Linear Referencing – Building a System of Record for Roads, Pipeline and Rail

Jim Barry
Tom DeWitte
Hunter Sinclair

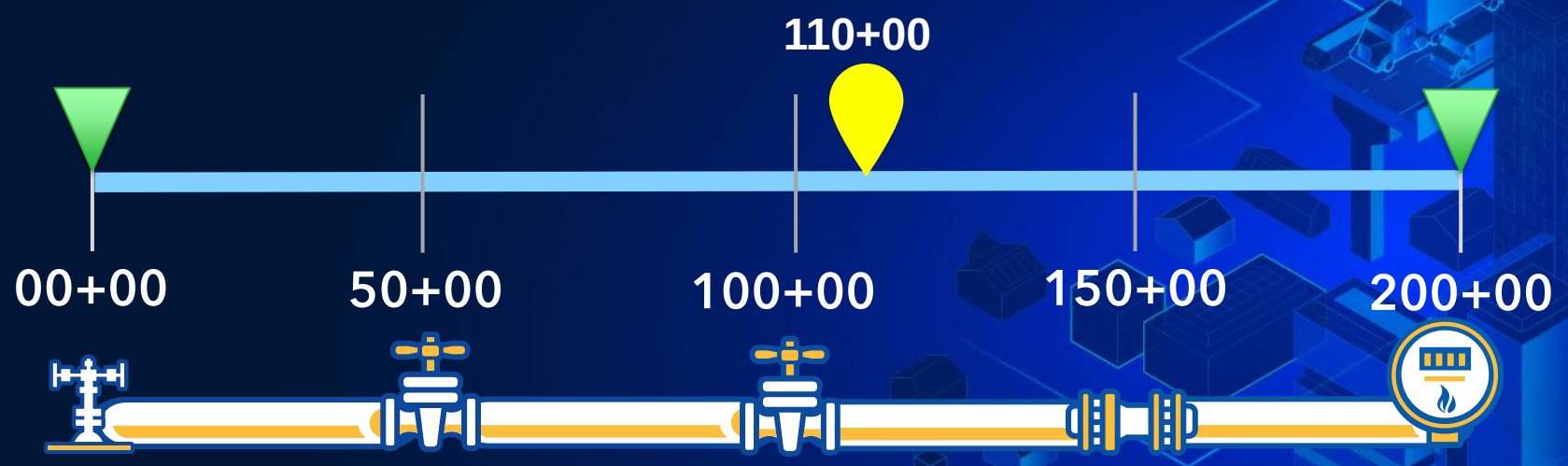
Agenda

- What is Linear Referencing?
- Using LRS for Data Management
- LRS for Developers
- The Road Ahead

What is Linear Referencing

A method of location and data management

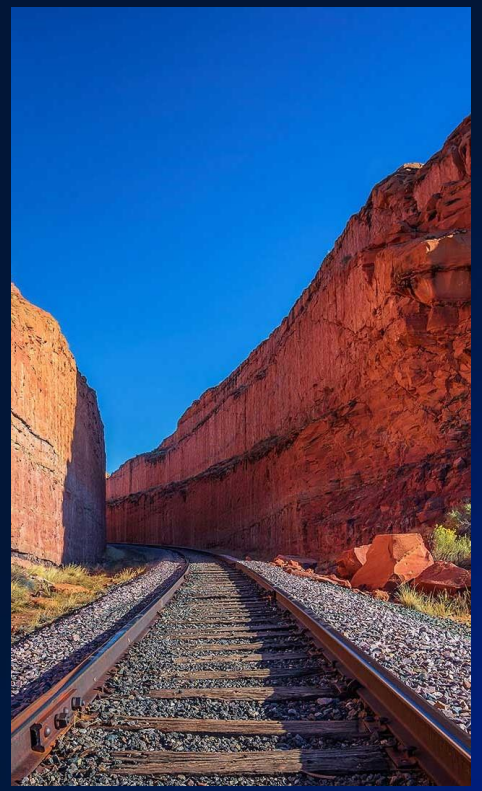
- Linear Referencing is a method of identifying a location
- Commonly used along long linear assets and features



