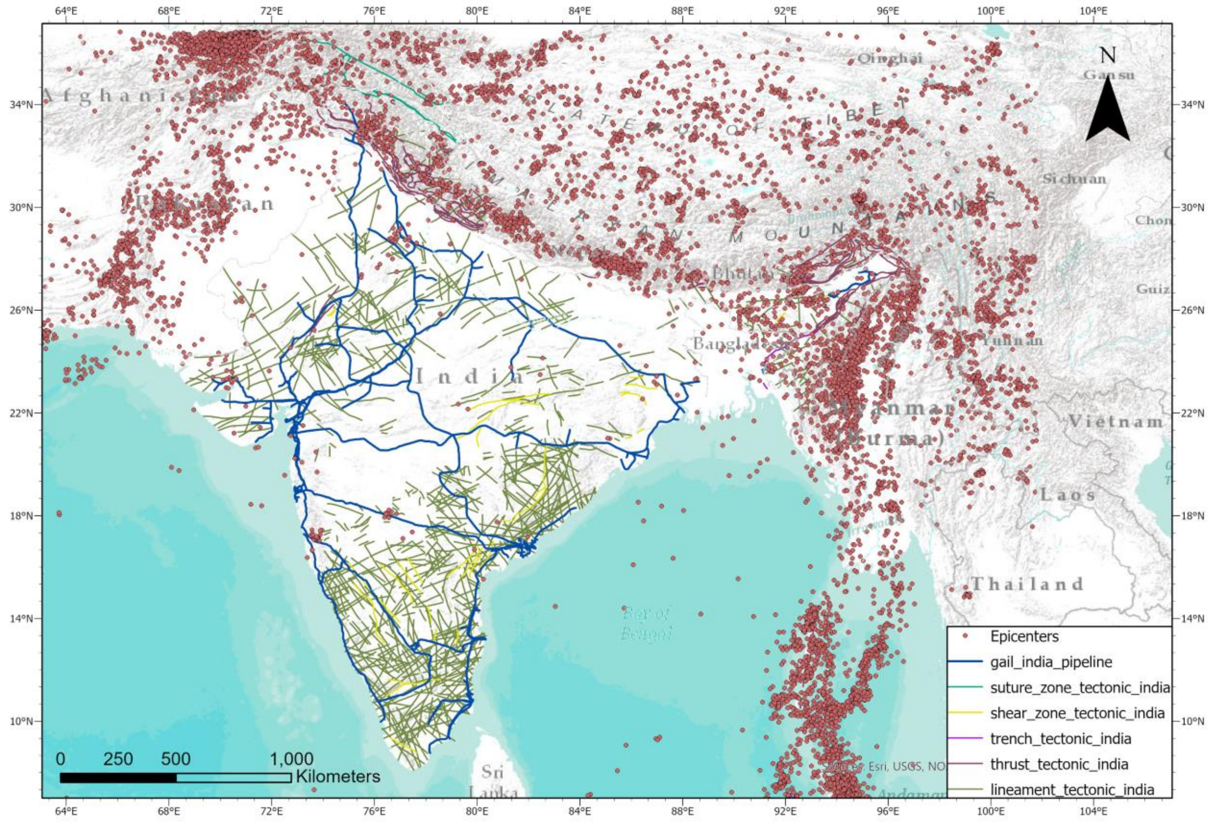
Specific criteria should be developed with consideration of location, susceptibility, and other appropriate factors

Table D.1 *(continued)*

Hazard type	Level	Grading basis
Bank erosion/channel avulsion	High	— Active riverbed undercutting, stream bank collapse or channel avulsion. Riverbed undercutting depth exceeds 1,0 m and stream banks show continuous signs of collapse; — Stream banks show obvious slump blocks; — A large number of block stones (poor roundness) were stacked in stream channel and many block stones have a diameter of more than 50 cm. — Region is susceptible to heavy rainfalls and watercourse has a history of flooding, overtopping and/or channel migration.
	Medium	— Recent, riverbed undercutting, stream bank collapse or channel avulsion has occurred. Riverbed undercutting depth is less than 1,0 m and the collapse along the stream banks is discontinuous and the scale is small; — Stream channel shows signs of slump block development; — There are slump blocks stacked in stream channel, but the number is small.
	Low	— Recent, there was no riverbed undercutting, stream bank collapse or channel avulsion; — Stream channel shows no signs of erosion.

