Application of Remote Sensing in Developing Idealized Flow Conditions in River Network Simulation

By Shahab Afshari

Ph.D. Candidate and Research Assistant at

Civil Engineering Department

Advisor Balázs M. Fekete

Assistant Professor at

Civil Engineering Department

The City College of New York

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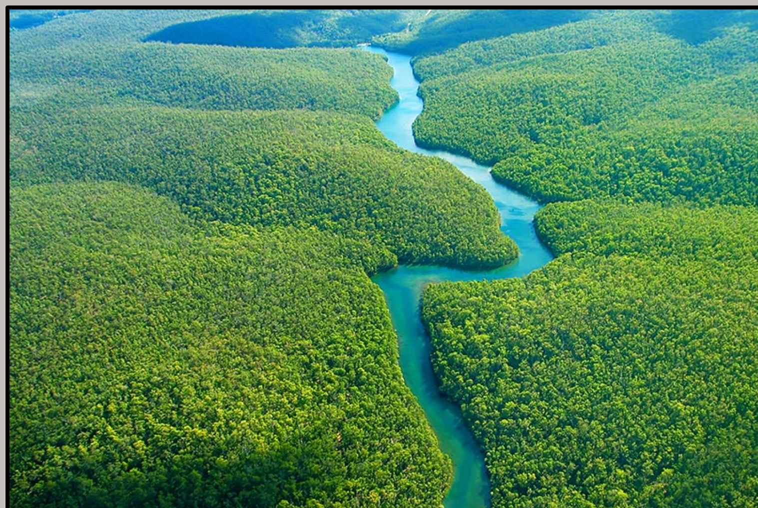
Introduction

- River Systems, the veins of the Earth



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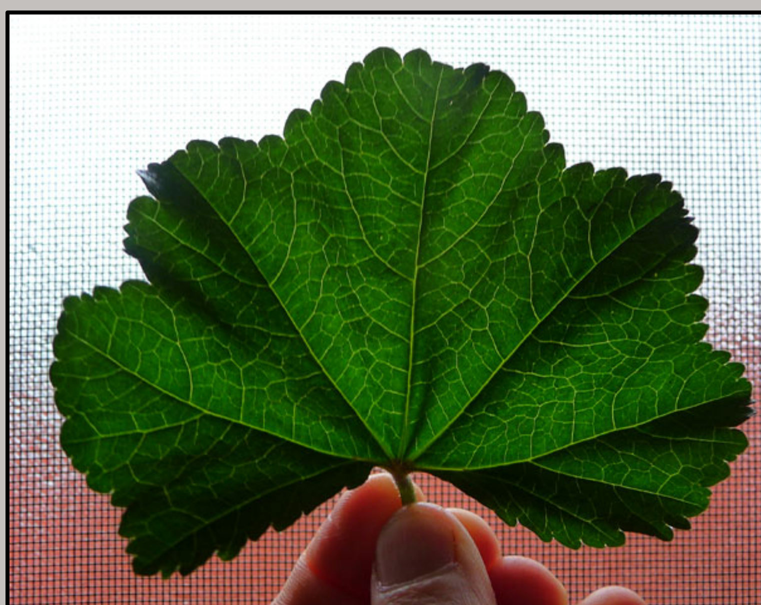


http://www.superfoods-for-superhealth.com/

http://hydrosheds.cr.usgs.gov/images/

Introduction

- River flow information is essential for many important uses across broad rang of scales.

  - Global water balances
  - Engineering design
  - Flood forecasting
  - Reservoir operation
  - Water supply
  - Environmental management
  - Recreation

Introduction

- Natural streams are characterized by changes in cross-section geometry, bed-slope, and geophysical properties (bed roughness, hydraulic slope, etc.) along their reaches.

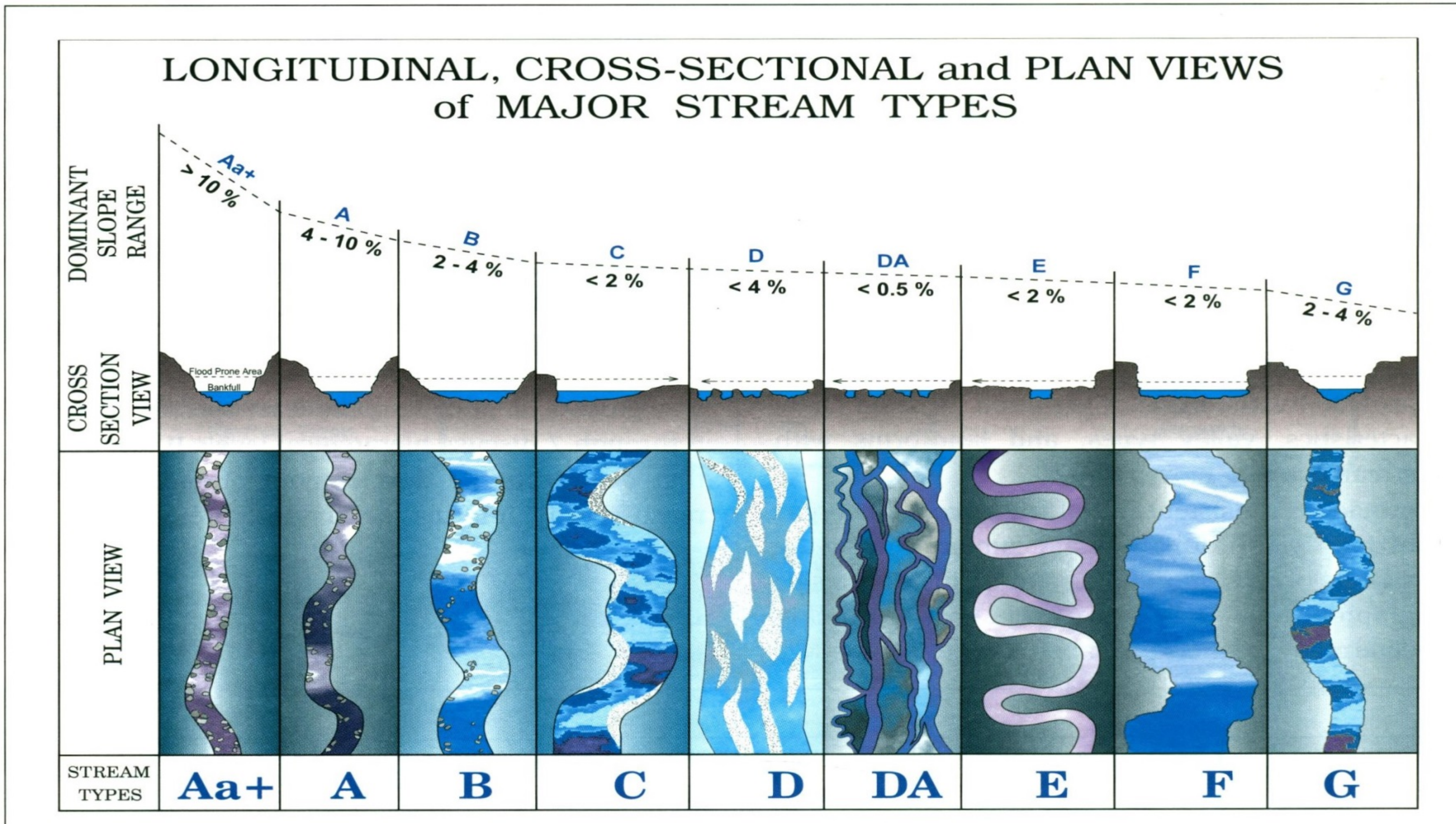


Figure is adopted from *Dave Rosgen*, (1996), *Applied River Morphology*, page 4-4.

Introduction

- Variations in the shape and size of the alluvial channel bed geometry result from several interacting features of the river system including effect of different flow regimes, bed-slope, sediment load, etc.