Who Uses Linear Referencing

Anyone Managing Long Linear Assets or Features

Roads



Railroads

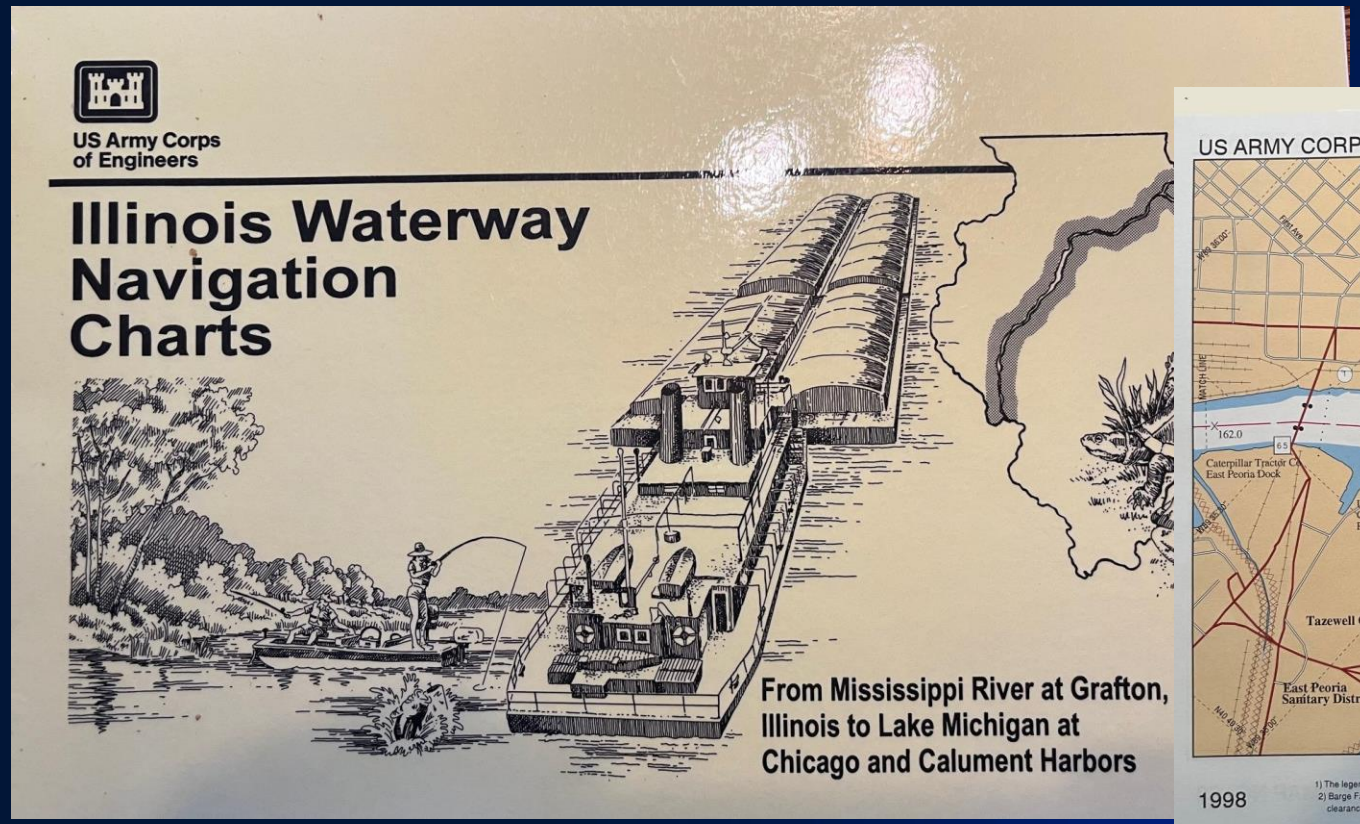
Pipelines

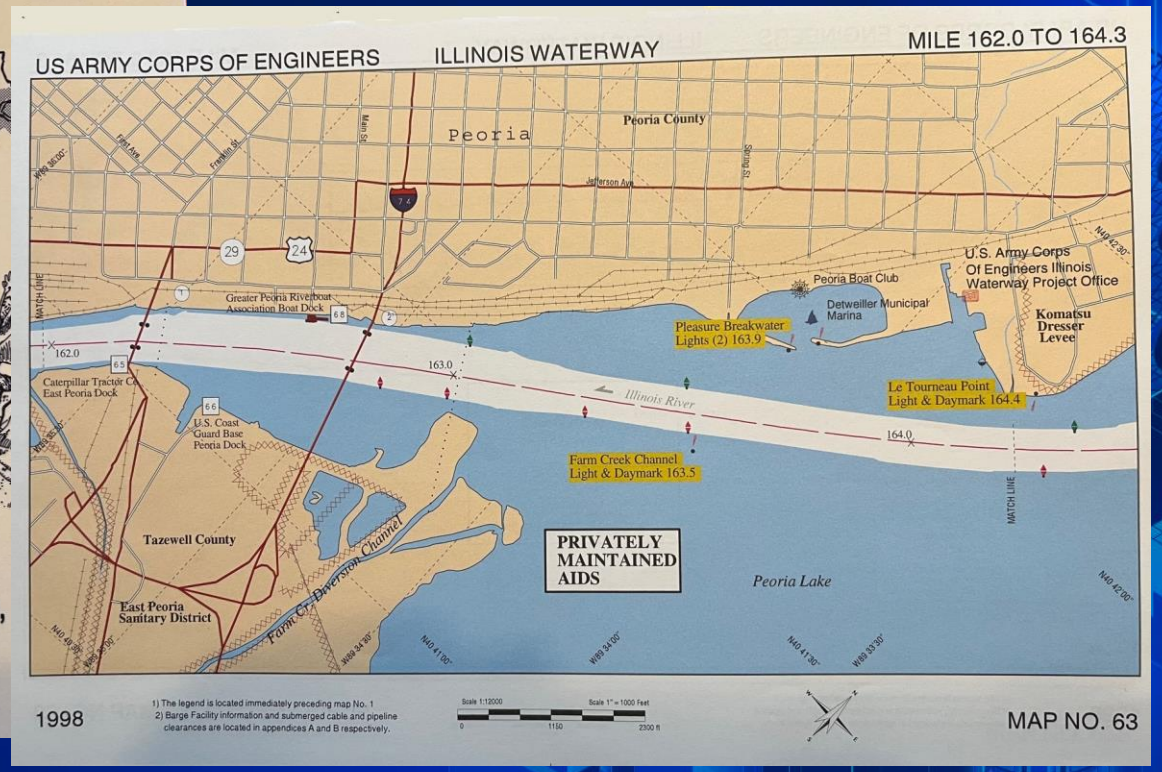
Rivers

Linear Referencing in Action

Water

- Navigable Waterways in the United States use linear referencing to communicate location
  - Route is the centerline of the navigation channel
  - Measure is in miles, as measured above the outflow of the river

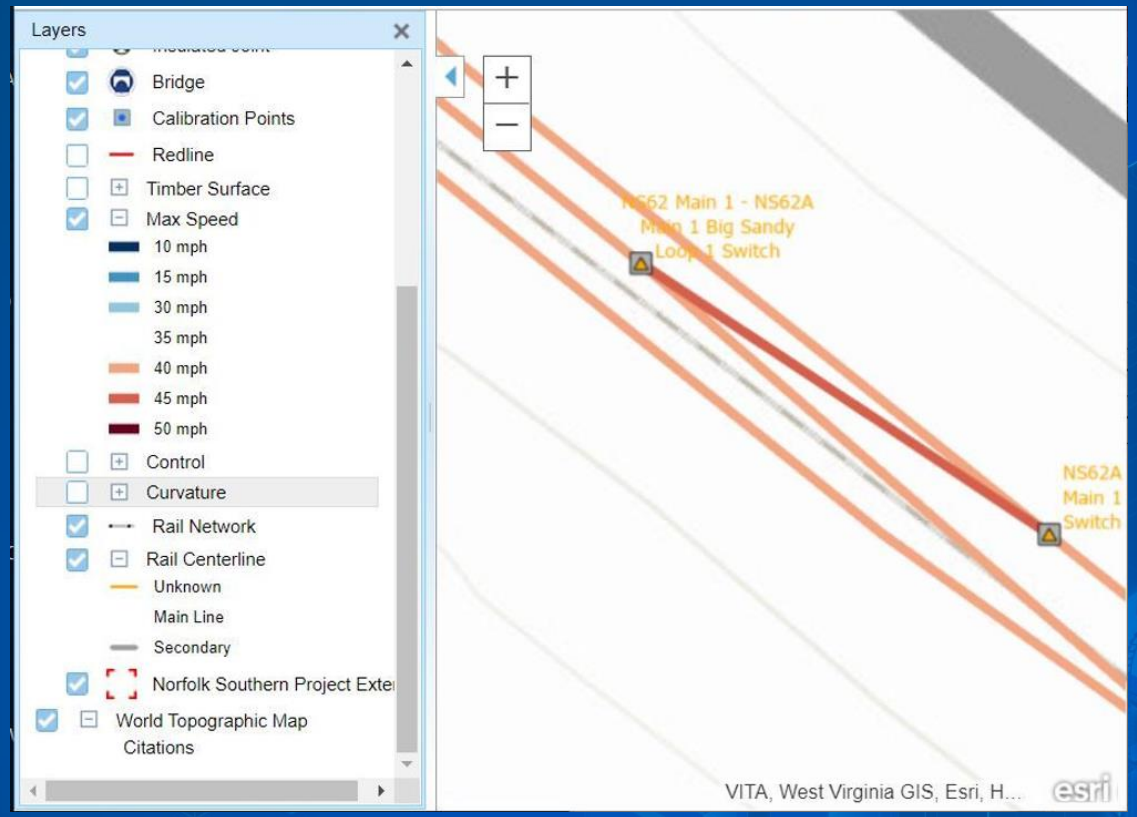




Linear Referencing in Action

Railroads

- Railroads in the United States use linear referencing to communicate location
  - Route is the railroad centerline
  - Measure is milepost, kilometrepost, stationing + offsets