Geotechnical Hazards

Geotechnical hazard



Earthquake

- Seismic-technics/historical epicenters
- Rupture-based method (source based model)

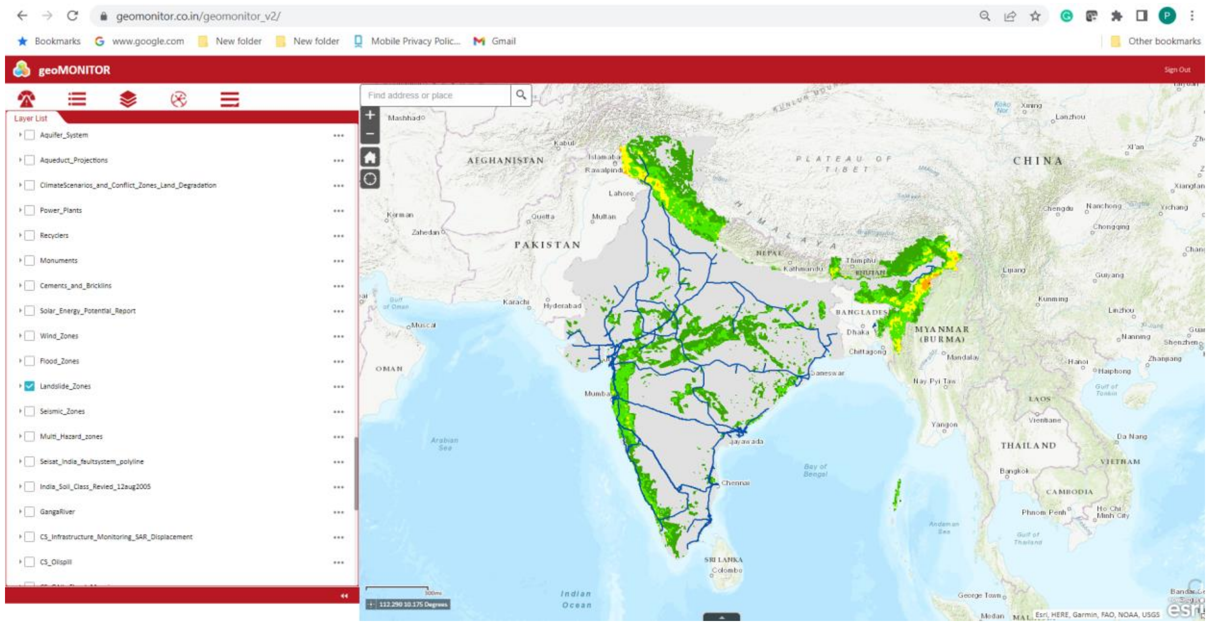
Landslides

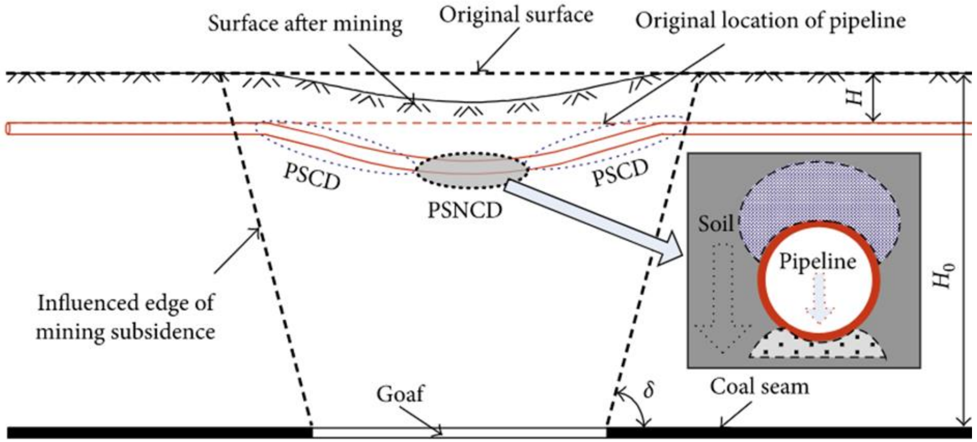
