Virginia's Stormwater Impact Evaluation Project

Project Overview

December 14th, 2007

Kevin Young, Dr. Randy Dymond, Dr. David Kibler

The Need for a Decision Support Tool

- An essentially limitless number of criteria influence BMP selection
  - Physical site characteristics
  - Regulatory requirements
  - Aesthetic, economic, and safety considerations
- At least 15 different BMPs are routinely employed to improve surface runoff quality

Problem Statement

- How can we effectively address the relevant criteria while objectively considering *all* BMP options?

Photos Courtesy of Virginia Stormwater Management Handbook (DCR, 1999)

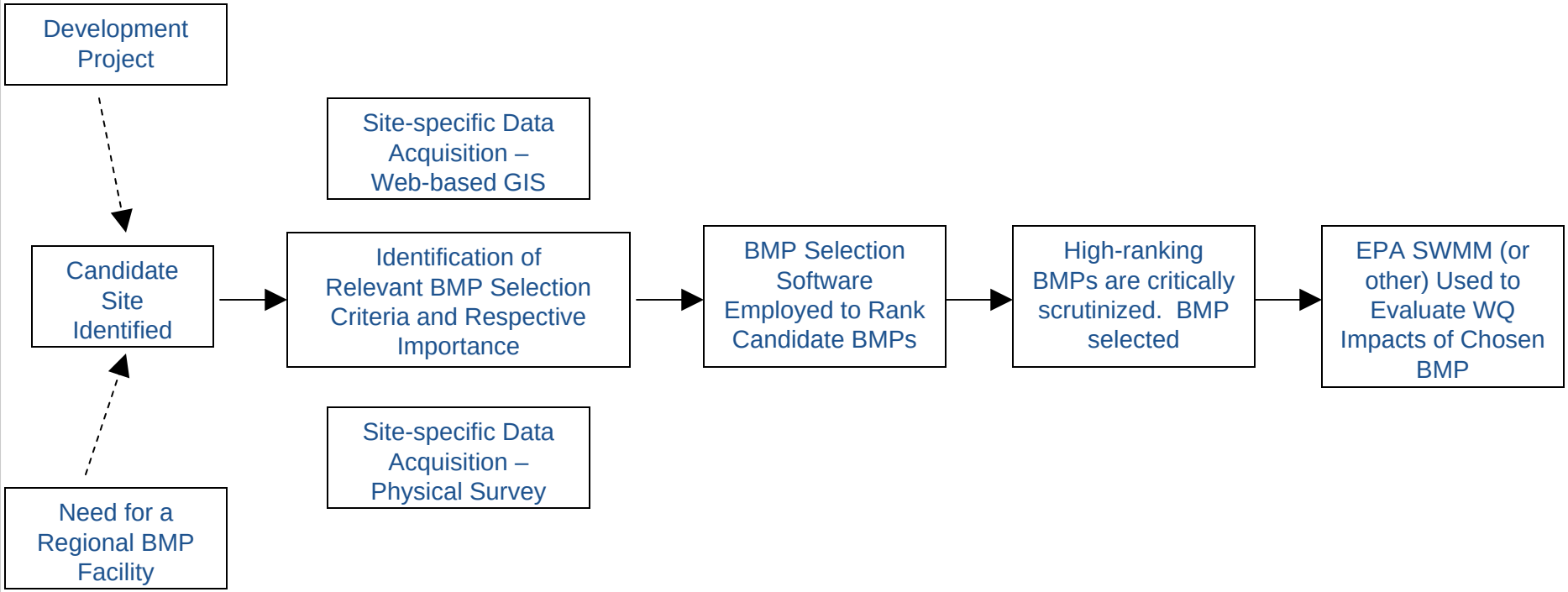
Project Tasks

1. Assembly of project stakeholder group
2. Development of BMP selection software
3. Assembly of a web-based GIS for the pilot watershed
4. Use of hydrologic modeling software to evaluate the downstream impacts of BMP implementation
5. Development of training manual and users' documents
6. Conduct training seminars

Project Stakeholders

- Local government officials (engineers and planners)
- Local Planning District Commission (NRVPDC)
- State Department of Conservation and Recreation (VA DCR)
- Private developers

Application Flowchart



Site, Regulatory, & Aesthetic Criteria Addressed Within the Project Scope

- ❑ Contributing Drainage Area
- ❑ Shallow Groundwater Depths
- ❑ Shallow Bedrock Depths
- ❑ Presence of HSG A
- ❑ Presence of HSG D
- ❑ Ability to Recharge Groundwater
- ❑ BMP Implementation Costs
- ❑ Annual O&M Costs
- ❑ New Impervious Cover (%)
- ❑ Peak Mitigation Performance
- ❑ Aesthetic Benefit/Liability
- ❑ Safety Issues
- ❑ Site Slopes
- ❑ TSS Removal Performance
- ❑ TP Removal Performance
- ❑ TN Removal Performance
- ❑ Hotspot Runoff

Included BMPs

- **Pond Class** (dry extended detention, enhanced, retention)
- **Infiltration Class** (trenches, basins, porous pavement)
- **Filter Class** (buffer strips, vegetated swales, sand filters, bioretention)
- **Constructed Stormwater Wetlands**
- **Proprietary Stormwater Technologies** (hydrodynamic separators, catch basin inserts, water quality inlets)
- **Low Impact Development Strategies** (vegetated roofs and rainwater capture & reuse)

The BMP Selection Tool

- The Analytic Hierarchy Process (AHP) is a decision-support algorithm for problems involving *multiple criteria*.

1. Competing BMP alternatives are evaluated for *each* available selection criteria. Rankings are static.

D.A. < 1 Ac	TSS Removal	Shallow GW
Filter Strip	Retention Basin	Enhanced ED Basin
Porous Pavement	Bioretention	Retention Basin
Bioretention	Sand Filters	Constructed Wetlands
Sand Filters	Veg Roof	Veg Roof
Veg Roof	Capture & Reuse	Capture & Reuse
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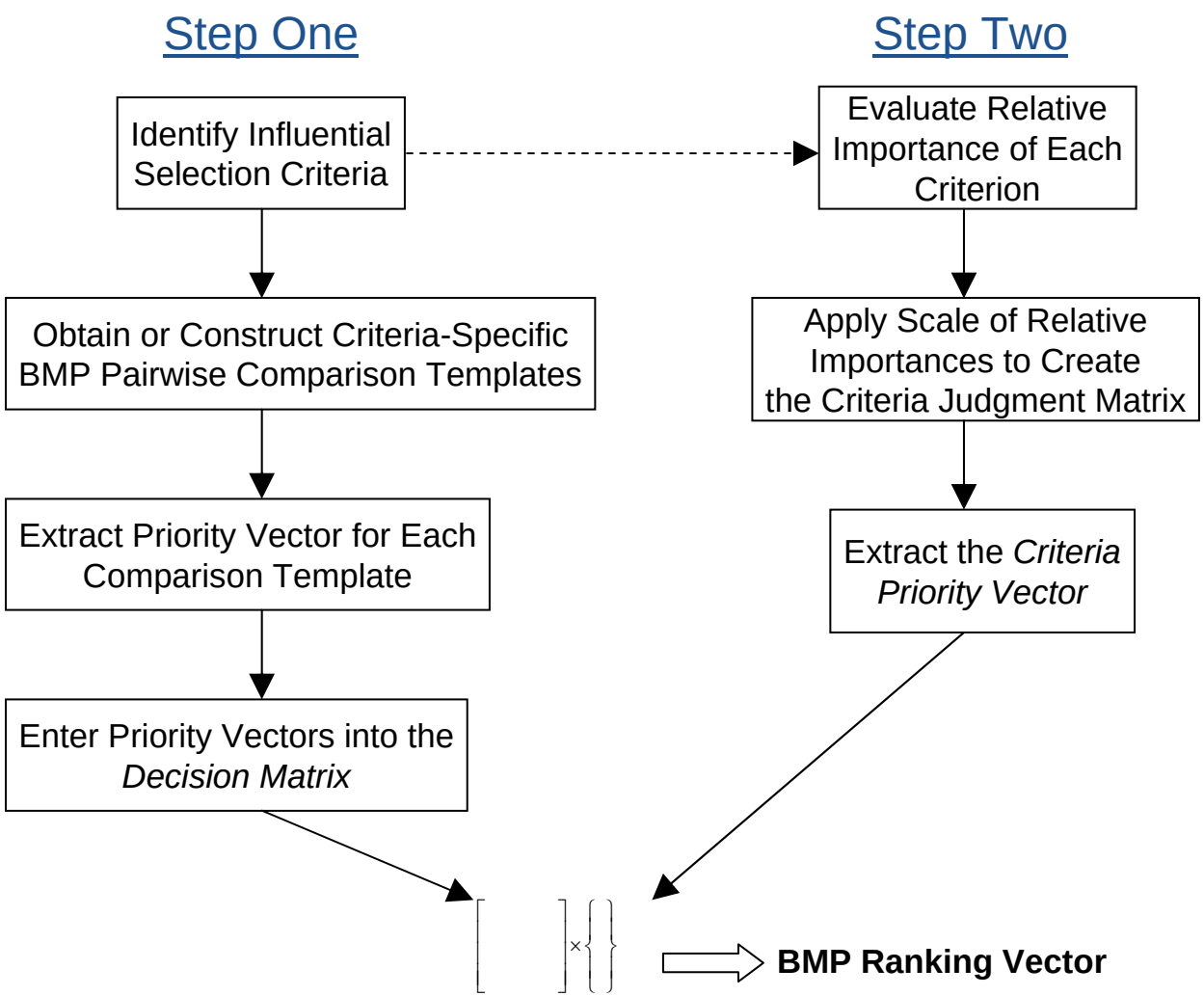
2. The user may establish rank (weighting) of the chosen criteria. Rankings may be modified.