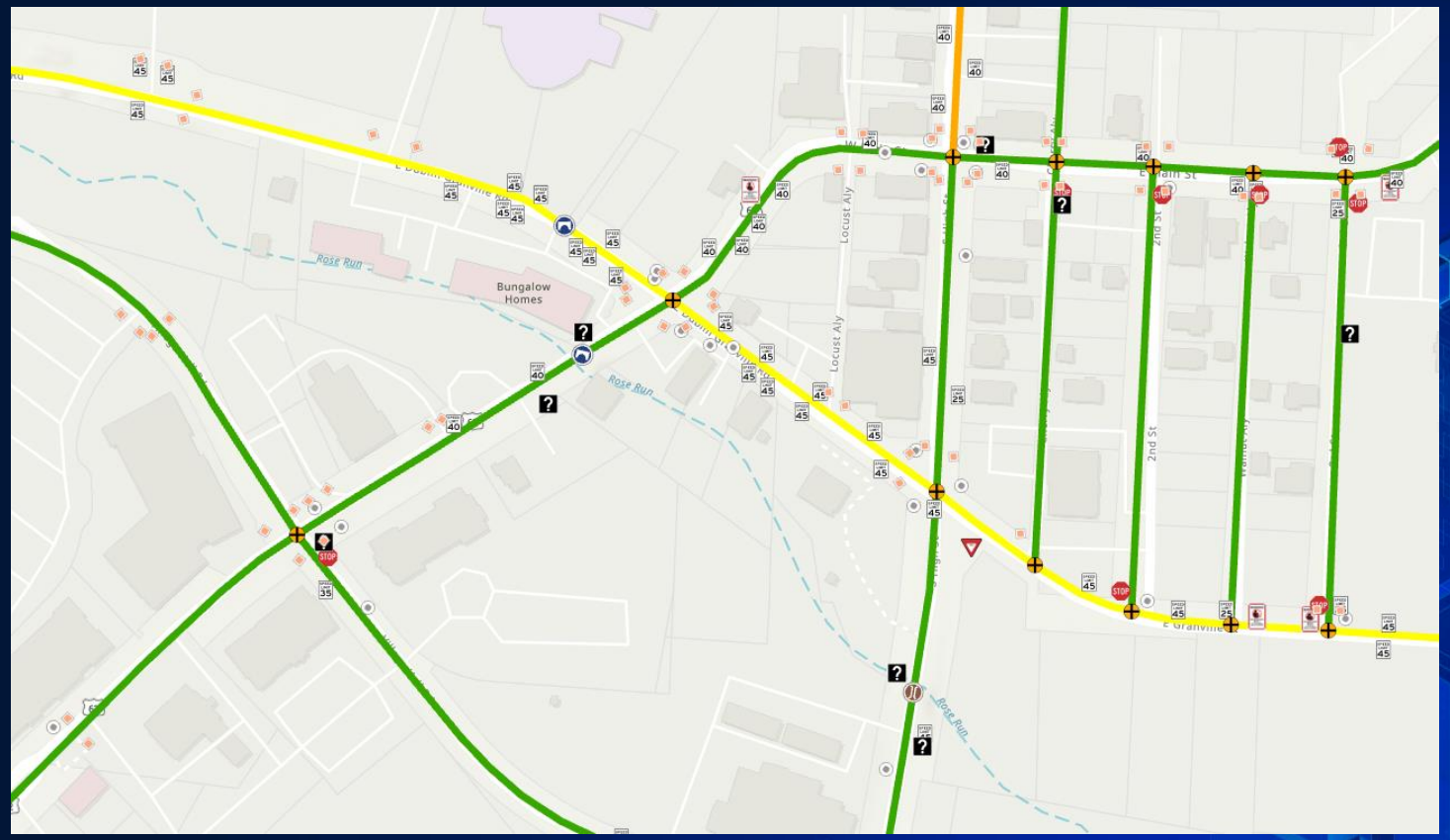


Linear Referencing in Action

Roads

Roads and Highways in the United States use linear referencing to communicate location

- Route is the centerline of the road
- Measure is in miles, as measured from a designated start location

