Underlying Causes of Flooding in *Haor* Region and Waterlogging in Sylhet City

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Few Observations

- The frequency, magnitude, and duration of flooding in Bangladesh have increased over the last few decades
  - Major floods: 1955→1974 (19 years)→1988 (14 yrs)→1998 (10 yrs)→ 2004 (6 yrs)→2010 (4 yrs)→ 2017 (7 yrs)→2022 (5 yrs)→2023 (1 yr)
- Landuse pattern has shifted toward built-up area (with more roads and embankments) and reduction in vegetation cover

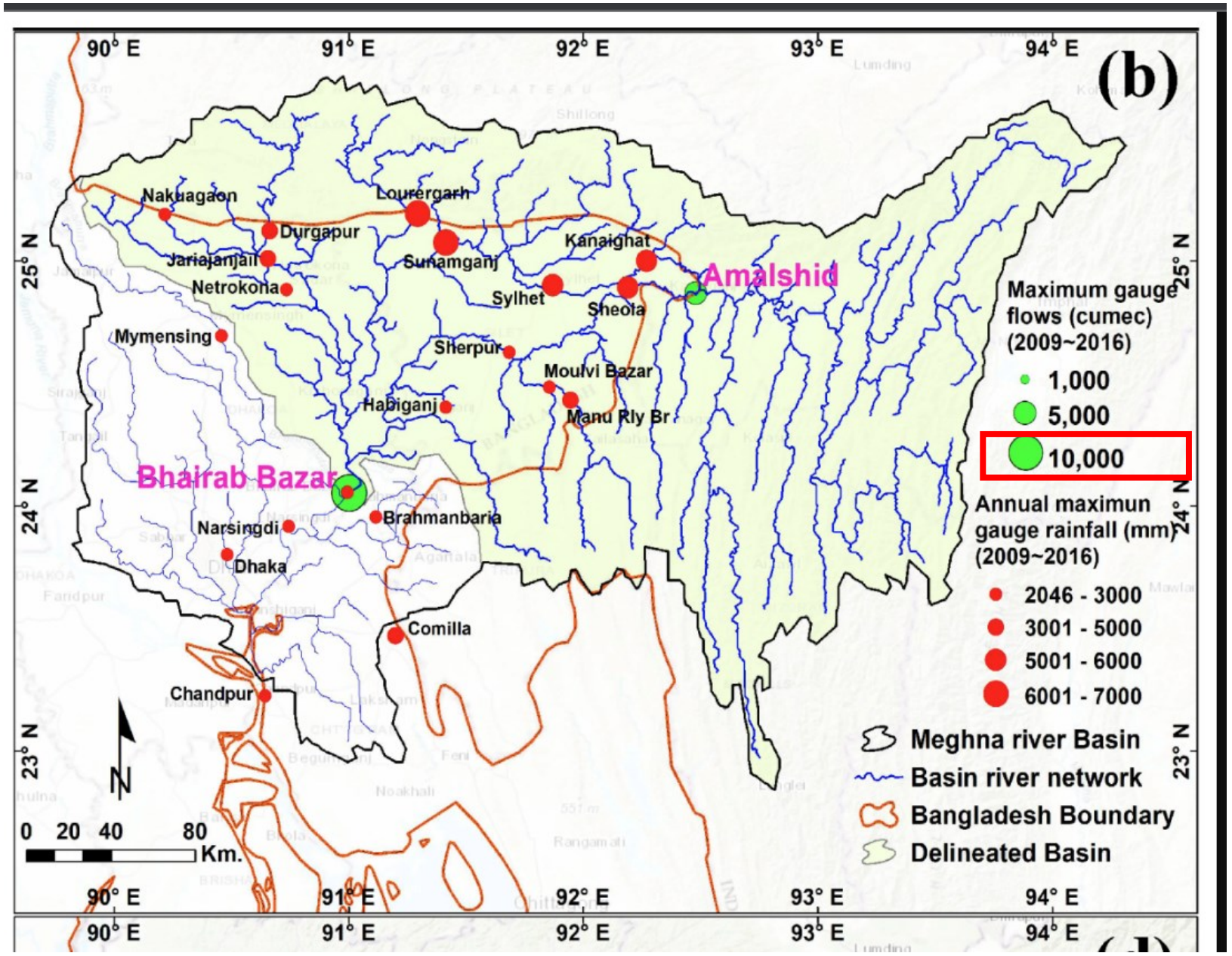
Basic Facts: Waterlogging and Flooding

Waterlogging and flashflood are caused by impediments to surface run-off and due to inadequate natural drainage network and storm drains in urban areas

Annual flooding is an important natural process for functioning of haor ecosystems and floodplain building process

Episodic flooding is caused by excessive rain in basin area that overwhelm natural drainage and exacerbated by reduction in water-carrying capacity due to silting up and impediment to overland flow created by humans in the form of frontal and lateral structures (roads, embankments, bridges, railroads, construction, unplanned urbanization, and clogging of storm drains.

Meghna Basin above the Bhairab Bridge



- https://www.mdpi.com/remotesensing/remotesensing-10-00828/article_deploy/html/images/remotesensing-10-00828-g001.png

Islam et al., 2018

Underlying Causes of the Episodic Flood Event

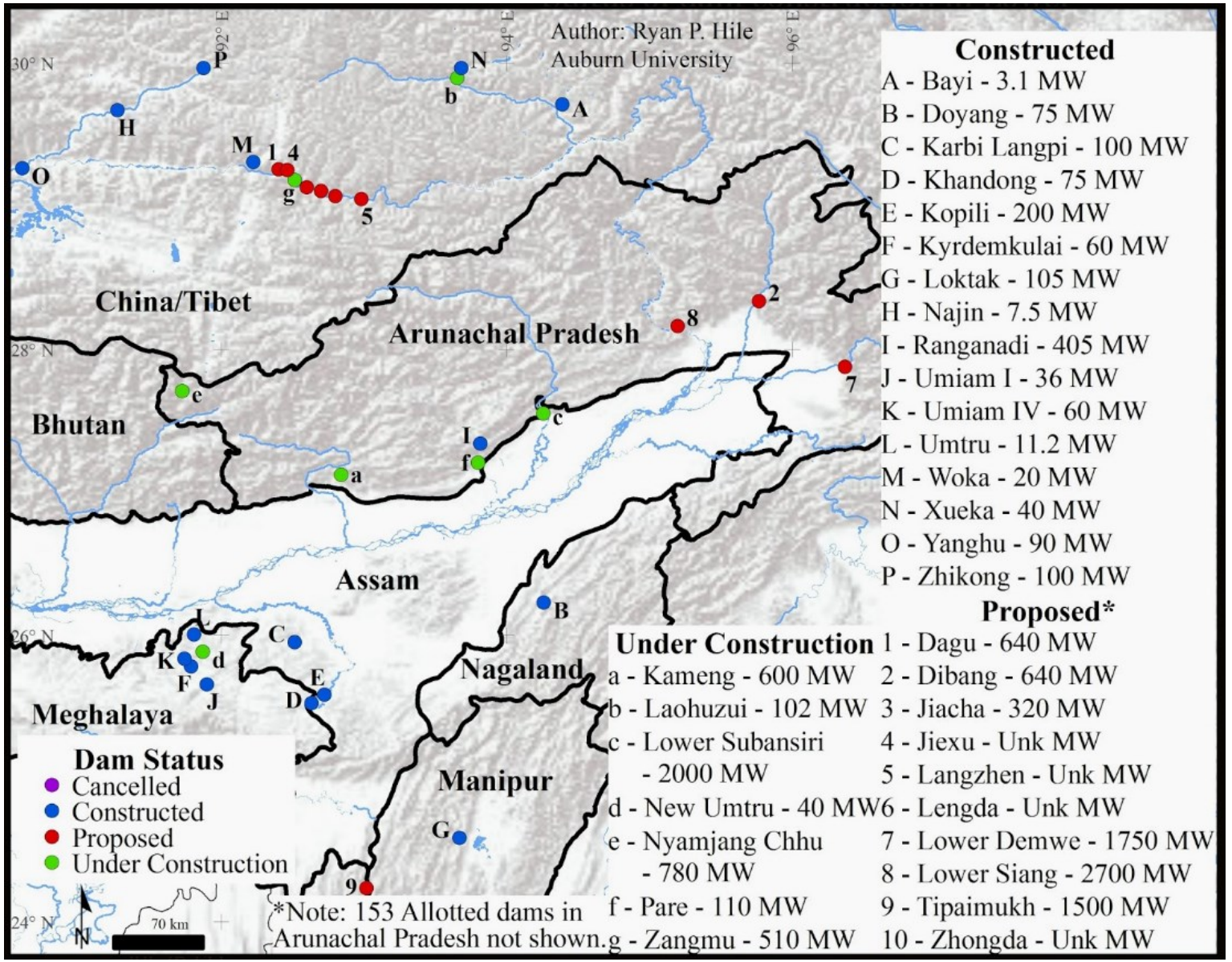
- **Global**
  - Excessive downpour in 2017 and 2022 caused by climate change
  - Deviation of the slow-moving Jetstream
  - Slow discharge of the Meghna river due backwater effect caused by sea-level rise

Underlying Causes of the Episodic Flood Event

Interbasin:

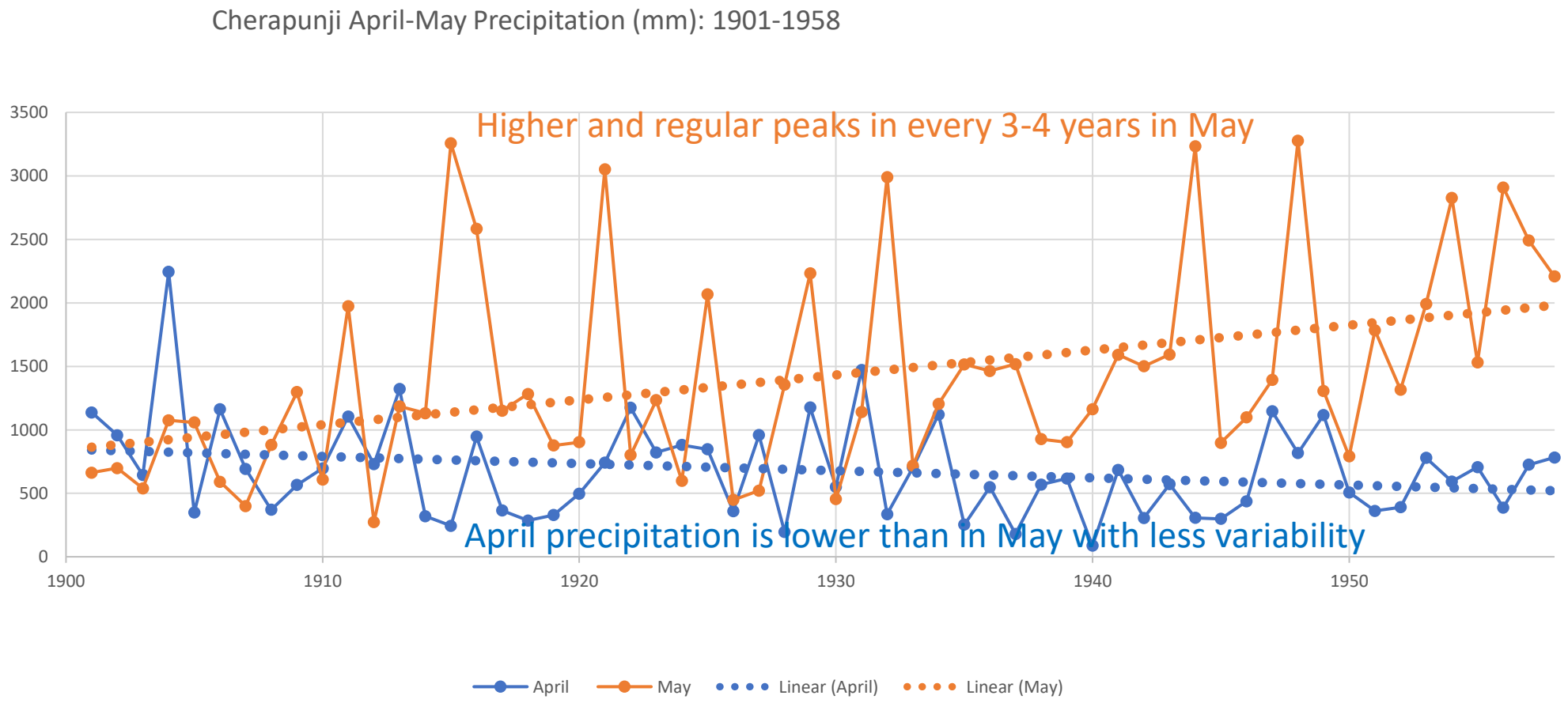
- The upstream India has been unilaterally controlling the flow of 46 transboundary rivers and stream in the Meghna Basin by constructing diversion projects, dams, hydel and irrigation project (Abdul Karim Kim, Somokal, June 17th, 2022)
- Massive loss of forest due to coal mining operations are ongoing in upstream region of the Meghna Basin, resulting in excessive siltation and water quality degradation in rivers downstream .

Status of the Dam Construction in NE India

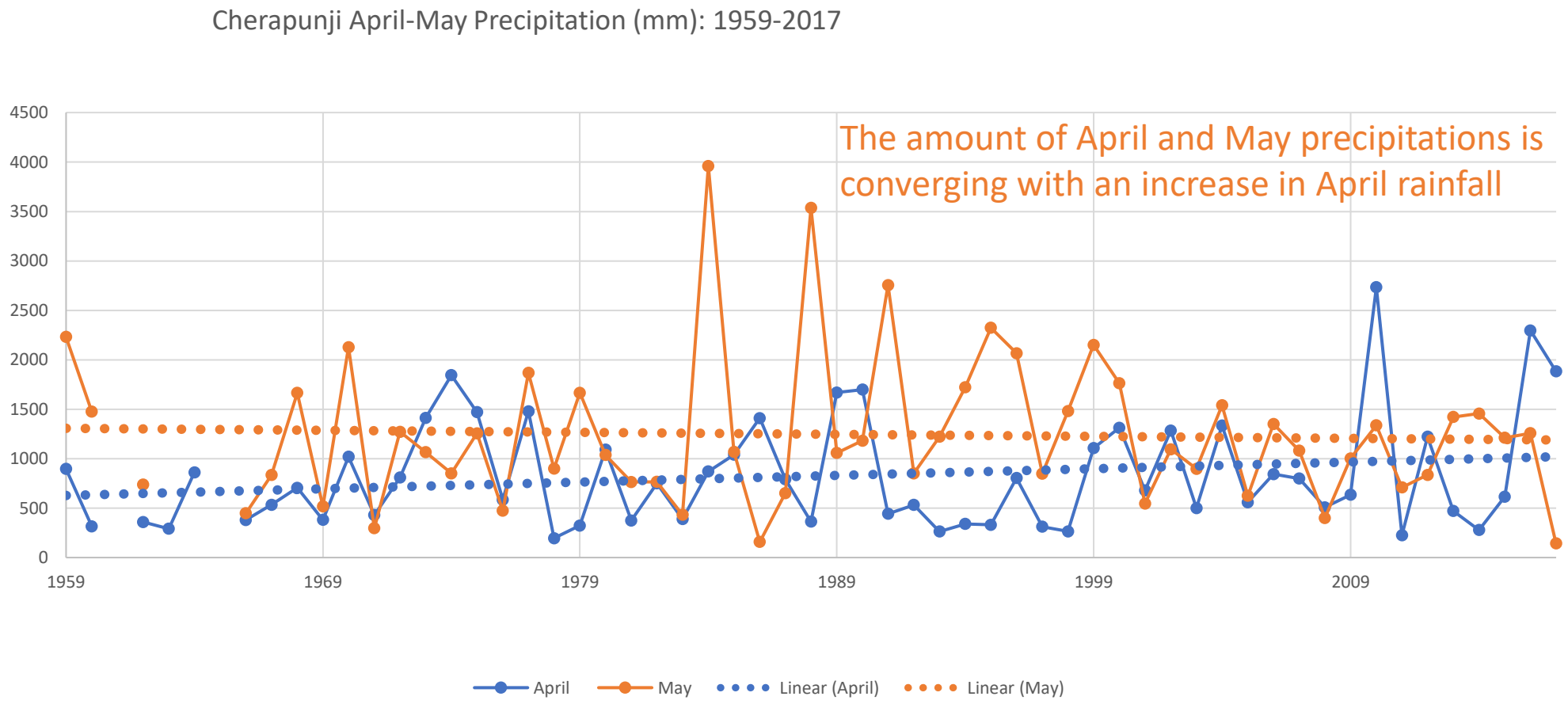


http://gangabrahma.blogspot.com/2014/08/busy-field-of-hydropower-in-eastern.html

Trend in April-May Precipitation Patterns at Cherapunji, Meghalaya during 1901-1958

