



www.thamesrevival.ca



ThamesRiver
CLEAR WATER REVIVAL



Committed to a Healthy and Vital Thames River

Hydraulic Modeling using GIS, Digital Elevation Mapping and Survey Data

Mahmoud R. Pejam, UTRCA



Outline



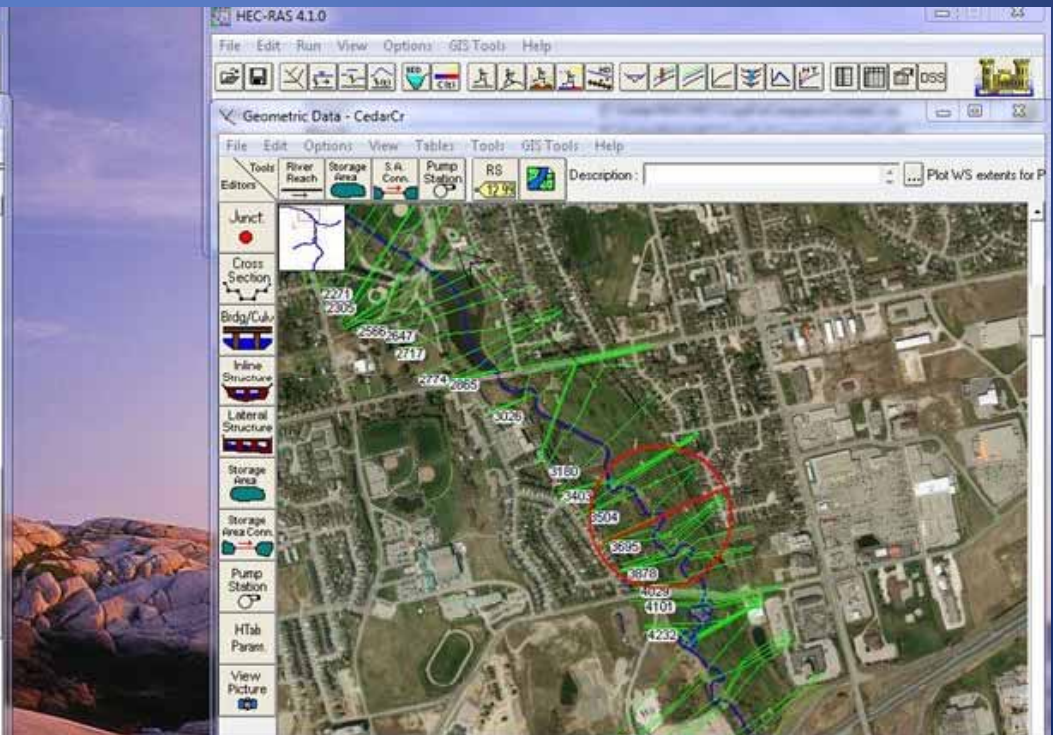
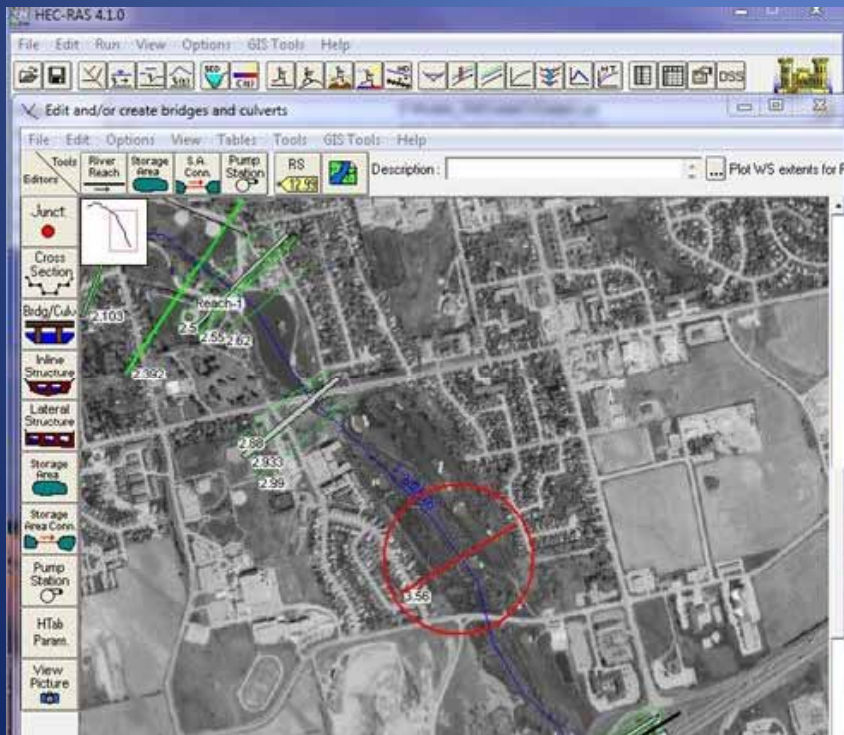
- Updating Hydraulic Models
 - GPS Field Survey
 - Digital Terrain Model (DTM)
 - Develop the Hydraulic Model
 - Calibration
- Hydrology
 - Catchment re-delineation using DEM
 - Hydrologic Modeling
- Flood Hazard Mapping
- Next Steps

Objectives

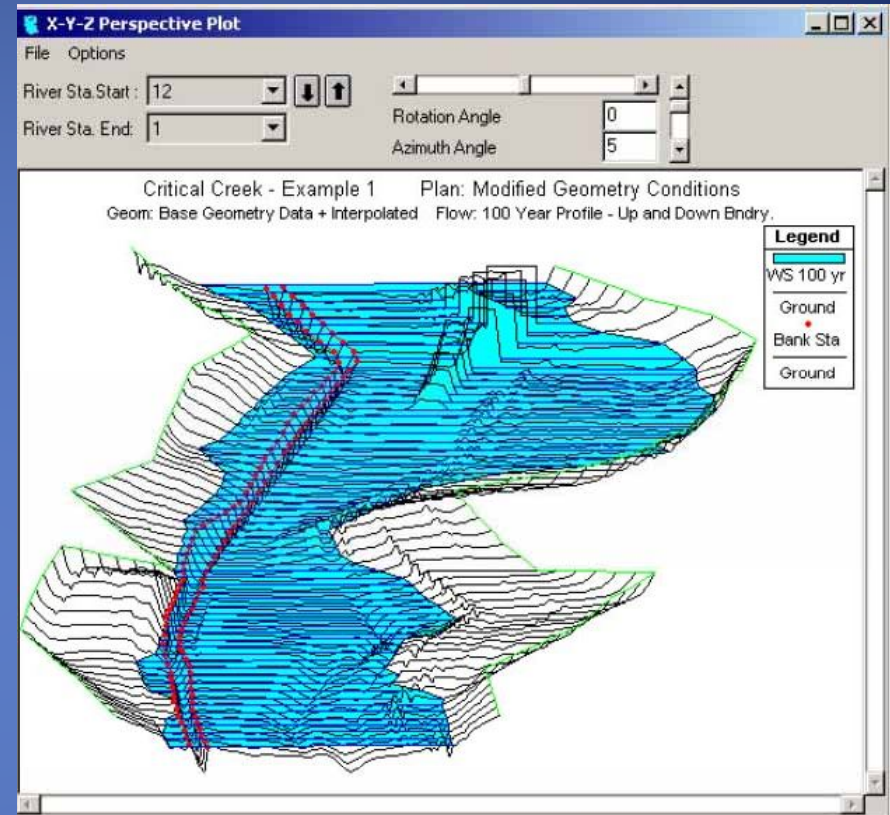
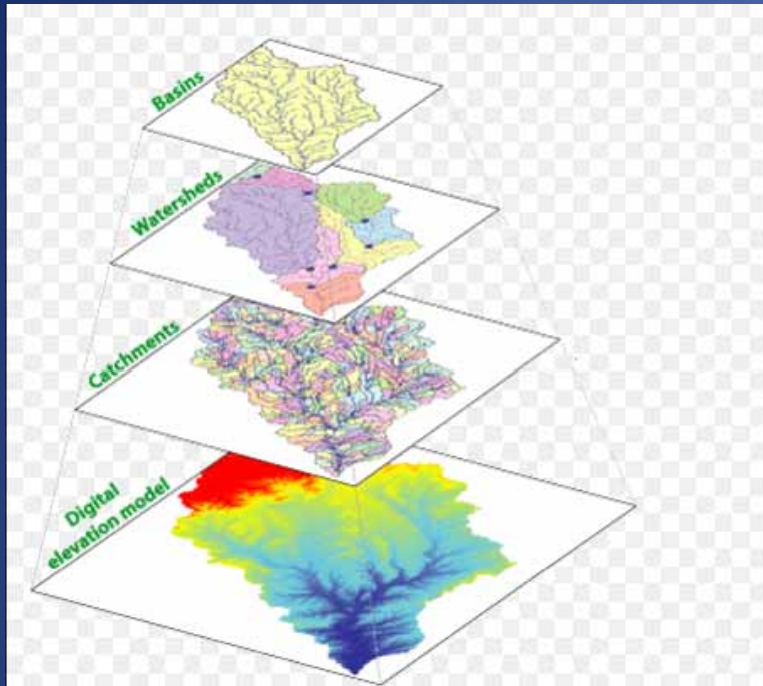


Develop a process to update and modernize watershed flood plain mapping

- Updating base information from 1970s to present
- Integration of GIS in hydraulic and hydrology
- Pilot areas
 - Thames River in London
 - Cedar Creek in Woodstock
 - Mud Creek in London

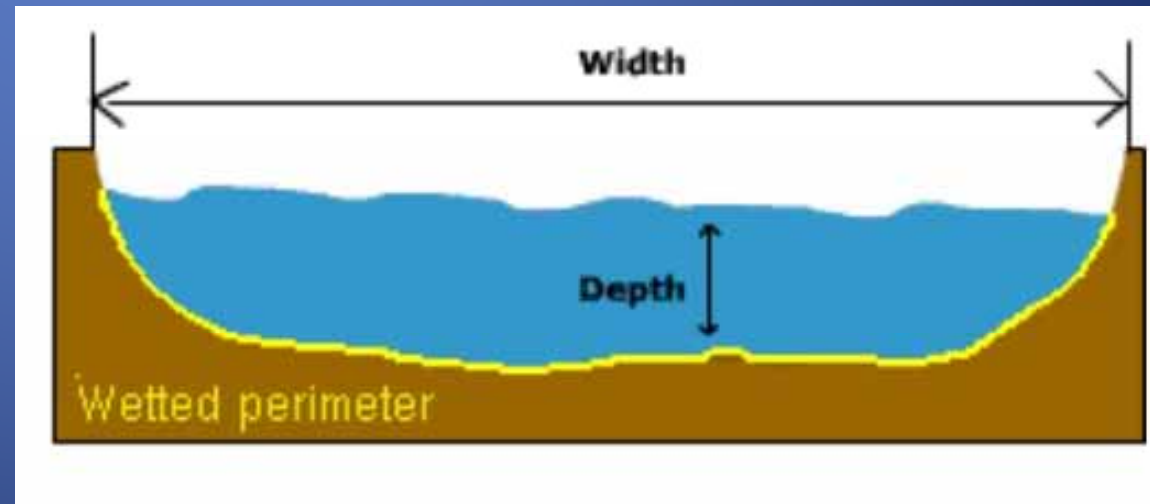
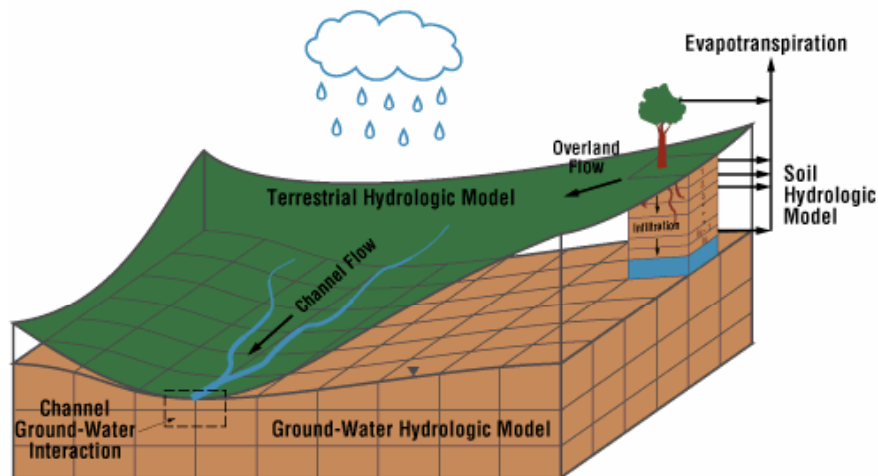


Hydrology and Hydraulic

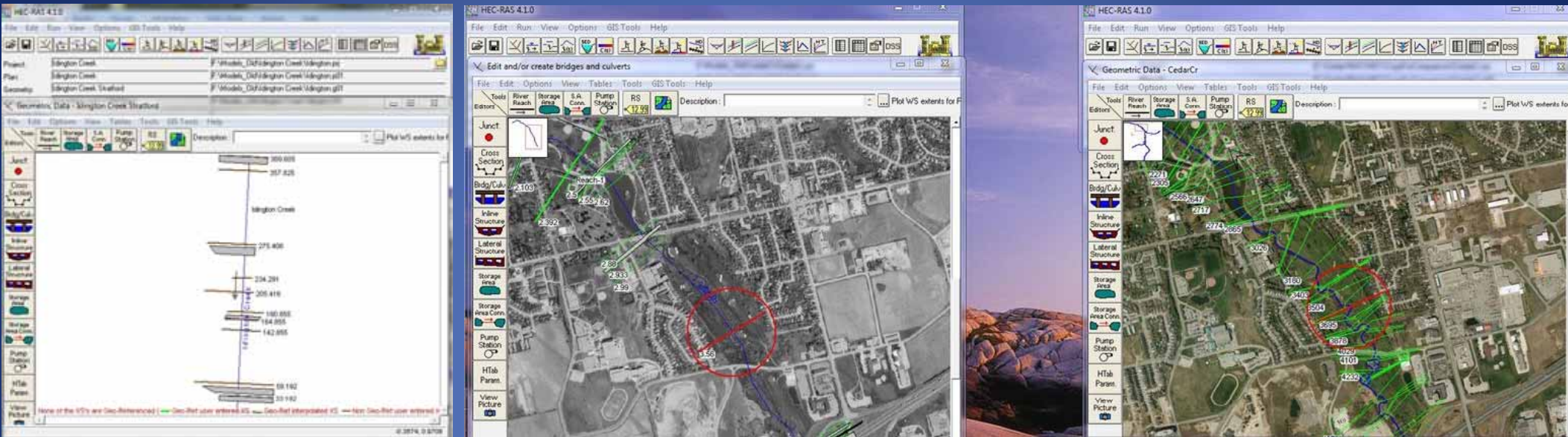


Hydrologic Model System (HMS)

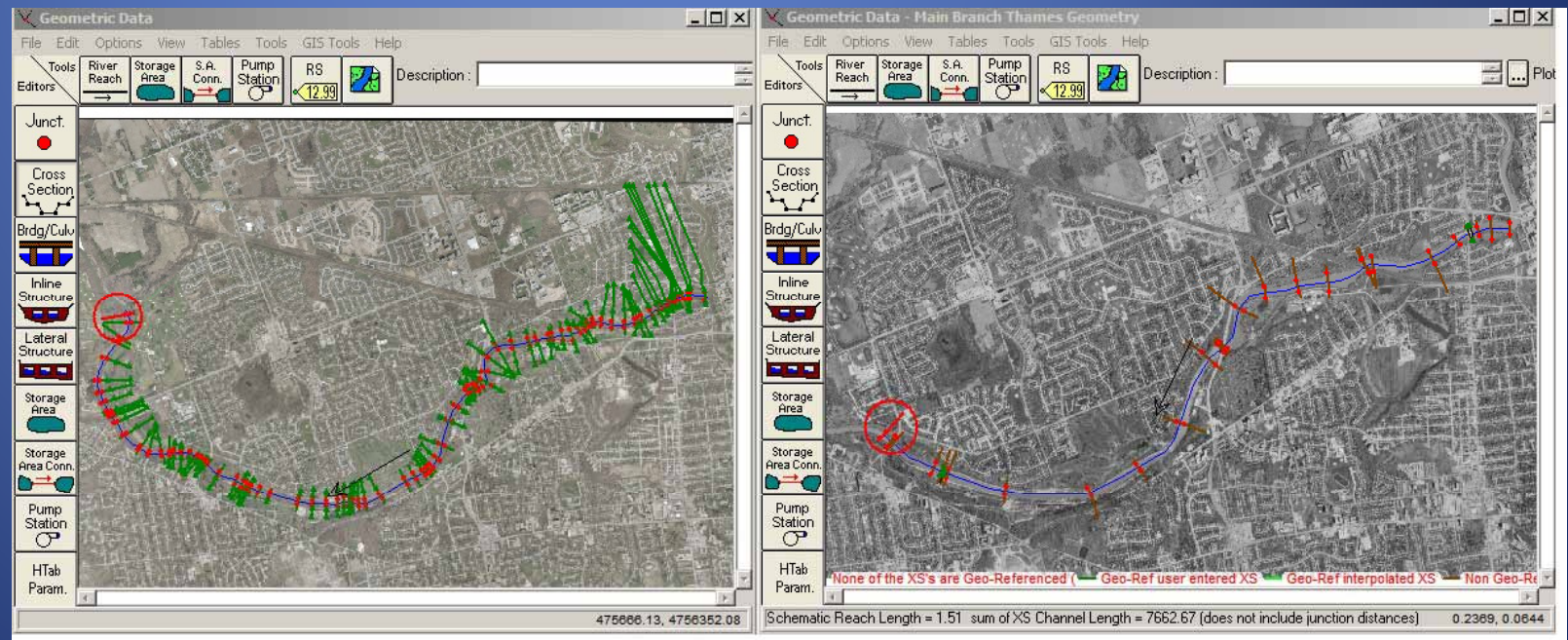
Hydrologic Model System



Updating Hydraulic Models Old vs. New



- Old Data (accuracy)
- Less Data (expensive)
- Not Easy to improve
- Hardware Limitations
- Software Limitations

