GIS in Water Resources
Final Project Report

Runoff Water Management in Bailadila Range, Kirandul, India

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Under Guidance of
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Run off water management in Bailadila Region

Introduction:

Dantewada District in Chhatisgarh state of India covers an area of 3,410.50 km² and population of 247,029 as per 2011 census. A Bailadila hill range is a 36 km long and 10 km wide hill range located in the Dantewada district of Chhattisgarh. The area is characterised by rugged terrain and heavy rainfall. It harbours rich biodiversity. Its upper ridges are covered with dense deciduous forest and the lower slopes and banks of the nalas consist of semi evergreen species. Varied physiographic elements and microclimatic conditions, in association with vegetation, have made this area a treasure house of medicinal plants. Excavation of iron ore by India's largest and world #4 mining company NMDC limited has caused immense damage to the Bailadila hills and adjoining water resources and land. Dankini and Shankhani rivers, the lifeline of Dantewada, in south Chhattisgarh have lost the sheen to iron ore, due to pollution of red oxide discharged from the mines after iron ore extraction on which around 100 villages are dependent as main source of water for drinking and agriculture. Apart from this most of the drinking water wells are also drying.

Background

Iron is generally mined by open cast or strip mining, rather than tunneling the earth. This method includes extracting minerals from an open pit. Mining operations on Bailadila hill has caused tremendous pollution in the water of river Sankhini and other rivers and streams. As a consequence of runoff from the mines, a 32 km stretch of the Sankhini river is called 'lal pani' (red water) by the Adivasis; who see the "earth bleeding from the wounds inflicted on it by the miners." The impact on both the terrestrial and aquatic ecosystems in the region has been tremendous. This project is an attempt to reach to a solution of this red water issue.

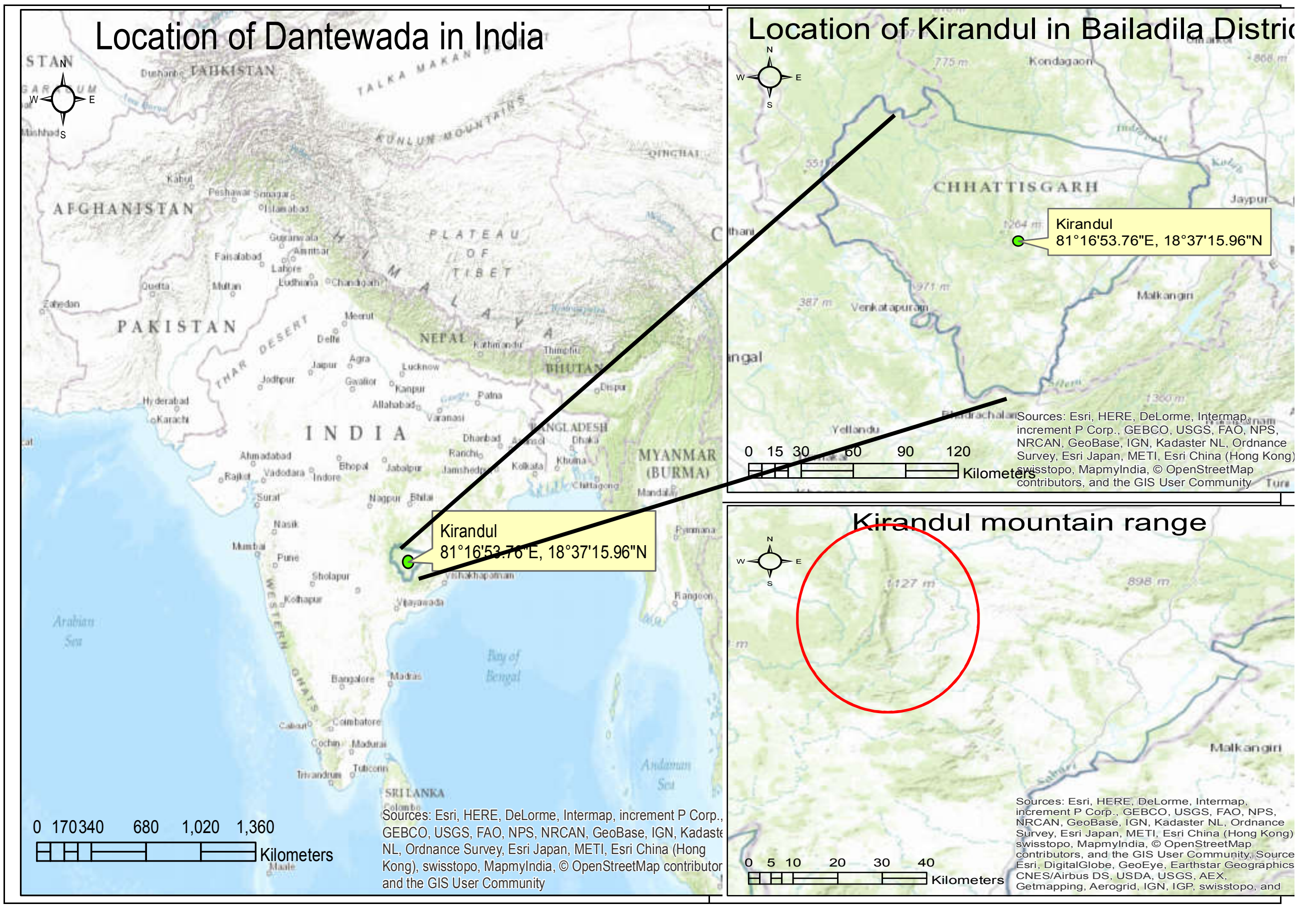
For runoff water management, NMDC limited is constructing a number of check dams, check bunds, gully nala and garland drain all around this mountain range. But these constructions are not helping much in achieving the prescribed water quality by Chhatisgarh state pollution control board because constructing dams all around the mountain stretch without knowing the water flow channels properly is expensive and existing dams need frequent desilting also in rainy season. Sometimes, water along with sand and gravel even damage the dams. So, study of terrain and water flow is necessary.