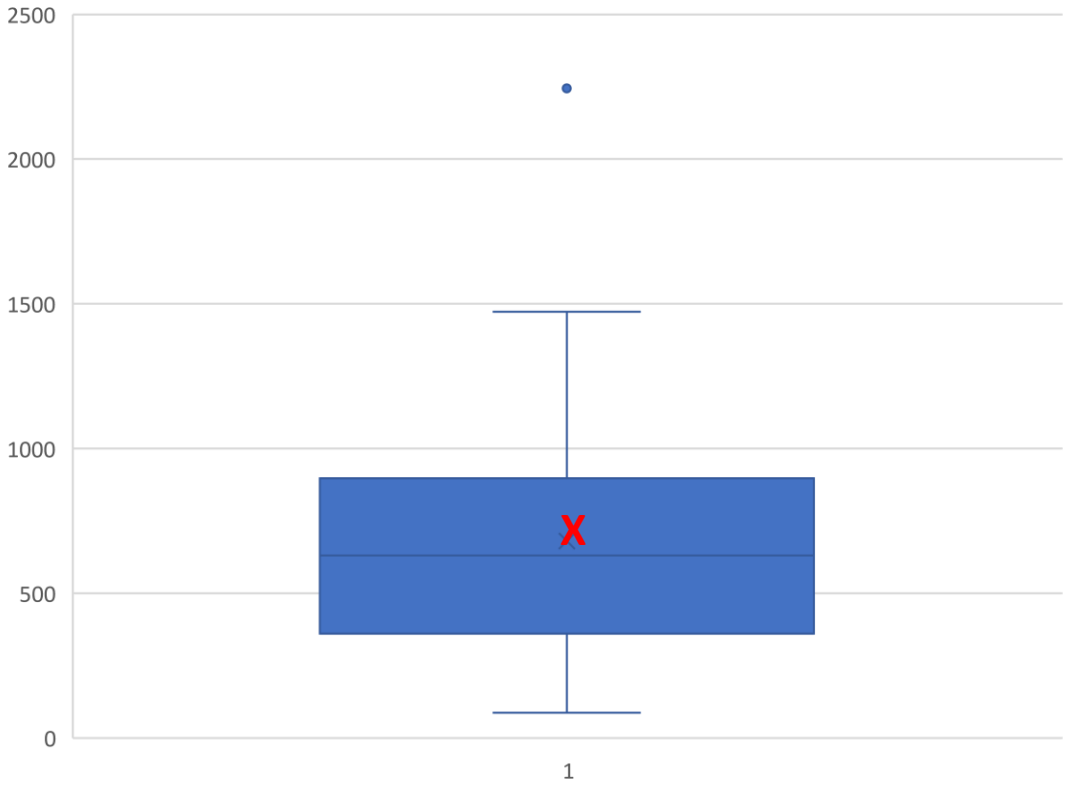


Trend in April-May Precipitation Patterns at Cherapunji, Meghalaya during 1959-2017

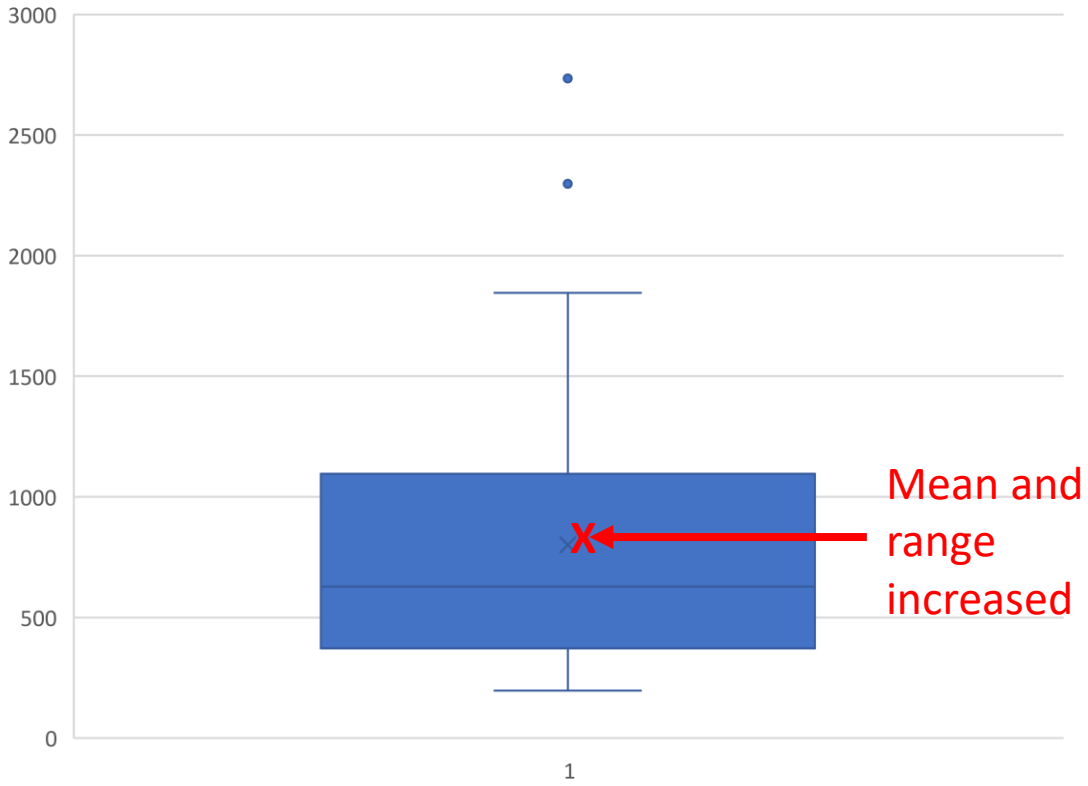


Changing total Precipitation Patterns in Cherapunji during 1901-1958 and 1959-2017

Annual Precipitation: 1901-58



Annual Precipitation: 1959-2016



Anova F(1, 113) 1.86; p<0.05 => Null hypothesis is not rejected (F>3.96 is needed to reject the null hypothesis)

Observations regarding recent precipitations

- Three floods occurred in Sunamganj-Sylhet region during 2022
- The damage to life and property has exceeded previous records
- Cherapunji in India received 4100 mm of rain during the first 20 days in June (2022), which is more than the amount received during the entire Manson season.
- Rain continued uninterrupted for 10 days
- A total of 2456 mm rainfall occurred in 3 days during June 15-17; It is worth mentioning that a total of 1262 mm rain was received in 8 days in 2017 that caused a serious flooding
- Sunamganj received about 1500 mm rain during the same period, which is about 60% of Cherapunji
- Antecedent Rain Condition made the floodplain saturated, which caused entire rain to become surface run-off that had to be discharged by existing inadequate natural drainage

Underlying Causes of the Episodic Flood Event

Domestic

*Water resources in Bangladesh has been dominated by cordon approach that encourages building of structures (polders, embankment, dams, etc.) that resulted in imdiments to surface run-off.

*Encroachment onto floodplain and land grabbing of riverbed are also a commonplace in Bangladesh.

*Foreign dependency, inefficiency and corruption in water resources management have resulted in a crippled flood management sector

Landuse changes in floodplains during 2000-2018

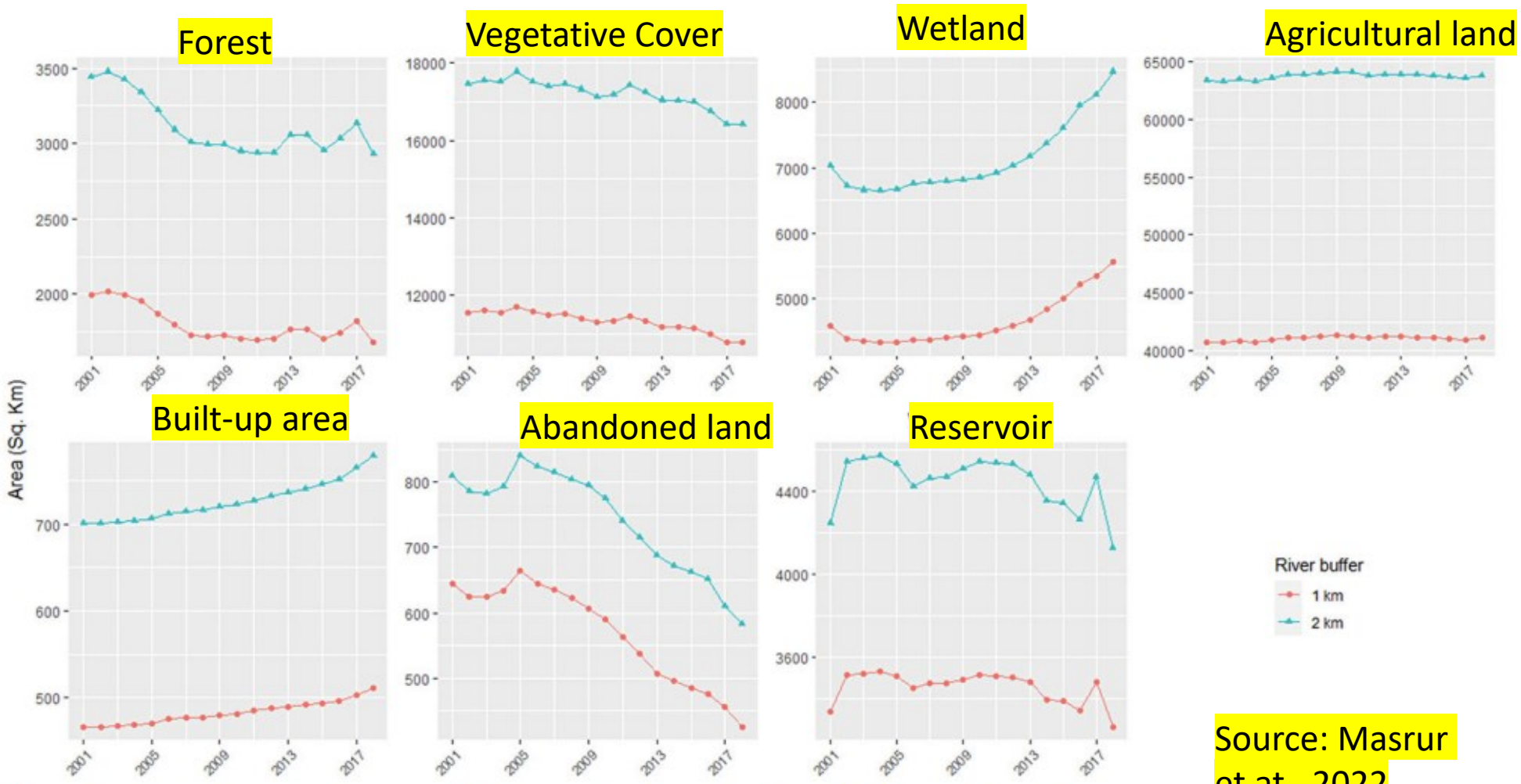
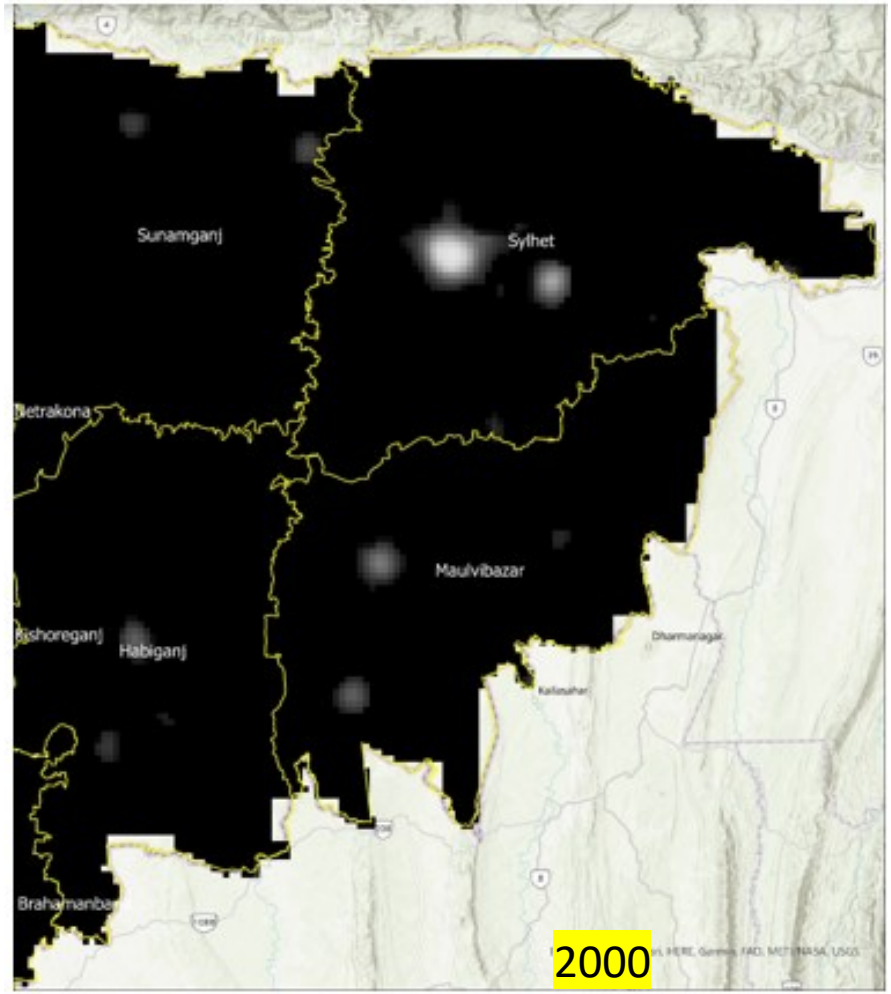


Figure 9. Annual pattern of major LULC areas (km^2) within 1- and 2-km of river buffers.

Source: Masrur et at., 2022

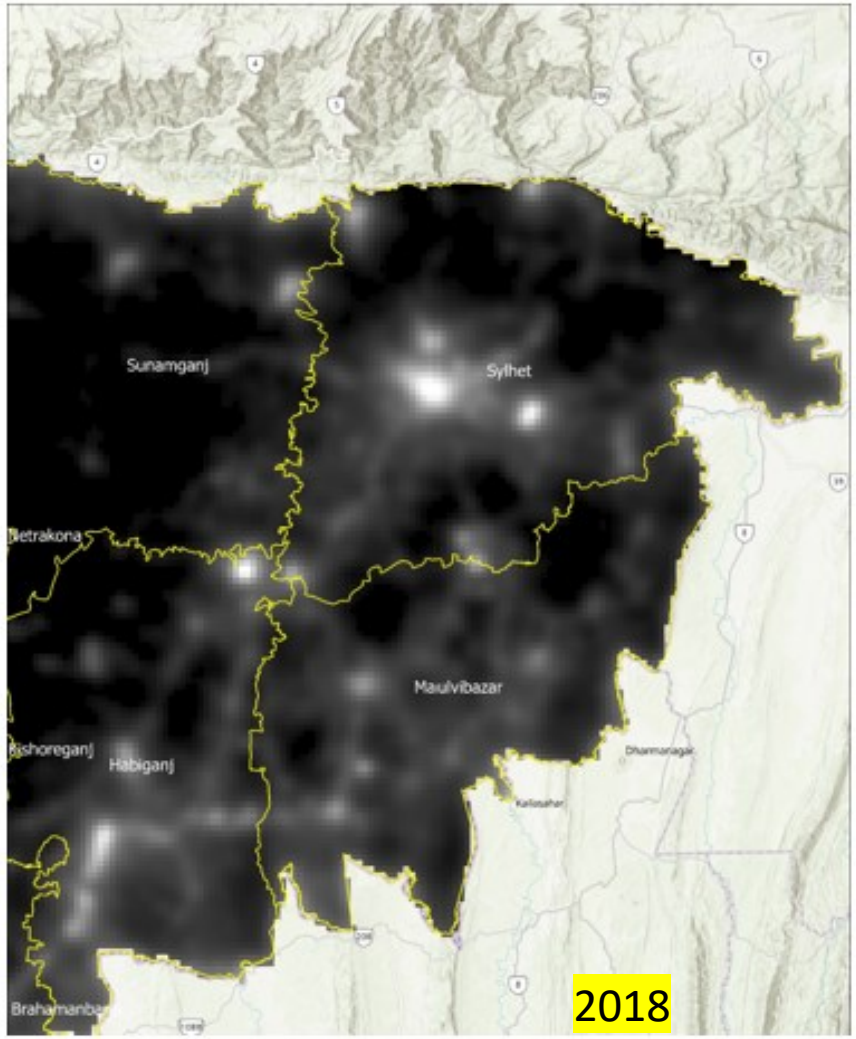
Change in Night Tile Light in Greater Sylhet Area: 2000-2018



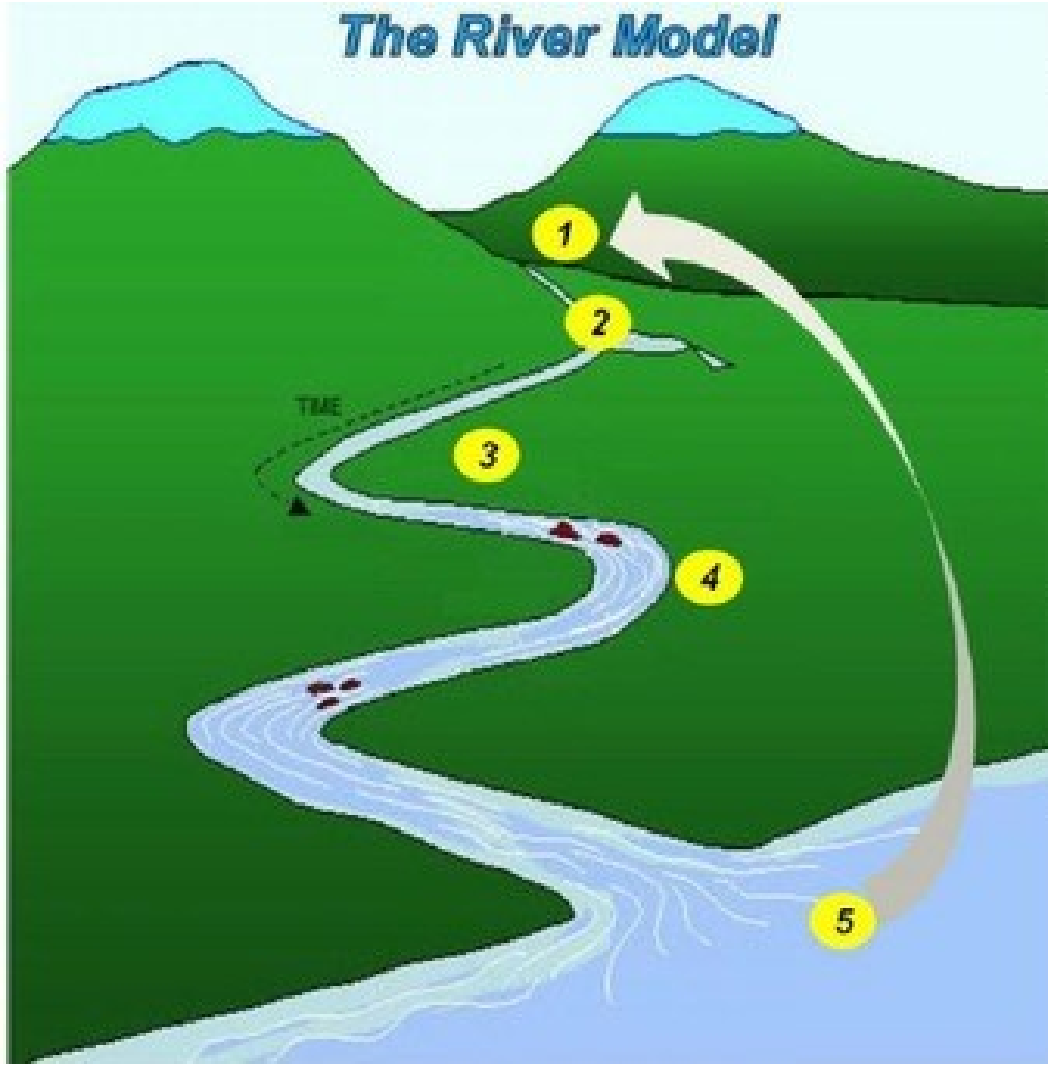
NTL luminosity data in **2000**. Bright areas indicate night lights.