- Rainfall induced
- Seismic induced

Soil Liquefaction

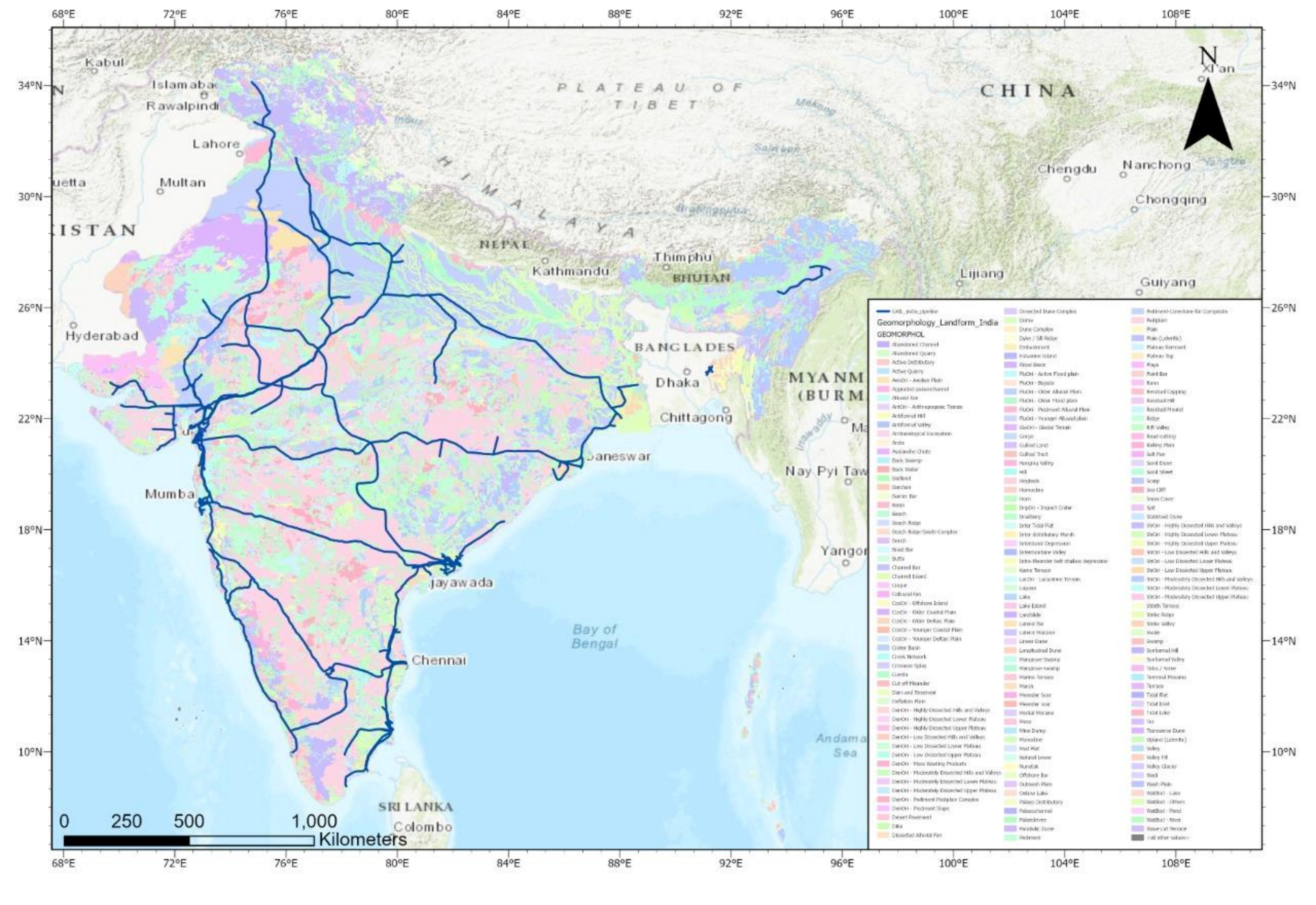
Land subsidence/soil erosion

Landslide/land subsidence hazard zones & pipeline network

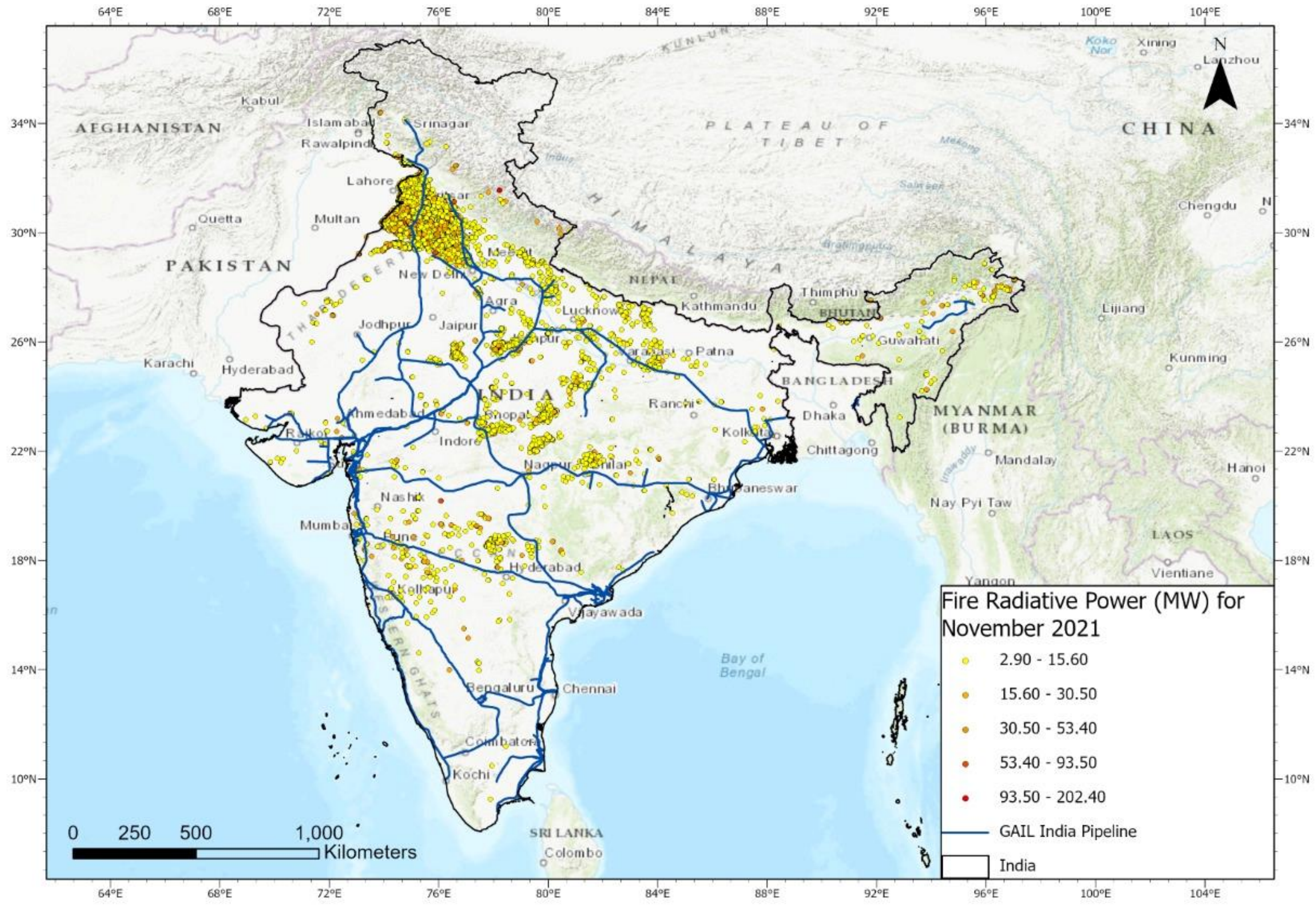




Geomorphology & Pipeline network



Wild fire, farm fire & pipeline network



Geohazard susceptibility grade **(qualitative assessment method)**

Specific criteria should be developed with consideration of location, susceptibility, and other appropriate factors