The development of flow lines and the amount of rainfall water coming from the Kirandul mountain range is the basic and essential step for runoff water management. Therefore, the aim of this project is to collect elevation data, land cover data and soil data on the basis of which flow lines can be developed and HEC HMS model can be prepared. These flow lines would increase the understanding of flow direction and area from which maximum ore erosion is occurring. HEC HMS model will help in predicting the maximum amount of rainwater going into the river in a day and the time it takes to meet the

Sankini river. On the basis of above project and estimations, a runoff water management method will be developed.

Study Area:

Bailadila/Kirandul mountain range is the only area in which rigorous mining by NMDC Limited is going on, which is causing red water issue in the whole region of Dantewada District. This area is of my personal interest because I worked with NMDC limited for 3 years and faced red water issue as the biggest challenge as an environmental engineer.



Bailadila lies in the Survey of India toposheet no. 65F/2 within latitude 18^{o}32'32" North and 19^{o}36'5" North and longitude 81^{o}13' & 81^{o}14'30".

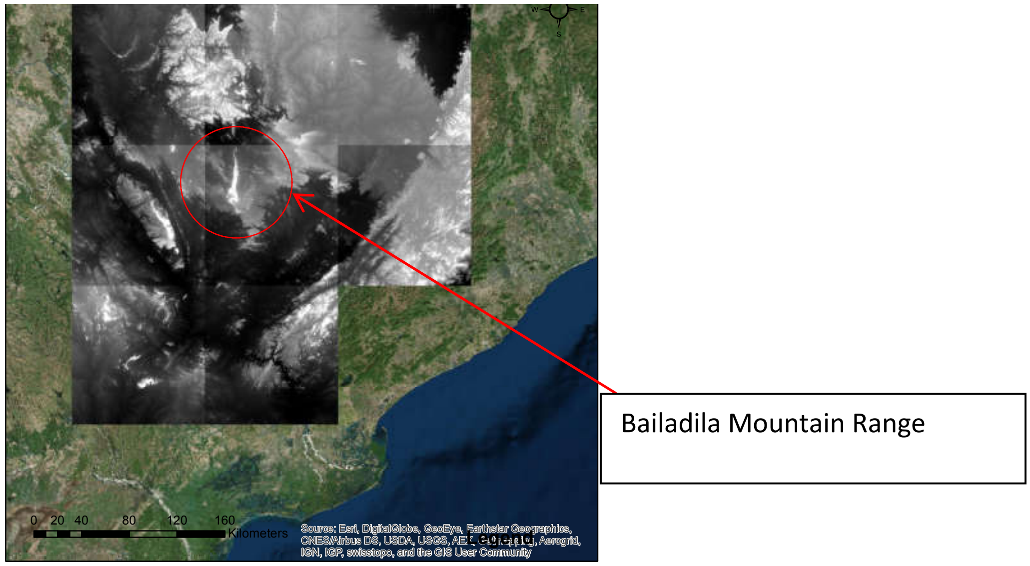
Methodology:

All data have been collected from the BHUVAN, USGS, ESRI, Indian Meteorological department and NMDC Limited data services. Since their geographic coordinate systems are WGS 1984 projection and datum, all maps are kept in this state. The projected coordinate system, which is used for this project, is The Universal Transverse Mercator coordinate system.

ARCHYDRO and HEC HMS are used to develop watershed, streamlines and estimation of rainwater runoff from Bailadila mountain range.

DEM data:

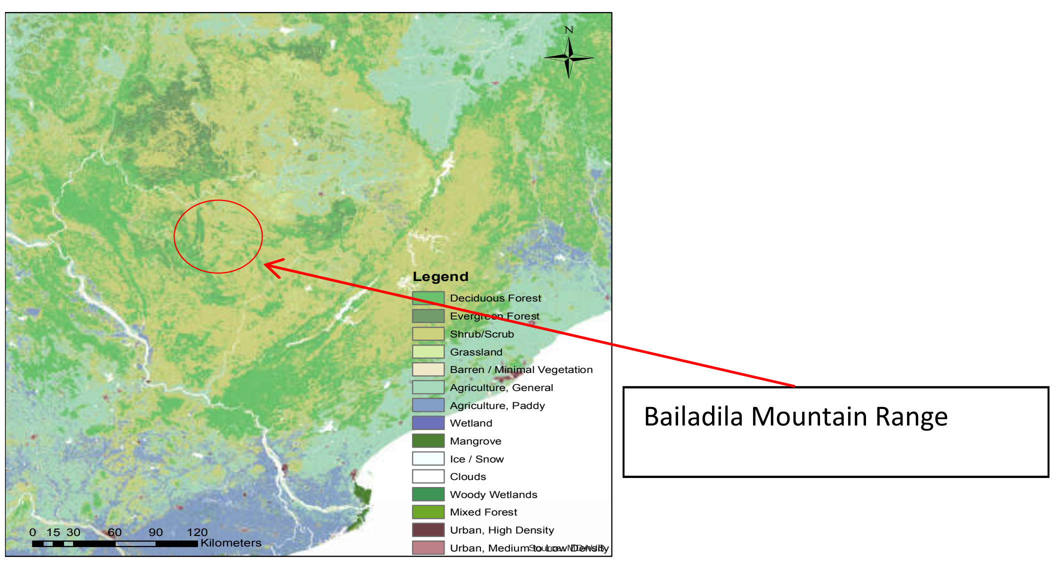
The DEM data is collected from BHUVAN, a software application, which allows users to explore a 2D/3D representation of the surface of the Earth. Bhuvan offers detailed imagery of Indian locations compared to other Virtual Globe Software, with spatial resolutions ranging up to 1 meter. Total eight (8) tiles have been downloaded from Bhuvan to cover the whole Dantewada district.



The tiles of DEM data have been merged by “Mosiac to new raster” tool in ARCGIS for further analysis. The highest elevation is 1265m above MSL at the mountain range.

