Consultancy Service for the Development of an Inundation, Flooding and Landslide National Risk Profile, Strategic Framework and Action Plans for Disaster Risk Management for the Republic of Mauritius

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Capacity and validation workshop

Swami Vivekananda International Convention Centre, Pailles, Mauritius, August 22-24, 2012

FLOOD HAZARD ASSESSMENT

Flood hazard is the chance that a flood event of a certain magnitude will occur in a given area within a given period of time

Flood event March 2008

FLOOD HAZARD ASSESSMENT

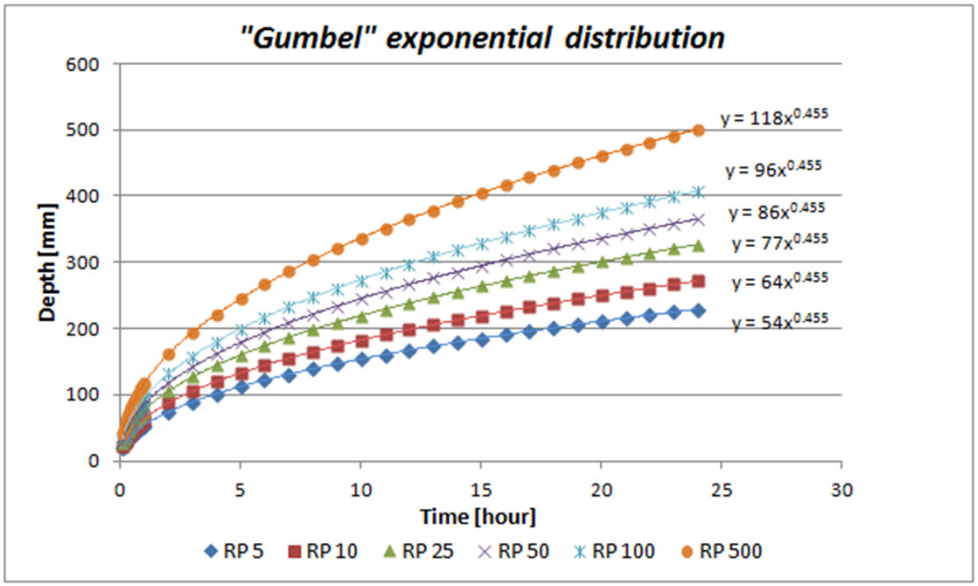
1. Extreme precipitation under current and future climate
2. Integrated Hydrologic & Hydraulic analysis
3. Flood hazard mapping

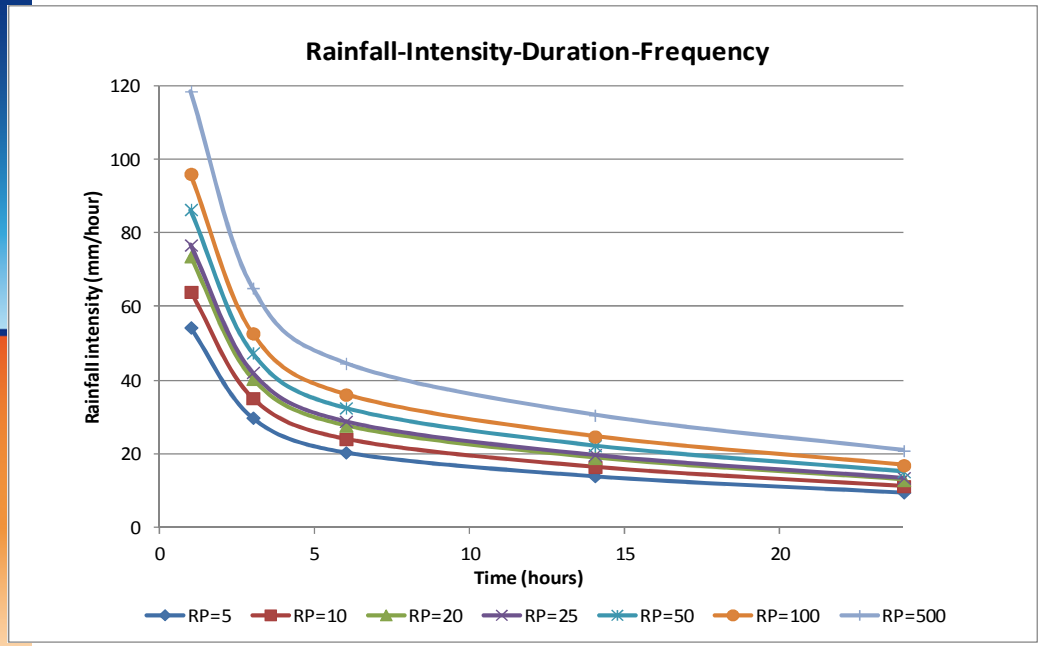
Extreme precipitation under current and future climate

One of the most widely used distributions of probability for extreme values (annual series) is the “Gumbel” distribution double exponential:

$$h = a * t^{n} \quad [mm]$$

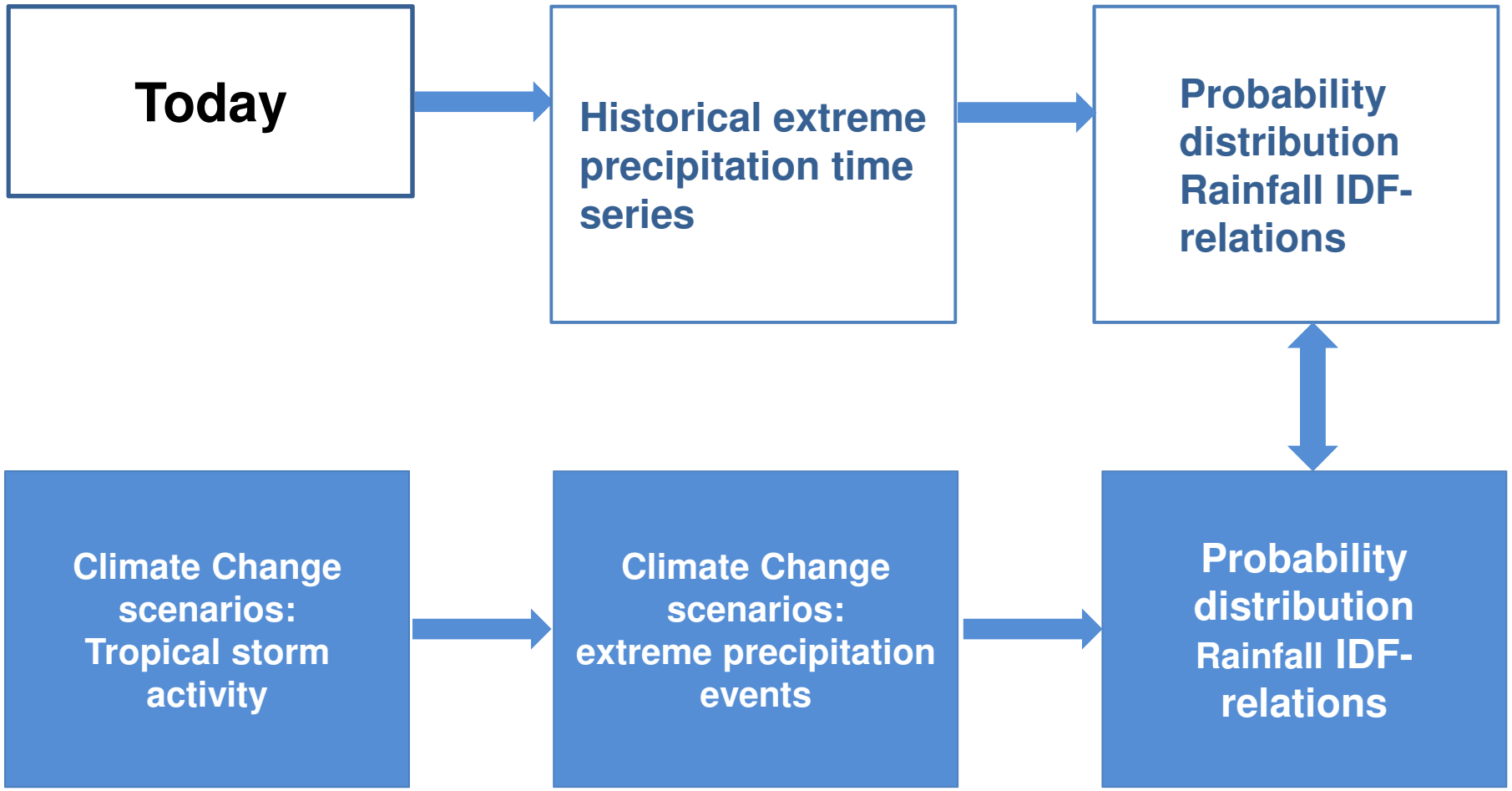
IDF curves - equations for Mauritius defined at Z=0 m.s.l