Criteria	Weight
Drainage Area	3
TSS Removal	9
Shallow GW	8

AHP Flowchart



Simple BMP Selection Scenario

Maintenance Yard Releasing Untreated Runoff

Physical Site Characteristics

- 0.75 Acres
- Situated in a High Visibility Location
- No Proposed Land Cover Change

Regulatory Requirements

- 80% TSS Reduction
- 35% TP Reduction
- 30% TN Reduction
- Peak Mitigation Not Req'd.

Other

- Consideration Given to Aesthetics

Select Criteria

- User Selects the Relevant Criteria Impacting the BMP Selection
- The User Weights the Relative Importance of Each Chosen Criteria

Criteria	y/n	Weight		Criteria	y/n	Weight
DA < 1 Ac	✔	2		New Impervious Cover < 40%		
DA 1-5 Ac				New Impervious Cover > 40%		
DA 5-10 Ac				Groundwater Recharge		
DA > 10 Ac				Peak Mitigation		
Shallow GW				Aesthetic Benefit	✔	3
Shallow Bedrock				TSS Reduction	✔	10
HSG A				TP Reduction	✔	10
HSG D				TN Reduction	✔	10
Implementation Cost				Hotspot Runoff		
Annual O&M Cost				Safety Considerations		

Sample Criteria Comparison

Criteria ranking vector is computed by the algorithm, based on user-specified weighting of various criteria

80% TSS Removal	**0.288**
35% TP Removal	**0.288**
30% TN Removal	**0.288**
Aesthetic Benefit	**0.093**
Site Area < 1 Acre	**0.043**

BMP Rankings

- BMP Comparison Vectors are Retrieved by the Algorithm
- A BMP Comparison Vector Exists for Each Chosen Criteria

BMP	DA < 1 AC	80% TSS	35% TP	30% TN	Aesthetic
Dry ED Basin	0.02	0.01	0.01	0.09	0.01
Enhanced ED Basin	0.01	0.01	0.01	0.09	0.01
Retention Basin	0.01	0.12	0.12	0.09	0.13
Constructed Wetlands	0.01	0.01	0.01	0.09	0.13
Veg WQ Swale	0.07	0.01	0.01	0.01	0.02
Veg Filter Strip	0.11	0.01	0.01	0.01	0.13
Infil Trench	0.07	0.12	0.12	0.09	0.02
Infil Basin	0.02	0.12	0.12	0.09	0.01
Porous Pavement	0.11	0.12	0.12	0.09	0.08
Bioretention	0.11	0.12	0.12	0.09	0.13
Sand Filters	0.11	0.12	0.12	0.09	0.08
Veg Roof	0.11	0.12	0.12	0.09	0.08
Capture & Reuse	0.11	0.12	0.12	0.09	0.08
Proprietary	0.11	0.01	0.01	0.01	0.08

Automated Matrix Multiplication

BMP Decision Matrix is Multiplied by Criteria Priority Vector

	80% TSS Removal	35% TP Removal	30% TN Removal	Aesthetic Benefit	Site Area < 1 Acre
Extended Dry Detention Pond	0.014	0.011	0.088	0.012	0.022
Enhanced Extended Detention Pond	0.014	0.096	0.088	0.012	0.013
Retention Pond	0.014	0.096	0.088	0.039	0.010
Infiltration Trench	0.129	0.096	0.088	0.039	0.066
Infiltration Basin	0.129	0.096	0.088	0.012	0.022
Porous Pavement	0.129	0.096	0.088	0.093	0.113
Constructed Wetlands	0.014	0.096	0.088	0.046	0.013
Bioretention	0.129	0.096	0.088	0.169	0.113
Filter Strip	0.014	0.011	0.010	0.169	0.113
Vegetated Swale	0.014	0.011	0.010	0.039	0.066
Stormwater Filtering Systems	0.129	0.096	0.088	0.093	0.113
Proprietary BMP Technologies	0.014	0.011	0.010	0.093	0.113
Vegetated Roof	0.129	0.096	0.088	0.093	0.113
Rainwater Capture and Reuse	0.129	0.096	0.088	0.093	0.113

X

0.288
0.288
0.288
0.093
0.043

Results

The Final Result Ranks Competing BMP Options

Bioretention	***0.111***
Porous Pavement	**0.103**
Stormwater Filtering Systems	**0.103**
Infiltration Trench	**0.096**
Infiltration Basin	**0.092**
Constructed Wetlands	**0.062**
Wet / Retention Pond	**0.061**
Extended Dry Detention Pond -- Enhanced	**0.059**
Extended Dry Detention Pond	**0.035**
Filter Strip	**0.031**
Proprietary BMP Technologies	**0.023**
Vegetated Swale	**0.016**

Evaluation of Results

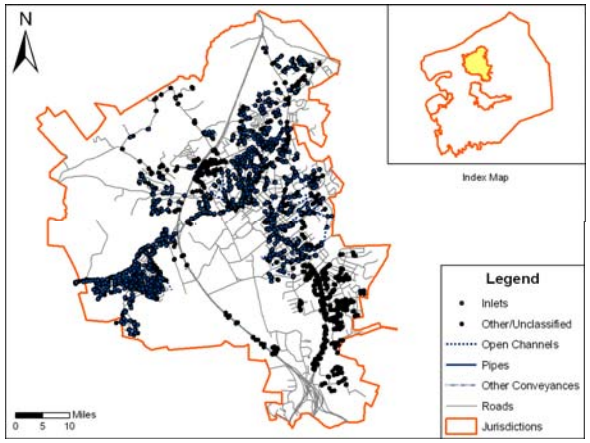
- It is Imperative That the Results Be Critically Scrutinized

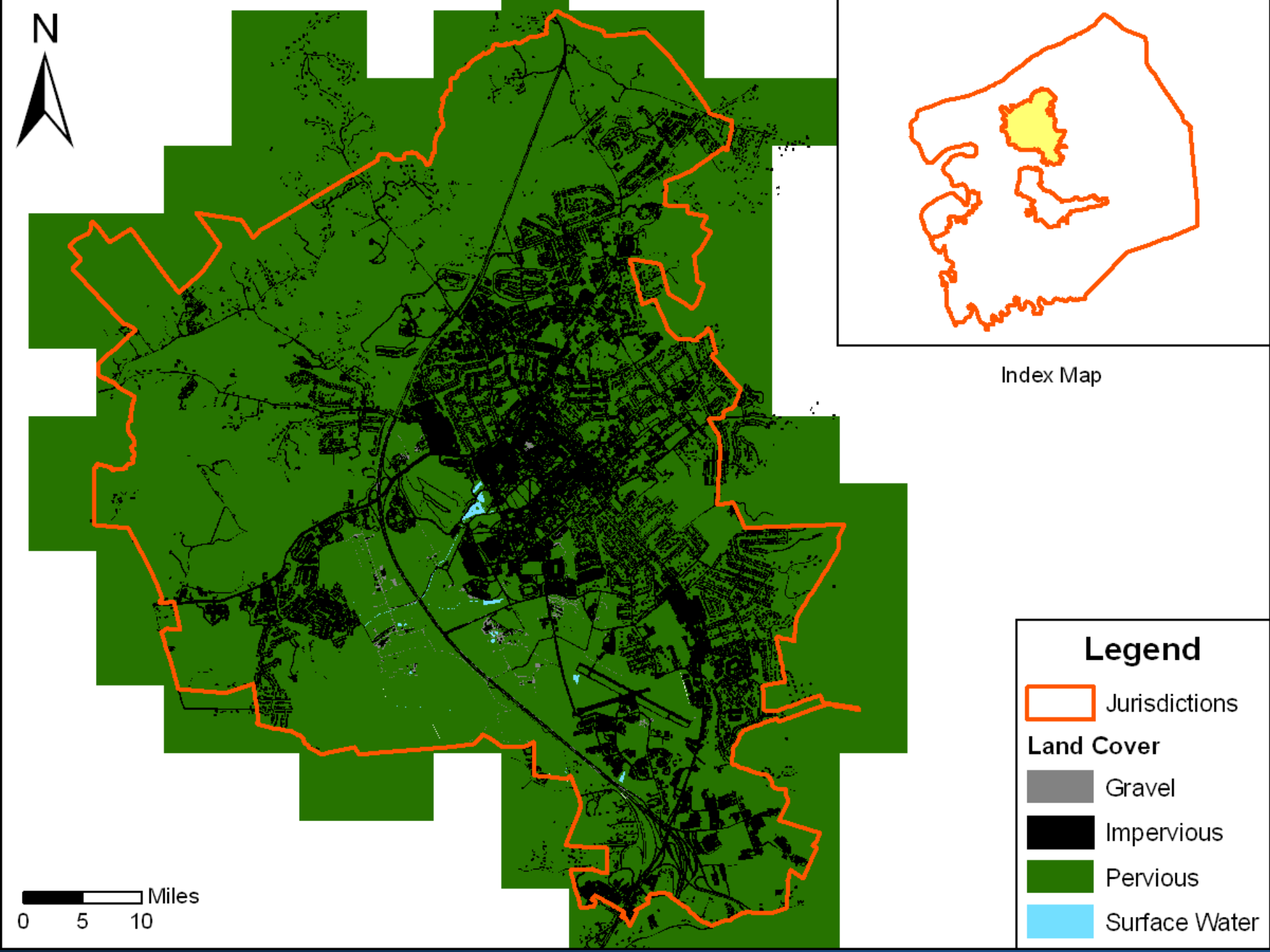
Criteria	Bioretention Performance
80% TSS Removal	86% Removal efficiency anticipated
35% TP Removal	59% Removal efficiency anticipated
30% TN Removal	38% Removal efficiency anticipated
Aesthetic Benefit	Adds pervious cover to the highly impervious site, also provides water quality improvement very unobtrusively.
Site Area Less Than 1 Acre	Ideally suited to small drainage sheds.