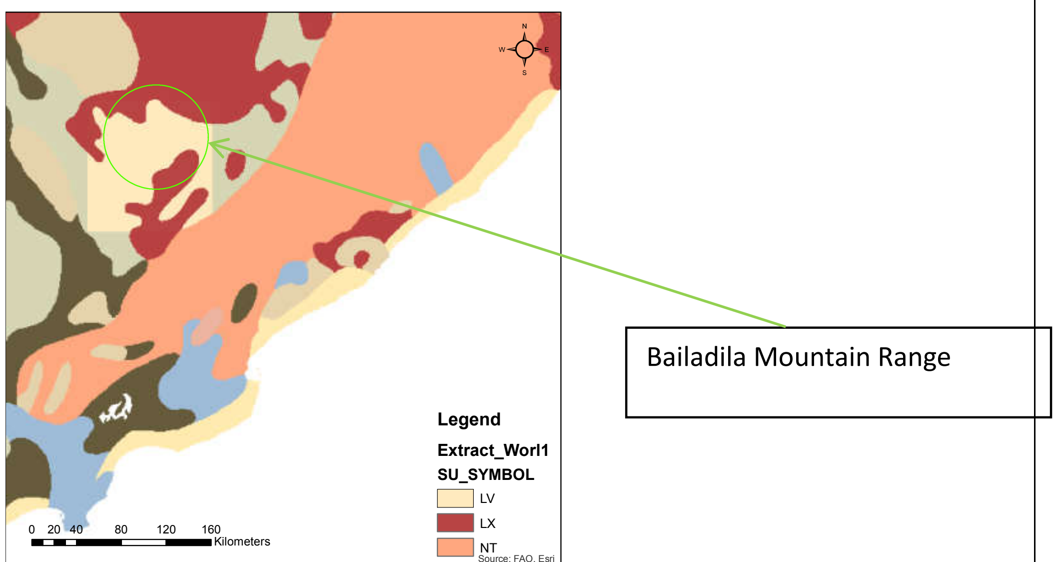
Landuse data:

MDA’s BaseVue 2013 Global Land Cover available on ArcGIS Online is used for landuse map. BaseVue 2013 is a 13-class land use/land cover dataset that covers the globe, except Antarctica, at 30m resolution. BaseVue is derived from Landsat 8, which was launched in February 11th, 2013, and began providing data shortly afterwards.



Soil data:

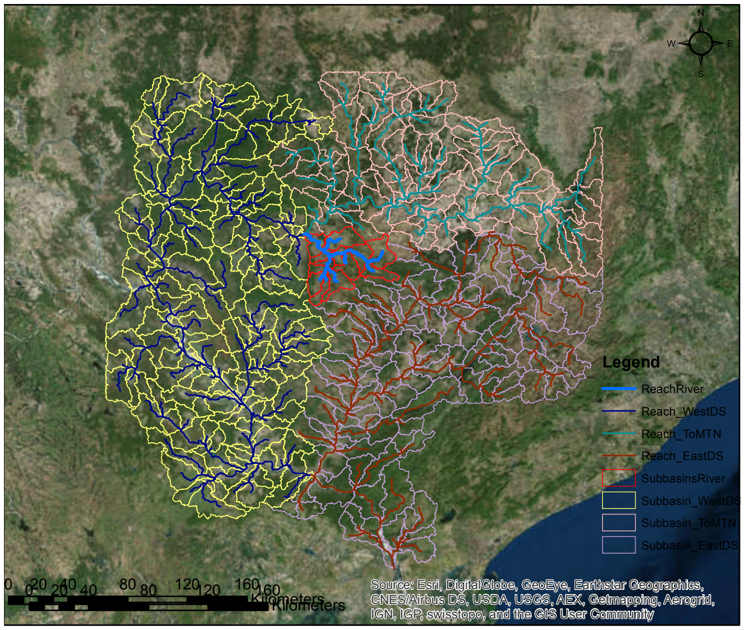
Soil is a key natural resource that provides the foundation of basic ecosystem services. Soil determines the types of farms and forests that can grow on a landscape. Soil helps regulate the Earth's climate by storing large amounts of carbon. Soil filters water. So, for this project also, infiltration in soil is one of the important factors in estimating the volume of rainwater runoff from Bailadila mountain range. Thus, World Soils Harmonized World Soil Database – Hydric is used to get the genral soil data by using ARCGIS online server http://landscape6.arcgis.com/arcgis/rest/services/World_Soils_HWSD_Hydric/_ImageServer. The HWSD is an aggregation of datasets. The data sources are the European Soil Database (ESDB), the 1:1 million soil map of China (CHINA), the Soil and Terrain Database Program (SOTWIS), and the Digital Soil Map of the World (DSMW).



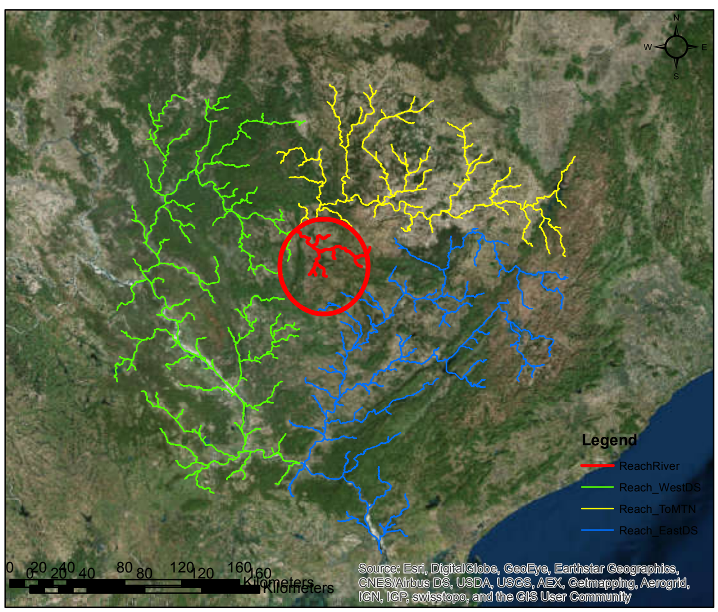
Subwatershed and stream network delineation:

ARCHYDRO is used to developed subwatershed and stream network delineation by applying these ARC HYDRO tools sequentially .