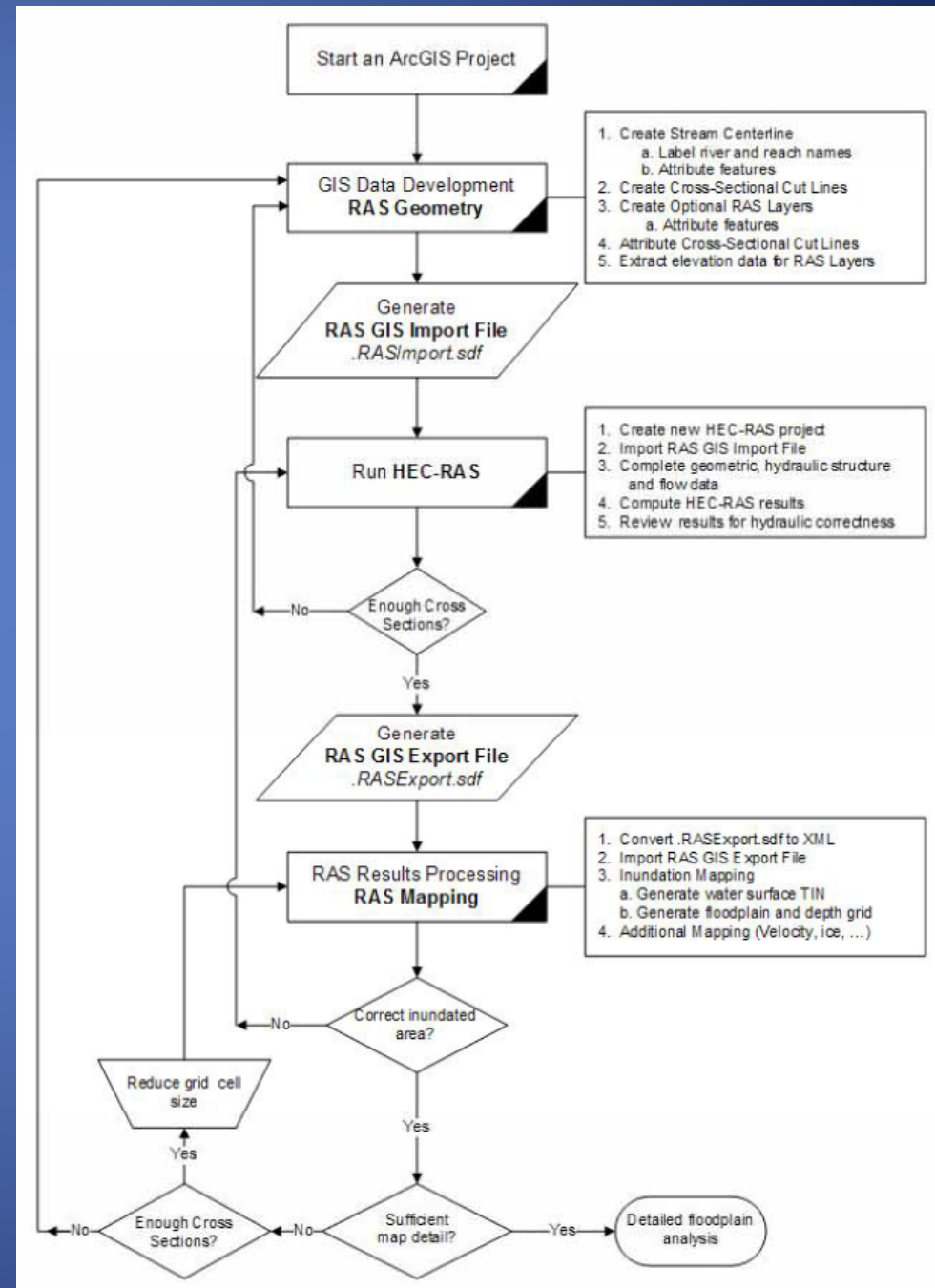
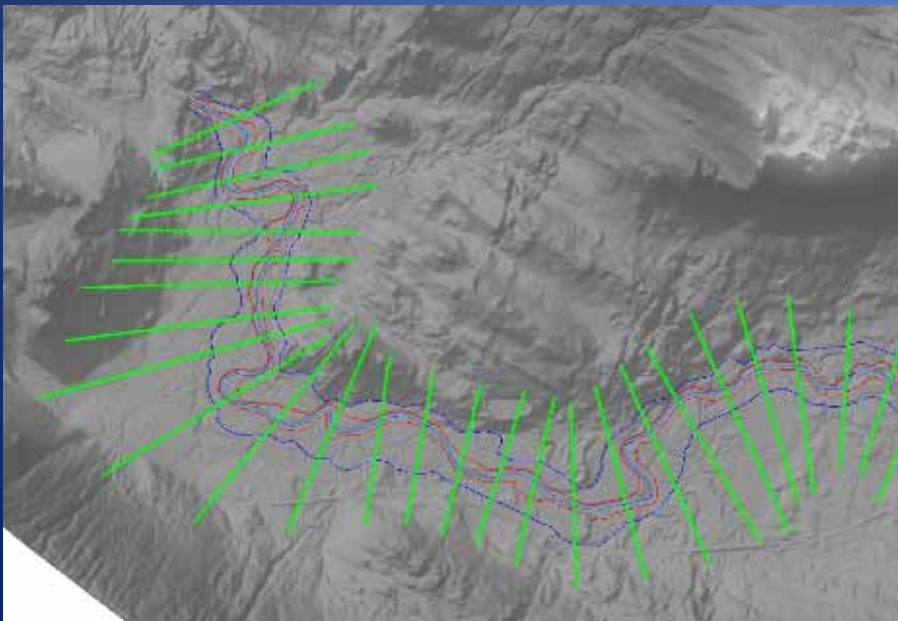
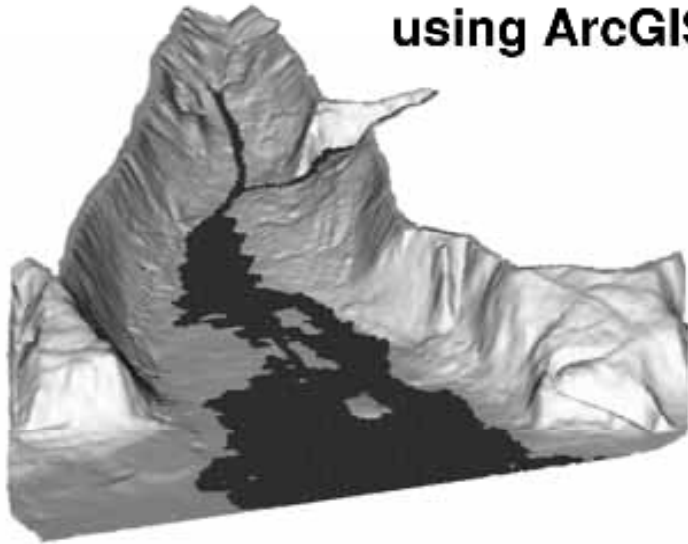


Use of GIS and New DEM

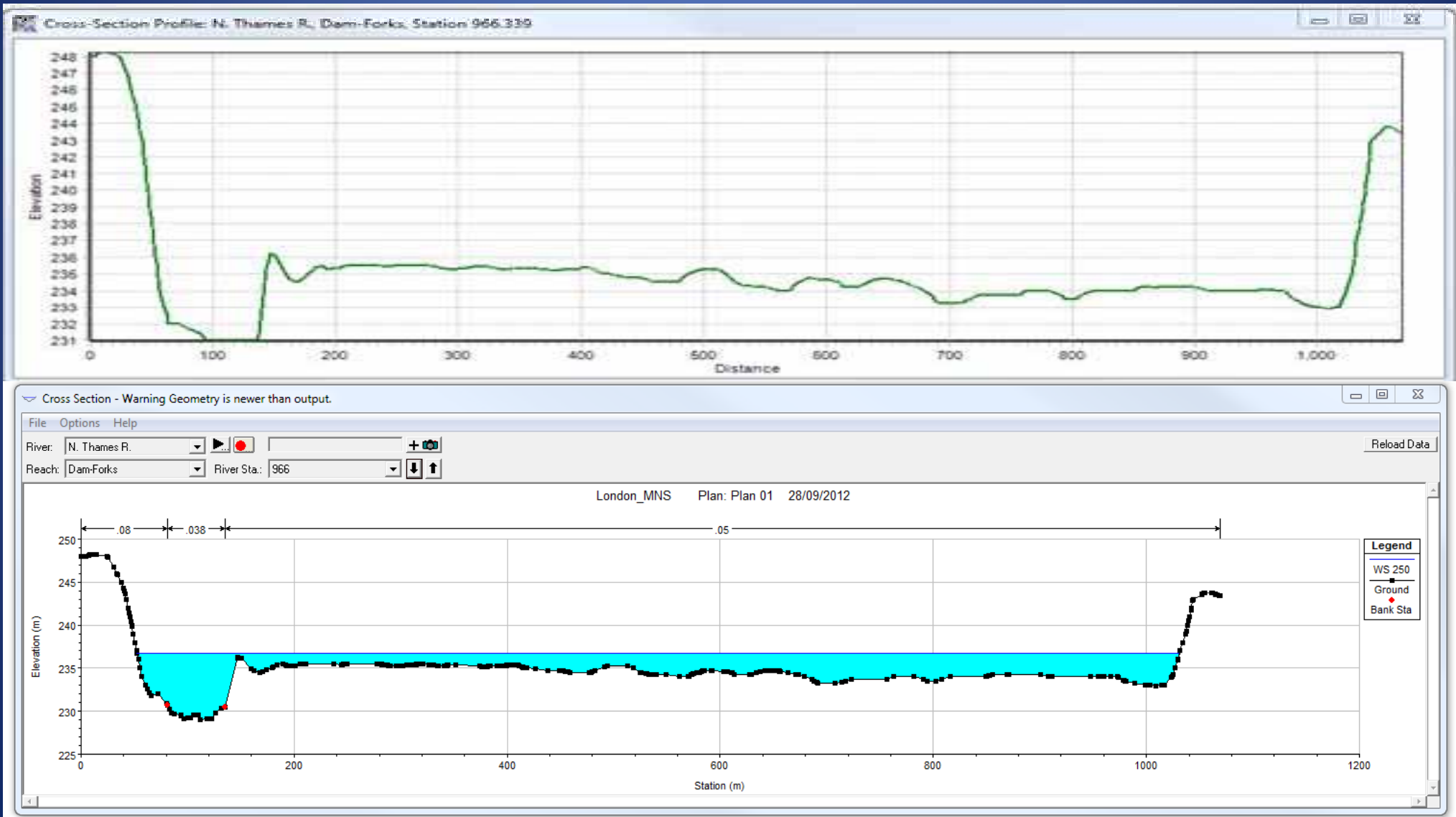


HEC-GeoRAS

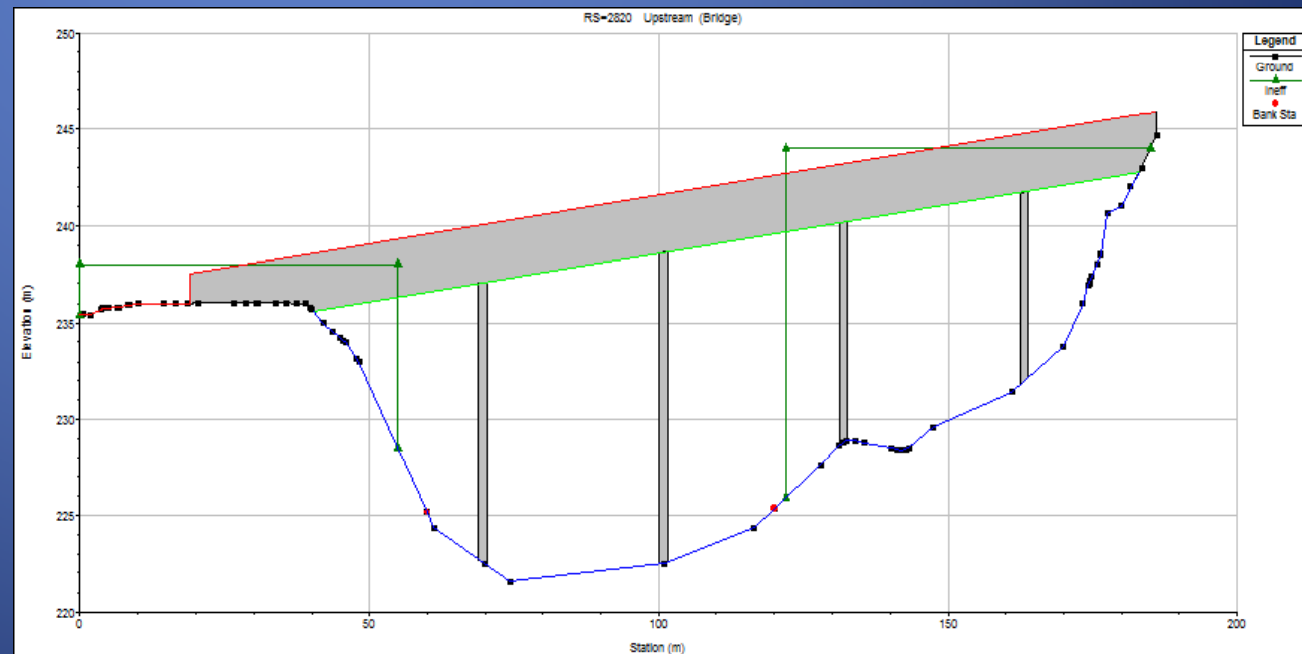
GIS Tools for Support of HEC-RAS using ArcGIS®



Channel Modification (DEM Limits)



Hydraulic Structures



GPS



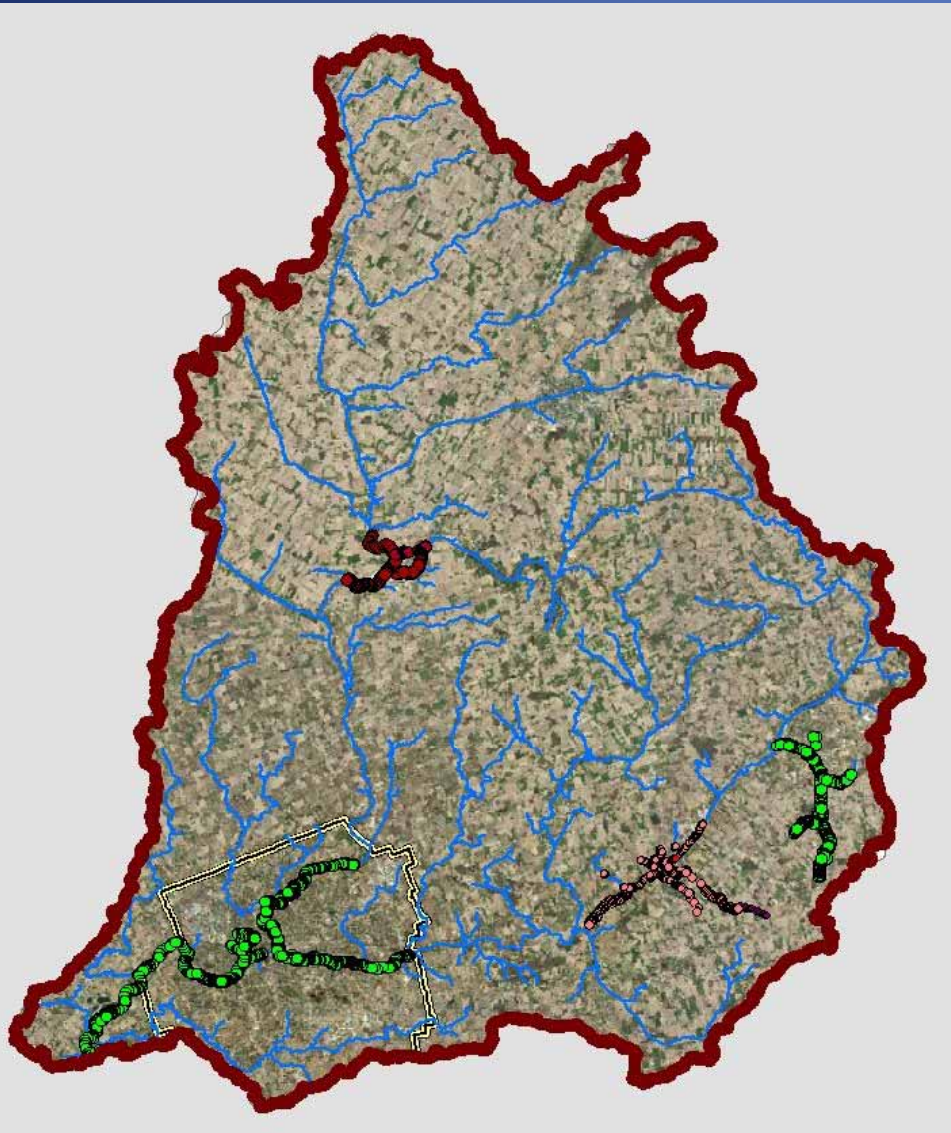
Surveying



GPS Surveying



- London
- Woodstock (Cedar Cr.)
- Other Priority Areas
- Ingersoll (Thames and Tributaries)
- St. Marys (Thames and Tributaries)