Web-based GIS of Pilot Watershed

- Scope of task: combine multiple data layers to provide readily accessible input data for the decision support software

- Data layers:
  - Sub-watershed areas
  - Existing storm sewer network
  - Delineation of land cover Soil types
  - Karst areas
  - Groundwater depths
  - Slopes / Topography
  - “Danger areas” of high illicit discharge potential

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Index Map
Legend
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Land Cover
Gravel
Impervious
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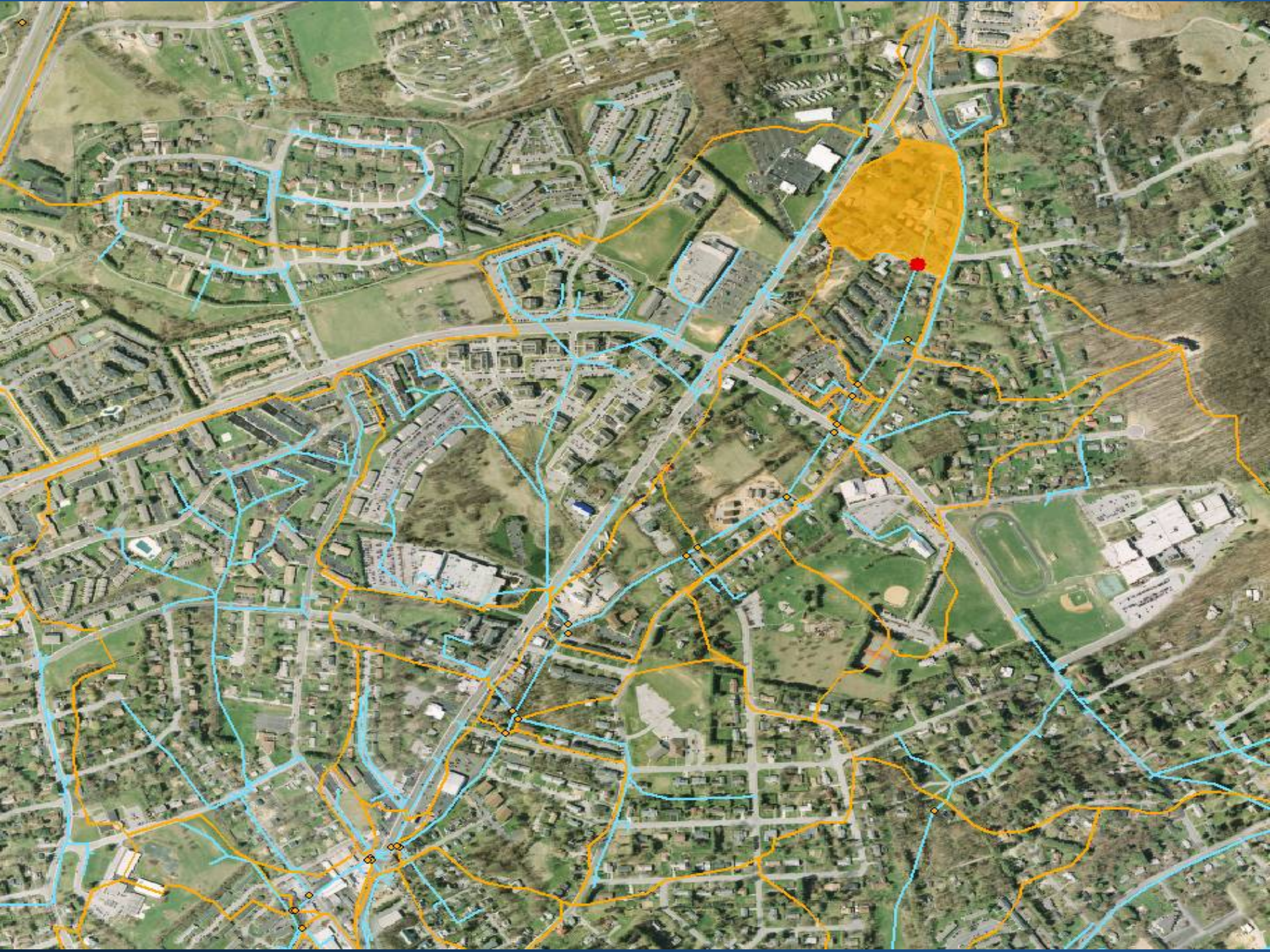
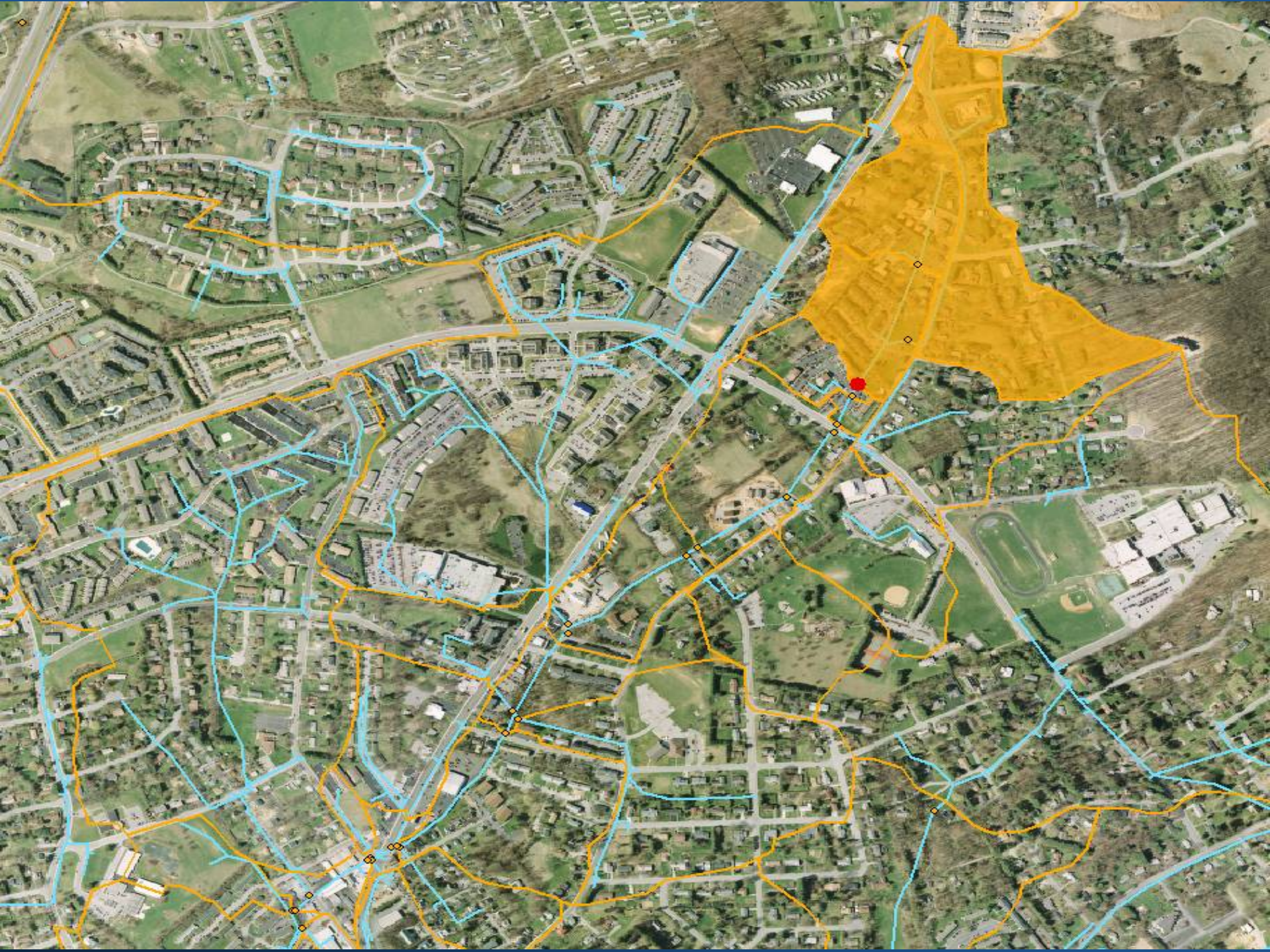
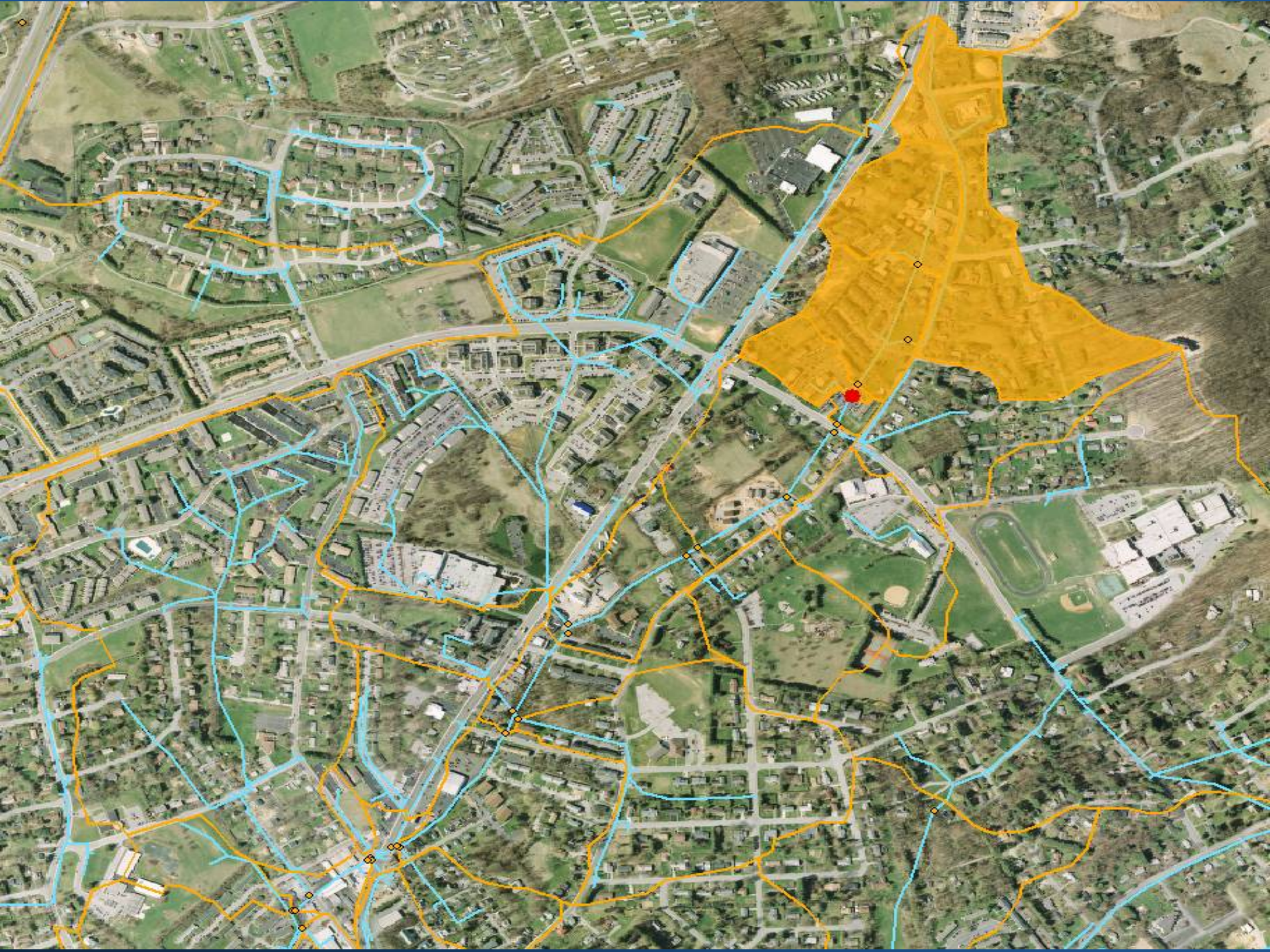
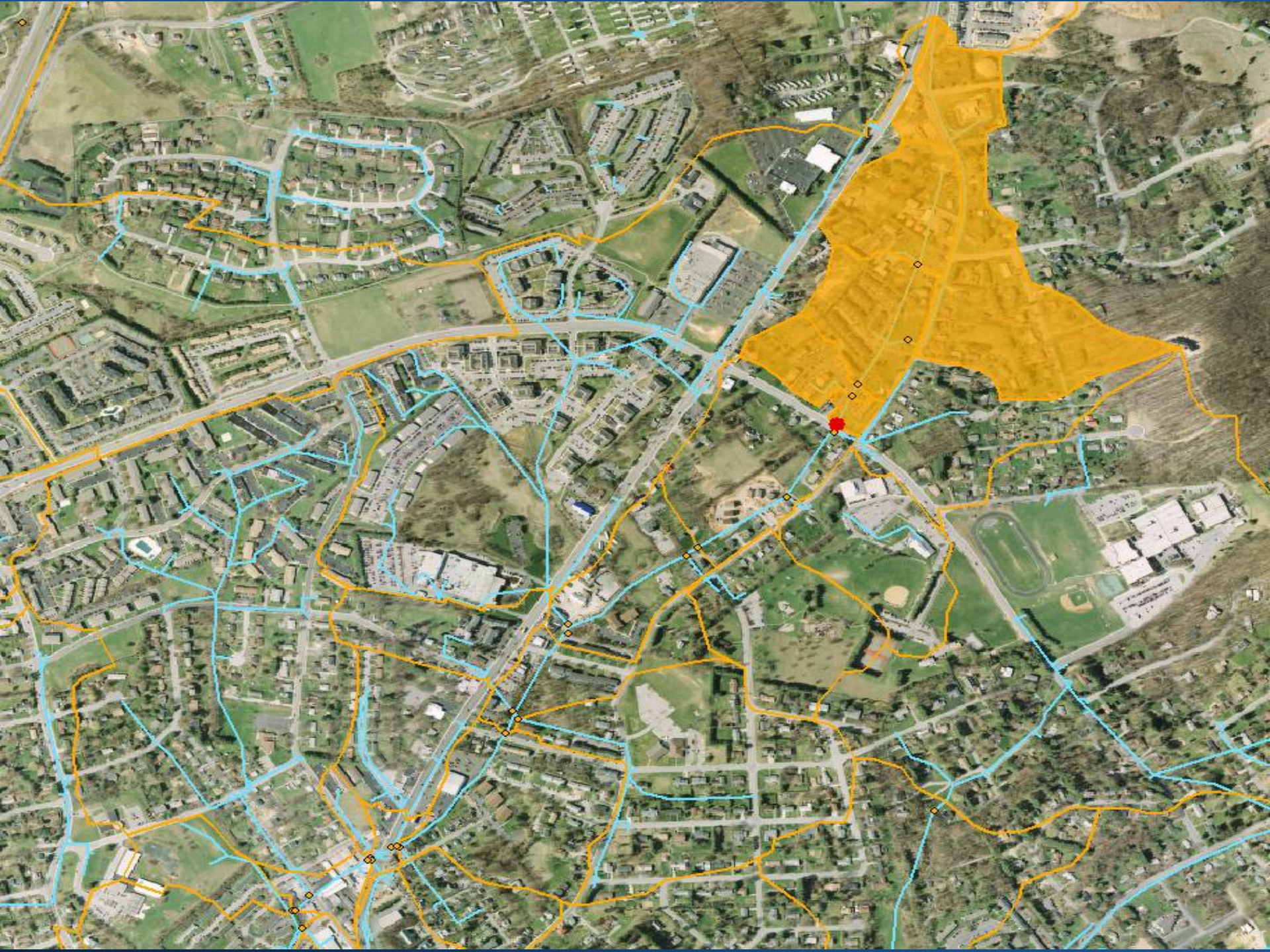
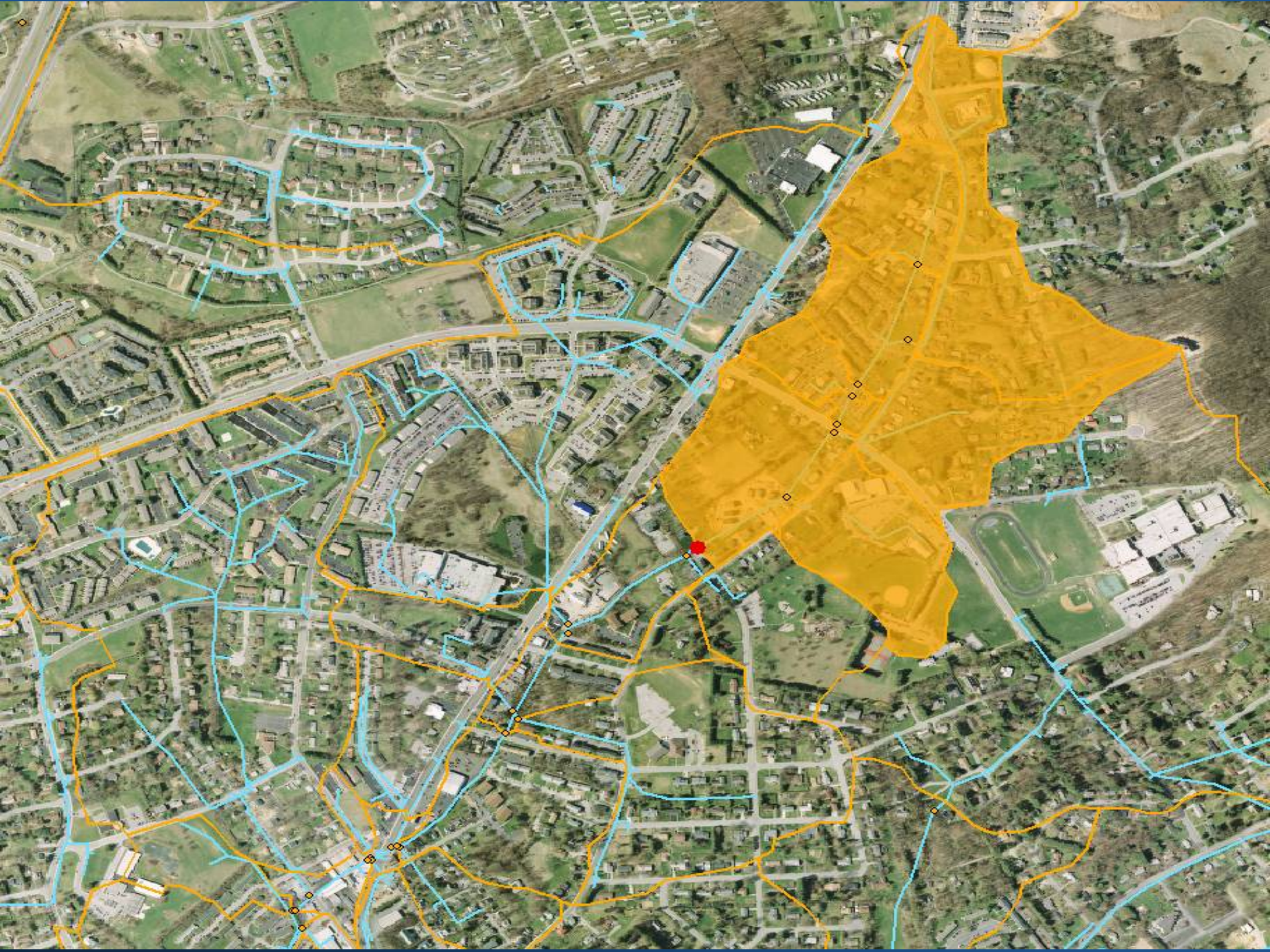
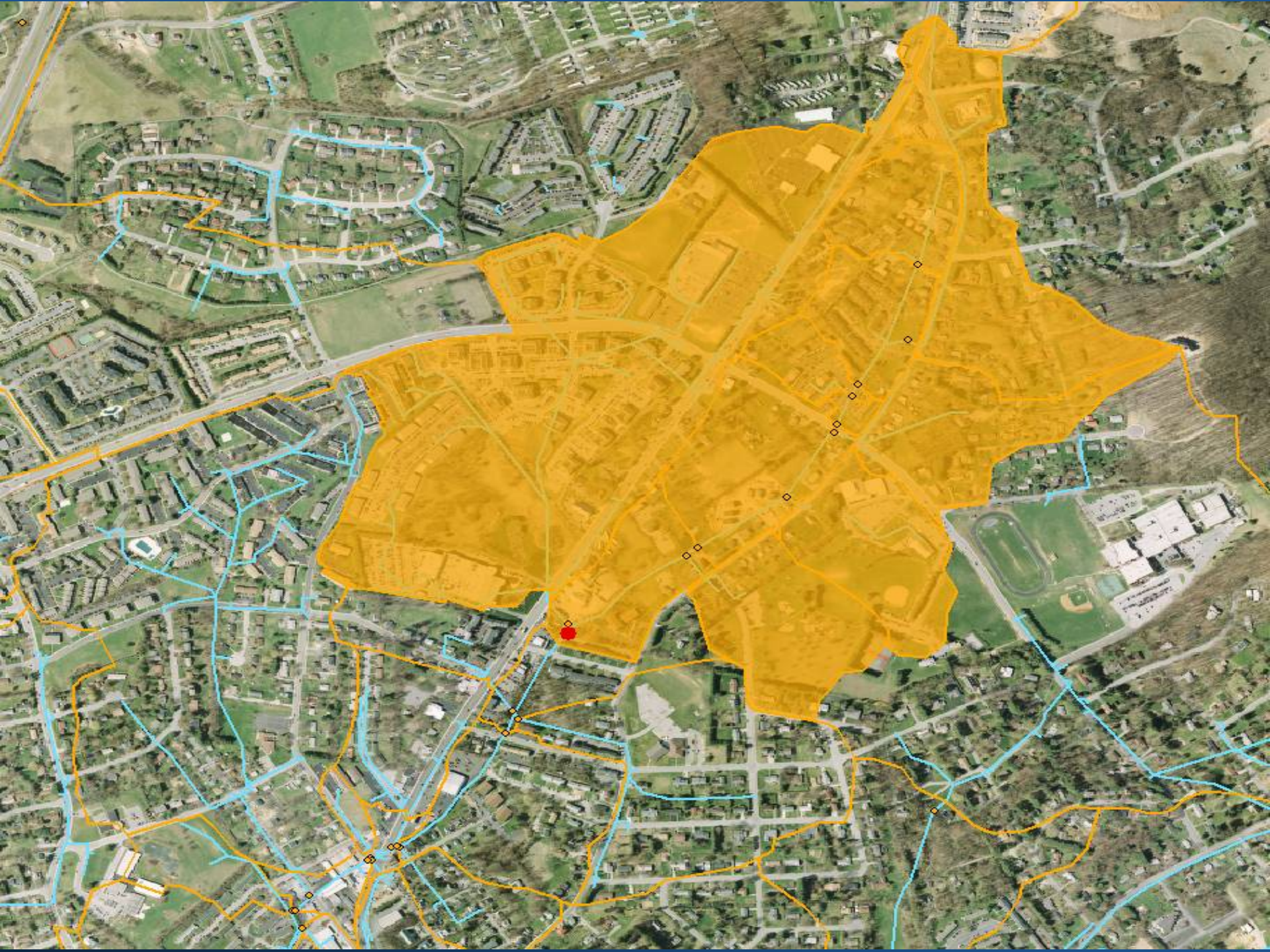