- DEM Manipulation
- Fill Sinks
- Flow Direction
- Flow Accumulation
- Stream Definition
- Stream Segmentation
- Catchment Grid Delineation
- Catchment Polygon Processing
- Drainage Line Processing



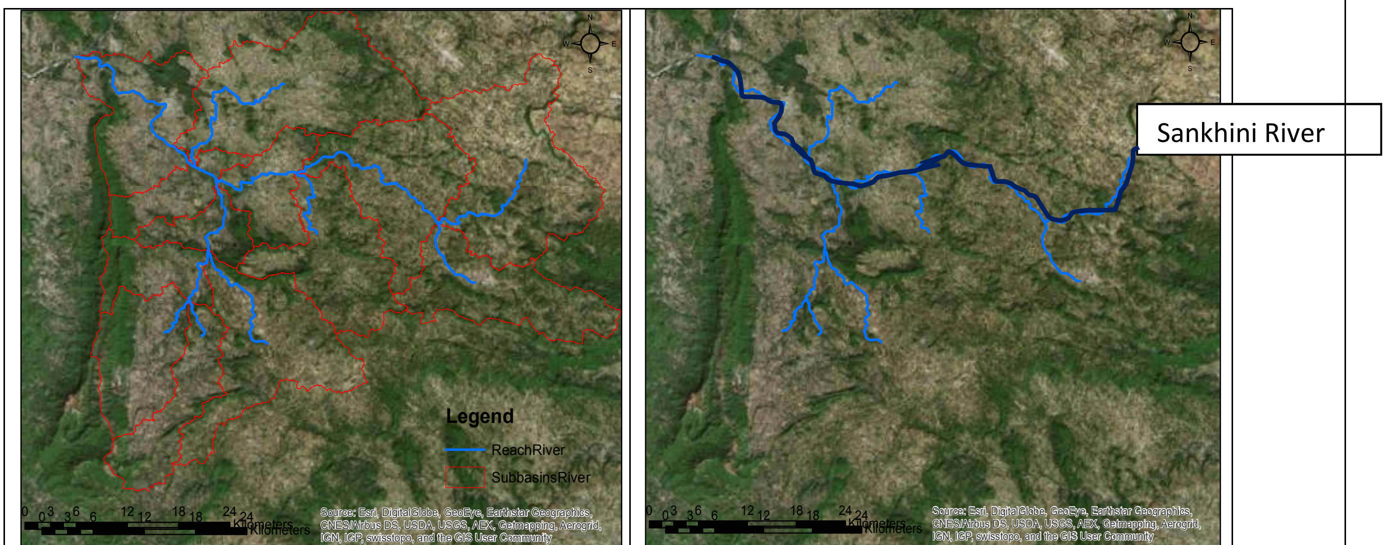
Since this stream network delineation and watershed is difficult for analyzing the stream networks in the study area, by changing catchment polygon processing value and making different shape files for streams going in different paths, a stream line flow map has been generated.



This stream networks show that only the stream heighted inside the red circle are actually going to the Sankhini River. Thus, 4 different watershed and reach have been developed.

1. Reach river
2. Reach west DS
3. Reach to MTN
4. Reach East Ds

Eastern side of the Bailadila mountain range rainwater goes into the Sankhini River named as ‘reach river’ but the western and southern flowlines named as Reach west DS & Reach to MTN goes into Mahandi river, which takes approximately two-third of the muddy rainwater from the Bailadila mountain range. Since, NMDC limited receives complains only due the muddy water from into Sankhini river, the area of study can be concentrated to “reach river” and the respective river sub-basin for now in this project scope. Further it should be expanded for the whole region to get accurate results.



There are total 12 sub-basin in Sankhini river basin. By seeing the second map, the stream networks generated by ARC hydro has been verified because all the streams are going into the Sankhini River perfectly.

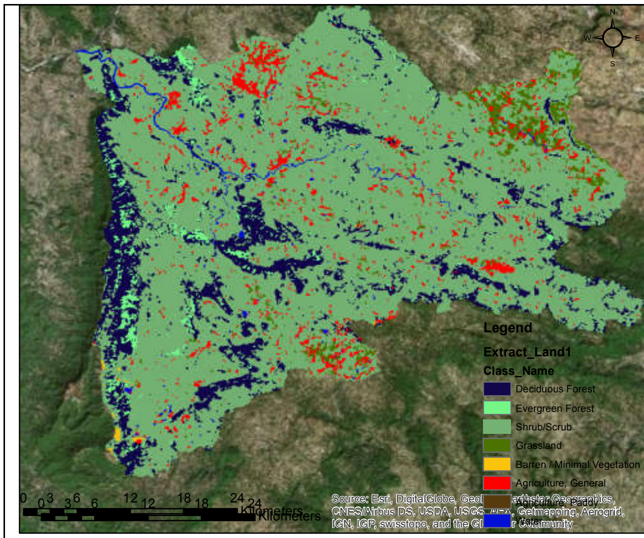
This shows that the stream networks generated by ARC HYDRO are correct and can be used for further study.

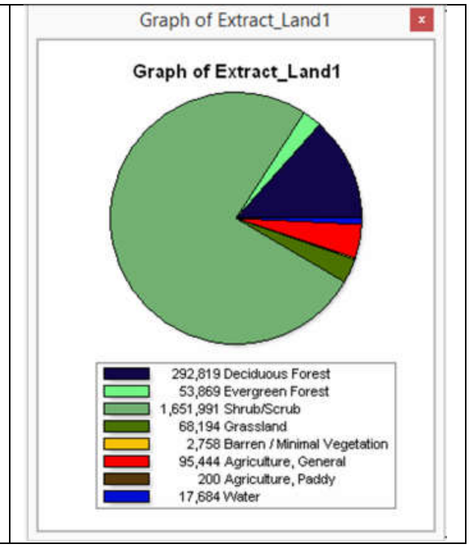
Note:

1. Till now, no organization provides the watershed and flowlines data in India. Only BHUVAN (developed by ISRO) provides this data but they are not downloadable. So, with the help of ARC HYDRO, the flowline and watershed data can be made available in India free of cost, so that any organization who wants to use it for their own purpose can use it free of cost.
2. BHUVAN has landuse data but not downloadable.
3. Till now, BHUVAN has not published any soil data for Chhattisgarh state. ESRI has published HWSD data for the whole world on 28th September 2015. So, anyone, having license of ARC GIS, can use this data.

After collecting all the data, the landuse and soil texture maps were made for study area by using “clip by mask”.