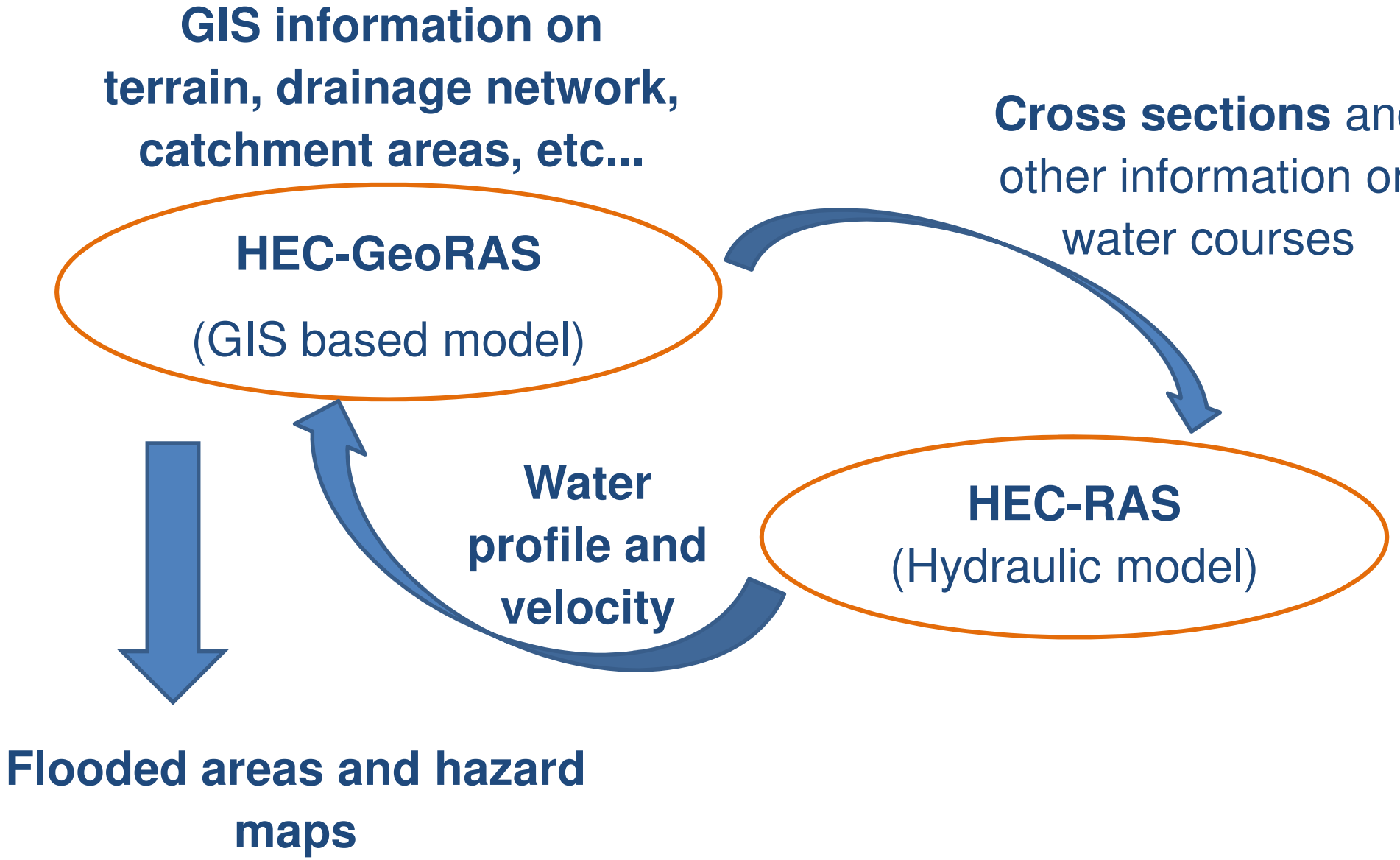


Taking into account ground’s elevation in ROM

1) Extreme precipitation under current and future climate



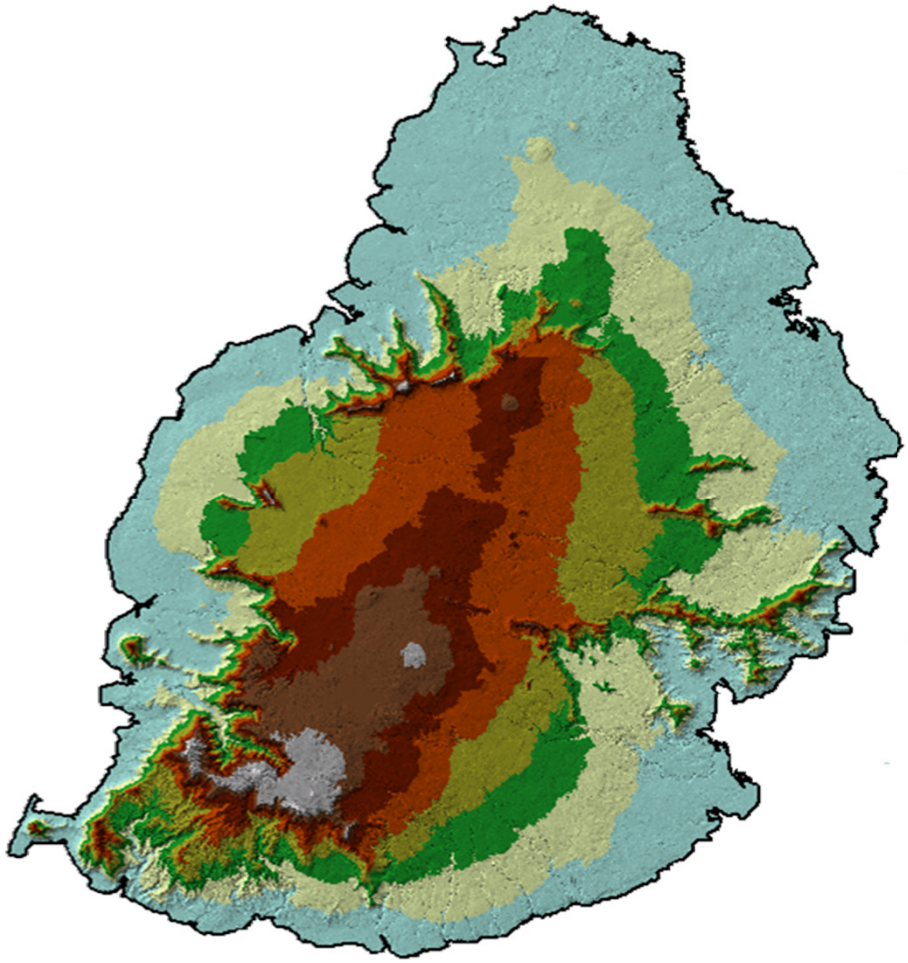
2) Integrated Hydrologic & Hydraulic analysis



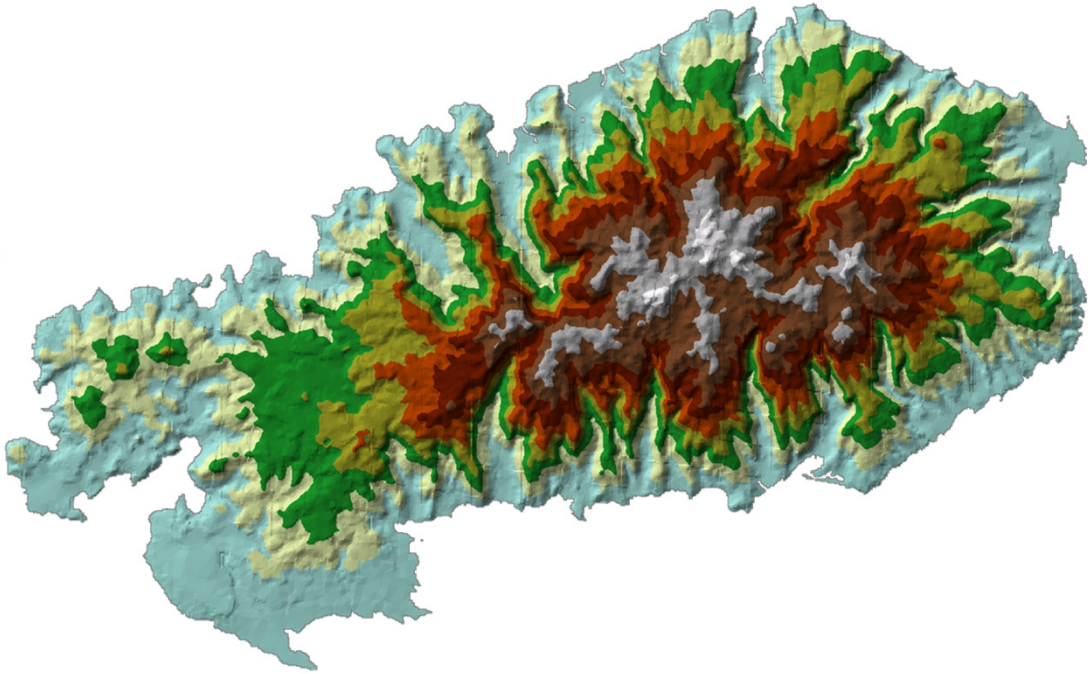
2) Integrated Hydrologic & Hydraulic analysis

Hydrological analysis: GIS information – DEM of ROM

Mauritius: DEM of 10x10 m grid



Rodrigues: DEM of 20x20 m grid



2) Integrated Hydrologic & Hydraulic analysis

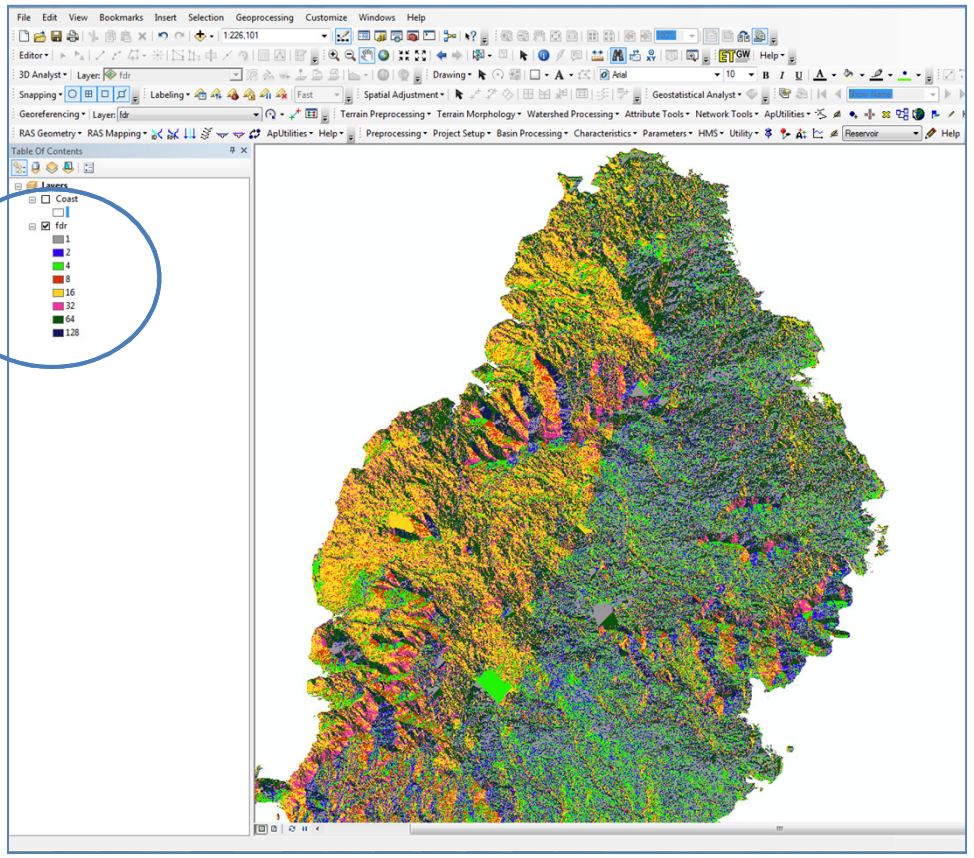
GIS application (*3D Analyst – HECGeoHMS*):

DEM (elevation of each pixel)

1) Fill pits (errors in the DEM due to interpolating the grid)

2) Flow direction

(defines the direction of the steepest descent for each terrain)

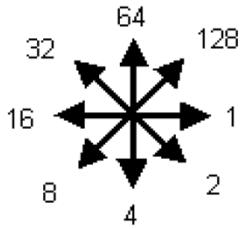


1 = east, 2= southeast,

4 = south, 8 = southwest,

16= west, 32=northwest,

64 = north, 128=northeast.