Hazard type	Level	Grading basis
Land subsidence	High	— Soils are known to be susceptible to collapse or are dispersive; — The surface shows significant settlement or collapse; — Surface shows a clear continuous fissure; — For karst collapse, limestone or dolomitic bedrock is present, with seasonally fluctuating groundwater levels that change greatly and the overlying unconsolidated formation thickness is less than 30 m; — Groundwater pumping volumes exceeds natural replenishment level; — Above ground structures show obvious deformation or destruction.
	Medium	— Surface shows slight settlement or collapse; — Surface shows a slight fissure; — Surface shows sporadic collapse pits; — For karst collapse, limestone or dolomitic bedrock is present, with small seasonal variations in underground groundwater levels that does not change much and the overlying unconsolidated formation thickness is 30 m to 80 m; — Groundwater pumping is basically balanced with natural replenishment level; — Above ground structures show slight deformation or destruction.
	Low	— Surface shows no deformation or ground fracture; — For karst collapse, limestone or dolomitic bedrock is not present, or if present then groundwater levels change slightly and the overlying unconsolidated formation thickness is larger than 80 m; — There is no groundwater withdraw or the amount of groundwater extraction is small.

Multi-hazard & pipeline network (total risk)

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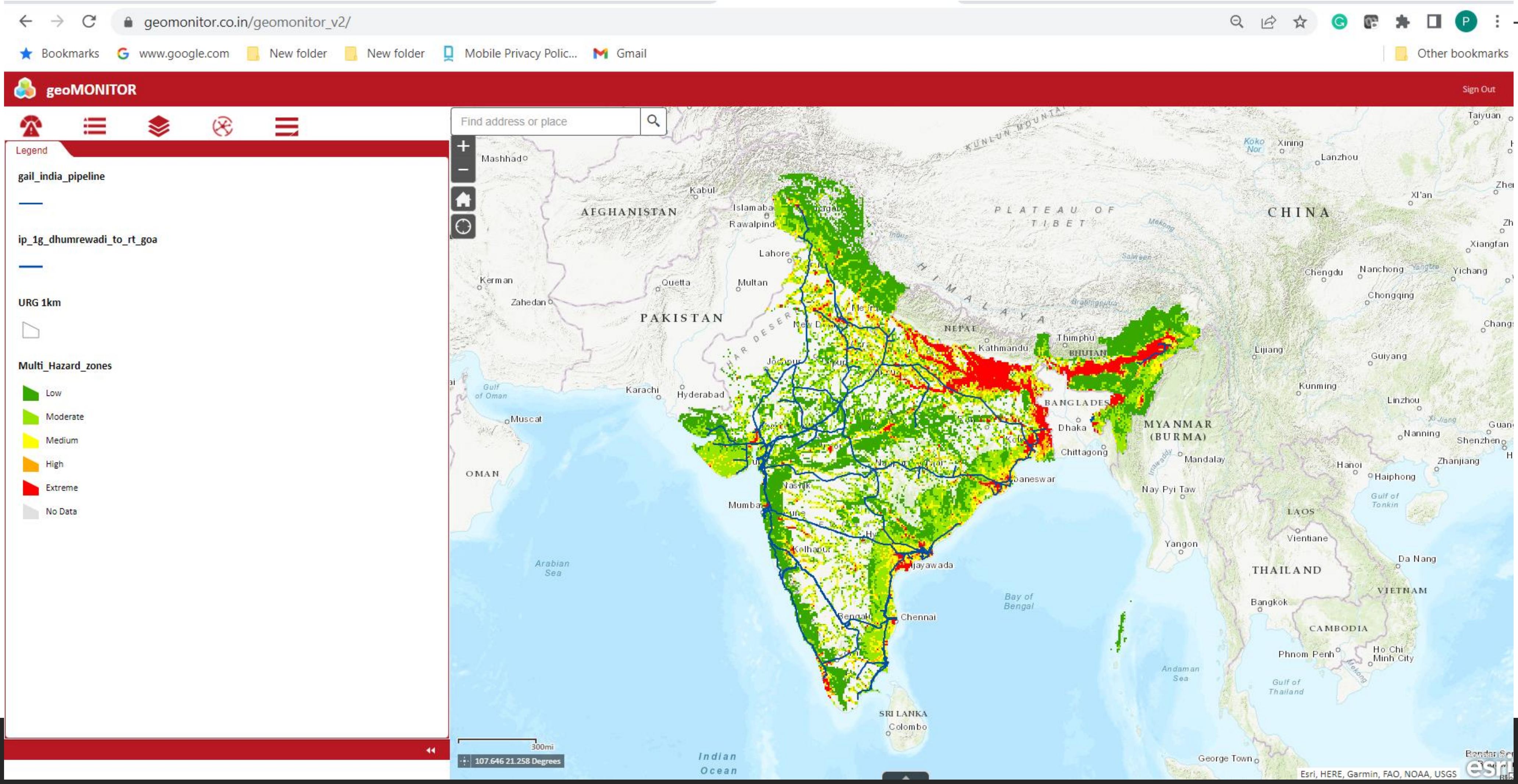
Multi- hazard & Pipeline



