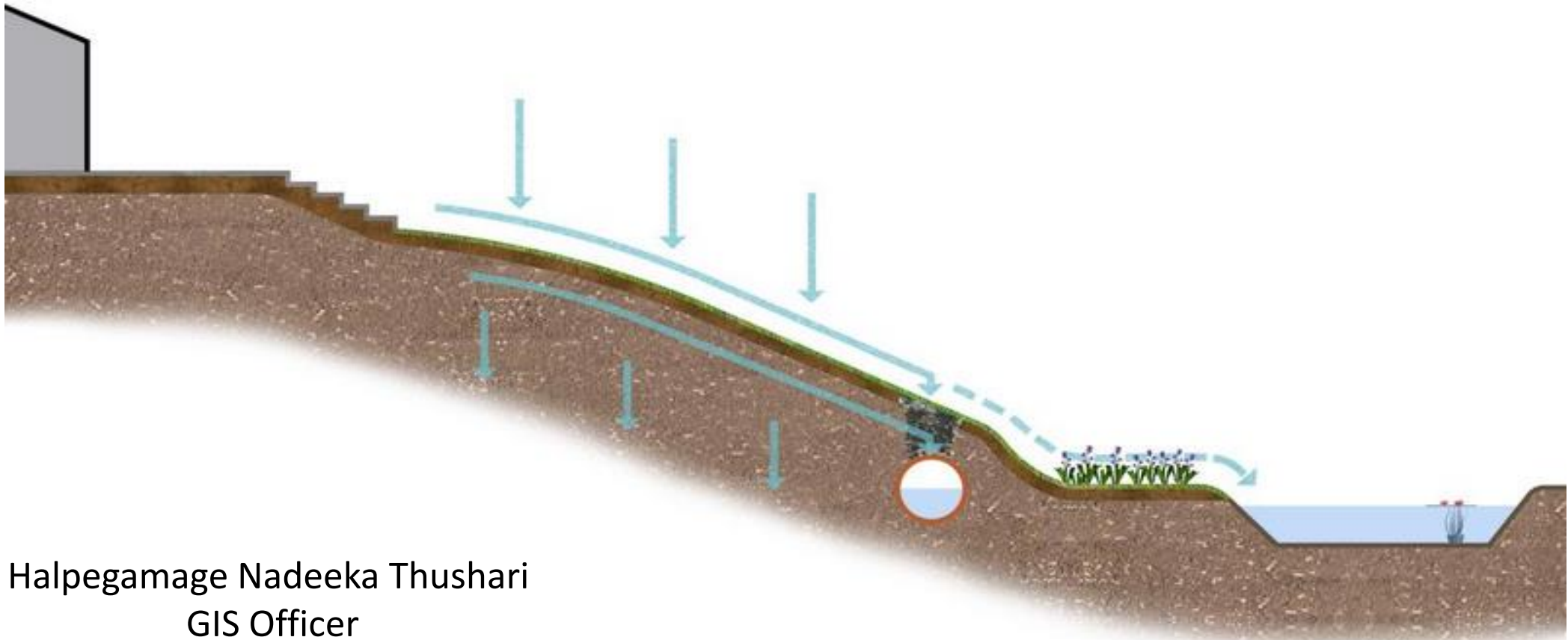


ESTIMATING PROBABLE PEAK RUNOFF FOR GREATER COLOMBO RIVER BASIN – SRI LANKA



Halpegamage Nadeeka Thushari
GIS Officer
Urban Development Authority
Sri Lanka

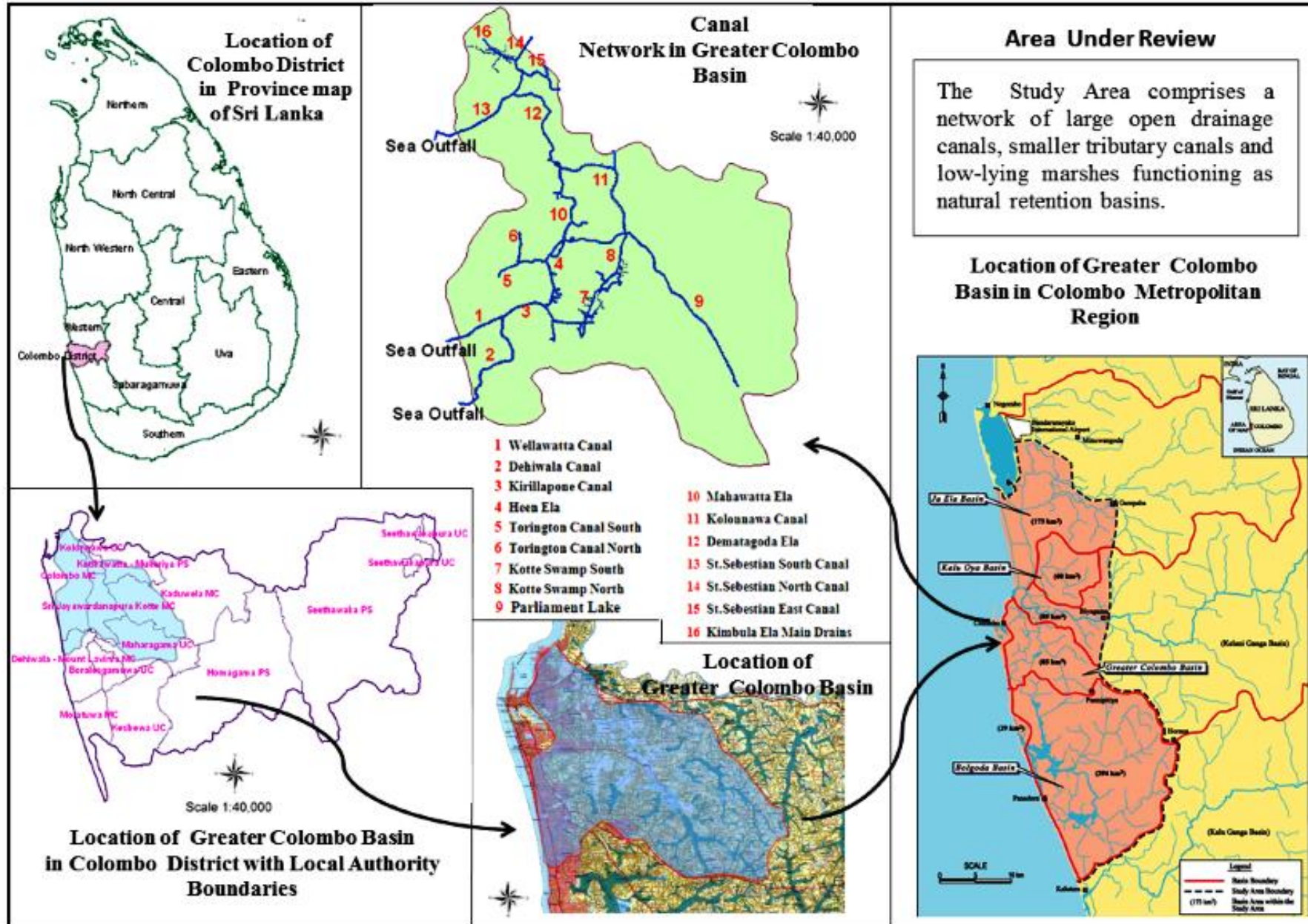
INTRODUCTION

Rainfall Excess =

Total Rainfall – (rain stored on land surface + rain infiltrated into underlying soil)

Rainfall excess = Peak Runoff = Peak Discharge

AREA UNDER REVIEW



OBJECTIVES

Main Objective

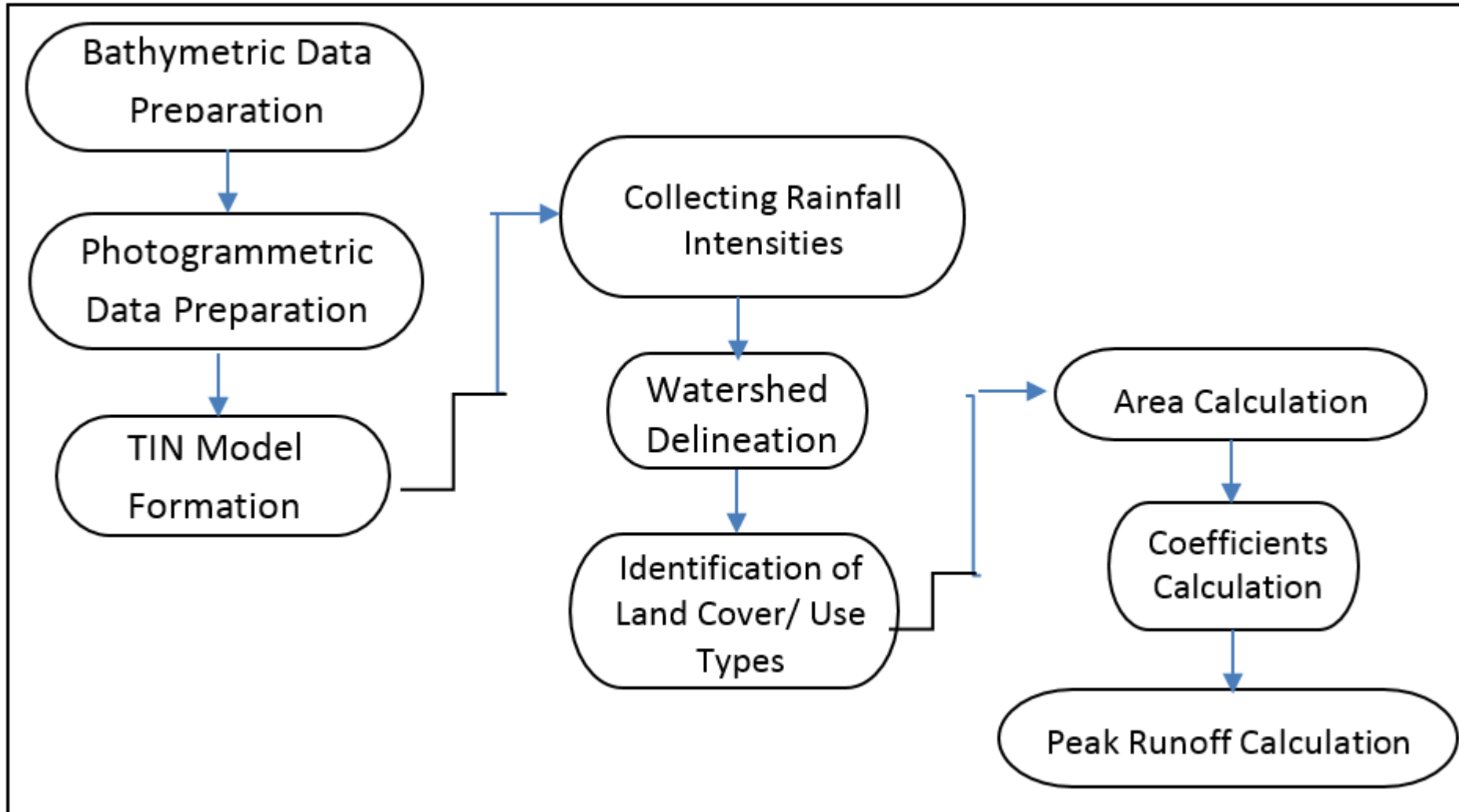
- To quantify the Peak Runoff

Other Objectives

To reach the above goal, followings should be received

- TIN Model Formation
 - Verifying Photogrammetric Data
 - Processing Bathymetric Data
- Watersheds Delineation
- Land Cover Types Identification

BASIC PROCESS



FORMULA USED

$$Q = c.i.A/360$$

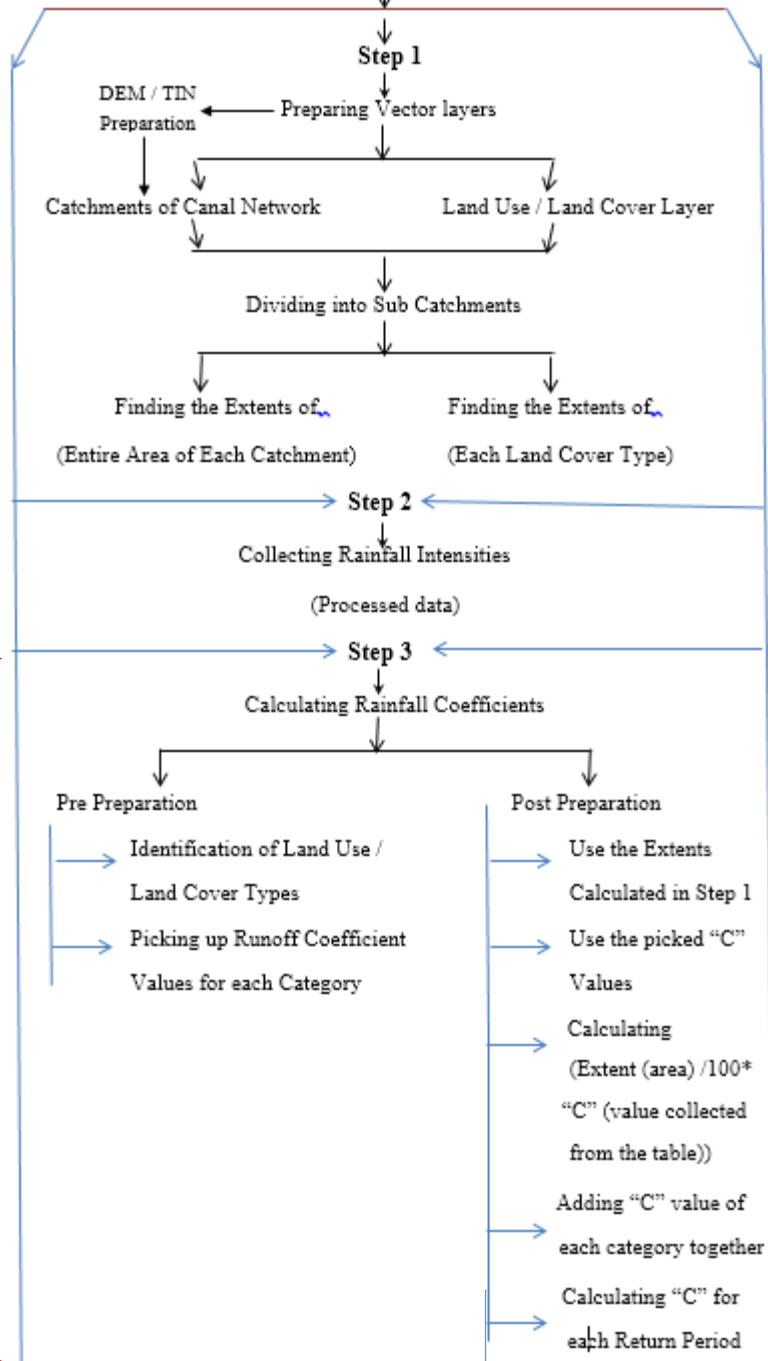
- Q (m³/s): peak discharge flow.
- c (a dimensional): runoff coefficient. It varies with the storm's return period, ground cover, and the uses of the land.
- i(mm/h): rainfall intensity.
- A (há.): drainage area.
- 360 is the coefficient that permits work with the different units in the SI System. To work in other unit system you have to do the conversions.