2) Integrated Hydrologic & Hydraulic analysis

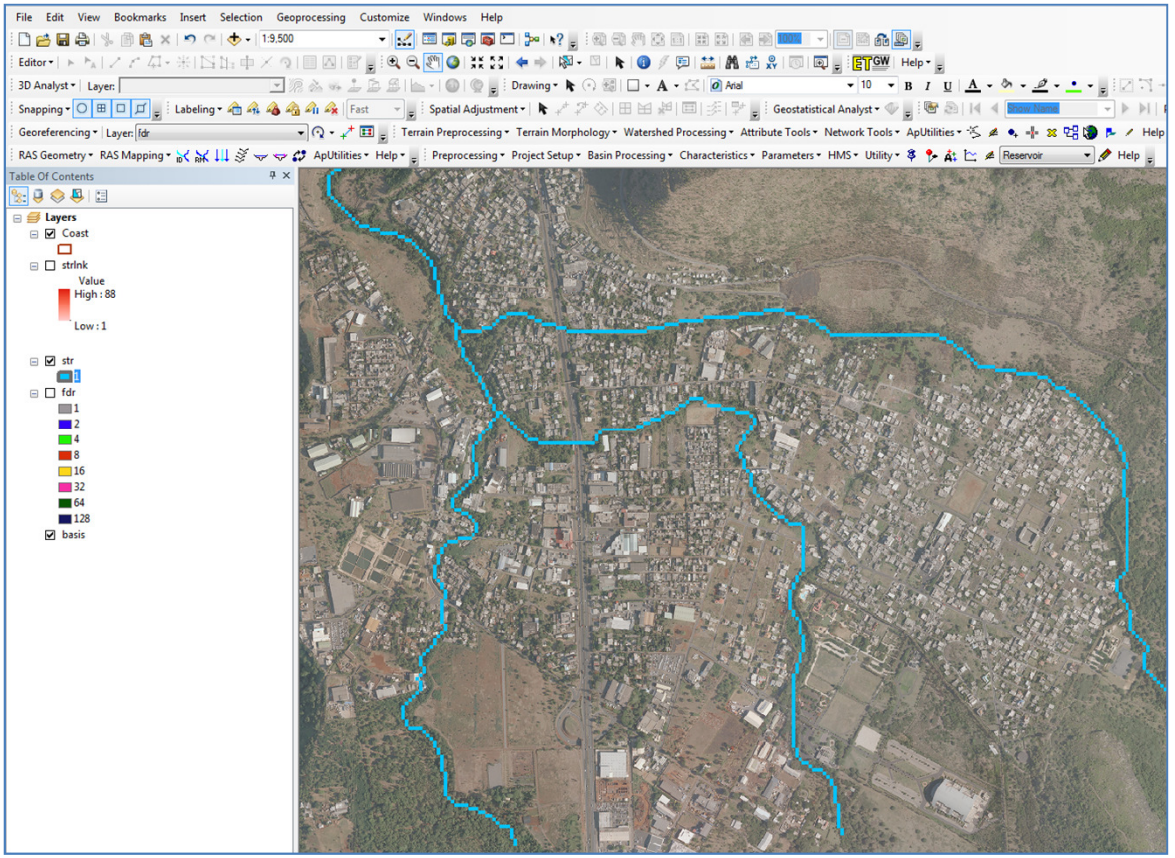
3) Flow accumulation (determines the number of upstream cells draining to a given cell)

4) Stream definition (classifies all cells with a flow accumulation greater than the user defined threshold as cells belonging to the stream

Thresold area	
Pixels	*km²*
10000	1
50000	5
100000	10

Minimum surface of drainage subbasin for Mauritius Island: **5 km²**

Rodrigues Island: **1 km²**

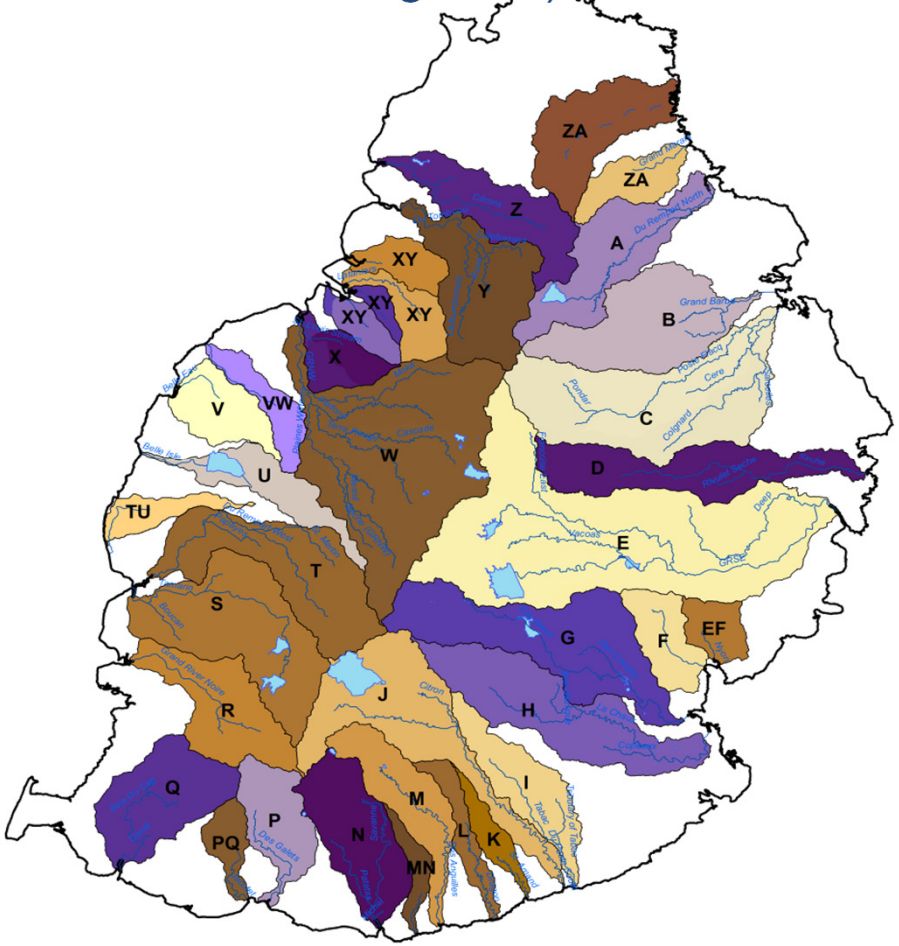


2) Integrated Hydrologic & Hydraulic analysis

Catchment basin	Main river name	Area (km2)	Main river length (km)
A	Du Rempart North	42.15	16.2
B	Francoise North	51.84	25.3
C	Du Poste Flacq	83.84	20.1
D	Seche	46.55	22.3
E	Grand River South East (GRSE)	161.90	35.3
EF	Nyon	11.91	4.9
F	Champagne	19.31	6.9
G	Des Creoles	67.73	21.4
H	La Chaux	58.09	24.0
I	Tabac	28.92	14.4
J	Du Poste South	62.26	27.6
K	St. Amand	9.18	10.5
L	Dragon	11.94	10.5
M	Des Anguilles	30.46	8.2
MN	Bain des Negresses	7.33	6.7
N	Savanne	39.06	13.0
P	Des Galetes	25.19	12.0
PQ	Jacotet	10.65	8.2
Q	Baie du Cap	39.76	15.1
R	Grand River Noire	37.78	13.5
S	Tamarin	65.43	17.7
T	Du Rempart West	55.36	19.0
TU	-	14.60	5.4
U	Belle Isle	23.78	15.7
V	Belle Eau	21.31	8.3
VW	-	14.66	6.7
W	Grand River North West (GRNW)	119.25	23.4
X	St. Louis Stream	15.20	6.6
XY	Lataniers	15.10	8.5
XY	Rivulet Terre Rouge	12.54	6.3
XY	Pouce Stream	9.64	4.5
XY	La Paix Stream	4.46	2.7
Y	Du Tombeau	45.78	19.5
Z	Citrons	36.13	13.5
ZA	Grand Marais	16.15	7.2
ZA	Goodlands (settlement name)	37.35	8.4

5) Catchment grid delineation

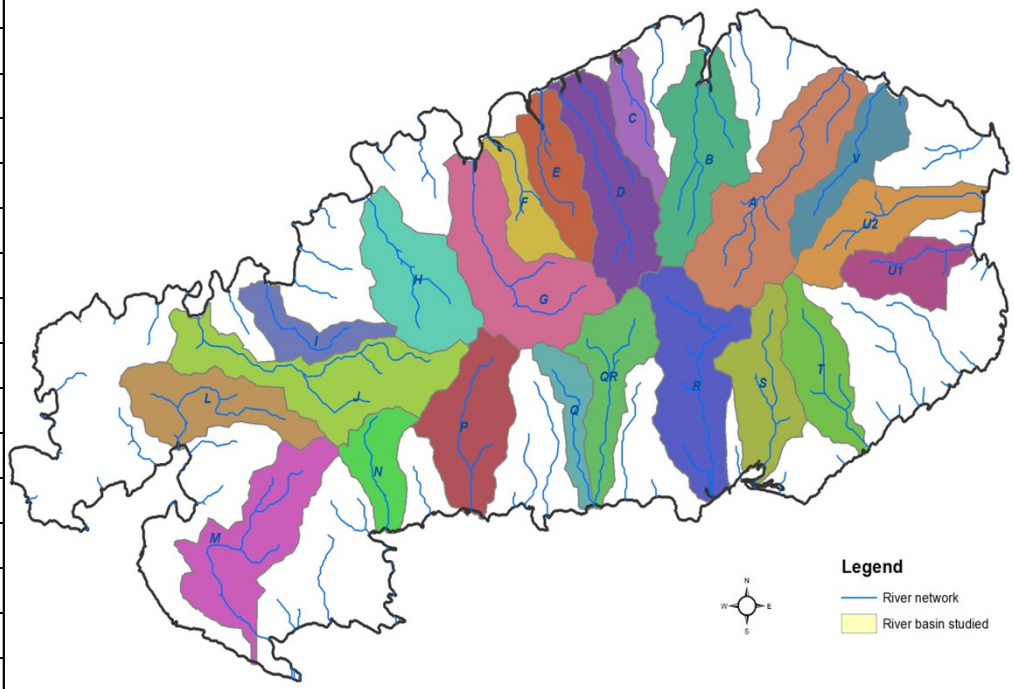
(delineates subbasin for every stream segment)



