GIS Tool for Simple Resilience Assessment of Highway Culverts

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Maine Sustainabiliy & Water Conference

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Background: DOT Crossing Classifications

- Major Spans: S ≥ 20 ft – *2,900 (some box, mostly bridge)*
- Minor Spans: 10 ≤ S < 20 – *1,300 (box & span)*
- Large Culverts: 5 ≤ S < 10 – *1,800 (mostly pipes)*
- Cross Culverts: S < 5 – *38,000 (mostly pipes)*
  - 1.5 ≤ S < 5 - *37,000*
- *Most (but not all) are over water*
- Difference bet Structure Type & Program Class
  - *Structurally: culvert = buried structure*
  - *Round: 5 ≤ D ≤ 8' for geomorphic design*
  - *Box: Typically Span 8 ≤ S ≤ 26'*

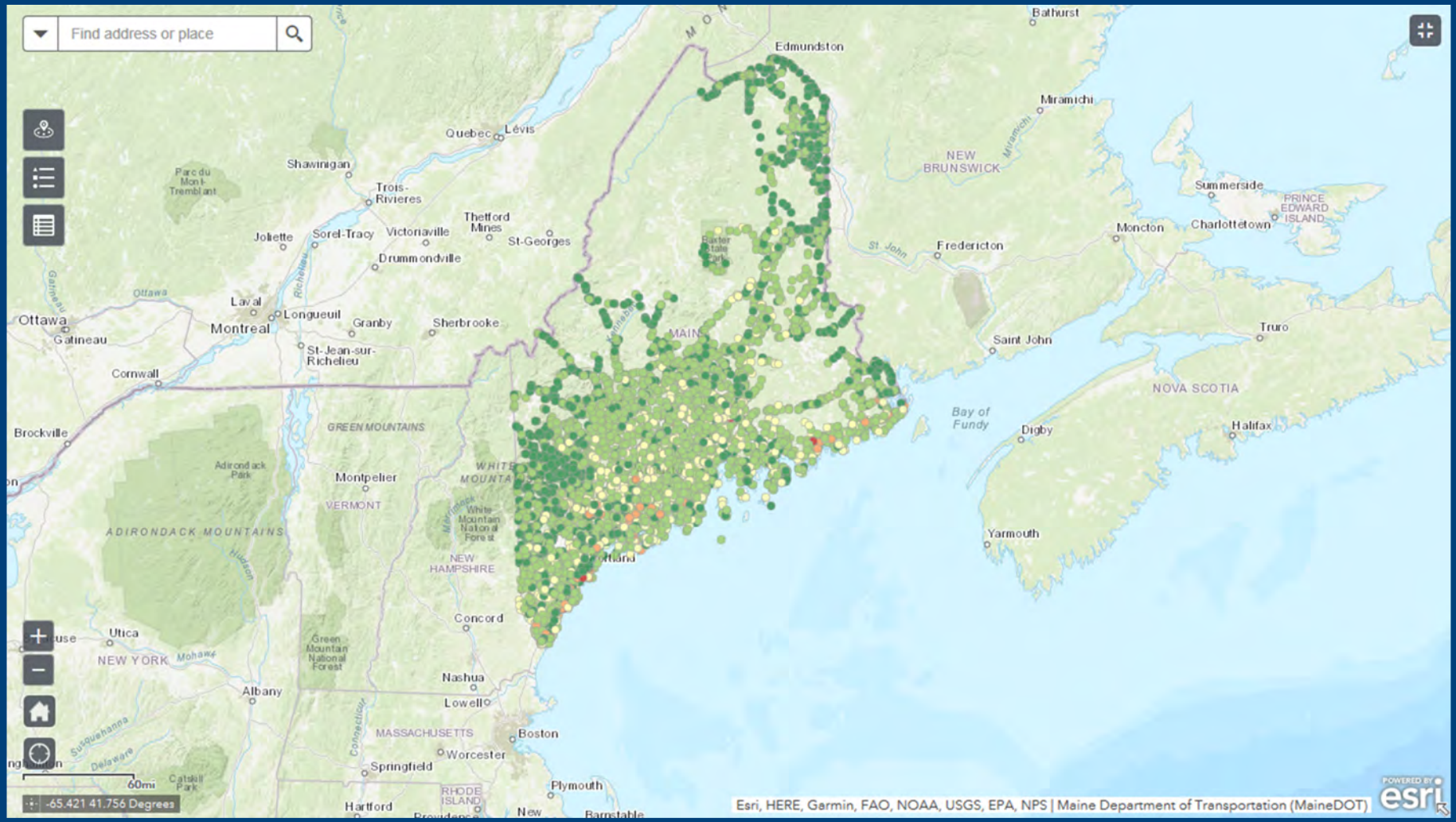
Some Background

- MaineDOT Climate & Resilience Work
  - Judy Gates (MaineDOT) & Sam Merrill (GEI)
  - Started with a coastal focus
    - **Two large coastal bridges**
    - **Several large coastal culverts**
  - Moved inland
    - **Pilot corridor assessments**
    - **Culvert vulnerability ranking**
  - TRAPPD – *program risk*
    - **Transportation Risk Assessment for Project Planning & Delivery**

Some Aspects of MaineDOT Climate Work

- Pilot / Demonstration
  - Not implemented system-wide
- Limited to Large Culverts & Bridges
  - *Relatively* small subset of all assets
- Assessment / Risk Orientation – Project Planning
  - *NOT* engineering or design
- Next Need to Address:
  - Many thousands of cross culverts – *in the Regions*
  - *Alexa! How big should the culvert be?*