Urbanization has increased in floodplain=> adverse impact on flooding

Source: Masrur, et al., 2022



Morphological Changes in a River Flowing Downstream



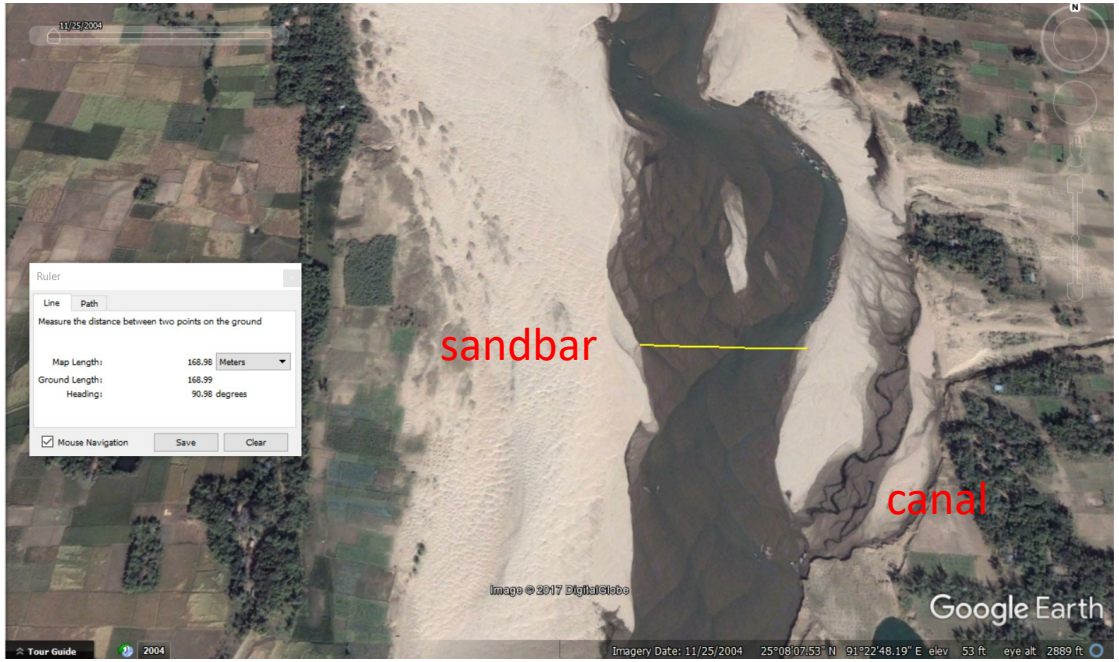
- Rivers become wider, deeper, and faster as they flow downstream to accommodate additional baseflow and flow from tributaries
- Cross-sectional area of rivers increases either by widening or deepening or both as they flow downstream
- Let's examine the morphology of the river system as they flow downstream (next few slides)

https://www.google.com/search?q=River+morphology+downstream&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjD89e7_ZjVAhVCaT4KHam3AnUQ_AUICigB&biw=1280&bih=890

Rakti River

- **The river narrows downstream, causing water to overflow the banks during rainy season**

Jadukata River: Reduction of the width from 168 m to 40 m during 2004-2017



23% of the original river width left in 13 years

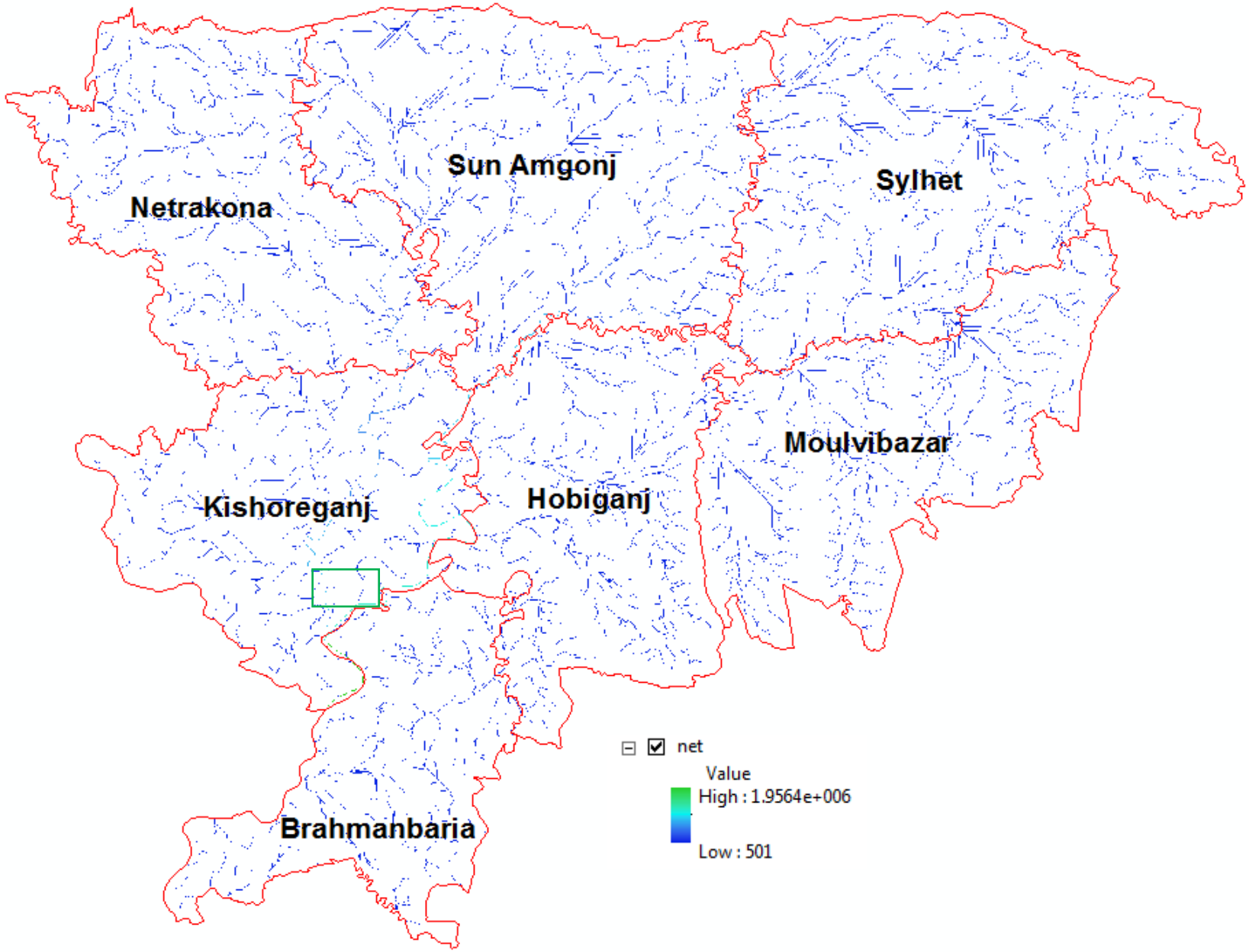
Change in riverbed upstream of Companyganj during 2004-2017

Lesson from observations

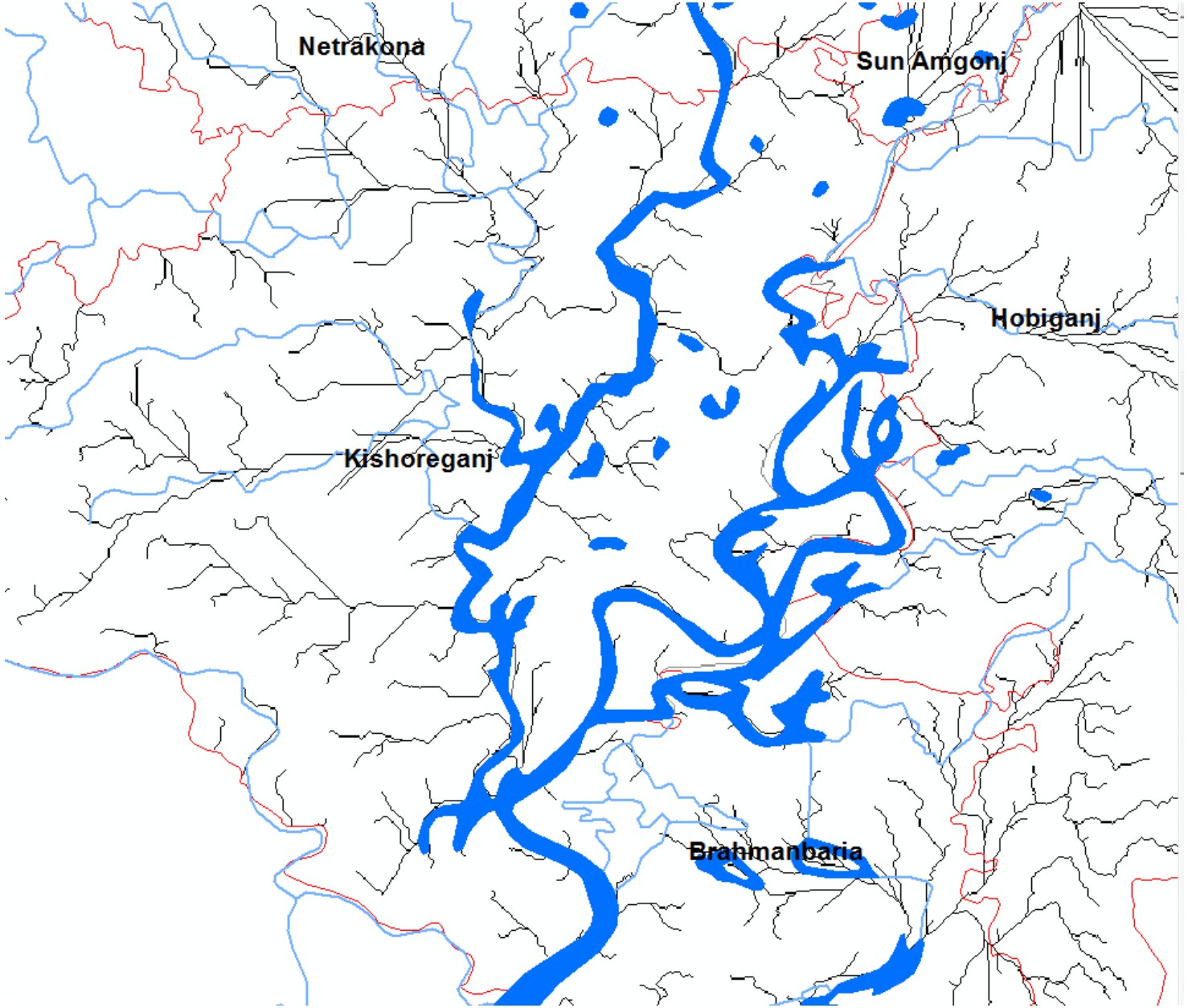
Most rivers in the haor region have smaller cross-sectional area in downstream locations, resulting in overflow of banks

Some rivers lost water-carrying capacity due to siltation, while others have been interfered with by humans

Computer-generated Drainage Network in Haor



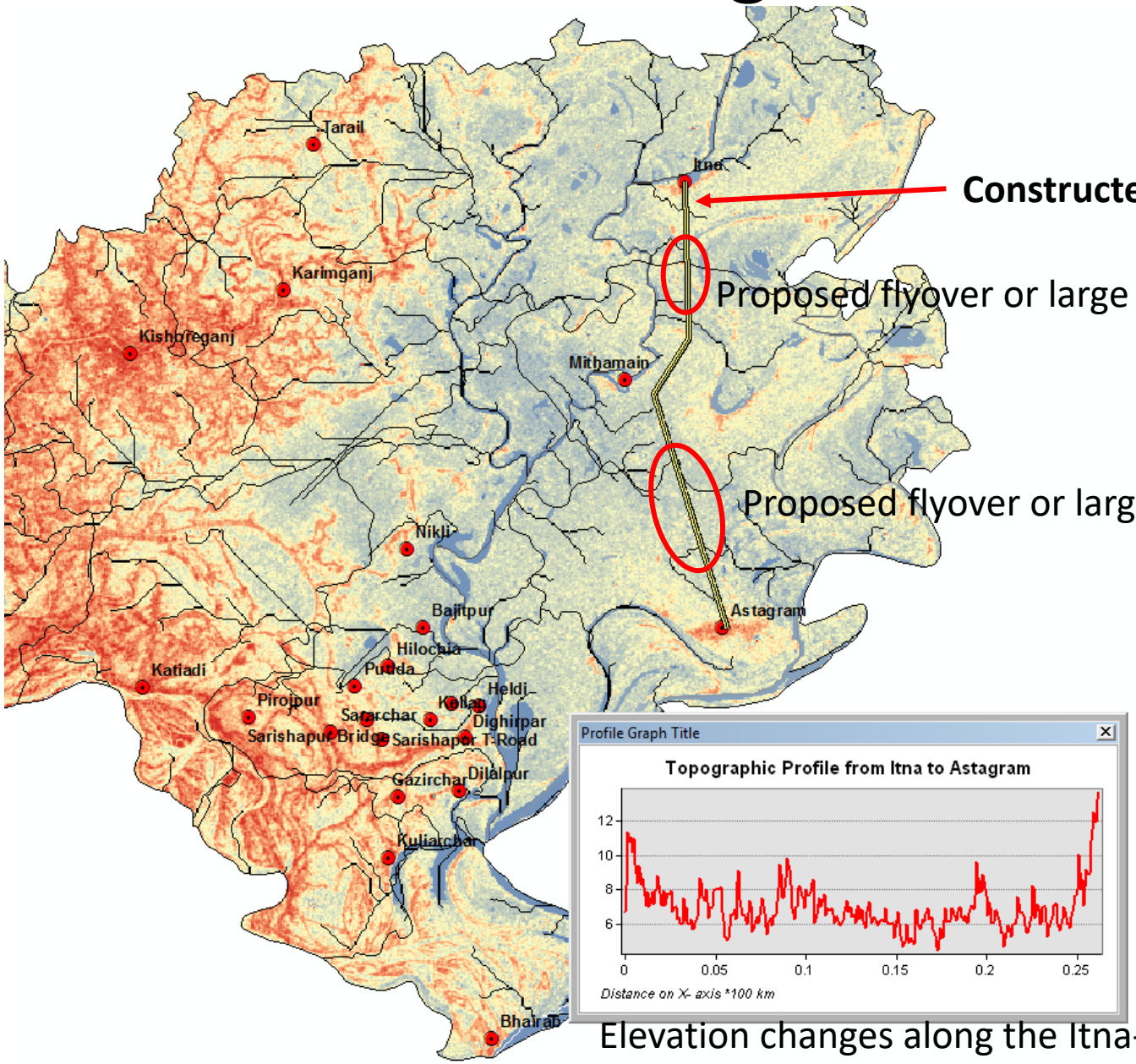
Natural Drainage vs. Computer-generated Drainage



Key:

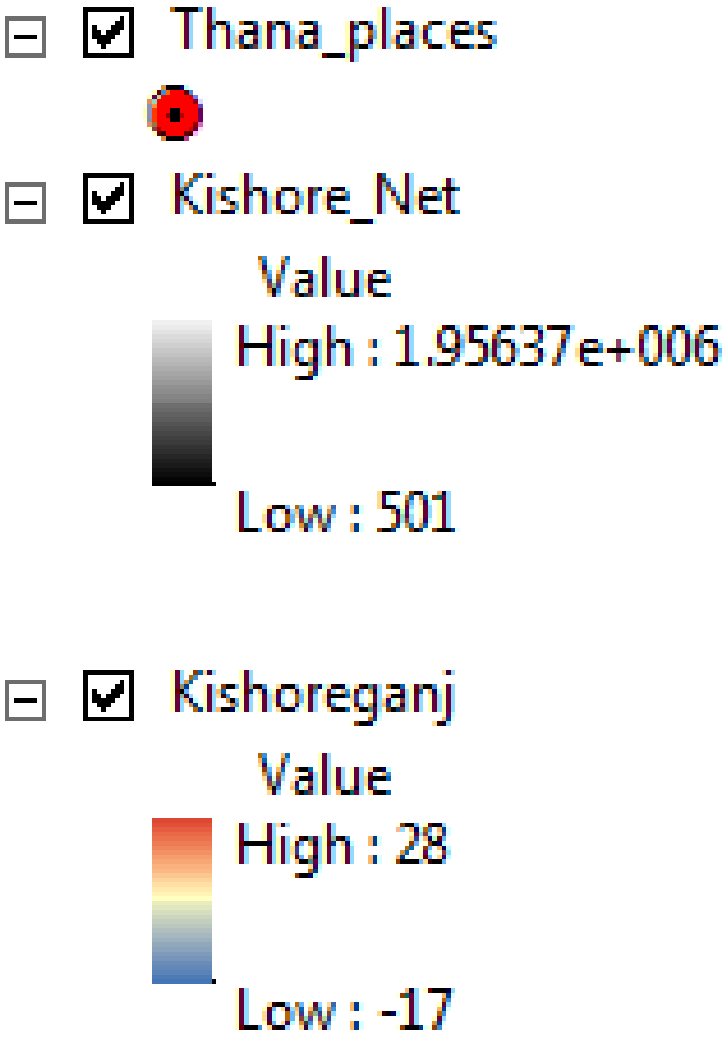
- Small Rivers
- Major Water Bodies
- Haor Zila
- Computerized Drainage
  - Value
  - High : 1.9564e+006
  - Low : 501

DEM of the haor region and the built highway

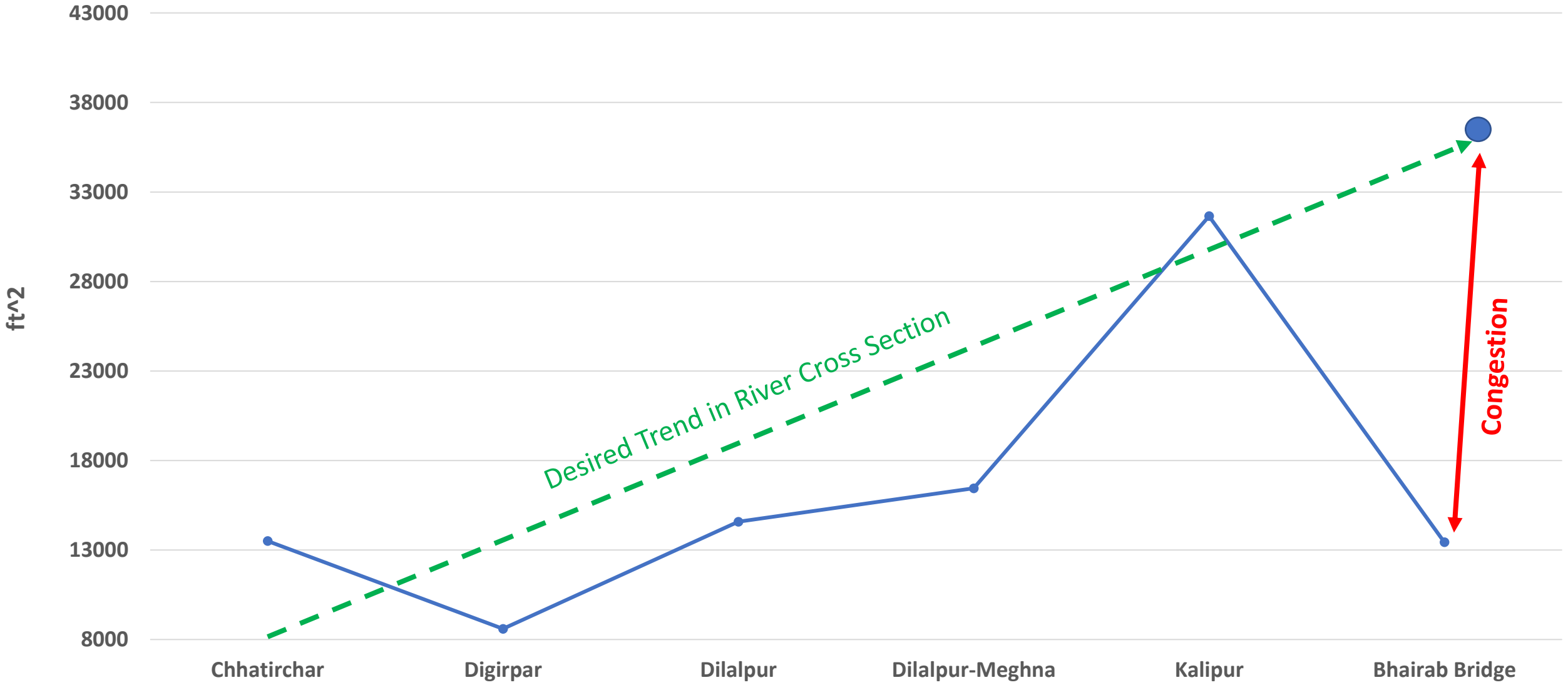


Elevation changes along the Itna-Mithamoin-Austagram highway

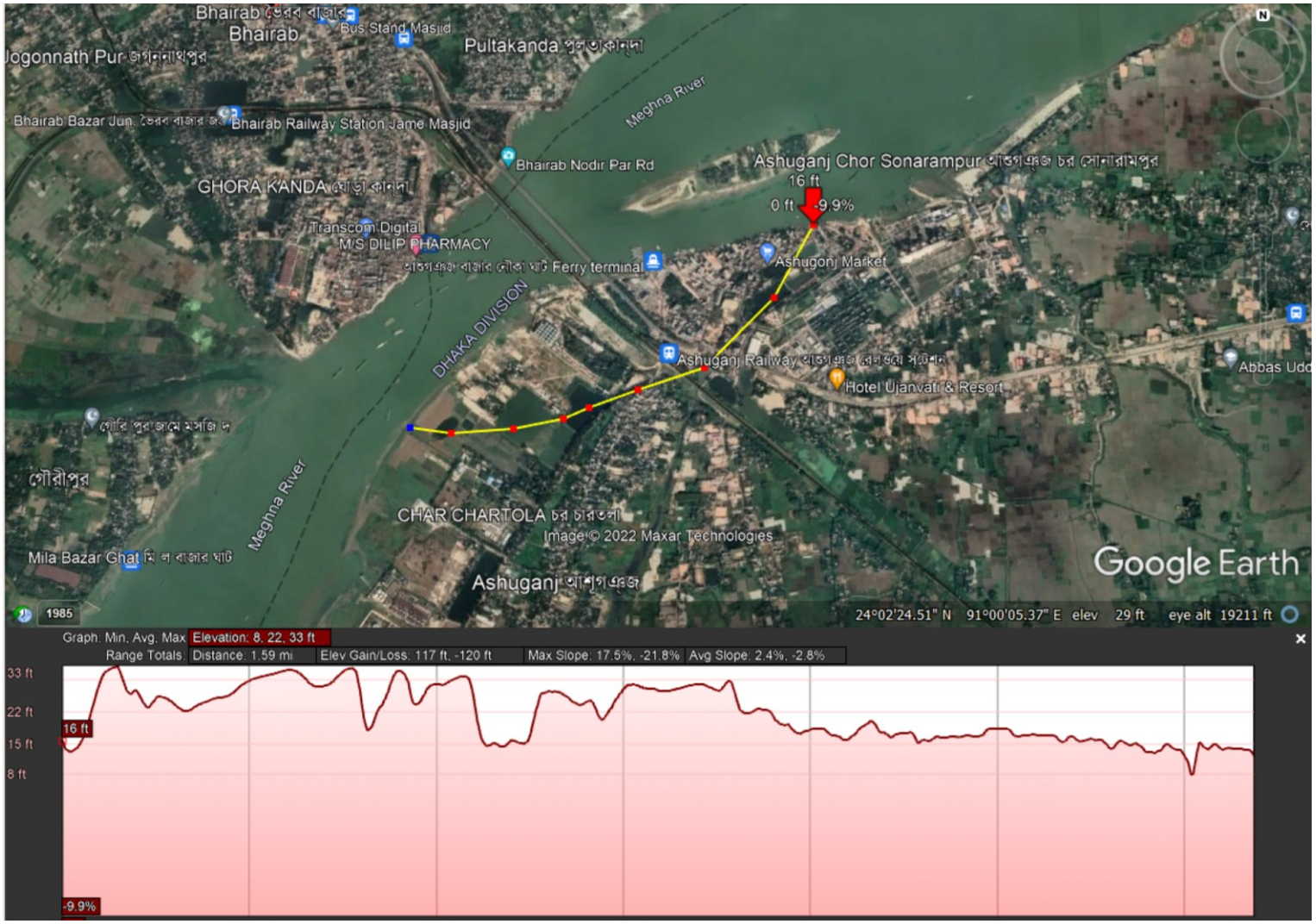
Legend:



Changes in the Cross Sectional Area of the Ghorautra-Meghna River



Proposed by-pass canal at Bhairab Bazar



Observations and Recommendations

It is important to have weather stations in all sub-districts.

Waterflow data should be made public via internet

Detailed survey of elevation and landuse changes in the haor regions need to be carried out at high resolution scales

Water-carrying capacity of natural and storm drainage need to be adjusted in accordance with basin development factor and climate change

Observations and Recommendations

*The cross-sectional area of the Meghna River under the Bhairab Bridge is inadequate to discharge water from the upstream region. The duration of flooding has likely increased due the bottleneck effect under the bridge. A detailed survey should be conducted to investigate this phenomenon.

* Feasibility of the proposed diversion canal need to be carried out immediately.

Observations and Recommendations

Since 57% of the Meghna Basin is situated outside of Bangladesh, it is imperative to establish a basin-scale integrated water-sediment management plan for all transboundary rivers.

Bangladesh need to ratify the UN Convention on Non-navigational Water Courses (1997) and should encourage upstream neighbor to ratify the law, and use this law as basis for dispute resolution.