2) Integrated Hydrologic & Hydraulic analysis

Rodrigues island – Watersheds Boundaries

Catchment basin	Main river name	Area (km^2)	Main river length (km)
A	Banane	5.8	4.9
B	Sygangue	3.9	2.8
C	Anse Aux Anglias	1.3	1.7
D	Cascade Pigeon	3.8	3.5
E	Camp Du Roi	2.3	2.1
F	Acacia	1.5	1.7
G	Baie Aux Huitres	5.0	4.1
H	Malgache	3.7	2.7
I	Baie Du Nord	1.6	2.7
J	Pistache	5.0	5.5
L	Canne	3.1	3.4
M	Anse Quitor	4.3	5.2
N	Fond Marechal	1.7	2.2
P	Cocos	3.6	3.0
Q	Du Sel	1.3	2.8
QR	Baleine	2.8	3.5
R	Cascade Victorie	4.6	4.3
S	Mourouk	2.9	2.9
T	Cascade Graviers	2.5	3.0
U1	Anse Ally	2.9	3.5
U2	St. Francois	1.9	2.0
V	-	2.2	2.8



2) Integrated Hydrologic & Hydraulic analysis

Identification of flood peak discharge: Rational method

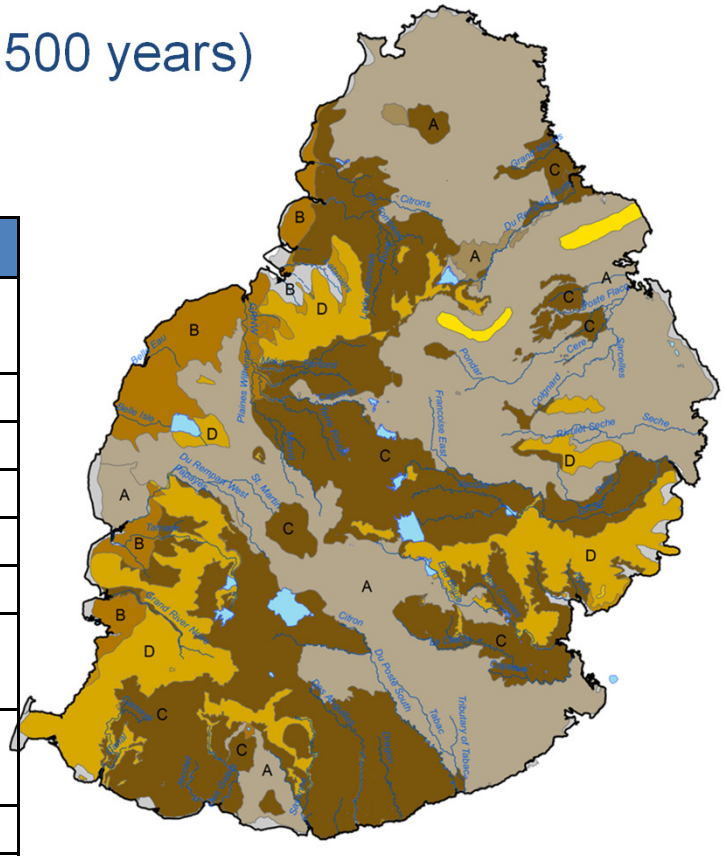
Peak discharge at a given outlet of a catchment area:

$$Q_T = 0{,}248 \times C_T \times I_T \times A$$

where:

- Q_T, discharge (m^3/s) for return period T (25,50,100,500 years)
- C_T, runoff coefficient for return period T
- I_T, intensity (mm/hour) for return period T
- A, catchment area (km^2)

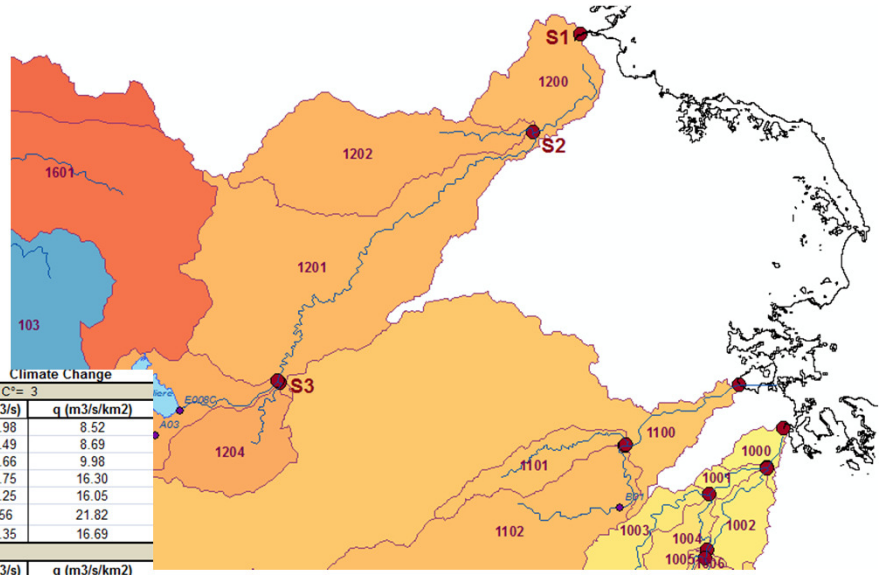
MAURITIUS	
Geology	**Soil Type**
Recent Fresh Basaltic Flows	A
Intermediate Fresh Basaltic Flows	B
Superficial Alluvium and Eluvium	B
Basalt	C
Brechia Series	C
Pyroclasts and Weathered Basaltic Flows	C
Recent Pyroclasts and Weathered Basaltic Flows	C
Ancient Basaltic Flows	D



2) Integrated Hydrologic & Hydraulic analysis

Peak flow estimation:

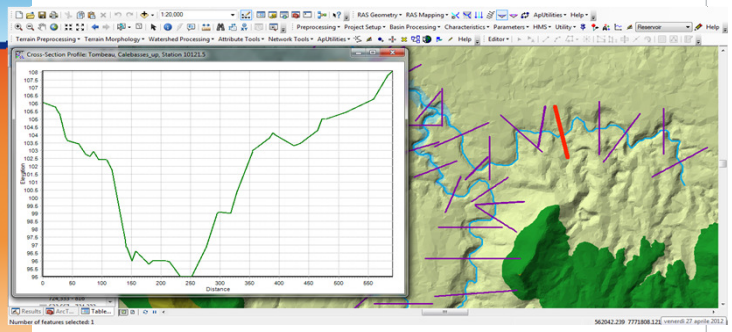
- current climatic condition
- climate change scenario