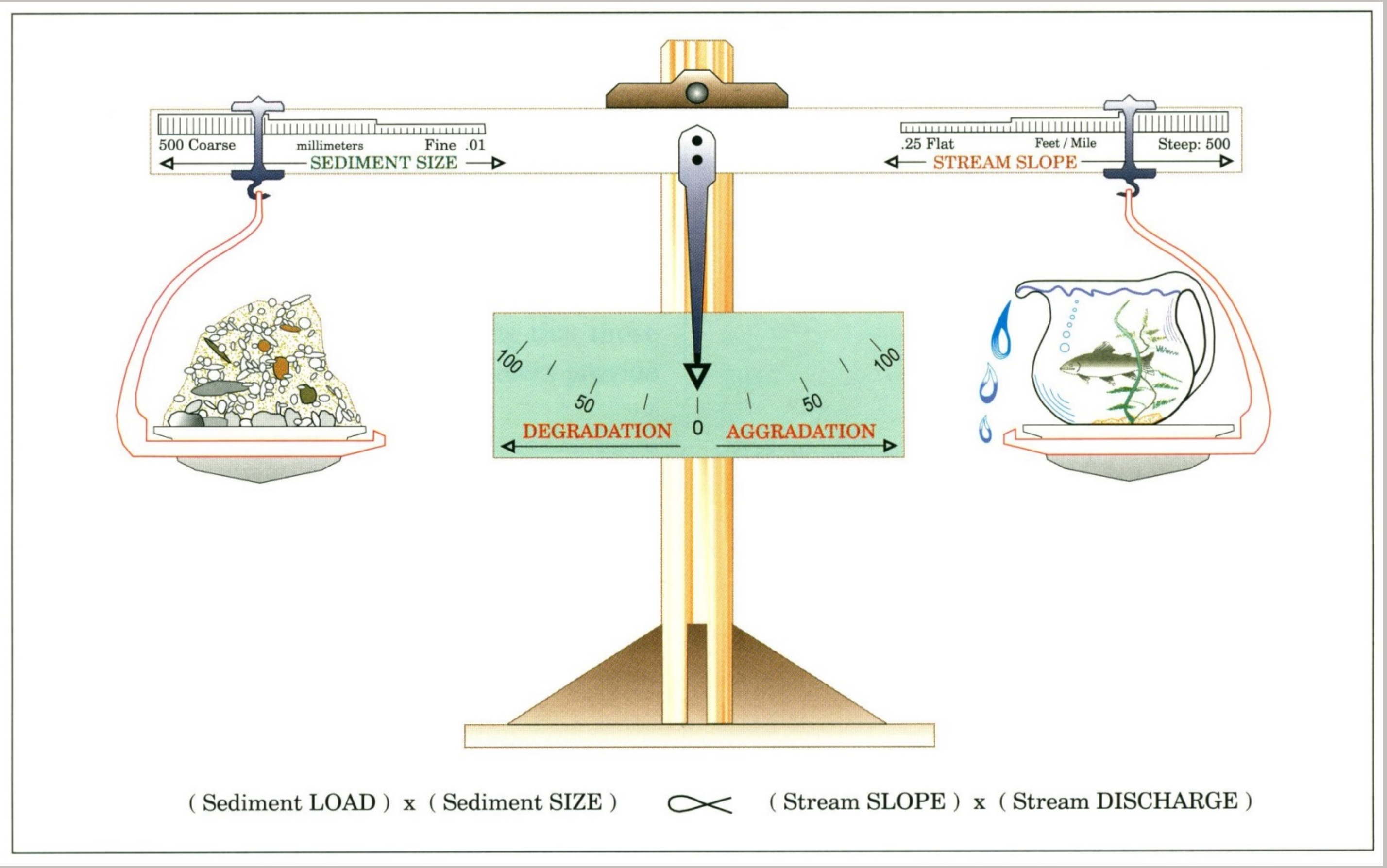
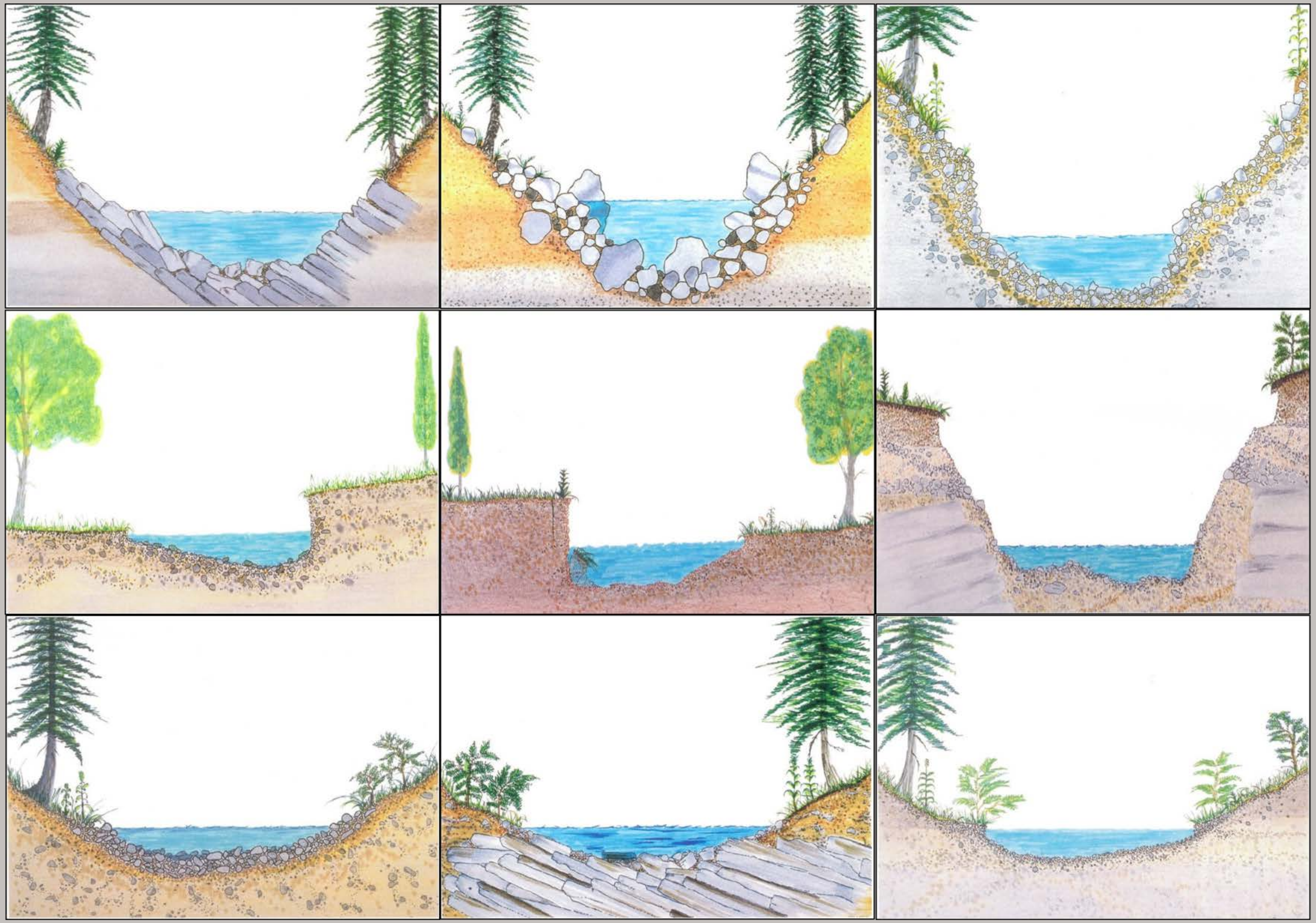


Figure is adopted from *Dave Rosgen*, (1996), *Applied River Morphology*, page 2-2.