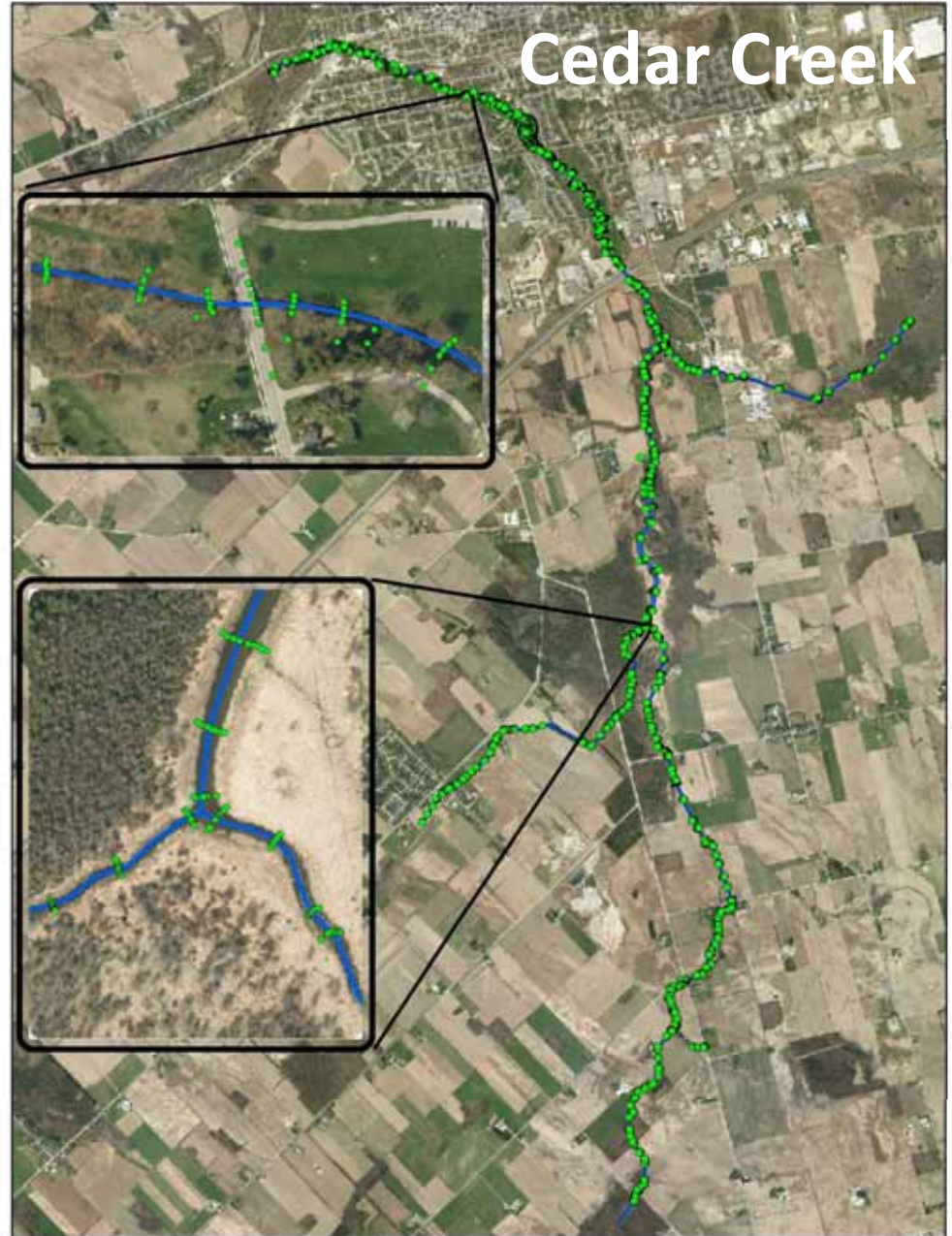
GPS Surveying



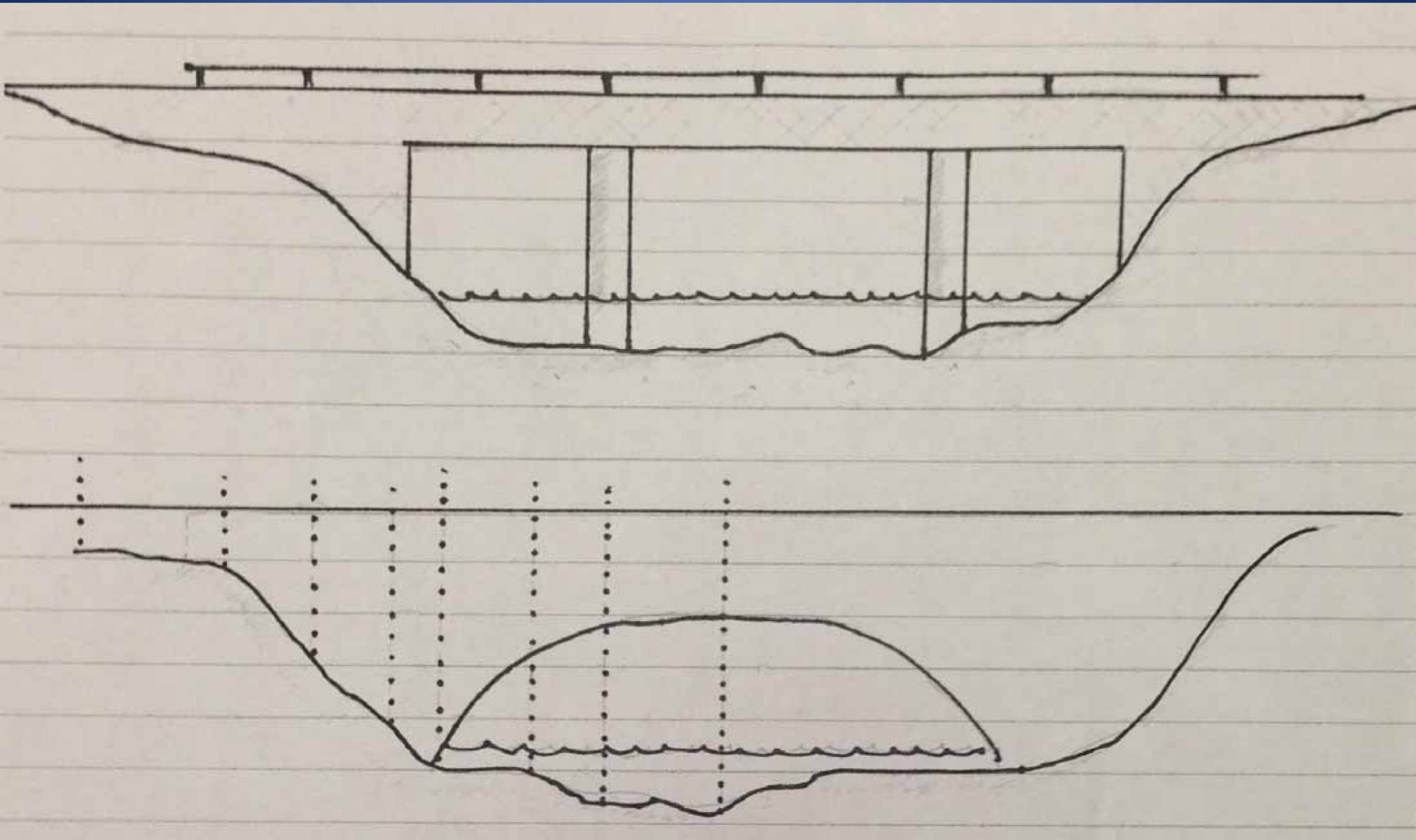
Thames River London



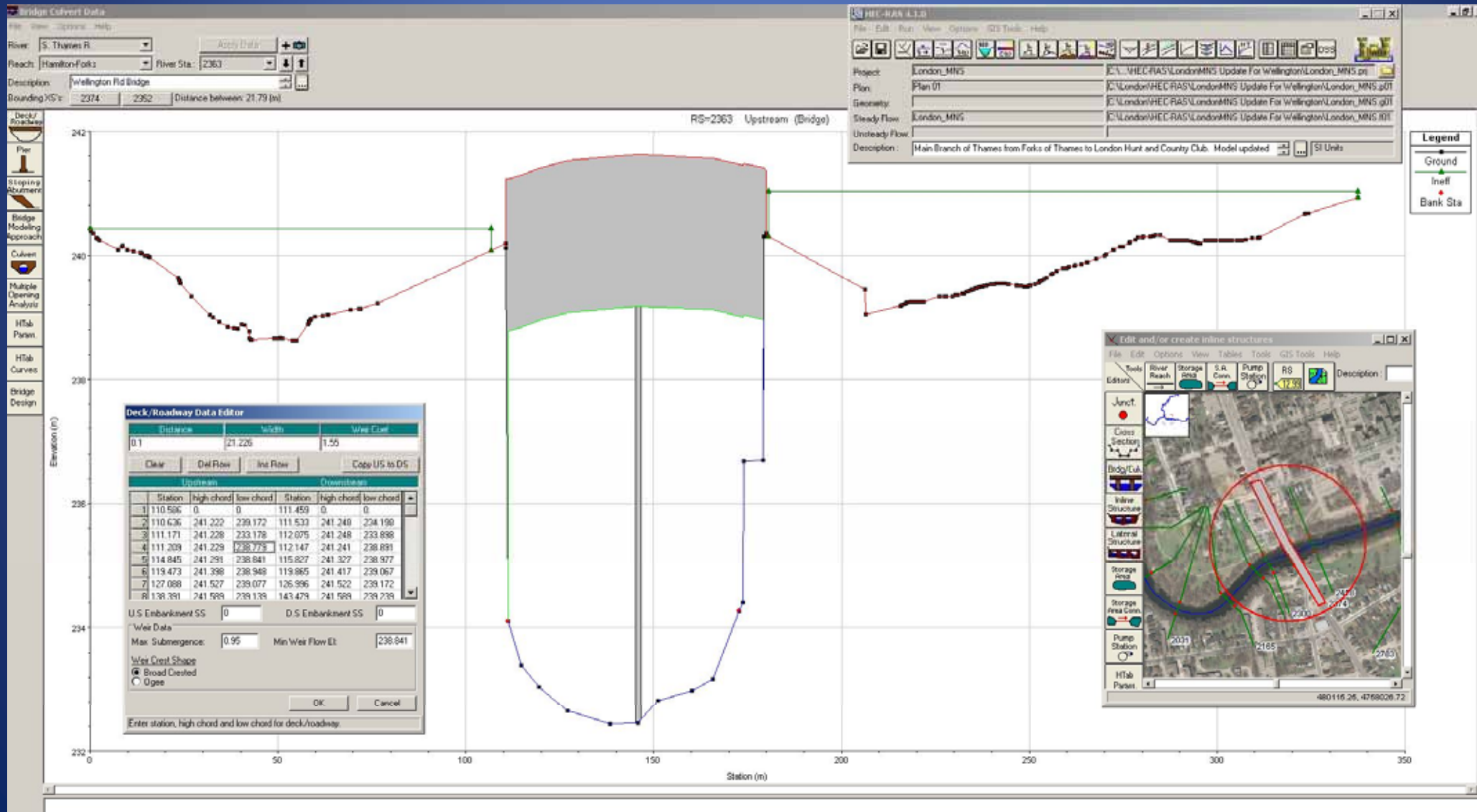
Cedar Creek



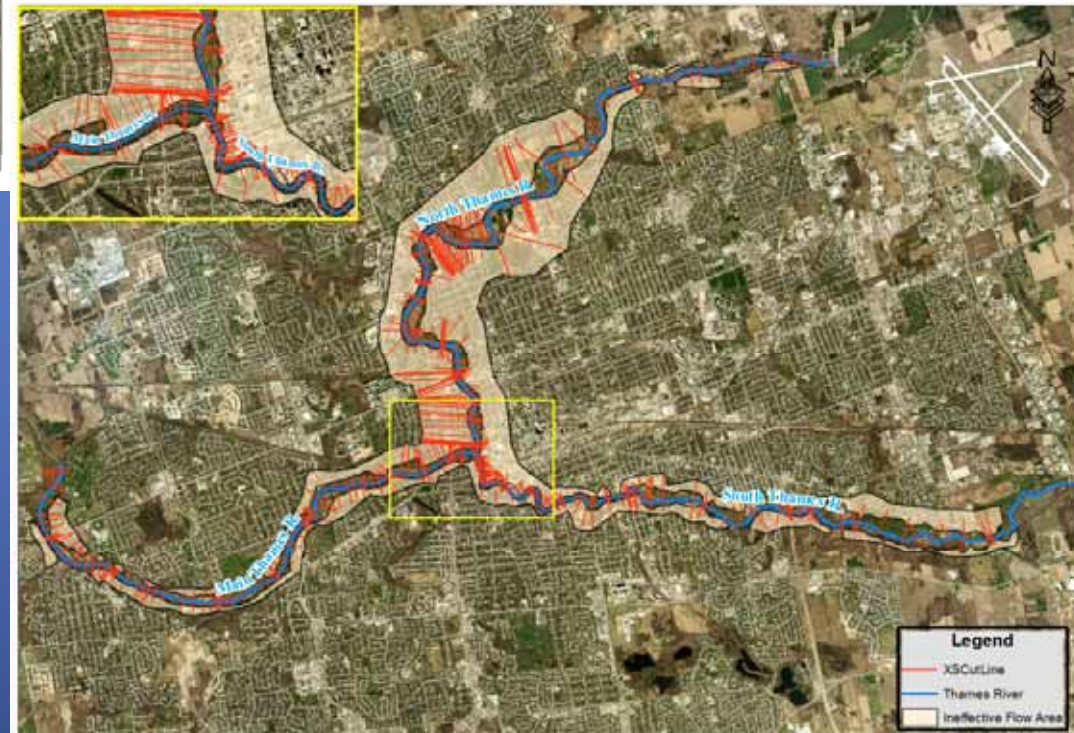
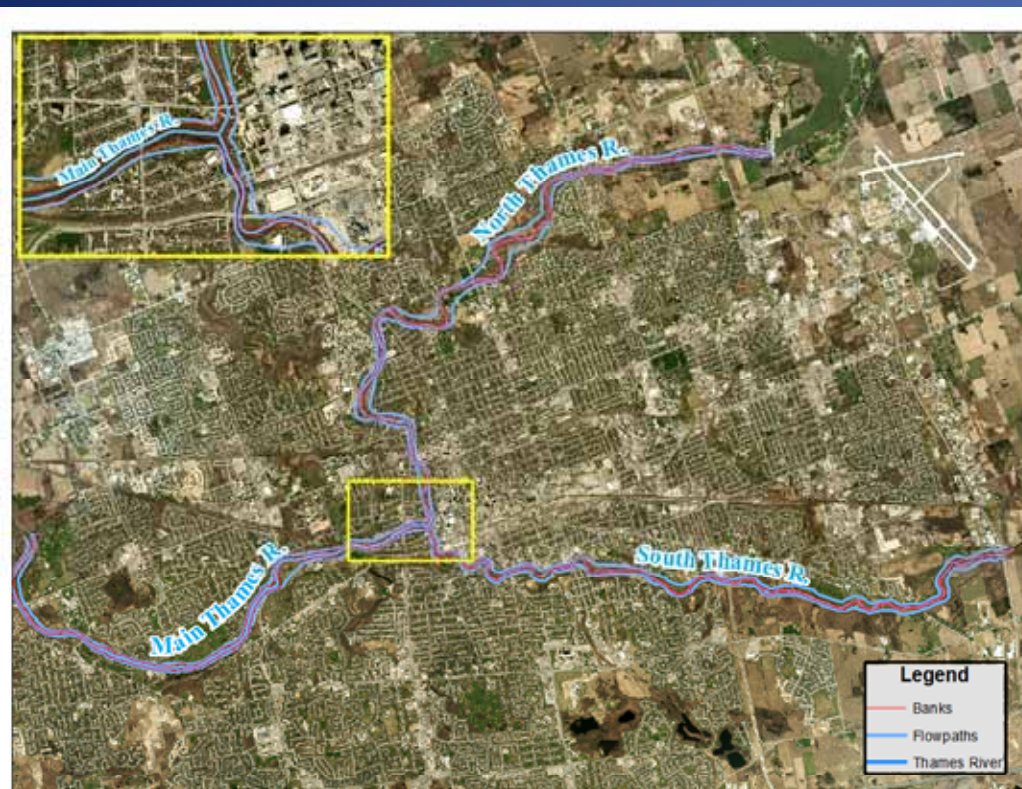
GPS Surveying Hydraulic Structures