Waterlogging in Sylhet City: Ways Forward

Bloomsburg University

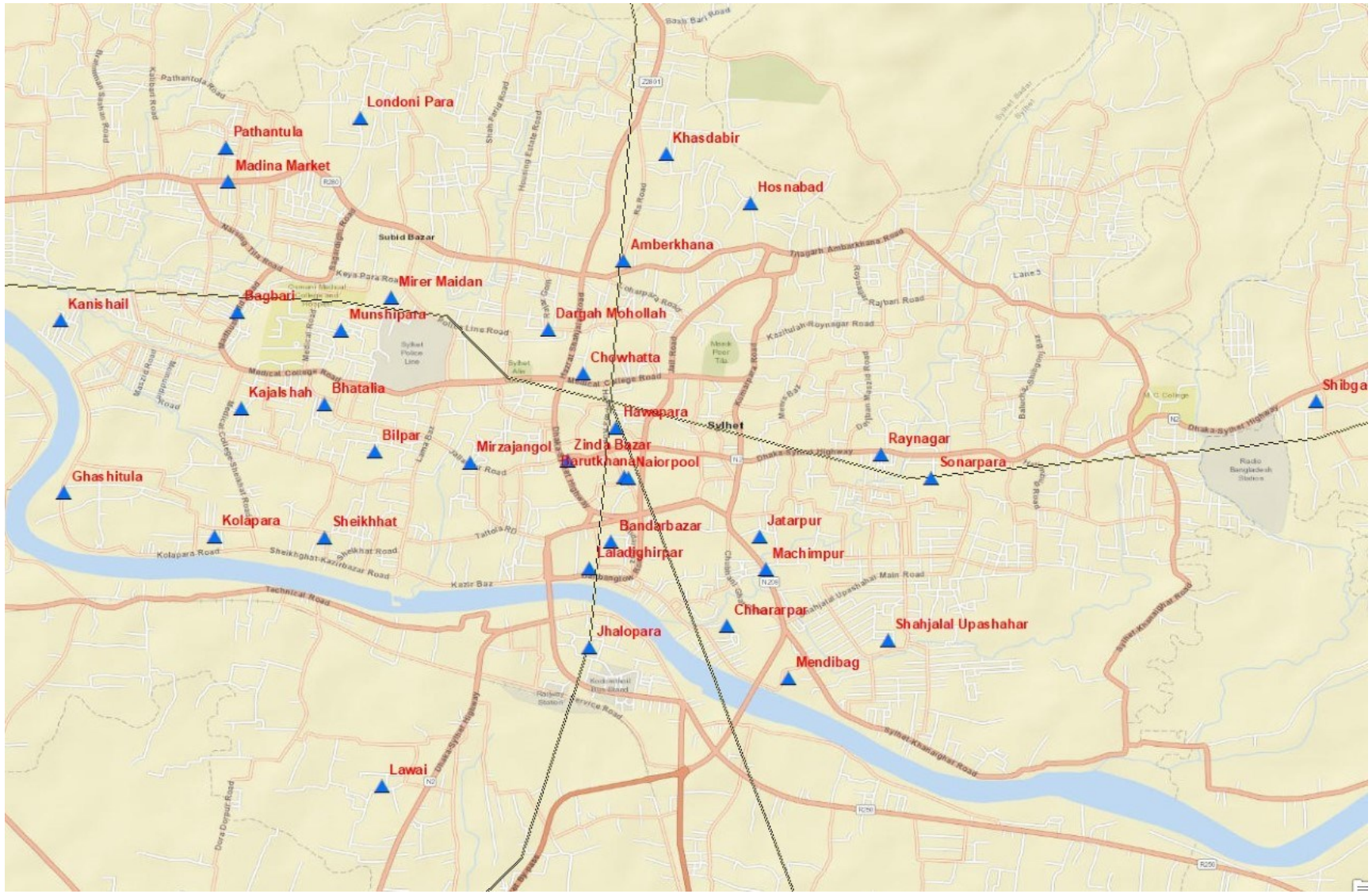
Lock Haven University

Mansfield University

COMMONWEALTH UNIVERSITY OF PA

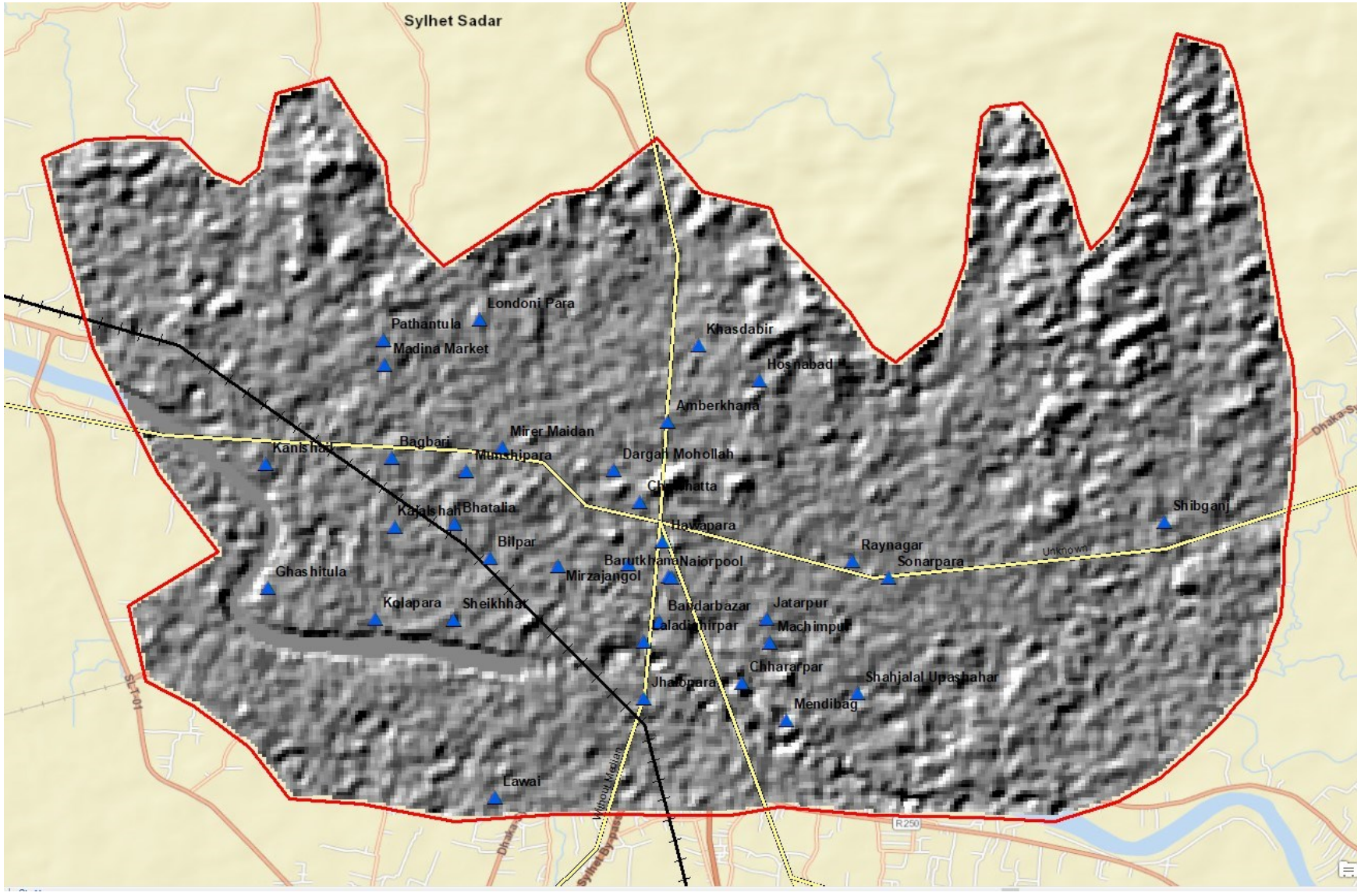

Sylhet City
Shahjalal University of Science and Technology
শাহজালাল বিজ্ঞান ও প্রযুক্তি বিশ্ববিদ্যালয়
HALDER PARA
LAKKATURA
Sylhet International Cricket Stadium
সিলেট আন্তর্জাতিক...
BRAHMMAN SASHAN
BANKALAPARA
Kumargaon Bus Stand (Bus service...
KARPARA
Jalalabad Ragib-Rabeya Medical College and...
জালালাবাদ রাগিব-রাবেয়া...
MALIPARA
Airport Rd
Sylhet Agricultural University
সিলেট কৃষি বিশ্ববিদ্যালয় (সিকৃবি)
Tilagarh Eco Park
টিলাগড় ইকোপার্ক
Modina Market Point
মদিনা মার্কেট পয়েন্ট
R280
KHASDABIR
Lakkatura Tea Garden
লাক্কাতুরা চা বাগান
AKHALIA BAZAR
JALALABAD
GOAITOLA
Alurtol Road
KHULIA PARA
SUBID BAZAR
AMBARKHANA
আম্বরখানা
Shahi Eidgah
শাহী ঈদগাহ
SHAHI EIDGAH
UTTAR BALUCHAR
ONOOTPUR
NEHARI PARA
Hazrat Shahjalal Mazar Sharif
হযরত শাহজালাল মাজার শরীফ
Hotel Noorjahan Grand
হোটেল নূরজাহান গ্র্যান্ড
Sylhet MAG Osmani Medical College
সিলেট এম. এ. জি. ওসমানী...
POLICE LINE
DEBPARA
DAPTARI PARA
Sylhet Bypass Rd
Medical College Rd
CHOWHATTA
R249
JHARJHARI PARA
SHENPARA
TILAGOR
KHANUWA
BHATALIA
TELI PARA
Sylhet Bkash Center
Tilagor Point
টিলাগড় পয়েন্ট
MAJUMDER PARA
Nobab Rd
LALADIGHIR PAR
JHARNER PAR
Nirvana Inn
নির্ভানা ইন
Sylhet
সিলেট
NAIORPUL
Bondor Bazar Sylhet
SONAR PARA
HATIMBUG
বাহাদুর লাটকা
LAMAPARA
MULLARRGOW
KHULIATULA
KALLYANPUR
KOLAPARA
Ali Amjad's Clock
আলি আমজাদের ঘড়ি
D BLOCK
A BLOCK
KHLOPHER
Surma River
Technical Rd
Rose View
রোজ ভিউ হোটেল
MIRA PARA
GOLAPBAG
LAMAAJRAY
GOUPSHER
BARAIKANDI
N208
SHAHJALAL UPASHAHAR
KUSHI GHAT
Sylhet
সিলেট
Sylhet Bus Stand
KAZIRKHOLA
TULTIKAR
NAYA BAZAR
Shahpora
GOWAL GAON
VARTHOKHOLA
KADAMTOLI
SARDER PARA
N2
Sheikh Hasina Shishu Park Alampur
MOMINKHOLA
মোমিনখোলা
DAKSHIN KUSHIGHAT

Locations of waterlogging in Sylhet City



Waterlogging is not confined an geographic area not it is connected to any particular river or stream.

DEM of Sylhet City

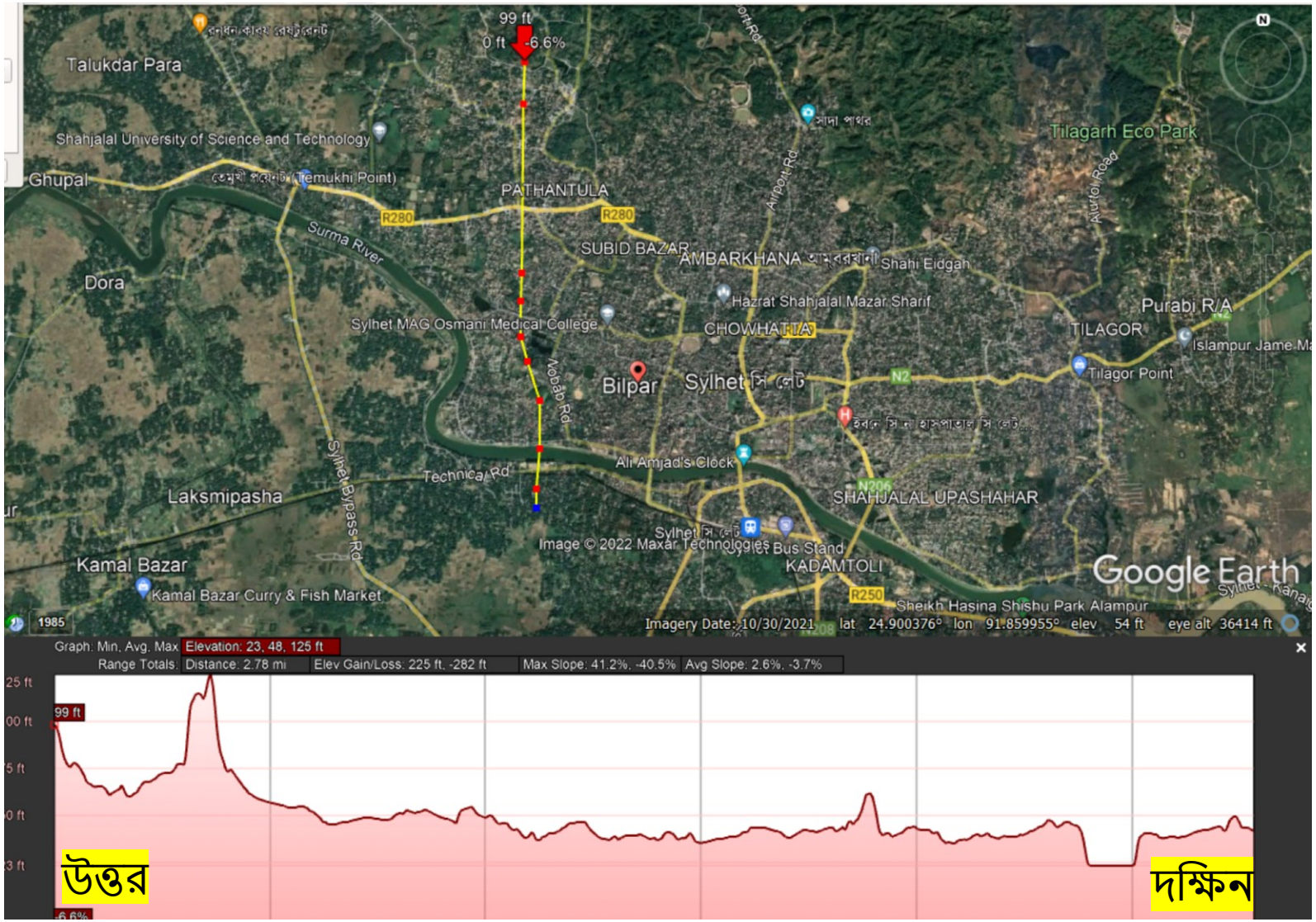


Abundance of hills in the NE part

Inadequate natural drainage

Eastern segment of the Surma River appears to be non-functional

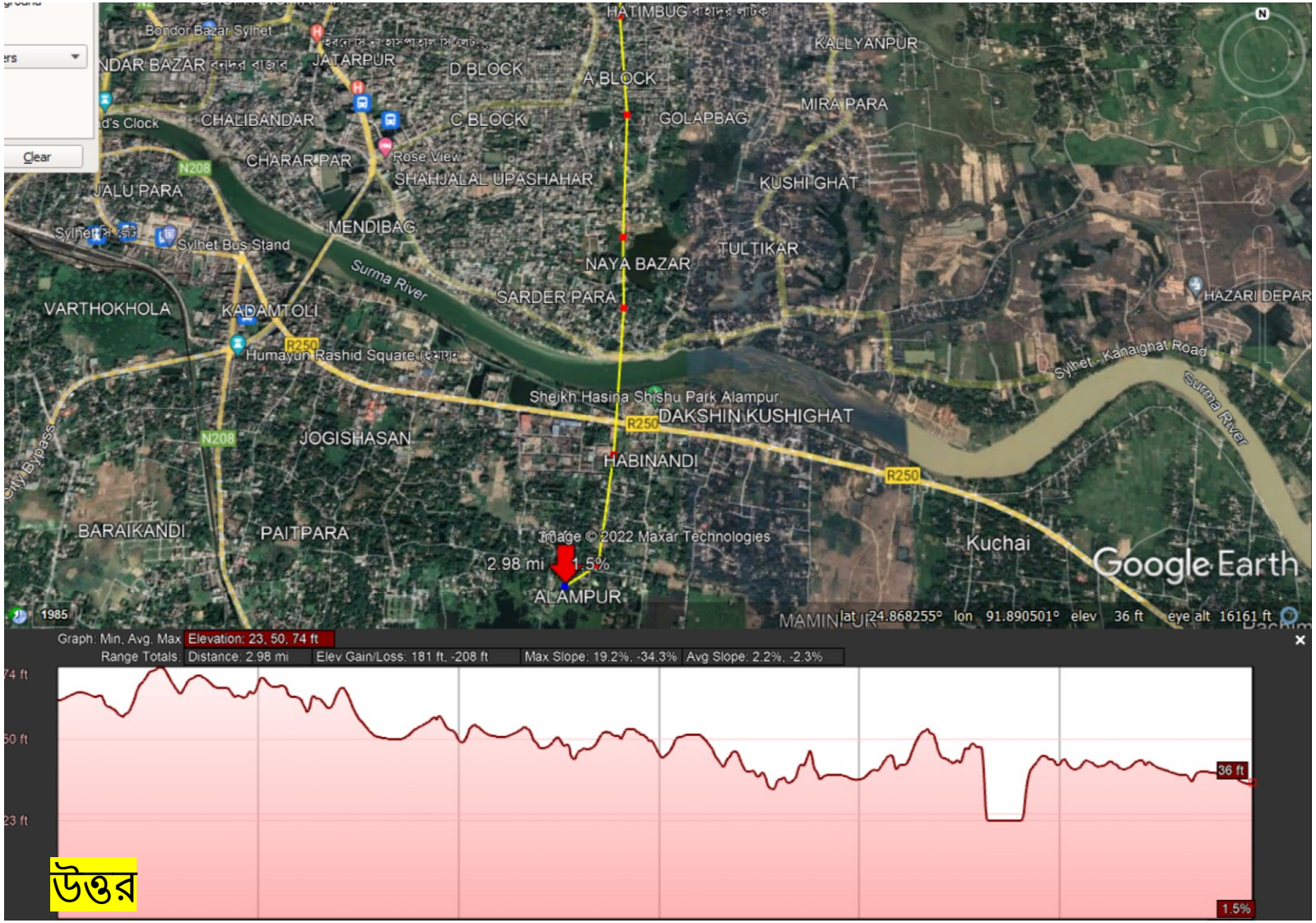
Topographic profile along a North-South Transect



The city area is titled toward south

East-west bound roads are impediments to surface run-off

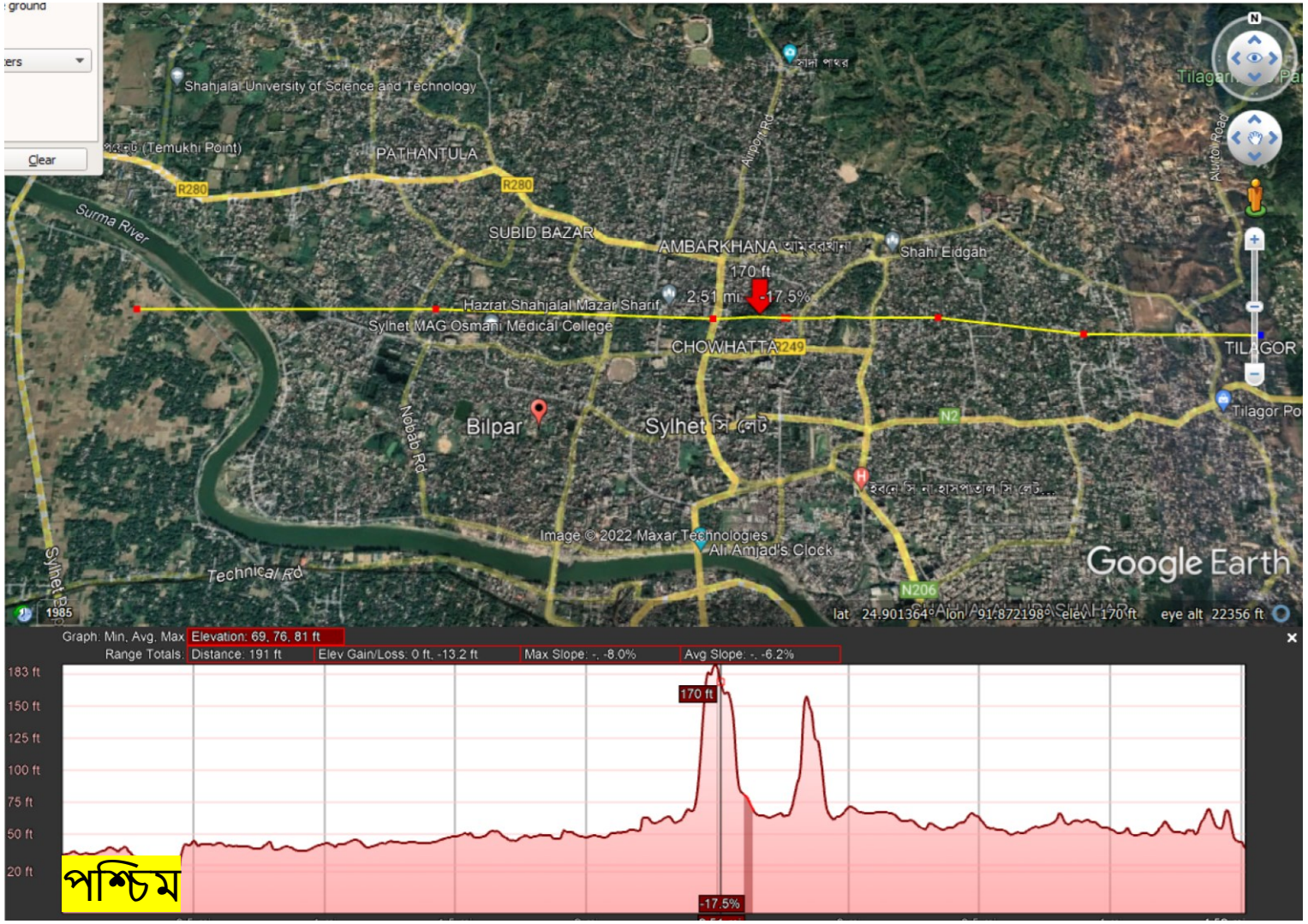
Topographic profile along a North-South Transect