Semi-quantitative assessment procedures (Risk Matrix)

Semi-quantitative assessment procedures for pipeline geohazard risk based on index scoring method are as follows:

a) calculate the risk probability index

b) divide the risk probability into five levels (Very high, High, Medium, Low, Very low) in accordance with risk probability index;

c) divide pipeline failure consequence into five grades: A, B, C, D, E;

d)determine individual pipeline geohazard risk in accordance with risk probability level and pipeline failure consequence grade.

Risk probability index and level	≥0,4 (≥0,2)	Very high	Very high	Very high	Very high	Very high	Very high
	0,2 to <0,4 (0,1 to <0,2)	High	High	High	High	High	Very high
	0,1 to <0,2 (0,05 to <0,1)	Medium	Moderate	Moderate	Moderate	High	High
	0,05 to <0,1 (0,01 to <0,5)	Low	Low	Low	Moderate	Moderate	Moderate
	<0,05 (<0,01)	Very low	Low	Low	Low	Low	Low
Risk matrix			A	B	C	D	E
			Pipeline failure consequence grade				

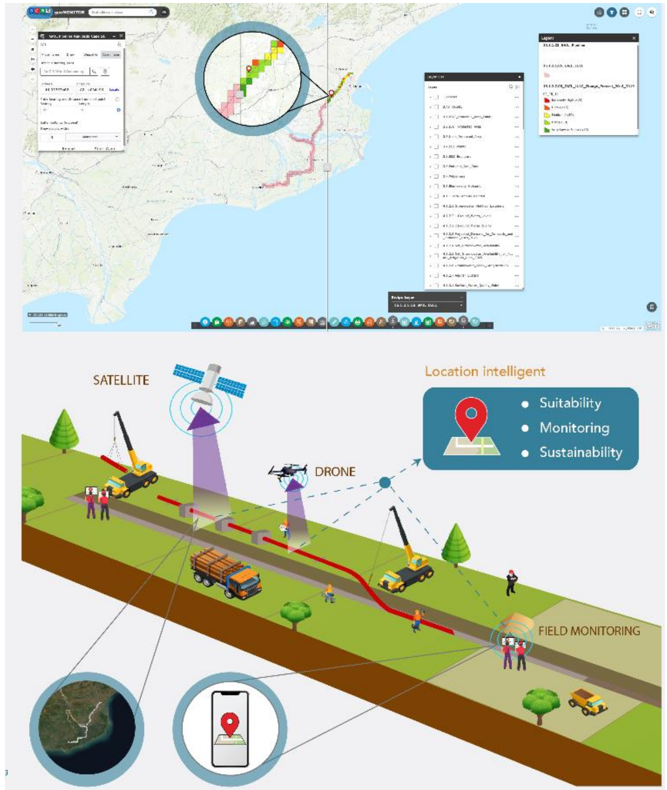
The risk probability index has specific values. Different numerical intervals correspond to relevant risk probability level. This table shows the numerical intervals corresponding to recommended risk probability levels. However, in consideration of the regional differences, users need to judge whether the numerical intervals are appropriate for the specific project, or adjust the intervals to fit the specific project by taking into account the pipeline operation, local geohazard characteristics, relevant working experience of the operator and its acceptable level of geohazard risk into consideration. With an accumulation of application experience, the corresponding relation between the numerical intervals and levels will become more and more reasonable and accurate.