METHODOLOGY

Finding A

Finding i

Finding C

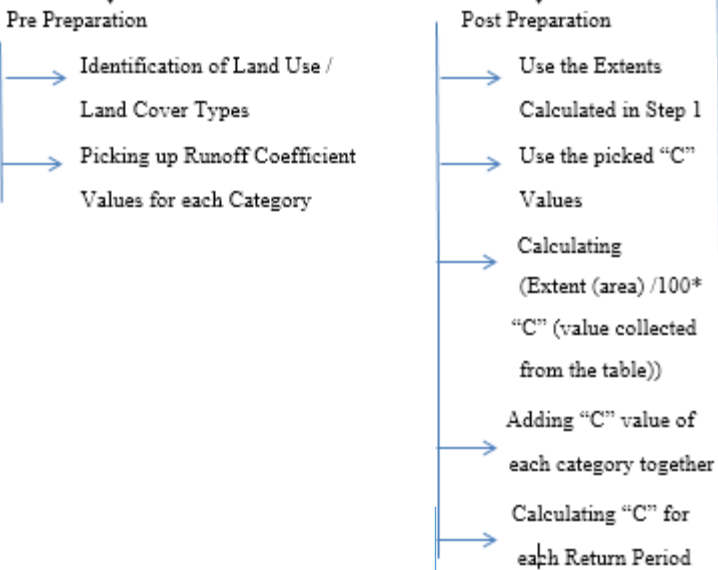


Step 2

Collecting Rainfall Intensities
(Processed data)

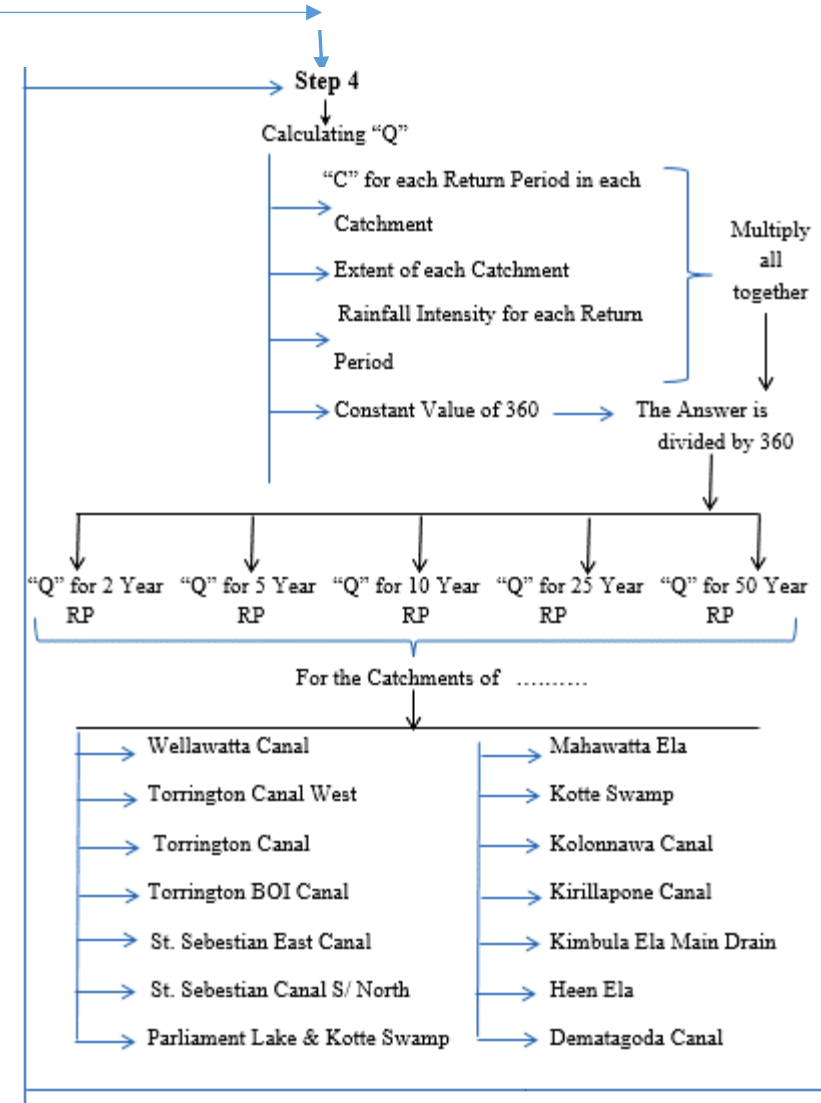
Step 3

Calculating Rainfall Coefficients



Solving Q

Results

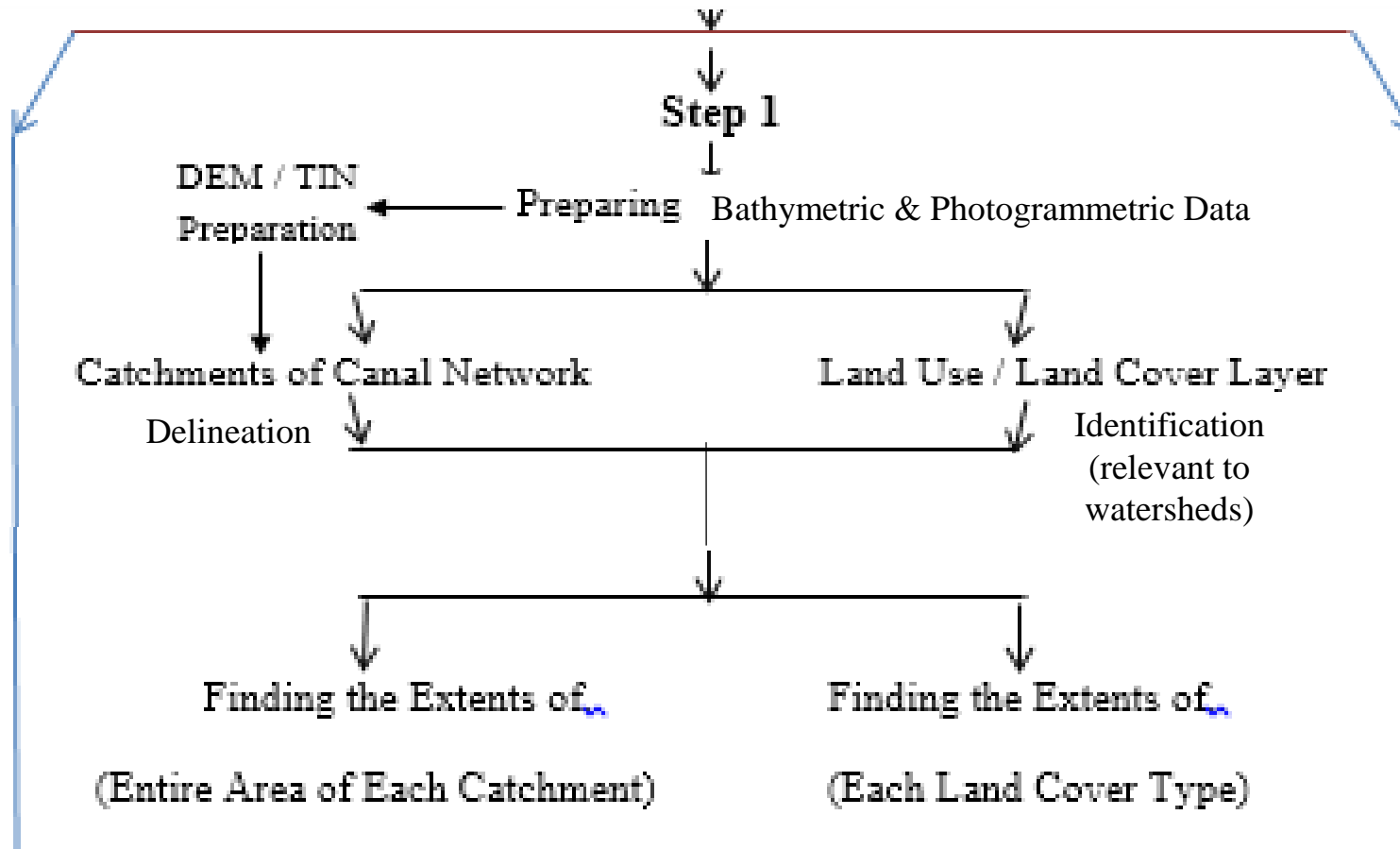


DATA USED

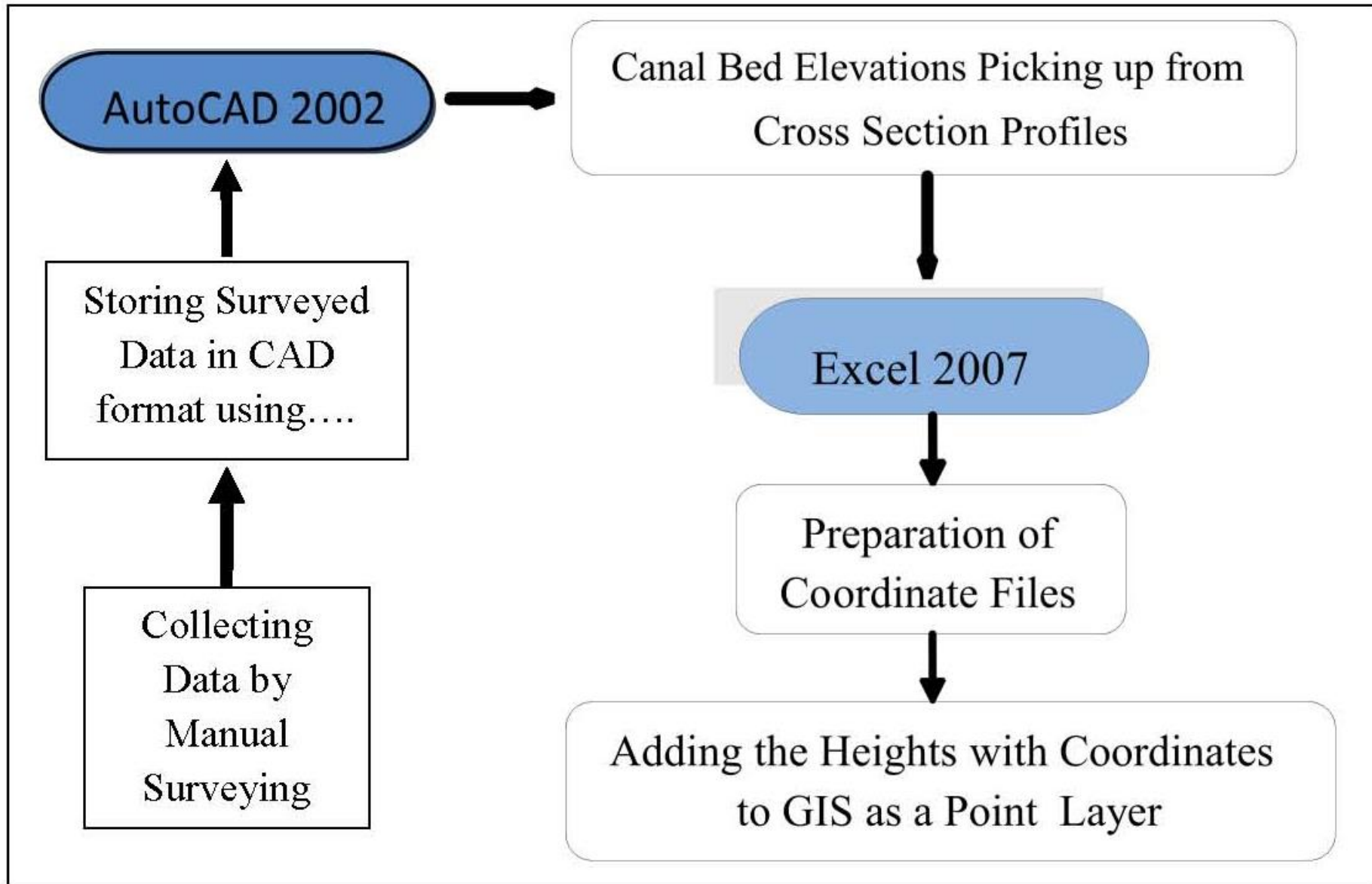
Study Depends On The Manually Collected Bathymetric Data & Processed Secondary Data

- Tabular Data
 - Bathymetric Data
 - Rainfall Intensities
- Spatial Data
 - Spot Heights
 - Contours
 - Boundary
 - Land Cover Types

* Finding “A” for Solving the Equation...

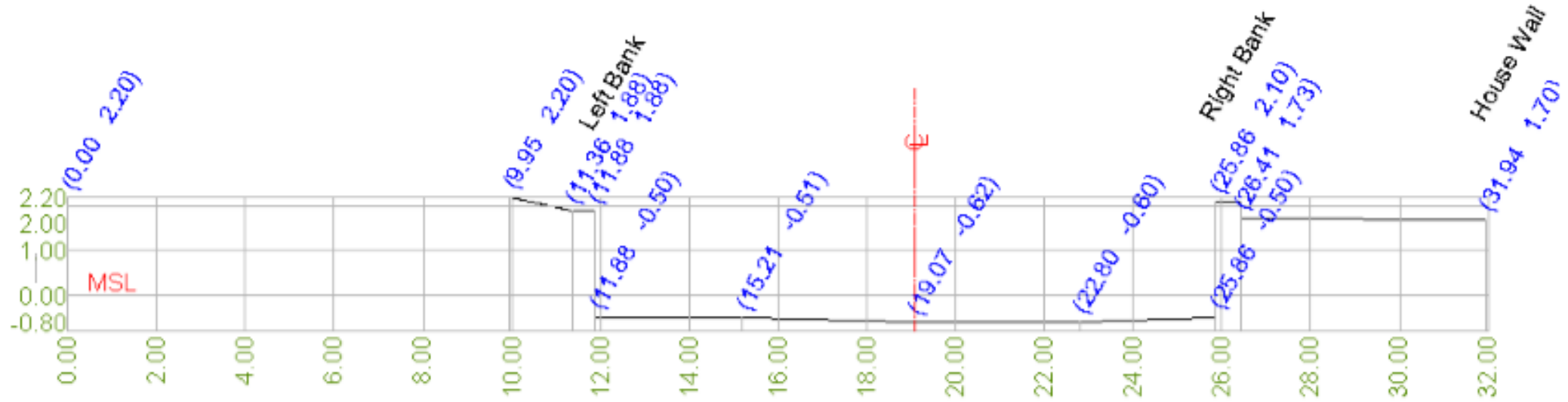


Processing Canal Bed Values



One of the Measured Cross Sections in Dematagoda Canal

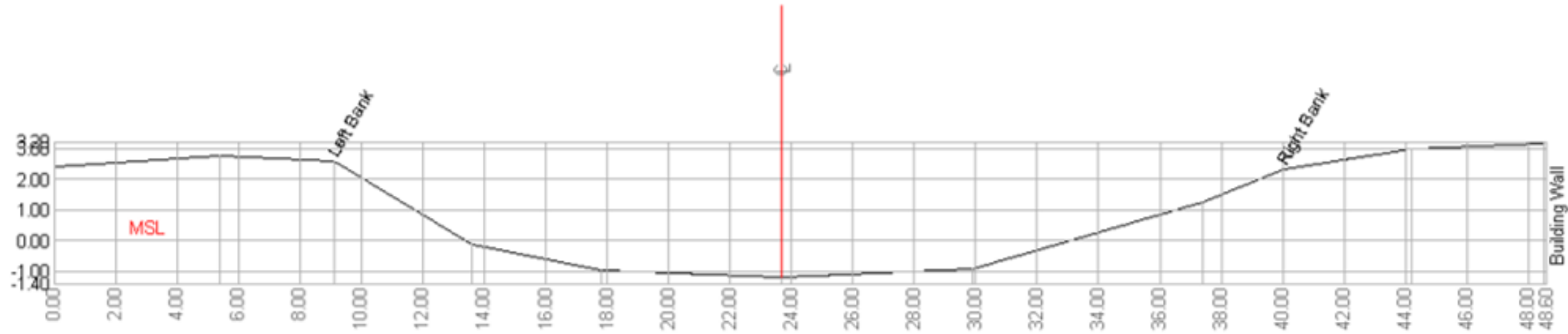
Profile DE-01 (CS - 0+000)



EXISTING GROUND LEVEL (m MSL)	2.20m	2.20m	1.88m	1.88m	-0.50m	-0.51m	-0.62m	-0.60m	-0.50m	2.10m	1.70m
DISTANCE	0.00m	9.95m	11.36m	11.88m	11.88m	15.21m	19.07m	22.80m	25.86m	26.41m	31.94m

A Closer View of One of the Profiles of Cross Sections for Heen Ela

Profile-H2 (CS - 0+027.1)



EXISTING GROUND LEVEL(m MSL)	2.39m	2.77m	2.57m	-0.11m	-0.96m	-1.20m	-0.95m	1.27m	2.29m	3.00m	3.14m
DISTANCE (m)	0.00m	5.40m	9.10m	13.60m	17.80m	23.70m	29.90m	37.40m	40.00m	44.20m	48.50m

Bathymetric Data Preparation

P1 Cs 0+000													
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
		Distance	Bearing				Distance	Coordinates					
Distance	Elevation	from Center	Degree	Minutes	Seconds	Distance	from Center	Latitudes	Departure	North	East	Elevation	Code
0.000	2.197	-19.070	351	18	3	351.3008333333	19.070	18.851	-2.884	493750.859	401064.996	2.20	cs0
9.950	2.2	-9.120	351	18	3	351.3008333333	9.120	9.015	-1.379	493741.023	401066.501	2.20	cs0
11.358	1.878	-7.712	351	18	3	351.3008333333	7.712	7.623	-1.166	493739.631	401066.714	1.88	cs0
11.876	1.878	-7.194	351	18	3	351.3008333333	7.194	7.111	-1.088	493739.119	401066.792	1.88	cs0
11.883	-0.504	-7.187	351	18	3	351.3008333333	7.187	7.104	-1.087	493739.112	401066.793	-0.50	cs0
15.206	-0.51	-3.864	351	18	3	351.3008333333	3.864	3.819	-0.584	493735.827	401067.296	-0.51	cs0
19.071	-0.62	0.001	171	18	3	171.3008333333	0.001	-0.001	0.000	493732.008	401067.883	-0.62	cs0
22.799	-0.6	3.729	171	18	3	171.3008333333	3.729	-3.686	0.564	493728.322	401068.444	-0.60	cs0
25.862	-0.5	6.792	171	18	3	171.3008333333	6.792	-6.713	1.027	493725.295	401068.907	-0.50	cs0
25.862	2.101	6.792	171	18	3	171.3008333333	6.792	-6.714	1.027	493725.294	401068.907	2.10	cs0
26.412	2.101	7.342	171	18	3	171.3008333333	7.342	-7.258	1.110	493724.750	401068.990	2.10	cs0
26.412	1.73	7.342	171	18	3	171.3008333333	7.342	-7.258	1.111	493724.750	401068.991	1.73	cs0
31.937	1.7	12.867	171	18	3	171.3008333333	12.867	-12.719	1.946	493719.289	401069.826	1.70	cs0
P2 Cs 0+049													
0.000	2.079	-20.951	12	45	20	12.75555556	20.951	20.434	4.626	493777.192	401109.722	2.08	cs1
11.778	2.079	-9.173	12	45	20	12.75555556	9.173	8.946	2.025	493765.704	401107.121	2.08	cs1
11.978	4.464	-8.973	12	45	20	12.75555556	8.973	8.751	1.981	493765.509	401107.077	4.46	cs1
11.985	4.464	-8.966	12	45	20	12.75555556	8.966	8.744	1.980	493765.502	401107.076	4.46	cs1
12.339	1.9	-8.612	12	45	20	12.75555556	8.612	8.399	1.901	493765.157	401106.997	1.90	cs1
12.807	1.9	-8.144	12	45	20	12.75555556	8.144	7.943	1.798	493764.701	401106.894	1.90	cs1

Calculation of Co-ordinates for Cross Sections (Manually Collected Bathymetric Data) in Dematagoda Canal

GIS supportive format of .shp file preparation for Bathymetric Point Data

The image displays the 'Add XY Data' dialog box in ArcGIS, which is used to add coordinate data to a map. The dialog box is titled 'Add XY Data' and contains the following fields and options:

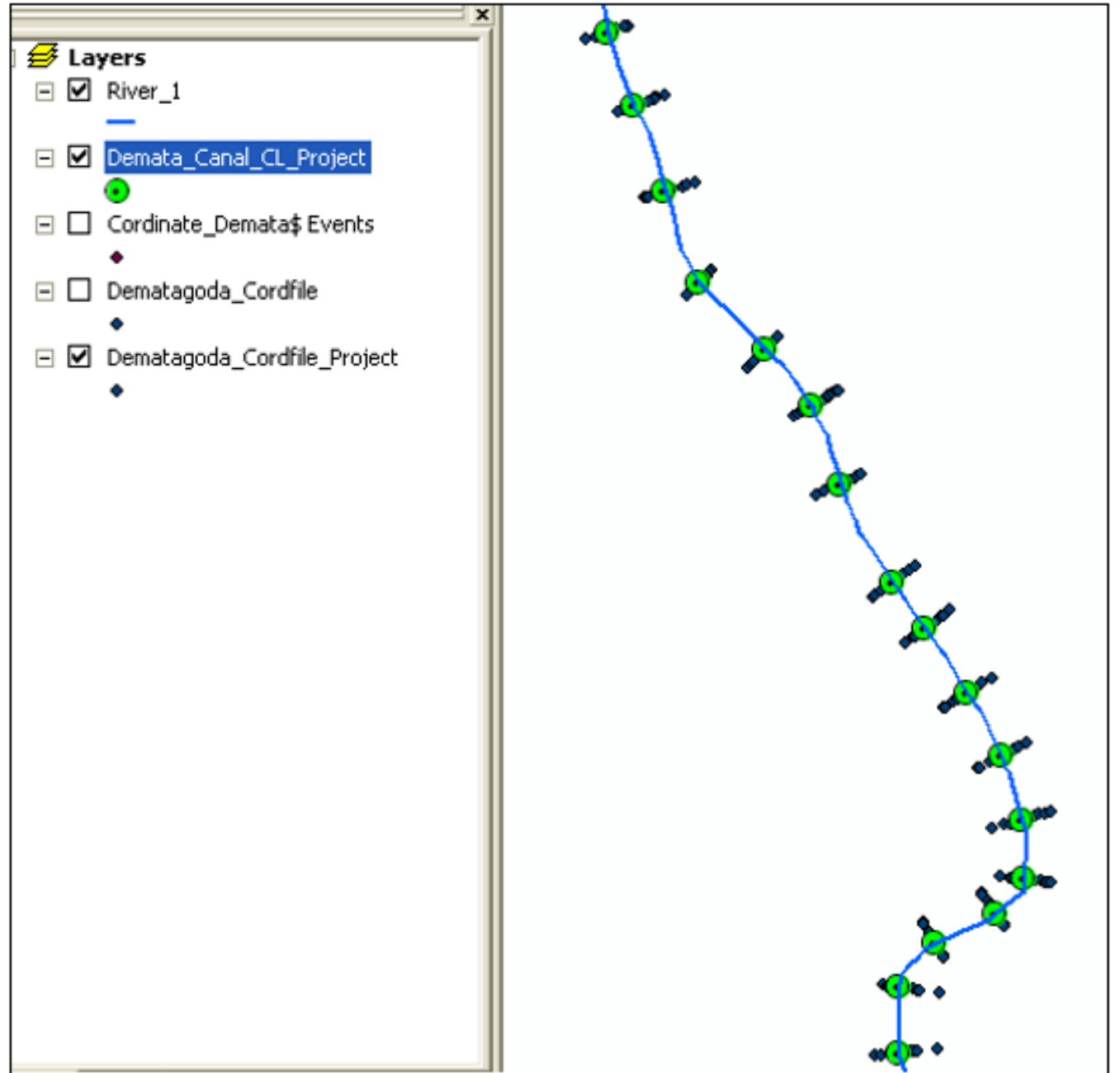
- Choose a table from the map or browse for another table:** A dropdown menu showing 'Cordinate_Demata\$'.
- Specify the fields for the X and Y coordinates:** Two dropdown menus. The 'X Field' is set to 'East' and the 'Y Field' is set to 'North'.
- Coordinate System of Input Coordinates:** A section with a 'Description' field containing 'Unknown Coordinate System' and an 'Edit...' button.
- Show Details
- Warn me if the resulting layer will have restricted functionality
- Buttons for 'OK' and 'Cancel'.

To the right of the dialog box is the 'Layers' panel, which shows a list of layers:

- River_1
- Cordinate_Demata\$ Events
- Dematagoda_Cordfile
- Dematagoda_Cordfile_Project

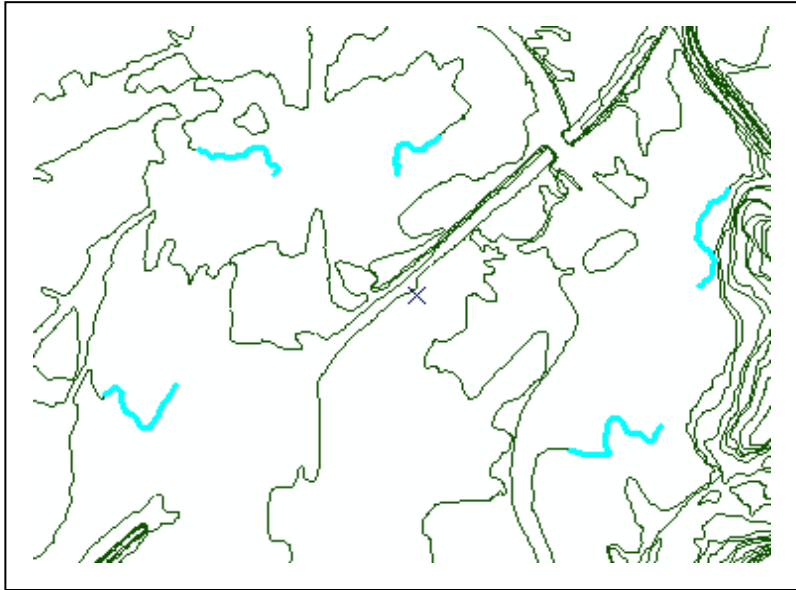
The map view on the right shows a blue line representing a river or channel, with numerous black dots representing bathymetric point data along its length.

Canal Line of Dematagoda Overlay over the Center point Coordinates of Measured Cross Sections



SPATIAL DATA

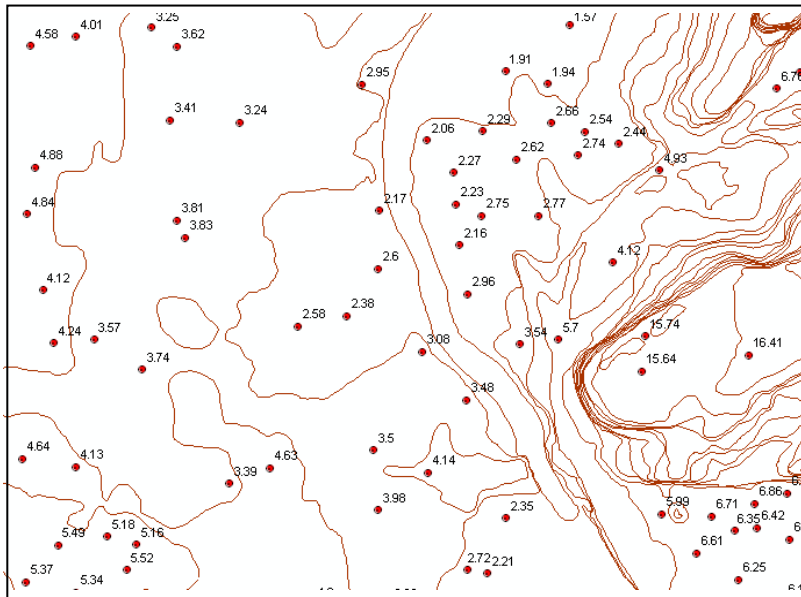
Verifying
Contours



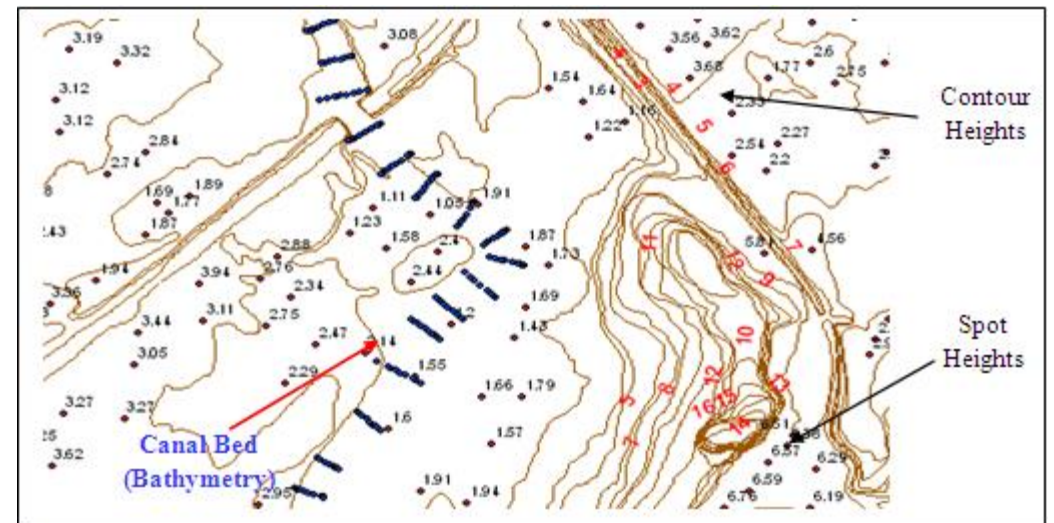
Verified
Contours



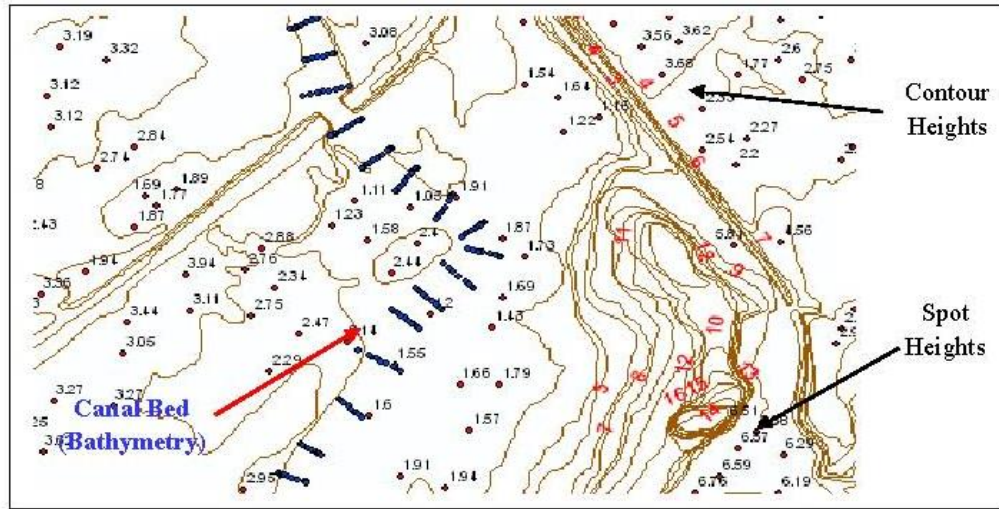
Verified Contours
with
Spot Heights



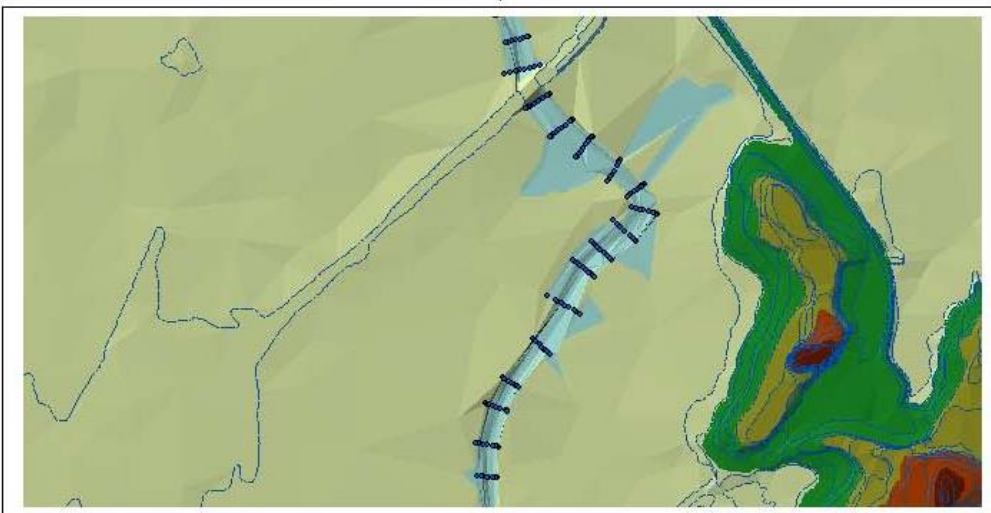
Verified Photogrammetric and Bathymetric data



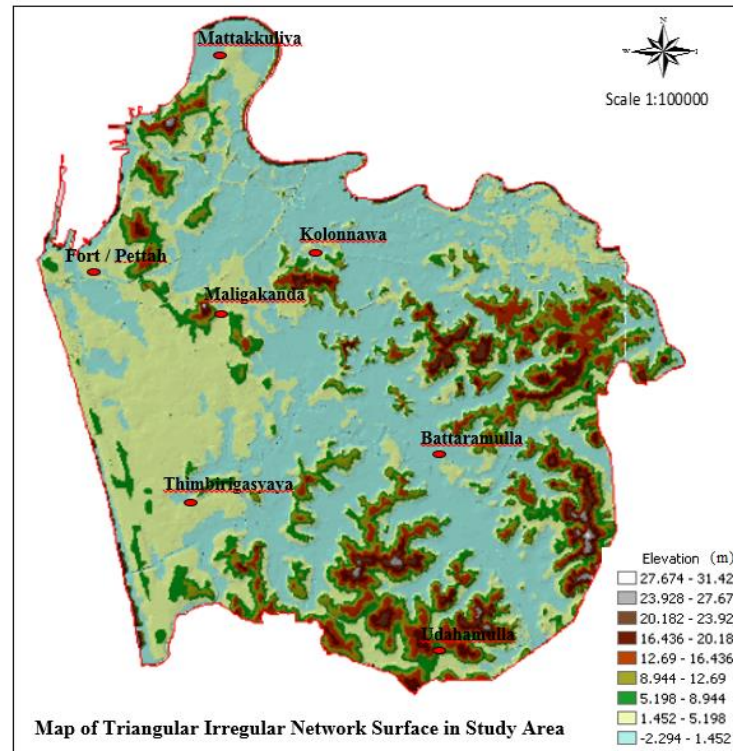
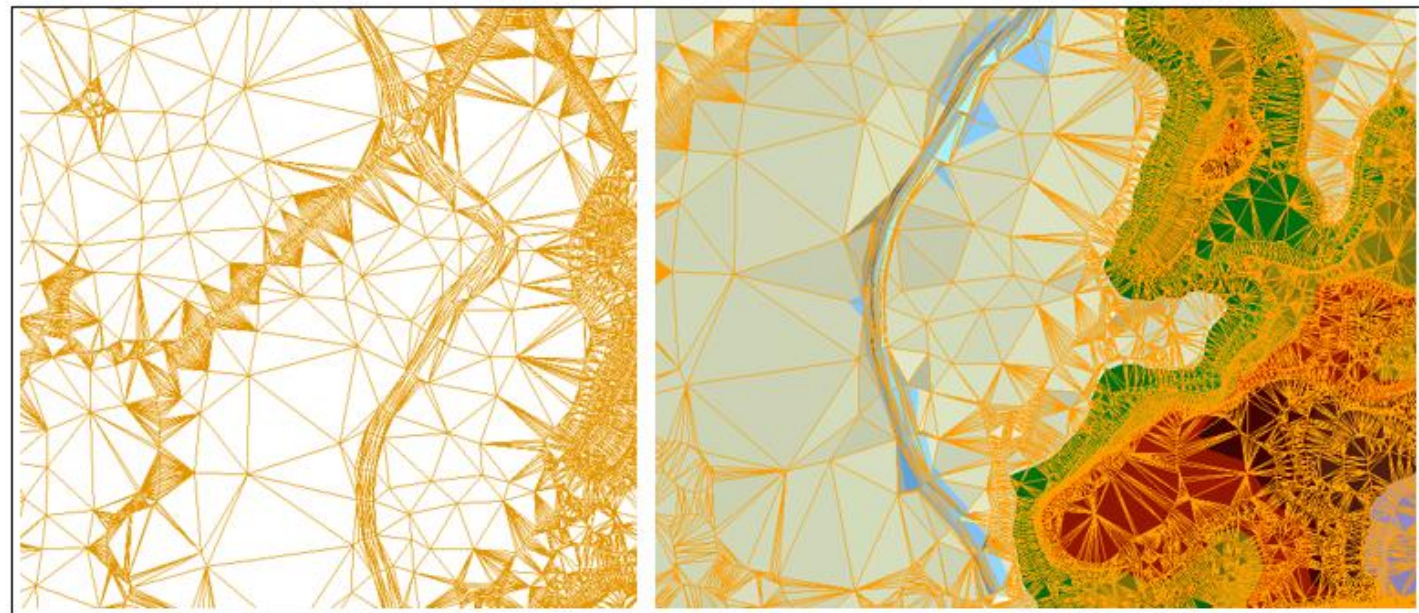
Combination of Bathymetric and Photogrammetric data in Preparation of TIN Model