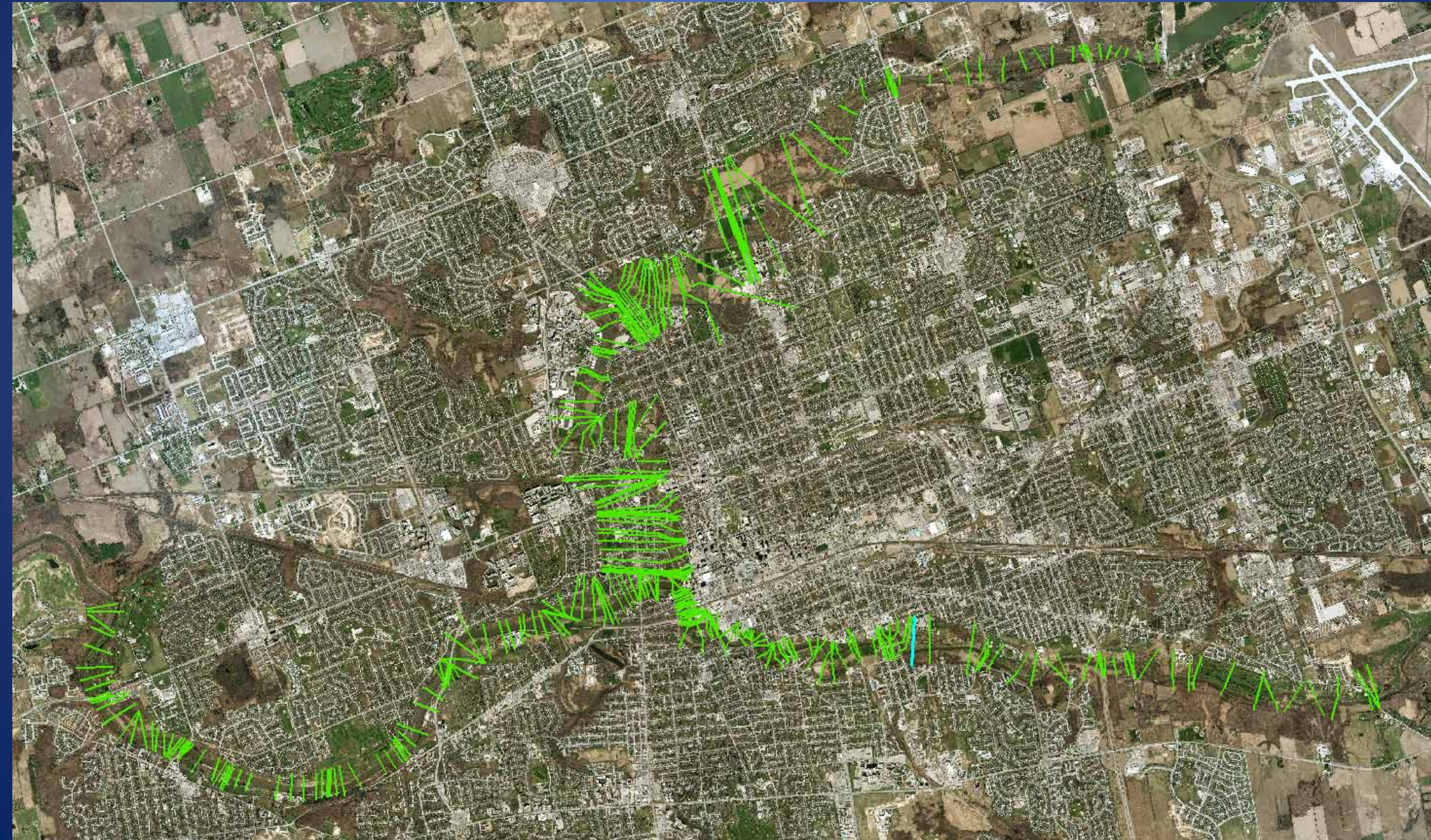
GPS Surveying Hydraulic Structures



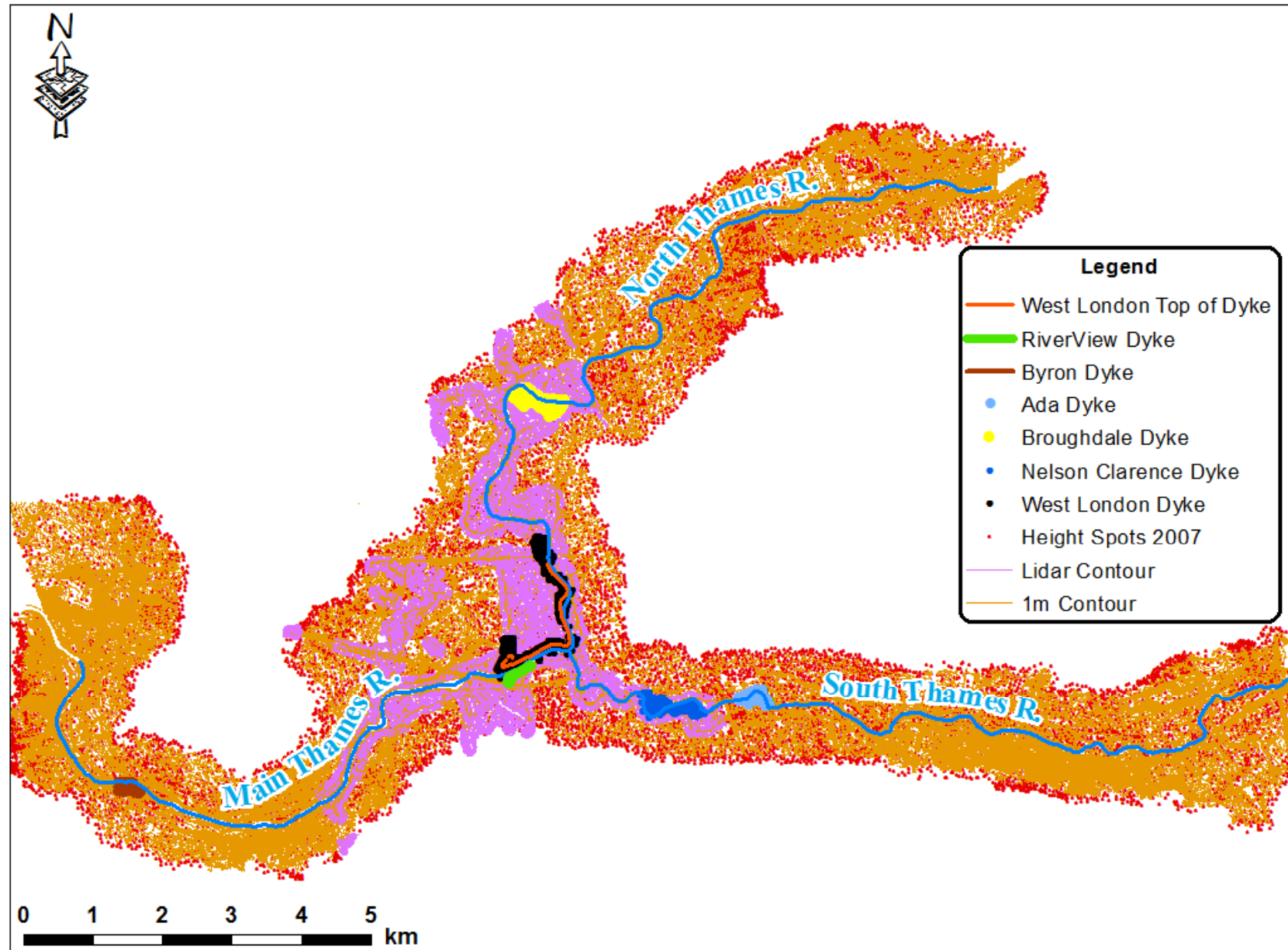
Creating Geo-Database



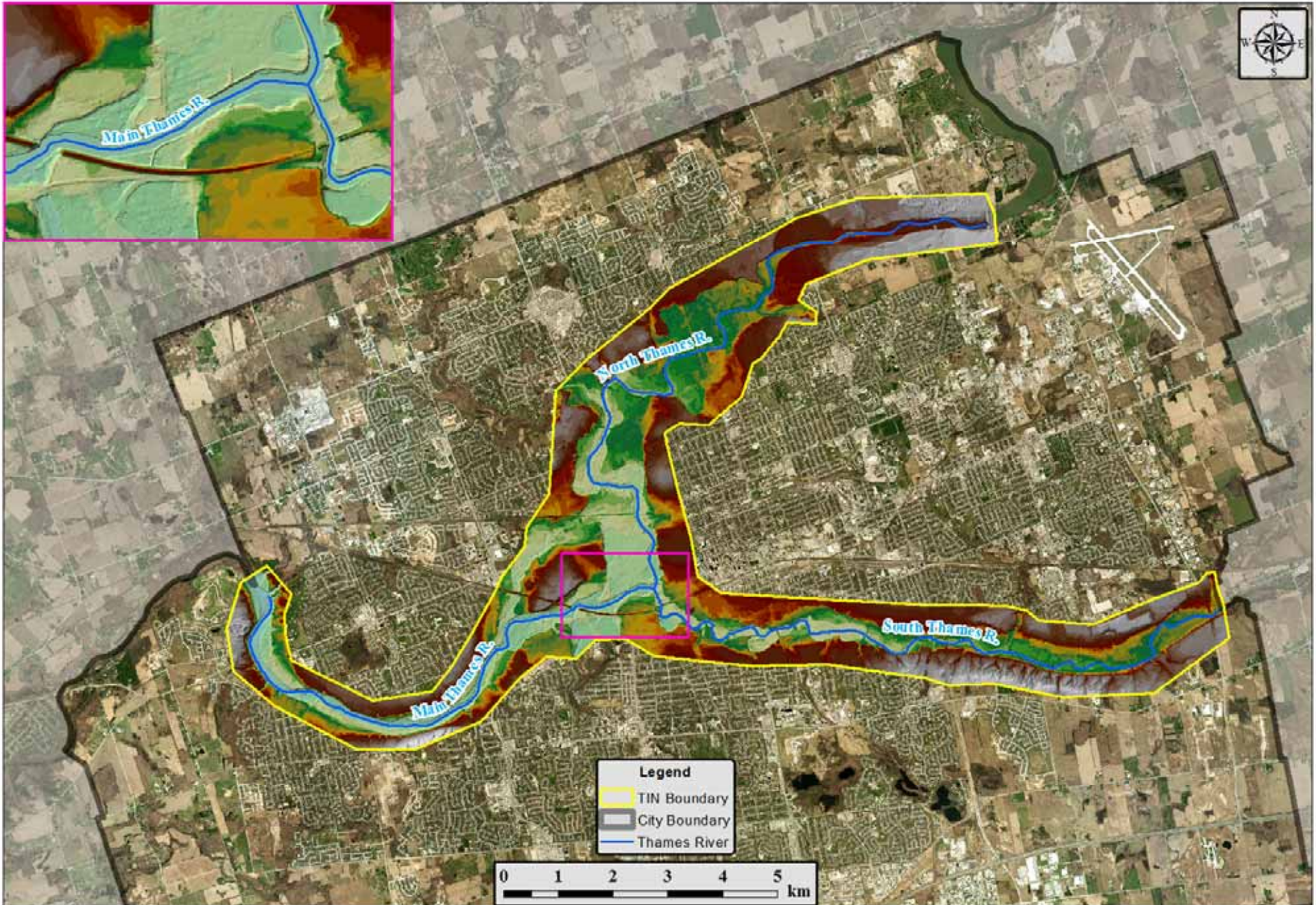
Creating Geo-Database



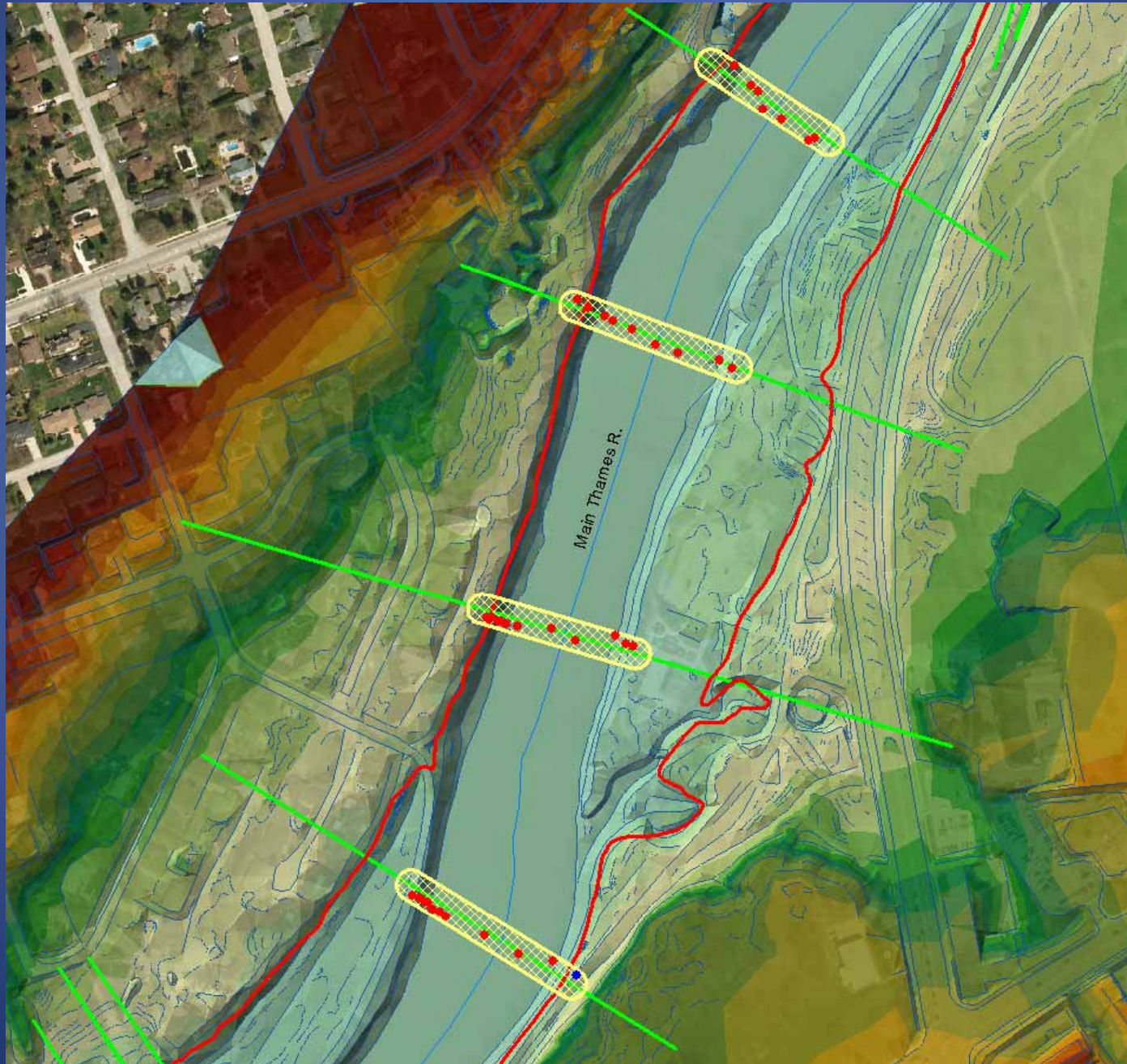
Creating TIN



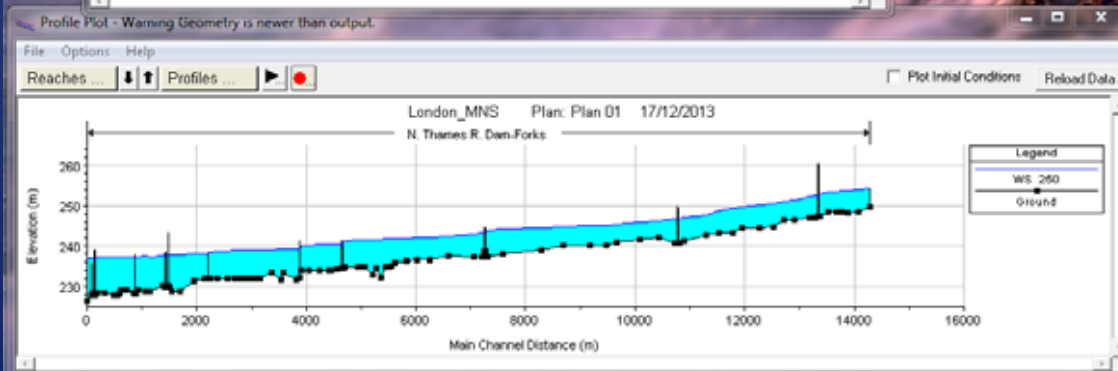
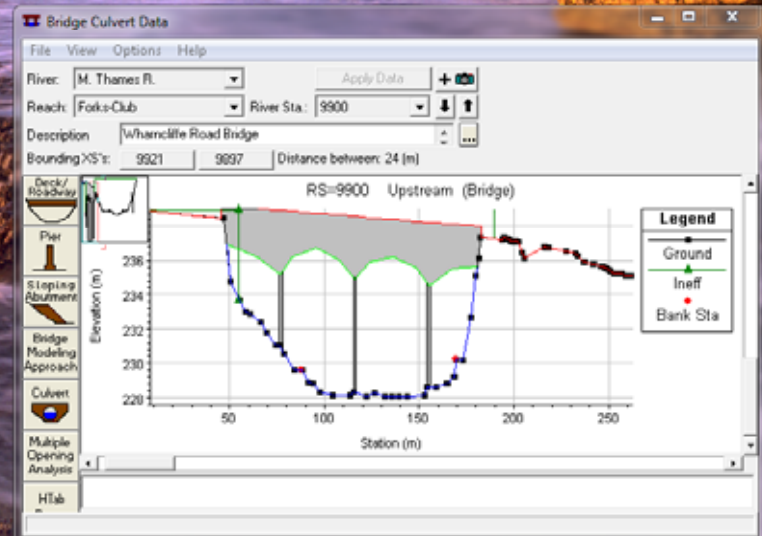
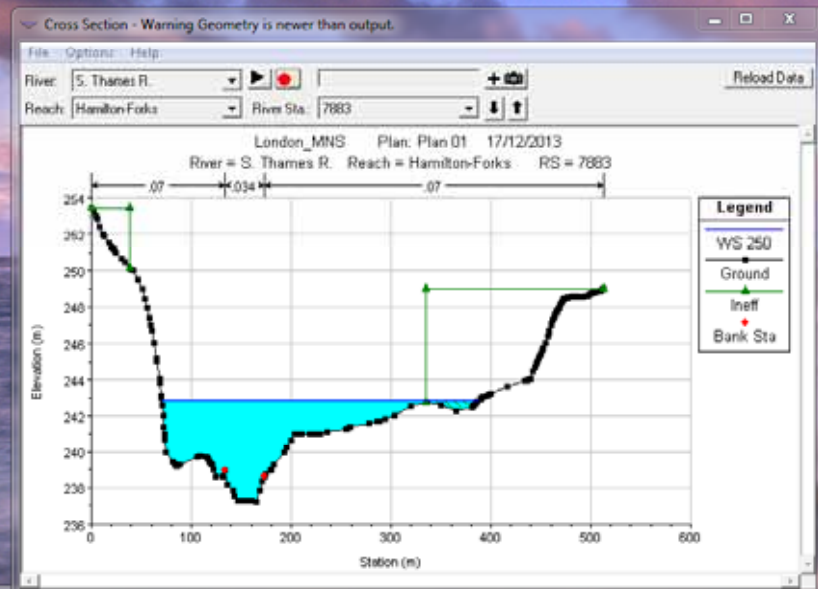
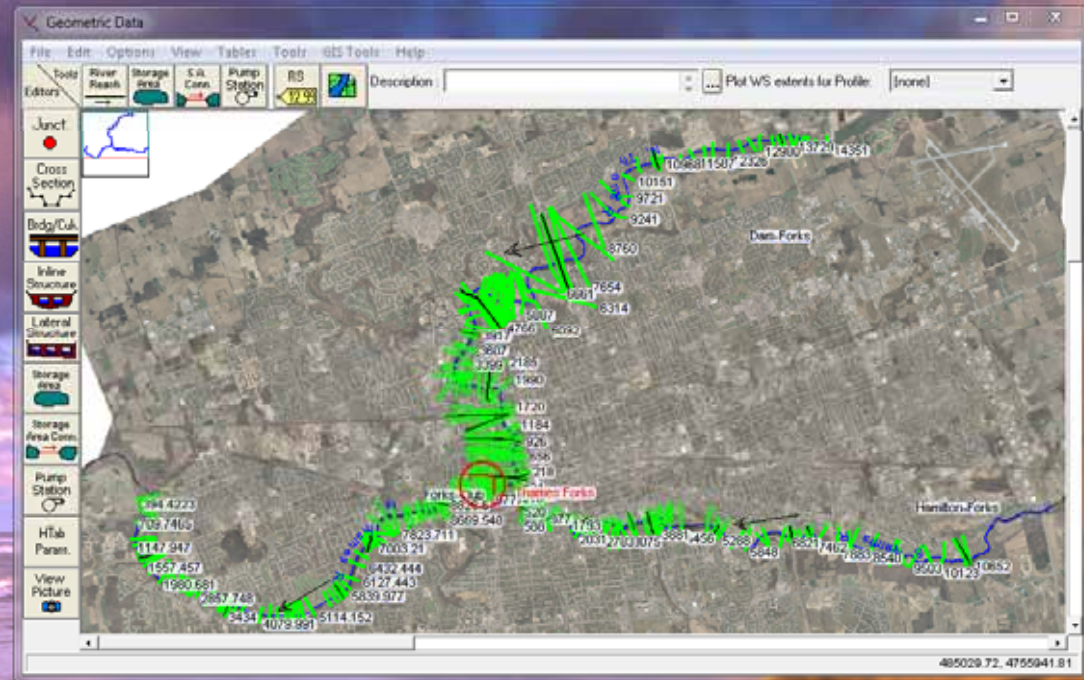
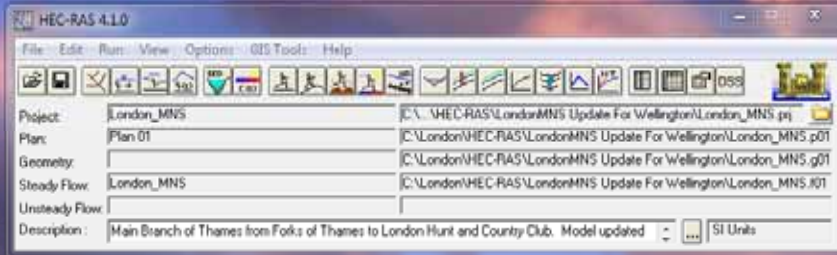
Creating TIN



Integrating Channel GPS Points

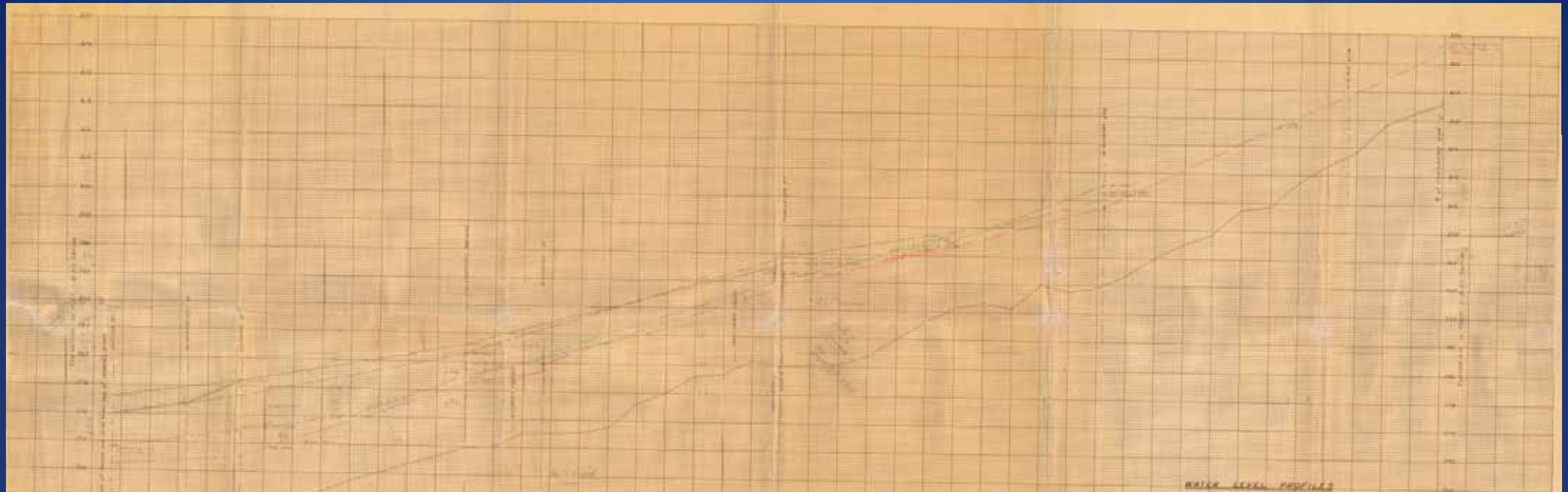


Developing HEC-RAS Hydraulic Model



Model Calibration

Historic Data



		1937 (250Y) Flood									
Location	Reach	Record (m)	Main Reach Flow 1834 (CMS)			Main Reach Flow 1750 (CMS)		Main Reach Flow 1615 (CMS)			
			Model (m)	Flow (CMS)	Diff (cm)	Model (m)	Diff (cm)	Model (m)	Diff (cm)	Model (m)	Diff (cm)
Riverside Dr.	Main	231.6	231.8	1834	20	231.6	0.00	231.3	-34		
Spring bank Dam	Main	232.2	232.2	1834	3	232	-0.19	231.7	-54		
Old Dam	Main	233.2	233.6	1834	37	233.3	0.13	232.9	-27		
Pedestrian Bridge	Main	234.0	234.1	1834	10	233.9	-0.10	233.5	-49		
Greenway Sewage	Main	235.2	235.7	1834	55	235.5	0.31	235.1	-11		
Douglas Ave.	Main	236.3	236.4	1834	14	236.2	-0.09	235.8	-50		
Whamcliffe Rd.	Main	236.4	236.5	1834	10	236.3	-0.12	235.9	-52		
Near Forks	Main	236.6	236.9	1834	27	236.6	0.00	236.2	-42		
		Average			22	0		-40			
Forks	South	236.7	236.8	850	14	236.6	-0.12	236.1	-62		
York St. Bridge	South	237.0	237.0	850	0	236.6	-0.34	236.2	-77		
CNR	South	237.1	237.1	850	8	236.8	-0.22	236.4	-62		
Ridout St. Bridge	South	237.7	237.9	850	22	237.5	-0.19	237.1	-52		
Hunt Dam	South	238.2	238.3	850	12	238.1	-0.11	237.8	-38		
Richmond Bridge	South	238.3	238.2	850	-2	238	-0.25	237.7	-55		
Wellington Bridge	South	239.1	239.4	850	35	239.3	0.20	238.9	-11		
Adelaide Bridge	South	240.0	240.3	850	34	240.3	0.34	240.3	34		
Egerton Bridge	South	240.8	241.1	850	34	241.1	0.29	241	18		
Meadowilly Bridge	South	242.3	242.6	850	29	242.8	0.26	242.6	23		
Hamilton Bridge	South	244.7	244.5	850	22	244.5	0.22	244.6	21		
		Average			19	0.00		-24			
Forks	North	236.7	236.9	1107	23	236.7	-0.05	236.2	-51		
Dundas St Bridge	North	236.7	236.9	1107	21	236.6	-0.06	236.2	-50		
Blackfriars St.	North	237.1	237.2	1107	8	236.9	-0.19	236.5	-61		
Oxford St. Br.	North	237.4	237.7	1107	30	237.5	0.07	237.1	-27		
CNR	North	237.1	237.7	1107	53	237.5	0.33	237.1	-1		
University Dr.	North	239.0	239.1	1107	10	239.1	0.05	239	-5		
Adelaide St.	North	242.8	243.1	935	25	243.1	0.24	243.1	24		
		Average			24	0.06		-24			