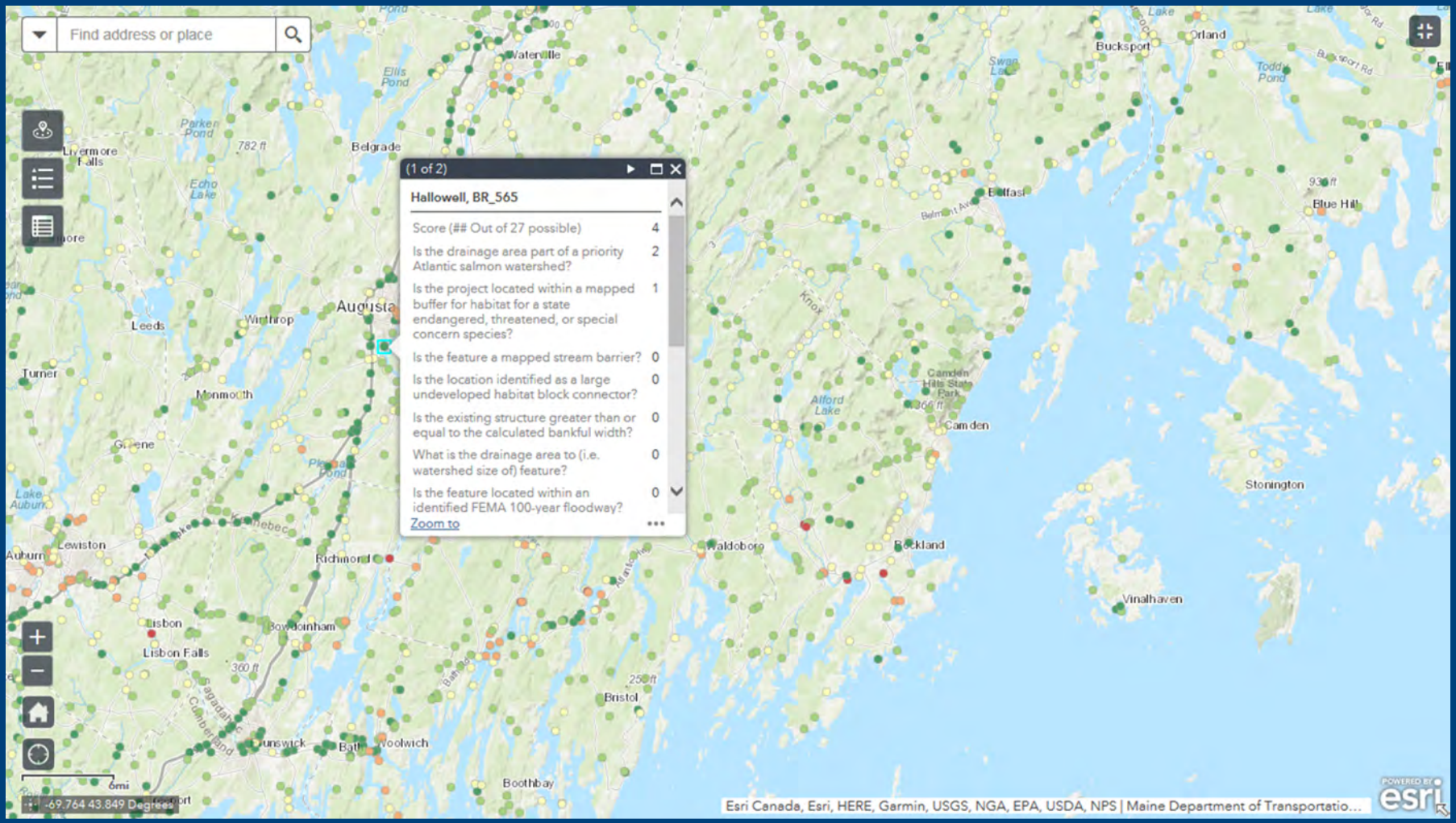
TRAPPD – *Program Risk*

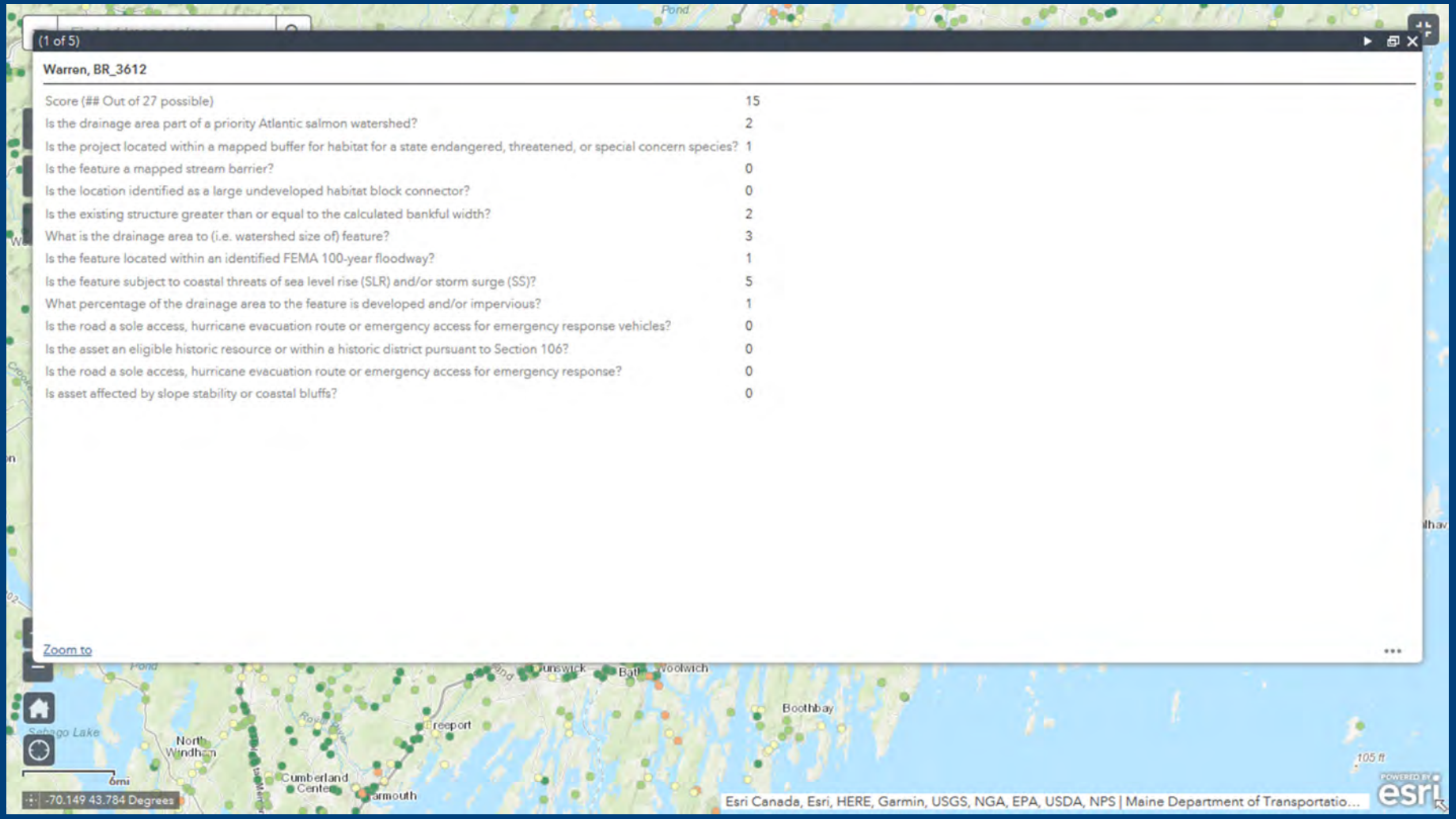


TRAPPD

- Currently limited to bridges & large culverts
- Based on existing or “easily” developed GIS data
  - Biggest challenge: hydrology info from StreamStats
- Not intended to be a design tool
  - *But contains useful unreported design info*
- As *currently* intended, utility relatively limited to
  - “small” number of assets at any one time
  - small number of DOT staff who might be using
- But potential of the idea is ***HUGE***!