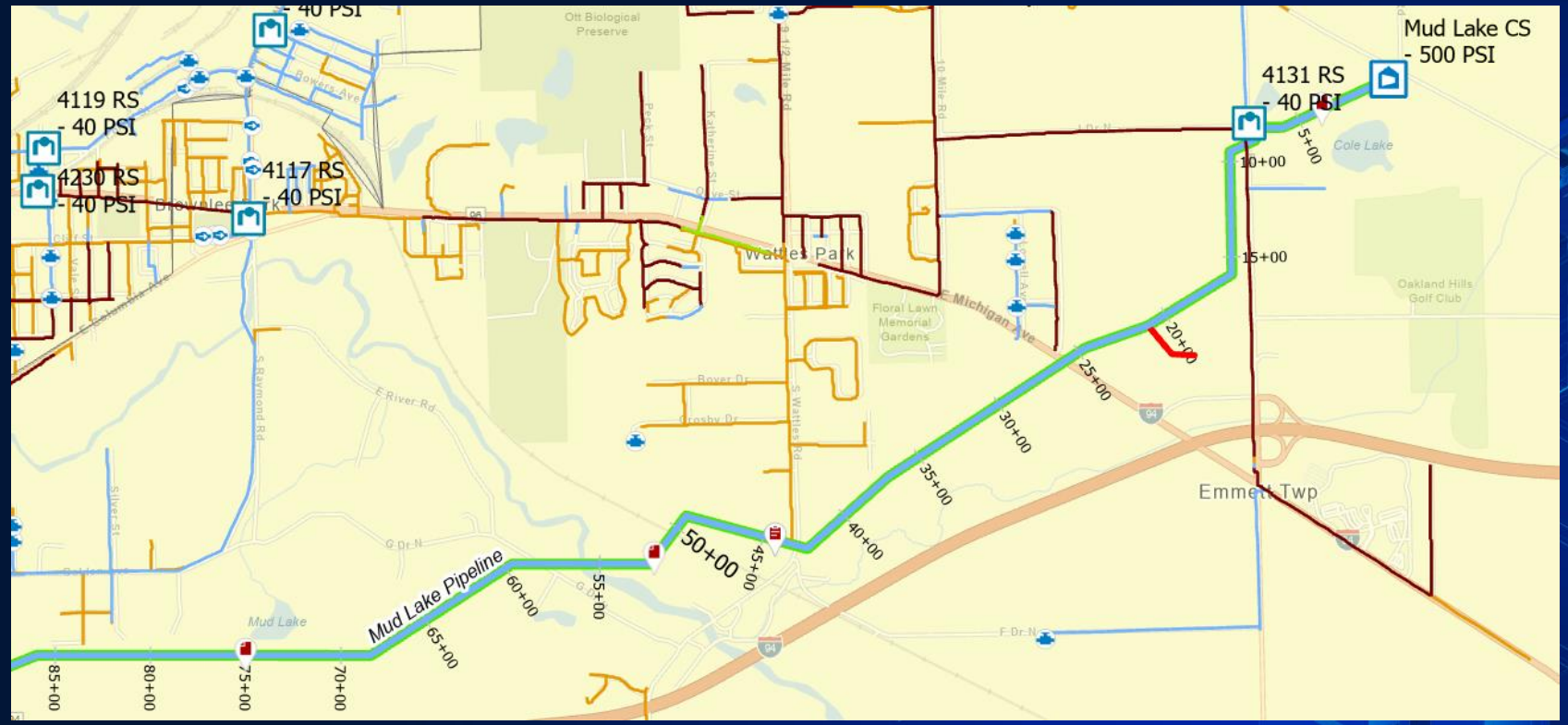


Linear Referencing in Action

Pipelines

Gas and liquid pipelines use linear referencing to communicate location

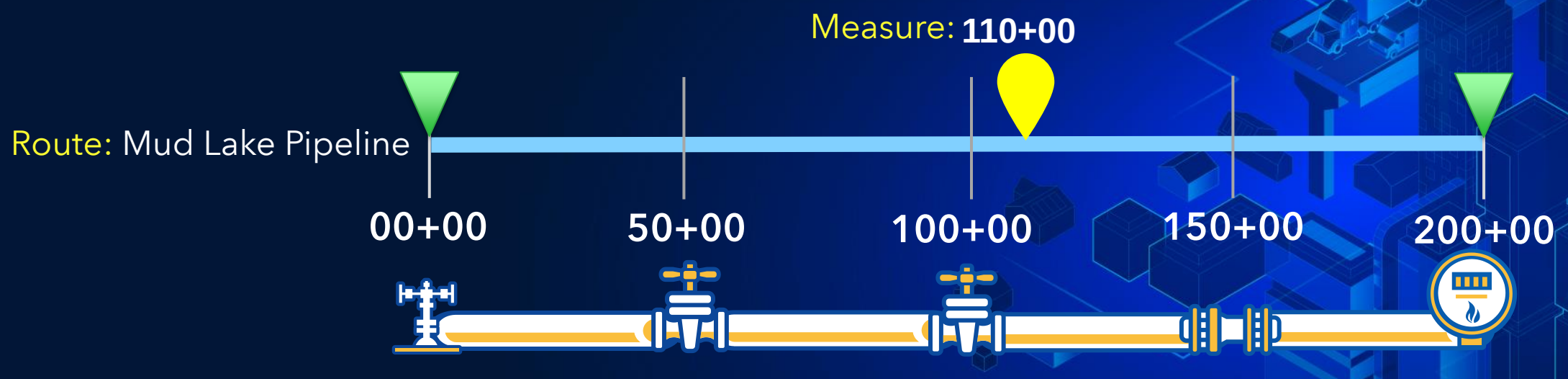
- Route is the name of the pipeline
- Measure is in feet or meters, as measured from the designated start location



How does Linear Referencing Work

Routes and Measures

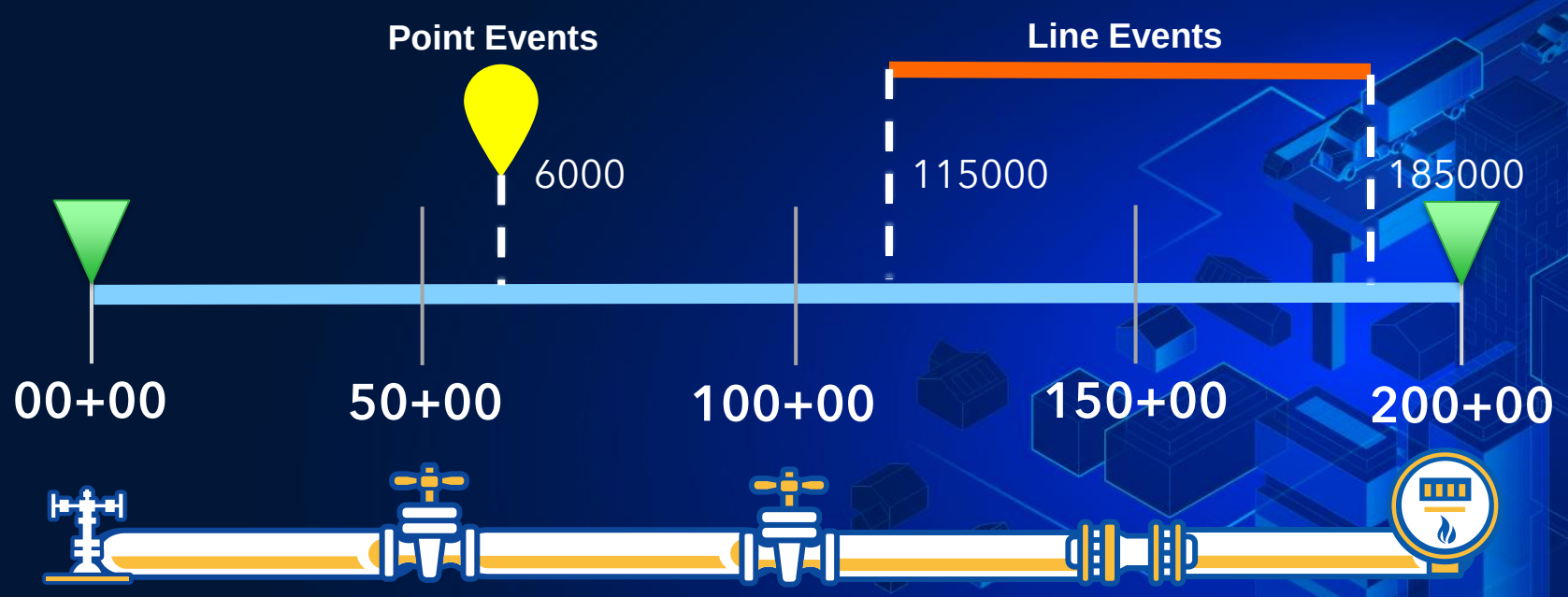
- A location in linear referencing can be identified by a route and a measure
- A Route is a unique name or ID given to a long linear asset or feature
  - Examples: Route = Mississippi River / Route = Interstate 90 / Route = Fargo Trunk Line
- A measure is the distance along the route