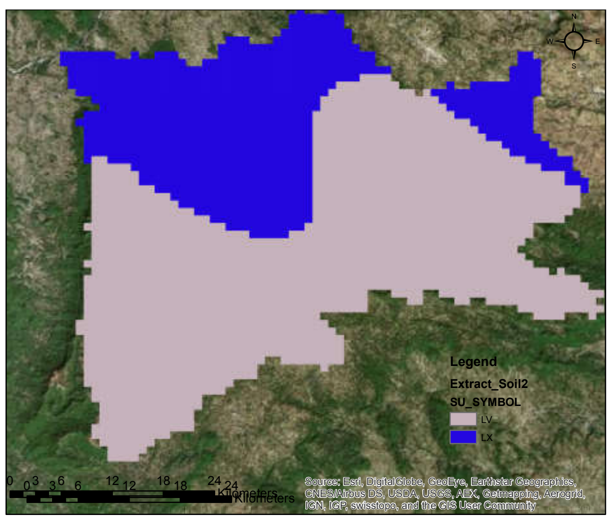
Landuse Map





By summarizing the land use map, it can be said that maximum part of this area is covered with shrub and scrub.

Soil Map:



The two soil types as per the World Soils Harmonized World Soil Database – Hydric in the study area are Luxisol and Luvisol. As per the UNESCO convention of Soil Classification:

1. Luvisol is soil with strong accumulation of clay in the B-horizon and not dark in color. Under the revised legend, this soil has clays with high cation exchange capacity.
2. Luxisol is a new soil class, formerly Luvisols, with clays with low cation exchange capacity.

Calculation of Retardance factor and Development of curve number raster map:

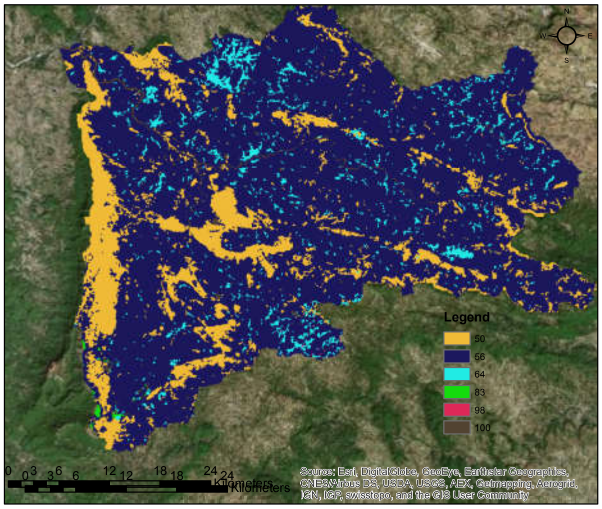
Retardance factor — It is a measure of surface conditions relating to the rate at which runoff concentrates at some point of interest. The term "retardance factor" expresses an inverse relationship to "flow retardance". Low retardance factors are associated with rough surfaces having high degrees of flow retardance, or surfaces over which flow will be impeded. High retardance factors are associated with smooth surfaces having low degrees of flow retardance, or surfaces over which flow moves rapidly.

Retardance factor depends on soil type and land use type. Our study region consists of luxisol and luvisol, which is mainly type B and type C soil. So, for calculation of retardance factor, which is same as curve number, has been developed by joining the soil type with land use map as per this retardance factor table.

Category	Description	A	B	C	D
Water	Open Water, Perennial Ice/Snow	10	10	10	10
Developed ROW	Developed Open Space	68	79	86	89
Cultivated Pasture	Hay/Pasture, Cultivated Crops	49	69	79	84
Forest	Deciduous, Evergreen, Mixed, Shrub/Scrub	30	55	70	77
Developed - Low Intensity	Developed - Low Intensity	51	68	79	84
Developed - Medium Intensity	Developed - Medium Intensity	57	72	81	86
Developed - High Intensity	Developed - High Intensity, Barren Land	77	85	90	92
Wetlands	Emergent Herbaceuous Wetlands, Woody Wetlands	98	98	98	98
Barren Land	Barren Land	76	85	90	93
Grassland	Dwart Scrub, Shrub, Herbaceous, Grasslands, Lichen, Moss	39	61	74	80

- **HSG Group A** (low runoff potential): Soils with high infiltration rates even when thoroughly wetted. These chiefly consist of deep, well-drained sands and gravels. Final infiltration rate is greater than 0.3 in/h.
- **HSG Group B** Soils with moderate infiltration rates when thoroughly wetted. These chiefly consist of soils that are moderately deep to deep, moderately well drained to well drained and moderately fine to moderately coarse textures (final infiltration rate of 0.15 to 0.30 in/h).
- **HSG Group C**: Soils with slow infiltration rates when thoroughly wetted. These chiefly consist of soils with a layer that impedes downward movement of water or soils with moderately fine to fine textures (final infiltration rate 0.05 to 0.15 in/h).
- **HSG Group D** (high runoff potential): These chiefly consist of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious materials (final infiltration rate less than 0.05 in/h).

By joining both the map with this table, Curve Number raster map is generated.

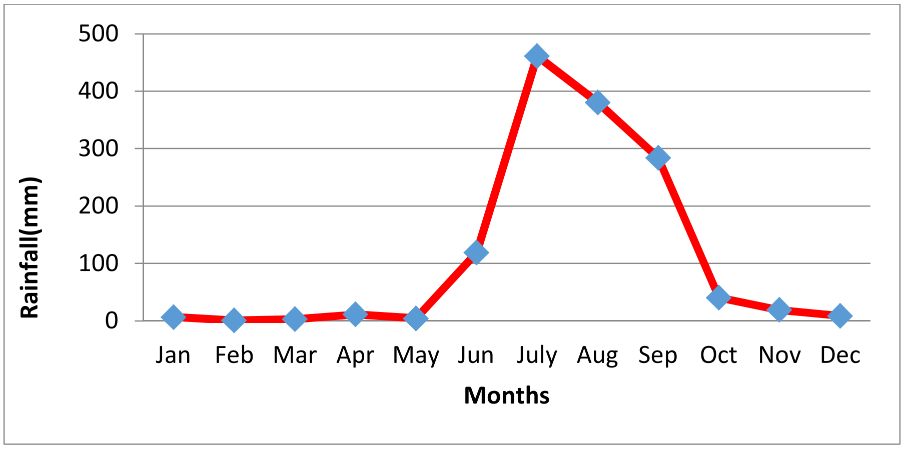


Luxisol and luvisol is a mixture of type B and type C soil. So our average CN number in the region is 56%. So, 56% of the rain infiltrates in the soils.