TRAPPD – Using & Reporting




(1 of 5)
Warren, BR_3612
Score (## Out of 27 possible) 15
Is the drainage area part of a priority Atlantic salmon watershed? 2
Is the project located within a mapped buffer for habitat for a state endangered, threatened, or special concern species? 1
Is the feature a mapped stream barrier? 0
Is the location identified as a large undeveloped habitat block connector? 0
Is the existing structure greater than or equal to the calculated bankful width? 2
What is the drainage area to (i.e. watershed size of) feature? 3
Is the feature located within an identified FEMA 100-year floodway? 1
Is the feature subject to coastal threats of sea level rise (SLR) and/or storm surge (SS)? 5
What percentage of the drainage area to the feature is developed and/or impervious? 1
Is the road a sole access, hurricane evacuation route or emergency access for emergency response vehicles? 0
Is the asset an eligible historic resource or within a historic district pursuant to Section 106? 0
Is the road a sole access, hurricane evacuation route or emergency access for emergency response? 0
Is asset affected by slope stability or coastal bluffs? 0
Zoom to
Brunswick
Bath
Woolwich
Boothbay
Freeport
North Windham
Cumberland Center
Sebago Lake
-70.149 43.784 Degrees
Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS | Maine Department of Transportatio...
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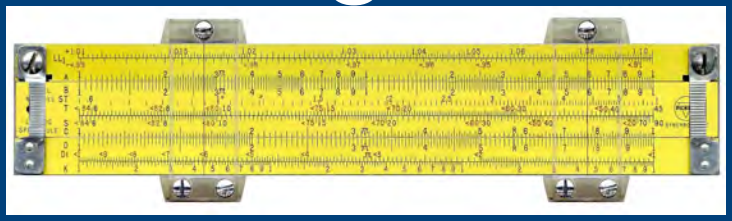
TRAPPD & Culvert Design



- Design info not reported – culvert size, BFW, hydrology, etc
  - But it *is* there (except for size) – just not reported
- Many thousands of cross-culverts
- Principle Program Risk Element for Cross-Culverts: ***Culvert Upsizing***
  - ***Other risk elements less critical in day-to-day work for most cross-culverts***

Core Ideas in TRAPPD that Transcend Specific Applications

- GIS basis
- Embedded Algorithms
  - As simple or complicated as you like
- Platform
  - Currently AGOL
  - Could be any “Map Viewer” or GIS platform
- Leverage these strengths for further uses
  - *Cross Culverts & Hydraulic Design!*

What If?

- Instead of limited to 4,000 bridges & large culverts …
  - *Widen the net to capture 37,000 cross culverts?*
- Instead of limited to risk scoring …
  - *Deliver preliminary culvert design info?*
- Instead of limited to use on a handful of projects every year by a few people
  - *Apply to many culverts state-wide by Region Engineers, Asset Managers & Project Coordinators?*

Motivations for Attacking Cross Culvert Challenge

- TRAPPD
  - Showed the possibilities
- Inland culvert vulnerability (Merrill / GEI)
  - Inching towards engineering
  - Still limited to Bridges / Large Culverts Data Set
- Mike Hogan at CT DOT
  - *Vulnerability Assessment and Adaption Analysis*
  - Further culvert work with StreamStats

What Triggers Culvert Upsizing?

- Traditionally, many / most cross culverts were not “designed”
  - “maintenance” culverts
  - Replace-in-Kind (RIK)
    - **Upsize if a known capacity problem**
    - **RIK otherwise**
  - Fish Passage – *bankfull width sizing*
    - **Modern regulatory requirements & expectations**
    - **Not based on traditional hydraulic sizing**
  - Hydrology
    - **Many / most cross-culverts never really “designed” for Hydrology/Hydraulics**
    - **Climate change?**

Culvert Upsizing: Why a Problem?

- From 2'D to 4'D pipe:
  - Not such a big deal
  - "incremental upsizing" often due to H&H capacity
- From 4'D pipe to 8'S x 6'R box with streambed
  - *This a BFD!*
  - Order-of-Magnitude upsizing usually due to environmental / fish passage requirements
- Can we capture this? *YES!*
  - **Hydrology**
  - **Hydraulics**
  - **Habitat**

Hydrology/Hydraulics in TRAPPD

- Hydrology Based on
  - USGS StreamStats for GIS analysis
    - **Watershed area, NWI wetlands, etc**
  - USGS regression equations for flow calcs
  - USGS regression equations for Bankfull Width (BFW)
- *But No Hydraulics*
  - *this is how you get culvert sizing*
  - *Simple equations, easy to implement*

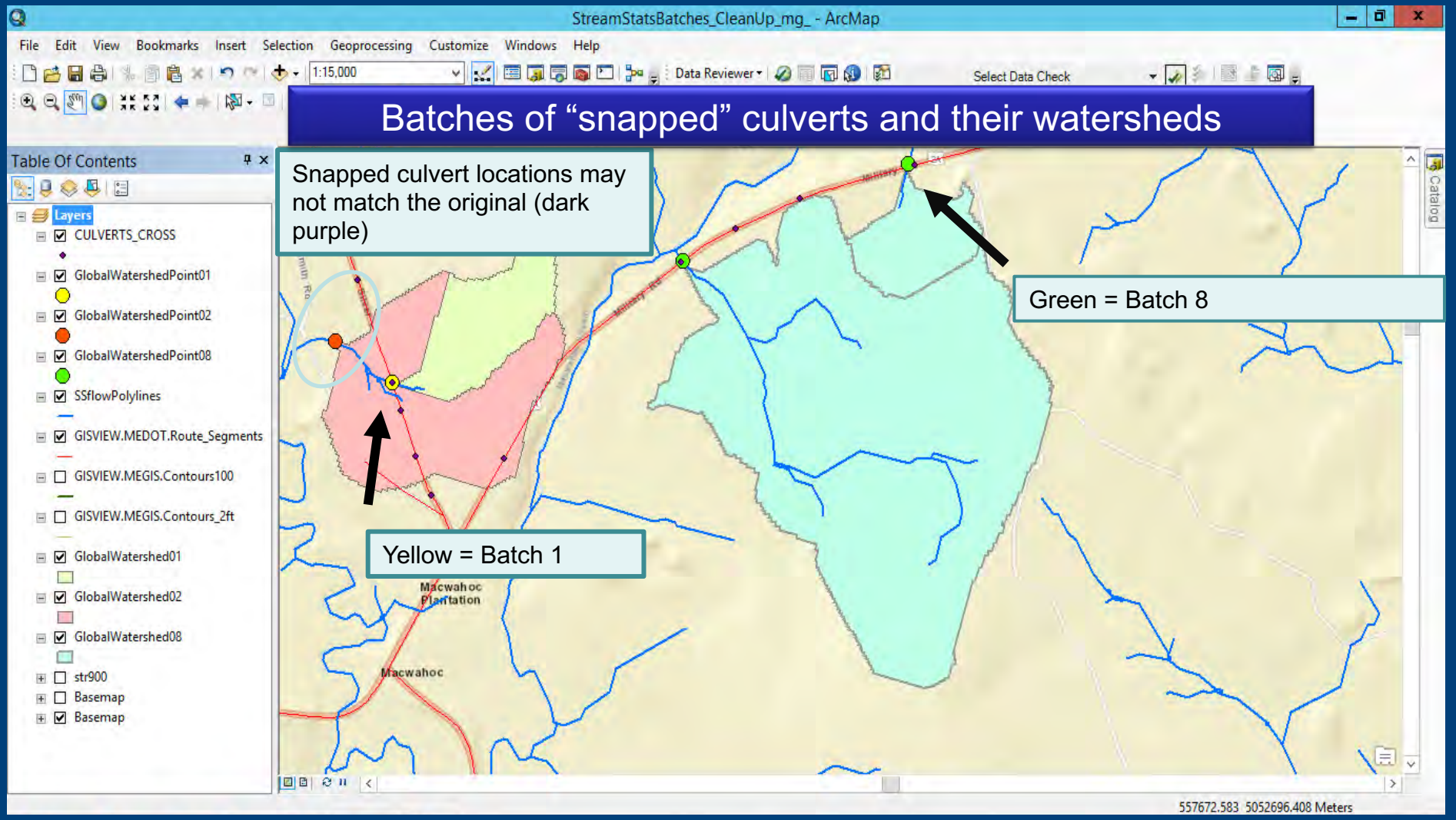
Where Do We Go?