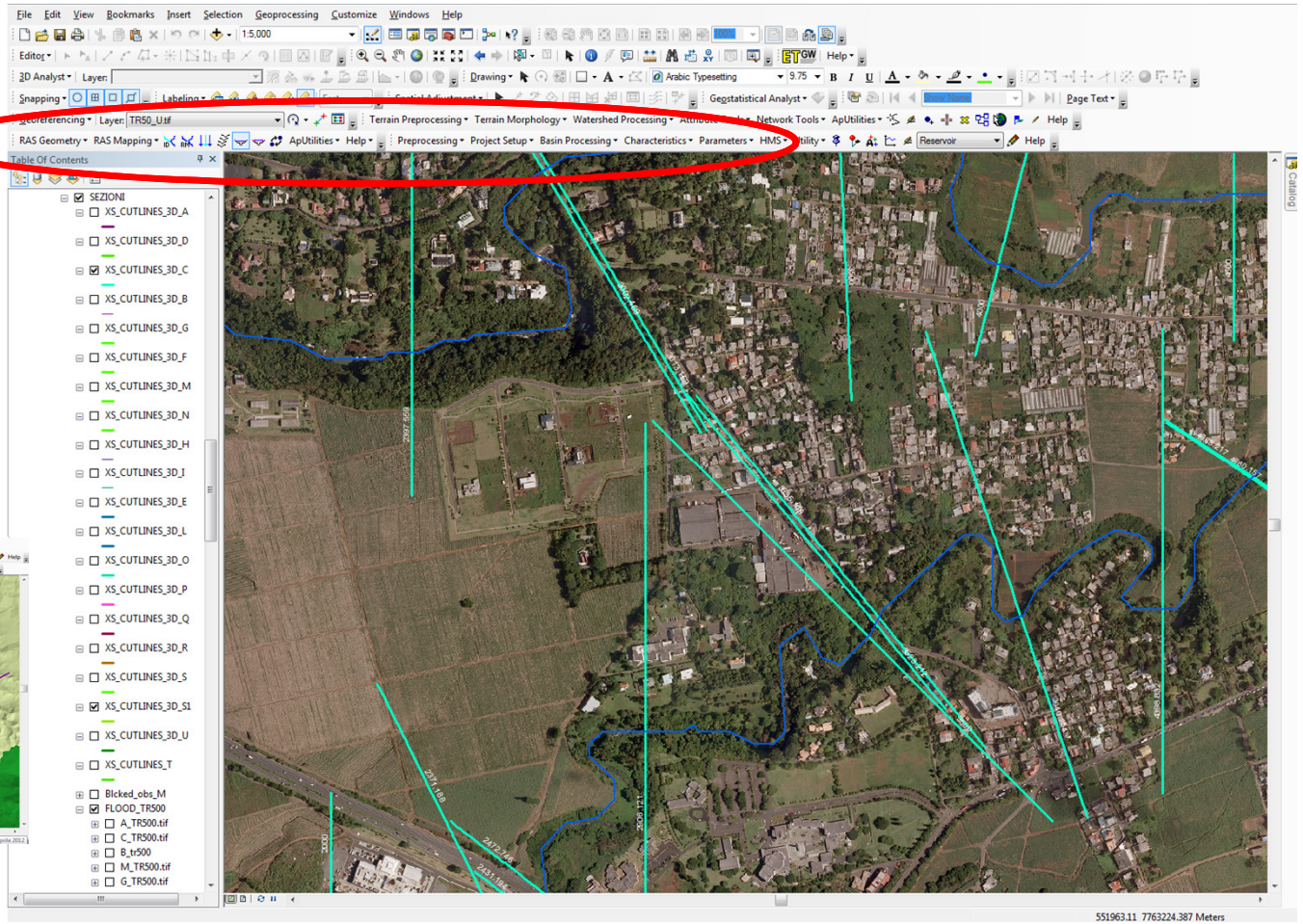


Portate con metodo razionale per il bacino A													Attuale		Climate Change	
Tr 500 an	500												C= 0.9		Delta C°= 3	
Sezione	Bacini sottesi	S (pixels)	S (km2)	L (km)	Z (m)	H (m)	Tc	P (mm)	I (mm/h)	Area factor	Inf (mm/h)	FARL	Q (m3/s)	q (m3/s/km2)	Q (m3/s)	q (m3/s/km2)
S1	1200+1201+1202+1203+1204	421535	42.15	16.2	0	177.2	4.7	247.2	52.4	0.97	19.6	0.9	304.2	7.2	358.98	8.52
S2v	1201+1202+1203+1204	381606	38.16	13.6	26	192.7	4.4	239.9	55.0	0.97	21.2	0.9	280.9	7.4	331.49	8.69
S2m_dx	1201+1203+1204	298321	29.83	13.6	26	215.1	3.8	226.5	59.0	0.98	20.0	0.9	252.3	8.5	297.66	9.98
S2m_sx	1202	83285	8.33	2.4	26	112.6	2.0	166.3	81.5	0.99	25.4	1.0	115.0	13.8	135.75	16.30
S3v	1203+1204	126036	12.60	2.6	173	295.8	2.0	172.3	84.5	0.99	12.7	0.8	171.4	13.6	202.25	16.05
S3m_dx	1204	40133	4.01	2.2	173	227.0	1.9	165.9	86.7	1.00	12.7	1.0	74.2	18.5	87.56	21.82
S3m_sx	1203	85903	8.59	2.6	173	328.0	1.6	152.3	97.1	0.99	12.7	0.7	121.5	14.1	143.35	16.69
Tr 100 an	100												C= 0.8			
Sezione	Bacini sottesi	S (pixels)	S (km2)	L (km)	Z (m)	H (m)	Tc	P (mm)	I (mm/h)	Area factor	Inf (mm/h)	FARL	Q (m3/s)	q (m3/s/km2)	Q (m3/s)	q (m3/s/km2)
S1	1200+1201+1202+1203+1204	421535	42.15	16.2	0	177.2	4.7	200.7	42.6	0.97	19.6	0.9	187.6	4.5	221.38	5.25
S2v	1201+1202+1203+1204	381606	38.16	13.6	26	192.7	4.4	194.8	44.7	0.97	21.2	0.9	171.8	4.5	202.70	5.31
S2m_dx	1201+1203+1204	298321	29.83	13.6	26	215.1	3.8	183.9	47.9	0.98	20.0	0.9	159.7	5.4	188.50	6.32
S2m_sx	1202	83285	8.33	2.4	26	112.6	2.0	134.9	66.1	0.99	25.4	1.0	74.1	8.9	87.46	10.50
S3v	1203+1204	126036	12.60	2.6	173	295.8	2.0	140.0	68.6	0.99	12.7	0.8	118.6	9.4	140.00	11.11
S3m_dx	1204	40133	4.01	2.2	173	227.0	1.9	134.8	70.4	1.00	12.7	1.0	51.4	12.8	60.70	15.12
S3m_sx	1203	85903	8.59	2.6	173	328.0	1.6	123.7	78.9	0.99	12.7	0.7	84.6	9.9	99.86	11.62
Tr 50 ann	50												C= 0.7			
Sezione	Bacini sottesi	S (pixels)	S (km2)	L (km)	Z (m)	H (m)	Tc	P (mm)	I (mm/h)	Area factor	Inf (mm/h)	FARL	Q (m3/s)	q (m3/s/km2)	Q (m3/s)	q (m3/s/km2)
S1	1200+1201+1202+1203+1204	421535	42.15	16.2	0	177.2	4.7	180.6	38.3	0.97	19.6	0.9	133.0	3.2	156.89	3.72
S2v	1201+1202+1203+1204	381606	38.16	13.6	26	192.7	4.4	175.4	40.2	0.97	21.2	0.9	120.9	3.2	142.71	3.74
S2m_dx	1201+1203+1204	298321	29.83	13.6	26	215.1	3.8	165.6	43.2	0.98	20.0	0.9	115.5	3.9	136.27	4.57
S2m_sx	1202	83285	8.33	2.4	26	112.6	2.0	121.4	59.5	0.99	25.4	1.0	54.2	6.5	64.01	7.69
S3v	1203+1204	126036	12.60	2.6	173	295.8	2.0	126.0	61.8	0.99	12.7	0.8	91.1	7.2	107.51	8.53
S3m_dx	1204	40133	4.01	2.2	173	227.0	1.9	121.3	63.4	1.00	12.7	1.0	39.5	9.9	46.65	11.62
S3m_sx	1203	85903	8.59	2.6	173	328.0	1.6	111.4	71.0	0.99	12.7	0.7	65.2	7.6	76.99	8.96
Tr 25 ann	25												C= 0.6			
Sezione	Bacini sottesi	S (pixels)	S (km2)	L (km)	Z (m)	H (m)	Tc	P (mm)	I (mm/h)	Area factor	Inf (mm/h)	FARL	Q (m3/s)	q (m3/s/km2)	Q (m3/s)	q (m3/s/km2)
S1	1200+1201+1202+1203+1204	421535	42.15	16.2	0	177.2	4.7	160.6	34.1	0.97	19.6	0.9	87.2	2.1	102.91	2.44
S2v	1201+1202+1203+1204	381606	38.16	13.6	26	192.7	4.4	155.9	35.7	0.97	21.2	0.9	78.5	2.1	92.62	2.43
S2m_dx	1201+1203+1204	298321	29.83	13.6	26	215.1	3.8	147.2	38.4	0.98	20.0	0.9	78.2	2.6	92.22	3.09
S2m_sx	1202	83285	8.33	2.4	26	112.6	2.0	107.9	52.9	0.99	25.4	1.0	37.4	4.5	44.14	5.30
S3v	1203+1204	126036	12.60	2.6	173	295.8	2.0	112.1	55.0	0.99	12.7	0.8	67.2	5.3	79.30	6.29
S3m_dx	1204	40133	4.01	2.2	173	227.0	1.9	107.9	56.4	1.00	12.7	1.0	29.2	7.3	34.45	8.58
S3m_sx	1203	85903	8.59	2.6	173	328.0	1.6	99.1	63.2	0.99	12.7	0.7	48.4	5.6	57.09	6.65
Tr 10 ann	10												C= 0.5			
Sezione	Bacini sottesi	S (pixels)	S (km2)	L (km)	Z (m)	H (m)	Tc	P (mm)	I (mm/h)	Area factor	Inf (mm/h)	FARL	Q (m3/s)	q (m3/s/km2)	Q (m3/s)	q (m3/s/km2)
S1	1200+1201+1202+1203+1204	421535	42.15	16.2	0	177.2	4.7	134.1	28.4	0.97	19.6	0.9	46.1	1.1	54.39	1.29
S2v	1201+1202+1203+1204	381606	38.16	13.6	26	192.7	4.4	130.3	29.9	0.97	21.2	0.9	40.2	1.1	47.43	1.24
S2m_dx	1201+1203+1204	298321	29.83	13.6	26	215.1	3.8	123.0	32.1	0.98	20.0	0.9	45.0	1.5	53.10	1.78
S2m_sx	1202	83285	8.33	2.4	26	112.6	2.0	90.1	44.1	0.99	25.4	1.0	22.6	2.7	26.63	3.20
S3v	1203+1204	126036	12.60	2.6	173	295.8	2.0	93.7	45.9	0.99	12.7	0.8	46.9	3.7	55.39	4.40
S3m_dx	1204	40133	4.01	2.2	173	227.0	1.9	90.2	47.1	1.00	12.7	1.0	20.4	5.1	24.12	6.01
S3m_sx	1203	85903	8.59	2.6	173	328.0	1.6	82.8	52.8	0.99	12.7	0.7	34.1	4.0	40.28	4.69

2) Integrated Hydrologic & Hydraulic analysis

HEC-GeoRAS 4.1.1: an extension for use ArcGIS, a general purpose Geographic Information System software program developed an copyrighted by the *Environmental Systems Research Institute, Inc., (ESRI)* Redlands, California . It is a set of ArcGIS tools designed to process geospatial data for use with the HEC-RAS hydraulic model



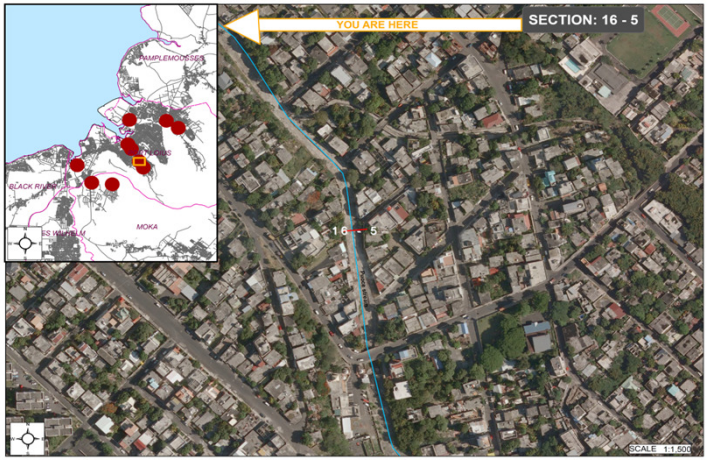


2) Integrated Hydrologic & Hydraulic analysis

Topographic survey

has been conducted to define the geometry when:

- the overlap of available DEM and aerial photos highlighted the uncertainty related to river's network
- the river network cross very high populated area
- you have to define the structures