Rainfall Data and anylysis:

The rainfall data has been collected from Indian Meteorological department. The India Meteorological Department (IMD), also referred to as the *Met Department*, is an agency of the Ministry of Earth Sciences of the Government of India. It is the principal agency responsible for meteorological observations, weather forecasting and seismology. They don't have the specific rainfall data for this region but the average rainfall data of dantewada district in which bailadila mountain range falls.

Rainfall (dantewada District)- 5 year monthly average(mm)												
Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2010	0.0	2.0	13.0	3.5	0.0	202.0	460.0	387.9	137.4	0.1	0.0	0.0
2011	0.0	0.0	0.0	0.0	0.0	14.4	398.9	155.5	110.3	19.5	10.5	0.0
2012	17.2	0.0	0.0	3.0	0.0	117.7	524.4	457.7	356.8	72.0	40.0	42.8
2013	0.0	0.4	1.0	40.2	2.7	125.6	278.2	390.3	335.8	45.4	0.0	0.0
2014	14.1	0.0	0.0	9.0	17.0	132.9	643.9	510.4	479.1	63.9	43.0	0.0
Monthly Average	6.26	0.48	2.8	11.14	3.94	118.52	461.08	380.36	283.88	40.18	18.7	8.56

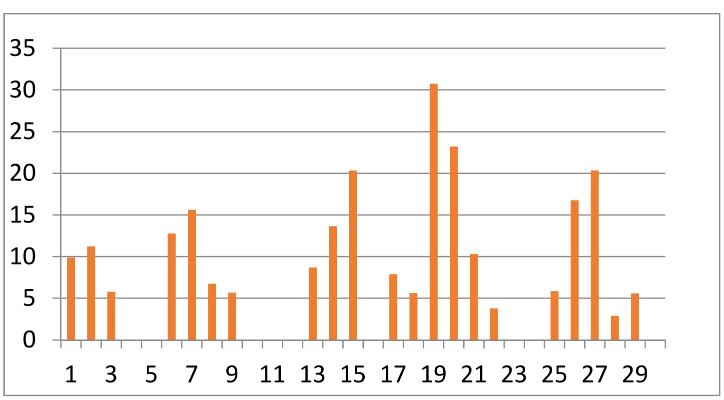


The rainy season in general last for four months from June to September. The maximum rainfall, on an average, is 461.08 mm in the month of July (taking average of last 5 year rainfall). IMD doesn't have daily rainfall data for this region. So, the daily rainfall data has been collected from NMDC limited, which does meteorological study every year for four seasons.

The daily rainfall data of monsoon season is:

July (2015)

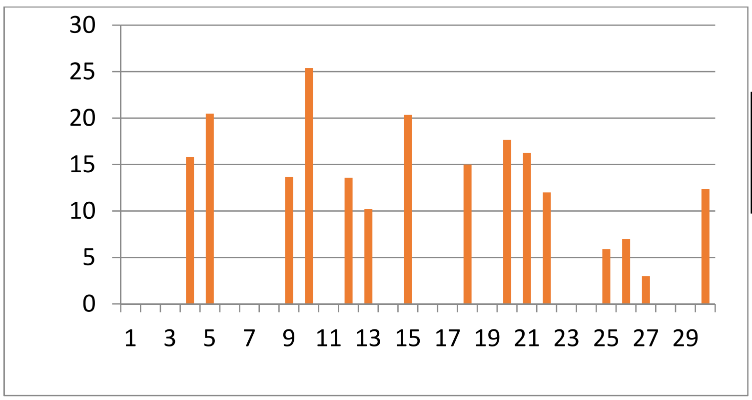
Date wise Rainfall in July 2015 (Source :NMDC Limited)									
1 9.89mm	2 11.23 mm	3 5.78 mm	4 0.00 mm	5 0.00 mm	6 12.78 mm	7 15.62 mm	8 6.73 mm	9 5.67 mm	10 0.00 mm
11 0.00 mm	12 0.00 mm	13 8.70 mm	14 13.64 mm	15 20.32 mm	16 0.00 mm	17 7.90 mm	18 5.63 mm	19 30.73 mm	20 23.23 mm
21 10.30 mm	22 3.80 mm	23 0.00 mm	24 0.00 mm	25 5.87 mm	26 16.78 mm	27 20.34 mm	28 2.90 mm	29 5.60 mm	30 0.00 mm
31 0.00 mm									



July has the 24 hour maximum rainfall of 30.73mm on 19th July 2015.

August 2015

Date wise Rainfall in July 2015 (Source :NMDC Limited)									
1 0.00 mm	2 0.00 mm	3 0.00 mm	4 15.80 mm	5 20.47 mm	6 0.00 mm	7 0.00 mm	8 0.00 mm	9 13.67 mm	10 25.37 mm
11 0.00 mm	12 13.59 mm	13 10.23 mm	14 0.00 mm	15 20.35 mm	16 0.00 mm	17 0.00 mm	18 15.00 mm	19 0.00 mm	20 17.67 mm
21 16.23 mm	22 12.00 mm	23 0.00 mm	24 0.00 mm	25 5.89 mm	26 7.00 mm	27 3.00 mm	28 0.00 mm	29 0.00 mm	30 12.35 mm
31 0.00 mm									