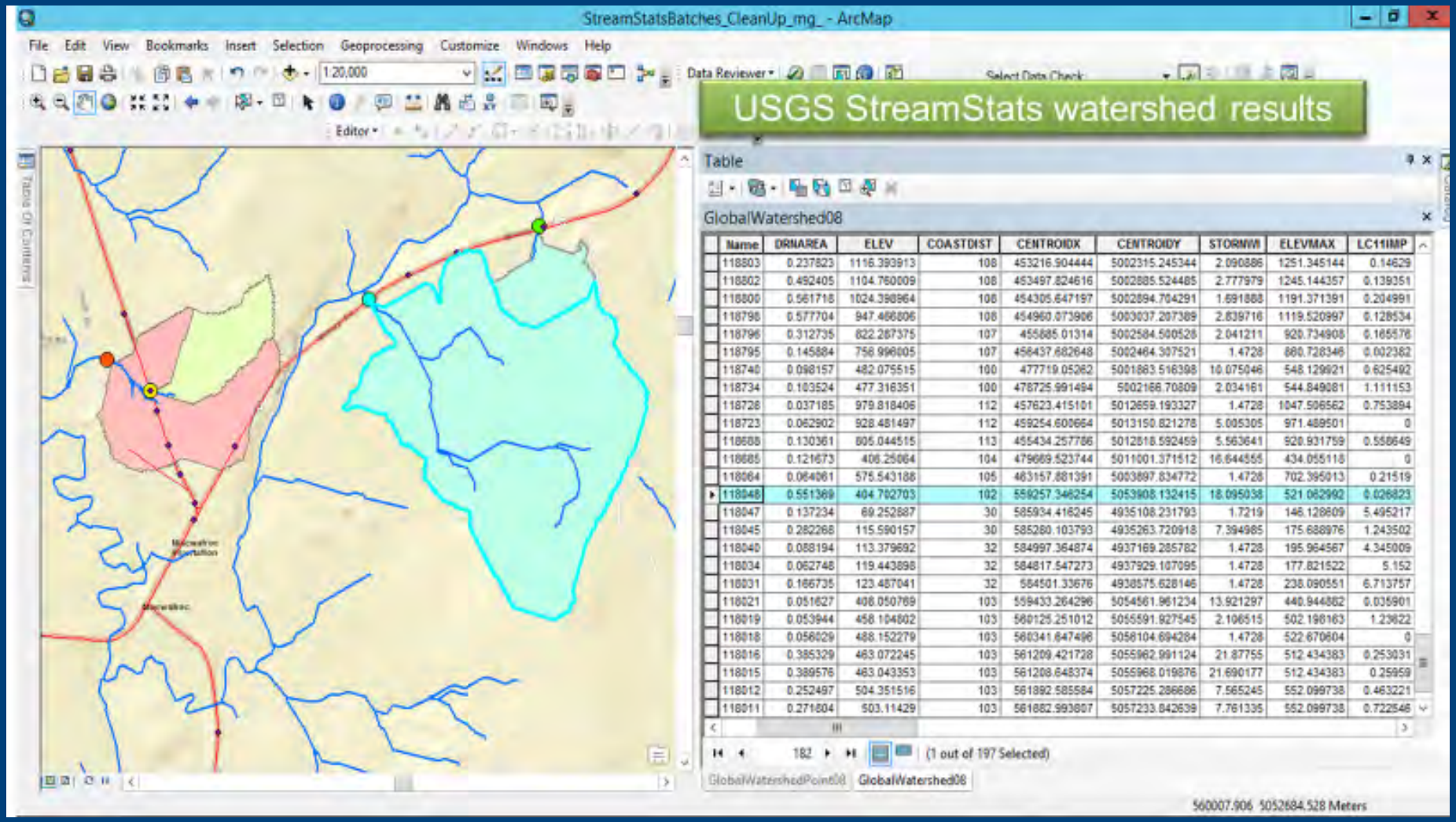
- Conceptually …
  - Just add cross-culverts to TRAPPD
  - *… not so fast*
- Practical Implementation …
  - Baby steps
  - Separate simple platform just for cross-culvert sizing
  - Test-run
  - See how it is received
  - Refine, improve and add to TRAPPD 2.0

Challenge: Numbers, Location & Stream Network

- 37,000 cross-culverts 1.5’ ≤ D < 5’
- Hydrology
  - Run StreamStats in “batch mode”
  - Location - “*SNAP*” DOT culvert locations to USGS “pixelated” stream network
  - We lost about 10,000 culverts that did not “snap”
    - **Lost in the ozone, still searching**
  - Run batches of 200 – about 120 batches!
  - Not all culverts snapped “correctly” – clean up
    - **Currently in progress**