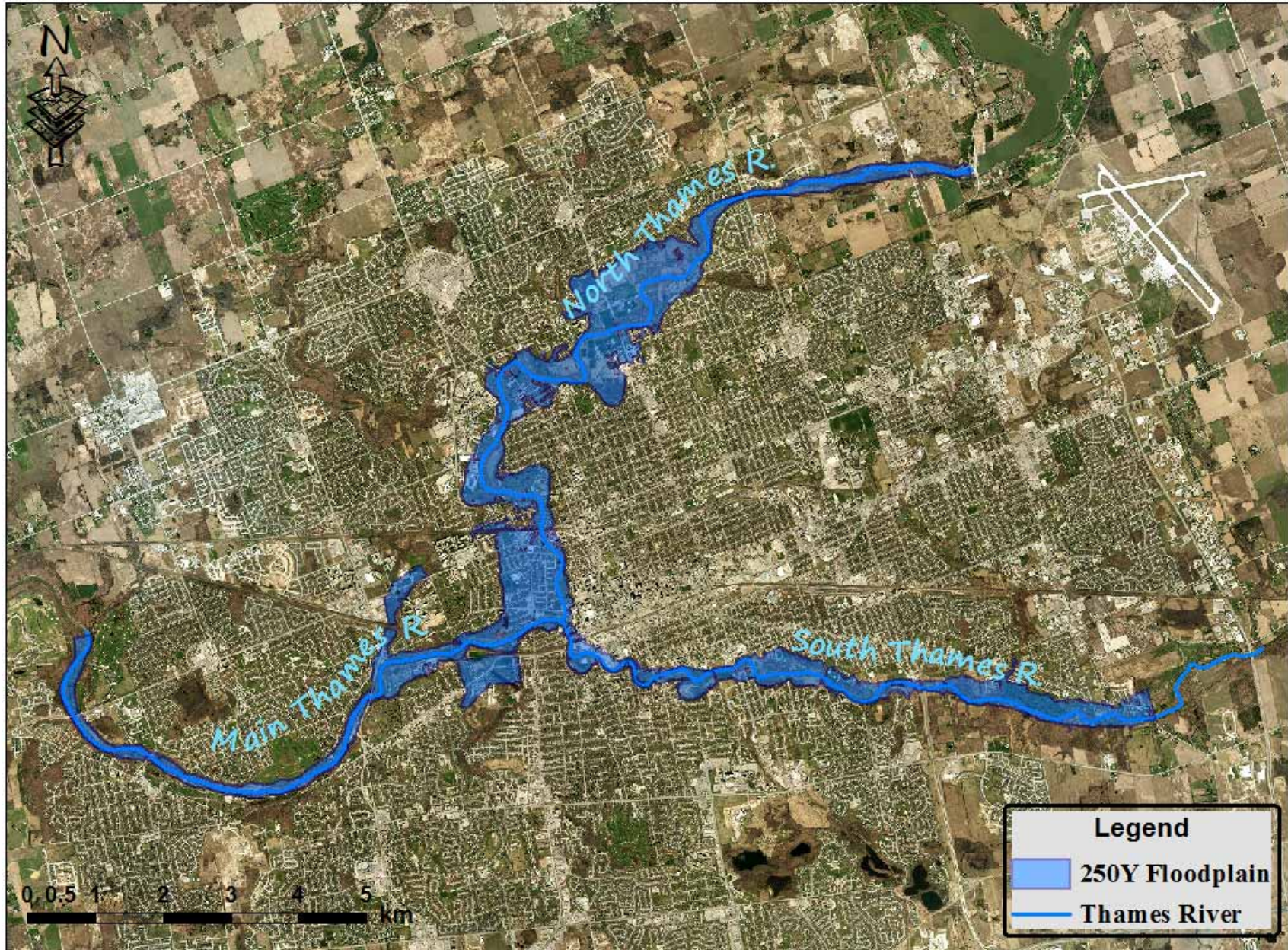
		1977 Flood				1937 Flood			
Location	Reach	Record (m)	Model (m)	Flow (CMS)	Diff (cm)	Record (m)	Model (m)	Flow (CMS)	Diff (cm)
Spring bank Dam	Main			966		232.2	232.2	1834	3
Old Dam	Main			966		233.2	233.6	1834	37
Pedestrian Bridge	Main			966		234.0	234.1	1834	10
Greenway Sewage	Main	232.9	232.9	966	-6	235.2	235.7	1834	55
Douglas Ave.	Main	233.5	233.6	966	11	236.3	236.4	1834	14
Whamcliffe Rd.	Main	233.7	233.7	966	7	236.4	236.5	1834	10
Near Forks	Main	234.0	234.0	966	-1	236.6	236.9	1834	27
		Average			3	Average			22
Forks	South			411		236.7	236.8	850	14
York St. Bridge	South	233.7	234.0	411	34	237.0	237.0	850	0
CNR	South	233.6	234.2	411	56	237.1	237.1	850	8
Ridout St. Bridge	South	234.3	234.6	411	32	237.7	237.9	850	22
Hunt Dam	South	235.3	235.4	411	9	238.2	238.3	950	12
Richmond Bridge	South	235.3	235.4	411	5	238.3	238.2	850	-2
Wellington Bridge	South	235.8	236.5	411	87	239.1	239.4	850	35
Adelaide Bridge	South	237.7	238.0	411	37	240.0	240.3	850	34
Egerton Bridge	South	238.3	238.6	411	27	240.8	241.1	850	34
Highbury Bridge	South	239.9	240.1	411	25			850	
Meadowilly Bridge	South			411		242.3	242.6	850	29
Hamilton Bridge	South	242.8	242.8	411	15	244.2	244.3	850	22
		Average			33	Average			19
Forks	North			715		236.7	236.9	1107	23
Dundas St Bridge	North	234.0	234.0	715	-1	236.7	236.9	1107	21
Queen St Bridge	North	233.9	234.0	715	9			1107	
Blackfriars St.	North	234.3	234.4	715	7	237.1	237.2	1107	8
Oxford St. Br.	North	234.9	235.1	715	21	237.4	237.7	1107	30
CNR	North			715		237.1	237.7	1107	53
University Dr.	North	238.0	238.0	715	-1	239.0	239.1	1107	10
Richmond St. N	North	239.6	239.6	569	0			935	
Adelaide St.	North	242.7	242.6	569	-8	242.8	243.1	935	25
Windemere Rd	North	243.5	243.5	569	-3			244.5	935
Highbury Ave.	North	245.8	245.9	569	5			246.9	935
Clarke Rd.	North	251.5	251.5	569	0			252.6	935
		Average			3	Average			24

Model Calibration

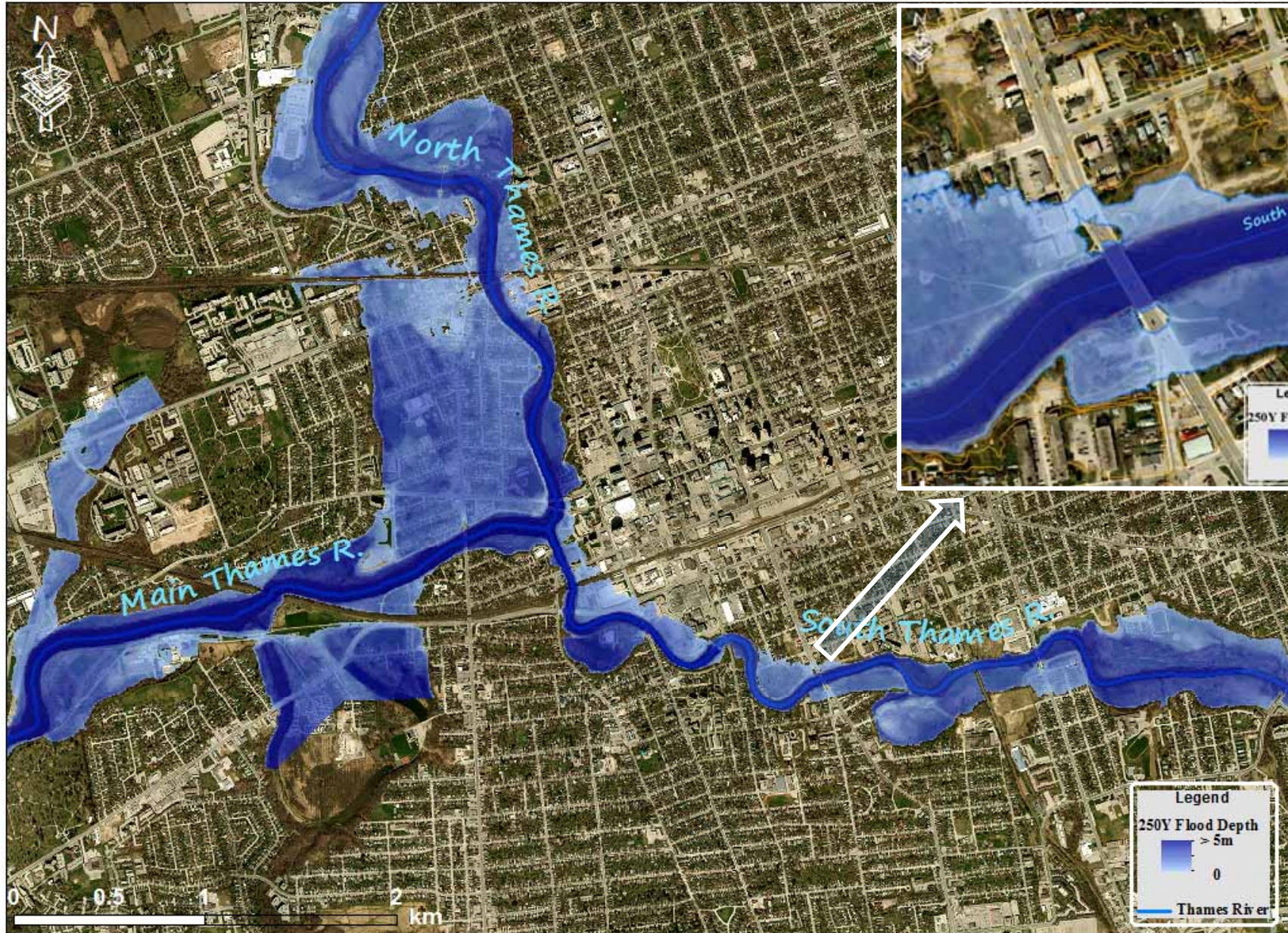
High Water Marking, Valuable Data for Calibration



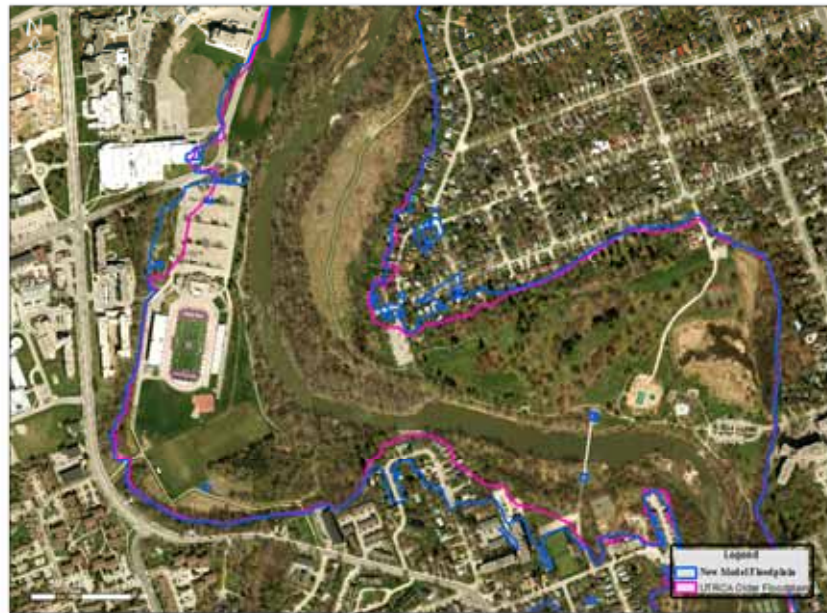
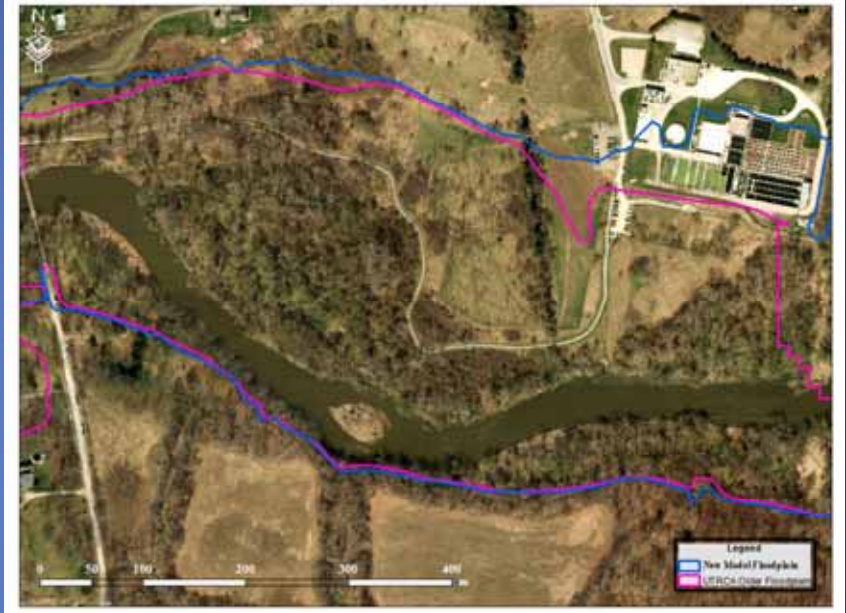
Flood Mapping