Linear Referencing Data Management

Managing Information along the route

- Uses routes and measures to create and maintain information, called events
- Two type of events: point and line



Linear Referencing Data Management

ArcGIS Capabilities for Managing Routes and Events

Administration

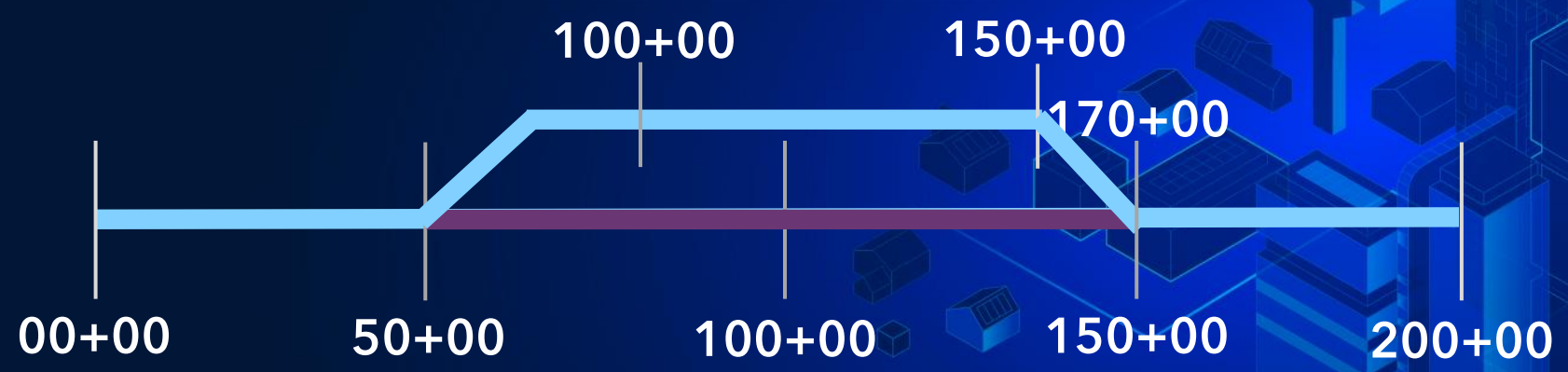
- Create ALRS
- Configure networks
- Configure events
- Define event behaviors
- …

Route Management

- Edit centerlines
- Edit routes
- Edit calibration points
- …

Event Management

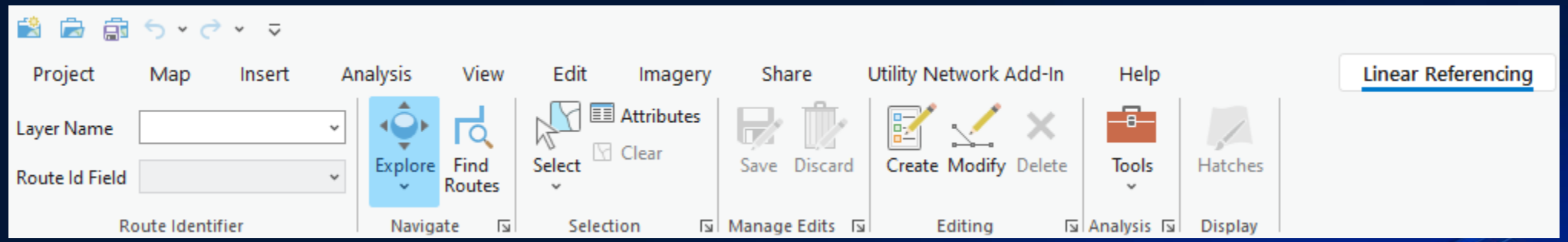
- Edit point events
- Edit line events
- Edit related tables
- …