Batches of “snapped” culverts and their watersheds




StreamStatsBatches_CleanUp_mg_ - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
USGS StreamStats watershed results
Table
GlobalWatershed08
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118802 0.492405 1104.760009 108 453497.824616 5002885.524485 2.777979 1245.144357 0.139351
118800 0.561718 1024.398964 108 454305.647197 5002894.704291 1.691888 1191.371391 0.204991
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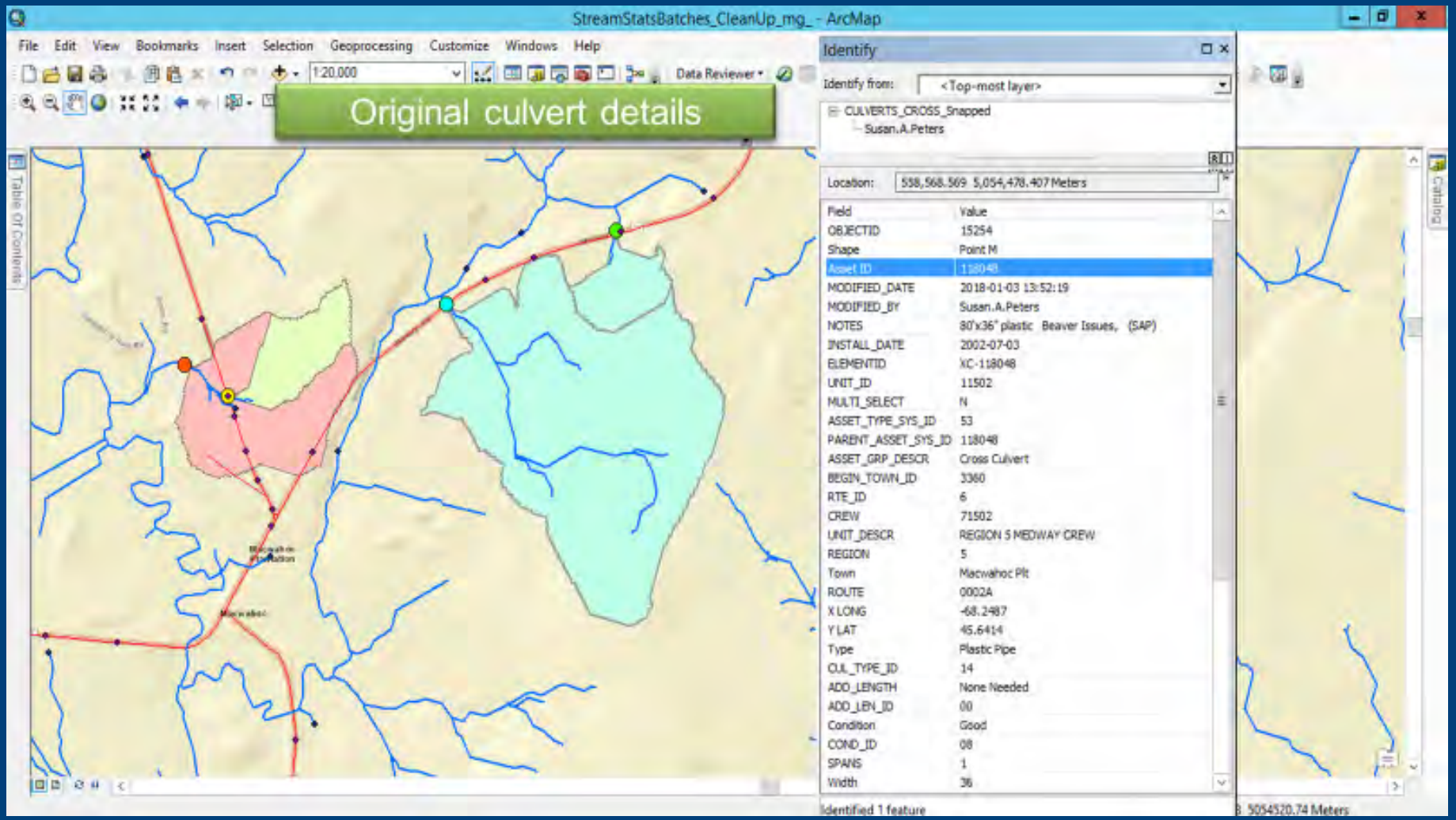
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Data Reviewer
Original culvert details
Identify
Identify from:
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CULVERTS_CROSS_Snapped
Susan.A.Peters
Location:
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Field Value
OBJECTID 15254
Shape Point M
Asset ID 118048
MODIFIED_DATE 2018-01-03 13:52:19
MODIFIED_BY Susan.A.Peters
NOTES 80'x36" plastic Beaver Issues, (SAP)
INSTALL_DATE 2002-07-03
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UNIT_ID 11502
MULTI_SELECT N
ASSET_TYPE_SYS_ID 53
PARENT_ASSET_SYS_ID 118048
ASSET_GRP_DESCR Cross Culvert
BEGIN_TOWN_ID 3360
RTE_ID 6
CREW 71502
UNIT_DESCR REGION 5 MEDWAY CREW
REGION 5
Town Macwahoc Plt
ROUTE 0002A
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Y LAT 45.6414
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ADD_LEN_ID 00
Condition Good
COND_ID 08
SPANS 1
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Identified 1 feature
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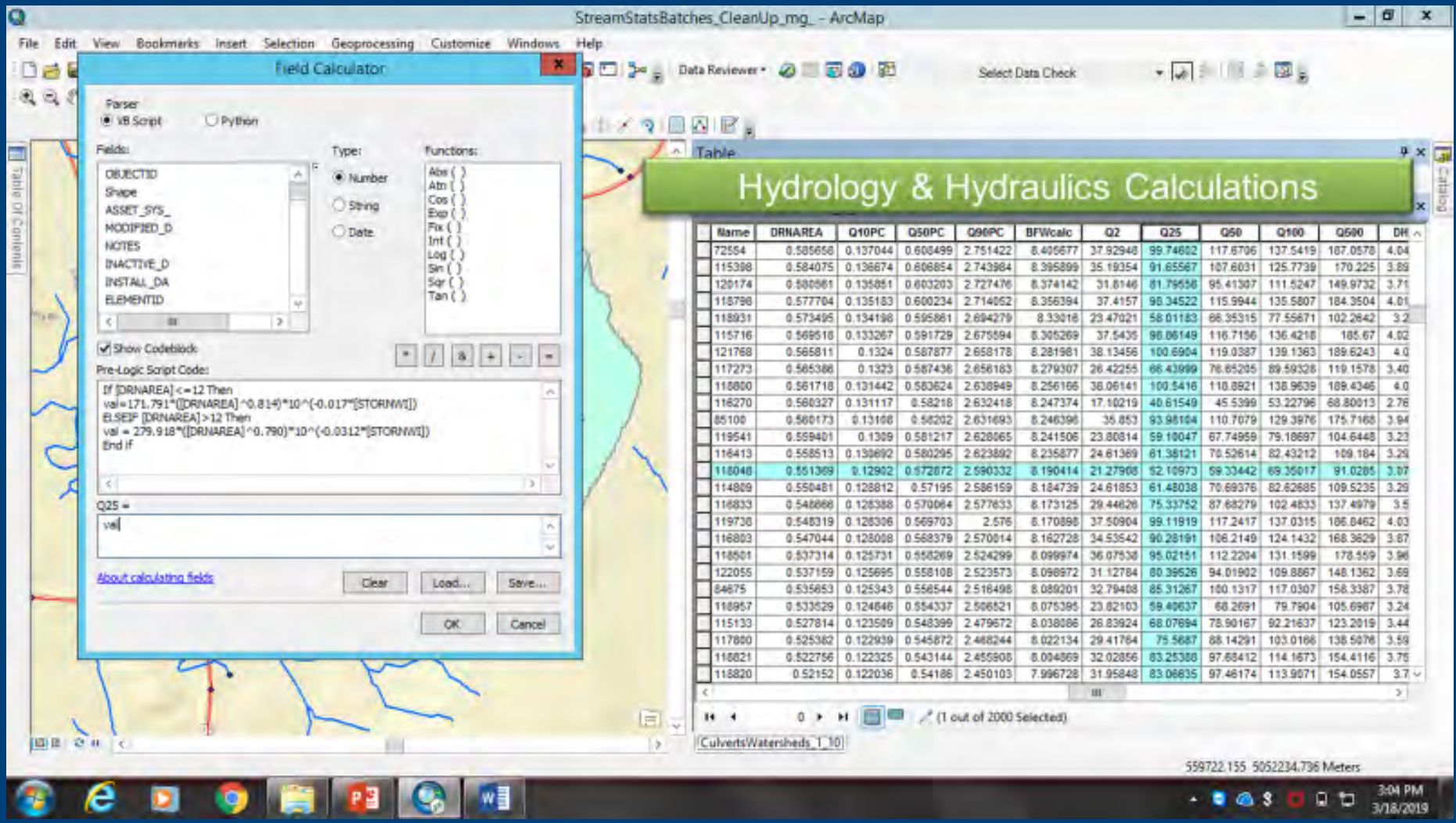
StreamStatsBatches_CleanUp_mg_ - ArcMap