Introduction

- Different River Morphology and Natural Riverbed Geometry



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Introduction

- Different River Morphology and Natural Riverbed Geometry

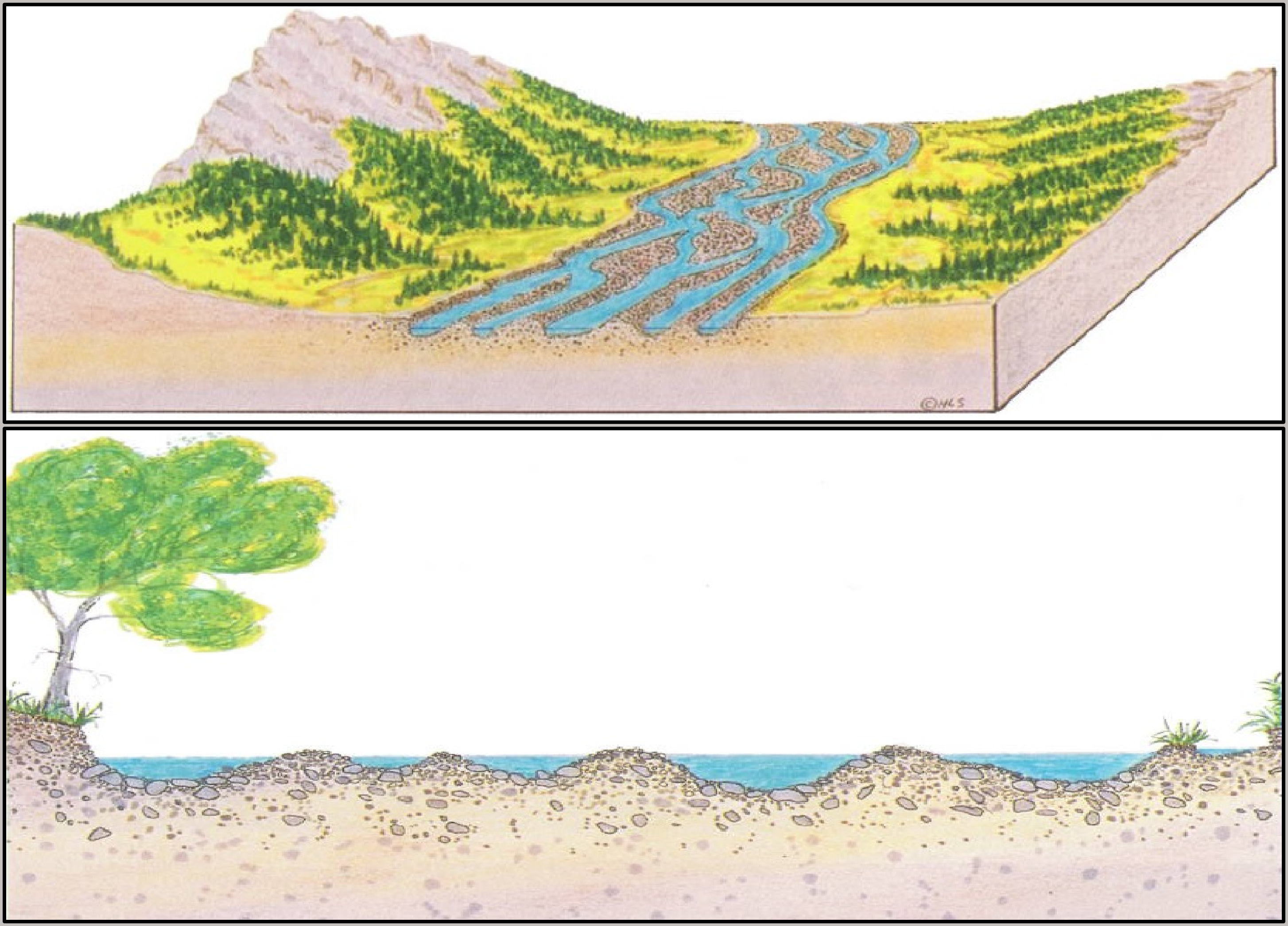
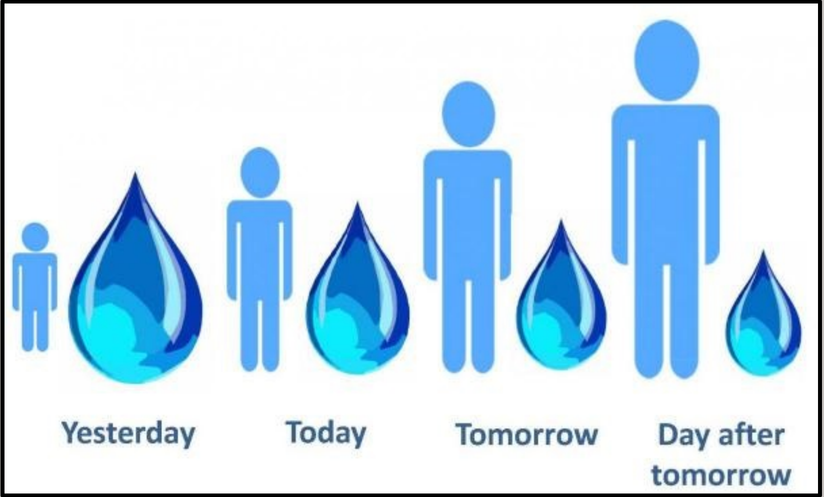


Figure are adopted from *Dave Rosgen*, (1996), *Applied River Morphology*, page 5-151

Introduction

- Vital need for fresh water in the future
- Growing of Population and Middle Class putting more stress on water bodies and fresh water demands
- Need for more accurate, timely and accessible streamflow data
- Rivers are essential resources for tracking amount of fresh water in hydrological cycle.



http://www.capsweb.org/blog/

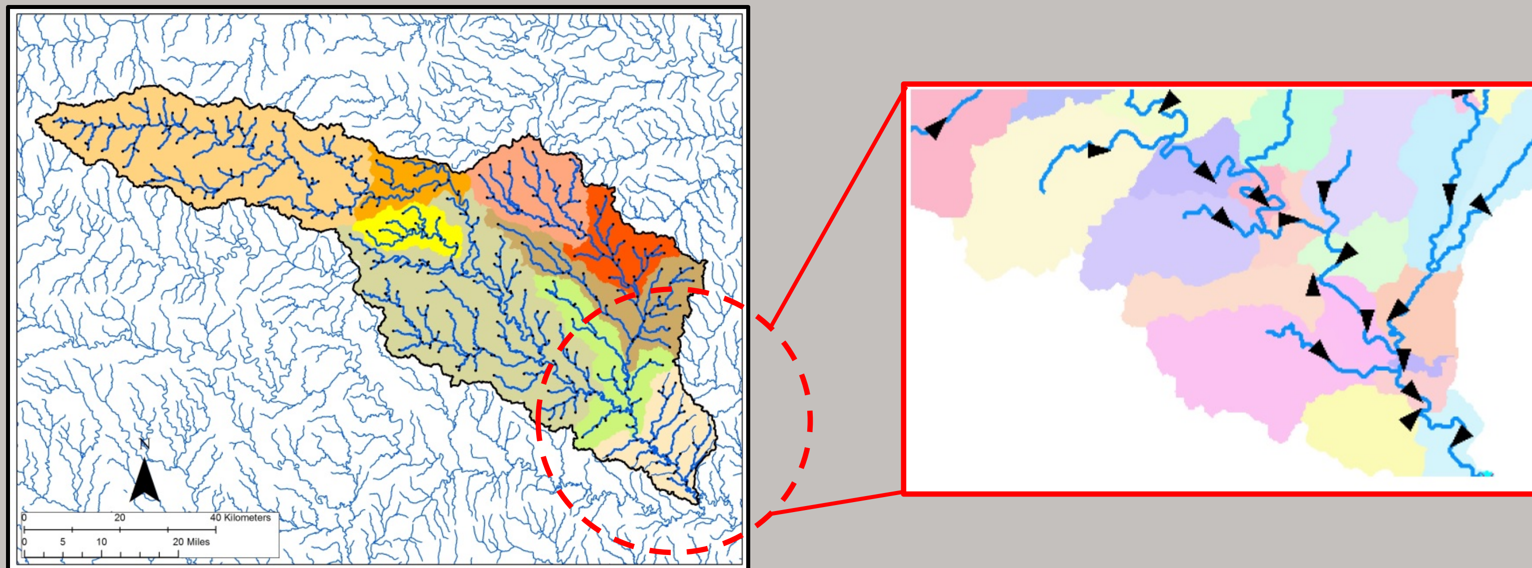
http://www.scientificamerican.com/report/water/

River Network Models – SimpleTools

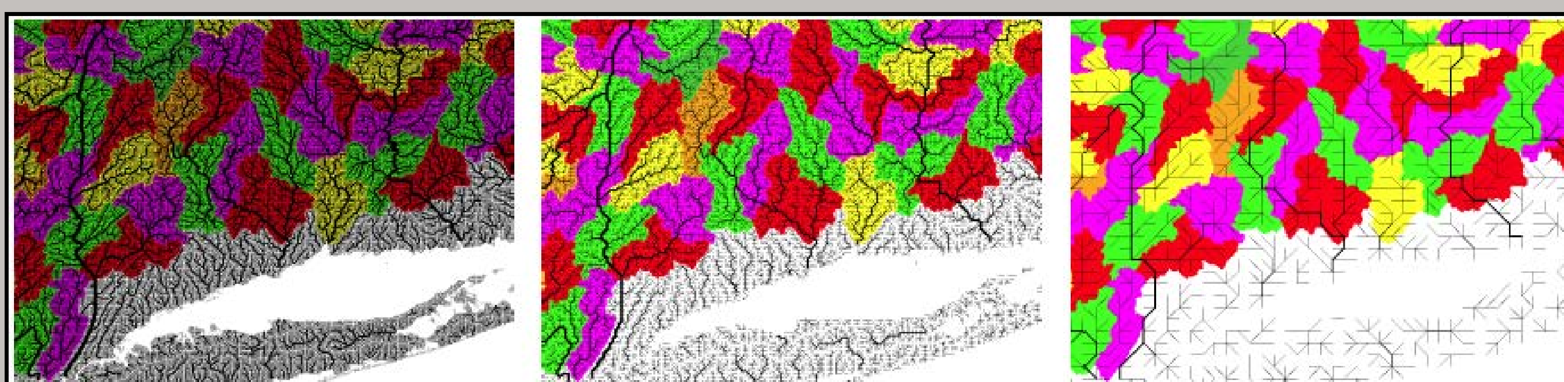
- River network models developed for spatially and temporally analyzing and estimating flow discharge over large domains, that can be exported to the other hydrological models.
- Simplification of either governing flow relations and physical boundary conditions of river extent, for example, riverbed geometry and geo-morphological features of river channels will turn river network models into feasible tools to be incorporated in regional and even global-scale fresh-water analysis.
- Two sets of river network model platform have been created : **1) Gridded River Network**
  2) Vectored River Network

River Network Models – Types

- Vectored River Network



- Gridded River Network



River Network Models – Structure

General Flow Equ.
(*Saint-Venant equ.*)

Actual Riverbed Geometry

Simplified Flow Routing Schemes

Uniform Regular Geometries

- **Muskingum-Cunge**
- Kinematic Routing
- Cascading Resv.
- etc.