a: Combined Bathymetric and Photogrammetric data



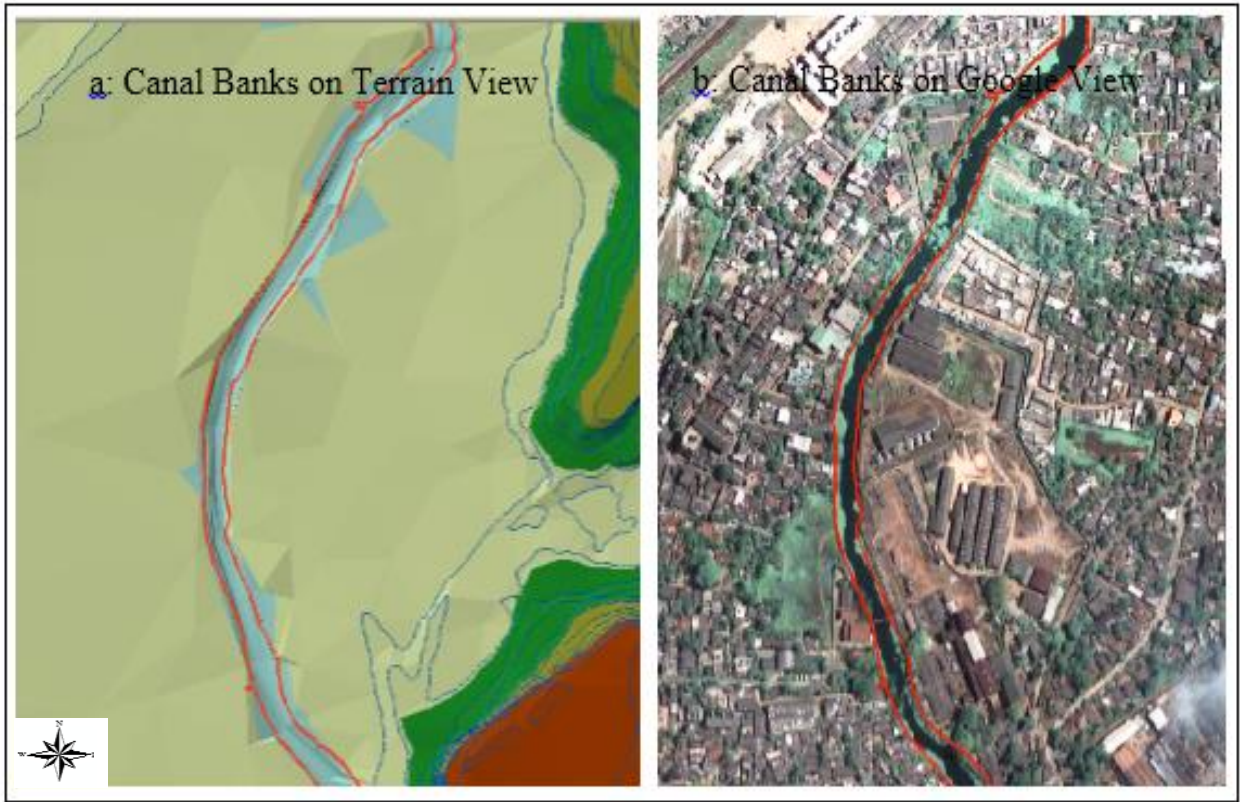
b: Output TIN Model



Map of Triangular Irregular Network Surface in Study Area

Triangulated Irregular Network Lines and Surface in a part of Study area

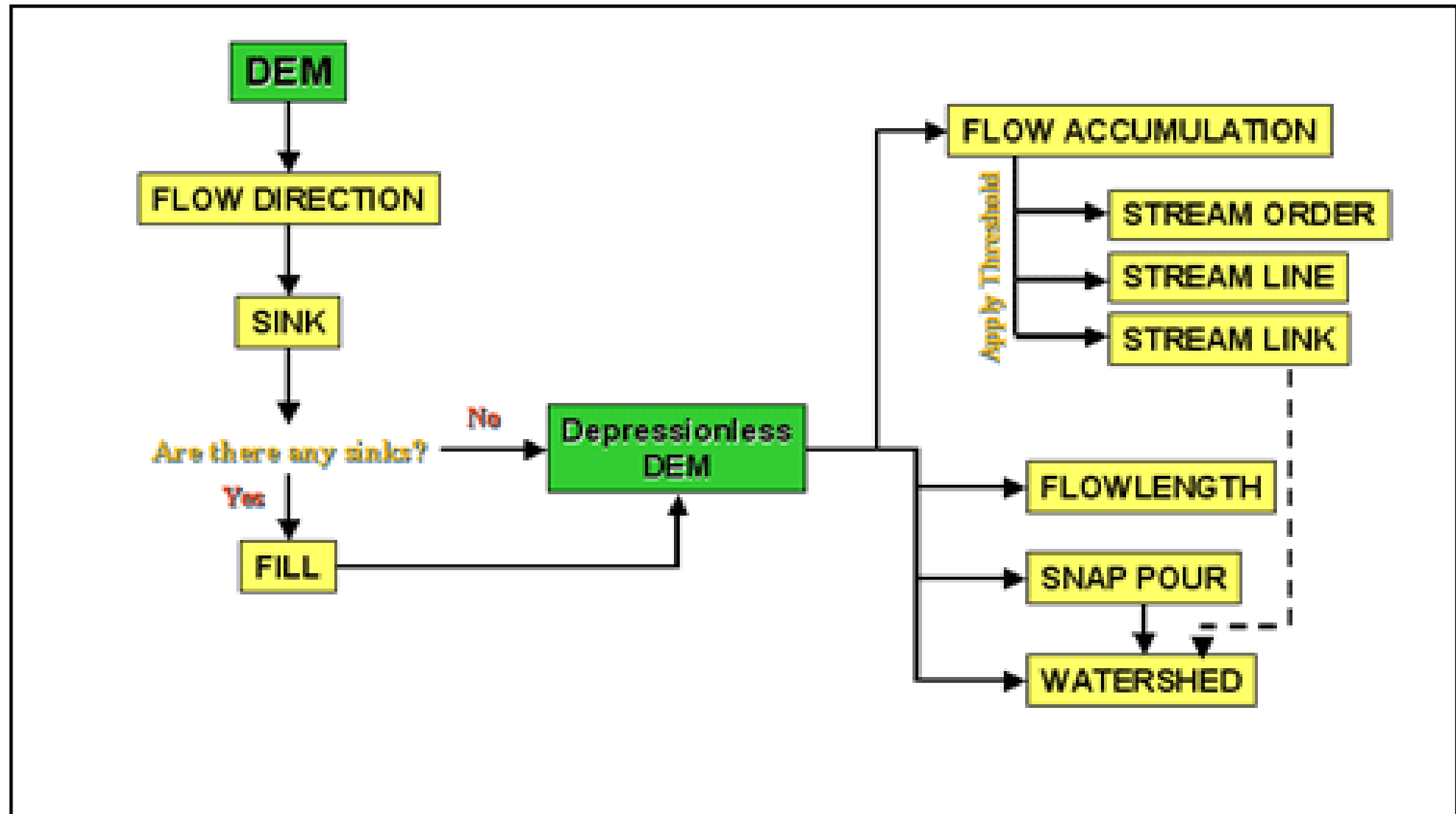
TIN Surface for the Entire Study Area



Part of Dematagoda Canal on Prepared TIN Surface

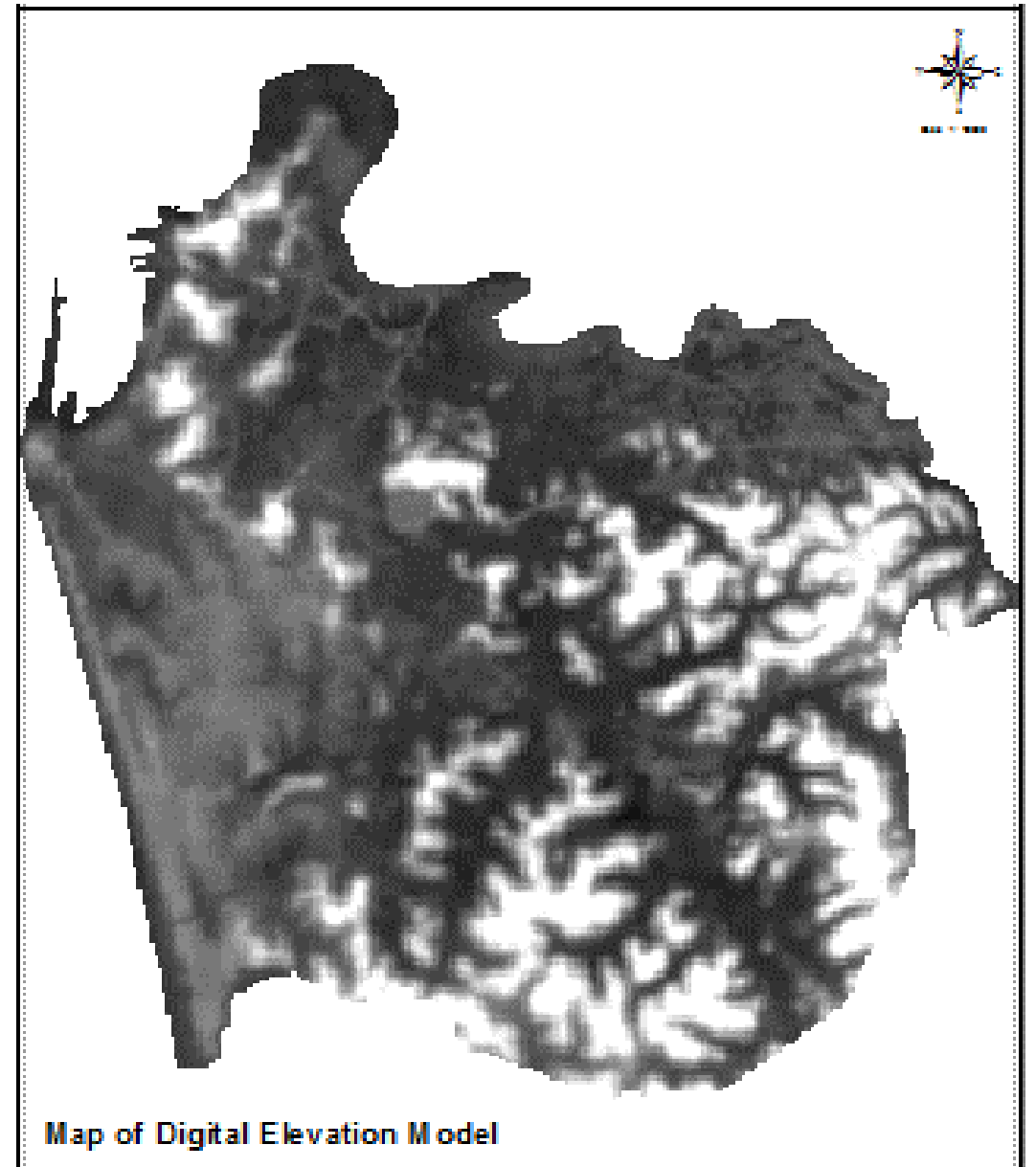
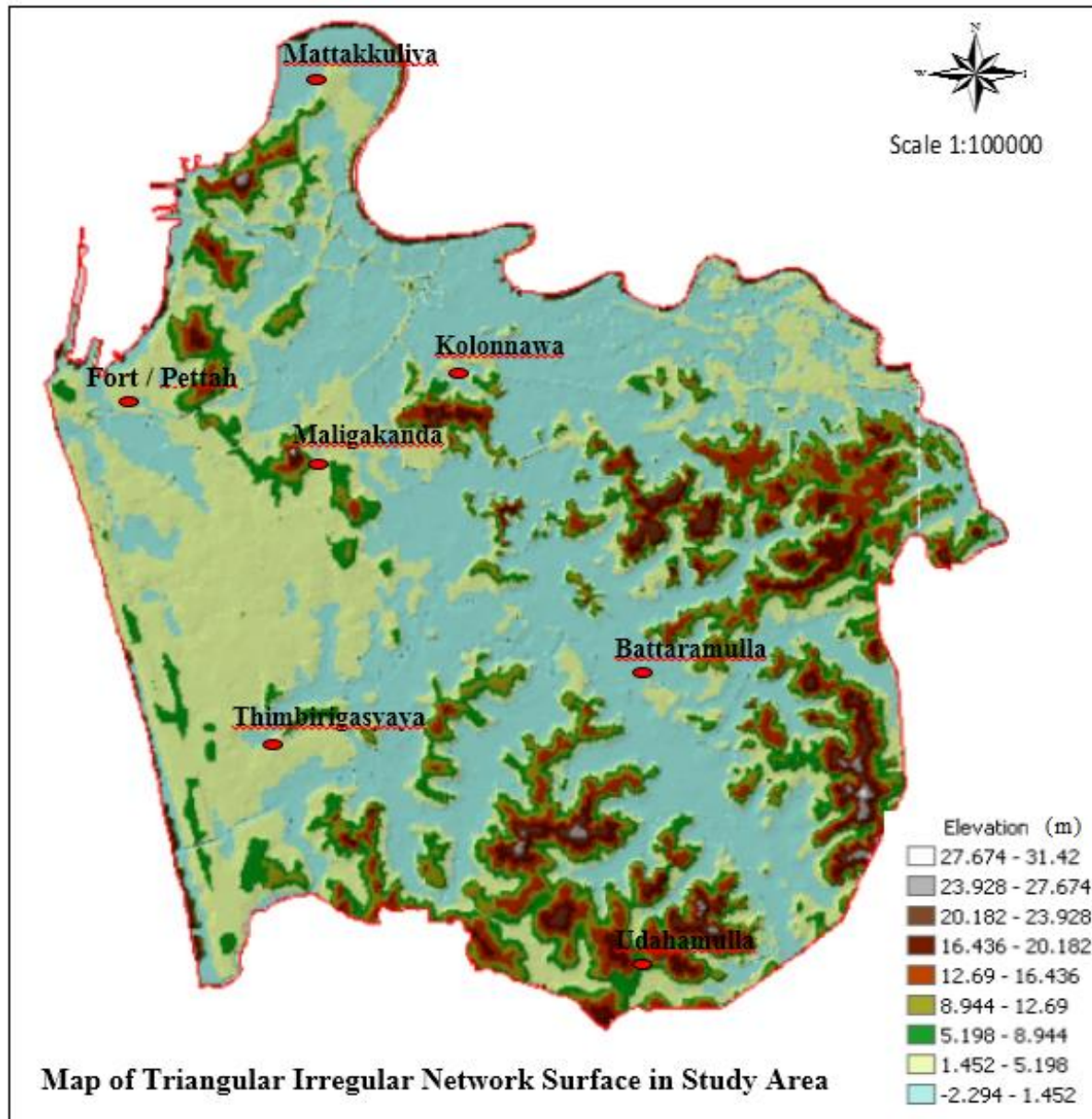