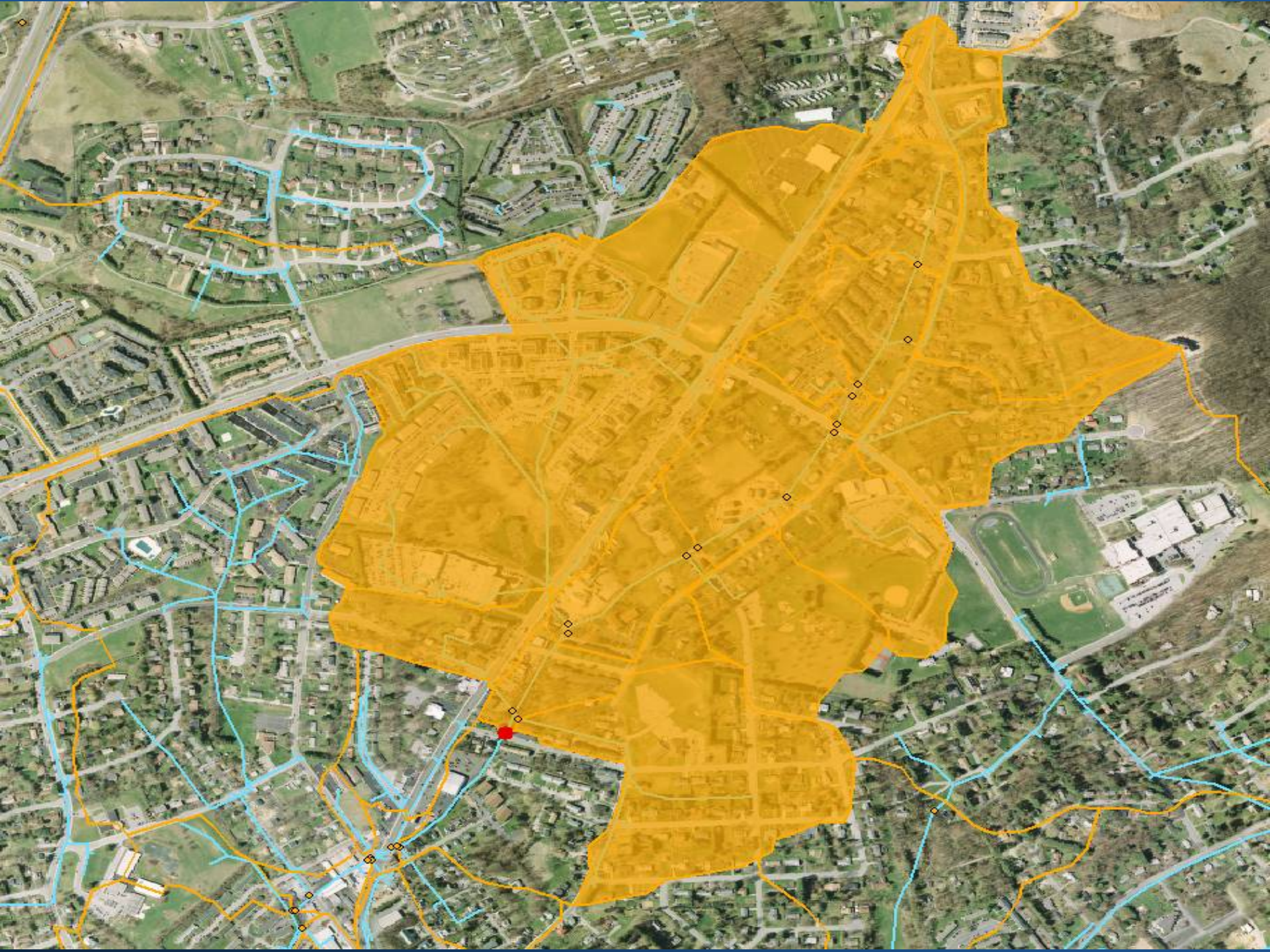


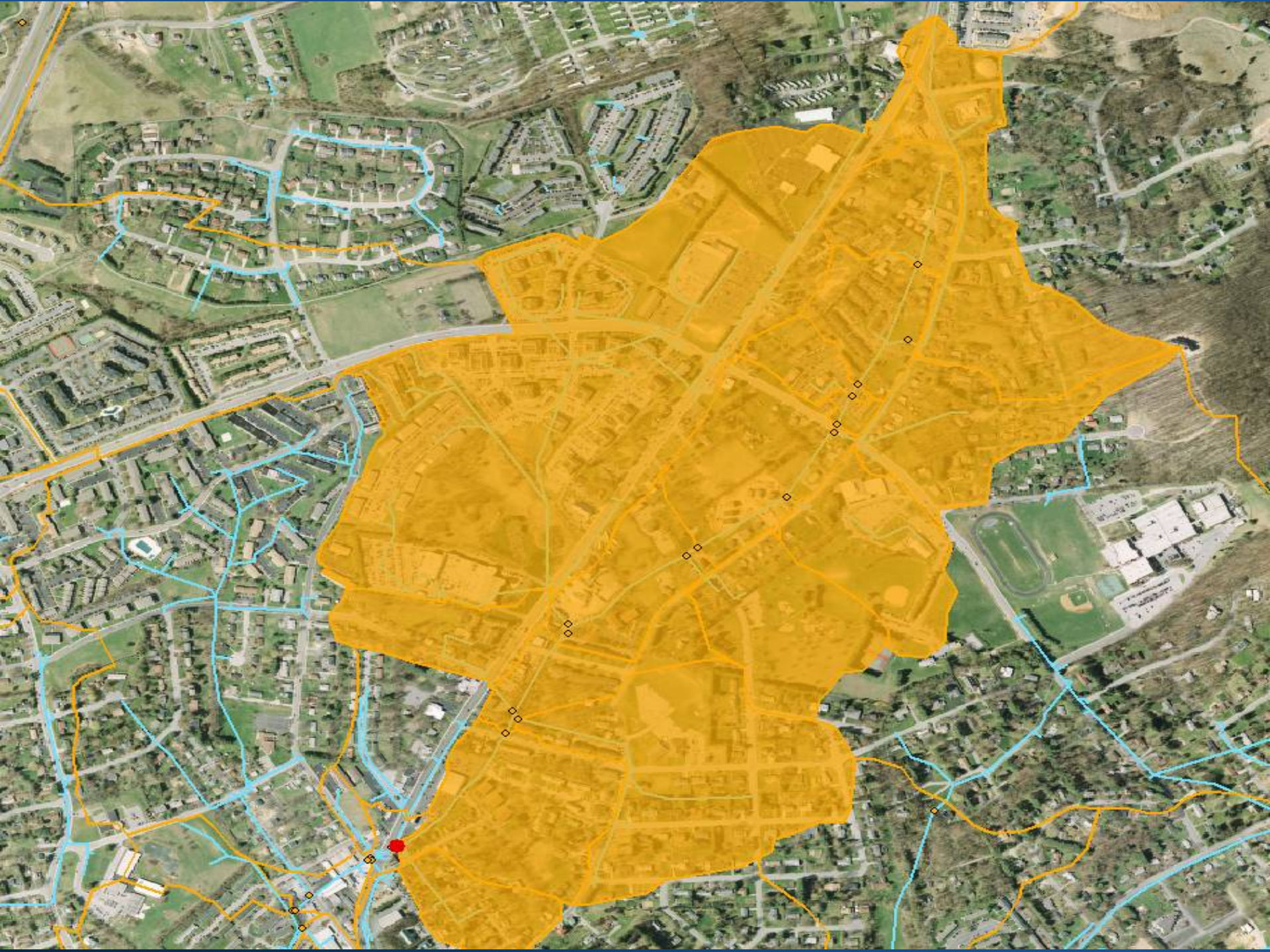


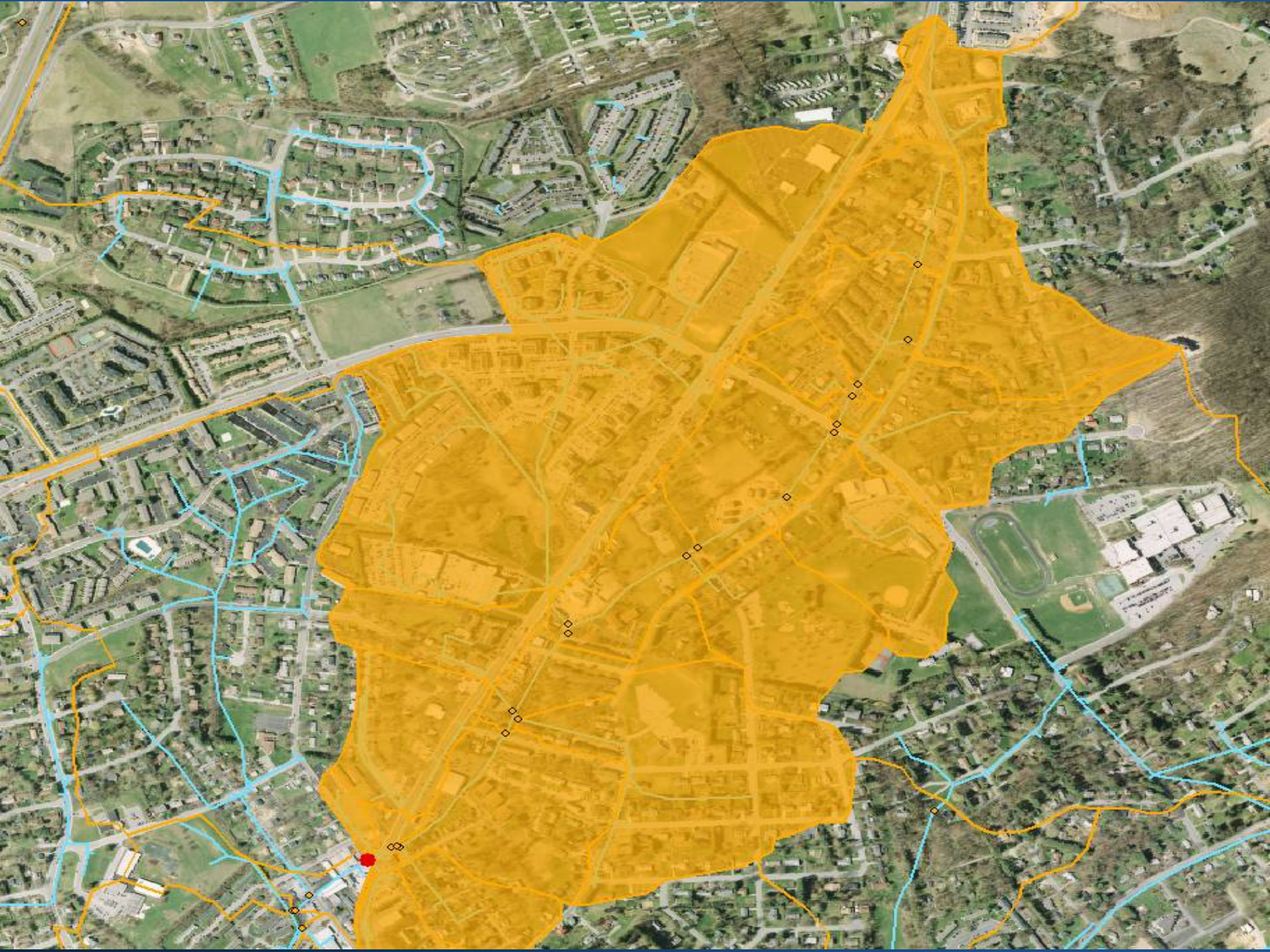


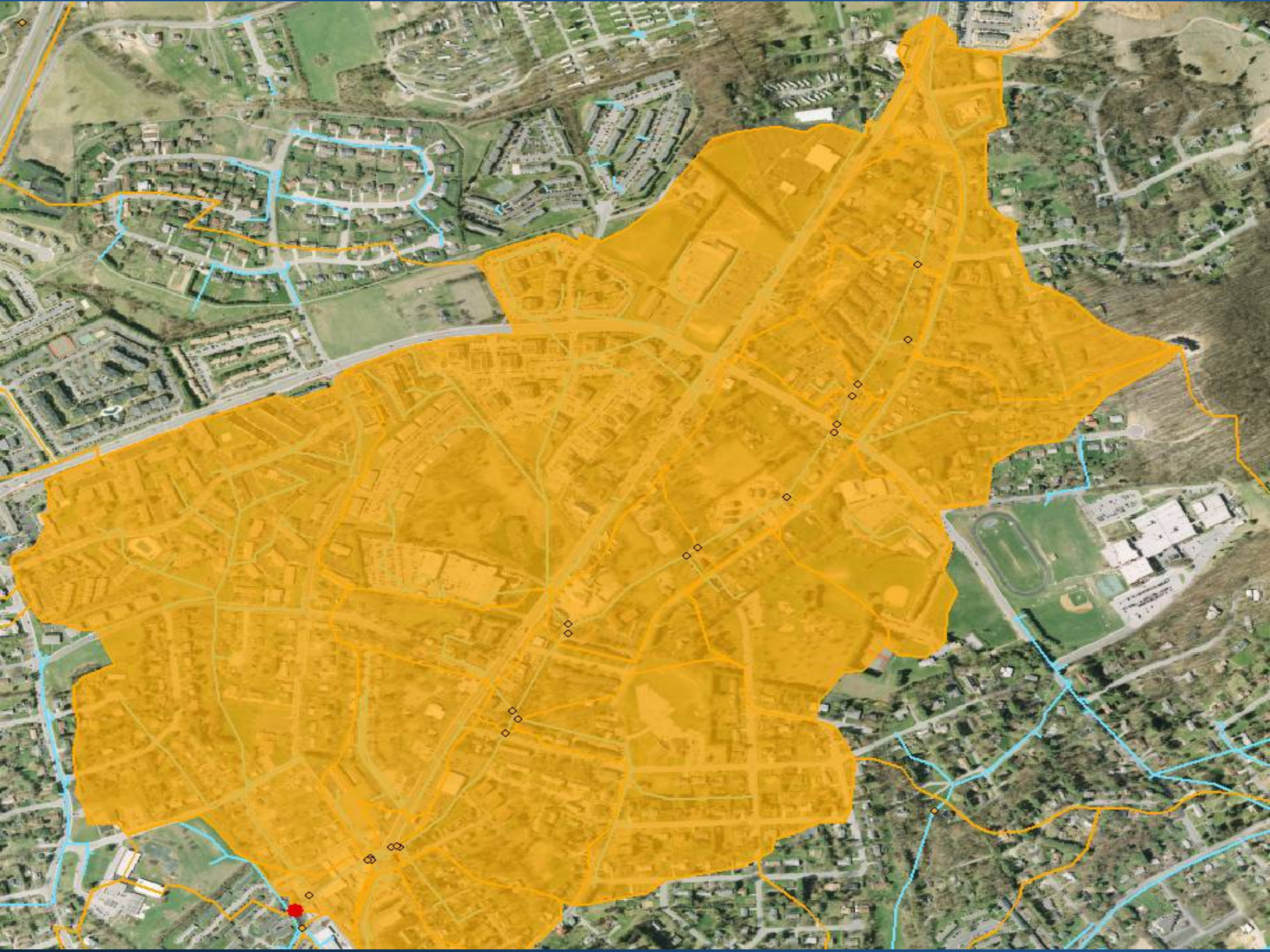










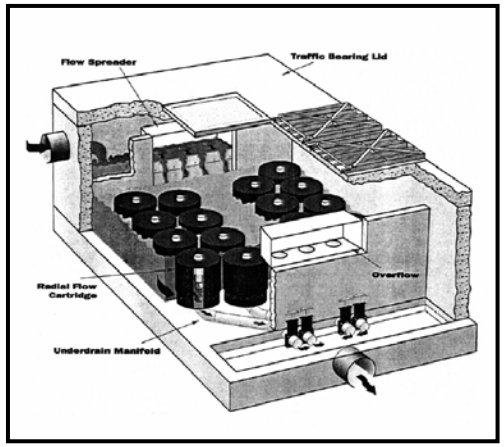


Stormwater Models

- Development of stormwater models is necessary in order to compare the ***relative*** performance of competing BMP strategies.