- Rectangle
- Trapezoid
- 2nd-order parabola

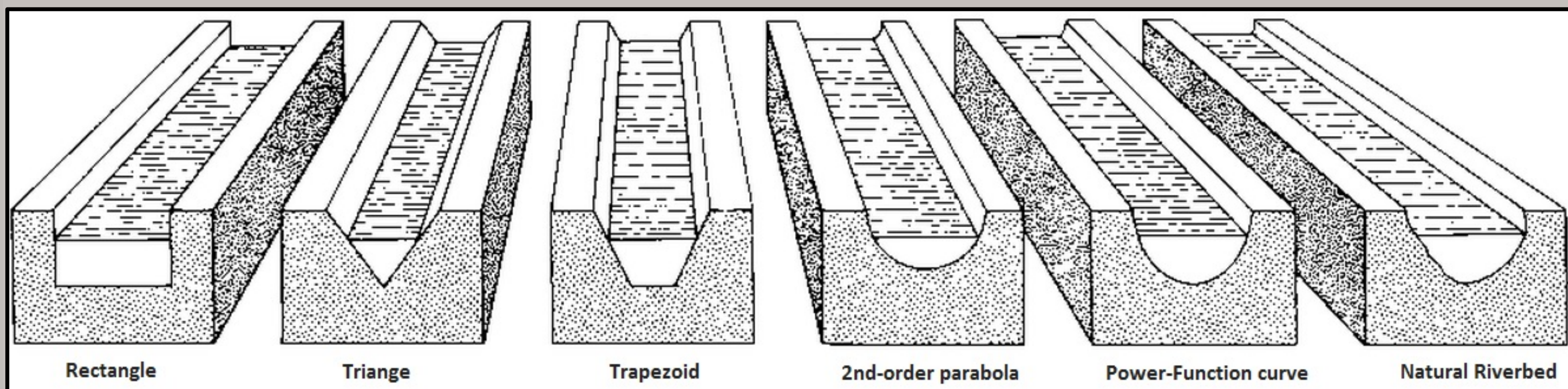
- Two basic structural components are:

1) simplified flow routing schemes
2) regular-shaped bed-geometries

Either of these components can be improved!

Improving Riverbed Geometry

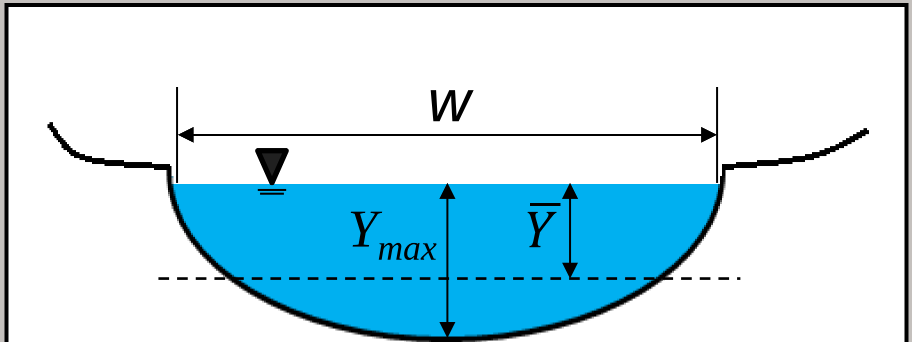
- Simplifying the river bed geometries could reduce the burden of assembling the required data.
- Implementing less detailed flow routing procedures could lower the computational burden.



- **Developing idealized riverbed geometries based on streamflow information, and employing them in flow routing schemes and river network models.**

Idealized Flow Conditions

- Average conditions over longer river reaches are more uniform and predictable based on flow and topography consideration.
- Average flow conditions expressed as power-law "**at-a-station**" hydraulic relationships between key channel components, (i.e. water depth, top-width, flow velocity, flow area against discharge) have been studied since 60's.



Idealized Geometry

- discharge (Q)
- mean depth ($\bar{Y}$)
- water surface width (W)
- flow velocity (U)
- flow area (A)

$\bar{Y}=cQ^f$ $W=aQ^b$ $U=kQ^m$ $A=sQ^r$

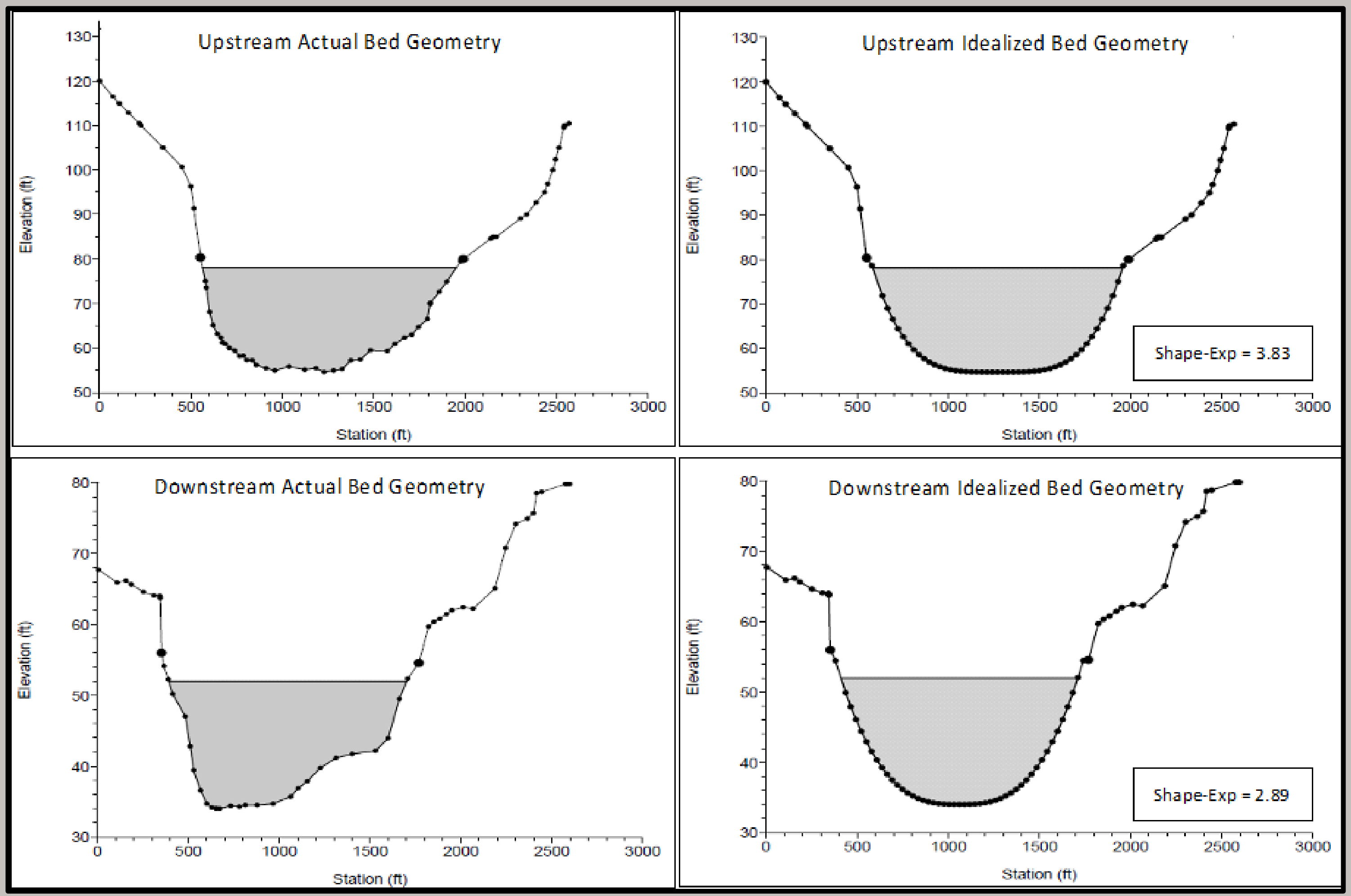
$$Q=\bar{Y}\,W\,U=c\,a\,k\,Q^{f+b+m} \longrightarrow \left.\begin{matrix} f+b+m \\ c\times a\times k \end{matrix}\right\} = 1$$