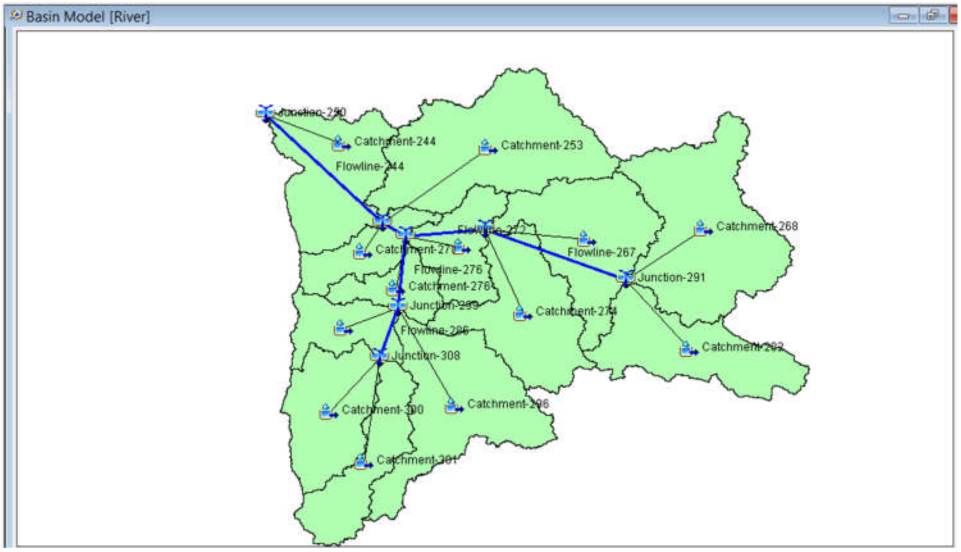


August has the 24 hour maximum rainfall of 25.37mm on 10th August 2015.

HEC HMS Model and Flow Analysis

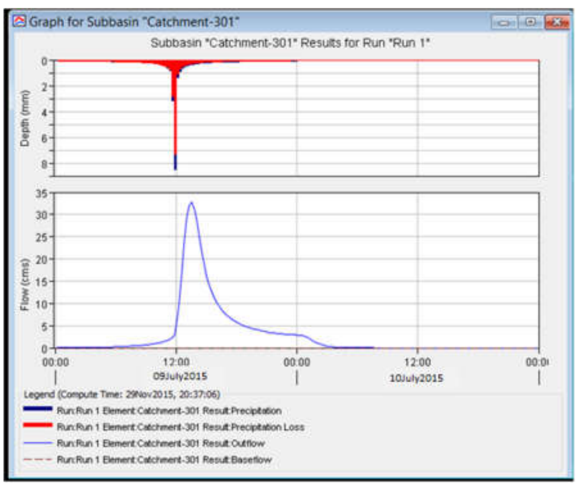
The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of dendritic drainage basins. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff.

So, for our river subbasin, an HEC-HMS model has been developed. It has 13 subbasin, 7 junctions and 6 reaches. The analysis of rainwater flow can be analyzed as 5 points i.e. Flowline 276, Catchment 271, 286, 300 and 301. The Flowline 276 has been chosen for analysis because this carries total volume of rainwater from the Bailadila Mountain going into the river. So the flow at this point will tell the exact amount of red water that is coming from the whole mountain range and needs to be treated. Catchment 271, 286, 300 and 301 are the catchments, which contribute in all the red water flow from Bailadila mountain range.



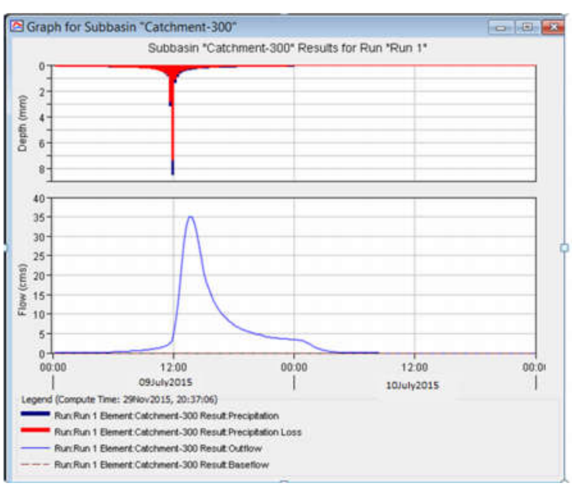
Since the maximum rainfall was 30.73mm on 19July 2015, the analysis is done for this day at all the points of interest.