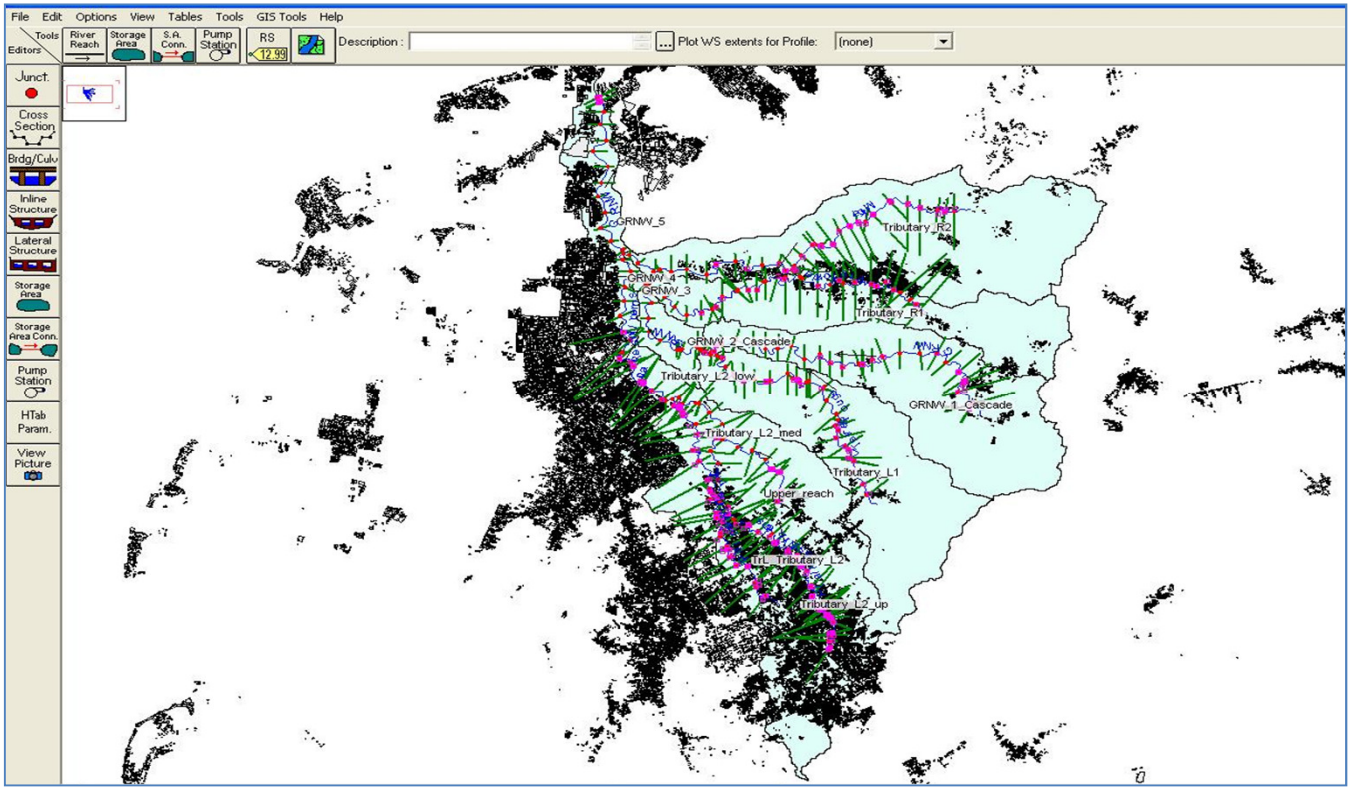
Topographic survey along La Pouce and S.Louis stream

Topographic survey along Rivière du Rempart

Topographic survey along Citrons river

2) Integrated Hydrologic & Hydraulic analysis

HEC-Ras - River Analysis System - developed by *US Army Corps of Engineers (Version 4.1 January 2010)* **:** 1D Hydraulic model, based on the finite difference method; it allows to perform water surface profile calculations for steady gradually varied flow in natural or constructed channels

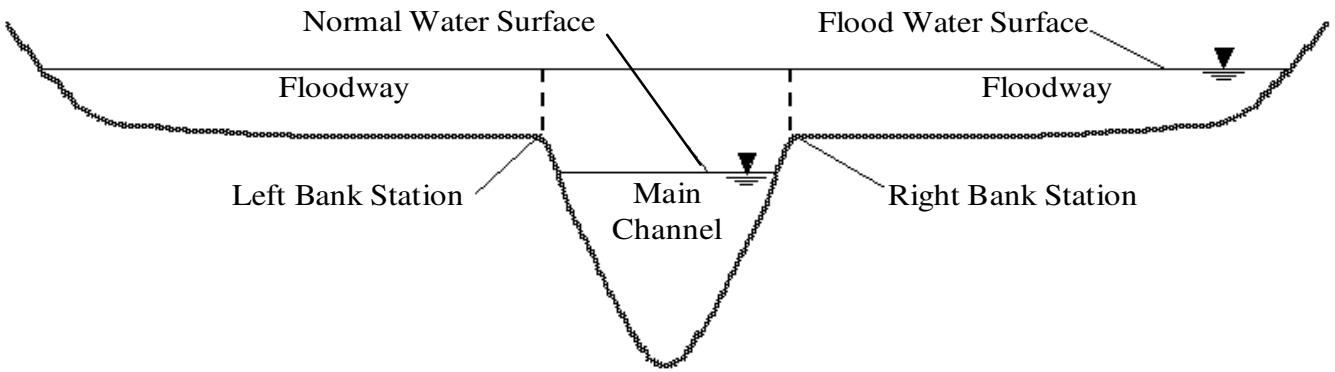


Hec-Ras model – Basin W - Grand River North West (GRNW).

2) Integrated Hydrologic & Hydraulic analysis

At each cross-section, several geometry parameters are required to describe shape, elevation, and relative location along the stream:

- River station (cross-section) number
- Lateral and elevation coordinates for each terrain point
- Left and right bank station locations
- Reach lengths between adjacent cross-sections
- *Manning's* roughness coefficients
- Channel contraction and expansion coefficients
- Geometric description of any hydraulic structures (bridges, culverts, weirs, etc.)

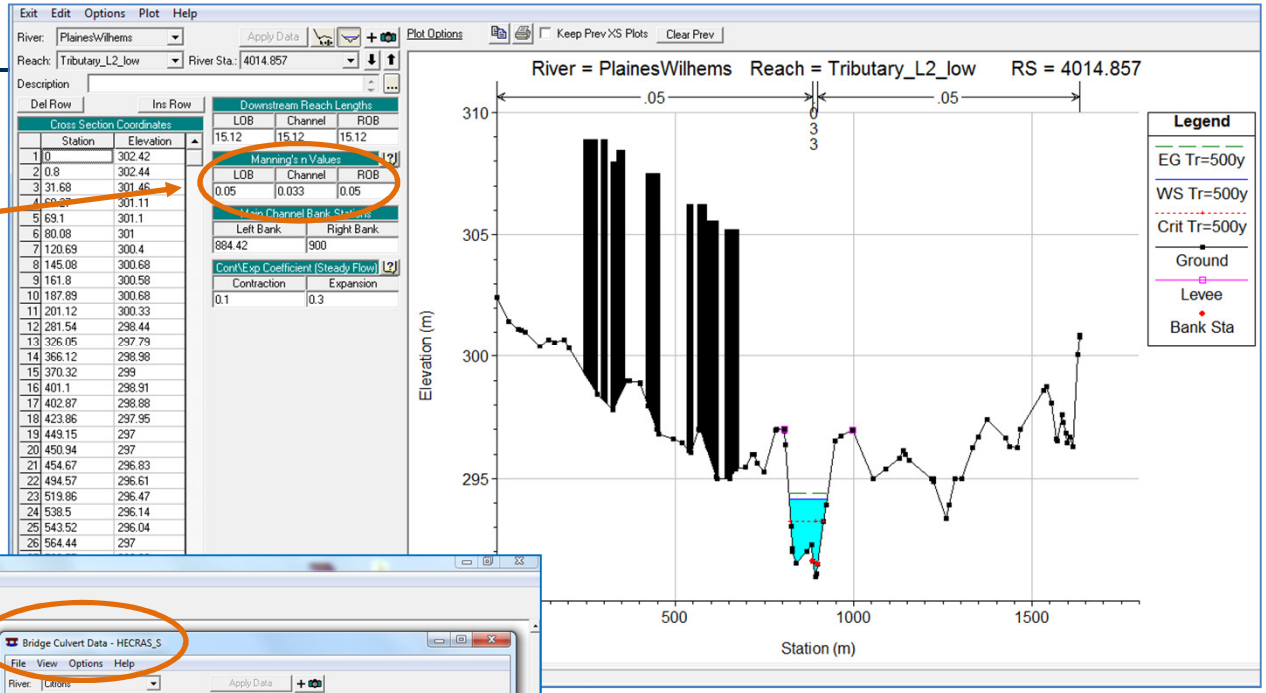


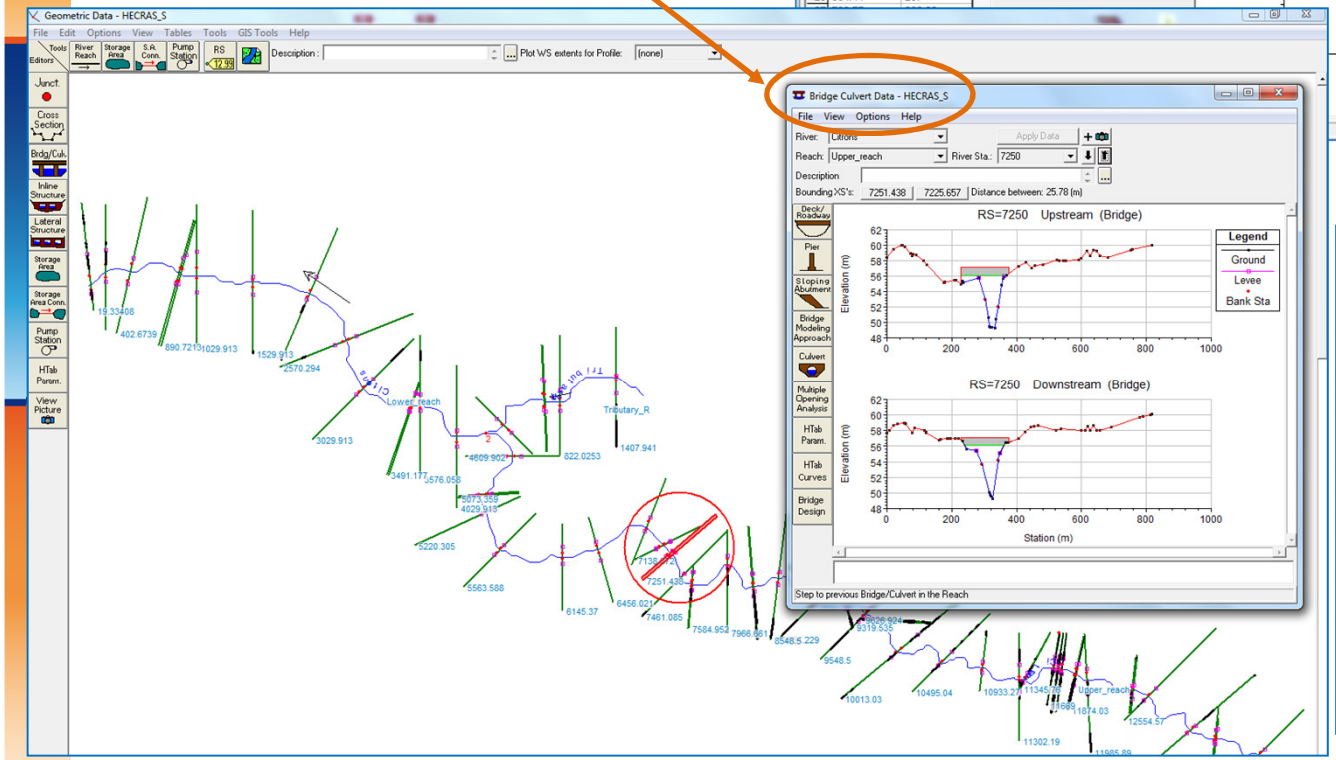
2) Integrated Hydrologic & Hydraulic analysis