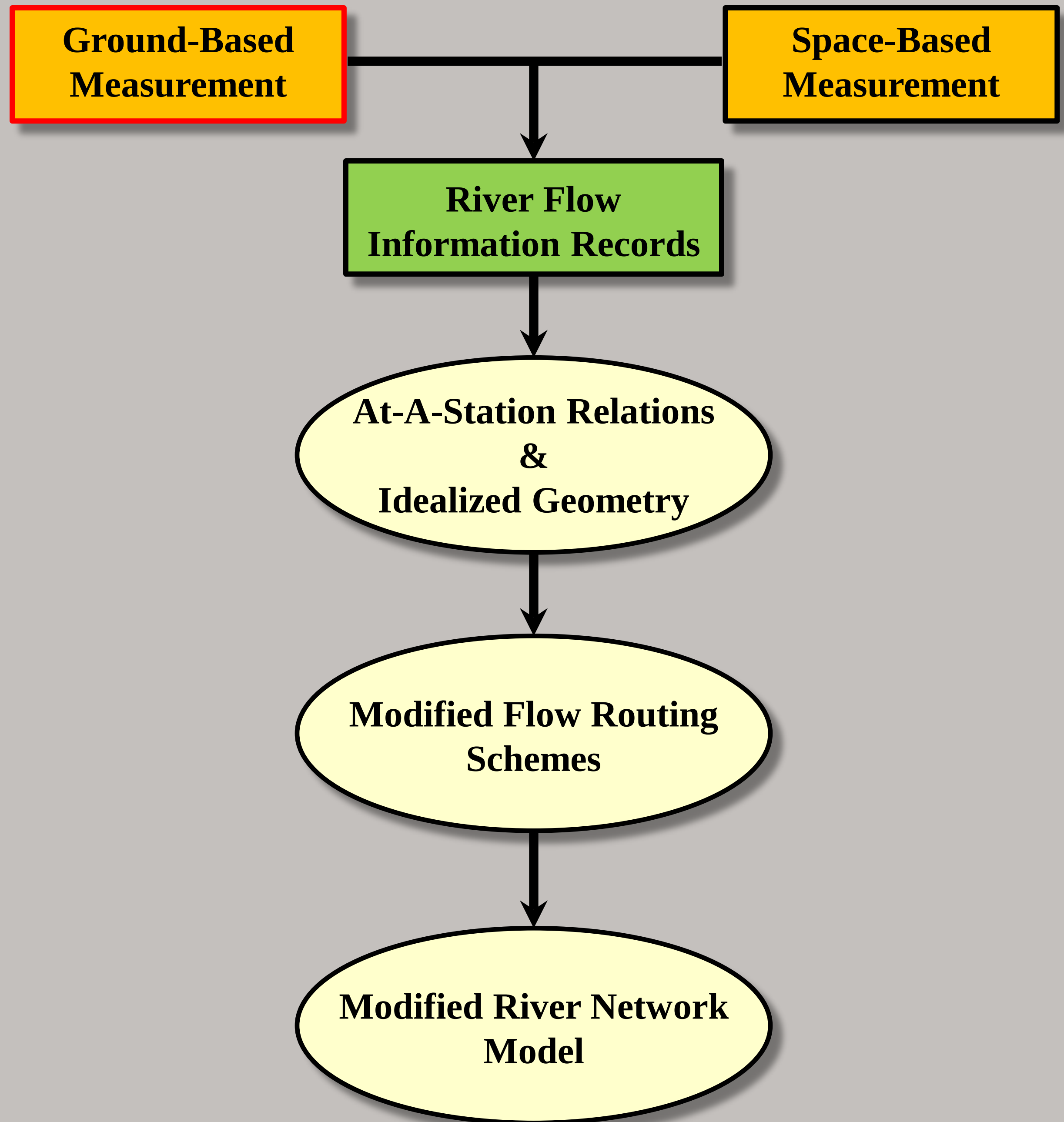
Idealized Geometry:

$$\bar{Y} = \frac{\beta\alpha W^{\beta}}{\beta+1}$$

Preliminary Experiment

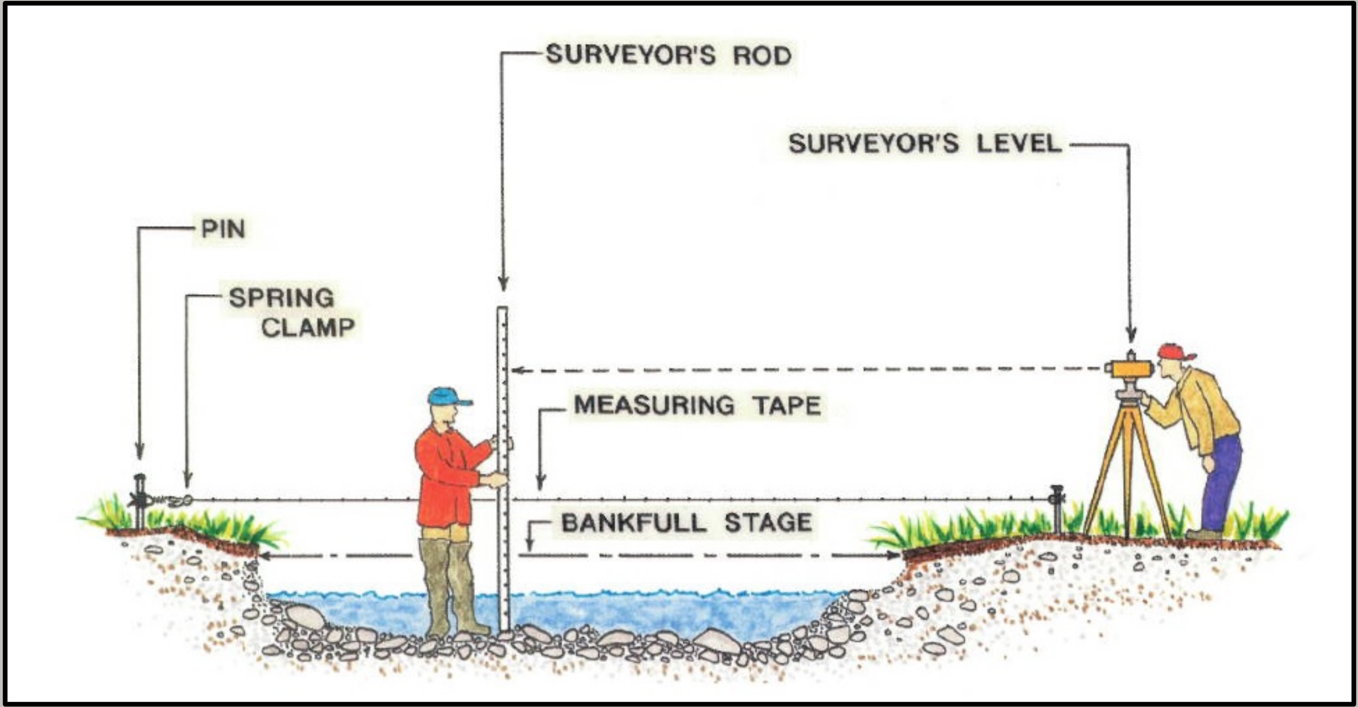
- Idealized geometries can be calculated and assigned alongside the river channel




Ground-Based Measurement
Space-Based Measurement
River Flow Information Records
At-A-Station Relations & Idealized Geometry
Modified Flow Routing Schemes
Modified River Network Model

Ground-Based Flow Measurement

- Establishing robust relationships for riverbed geometry and its hydraulic properties will require analysis of river surveyed data for wide range of various sizes with different flow regimes over diverse landscapes and regional domains.
- There are several sources, e.g. national/private agencies that provide in-situ streamflow measurement



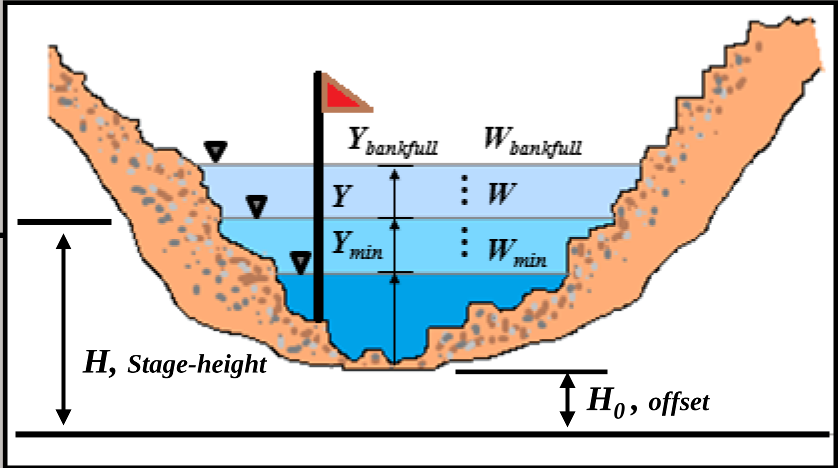
Figures are adopted from *Dave Rosgen*, (1996), *Applied River Morphology*. page 5-24