  - Link GIS data with stormwater model and simulate various user-defined storm events on a given watershed
  - BMP strategies evaluated based on runoff quantity and quality parameters

SWMM - BMP Modeling

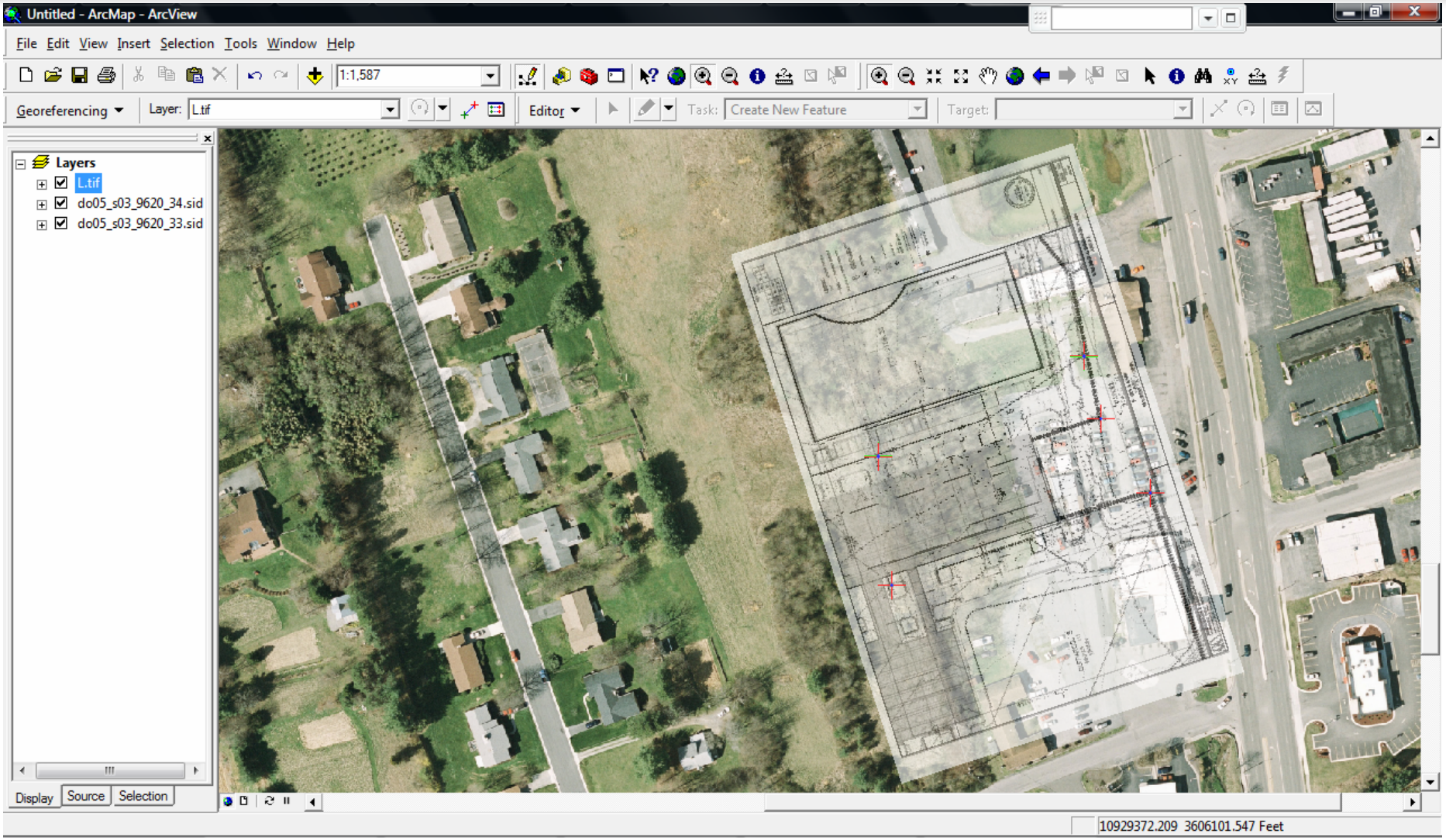
- Model elements such as storage nodes, subcatchments, and conduits can be used individually or in conjunction to represent various BMPs