Catchment 301



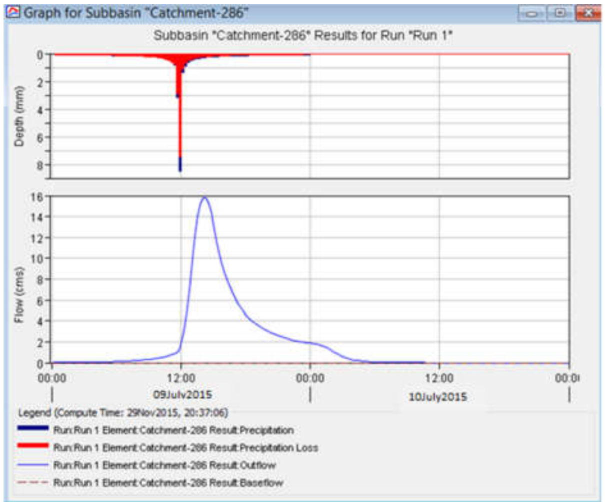
Peak flow: $33m^3/s$ at around 1pm

Catchment 300



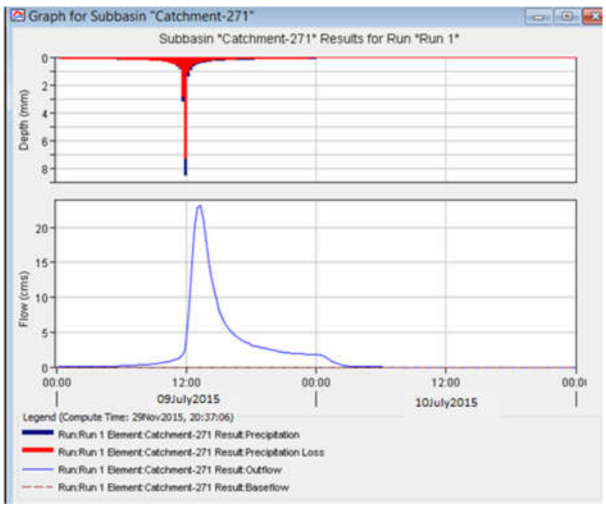
Peak flow: $35m^3/s$ at around 1pm

Catchment 286



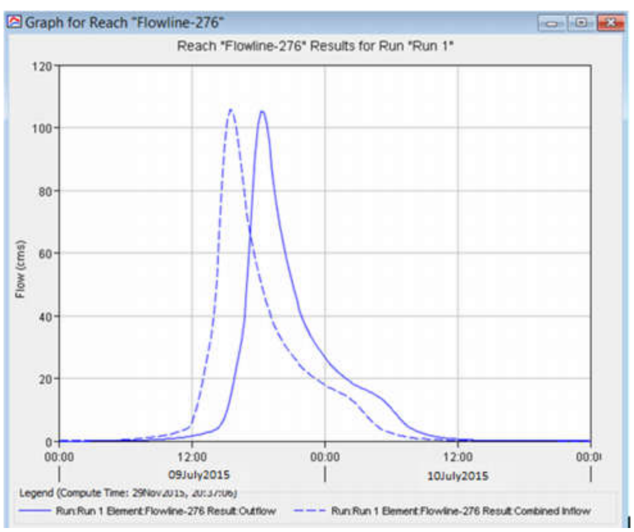
Peak flow: $16m^3/s$ at around 1pm

Catchment 271



Peak flow: $24.5m^3/s$ at around 1pm

Flowline 276



Maximum rainwater flow: $105.9m^3/s$ at around 6pm

Volume under the curve = 189360 m^3/day

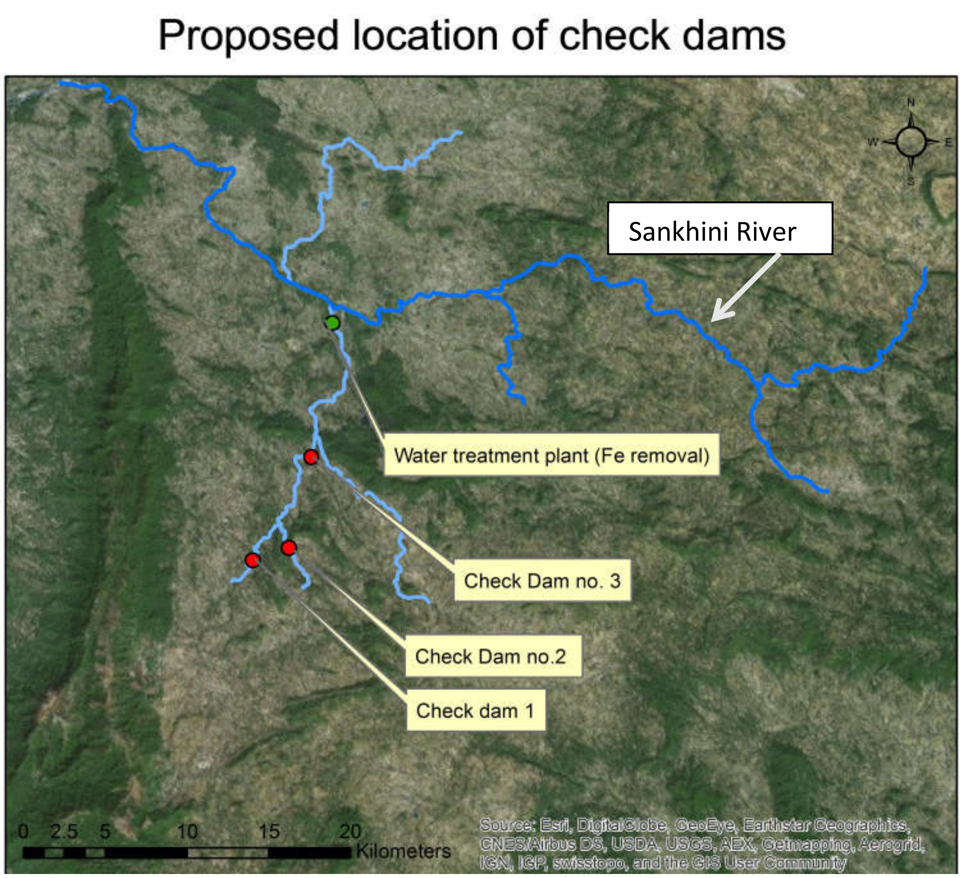
Results:

1. Maximum runoff is from catchment 300 i.e. 30m^3/s at around 1 pm.
2. Maximum water flow in the flowline 271 is 105m^3/s at around 6 pm.
3. Total Volume of water went into the river is 189360m^3 on 19th July.
4. Its takes 5 hours for water to reach the Sankhini river from the mountain range.

Conclusion:

Although our study region was only on eastern side of the Bailadila mountain range from where rainwater goes into the Sankhini River, the western and southern flowlines go into Mahandi River, which contains approximately two-third of the muddy rainwater from the Bailadila mountain range. So, it is required to study streams and flowlines for that region too to study impact of mining on water quality. The Sankhini River is mainly covered with clay loamy soil having landuse class type of scrub and shrub. The average curve number of this region is 56 which imply that 56% of rainwater flows to the river and 44% infiltrates into the soil. The area is characterized by rugged terrain and heavy rainfall i.e. 450 mm on an average in the month of July. So, the Bailadila Mountain is highly eroded.

Suggested constructions:



Treatment methods cannot be done in the flowline 276 since total water quantity flowing in the river in a day of highest rainfall is 189360m^3 (by calculating the area under the graph of flowline 276) that will require a big reservoir to be constructed for settlement. So, the best option is to construct check dams and check bunds on flowlines 286 and 276. By making the check dams and small check bunds, maximum ore and soil will be removed from the water before reaching flowline 276 after which it can be treated for removing iron content and rest TDS.

Study has been limited to eastern side of the region, but studying the entire region will give better understanding of water management practices. Mining technics and environment management practices in mining also impact the water runoff. So, techniques like desilting of tailing dam, check dams and check bunds, geo coir matting and plantation on waste dump & all around the mining lease area will be a few ways to improve the water quality. If this problem is not solved early, this may cause the mining to stop in this region forever. Improving the water quality of the Sankhini river will not only help the company to continue mining but also improve lives of villagers. It will also save a ton of money for the company that is to be paid every year as compensation to the local people and government.

References:

1. bhuvan.nrsc.gov.in
2. World Soils Harmonized World Soil Database – Hydric
3. MDA's BaseVue 2013 Global Land Cover data
4. NMDC Limited : https://www.nmdc.co.in
5. www.thehindu.com/news/.../red-water.../article6183876.ece

Be a part of Solution

Not the Pollution!!