Ground-Based Flow Measurement

USGS/NWIS

Daily Data

Surveyed Data

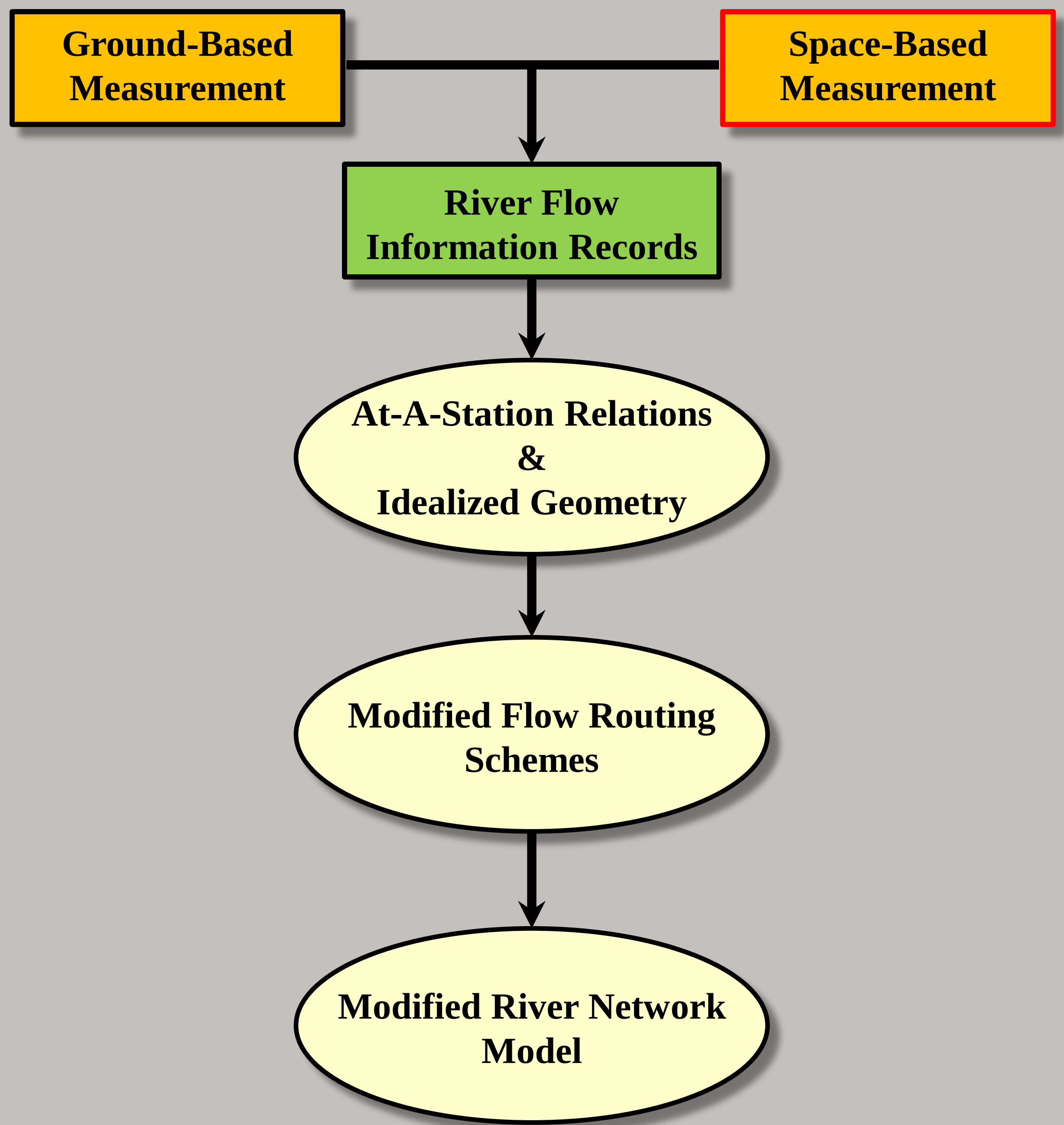


H: Stage-height
Q: Discharge

$H = c * Q^f + H_0$
$Y = H - H_0$

Y : maximum water depth in a river cross-section

- Provides daily Mean, Maximum, and Minimum time-series of stage-height and corresponding discharge values.
- They will be used as basic limiting tools for selecting surveyed data in following studies.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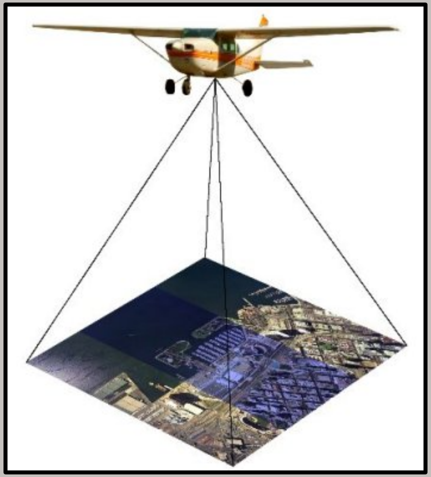
Space-Based Flow Measurement

- Application of remote sensing techniques for data acquisition over river extents is becoming as an alternative surveying approach along with field measurements.
- Remote sensing surveys can provide full range of spatial and temporal variation in river systems at regional and continental scales captured through various satellite-based, or airborne products

Digital rendering of the SWOT satellite.

http://www.satellitetoday.com/technology/

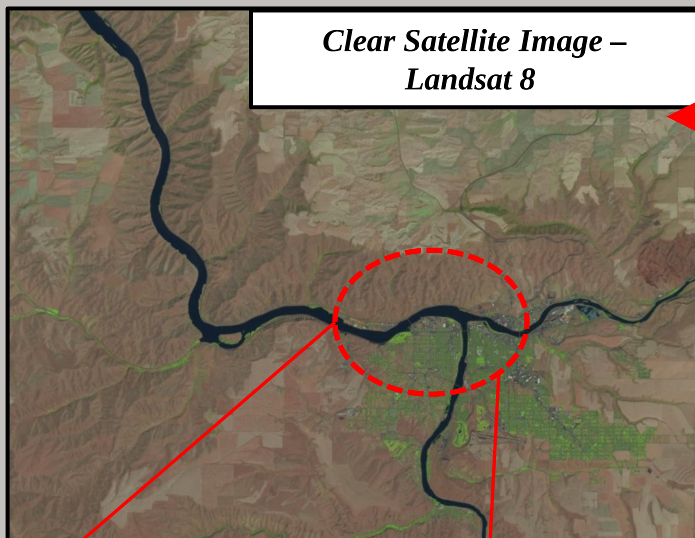


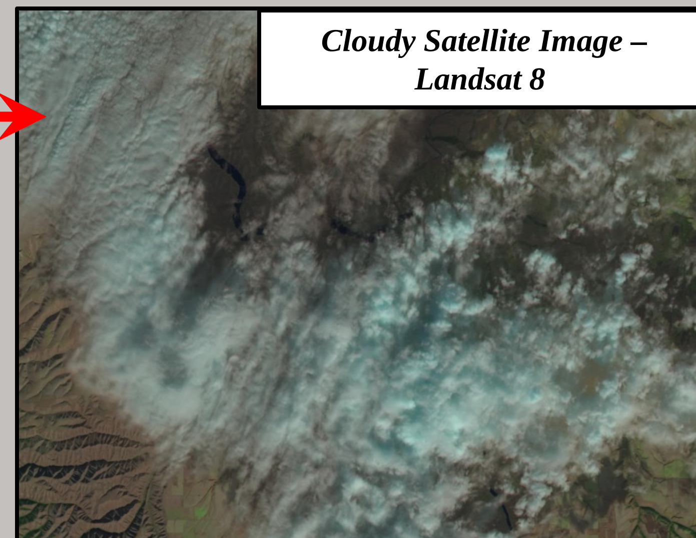
http://www.san-lo.com/photogrammetry.html/

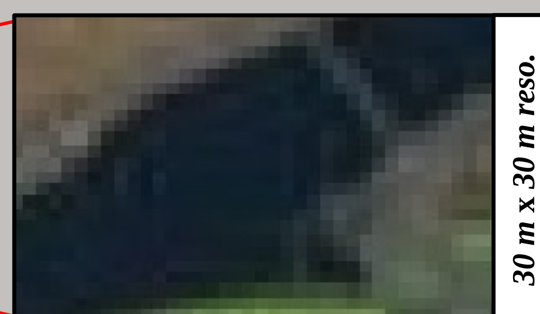
http://www.san-lo.com/photogrammetry.html

Space-Based Flow Measurement

- Since 1990, studies have suggested that remotely sensed data captured from rivers could be used to directly estimate the discharge, geometrical and physical components of river extent at a specific location, typically where ground-based data is difficult to obtain.