Process of Watersheds Delineation



Analysis

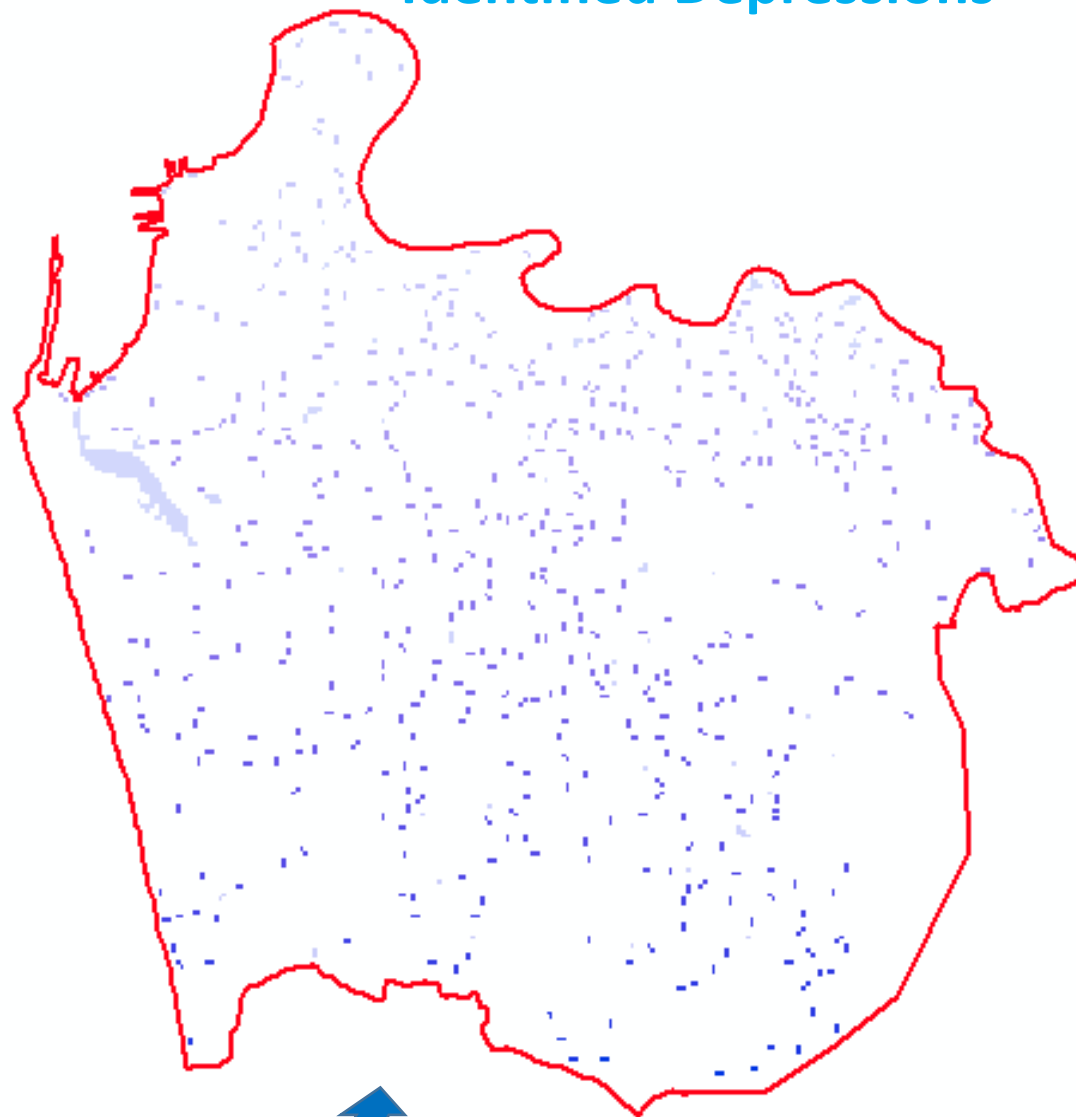
CONVERTING TIN TO A RASTER DEM



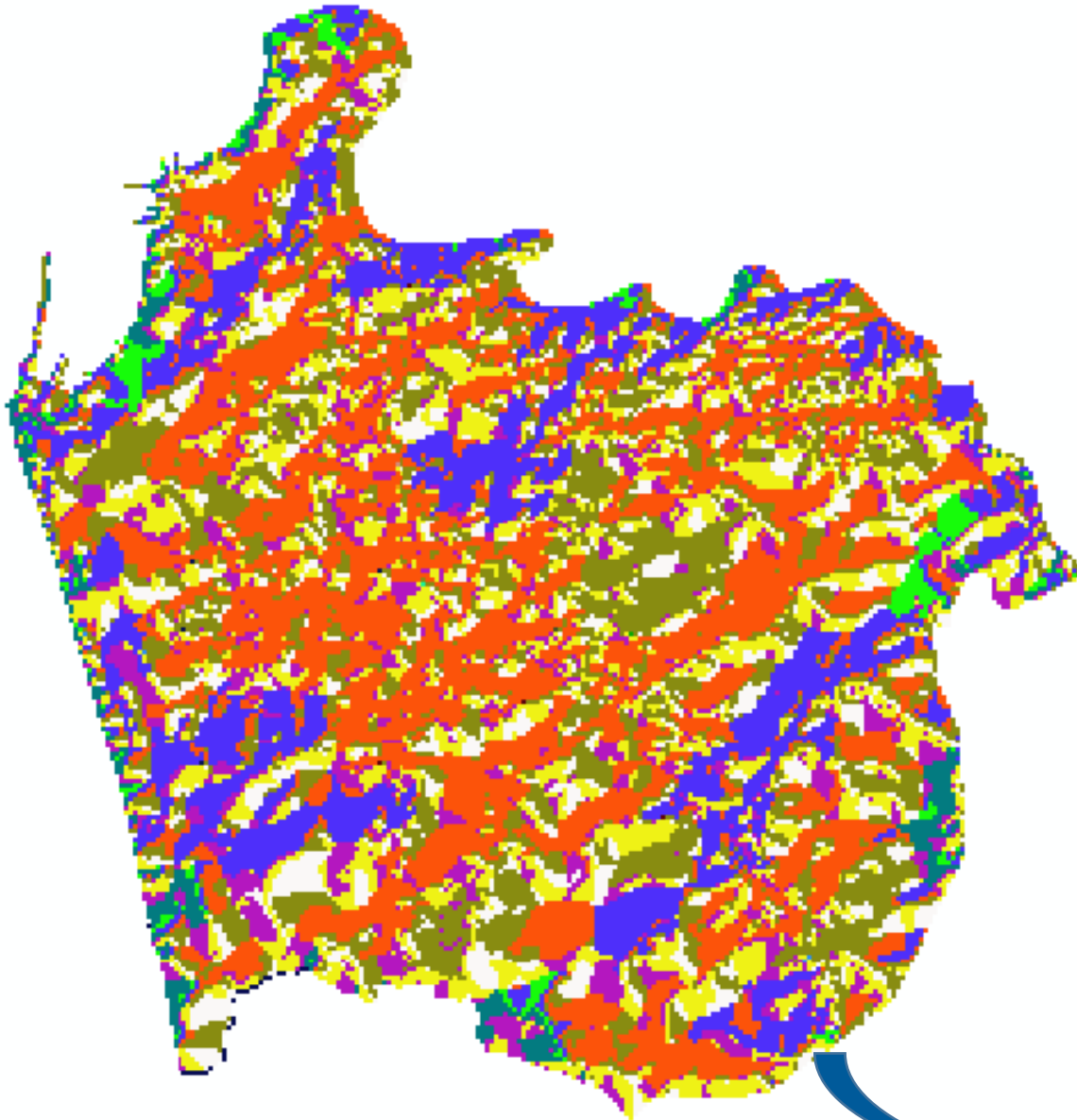
Flow Direction Raster



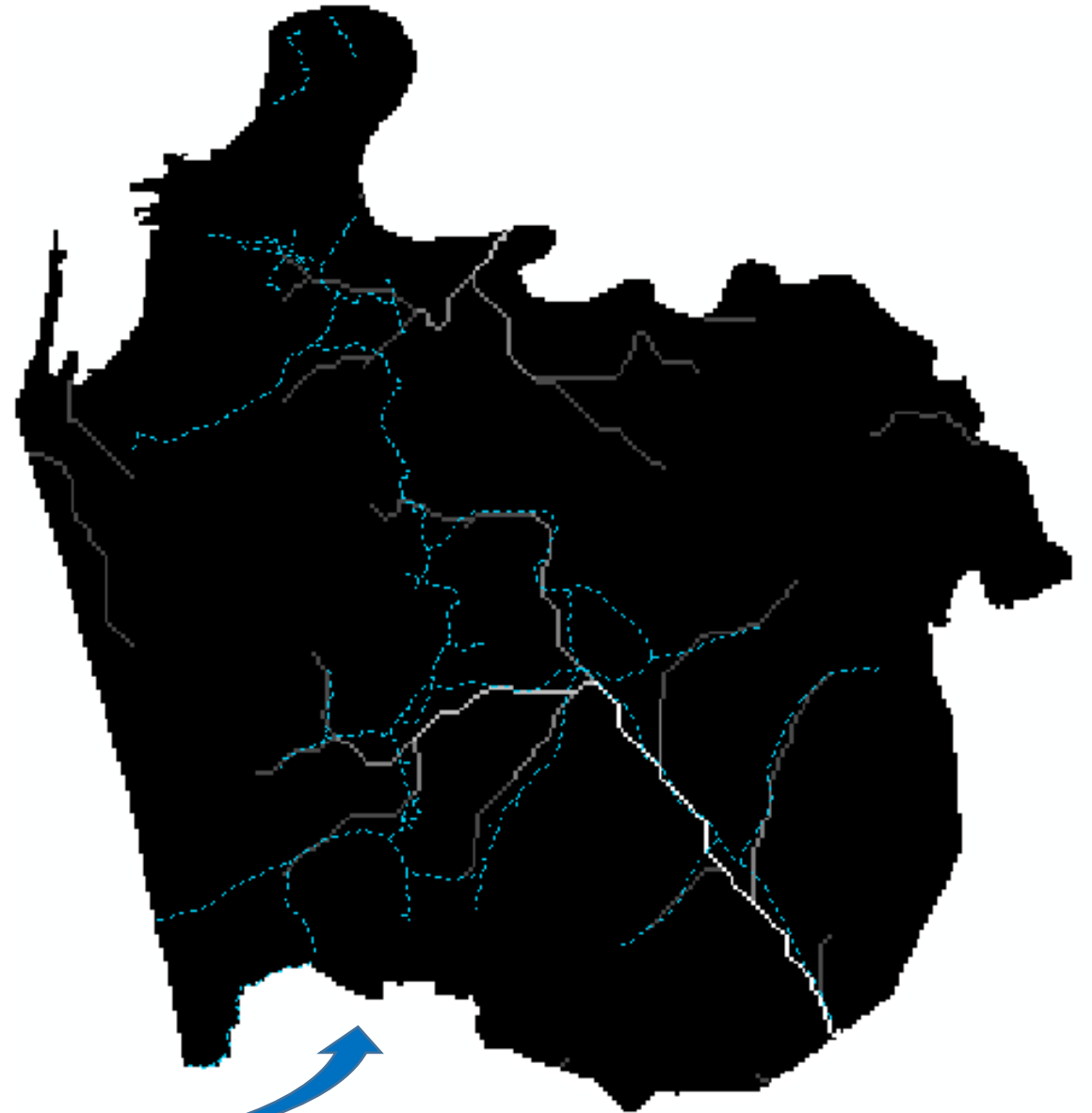
Identified Depressions



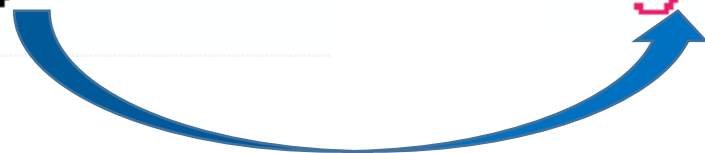
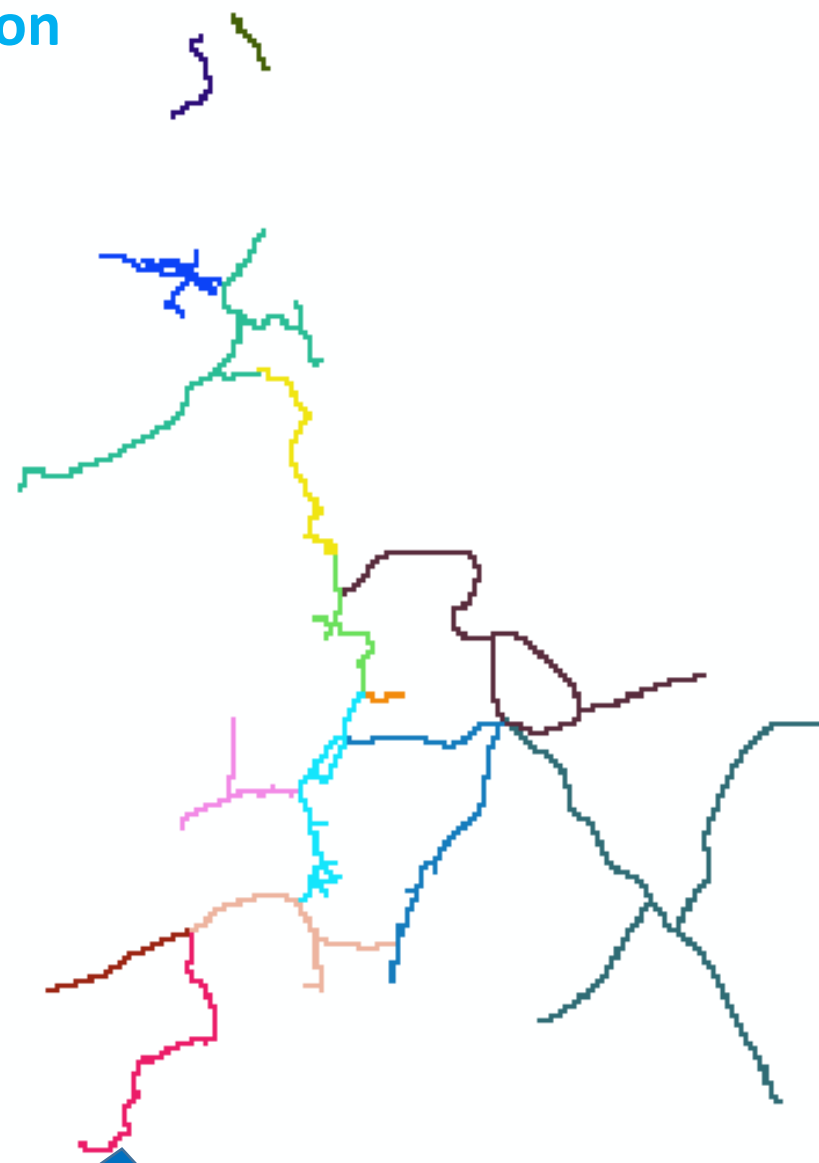
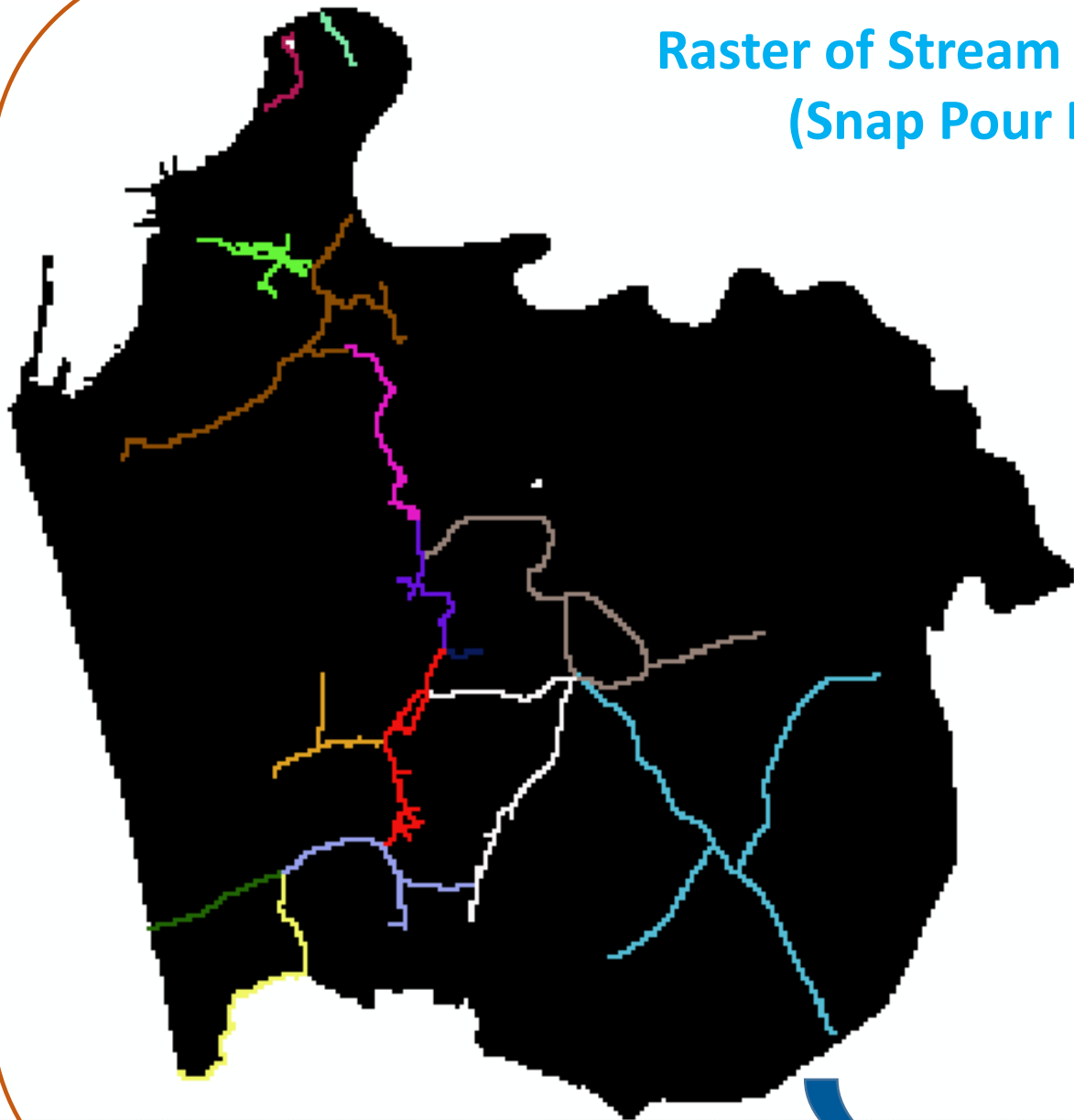
Filled Flow Direction Raster



Flow Accumulation Raster

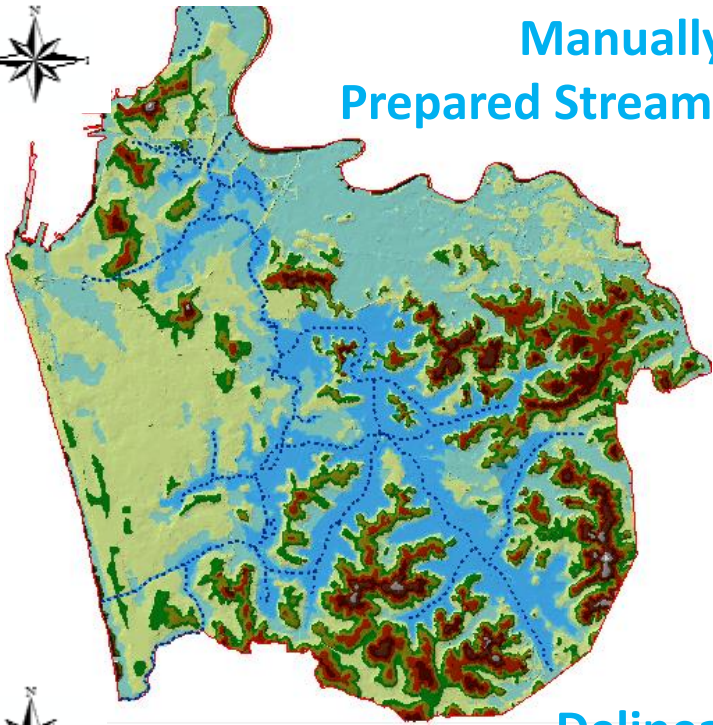


Raster of Stream Delineation (Snap Pour Points)