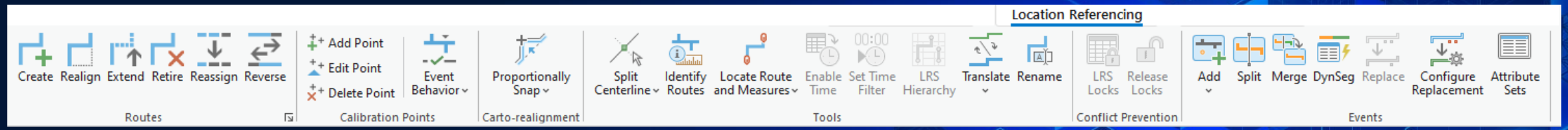
Linear Referencing Data Management

ArcGIS Pro Tools

Linear Referencing Ribbon



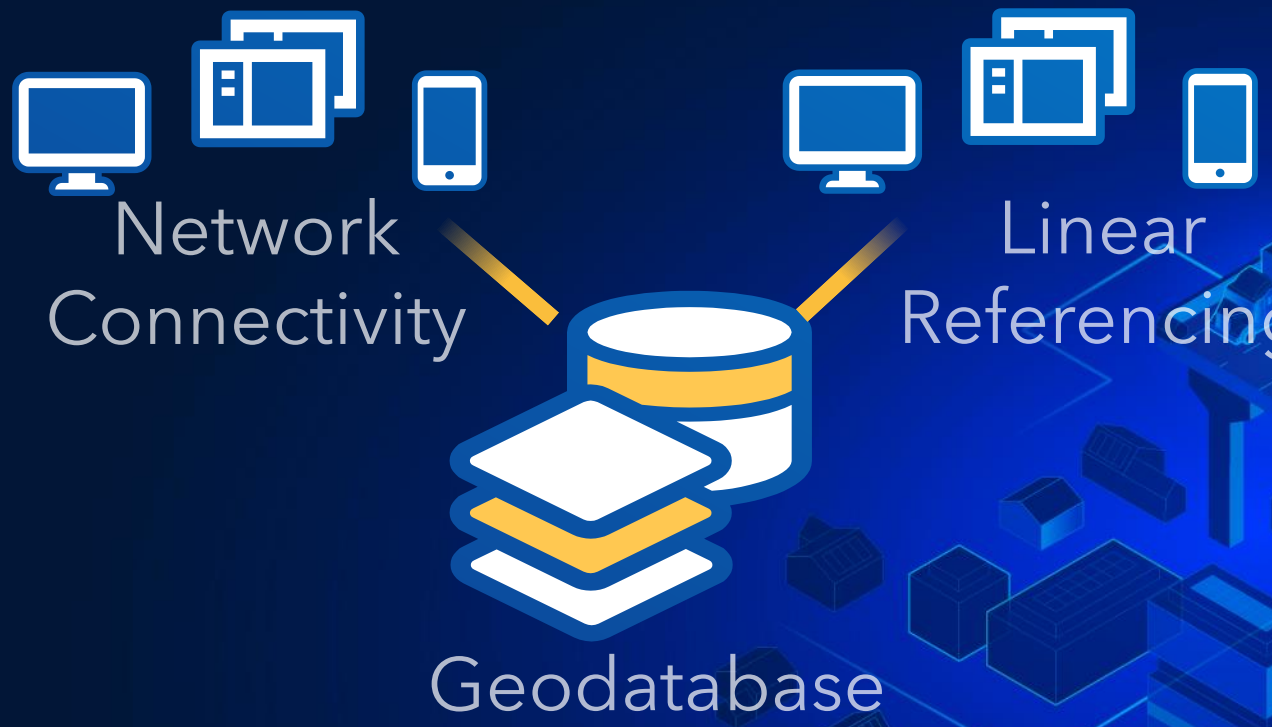
Location Referencing Ribbon

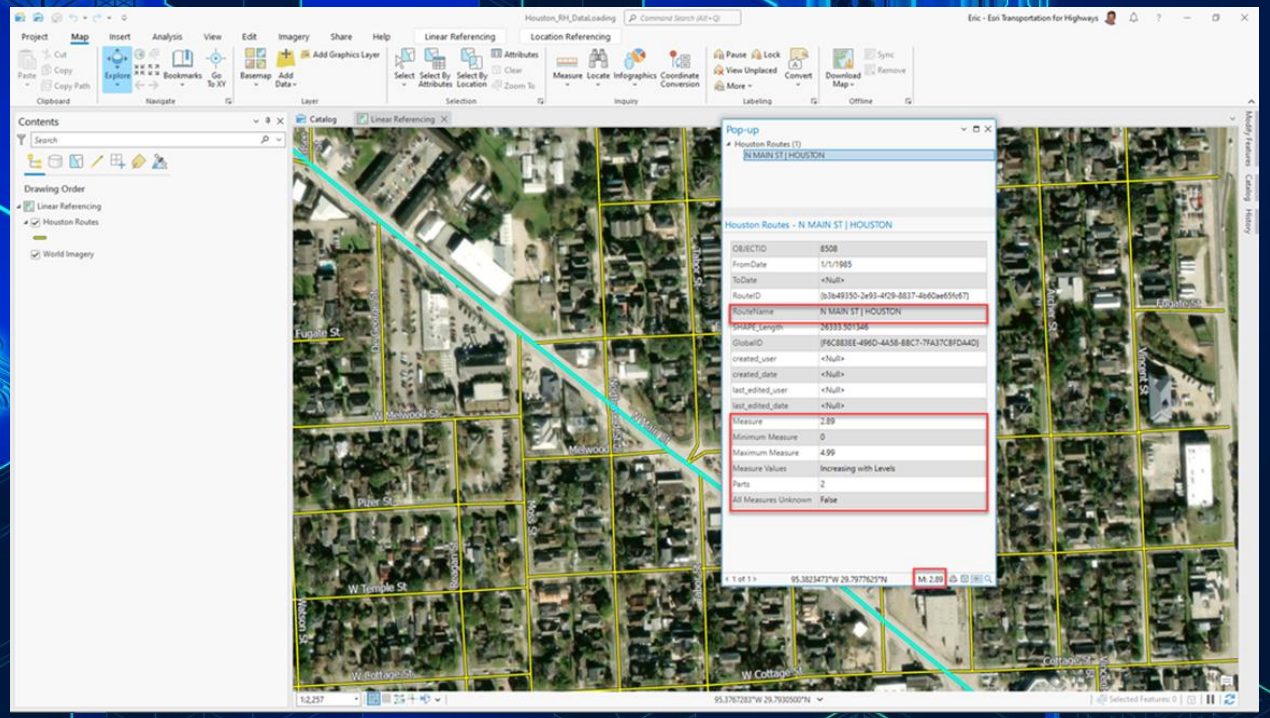


Compatible with Utility Network

Data Management with ArcGIS

- Single representation of assets
- Edit assets with linear referencing and network topology tools