NOTE 1 This table is based on SY/T 6828-2017, Table B.2.

NOTE 2 In the risk probability index, values outside the brackets are suitable for landslides, rockfalls, debris flows, land subsidence, permafrost and seismic hazards. Values within the brackets are suitable for bank erosion/channel avulsion, surface and backfill erosion, collapsible soil or other similar soil. Other hazards can be individually assessed as to the appropriate risk probability index group.

Way forward

Technology & scientific data integration



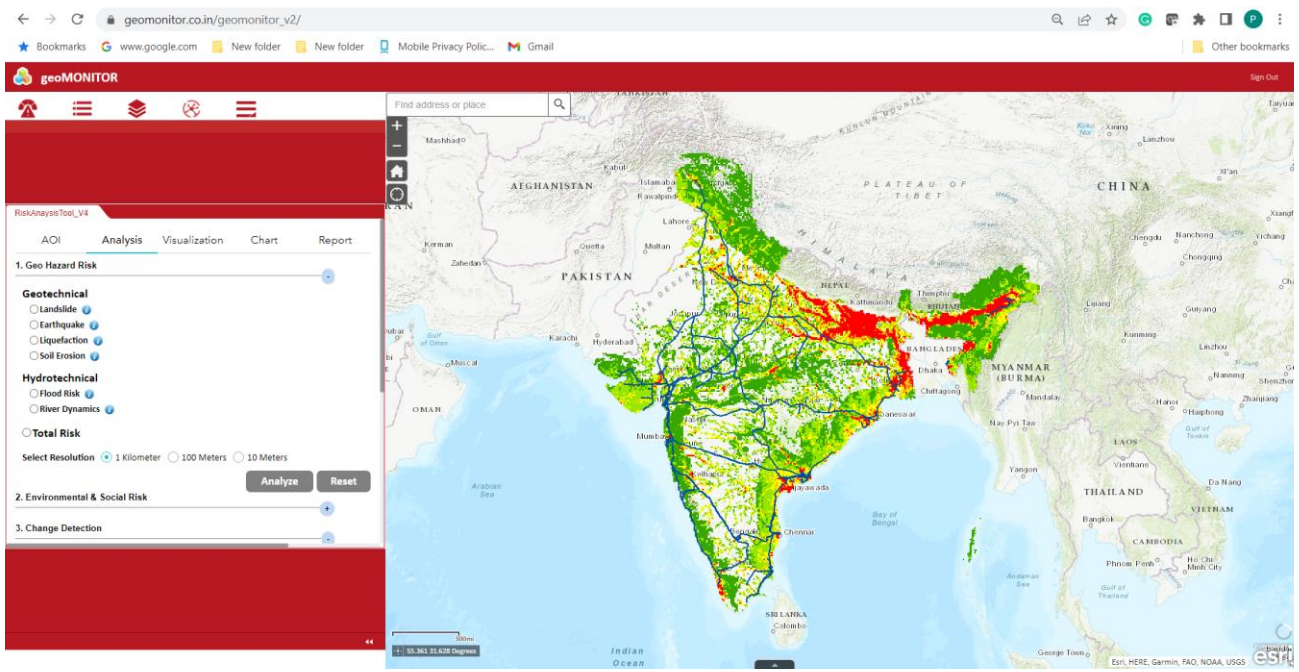
Integrate Long term river dynamics

Integration of real time data derived from field sensors (IoT), satellite imageries, drone surveys and crowd sourcing.

Integration with robust geospatial platform.

Integration of land use and land cover data for change detection (optical and SAR sensors)

WebGIS based tool and near real time analysis



Geohazards

- Geotechnical
- Hydrotechnical

Environmental and social risk & regulations

- Biodiversity hotspots
- High consequence areas
- Conflict areas
- Protected areas
- Forest fires

Change detection

- Encroachment
- Displacement
- Vegetation analysis along ROW
- Water body monitoring along ROW

Thank you

CONTACT US : HTTPS://WWW.GCRS.CO.IN/

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