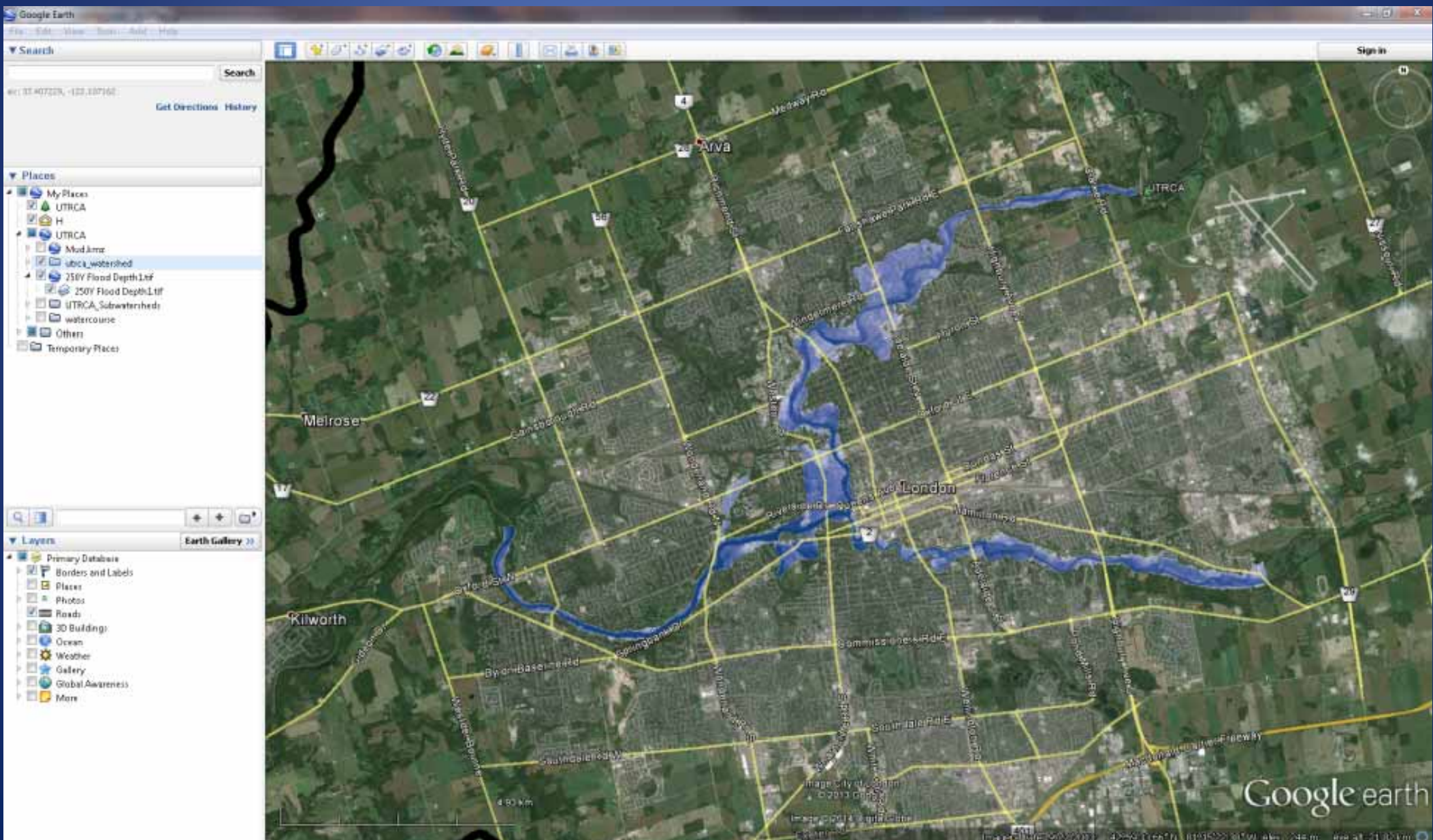
Flood Mapping



Old vs. New Flood Lines



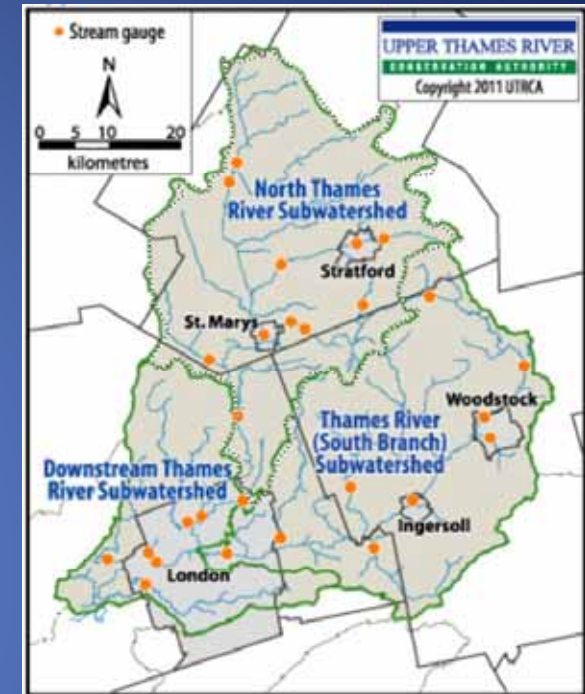
Flood Mapping Potentials



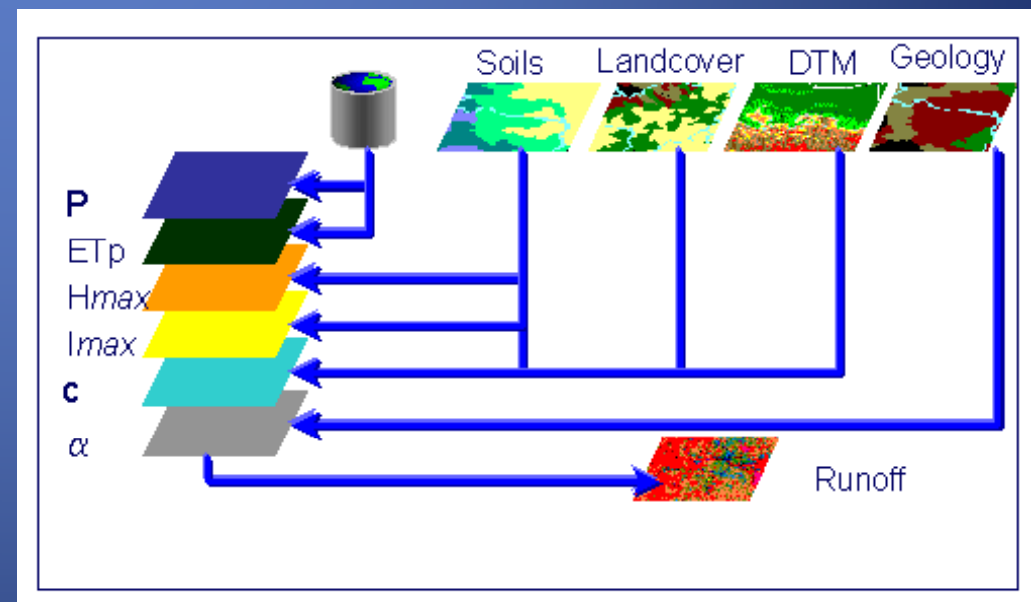
Hydrology Methods



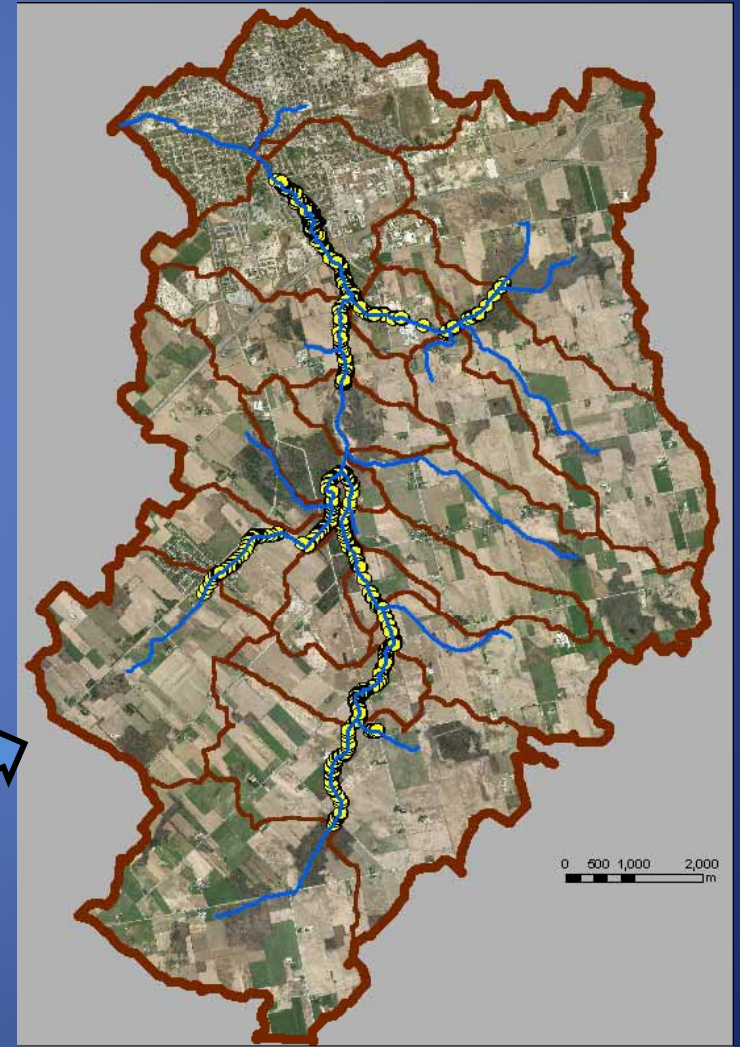
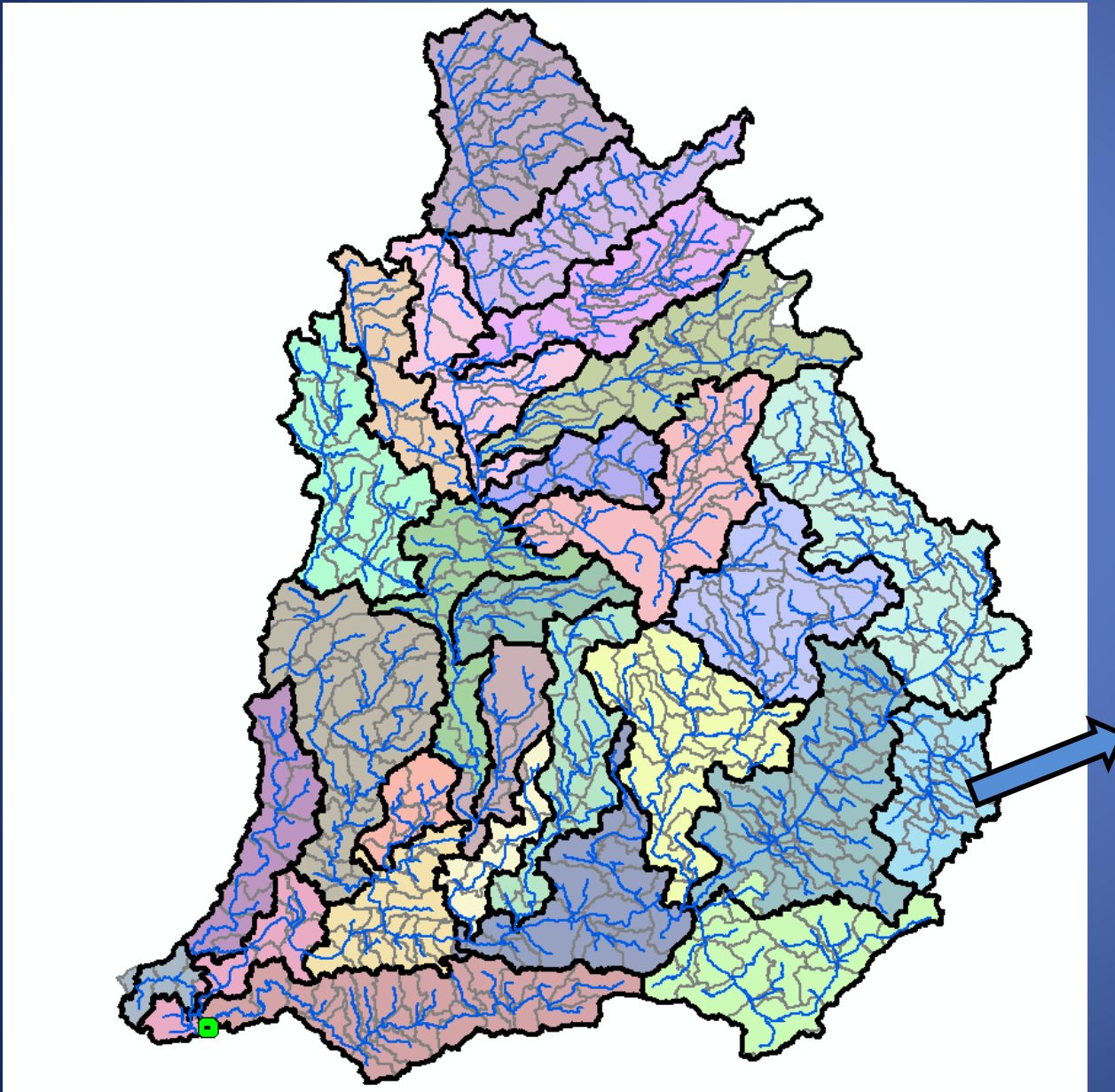
- Statistical Analysis of Flow Data



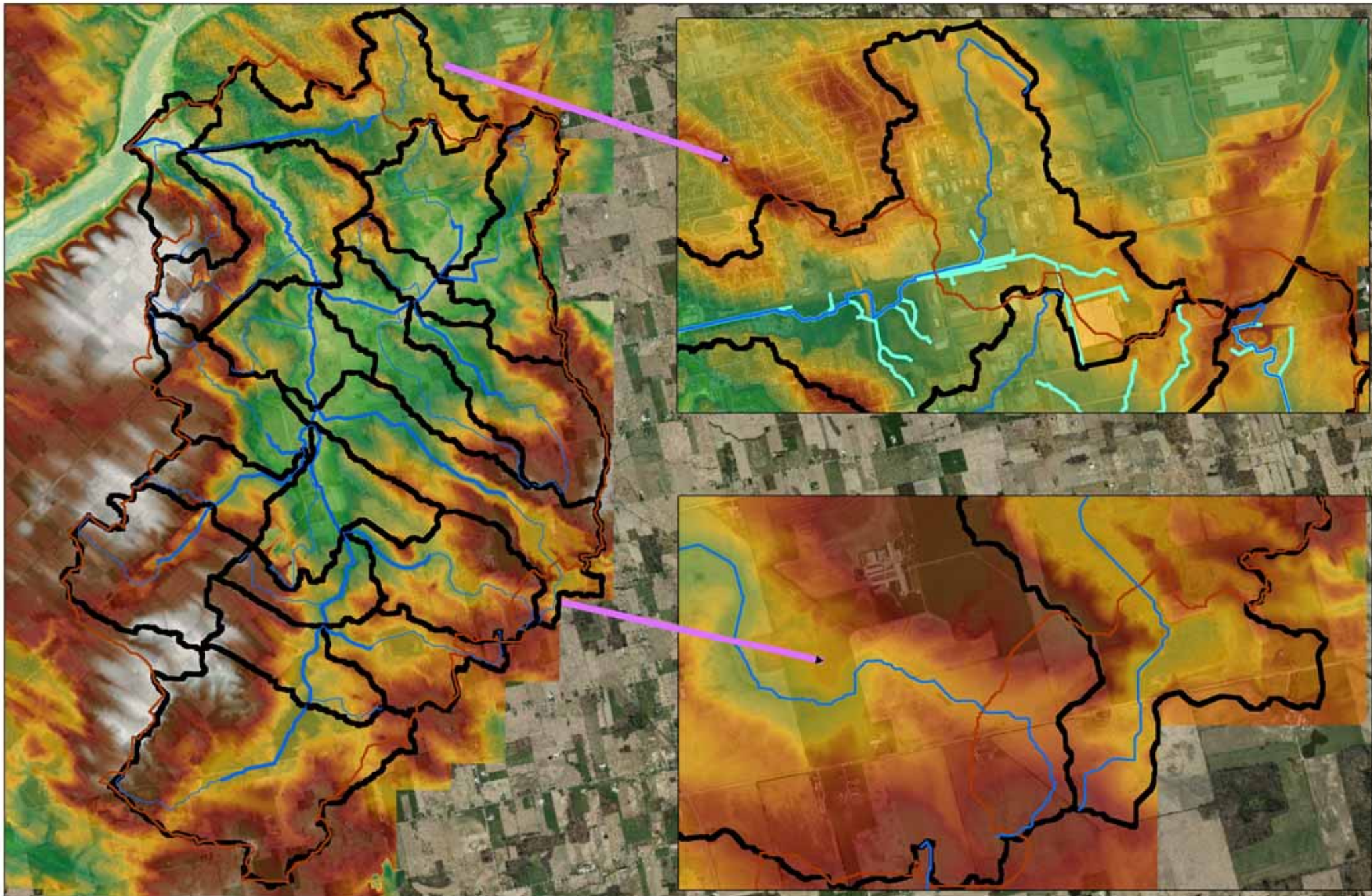
- Hydrologic Models



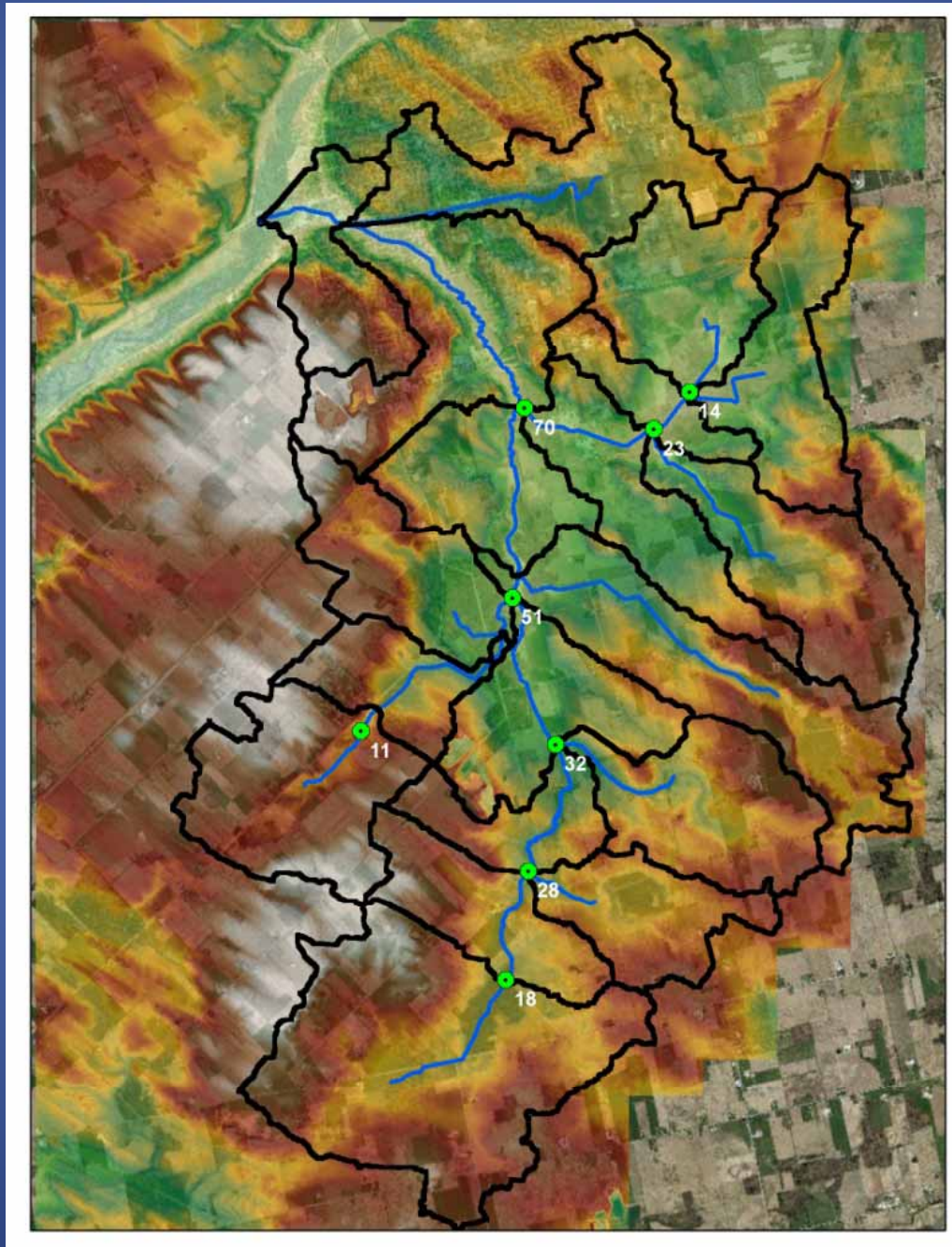
Catchment Delineation



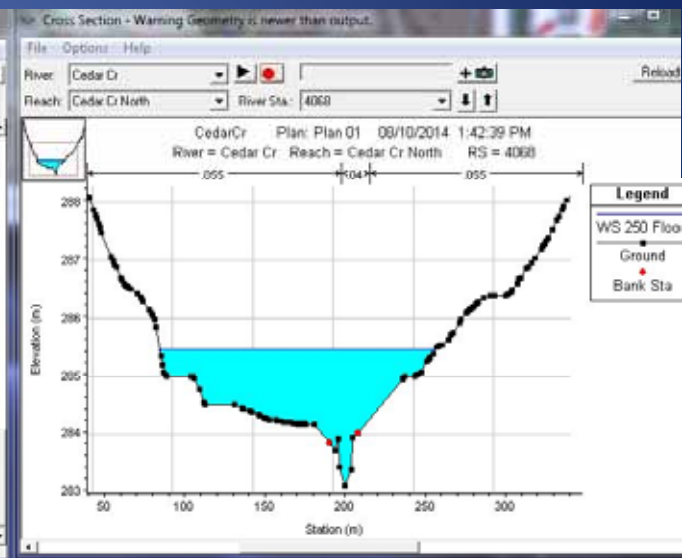
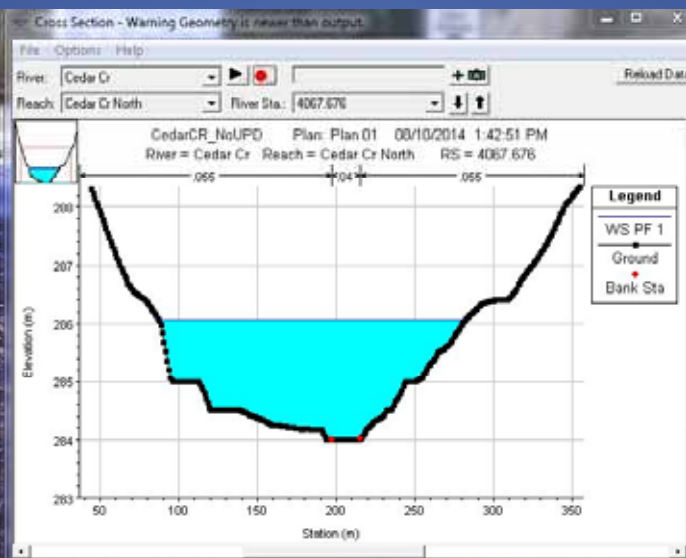
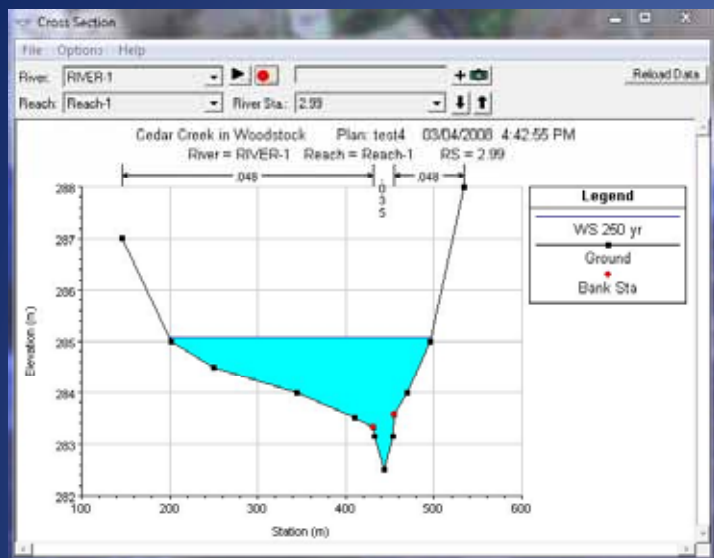
Catchment Delineation



Flow Calculation



With or Without GPS Survey With or Without DEM



Developing HEC-RAS Hydraulic Model



HEC-RAS 4.1.0

File Edit Run View Options GIS Tools Help

Project: CedarCr C:\Cedar\RAS\HEC\CedarCr.prj
 Plan: Plan 01 C:\Cedar\RAS\HEC\CedarCr.p01
 Geometry: CedarCr C:\Cedar\RAS\HEC\CedarCr.g01
 Steady Flow: CedarCr C:\Cedar\RAS\HEC\CedarCr.f01
 Unsteady Flow:
 Description: SI Units

Steady Flow Data - CedarCr

File Options Help

Enter/Edit Number of Profiles (25000 max): 1 Reach Boundary Conditions ... Apply Data

Locations of Flow Data Changes

River: Cedar Cr Add Multiple...
 Reach: Cedar Cr South River Sta.: 15181 Add A Flow Change Location

Flow Change Location			Profile Names and Flow Rates	
River	Reach	RS	250 Flood	
1	Cedar Cr	Cedar Cr South	15181	18.5
2	Cedar Cr	Cedar Cr South	13464	28.26
3	Cedar Cr	Cedar Cr South	11012	32
4	Cedar Cr	Cedar Cr Middle	8664	50.6
5	Cedar Cr	Cedar Cr North	5697	70
6	Cedar Cr East	Cedar Cr East	2690	14.2
7	Cedar Cr East	Cedar Cr East	1938	23.4
8	Cedar Cr West	Cedar Cr West	3505	11.4

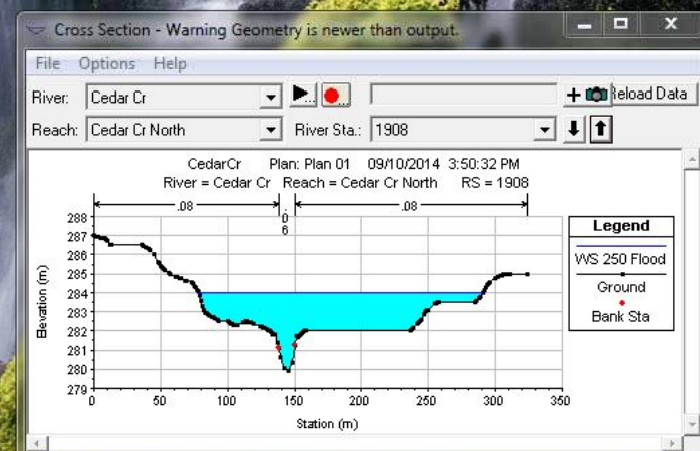
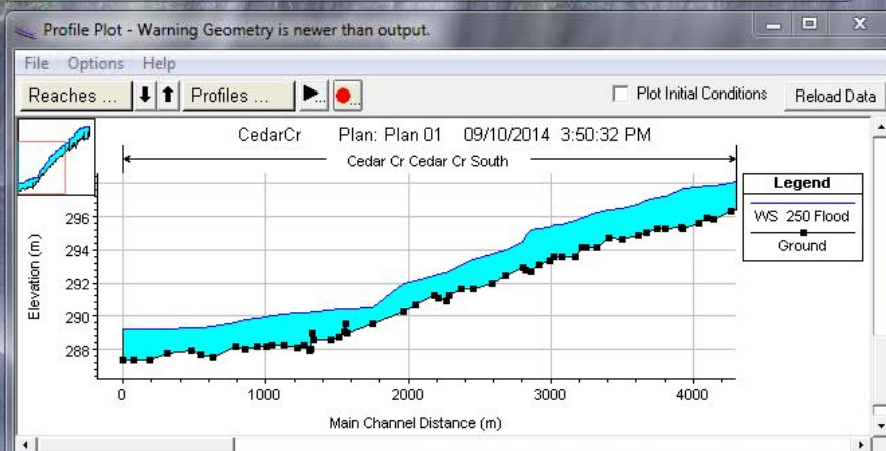
Edit Steady flow data for the profiles (m3/s)