The city area is titled toward south

East-west bound roads are impediments to surface run-off

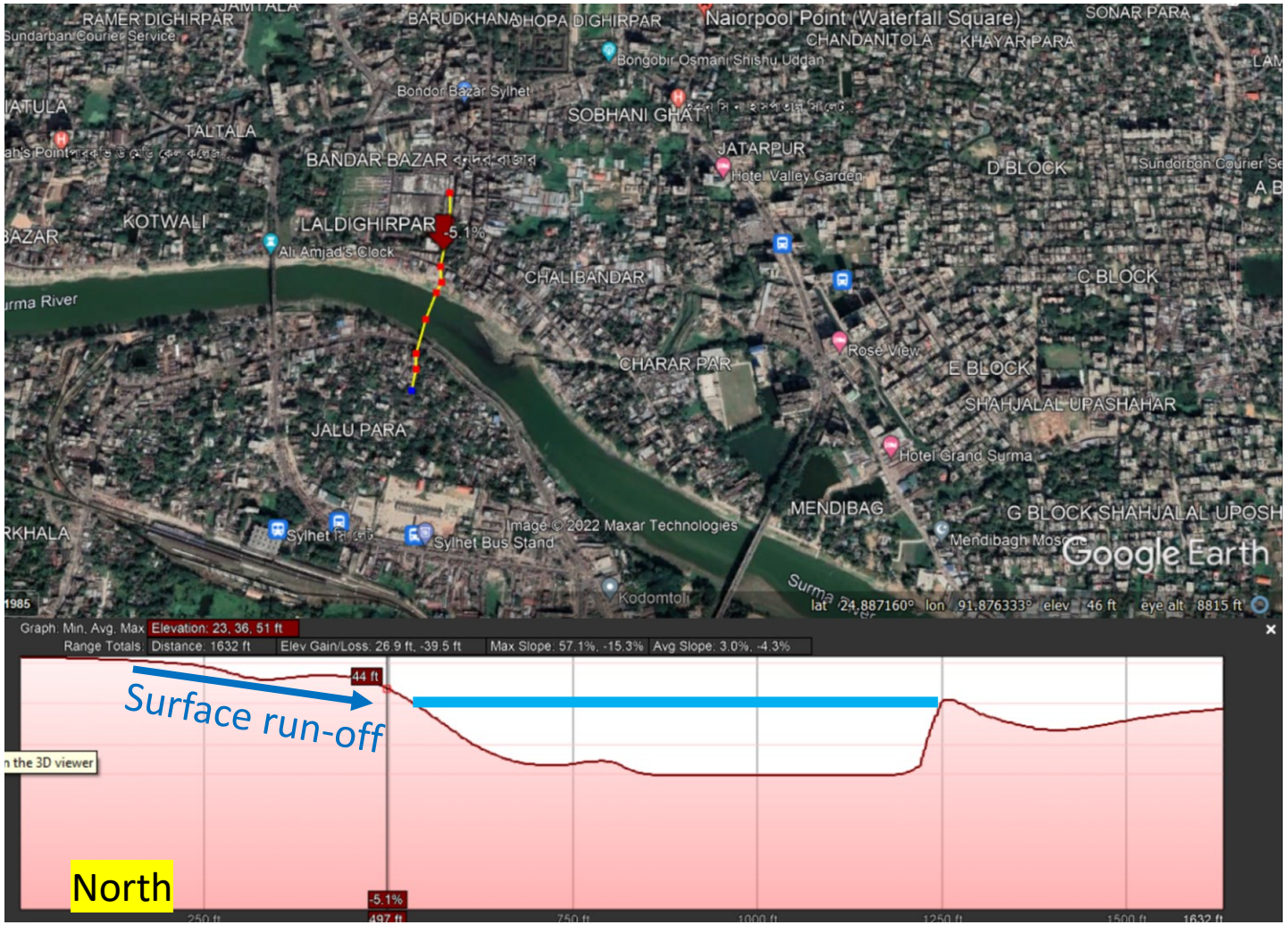
West-East Topographic Profile along a Transect



The western part of the city slope to west, and the eastern part slopes to east

North-south bound roads are impediments to surface run-off

North-South Topographic Profile across the Surma River

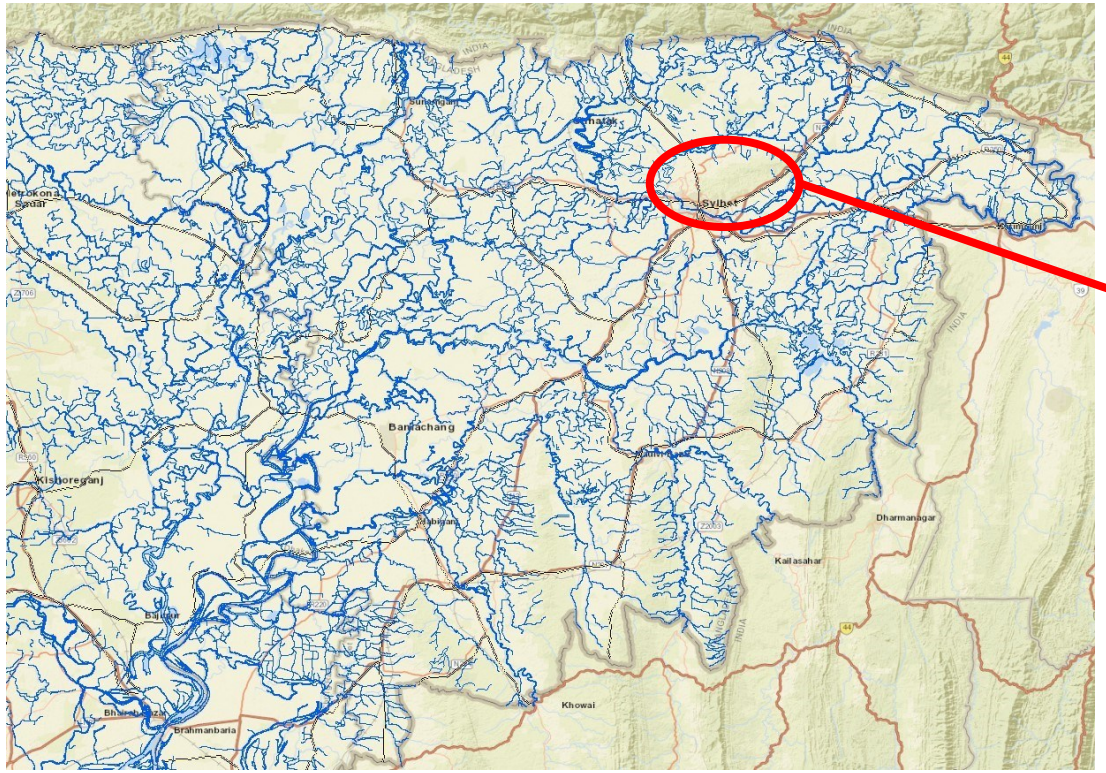


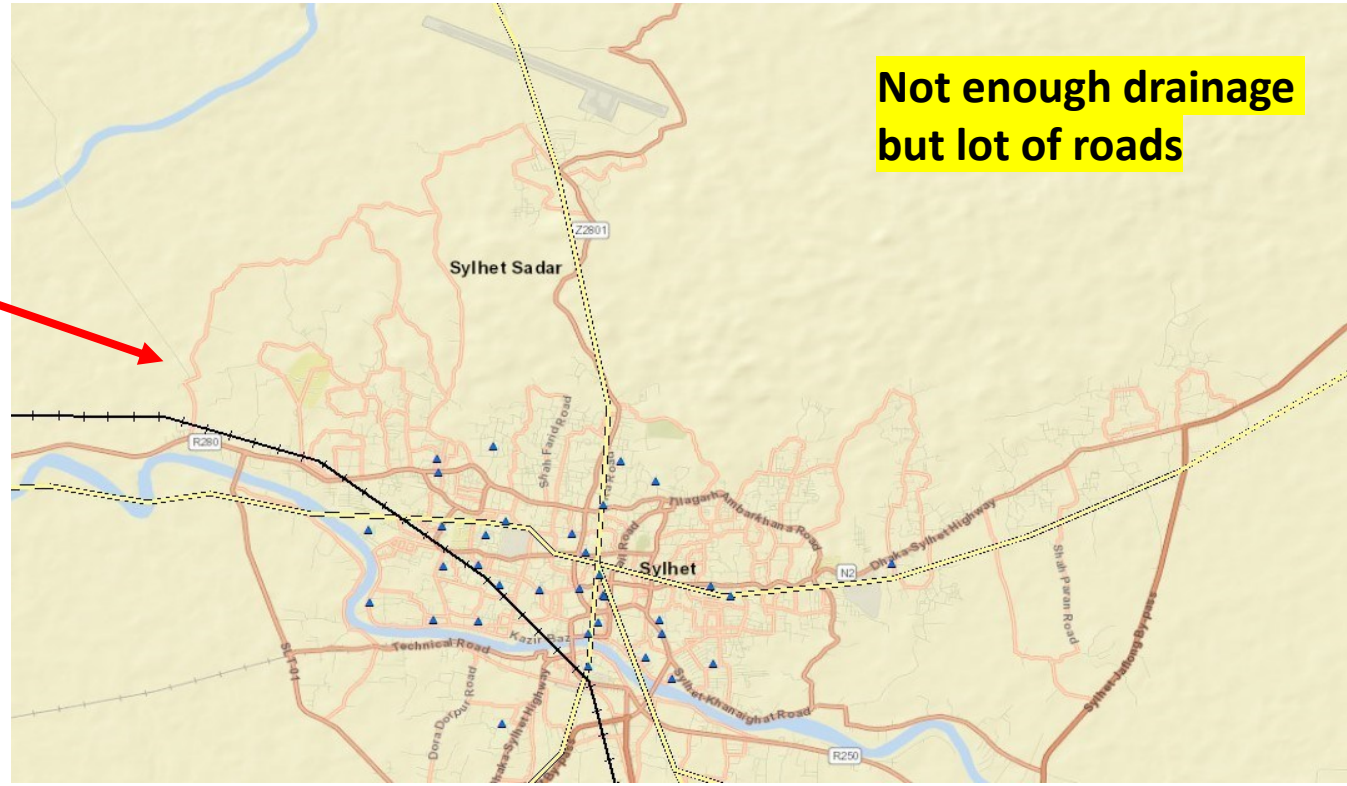
The northern side of the river is taller than the southern side. The northern side should not flood before the southern side, but normal rainfall causes waterlogging on the northern side. This is a localized problem.

What are the potential causes of waterlogging?

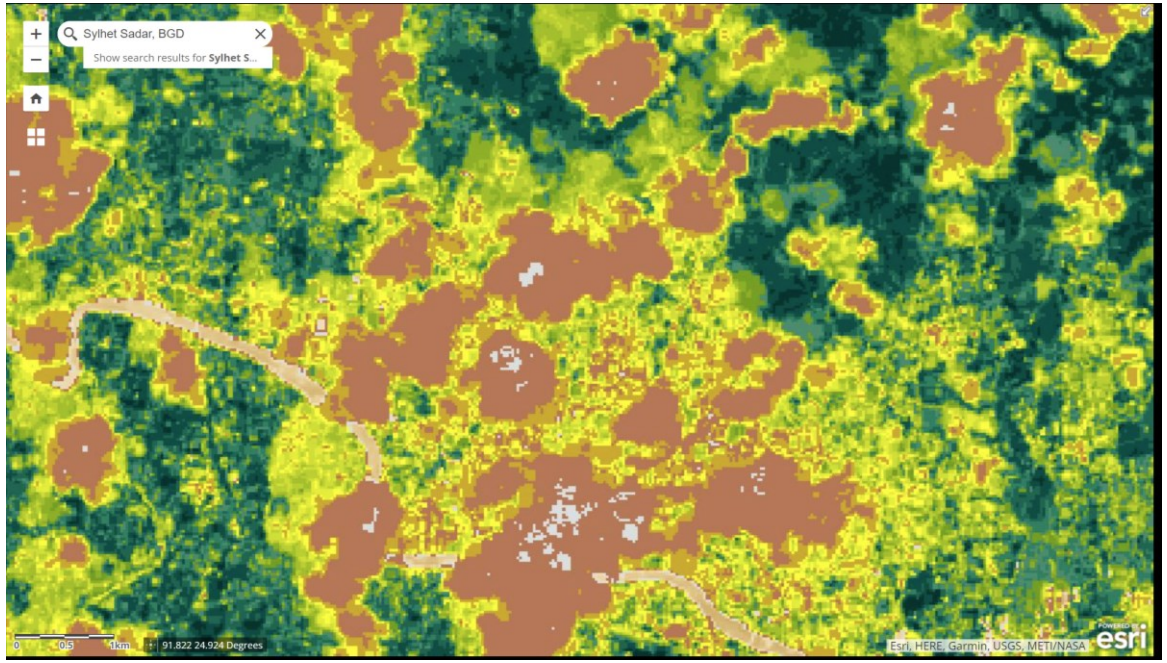
- Natural drainage network appears to be inadequate, and the physical condition of the existing ones are not in acceptable condition
- Lack of adequate storm drain system in the city
- The existing road are impediment to surface run-off. There is not enough bridges and culverts to allow free flow of surface run-off
- Lack of adequate ponds, rention reservoirs and wetlands within the periphery of the city
- Unplanned urbanization and hill-cutting are resulting in siltation of drainage network
    - Let's see a few slides

Lack of natural drainage in Sylhet City

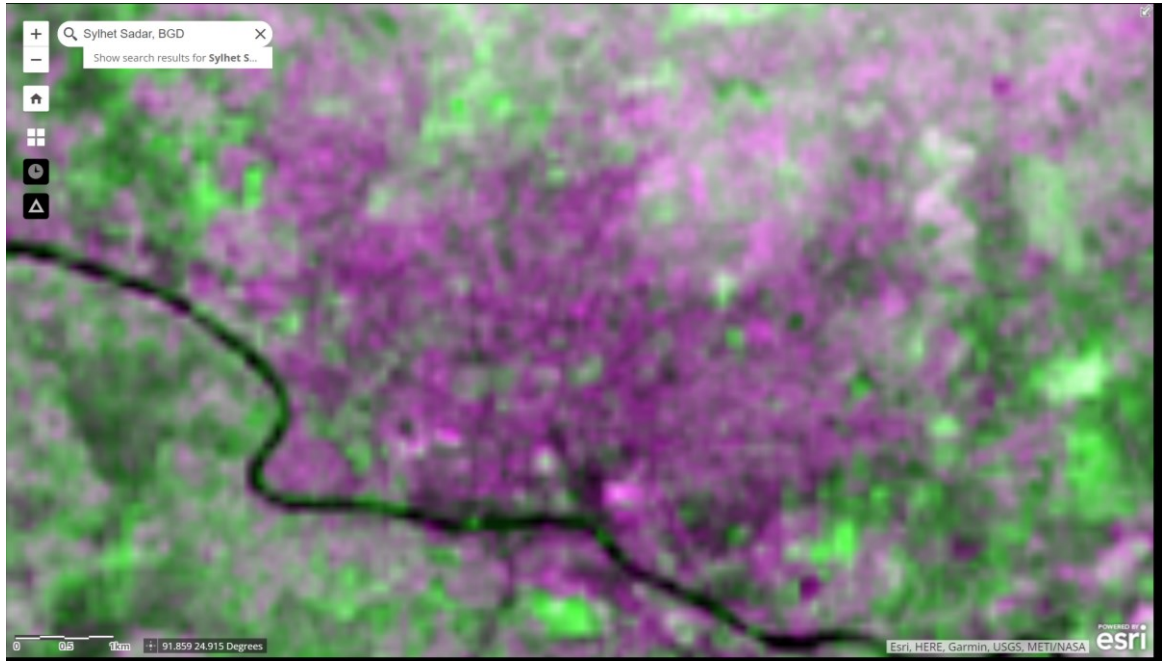




Change in Vegetative Cover (1975-2021)



Satellite image: dark green represents vegetation and orange represents built-up area (2021)

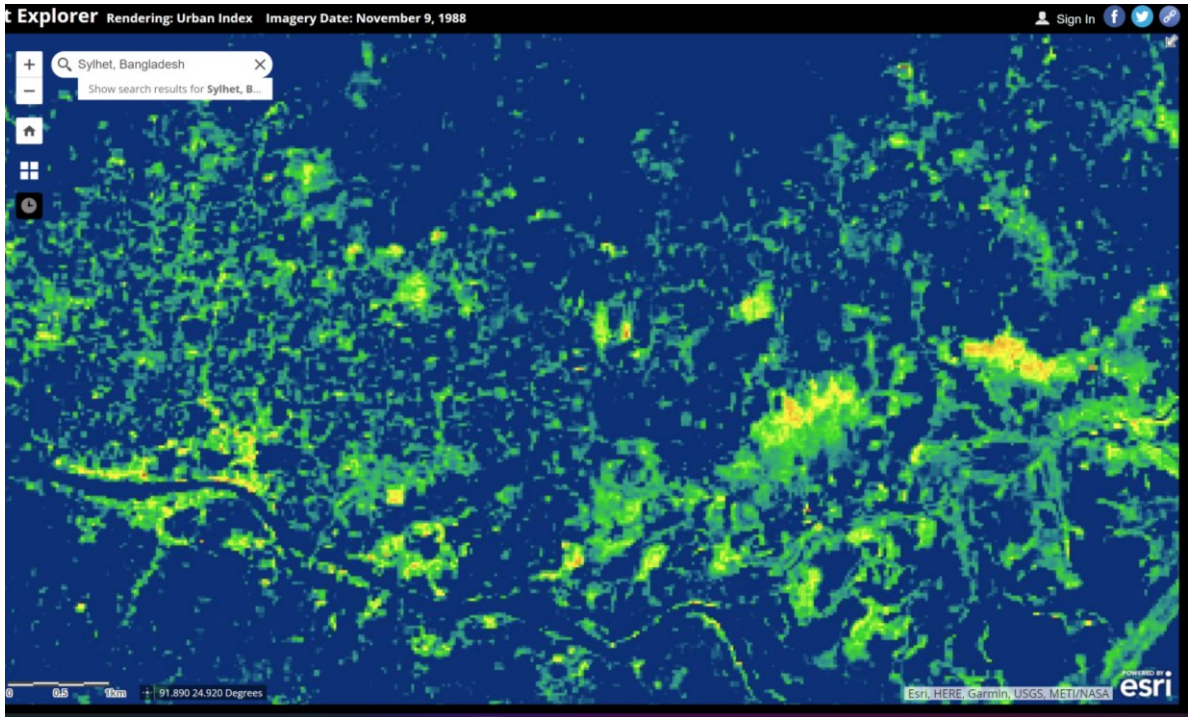


Analysis of satellite image: Purple represent areas that are converted to built-up from other landuses between 1975 and 2021