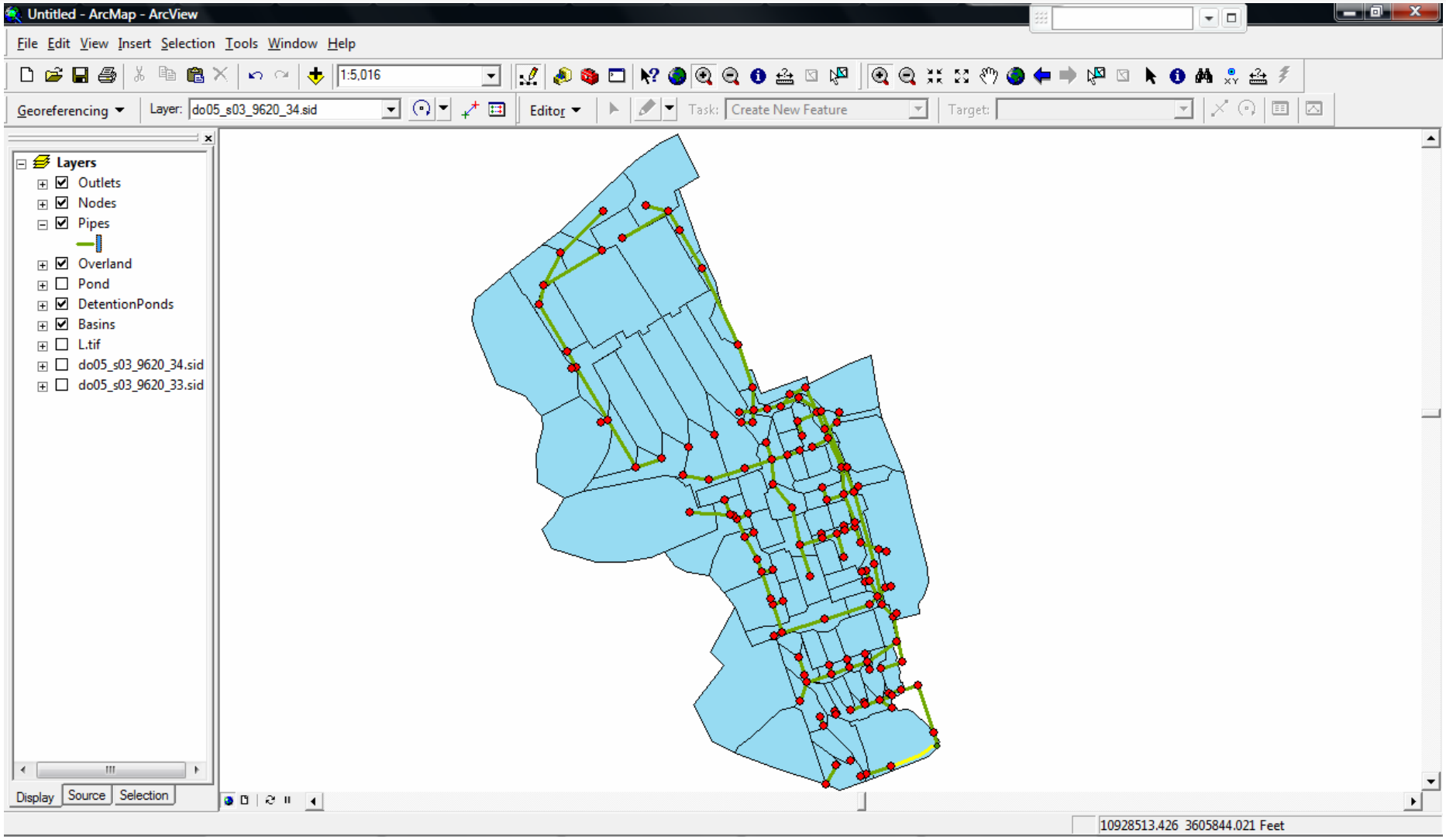
Graphics Courtesy of Virginia Stormwater Management Handbook (DCR, 1999)

- Model weaknesses exist such that user may have to employ cumbersome “tricks” to represent most BMPs

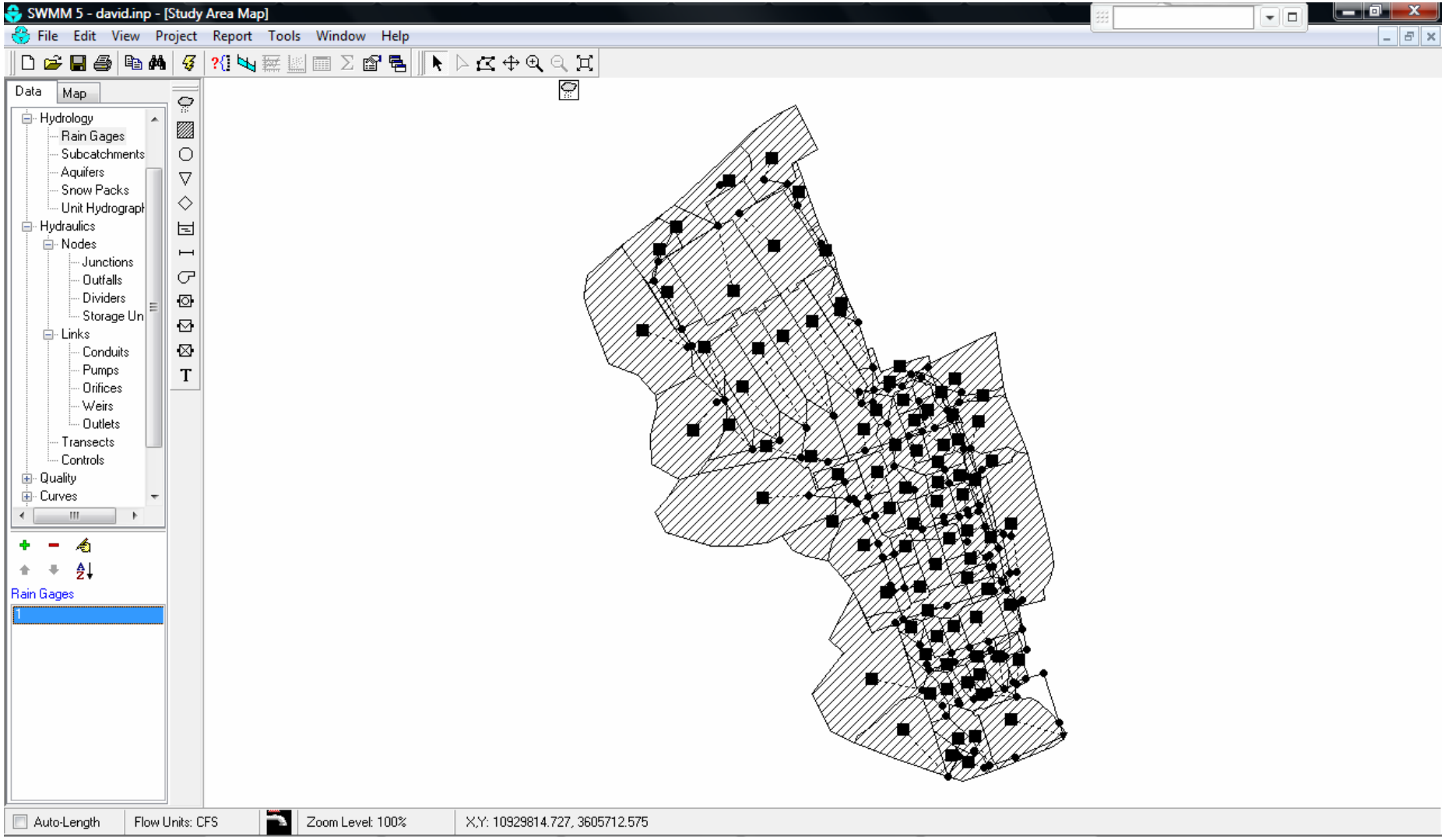
Georeferenced Plan Sheet



GIS Editing to Create SWMM Network



GIS Data Converted to SWMM



Project Status

1. Assembly of project stakeholder group – *Completed*
2. Development of BMP selection software – *Programming Phase*
3. Assembly of a web-based GIS for the pilot watershed – *Ongoing*
4. Use of hydrologic modeling software to evaluate the downstream impacts of BMP implementation – *SWMM Model Completed*
5. Development of training manual and users' documents – *Spring*
6. Conduct training seminars – *Spring*

Ongoing Research Efforts

1. Center for Geospatial Information Technology at Virginia Tech (CGIT) *www.cgit.vt.edu*

2. EPA Region 3 “No Net Impact” Proposal

3. Wal Mart Research Grants
   a. BMP Implementation
   b. Sustainable Design

4. Land Development Design Initiative (LDDI) *www.lddi.net*