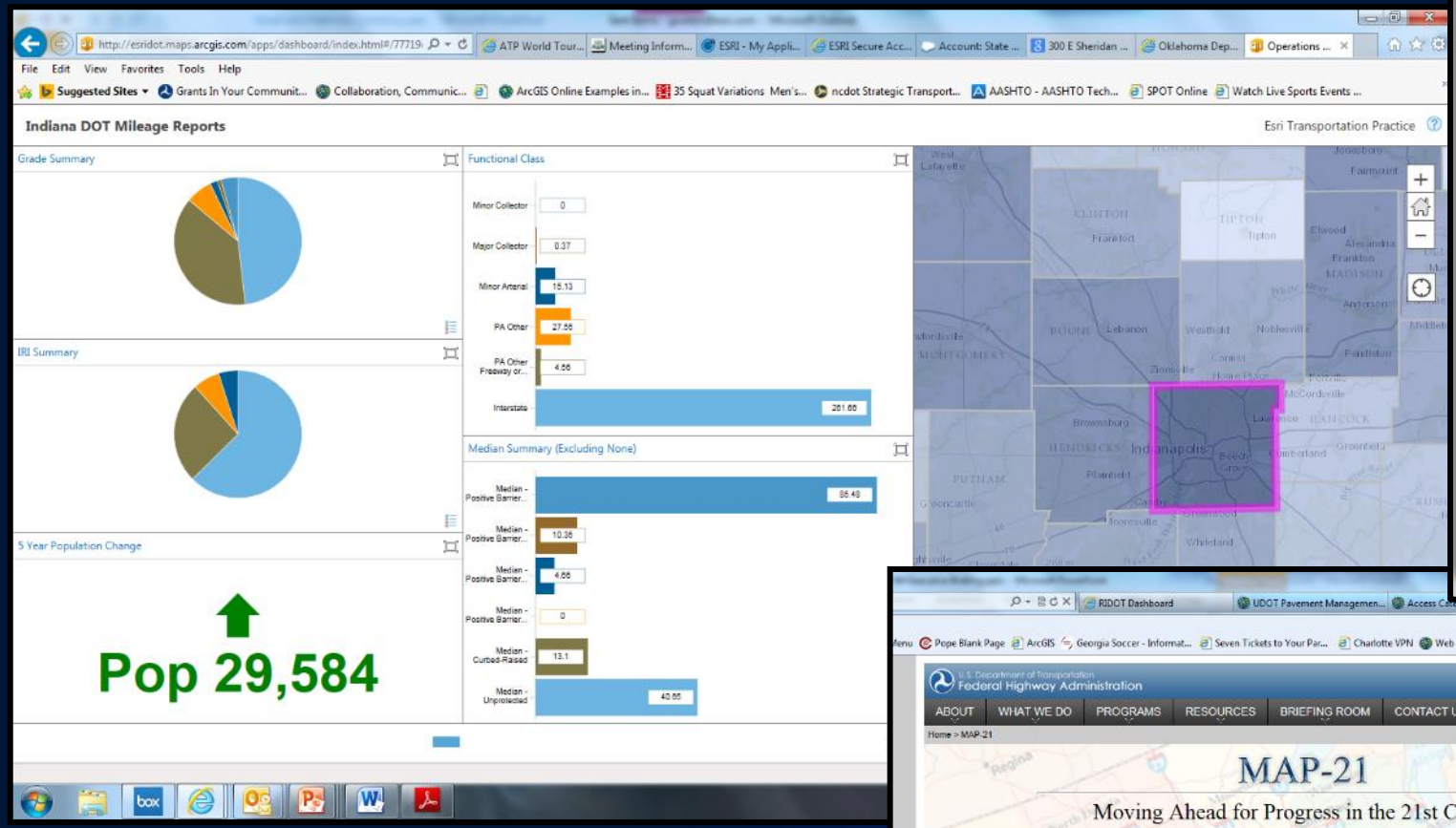


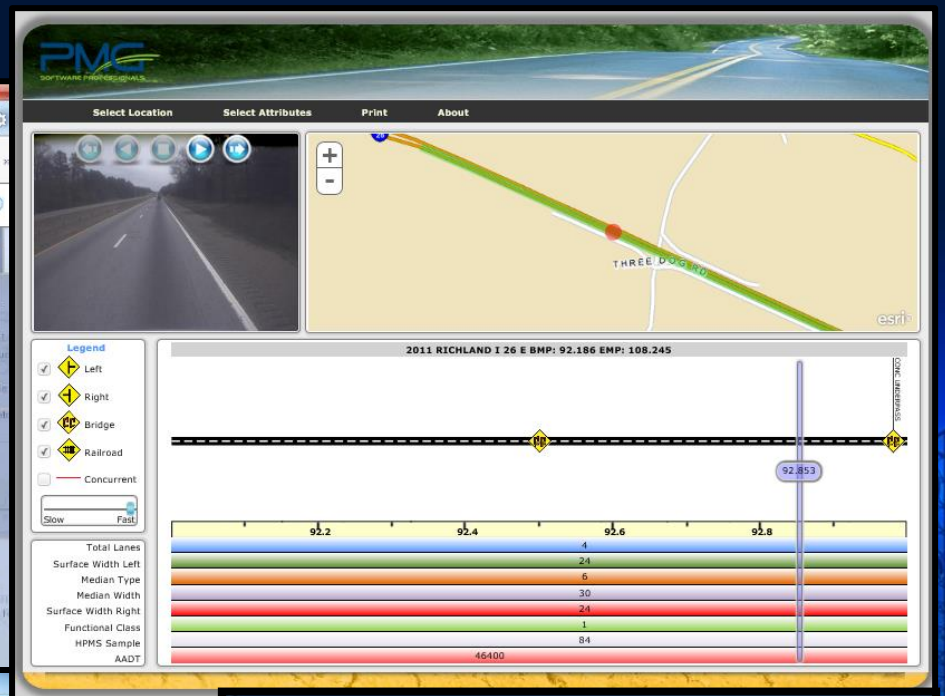
Linear Referencing vs ArcGIS Location Referencing

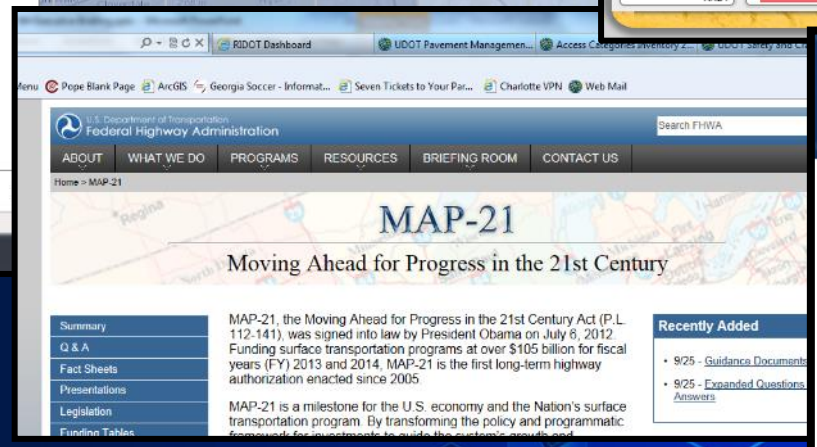
Hunter Sinclair

The goals for Linear Referencing

Supporting Federal requirements, providing data integration and establishing a data driven decision environment