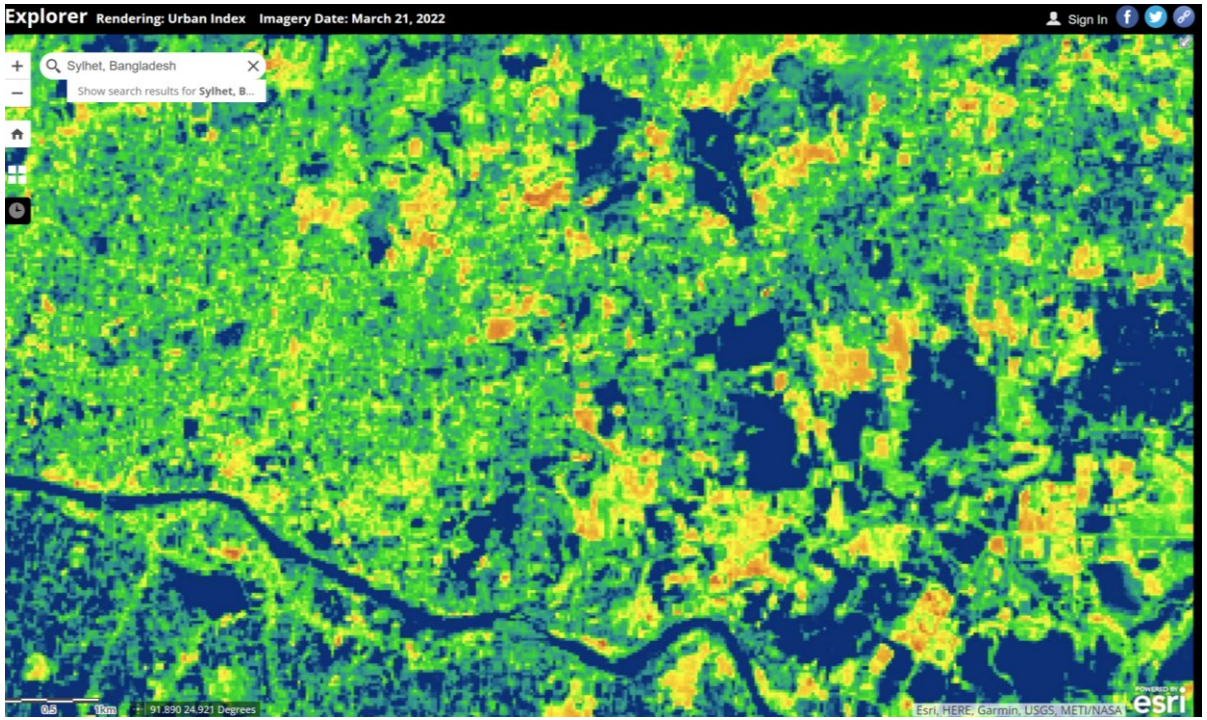
Impact on surface run-off: Vegetative area vs. impervious area

- One inch of rain over one acre of land generates 27,152 gallons of water
- One acre of vegetated land generates 750 gallons of surface run-off
- Same amount of rain on impervious surfaces generate 27,000 gallons of surface run-off, i.e. 36 times more run-off that need to be accommodated by drainage network

Change in the extent of urbanization: 1988-2022

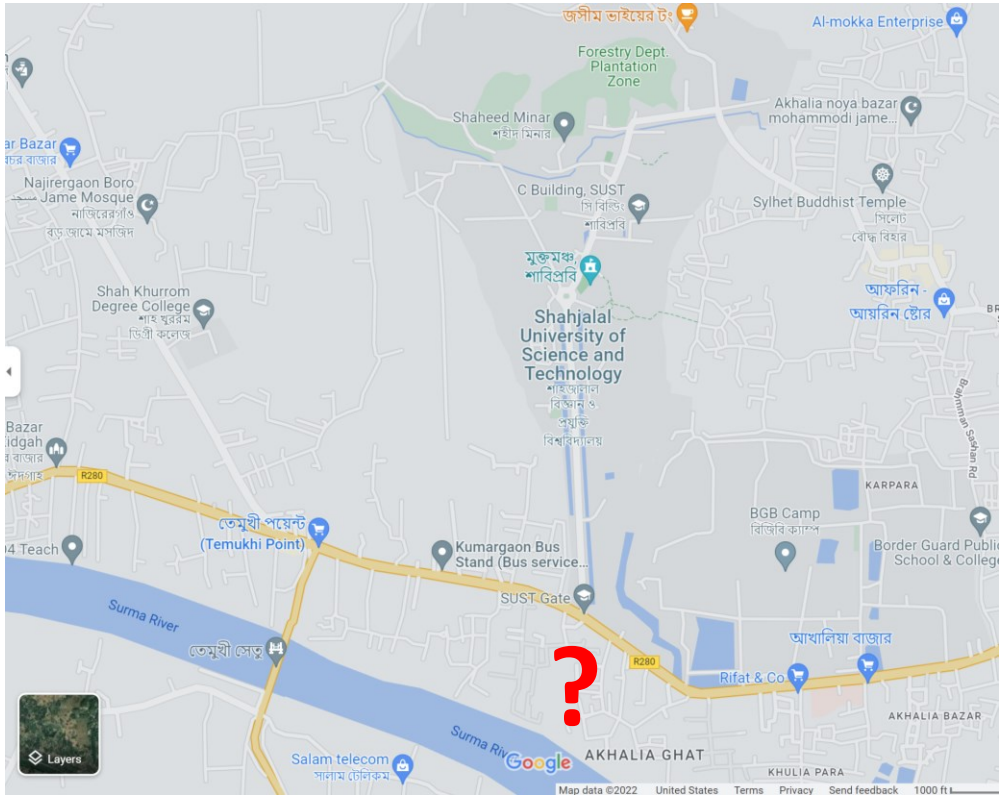


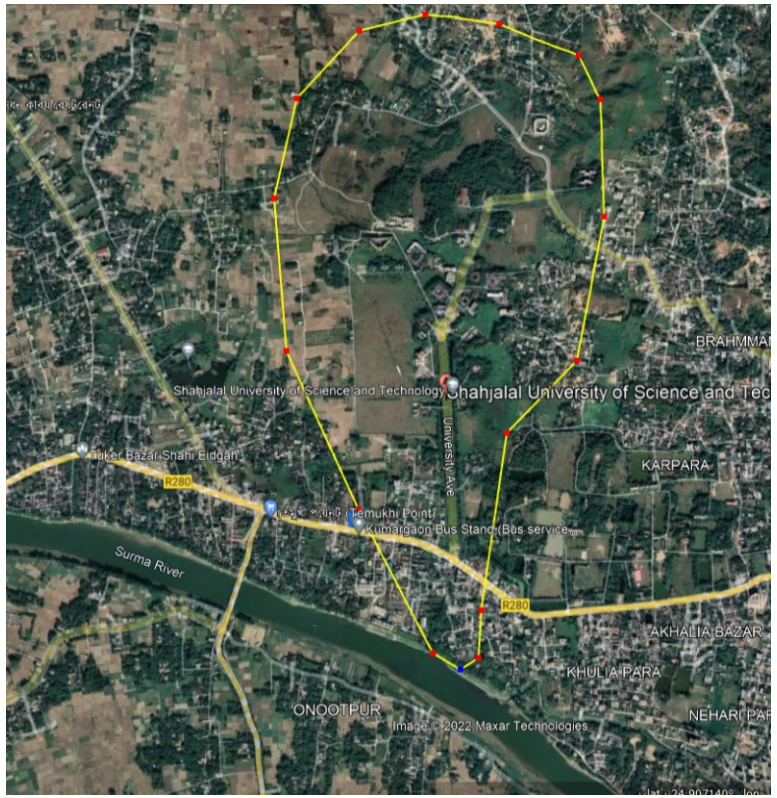
Yellow-green represents urban areas in 1988



Extent of urbanization in 2022

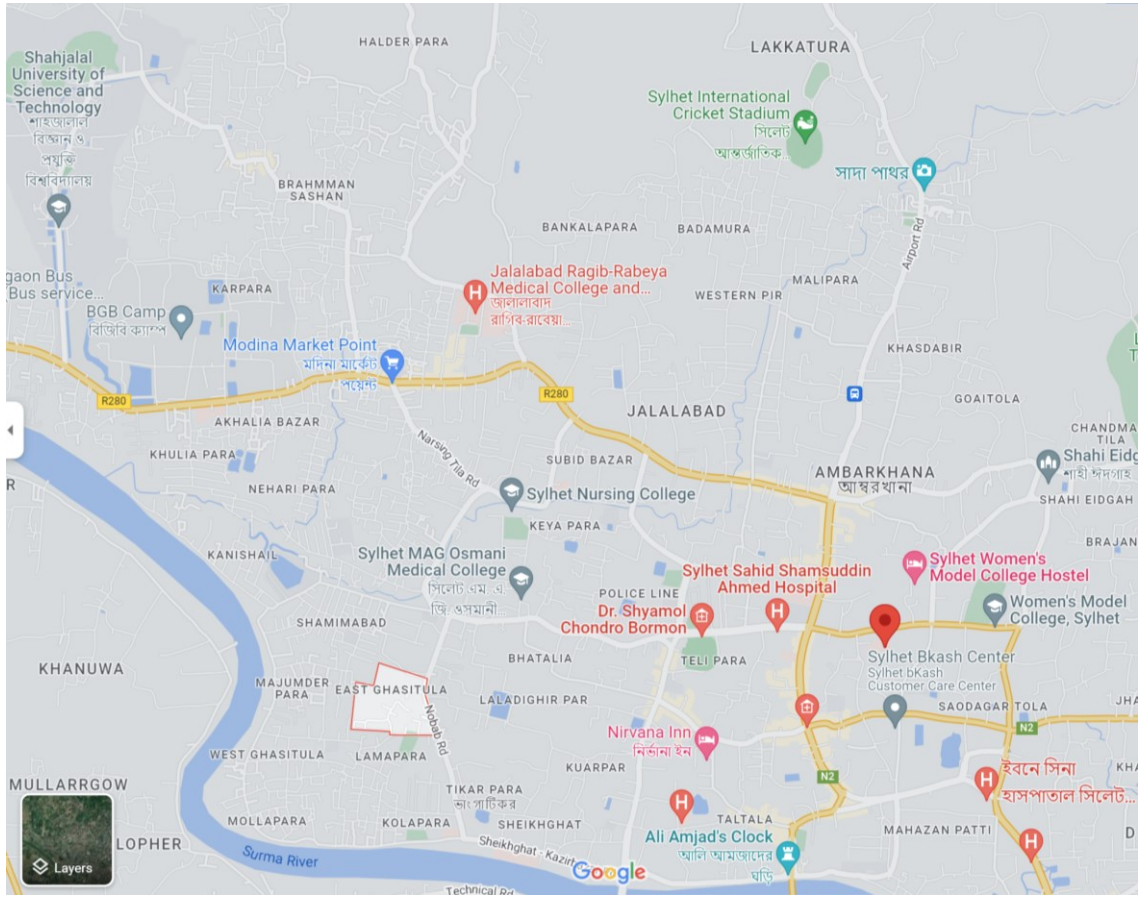
State of the drainage near SUST

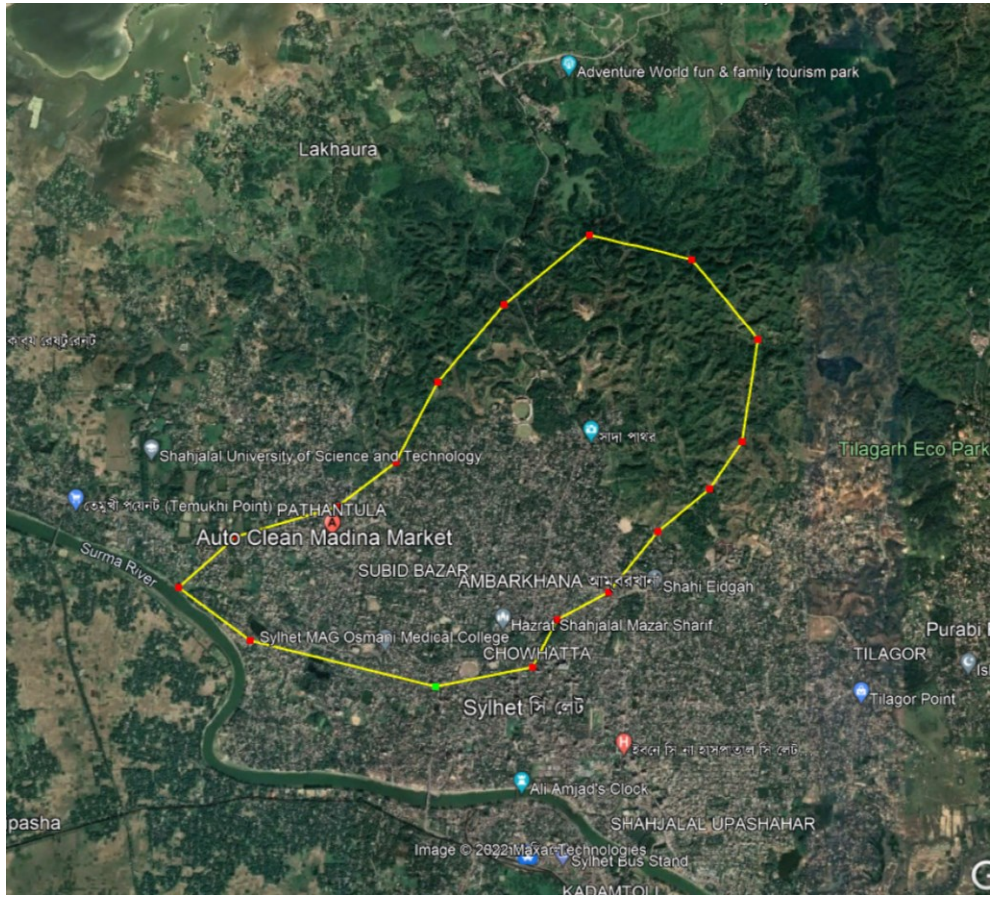




Watershed area~ 2.6 sq.km= 665 acres~ 1 sq.mi=> Desired cross section of the canal = 72*(area in sq.mi)^0.657 = 73 sq.ft= 10 ft * 7.3 ft for natural landuse and land cover