Geometric Data - CedarCr

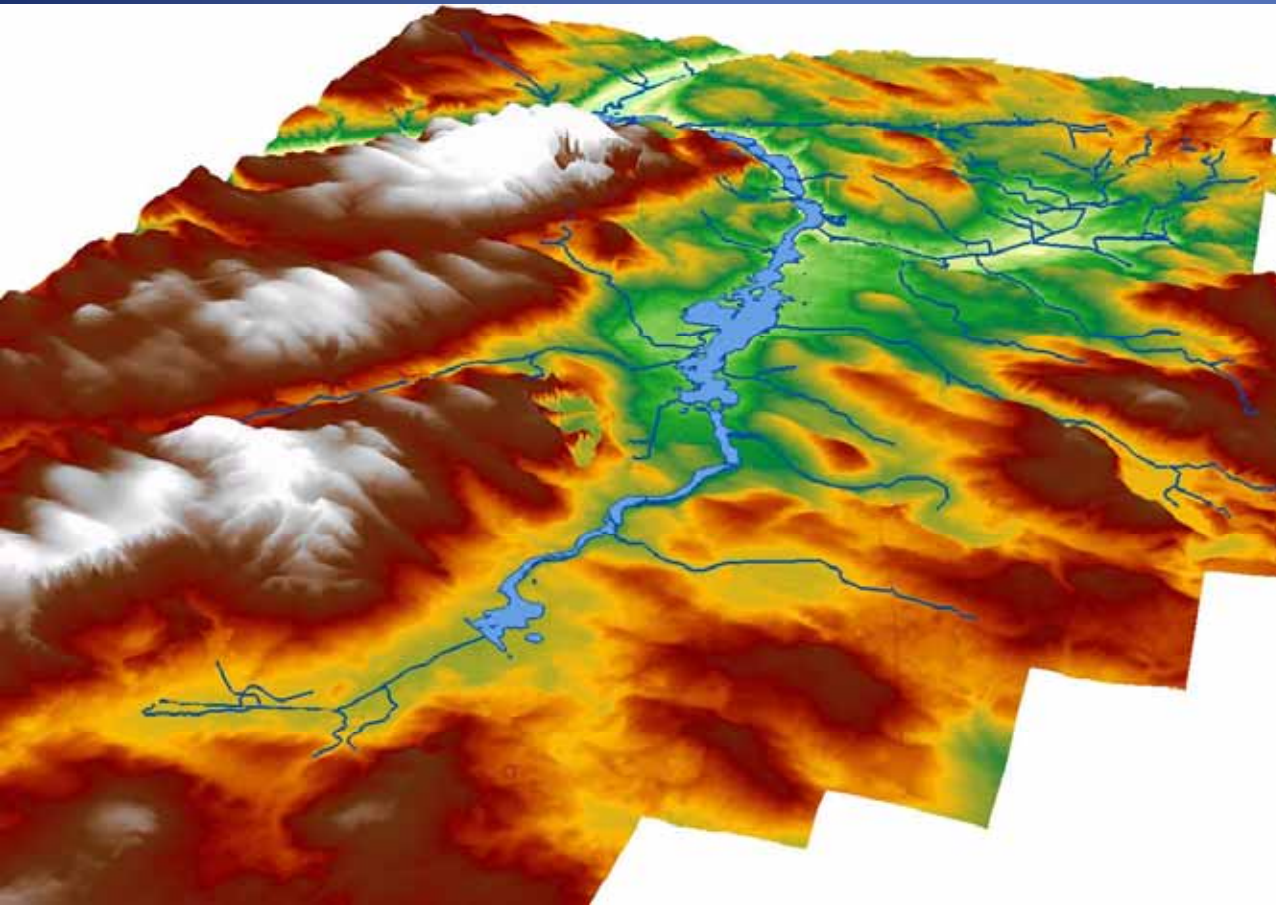
File Edit Options View Tables Tools GIS Tools Help

Tools River Reach Storage Area S.A. Conn. Pump Station RS Description: 12.99

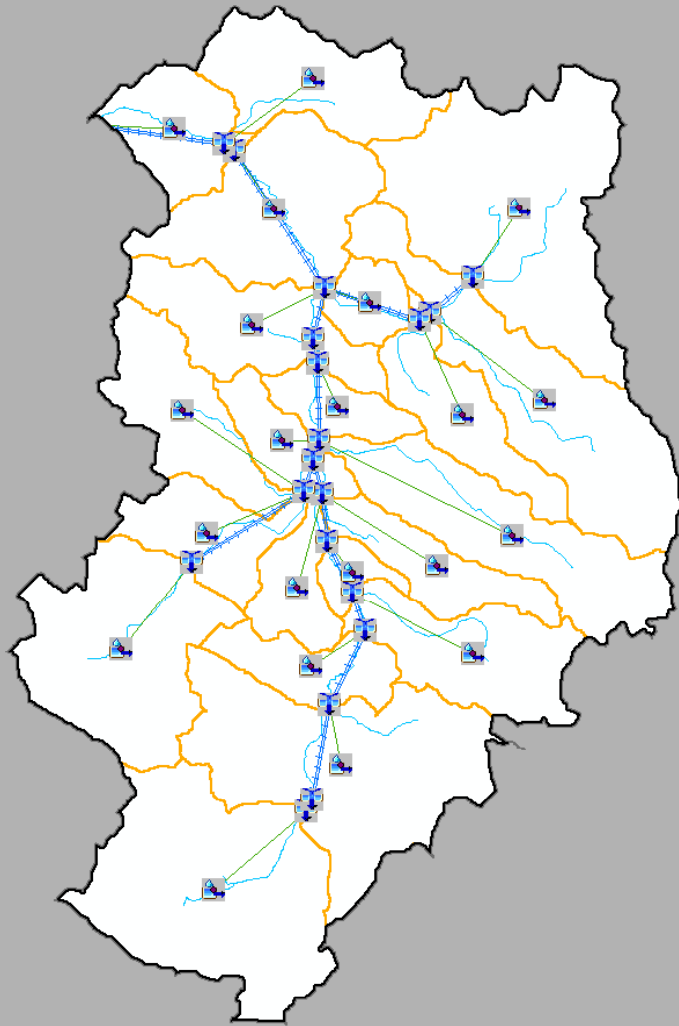
518913.24, 4764234.77



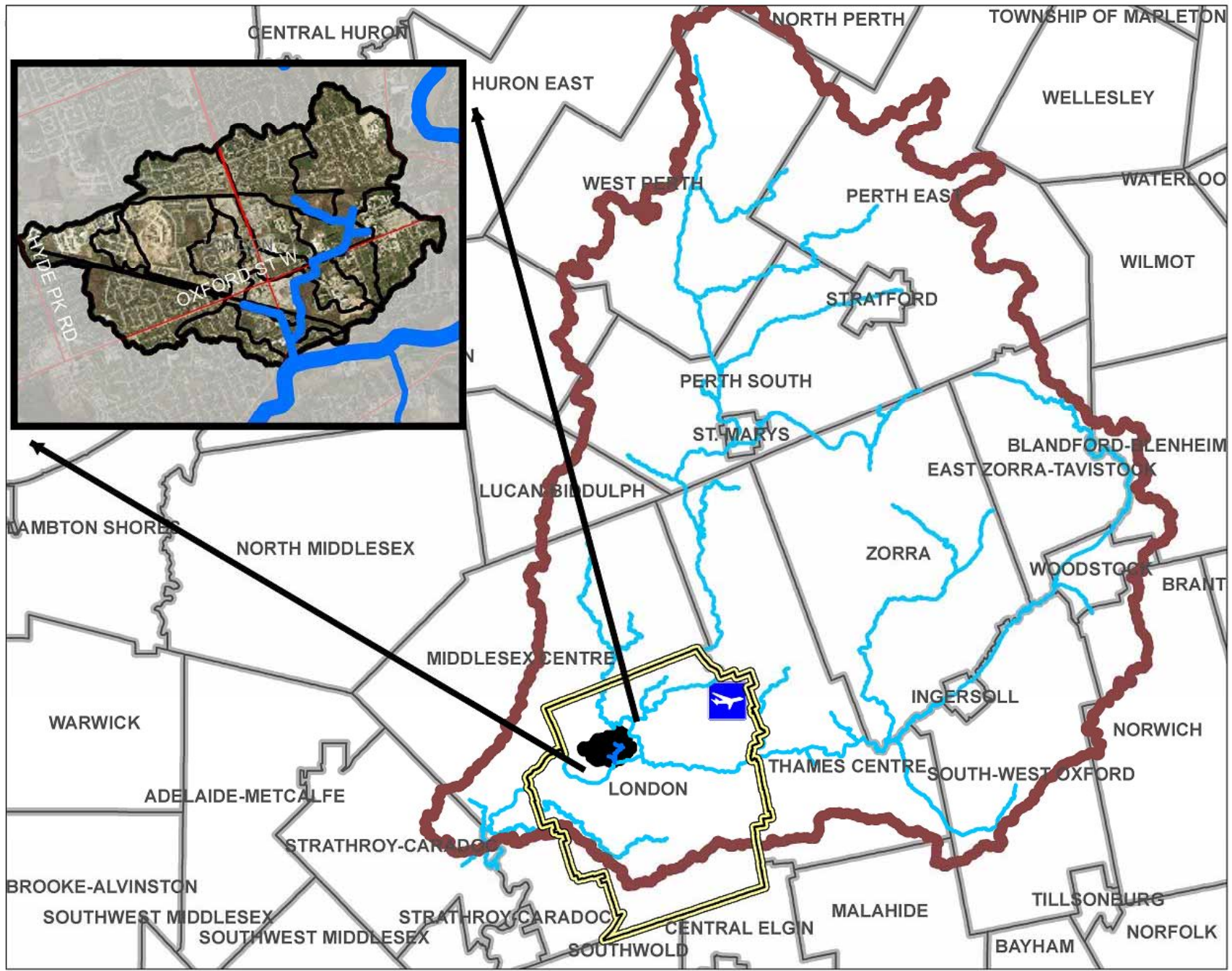
Flood Mapping



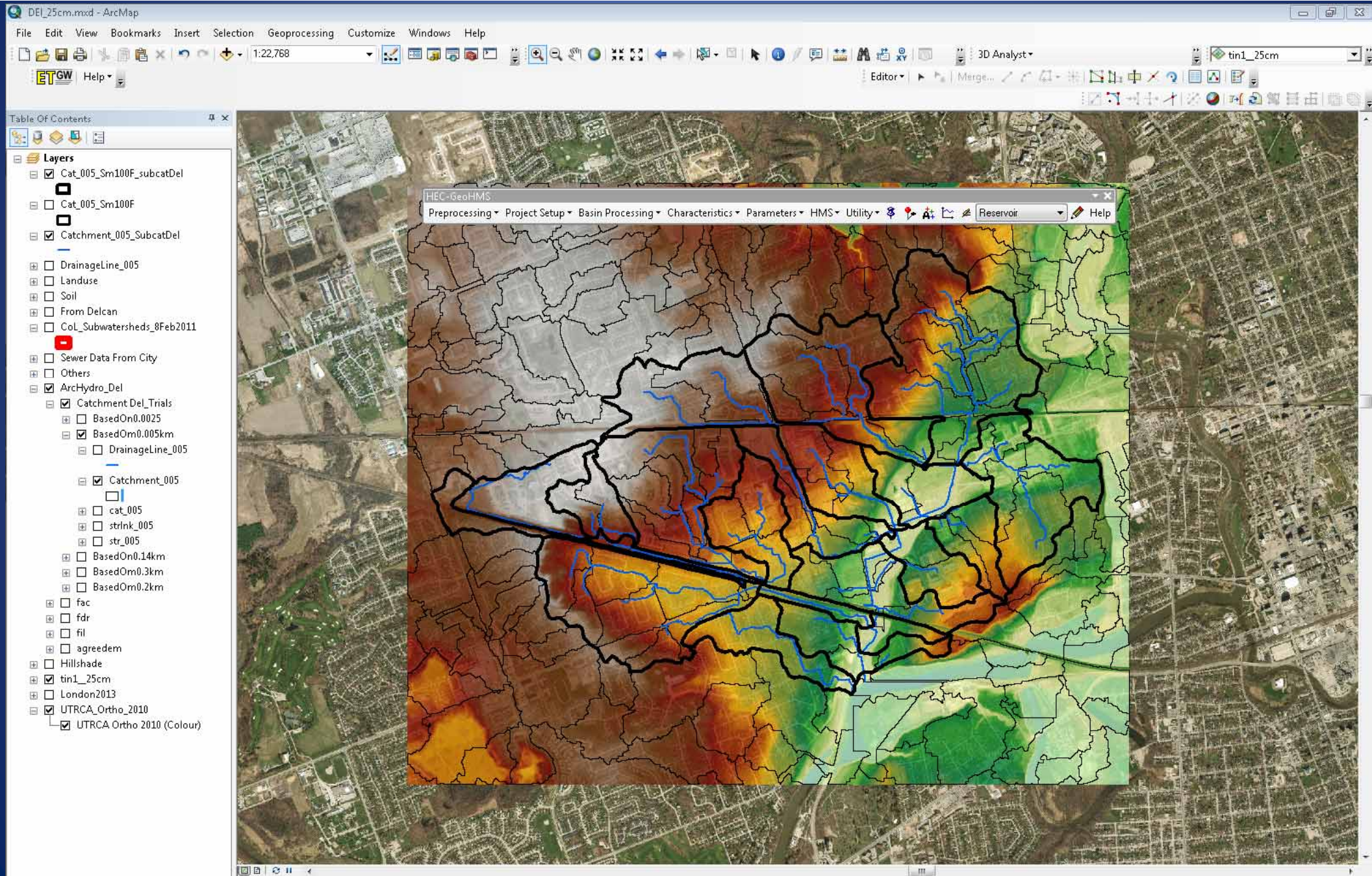
Developing Hydrologic Model in GIS



Mud Creek Study Area



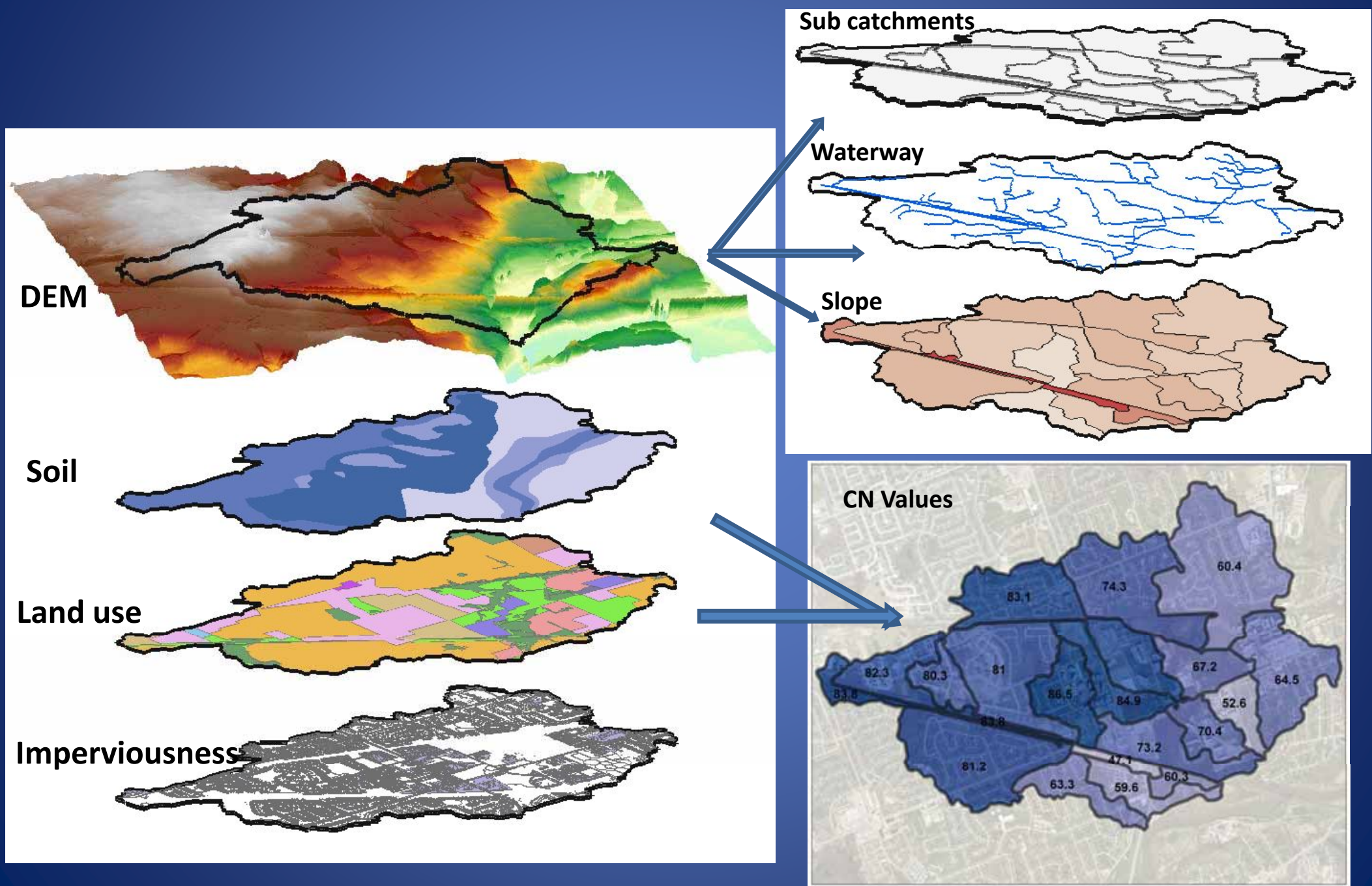
Catchment Delineation in Mud Creek



Catchment Delineation in Mud Creek



Hydrologic Model Development



Hydrologic Model Mud Creek 2013 Flood



PCSWMM 2013 Professional 2D -- MudCreek5_2013Storm_Flow Length Change

File Map Table Graph Profile Details Status Documentation

Project: Map

Simulation Options: Climatology, Rain Gages, Aquifers, Snow Pads, Unit Hydrographs, LID Controls, Transects, Control rules, Pollutants, Land Uses, Curves, Time Series, Time Patterns

Layers:

- Junctions
- Outfalls
- Dividers
- Storages
- Conduits
- Pumps
- Orifices
- Weirs
- Outlets
- Subcatchments
- DrainageLine_005
- StrMH
- StrPipes
- UT_UT ...
- CulvertsFromCkyLayer
- RiverFromDelcan
- London2007_15cm50x
- w001001

Map: [Aerial view of the model area with conduits and junctions highlighted in blue and green.]