HEC-RAS Graphical Interface

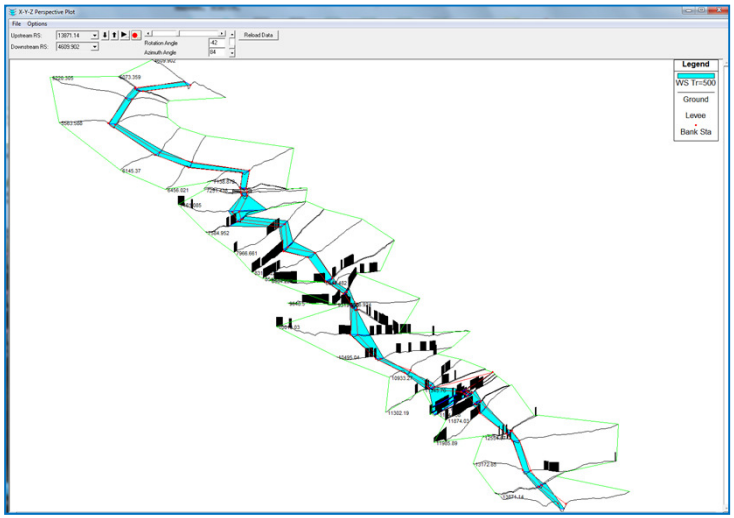
Manning's value: coefficient to evaluate energy losses

The effects of hydraulic structures such as bridges, culverts or dams may be considered in the computation



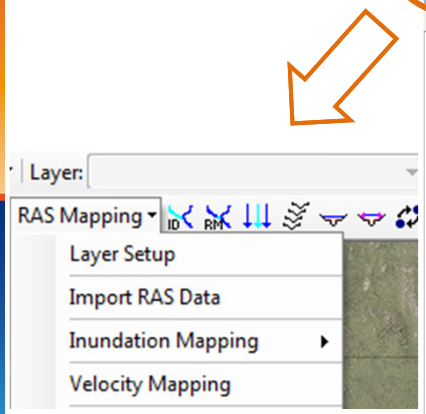


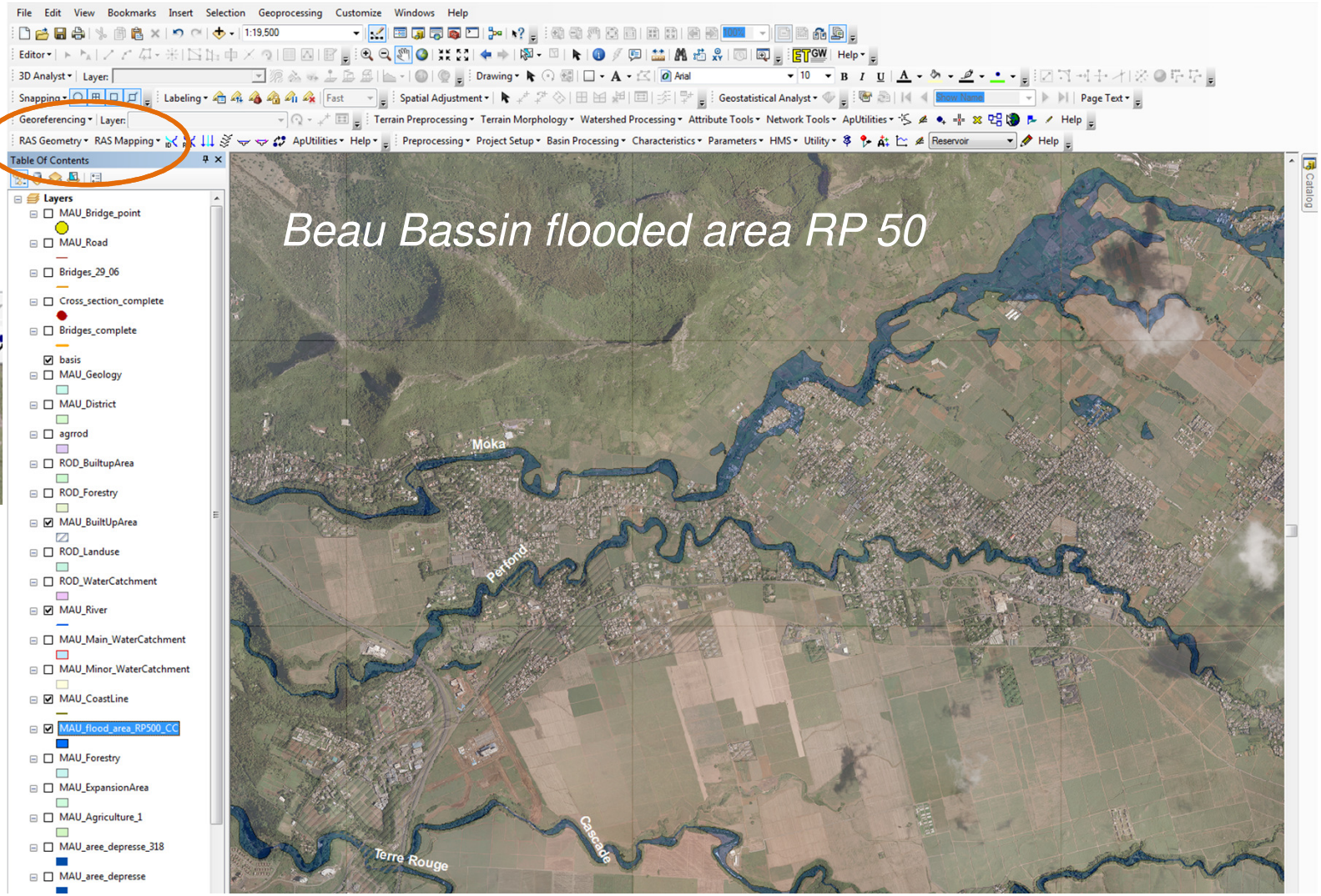
Citrons river – 3D hydraulic profile (RP500)



3) Flood hazard mapping

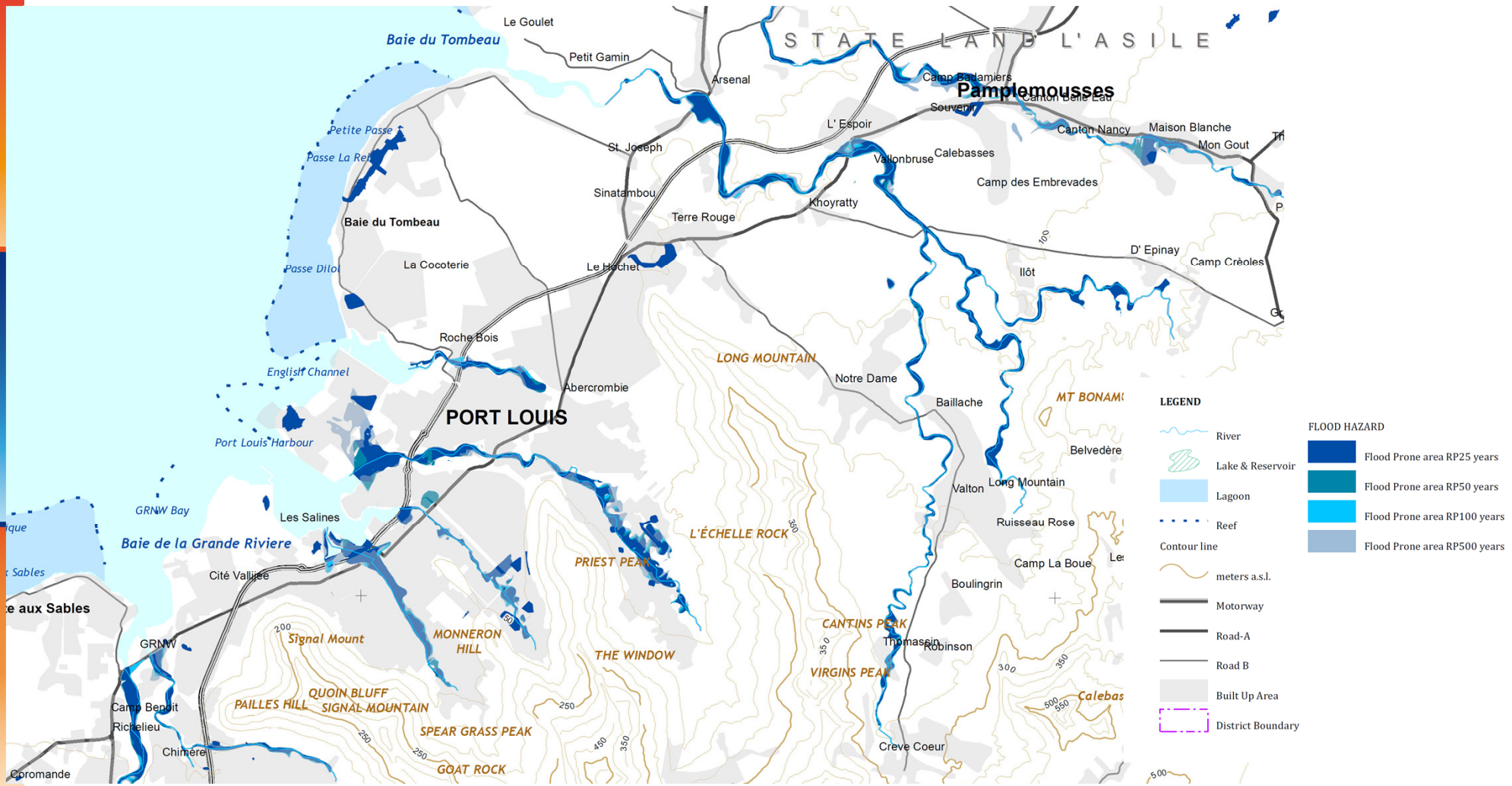
ArcGIS → Hec-RAS → ArcGIS–HecGeorasPost processing