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Field Calculator
Parser
VB Script
Python
Fields:
OBJECTID
Shape
ASSET_SYS_
MODIFIED_D
NOTES
INACTIVE_D
INSTALL_DA
ELEMENTID
Type:
Number
String
Date
Functions:
Abs ( )
Atn ( )
Cos ( )
Exp ( )
Fix ( )
Int ( )
Log ( )
Sin ( )
Sqr ( )
Tan ( )
Show Codeblock
Pre-Logic Script Code:
If [DRNAREA] <= 12 Then
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ELSEIF [DRNAREA] > 12 Then
val = 279.918*([DRNAREA]^0.790)*10^(-0.0312*[STORNWI])
End If
Q25 =
val
About calculating fields
Clear
Load...
Save...
OK
Cancel
Table
Hydrology & Hydraulics Calculations
Name DRNAREA Q10PC Q50PC Q90PC BFWcalc Q2 Q25 Q50 Q100 Q500
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115398 0.584075 0.136674 0.606854 2.743984 8.395899 35.19354 91.65567 107.6031 125.7739 170.225
120174 0.580561 0.135851 0.603203 2.727476 8.374142 31.8146 81.79556 95.41307 111.5247 149.9732
118796 0.577704 0.135183 0.600234 2.714062 8.356394 37.4157 96.34522 115.9944 135.5807 184.3504
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85100 0.560173 0.13108 0.58202 2.631693 8.246396 35.853 93.98104 110.7079 129.3976 175.7168
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114809 0.550481 0.128812 0.57195 2.586159 8.184739 24.61853 61.48038 70.69376 82.62685 109.5235
116833 0.548666 0.128388 0.570084 2.577633 8.173125 29.44626 75.33752 87.68279 102.4833 137.4979
119736 0.548319 0.128306 0.569703 2.576 8.170898 37.50904 99.11919 117.2417 137.0315 186.8462
116803 0.547044 0.128008 0.568379 2.570014 8.162728 34.53542 90.28191 106.2149 124.1432 168.3629
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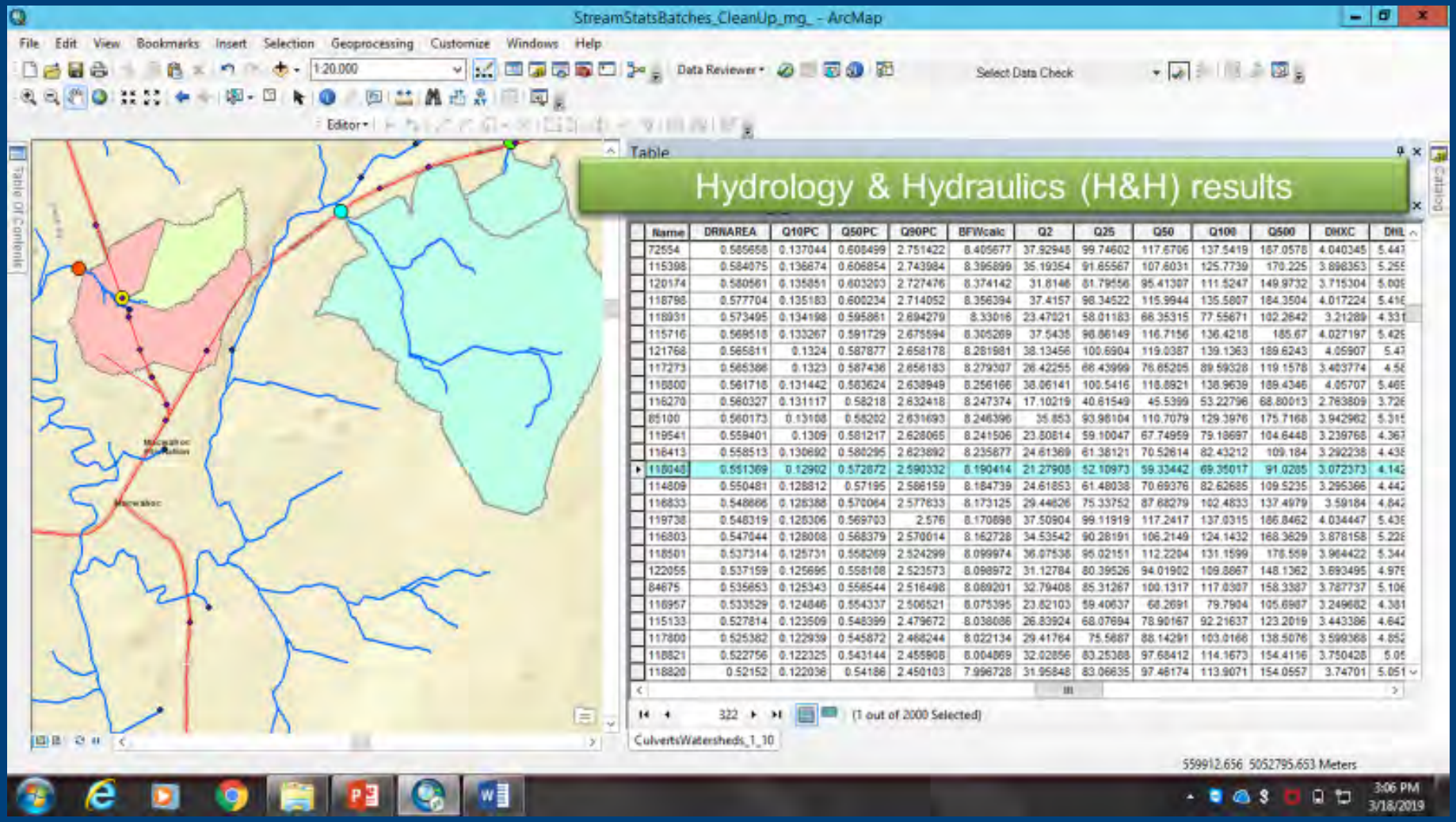
3/18/2019