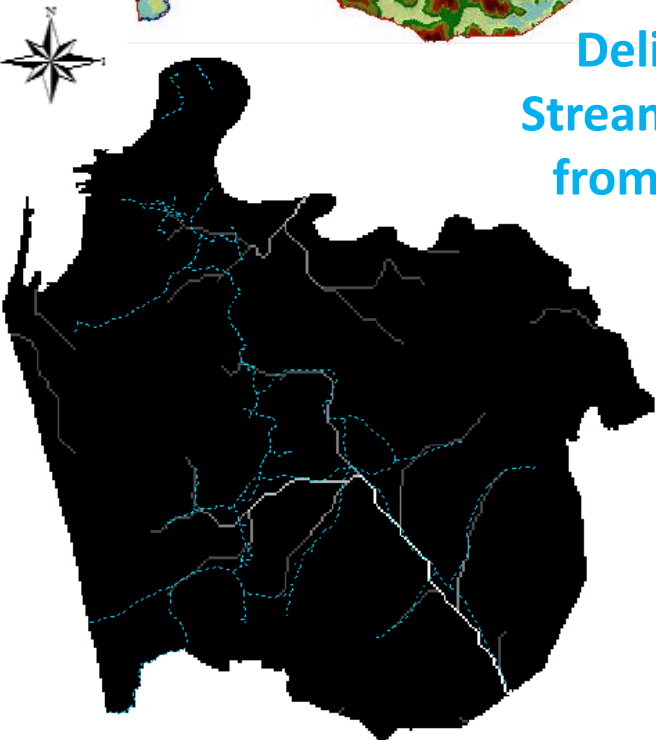


Results

**Manually
Prepared Stream Network**



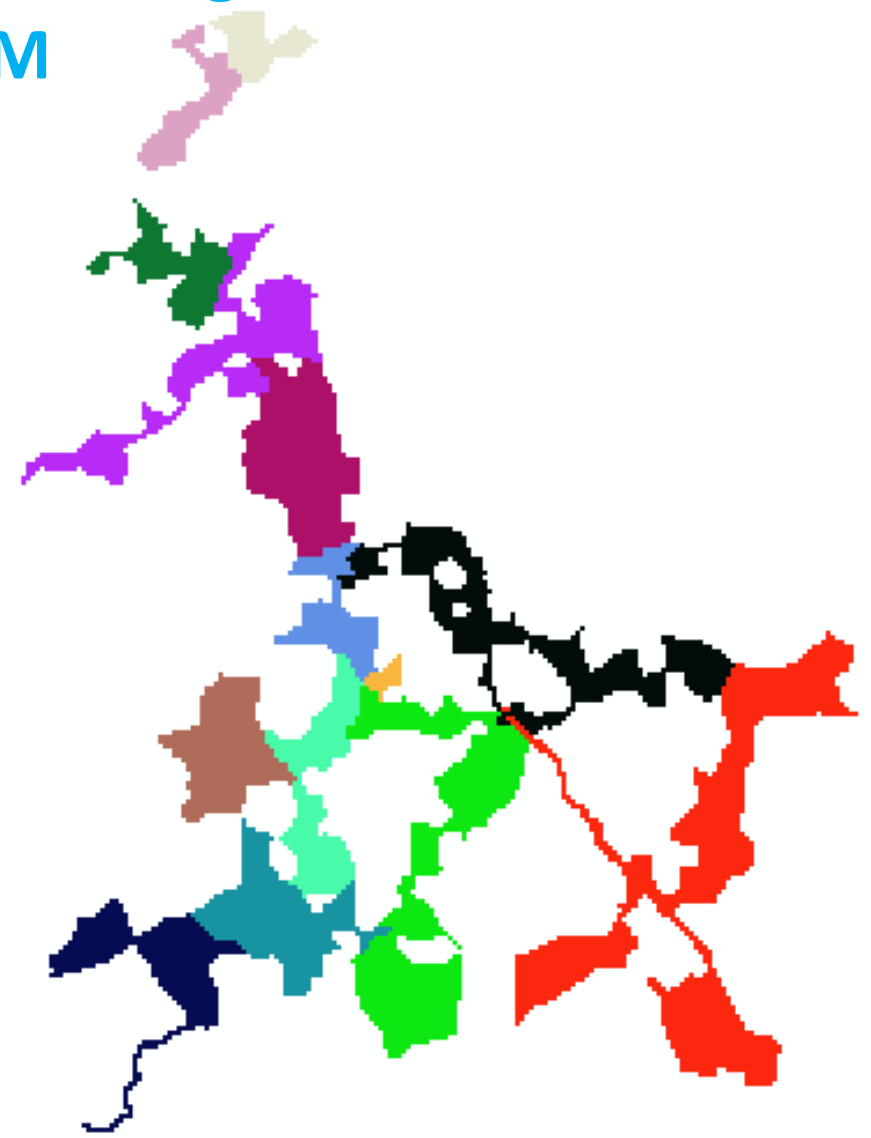
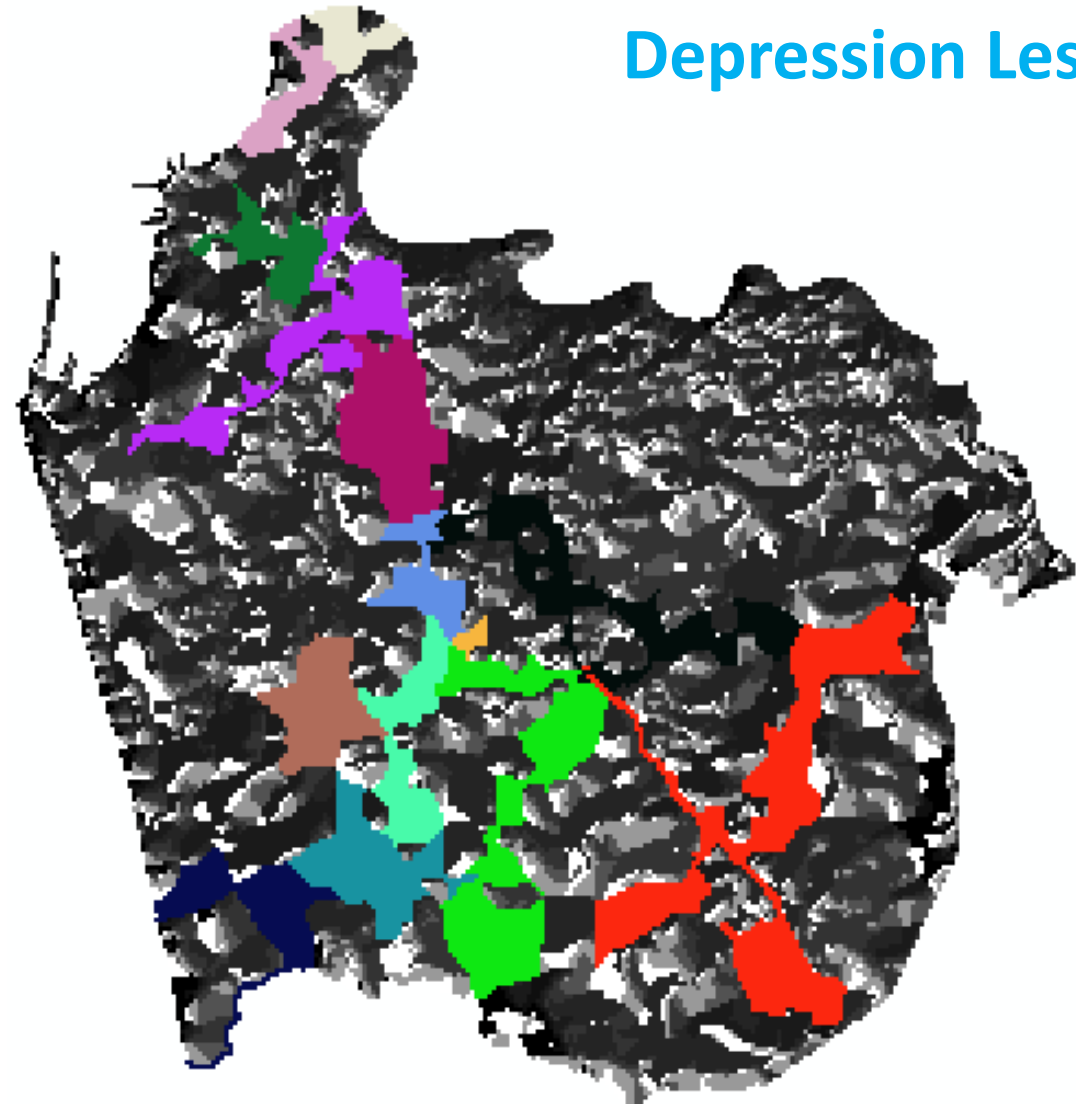
**Delineated
Stream Network
from the DEM**



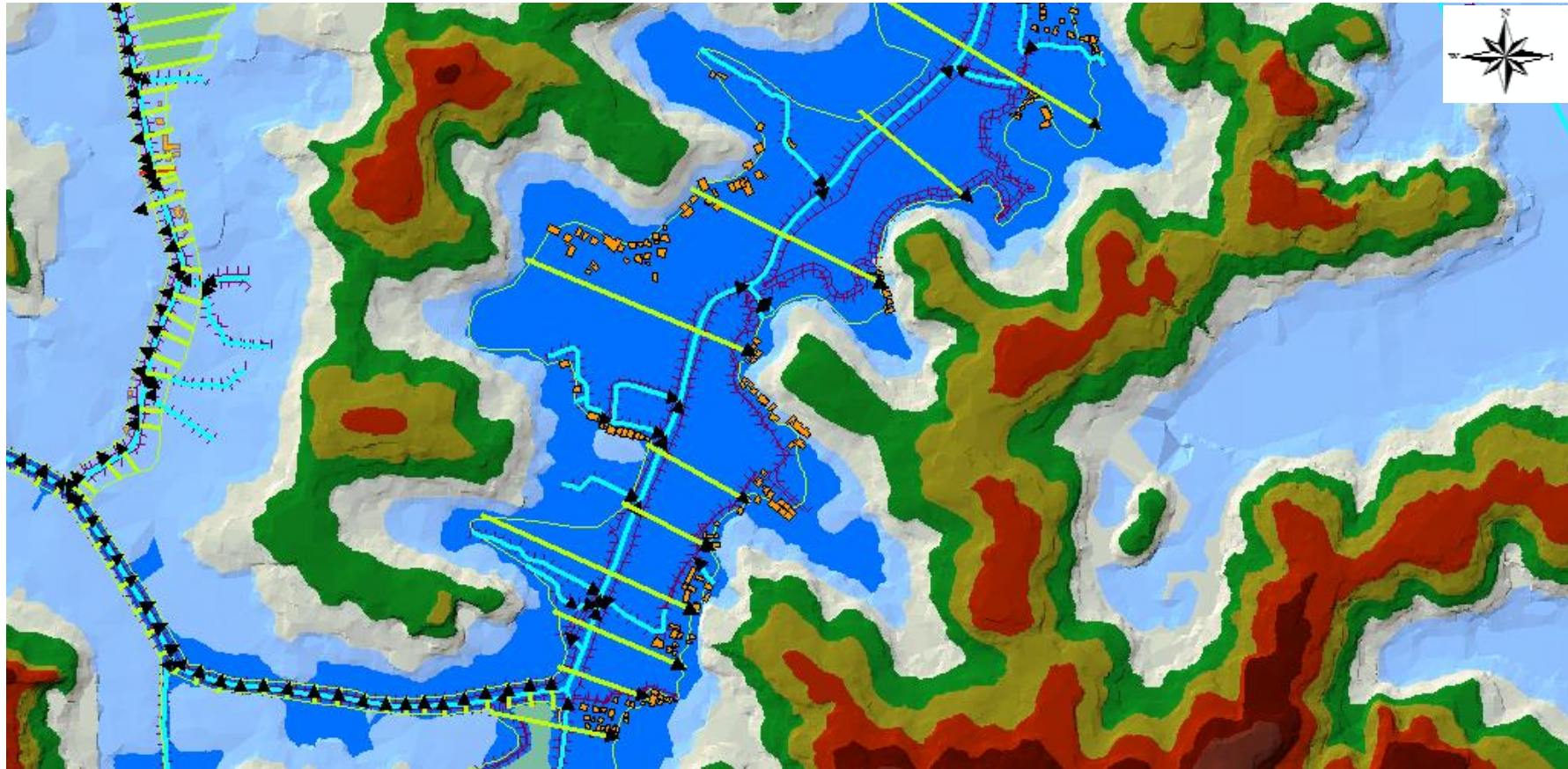
Delineated Stream Network



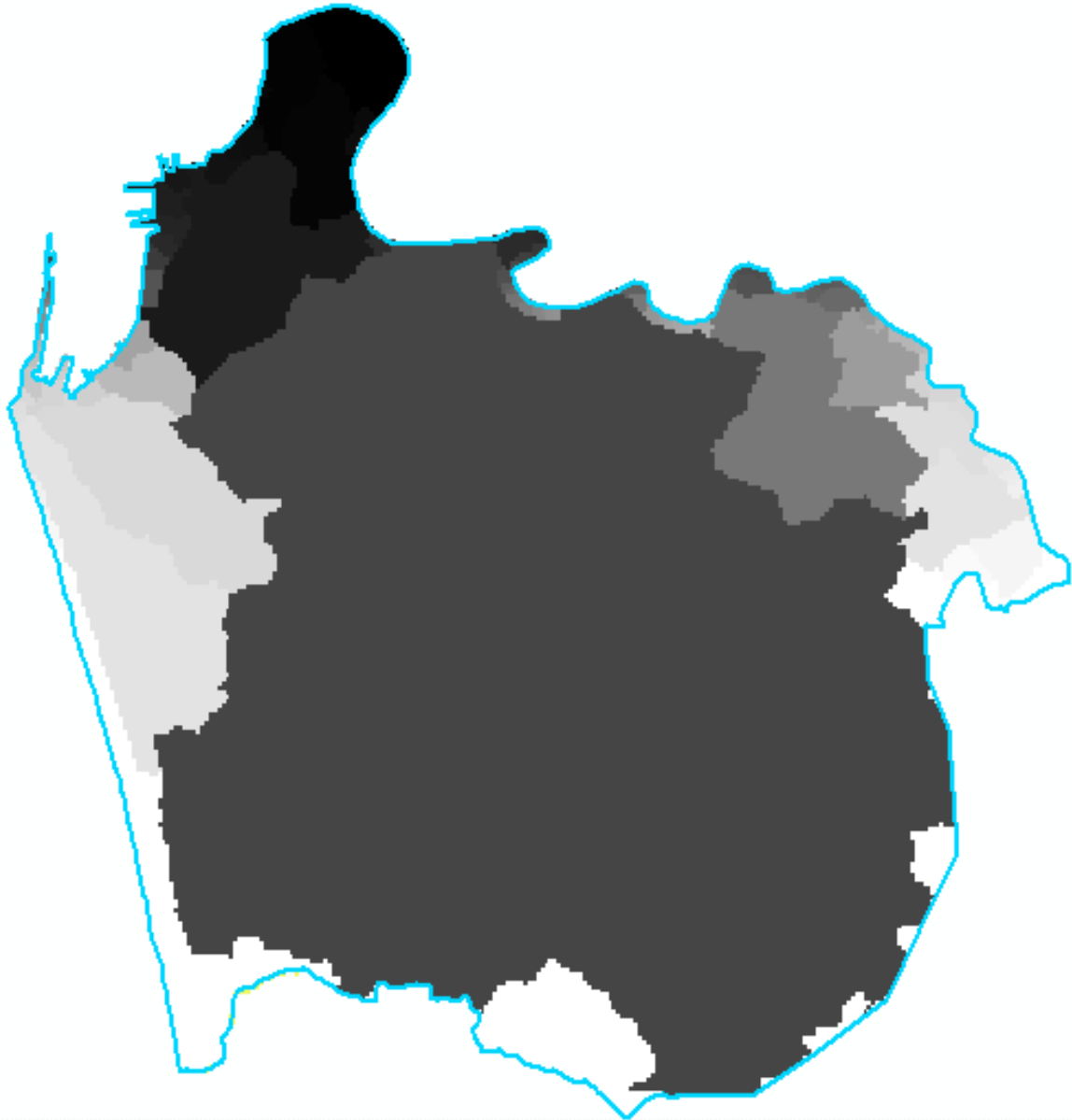
Delineated Sub Catchments using Depression Less DEM