3) Flood hazard mapping

FLOOD HAZARD LEVEL	
Return Period of flood Event	**Scenario**
25 years	Floods with a high probability
50 years	Floods with a medium probability
100 years	Floods with a low probability
500 years	Extreme event



3) Flood hazard mapping

FLOOD HAZARD LEVEL	
Return Period of flood Event	**Scenario**
25 years	Floods with a high probability
50 years	Floods with a medium probability
100 years	Floods with a low probability
500 years	Extreme event

3) Flood hazard mapping

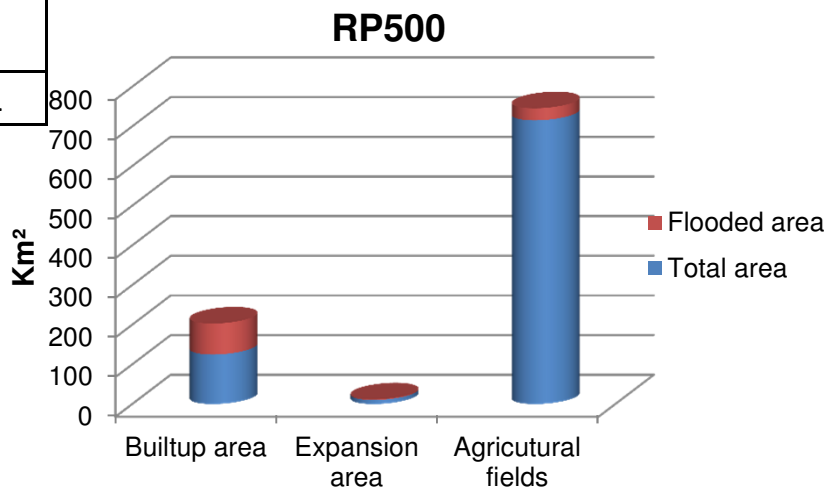
The impact of the flood hazard on the land use in Mauritius island

LANDUSE	RP 25		RP 50		RP 100		RP 500	
	%	km²	%	km²	%	km²	%	km²
Built up area	20%	5.1	19%	5.8	20%	6.6	71%	78.1
Expansion area	4%	1.0	3%	1.0	4%	1.4	1%	1.6
Agricutural fields	76%	19.2	78%	24.0	76%	24.9	28%	30.4
TOTAL		**25.3**		**30.9**		**32.9**		**110.1**

The percentage value was referred to the total extension of flooded area

Total flooded area

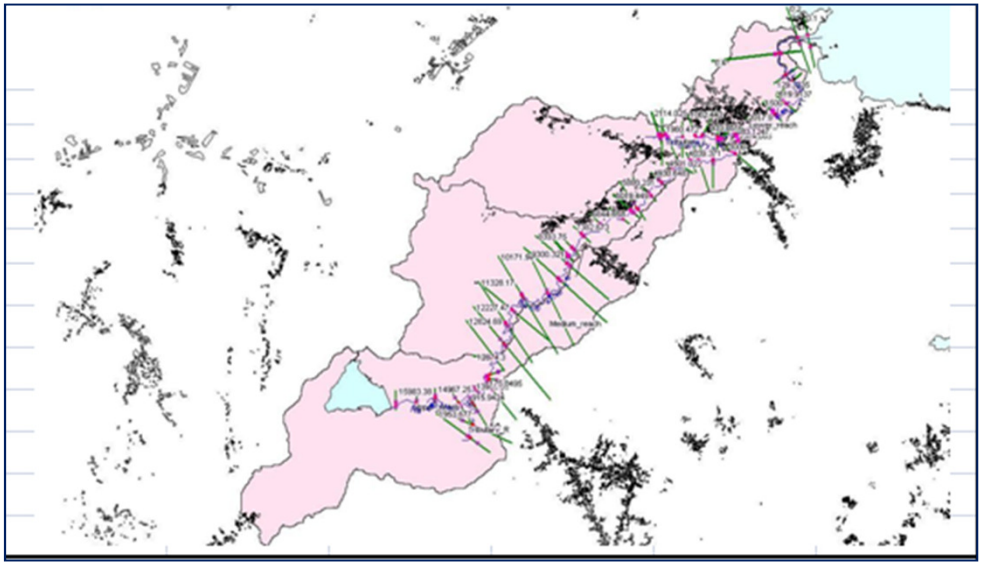
LANDUSE	RP 25		RP 50		RP 100		RP 500	
	%	km	%	km	%	km	%	km
Motorway	3%	2.4	2%	3	3%	3	2%	3
Main road	20%	18	19%	20	20%	24	20%	29
Secondary road	77%	68	78%	80	77%	90	77%	109
TOTAL		**88**		**103**		**117**		**141**



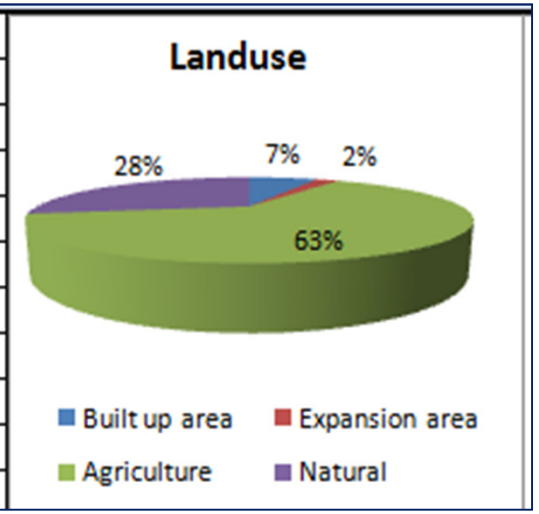
3) Flood hazard mapping

Statistical results of Basin A (ANNEX 6)

- Extension of different land use studied categories and infrastructures
- Percentage of land use categories in basin area



Landuse	%	km²
Built up area	7%	2.84
Expansion area	2%	0.93
Agriculture	63%	26.65
Natural	28%	11.74
		42.15
Road	**%**	**km**
Motorway	0%	-
Primary	33%	25.86
Secondary	67%	53.62
		79.48



3) Flood hazard mapping

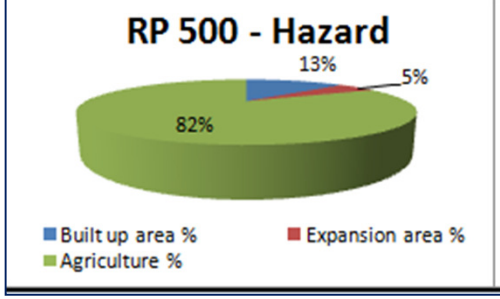
Statistical results of Basin A (ANNEX 11)

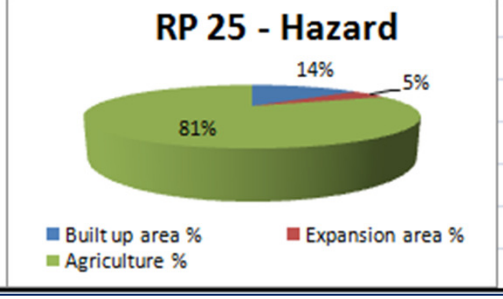
- Extension of total flooded area in basin A
- Extension of flooded area divided for different land use

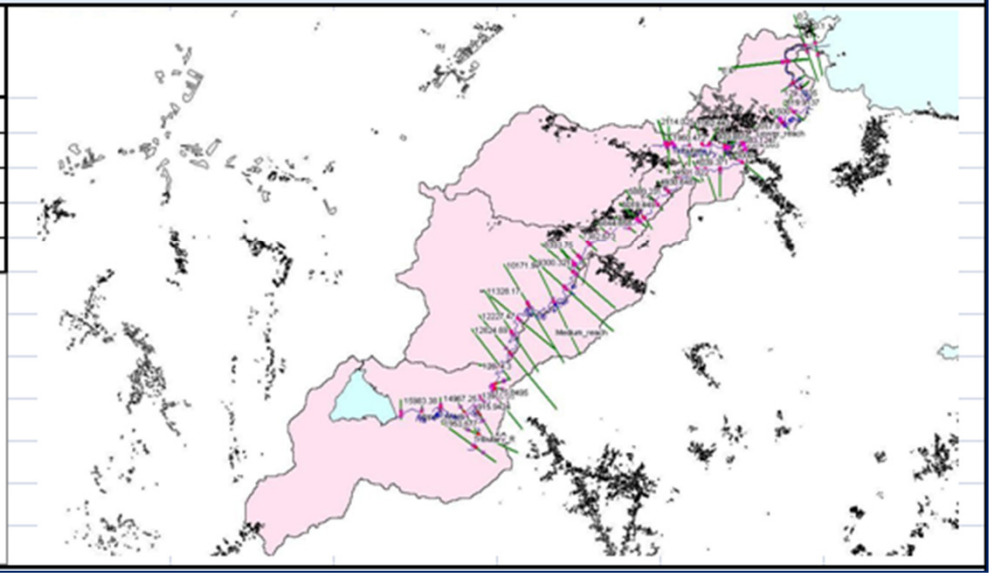
BASIN A - Du Rempart North

HAZARD

RP	Q [m³/s]	Total flood area [m²]	Flooded built up area [m²]	Flooded expansion area [m²]	Flooded agriculture [m²]
RP 500	359	1,500,372	194,888	71,931	1,233,554
RP 100	221	1,402,421	186,628	64,694	1,151,100
RP 50	157	1,270,907	181,753	56,872	1,032,282
RP 25	103	1,223,405	176,866	57,592	988,947
Lowlands	-	409,065	14,070	0	394,996







Thank you for your attention