Name	DRNAREA	Q10PC	Q50PC	Q90PC	BFIWcalc	Q2	Q25	Q50	Q100	Q500	DHXC	DHL
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115398	0.584075	0.136874	0.606854	2.743984	8.395899	35.19354	91.65567	107.6031	125.7739	170.225	3.898353	5.255
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121768	0.565811	0.1324	0.587877	2.658178	8.281981	38.13456	100.6904	119.0387	139.1363	189.6243	4.05907	5.47
117273	0.565386	0.1323	0.587436	2.656183	8.279307	26.42255	68.43999	76.65205	89.59328	119.1578	3.463774	4.58
118800	0.561716	0.131442	0.583624	2.638949	8.256166	38.06141	100.5416	118.8921	138.9639	189.4346	4.05707	5.465
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119541	0.559401	0.1309	0.581217	2.628065	8.241506	23.80814	59.10047	67.74959	79.18697	104.6448	3.239768	4.367
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114809	0.550481	0.128812	0.57195	2.586159	8.184739	24.61853	61.48038	70.69376	82.62685	109.5235	3.295366	4.442
116833	0.548866	0.128388	0.570064	2.577633	8.173125	29.44826	75.33752	87.68279	102.4833	137.4979	3.59184	4.842
119738	0.548319	0.128306	0.569703	2.576	8.170698	37.50904	99.11919	117.2417	137.0315	186.8462	4.034447	5.439
116803	0.547044	0.128008	0.568379	2.570014	8.162728	34.53542	90.28191	106.2149	124.1432	168.3629	3.878158	5.228
118501	0.537314	0.125731	0.558269	2.524299	8.099974	36.07536	95.02151	112.2204	131.1599	178.559	3.964422	5.344
122055	0.537159	0.125696	0.558108	2.523573	8.098972	31.12784	80.39526	94.01902	109.8867	148.1362	3.693495	4.979
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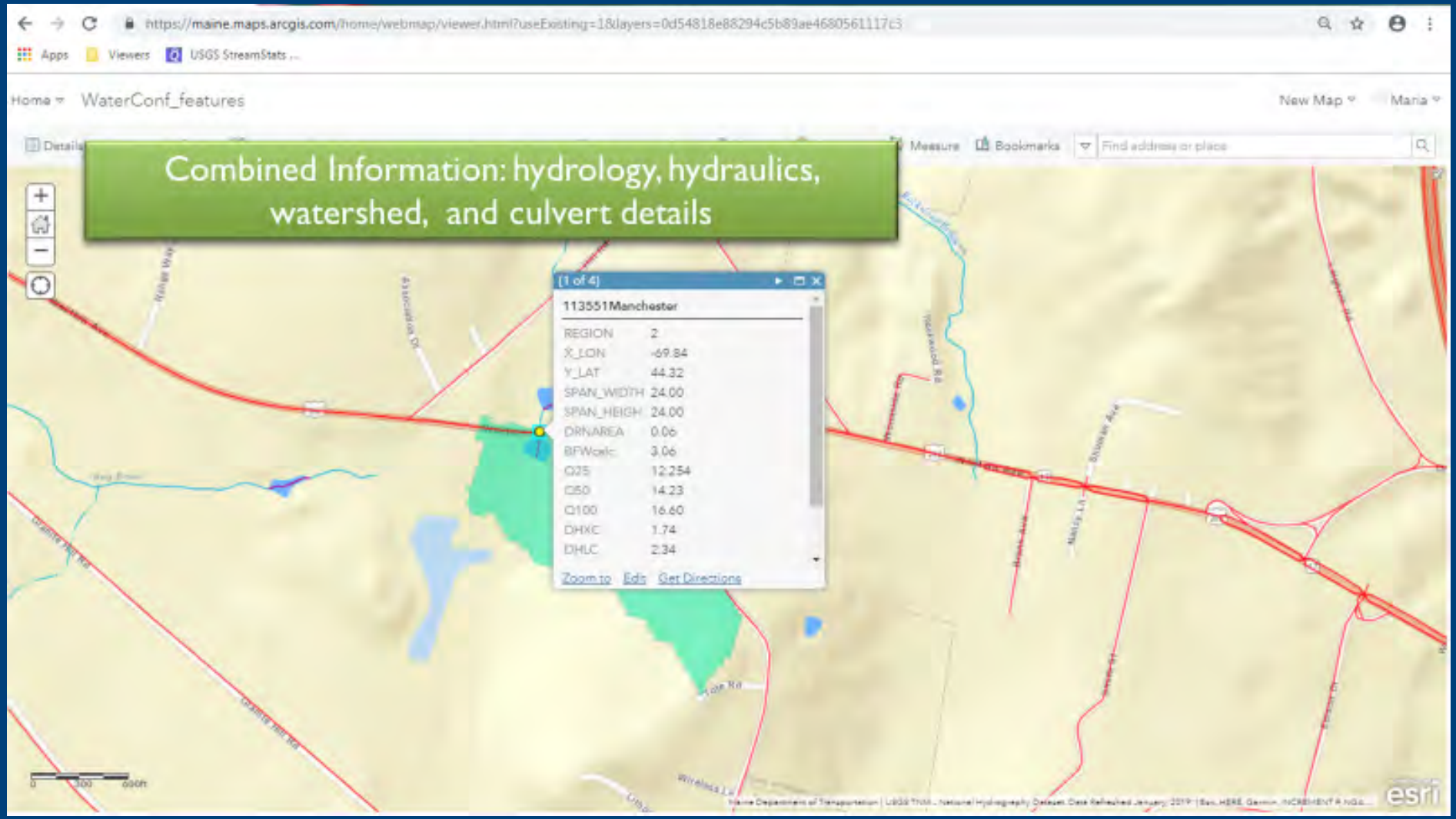
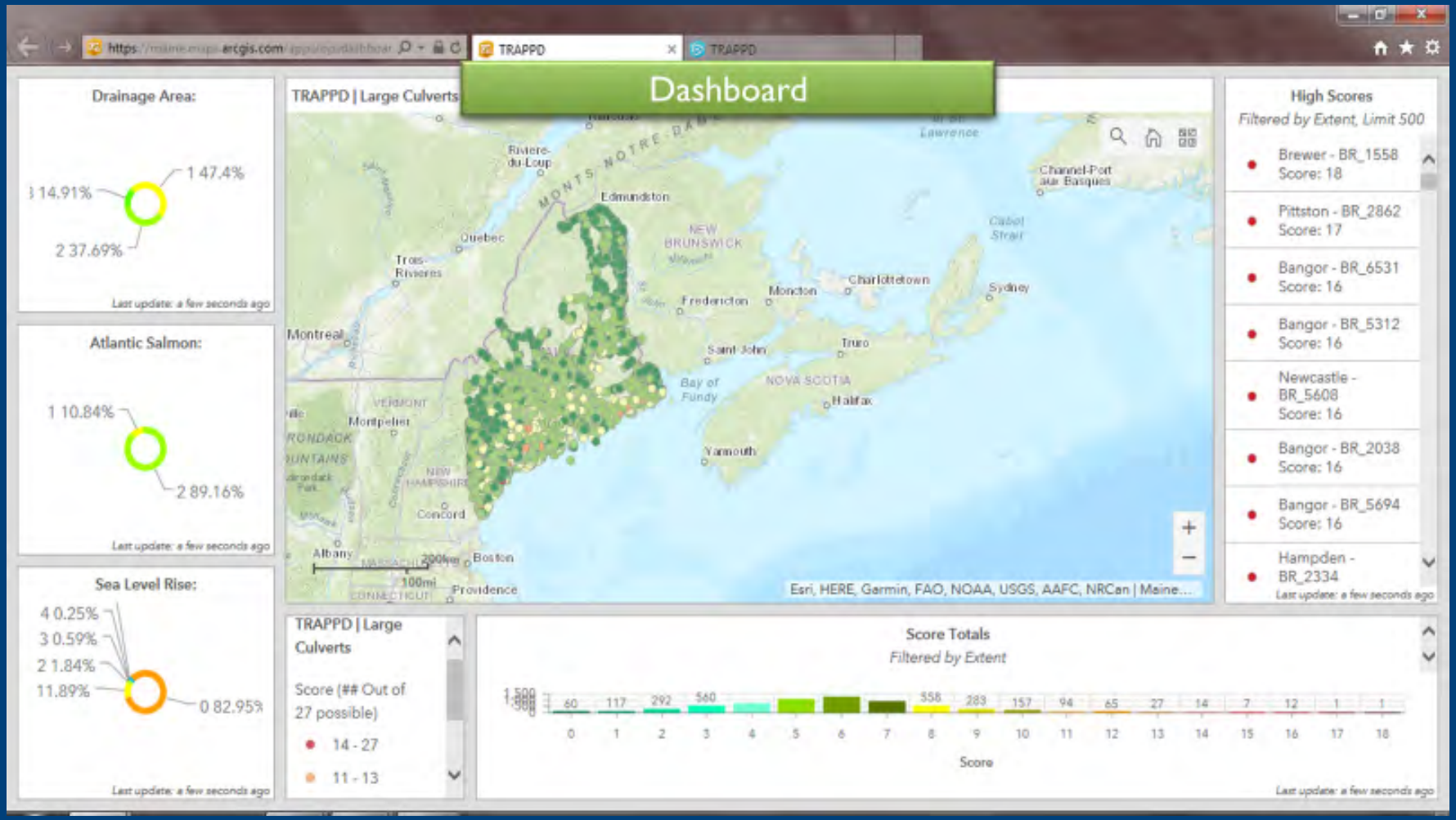
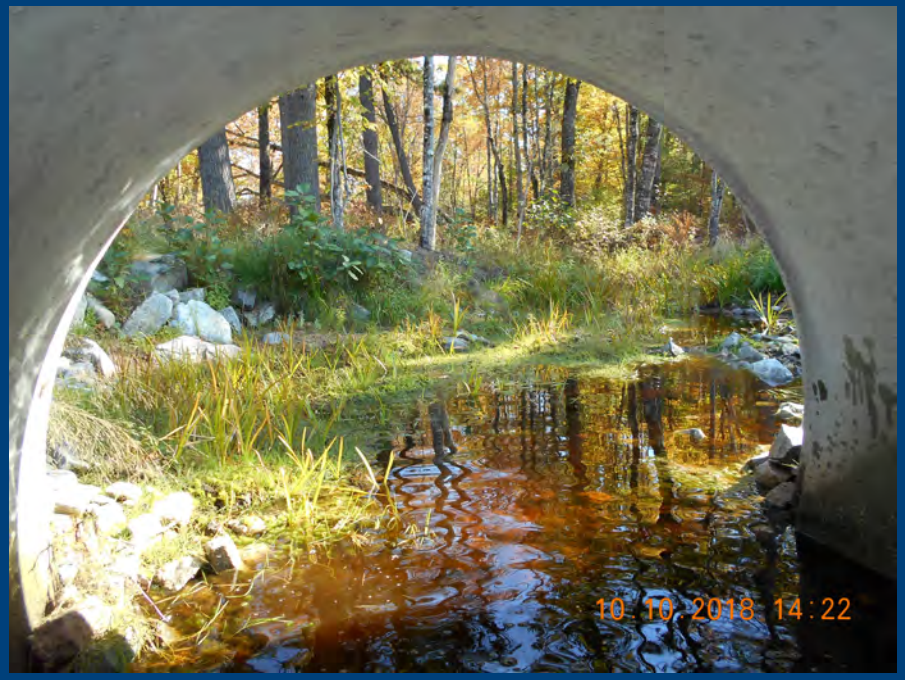
116957	0.533529	0.124846	0.554337	2.506521	8.075395	23.82103	59.40637	68.2691	79.7904	105.6987	3.249682	4.381
115133	0.527814	0.123509	0.548399	2.479672	8.038086	26.83924	68.07694	78.90167	92.21637	123.2019	3.443386	4.642
117800	0.525382	0.122939	0.545872	2.468244	8.022134	29.41764	75.5687	88.14291	103.0166	138.5076	3.599368	4.852
118821	0.522756	0.122325	0.543144	2.455908	8.004869	32.02856	83.25388	97.68412	114.1673	154.4116	3.750428	5.05
118820	0.52152	0.122036	0.54186	2.450103	7.996728	31.95848	83.06635	97.46174	113.9071	154.0557	3.74701	5.051