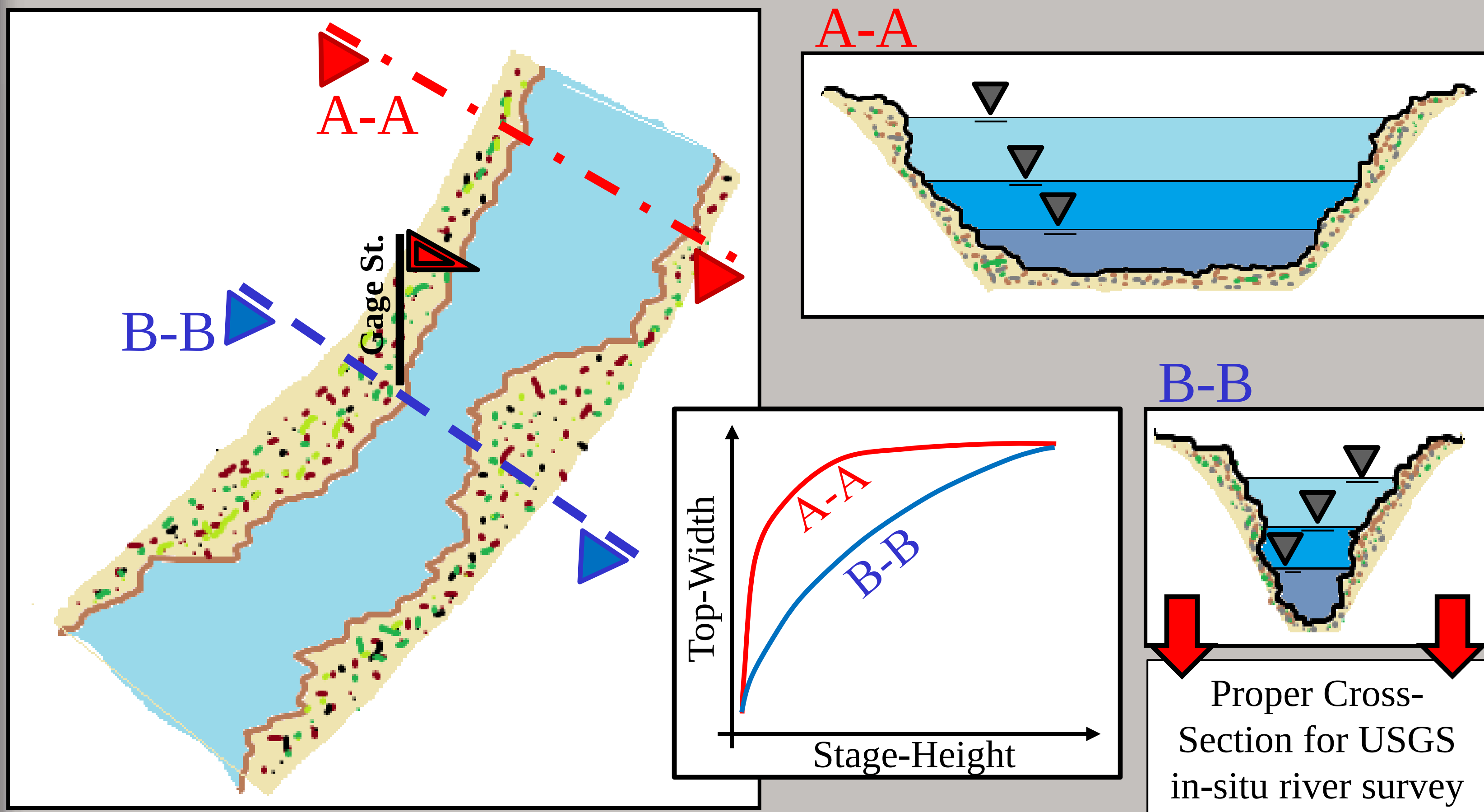


Landsat Missions

Space-Based Flow Measurement

- **Gaging Reach vs. Gaging Stations**

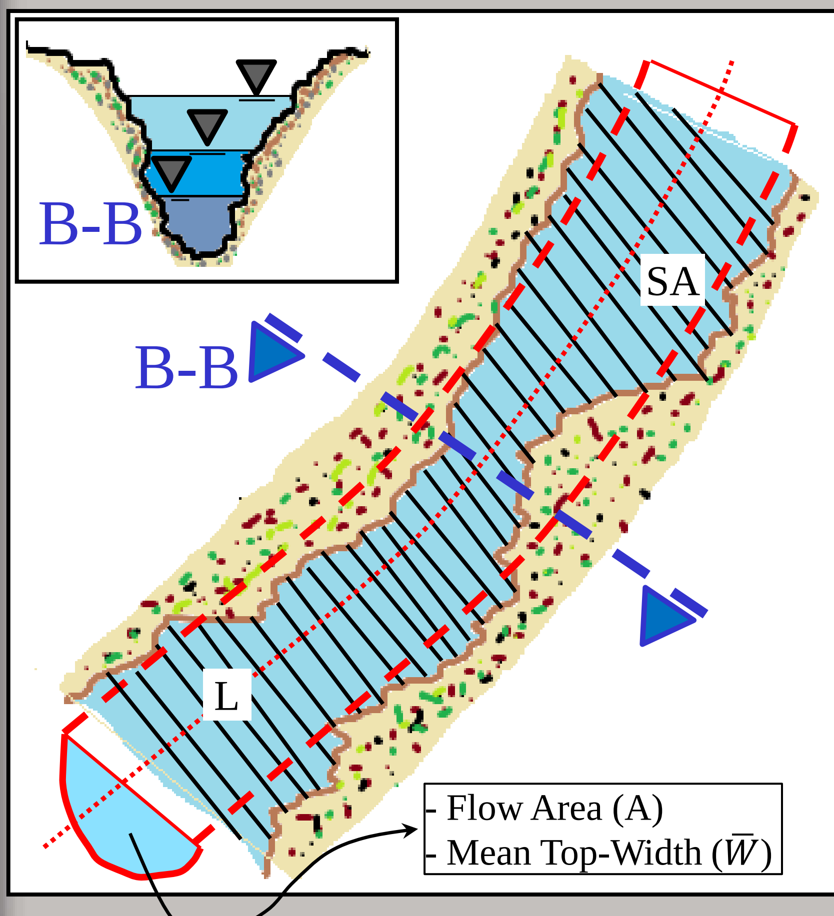
Temporal and spatial variation of the size and shape of alluvial channel alongside the reach would restrict the gaging station to geometrically represent just the immediate vicinity.

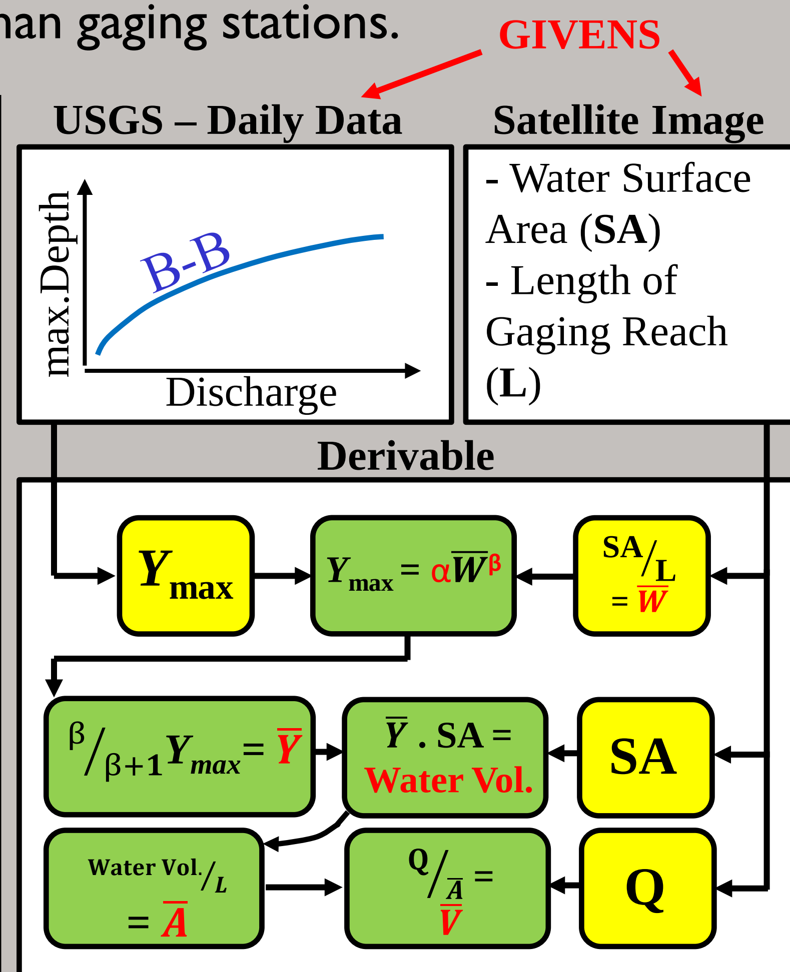


Space-Based Flow Measurement

- **Gaging Reach vs. Gaging Stations**

Advantages of the remote sensing, or specifically, satellite optical imagery over other river surveying techniques is the development and utilization of **gaging reaches** rather than gaging stations.