Sorry state of the Malni Chhara

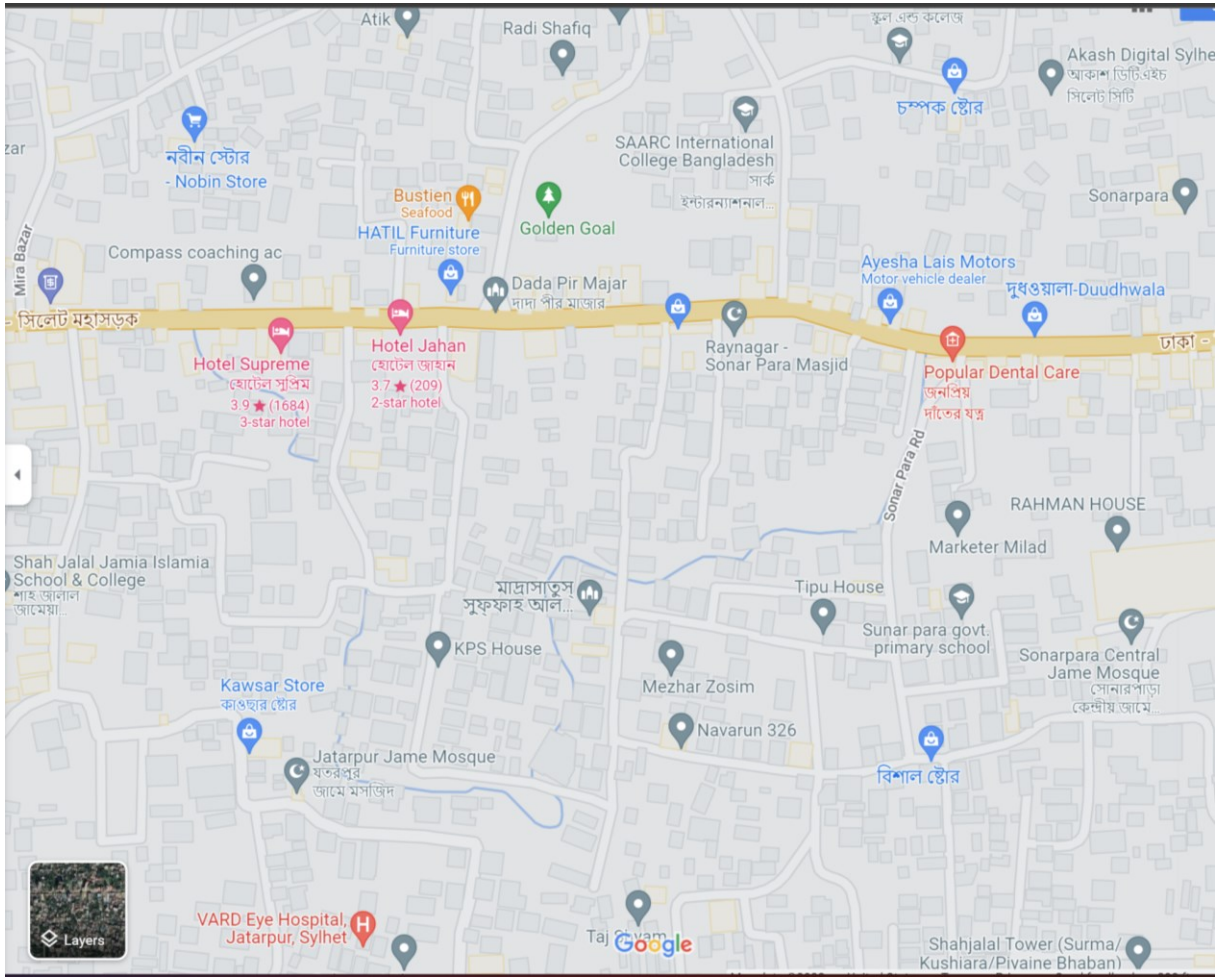


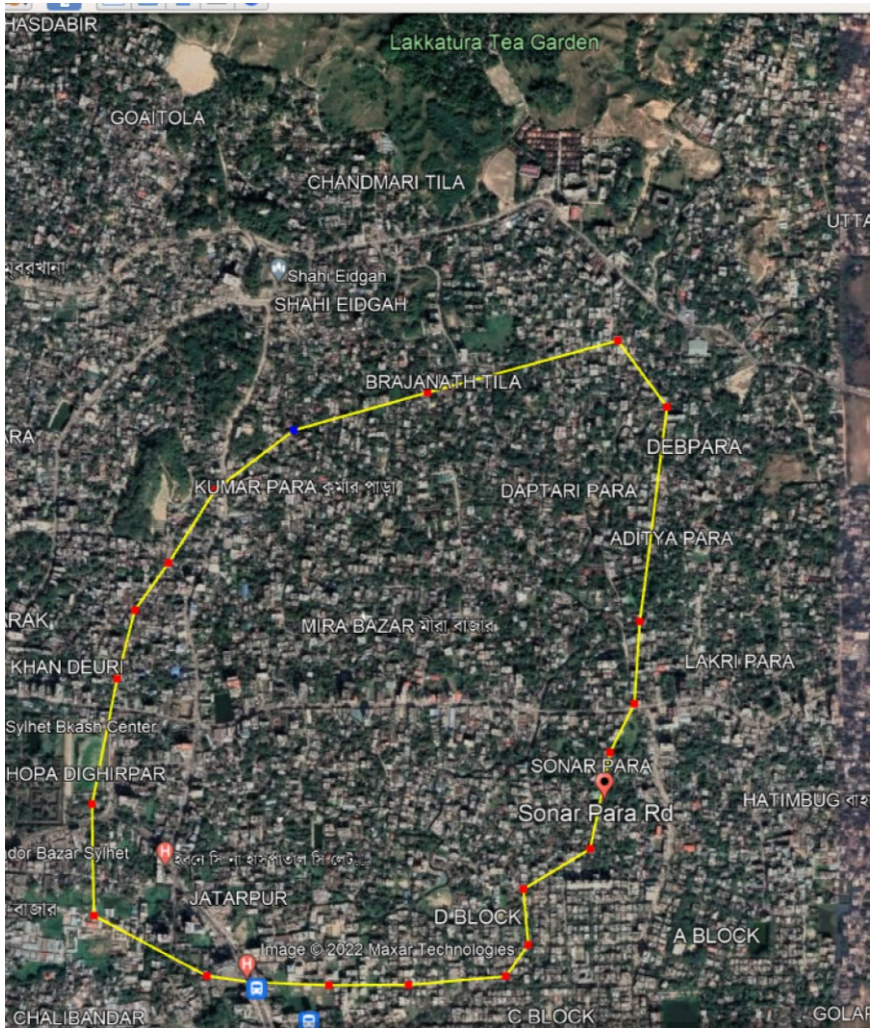


Watershed area~ 10 sq. km=2500 acres=3.86 sq. miles

State of natural creeks in Sylhet

Sonar Para Road Canal



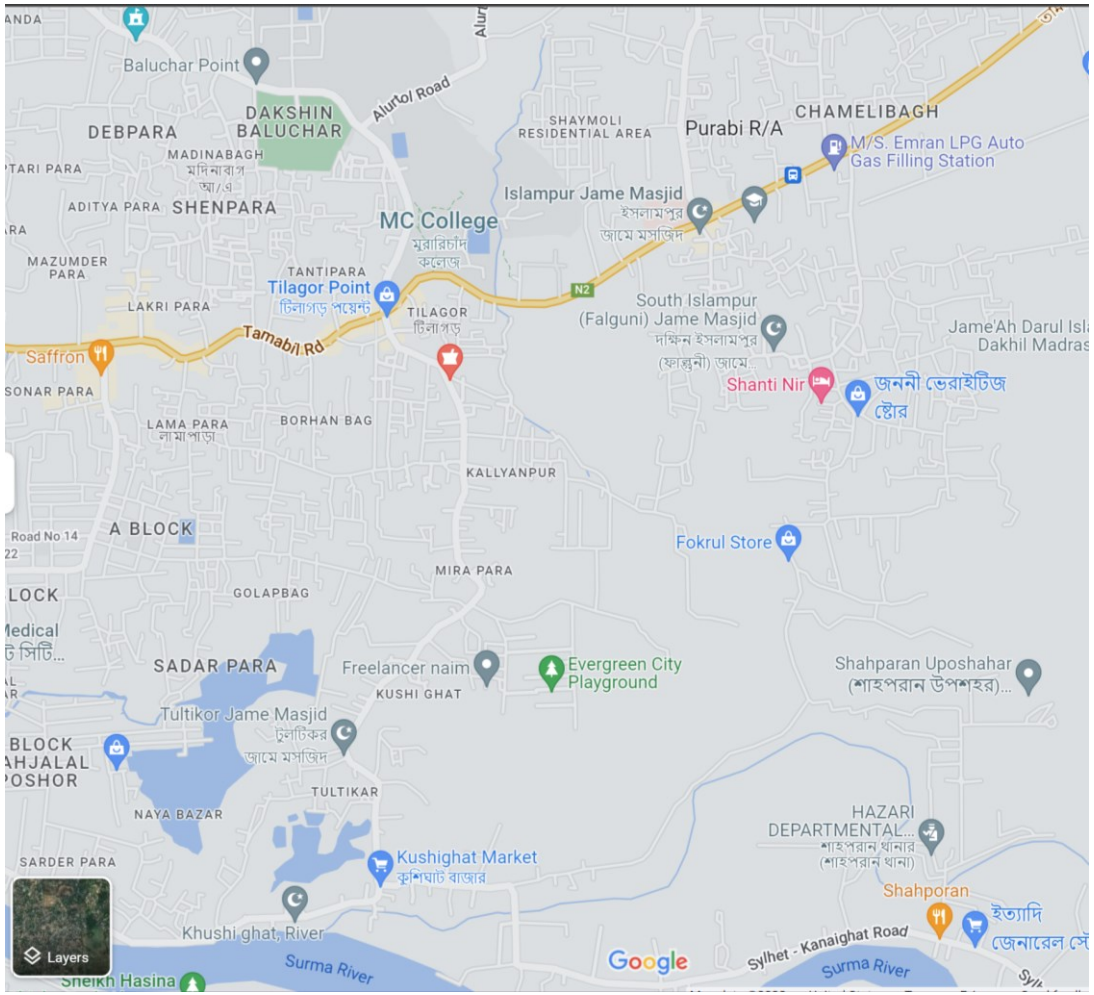


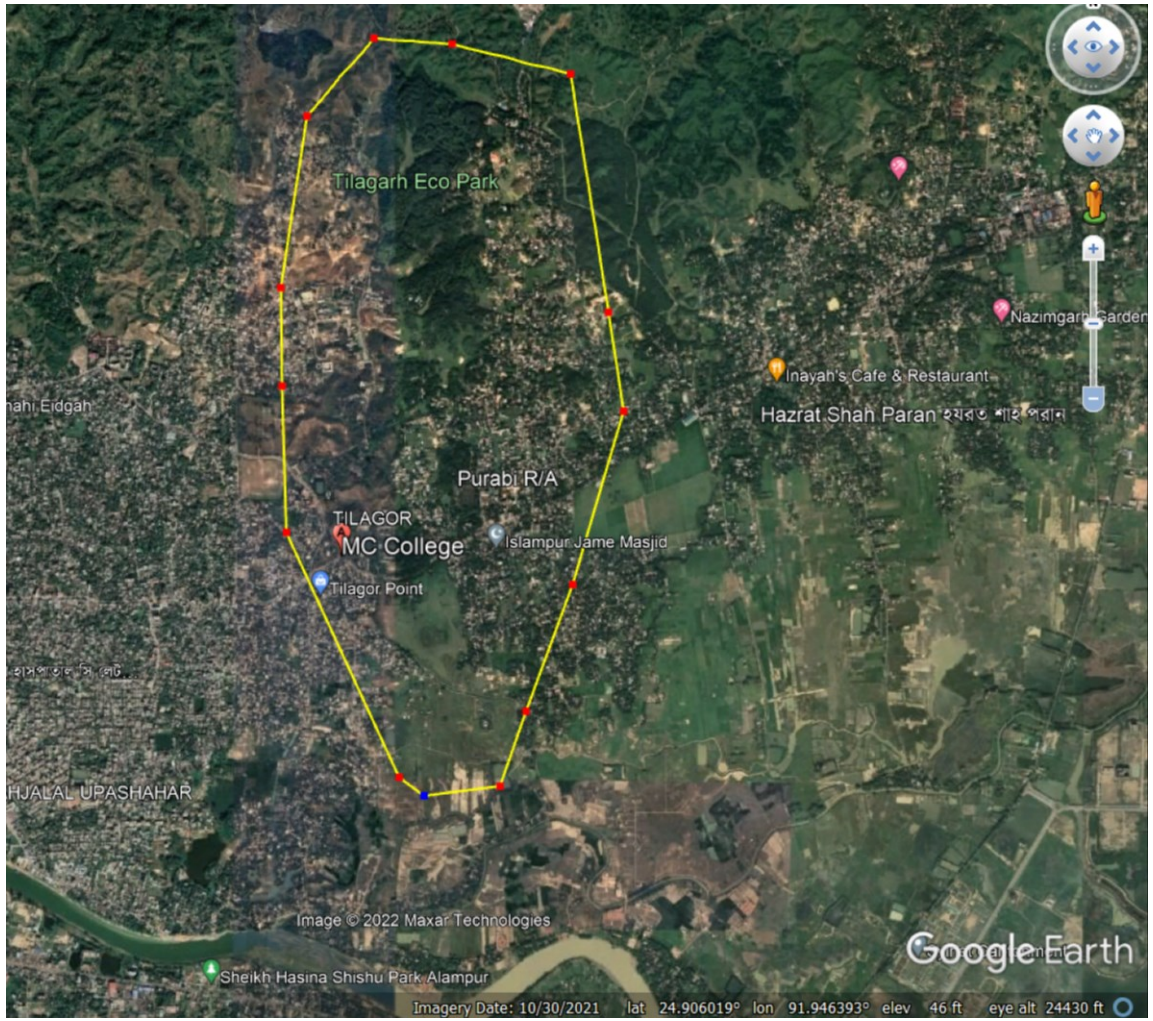
Watershed area~ 1 sq.km~ 250 acres=0.387 sq.mi

A worked-out example

- If one sq.km area (such as the Sonar Para Canal) receives 90 mm of rain, then 90,000 m^3 of water will be generated. If these waters cumulates in 10% of the low-lying elevations, then the depth of water will be 0.9 m or 2.9 feet (waist-deep)
- These rain event will generate a maximum flow of 70 to 90 cusec for a few minute, following the Rational Equation below:
    - Rational Equation = Q_p = CiA (where C=0.70-0.95; i=0.4 in/hr; A=250 acres)
- If there is a culvert with a cross sectional area of 25 sq.ft (5 ft * 5 ft), then water velocity will reach up to 3 to 4 ft/sec (very fast).

Murari Chand College Creek



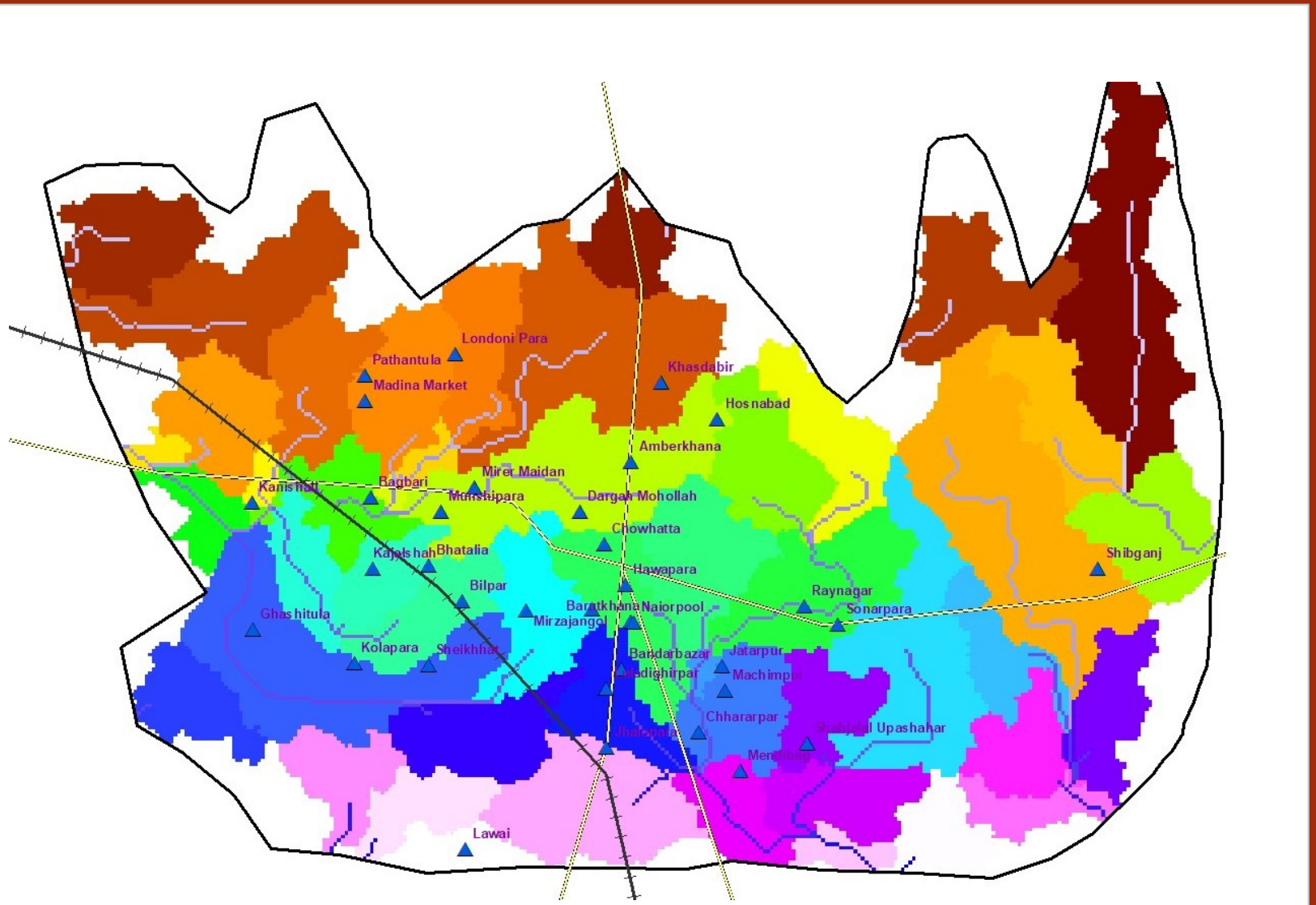


Watershed area~ 7 sq. km= 1729 acres= 2.7 sq. mi

Hydrologic Analysis of the Creeks in Sylhet

Name of Creek	Watershed Area $(mi)^2$	Watershed Area (acres)	Expected minimum cross-sectional area of natural creek (ft^2)	Peak discharge (Q_p) in cusec from a 0.4 inch/hour rain
Malni Chhara	3.86	2500	175	700
Murarichand College Creek	2.7	1729	138	484
SUST Canal	1	665	73	186
Sonar Para Canal	0.37	250	38	70

For reference, area of Sylhet City is about 10 sq. miles; Avg. flow in Surma is 29,828 cusec
Cross-sectional area of natural creeks in f^{t2} = C = 3*24 (area of watershed in $mile^2$)^0.657



Area-based sub-watersheds for natural drainage network

Similar hydrologic analysis has to be the cornerstone of all future plans for management of surface run-off and waterlogging issues. This type of watershed and natural drainage delineation can serve as guide in identifying and recovering abandoned and encroached channels and creeks. Strom drain also need to follow natural slope of the watershed and sub-watersheds.

Recommendations: Things to pay attention to in Sylhet City

- Need to survey the current water holding capacity of the existing ponds, retention reservoirs, and creeks

- It is important to adjust the carrying capacity of the drainage network and storm drain in line with the landuse and climate induced additional surface run-off
- Proper policy needed to prevent indiscriminate landuse and land cover changes through unplanned urbanization and hill-cuttings.

- It is important to adopt the Least Impact Development (LID) elements (rainwater retention reservoir, ponds, rain garden, rooftop garden, rain barrels, bio-swale, etc.) to the newly urbanized areas

Recommendations: Things to pay attention to in Sylhet City (cont'd)

- Efficiency of the storm and sewage drains need to be guranteed
- Flood-tolerant building structure need to be encouraged, if not mandated, when building on floodplain
- Storm and sewage drains should follow natural slope of the land and be connected (storm water) to natural drainage when and if appropriate.

Thank you!!!

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