https://maine.maps.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=0d54818e88294c5b89ae4680561117c3
Apps
Viewers
USGS StreamStats ...
Home
WaterConf_features
New Map
Maria
Measure
Bookmarks
Find address or place
Combined Information: hydrology, hydraulics, watershed, and culvert details
(1 of 4)
113551Manchester
REGION 2
X_LON -69.84
Y_LAT 44.32
SPAN_WIDTH 24.00
SPAN_HEIGH 24.00
DRNAREA 0.06
BFWoslc 3.06
Q25 12.254
Q50 14.23
Q100 16.60
DHXC 1.74
DHLC 2.34
Zoom to
Edit
Get Directions
esri


TRAPPD
TRAPPD
Dashboard
Drainage Area:
1 47.4%
2 37.69%
Last update: a few seconds ago
Atlantic Salmon:
1 10.84%
2 89.16%
Last update: a few seconds ago
Sea Level Rise:
4 0.25%
3 0.59%
2 1.84%
11.89%
0 82.95%
Last update: a few seconds ago
TRAPPD | Large Culverts
Esri, HERE, Garmin, FAO, NOAA, USGS, AAFC, NRCan | Maine...
High Scores
Filtered by Extent, Limit 500
Brewer - BR_1558 Score: 18
Pittston - BR_2862 Score: 17
Bangor - BR_6531 Score: 16
Bangor - BR_5312 Score: 16
Newcastle - BR_5608 Score: 16
Bangor - BR_2038 Score: 16
Bangor - BR_5694 Score: 16
Hampden - BR_2334
Last update: a few seconds ago
TRAPPD | Large Culverts
Score (## Out of 27 possible)
14 - 27
11 - 13
Score Totals
Filtered by Extent
60 117 292 560 358 283 157 94 65 27 14 7 12 1 1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Score
Last update: a few seconds ago

Observations & Conclusions



- Simple concept
- Simple mechanics
  - But tedious!
  - Takes time
- Key element
  - Good asset (culvert) database
  - Impossible otherwise
- Concept applicable to any organization with a collection of culverts
  - Towns – see Martha Shiels work at USM – Muskie School

Questions?

- Thank you

- Charles Hebson

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