Preliminary Experiment in Remote Sensing

- Single River Reach: Savannah River at Burtons Ferry Bridge

- Total length: 38 mile (~60 km).
- Landsat 4-5 TM, and 8-OLI/TIRS Band 5 (1.55 – 1.75 µm)

- USGS/NWIS Daily Data :
  - Site No. 02197500
  - Latitude: 32°56‘20" NAD27
  - Longitude: 81°30‘10" NAD27
  - Drainage area: 8,650 sq. miles
  - Gage datum 52.42 feet above NGVD29

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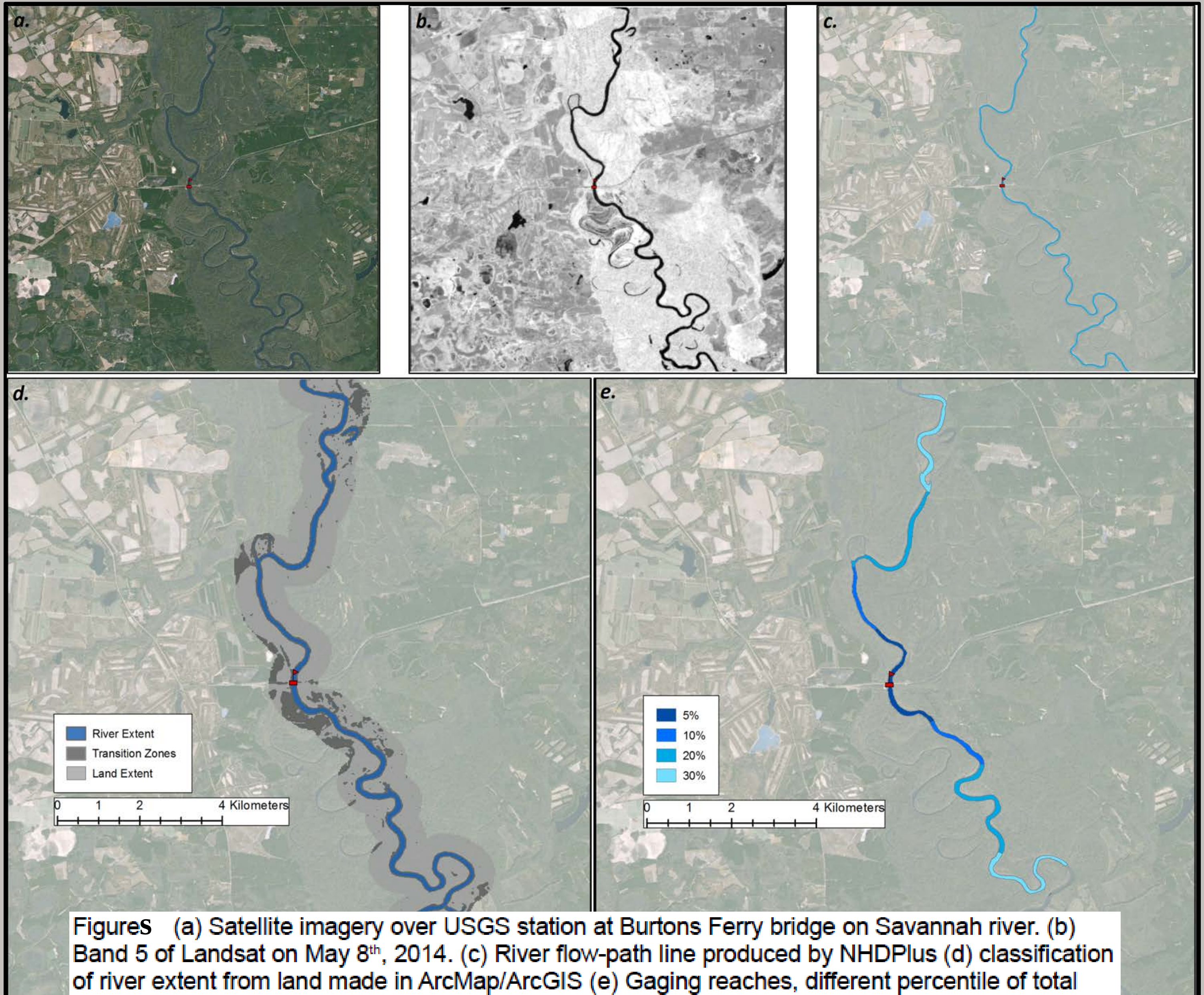
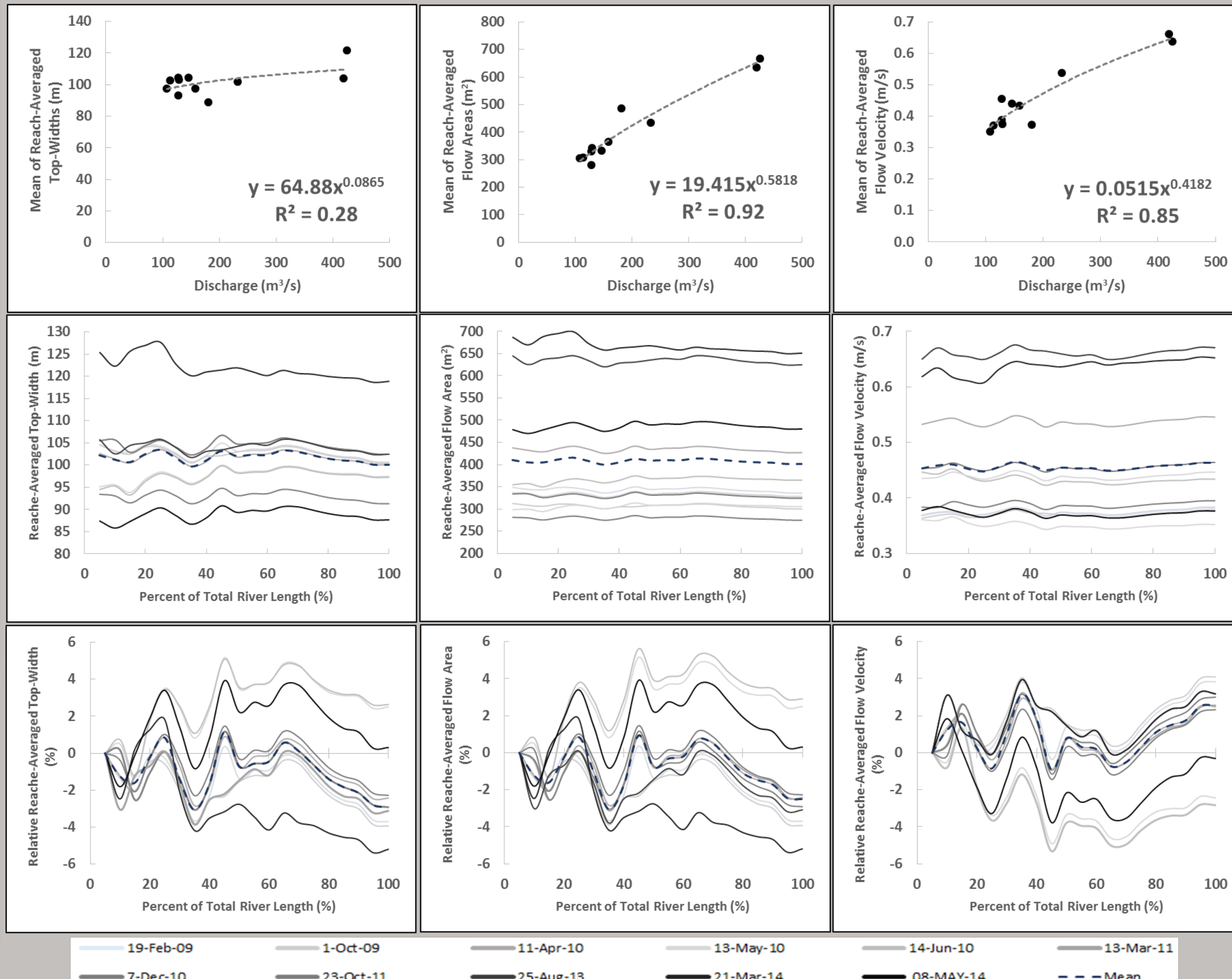
Preliminary Experiment in Remote Sensing



Figures (a) Satellite imagery over USGS station at Burtons Ferry bridge on Savannah river. (b) Band 5 of Landsat on May 8th, 2014. (c) River flow-path line produced by NHDPlus (d) classification of river extent from land made in ArcMap/ArcGIS (e) Gaging reaches, different percentile of total reach segment.

Preliminary Experiment in Remote Sensing



Remote Sensing of Rivers, A Practical Approach???

No. of Rivers	Mean Length (km)	Total length (km)	Width (m)	Area (km^2)
28 550 000	1.6	45 660 000	0.8	36 500
6 000 000	3.7	22 061 000	1.8	39 200
1 260 000	8.5	10 660 100	3.7	39 600
264 000	19.5	5 151 100	8.3	42 500
55 500	44.8	2 489 000	29.3	72 800
11 700	103.2	1 202 700	73.3	88 100
2450	237.4	581 200	131.5	76 400
515	546.2	280 800	264.5	74 300
110	1256.7	135 700	608.5	82 600
23	2891.7	65 600	988.5	64 900
5	6653.8	31 700	803.0	25 400
1	6437.0	6440	3079.0	19 800
36,144,304	**18,204.1**	**88,325,340**	**5992.2**	**662,100**

Adopted from *Downing et. al.*, 2010

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"Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time. It sings a song of wisdom and life for greater life far greater than man can hear…" Norman Maclean, 1976

Questions and Comments

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