Profile:

- Conduit C11: Flow = 2.5 m³/s, Depth = 2.896 m
- Conduit C10: Flow = 4.311 m³/s, Depth = 3.204 m
- Conduit C1: Flow = 7.429 m³/s, Depth = 2.585 m

Tables: Conduits

Name	Inlet Node	Outlet Node	Description	Tag	Length (m)	Roughness	Inlet Offset (m)	Outlet Offset (m)
C3	SWMF-1	SWMF-2			798.93	0.01	0	
C4	SWMF-2	J4			355.05	0.01	0	
C5	J4	SWMF-3			521.46	0.01	0	
C6	J3	J4			1238.23	0.01	0	
C8	SWMF-3	J6			149.56	0.01	0	
C10	J9	J10			121.87	0.01	0	
C13	J12	J9			767.6	0.01	0	
C9	J8	J10			211.35	0.01	0	
C11	J7	J9			367.38	0.01	0	
C14	J11	J14			53.4	0.01	0	
C10	J15	J16			88.06	0.01	0	
C19	J6	J16			240.83	0.01	0	
C20	J16	J17			213.21	0.01	0	
C15	J14	J19			214.02	0.01	0	

Attributes:

- Transect: C1
- Conduit: C1
- Name: C1
- Inlet Node: J10
- Outlet Node: J1
- Description: Tag
- Length (m): 346.15
- Roughness: 0.01
- Inlet Offset (m): 0
- Outlet Offset (m): 0
- Initial Flow (m³/s): 0
- Flow Limit (m³/s): 0
- Entry Loss Coeff.: 0
- Exit Loss Coeff.: 0
- Avg. Loss Coeff.: 0
- Flap Gate: NO
- Cross Section: IRREGULAR
- Geom1 (m): 0
- Geom2 (m): 0
- Geom3 (m): 0
- Geom4 (m): 0
- Barrels: 1
- Transect: C1
- Shape Curve: Culvert Code
- Results:
 - Max. Flow (m³/s): 14.848
 - Time Max. Flow: 01/20/2014 01:
 - Max. Velocity (m/s): 0.57
 - Max/Full Flow: 0.16
 - Max/Full Depth: 0.56
 - Max. Spread (m): 39.537
 - Full Both Ends (h): 0
 - Full Upstream (h): 0
 - Full Downstream (h): 0
 - Above Full Normal: 0
 - Capacity Limited (h): 0
- Shape:
 - Slope (m/m): 0.0019
 - Lid: 17
 - Count: 1
 - Points: 8
 - Parts: 1

Graph:

- Series: [Graph showing flow rate (m³/s) and total flow (m³/s) over time from Jan 28 to Jan 29, 2014. A vertical red line marks the time 1/28/2014 8:32:00 AM.

Graph Status Details Documentation

1/28/2014 8:32:00 AM

Hydrologic Model Chicago 3h Storm



PCSWMM 2013 Professional 2D -- MudCreek5_Flow Length Change

File Map Table Graph Profile Details Status Documentation

Project: Map

Title: Simulation Options, Climatology, Rain Gages, Aquifers, Snow Packs, Unit Hydrographs, LID Controls, Transsects, Control rules, Pollutants, Land Uses, Curves, Time Series, Time Patterns

Layers: Junctions, Outfalls, Dividers, Storages, Conduits, Pumps, Orifices, Weirs, Outlets, Subcatchments, DrainageLine_005, StnMH, Stn Pipes, UT_UT ..., CulvertsFromCityLayer, Landuse, RiverFromDelcan, London2007_15Cov50c, w001001

Open Street Maps

Table: Subcatchments

Name	X-Coordinate	Y-Coordinate	Description	Tag	Rain Gage	Outlet	Area (ha)	Width (m)	FL (m)
S1	477010.697152441	4760432.60714467			Chicago_3hr	J7	110.4591	3301.705	3
S2	475602.04444434	4759997.28413412			Chicago_3hr	J2	86.5903	2737.471	3
S3	477571.360830448	4759546.07860984			Chicago_3hr	J8	61.9397	2319.739	3
S4	476198.461360595	4760311.49054077			Chicago_3hr	J12	75.7026	2755.944	2
S5	476826.605054886	4759581.68550489			Chicago_3hr	J10	27.6727	1006.593	2
S6	476008.317849508	4759458.88889801			Chicago_3hr	J11	30.306	1664.636	2
S7	474051.008089158	4759527.53250599			Chicago_3hr	J3	31.6124	1327.446	2
S8	475628.392459204	4759333.84107189			Chicago_3hr	J4	34.8996	1282.584	2
S9	473856.674486063	4759350.16299729			Chicago_3hr	J4	14.3455	259.089	2
S10	477179.633205109	4759199.89996532			Chicago_3hr	J1	20.4066	820.54	2
S11	476888.251608333	4759003.64037797			Chicago_3hr	J14	24.5676	1111.387	2
S12	475085.674241259	4759554.02327522			Chicago_3hr	SWMF-2	73.6103	1864.908	3
S13	476524.893821111	4758896.98840063			Chicago_3hr	J19	41.7978	3343.824	2
S14	474771.946140559	4750774.20014933			Chicago_3hr	J4	84.8713	1537.305	5

Attributes: 950.7 m, 293.2 m, Previous area, Impervious area

Subcatchment: S16

Attributes: Name: S16, X-Coordinate: 475726.188999, Y-Coordinate: 4758475.47823, Description, Tag, Rain Gage: Chicago_3hr, Outlet: J17, Area (ha): 27.8795, Width (m): 550.583, Flow Length (m): 293.247, Slope (%): 1.5, Imperv (%): 39, N Imperv: 0.013, N Perv: 0.25, Distore Imperv (mm): 1, Distore Perv (mm): 4, Zero Imperv (%): 0, Subarea Routing: OUTLET, Percent Routed (%): 100, Curb Length: 0, Snow Pack: 0, LID Controls: 0, Groundwater: NO, Infiltration: Curve_number, Drying Time (days): 5, Conductivity (mm/d): 0.5, Curve number: 60, Results: Precipitation (mm): 86.61, Runoff (mm): 0, Evaporation (mm): 0, Infiltration (mm): 40.71, Runoff Depth (mm): 45.1, Runoff Volume (M): 12.57, Peak Runoff (m³/s): 7.19, Runoff Coefficient: 0.521, Shape: Uid: 16, Count: 1, Points: 561, Parts: 1, Area (m²): 278794.77, Area (ha): 27.8795, Inverse Area (ha): 10.8226150000

Name [Name]: User-assigned name of subcatchment.

Graph: Series

Jan 28 Tue 2014

Graph Status Details Documentation

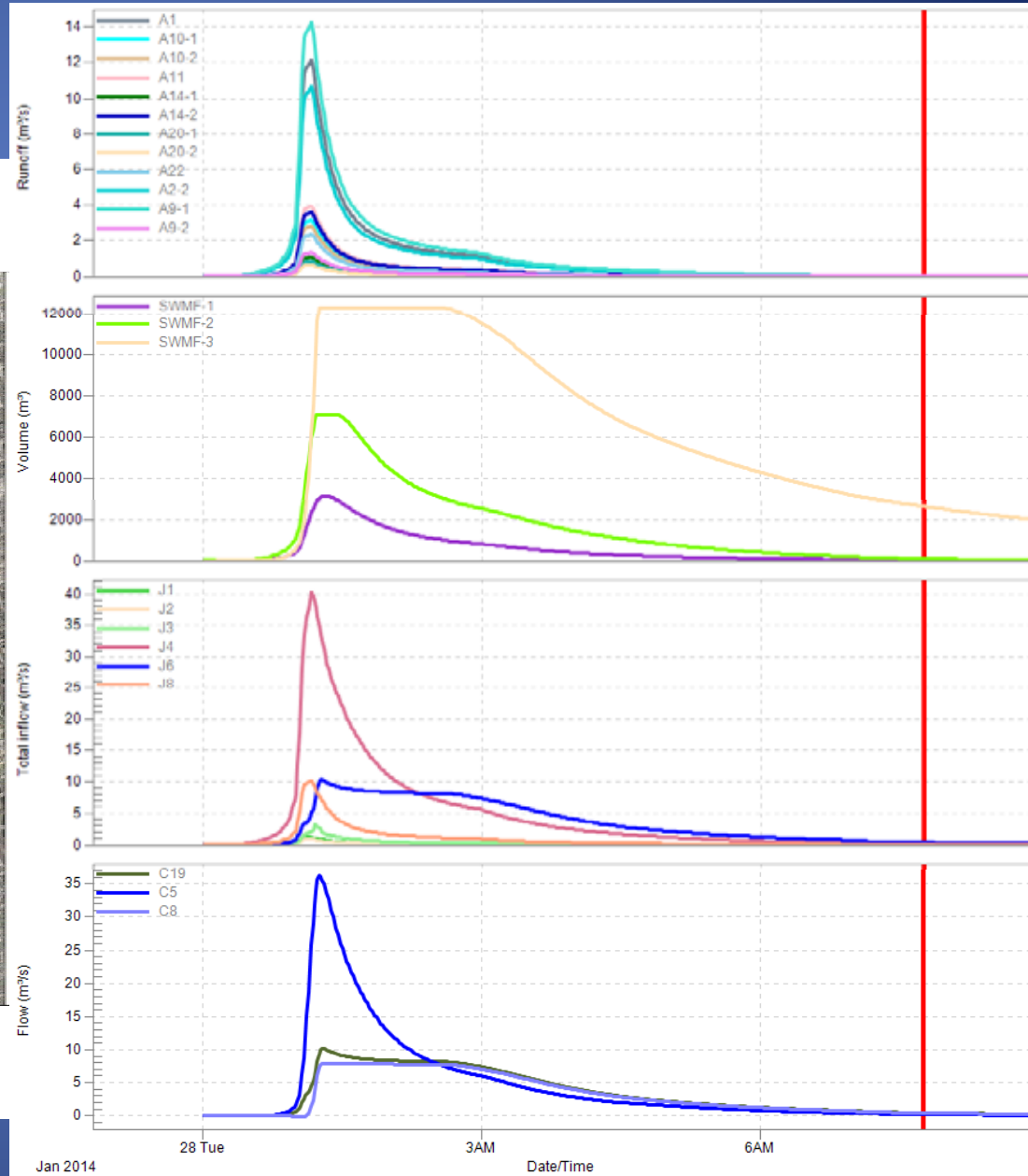
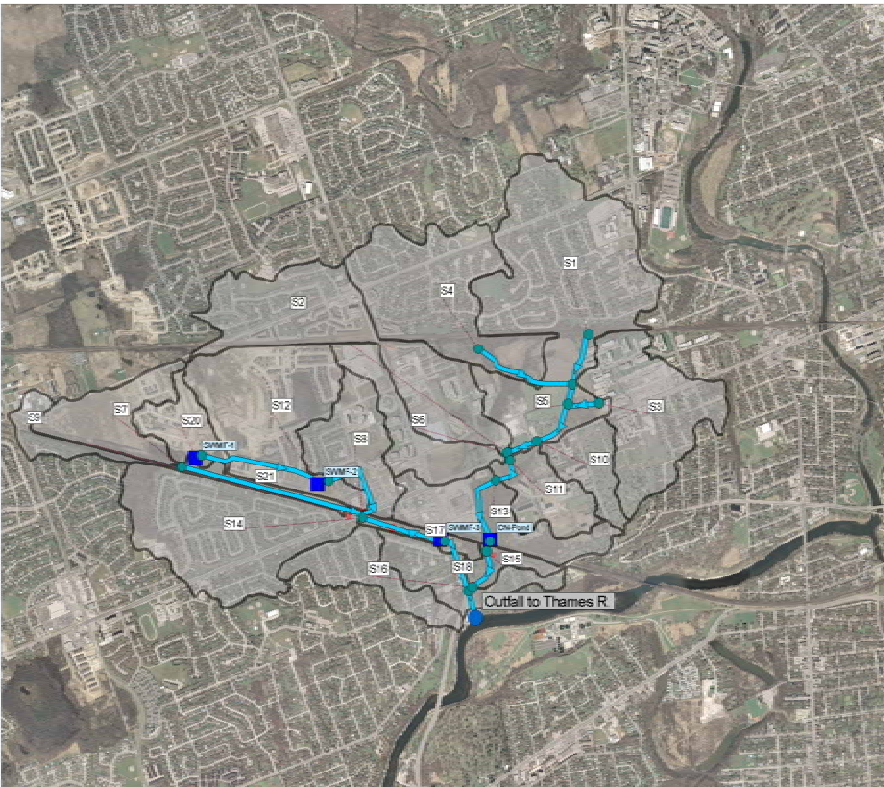
Links: P1: 0.034 m/s, C17: 0.034 m/s, P2: 0.357 m/s, C4: 0.357 m/s, C5: 1.566 m/s, P3: 1.566 m/s, C8: 1.561 m/s, C19: 3.988 m/s, D: 0.9 m, 1.95 m, 2.284 m, 1.9 m, 2.7 m

HGL

Nodes: SWMF-1: H: 261.2271 m, R: 263 m; J13: H: 262.0777 m, R: 262.9 m; SWMF-2: H: 250.5219 m, R: 253.5 m; J18: H: 249.3637 m, R: 251.1 m; J4: H: 244.0127 m, R: 246.518 m; SWMF-3: H: 238.7 m, R: 242 m; J20: H: 236.0076 m, R: 240.5 m; J6: H: 229.7194 m, R: 232 m; Outfall: H: 229.2187 m, R: 229 m

PCSWMM

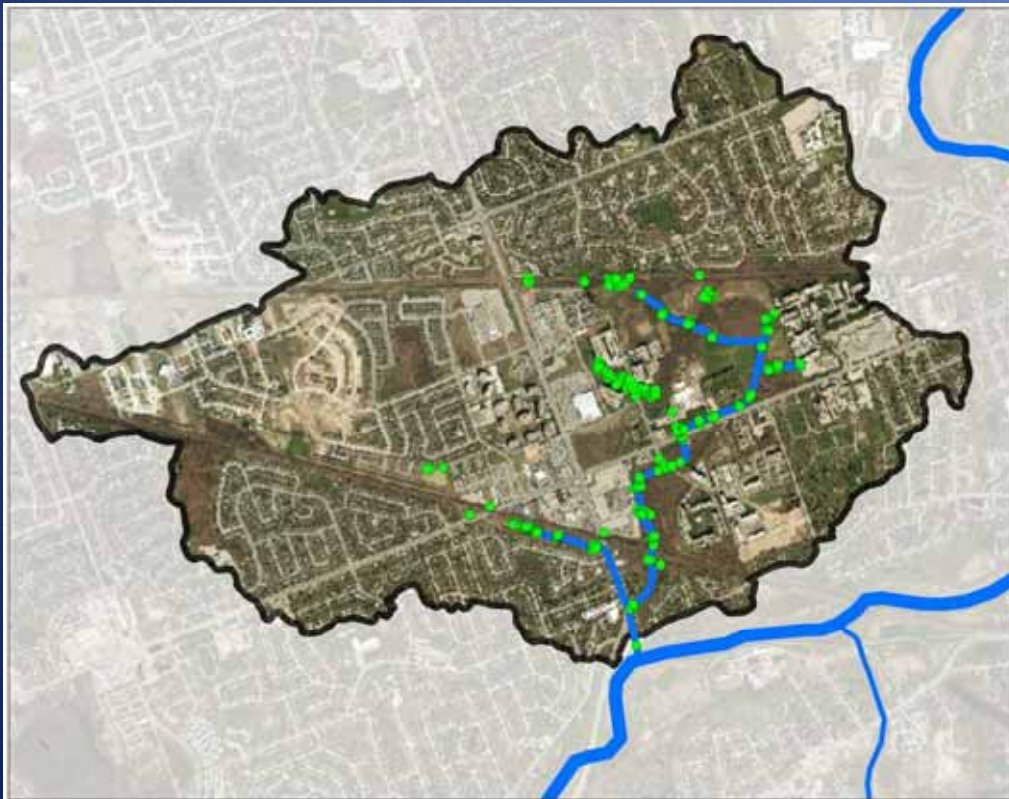
Some Results



Creating RAS Layers - GIS



Same Procedures



Developing HEC-RAS Hydraulic Model



HEC-RAS 4.1.0

File Edit Run View Options GIS Tools Help

Project: MudCreek2014 C:\MudCreek\RAS\HEC\MudCreek2014.prj
 Plan: Plan 01 C:\MudCreek\RAS\HEC\MudCreek2014.p01
 Geometry: MudCreek2014 C:\MudCreek\RAS\HEC\MudCreek2014.g01
 Steady Flow: MudCreek2014 C:\MudCreek\RAS\HEC\MudCreek2014.f01
 Unsteady Flow:
 Description: SI Units

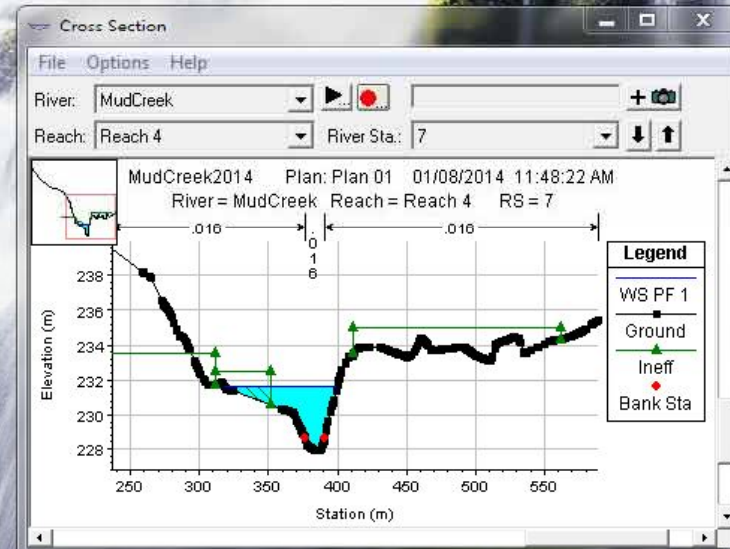
Geometric Data - MudCreek2014

File Edit Options View Tables Tools GIS Tools Help

Tools River Reach Storage Area S.A. Conn. Pump Station RS Description: 12.99

Junct. Cross Section Brdg/Culv Inline Structure Lateral Structure Storage Area Storage Area Conn. Pump Station HTab Param. View Picture

477536.03, 4760298.70



Steady Flow Data - Mud...

File Options Help

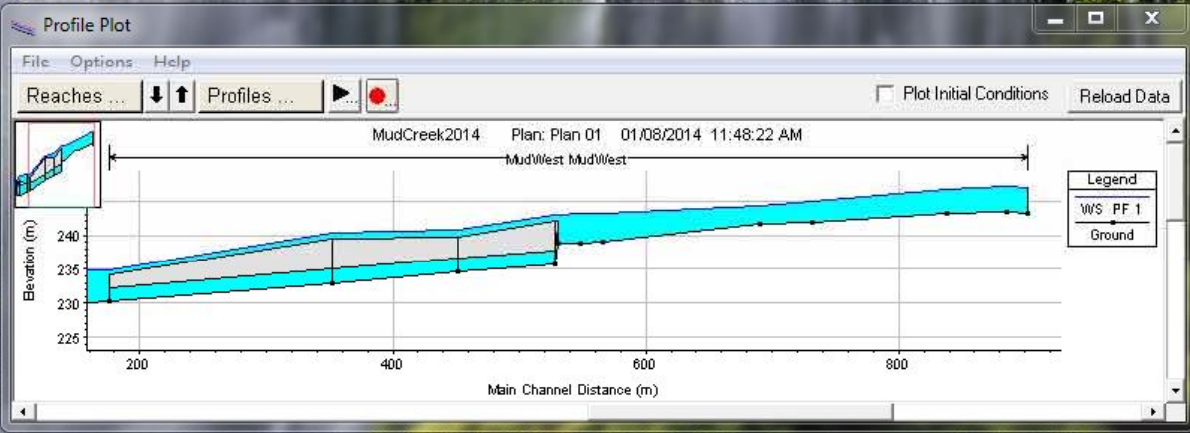
Enter/Edit Number of Profiles (25000 max): 1

Locations of Flow

River: MudCreek Reach: Reach 1 River Sta.: 21

Flow Change Location

	River	Reach	RS	PF 1
1	MudCreek	Reach 1	2153	29.151
2	MudCreek	Reach 2	2005	46.306
3	MudCreek	Reach 3	1853	58
4	MudCreek	Reach 3	1343	69.4
5	MudCreek	Reach 3	1074	62.55
6	MudCreek	Reach 4	151	89
7	MudWest	MudWest	756	90
8	MudWest	MudWest	386	90



Next Steps...



- Continue Field Surveys For Entire Watershed
- Complete or Improve Pilot Studies
 - Cedar Creek
 - Mud Creek
 - Thames River in London
- And apply methods to the rest of watershed....

Future