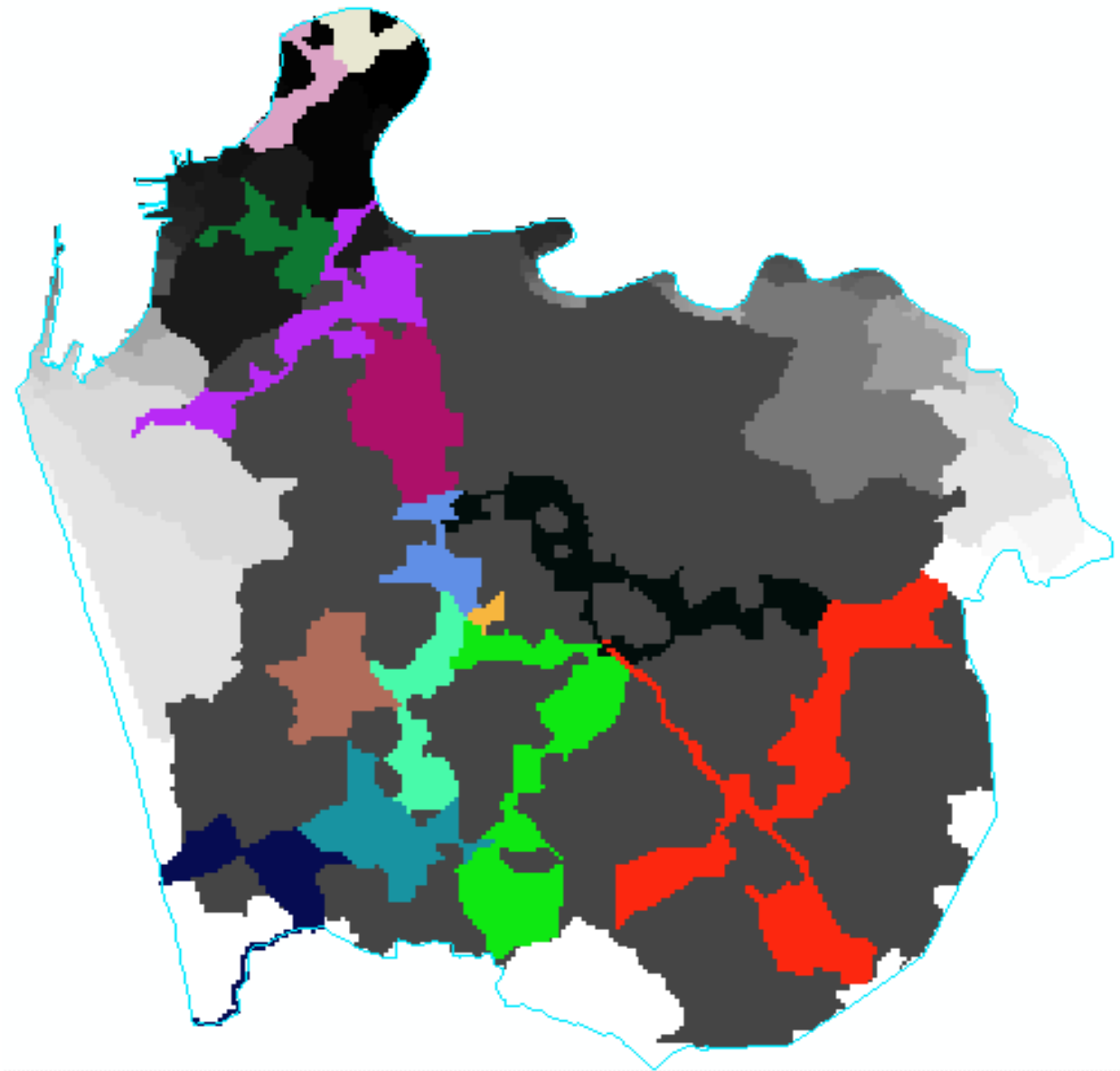
Delineated Catchment Area of Kotte Swamp - South



**Delineated River Basin
Using ArcGIS Hydrological Function**



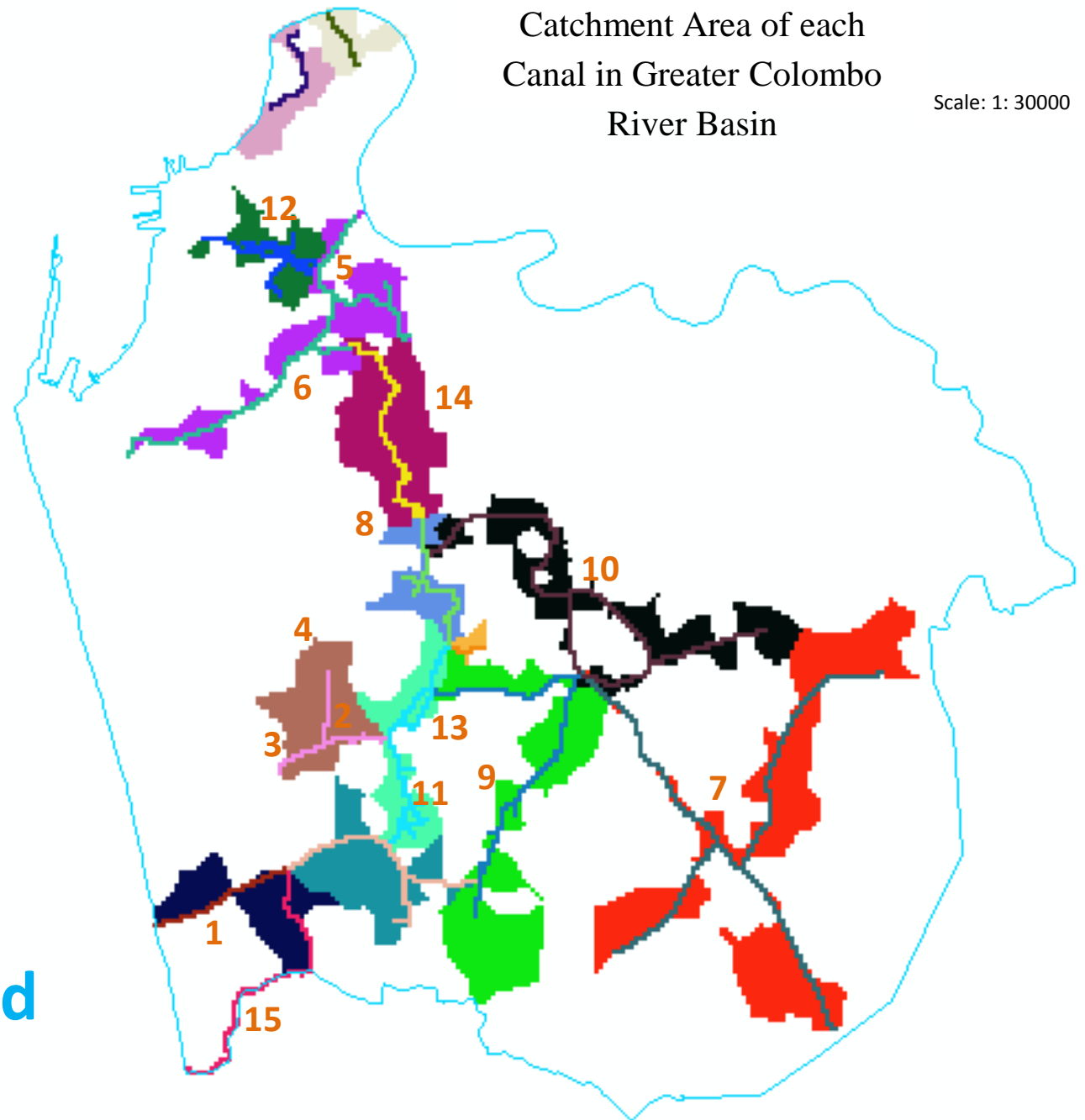
**Delineated Sub Watersheds & the Basin
Using ArcGIS Hydrological Function**



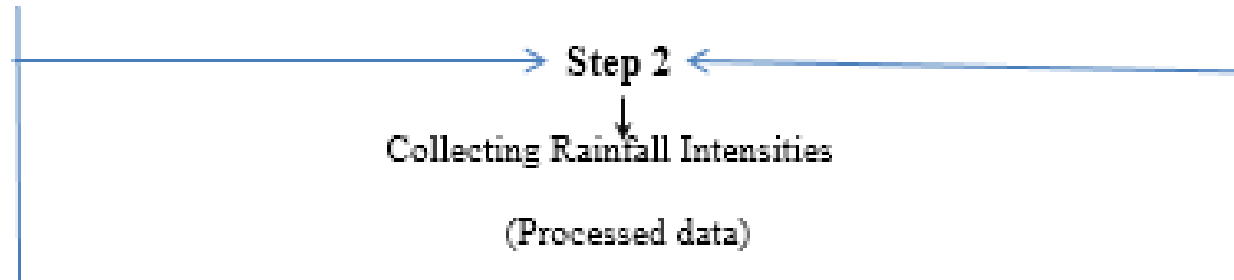
No	Descriptio	Area in Hectares
1	Wellawatta Canal	10.05
2	Torrington West	5.70
3	Torrington canal	19.81
4	Torrington BOI	1.46
5	St Sebestian East	22.27
6	St Sebestian Canal South / North	57.44
7	Parliament Lake	357.38
8	MahawattaEla	56.45
9	Kotte Swamp	112.32
10	Kolonnawa Canal	319.79
11	Kirillapone Canal	121.65
12	Kimbula Ela Maindrain	9.17
13	HeenEla	94.51
14	Dematagoda Canal	27.56
15	Dehiwala Canal	11.14

Source: Prepared by Author, 2011

Delineated Sub Watersheds and Extents of the Area



* For Finding “i” of the Formula...



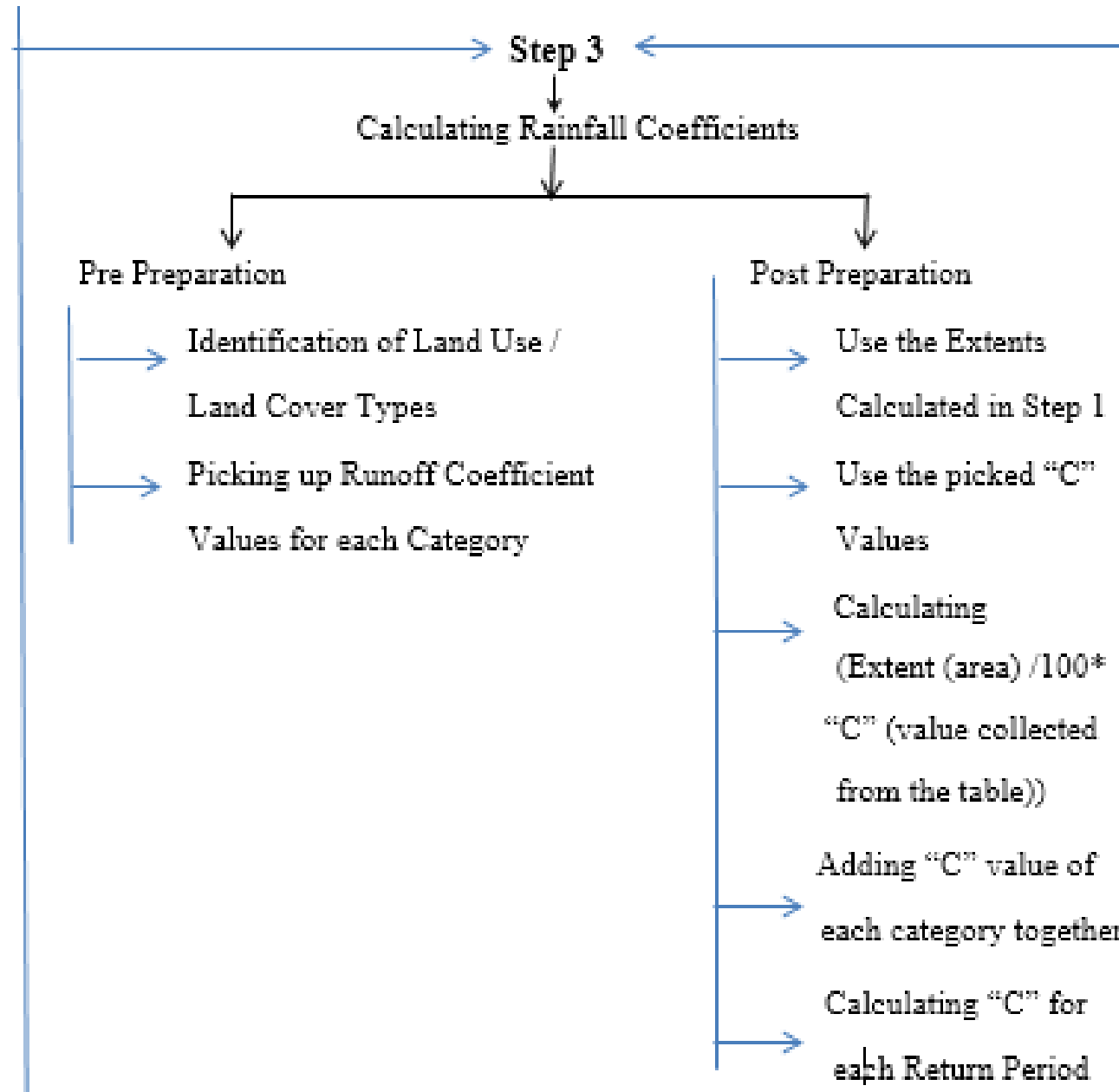
Tabular Data

Probable Annual Daily Maximum Rainfall in Study Area

Daily Maximum Rainfall Suggested From Statistical Analysis		
T(YEARS)	P-DAILY (mm)	REMARKS
2	134.7	
5	195.0	
10	254.1	
25	360.9	
50	472.7	
100	621.6	
38	426.5	November 2010 Rainfall

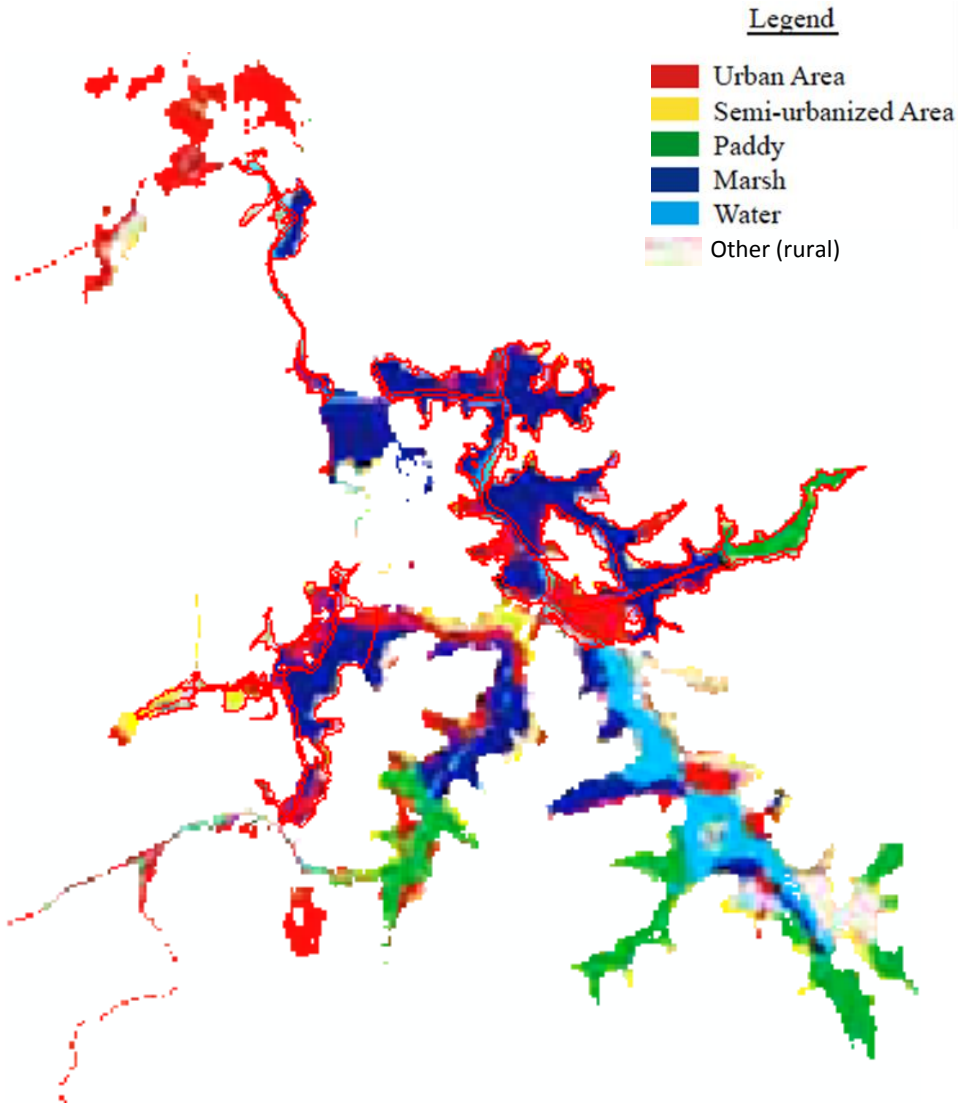
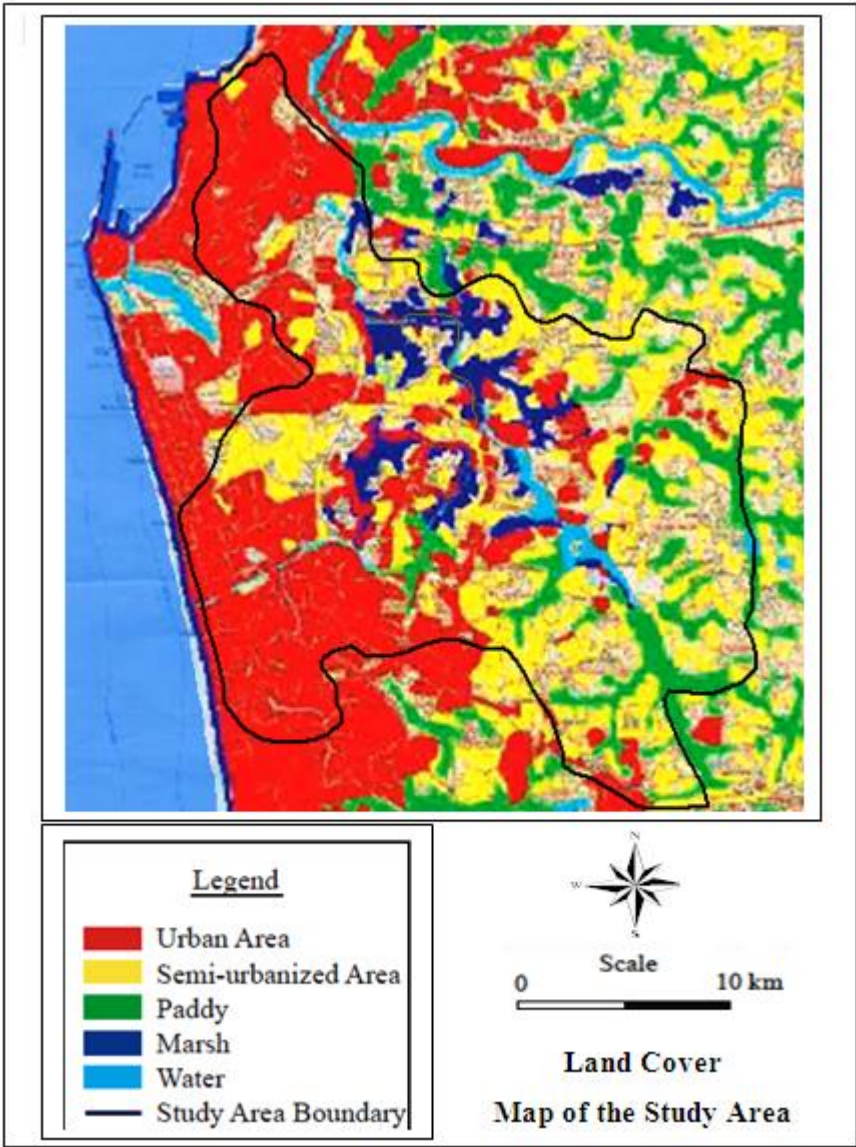
Source: Hydrological Division of Sri Lanka Land Reclamation and Development Cooperation

* Finding “c” for Solving the Equation...



Analysis

Identified Land Cover Types for the Entire Study Area



Identified Land Cover Types & Extents of Few Catchments

Canal	Land Cover	Extent (ha)	Percentage
Heen Ela	Marshy	76.19	80.62
	Semi Urbanized Area	3.89	4.12
	Urbanized Area	5.23	5.53
	Heen Ela (Water)	9.2	9.73
			94.51
Torrington Canal	Semi Urbanized Area	14.20	71.68
	Urbanized Area	3.72	18.78
	Torrington canal(Water)	1.89	9.54
			19.81
Dematagoda Canal	Marshy	13.84	42.45
	Semi Urbanized Area	6.56	20.12
	Urbanized Areal	3.39	10.40
	Dematagoda Canal(Water)	8.80	26.99
			32.60

PRE PREPARATION FOR CALCULATING RUNOFF COEFFICIENTS

Character of surface	Return Period (years)						
	2	5	10	25	50	100	500
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
<i>Poor condition (grass cover less than 50% of the area)</i>							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
<i>Fair condition (grass cover on 50% to 75% of the area)</i>							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
<i>Good condition (grass cover larger than 75% of the area)</i>							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0-2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Urban

Semi Urban

Paddy

Marshy

Other

Estimated the "c" as to suit for the study area, by keeping Weights to Identified Land Cover types using Typical Runoff Coefficients in Table 9 in Annex B for use in the Rational Method

Identified Land Cover Types(Entire Study Area)	Extent (ha)	Percentage							
Urban area	2930.63	39.75%							
Semi-urbanized area	2782.65	37.74%							
Paddy lands	543.64	7.37%							
Marshy	225.06	3.05%							
Water Bodies	240.89	3.27%							
Others (rural area/ Grasslands)	650.45	8.82%							
The values picked from the Runoff Coefficient Table									
				Return Period					
Developed			2	5	10	25	50		Land Cover
Concrete / roof			0.75	0.80	0.83	0.88	0.92		Urbanized
Grass Area									
<i>Poor condition (grass cover less than 50% of the area)</i>									
Flat 0-2%			0.32	0.34	0.37	0.40	0.44		Semi-urbanized
Grass Area									
<i>Fair condition (grass cover 50% to 75% of the area)</i>									
Flat 0-2%			0.25	0.28	0.30	0.34	0.37		Paddy lands
Grass Area									
<i>Good condition (grass cover larger than 75% of the area)</i>									
Flat 0-2%			0.21	0.23	0.25	0.29	0.32		Marshy
Undeveloped									
Flat 0-2%			0.31	0.34	0.36	0.40	0.43		Others

Table 3-6 Runoff Coefficients for use in the Rational Method

Results

Calculating Runoff Coefficients for the Catchment Areas

The way of estimating "c" using the prepared data on Table 10 in Annex B

An example:-

Urban Area (extent)	=	39.75%	5.53
"c" for 2 year return period	=	0.75	0.75
"c" for 2 year return period in Urban Area in the Study area	=	0.041475	$= (5.53/100 * 0.75)$

Heen Ela

Calculating "c" for 2 Year Return Period	Calculating "c" for 5 Year Return Period
0.0415 Urban Area	0.04424 Urban Area
0.0132 Semi-urbanized area	0.014008 Semi-urbanized area
0.1693 Marshy	0.185426 Marshy
0.22396 Total = c	0.24367 Total = c

Calculating "c" for 10 Year Return Period	Calculating "c" for 25 Year Return Period
0.045899 Urban Area	0.048664 Urban Area
0.015244 Semi-urbanized area	0.01648 Semi-urbanized area
0.20155 Marshy	0.233798 Marshy
0.26269 Total = c	0.29894 Total = c

Calculating "c" for 50 Year Return Period

0.050876 Urban Area
0.018128 Semi-urbanized area
0.257984 Marshy
0.326988 Total = c

Dematagoda Canal

Calculating "c" for 2 Year Return Period	Calculating "c" for 5 Year Return Period
0.0780 Urban Area	0.0832 Urban Area
0.0644 Semi-urbanized area	0.068408 Semi-urbanized area
0.0891 Marshy	0.097635 Marshy
0.23153 Total = c	0.24924 Total = c

Calculating "c" for 10 Year Return Period	Calculating "c" for 25 Year Return Period
0.08632 Urban Area	0.09152 Urban Area
0.074444 Semi-urbanized area	0.08048 Semi-urbanized area
0.106125 Marshy	0.123105 Marshy
0.26689 Total = c	0.29511 Total = c

Calculating "c" for 50 Year Return Period

0.09568 Urban Area
0.088528 Semi-urbanized area
0.13584 Marshy
0.320048 Total = c

RUNOFF COEFFICIENTS ESTIMATION

Torrington Canal

Calculating "c" for 2 Year Return Period	Calculating "c" for 5 Year Return Period
0.1409 Urban Area	0.15024 Urban Area
0.2294 Semi-urbanized area	0.243712 Semi-urbanized area
0.3702 Total = c	0.39395 Total = c

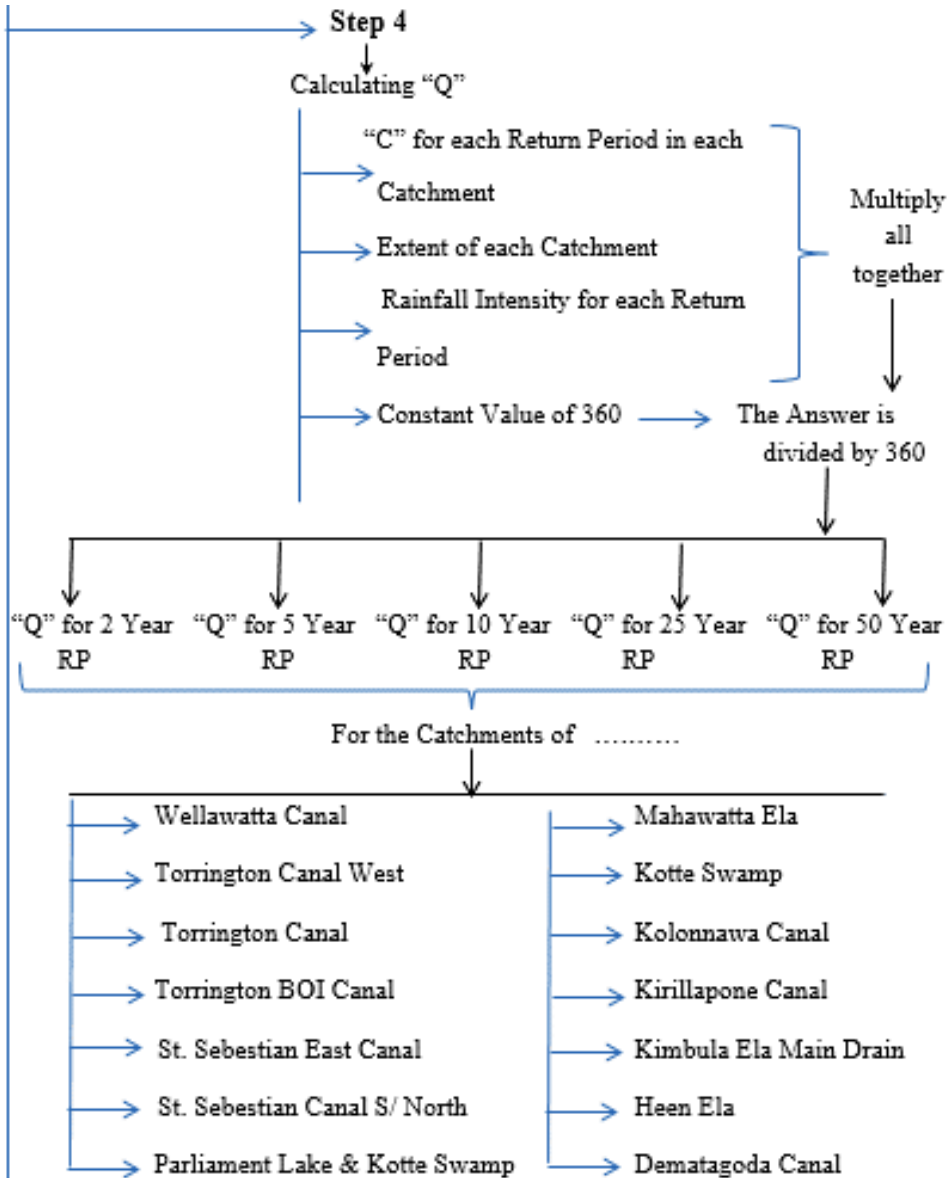
Calculating "c" for 10 Year Return Period	Calculating "c" for 25 Year Return Period
0.155874 Urban Area	0.165264 Urban Area
0.265216 Semi-urbanized area	0.28672 Semi-urbanized area
0.42109 Total = c	0.45198 Total = c

Calculating "c" for 50 Year Return Period

0.172776 Urban Area
0.315392 Semi-urbanized area
0.488168 Total = c

FOR SUB CATCHMENTS

RELEVANT TO CONSIDERED RETURN PERIODS



Final Result

Acquired Results for Each Catchment of the Considered (Sampling) Canal of the Canal Network

Torrington Canal					
Return Period	c	i	A(ha)	Constan	Q
2 Year	0.37	134.7	19.81	360	2.743
5 Year	0.39	195.0	19.81	360	4.185
10 Year	0.42	254.1	19.81	360	5.873
25 Year	0.45	360.9	19.81	360	8.937
50 Year	0.49	472.7	19.81	360	12.75

Heen Ela					
Return Period	c	i	A(ha)	Constan	Q
2 Year	0.22	134.7	94.51	360	7.7797
5 Year	0.24	195.0	94.51	360	12.286
10 Year	0.26	254.1	94.51	360	17.344
25 Year	0.30	360.9	94.51	360	28.424
50 Year	0.33	472.7	94.51	360	40.952
Dematagoda Canal					
Return Period	c	i	A(ha)	Constan	Q
2 Year	0.23	134.7	32.6	360	2.8055
5 Year	0.25	195.0	32.6	360	4.4146
10 Year	0.27	254.1	32.6	360	6.2127
25 Year	0.30	360.9	32.6	360	9.8045
50 Year	0.32	472.7	32.6	360	13.698

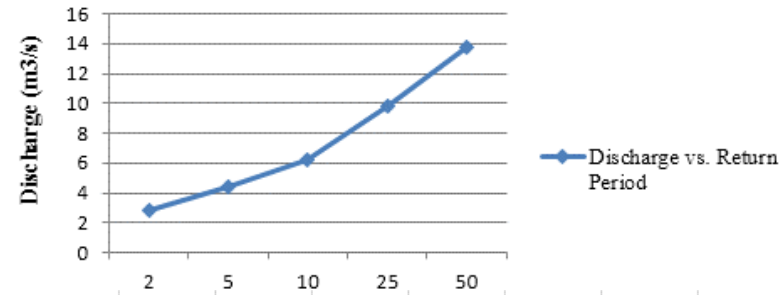
Estimated Peak Runoff for Dematagoda Canal, Heen Ela and Torrington Canal (as a sampling result)

Return Period (Years)	2 year	5 year	10 year	25 year	50 year	Canals
Peak Runoff (m ³ /sec)	2.81	4.41	6.21	9.80	13.70	<u>Dematagoda</u>
Peak Runoff (m ³ /sec)	7.78	12.29	17.34	28.42	40.95	<u>HeenEla</u>
Peak Runoff (m ³ /sec)	2.74	4.19	5.87	8.94	12.75	Torrington

Dematagoda Canal

	Return Period	c	i	A(ha)	Constant	Q
2	2 Year	0.23	134.7	32.6	360	2.8055
5	5 Year	0.25	195.0	32.6	360	4.41458
10	10 Year	0.27	254.1	32.6	360	6.21275
25	25 Year	0.30	360.9	32.6	360	9.80445
50	50 Year	0.32	472.7	32.6	360	13.6978

Discharge vs. Return Period (Probable Peak Runoff)



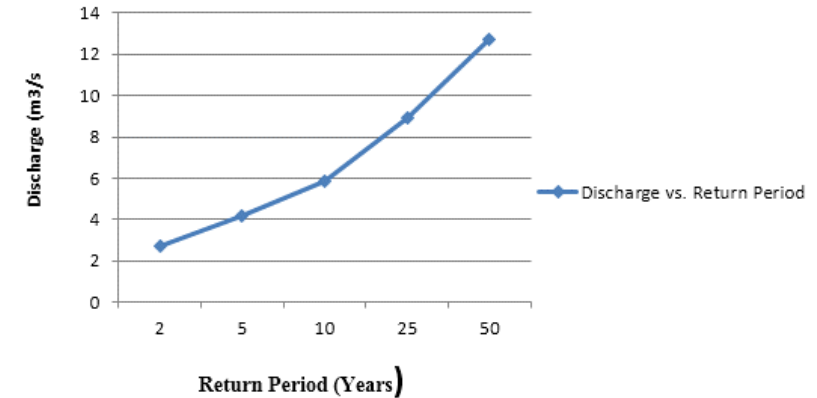
Dematagoda Canal,

Rainfall Vs. Discharge

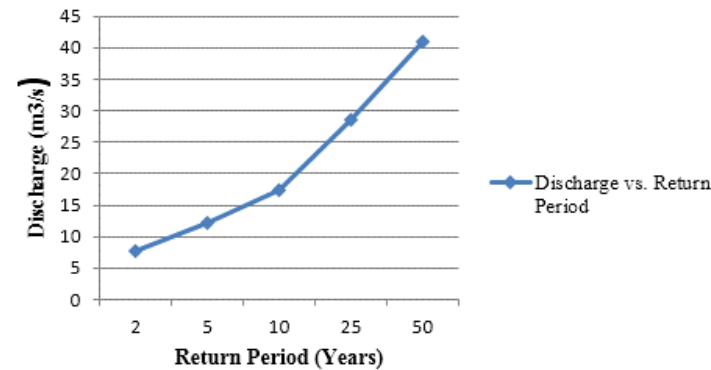
Torrington Canal

	Return Period	c	i	A(ha)	Constant	Q
2	2 Year	0.37	134.7	19.81	360	2.74253
5	5 Year	0.39	195.0	19.81	360	4.18486
10	10 Year	0.42	254.1	19.81	360	5.87267
25	25 Year	0.45	360.9	19.81	360	8.93679
50	50 Year	0.49	472.7	19.81	360	12.7457

Discharge vs. Return Period (Probable Peak Runoff)



Return Period vs. Discharges (Probable Peak Runoff)



Heen Ela

	Return Period	c	i	A(ha)	Constant	Q
2	2 Year	0.22	134.7	94.51	360	7.77975
5	5 Year	0.24	195.0	94.51	360	12.2863
10	10 Year	0.26	254.1	94.51	360	17.3442
25	25 Year	0.30	360.9	94.51	360	28.4239
50	50 Year	0.33	472.7	94.51	360	40.952

Heen Ela and Torrington Canal

CONCLUSION

The following conclusions were made based on the literature review and through the analysis carried out in this study.

- Hydrological function of ArcGIS is a very powerful tool to delineate the hydrological phenomena like watersheds & stream links.
- Accurate Terrain Surface gives the precise terrain information.
- Applied equation (Rational Method) is most effective in urban areas with drainage areas of less than 200 acres and, is most commonly used method of determining peak discharge from small drainage areas.

REFERENCE

1. <http://www.brighthubengineering.com/hydraulics-civil-engineering/42770-how-to-calculate-an-urban-drainage-system>.
2. <http://sites.tufts.edu/gis/files/2013/11/Watershed-and-Drainage-Delineation-by-Pour-Point.pdf>
3. Watershed Delineation, GIS Tutorial, CEE 577, Spring 2013 Liz Isenstein.
4. Bikram Manandhar et al, MSc, Watershed Management, Tribhuvan University, Institute of Forestry, Pokhara, Floodplain Analysis And Risk Assessment Of Lothar Khola (Stream).
5. Arizona Department of Water Resources Dam Safety Section, State Standard for Floodplain Hydraulic Modeling, 500 North Third Street, Phoenix, Arizona 85004.
6. Watershed and Drainage Delineation by Pour Point in ArcMap 10 , Barbara Parmenter and Jack Melcher, Revised January 10, 2012
7. Japan International Cooperation Agency, Nippon Koei Co.,Ltd., The Study On Storm Water Drainage Plan for the Colombo Metropolitan Region In The Democratic Socialist Republic of Sri Lanka, Final Report, Volume III, Supporting Report, March 2003.
8. Majed Subhi Abu Sharkh, Estimation of Runoff for Small Watershed Using Watershed Modeling System (WMS) and GIS, Associate Professor of Civil Engineering College of Engineering and Technology, Palestine Polytechnic University, 2009.

End