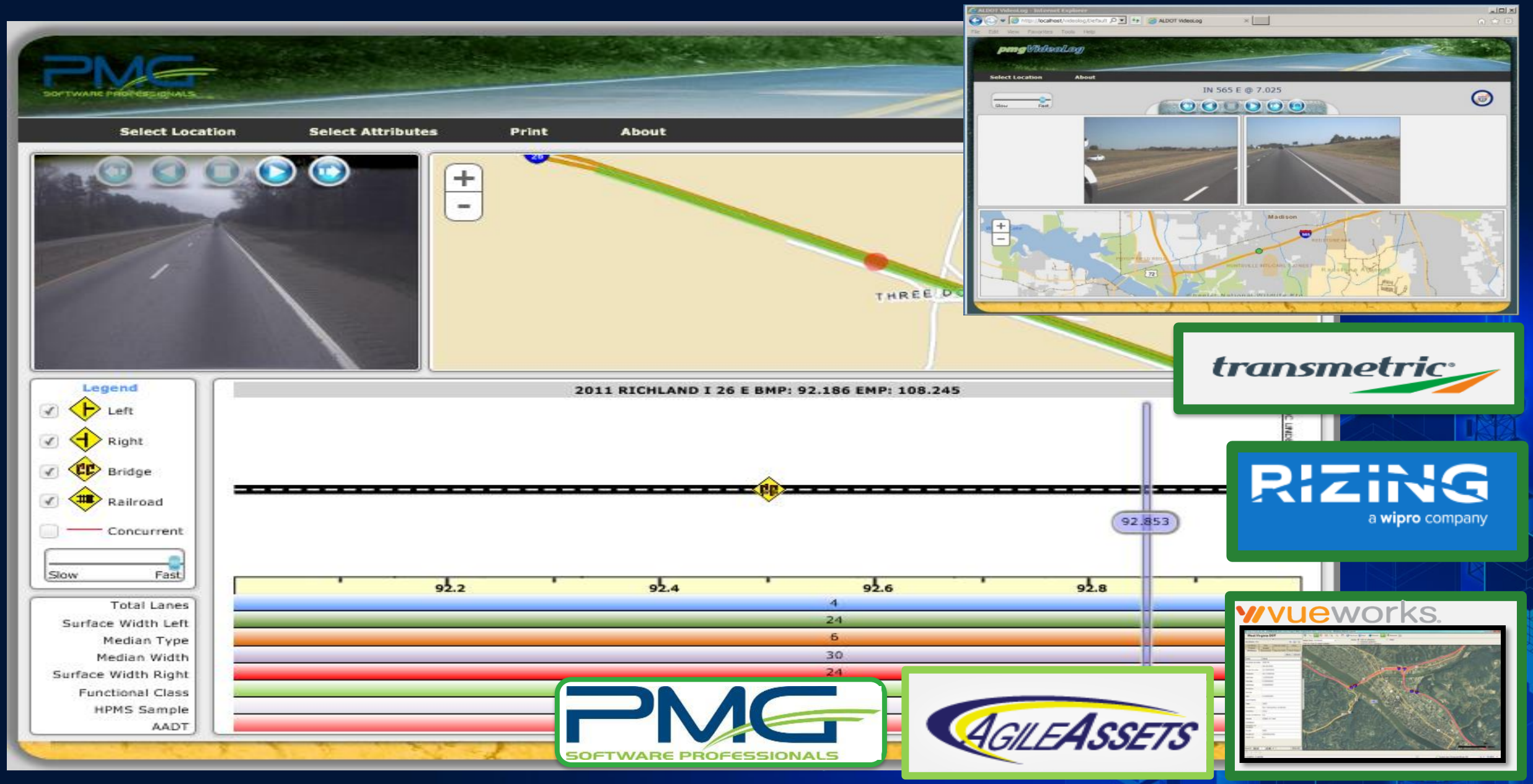






Business Applications with COTS integration to Location Referencing

Additional business value for Roads and Highways



Location Referencing is simply part of the ArcGIS System

ArcGIS Location Referencing

Web Apps

- Line and point event editing
- Data queries
- Quality checks
- Reporting
- Address Management

Pro

- Network and Centerline Management
- Route and Event Loading
- Geoprocessing tools
- Data Reviewer and Workflow Manager included

Enterprise

- Location Referencing web services
- Developer API samples
- Integration with the Utility Network

Location Referencing With ArcGIS Enterprise

Provides a simple, open web interface to linear referencing services hosted by ArcGIS Enterprise

Linear Referencing Service

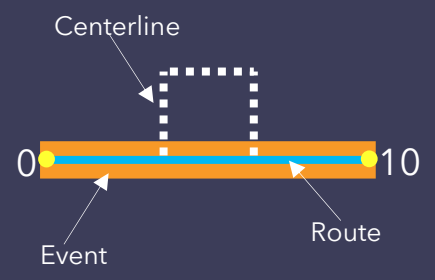
Apply Edits
Acquire locks
Locks
Check Events
Remove Overlapping Centerlines
Derive Event Measures
Measure to Geometry
Query Attribute Set
Translate
Concurrencies
Append Routes
Apply Event Behaviors
Generate Events
Release Locks
Geometry to Measure
Delete Version
Generate Routes
Create Version

Supports Esri's Feature Services Architecture – feature service editing across the ArcGIS Platform including ArcGIS Pro and web apps

Event Behaviors

After route edits, measure behavior rules can be applied to events.

Before Editing



Stay Put

Preserves geographic location. Measures may change.

Move

Preserves measures. Geographic location may change.

Retire

Event gets retired.

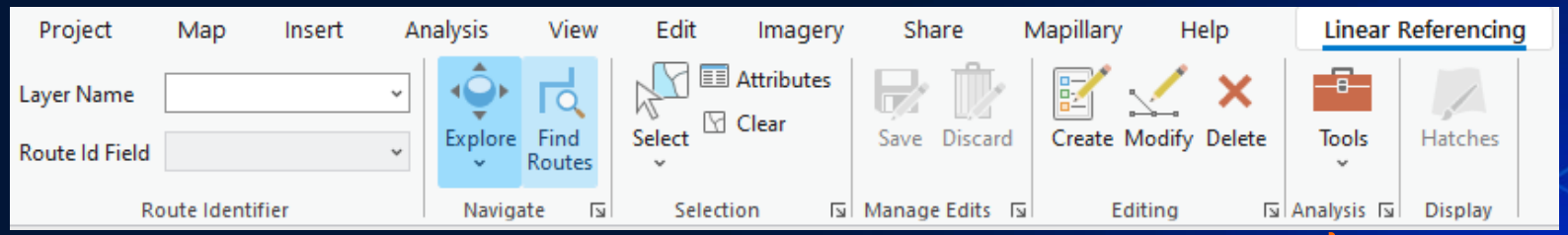
Linear Referencing Toolbox

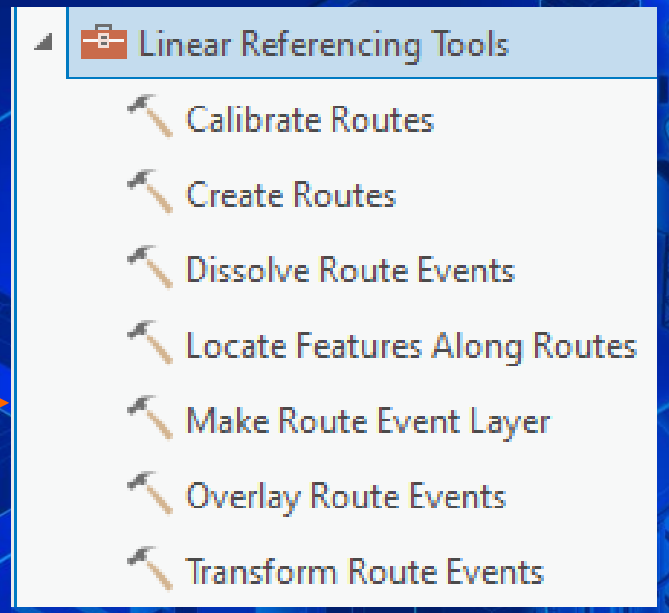
Create Routes
- Migrate from existing feature layer
- OR Create from scratch
- Make Route Tool
- Use existing measures or ArcGIS generated

Inspect Data
- View M-Values for vertexes and points
- View Route Measures using the Explore tool
- Find Routes by providing M-Values

Perform Analysis
- Locate Features Along Route
- Overlay Route Events
- Transform Route Reference of Events

Visualize Route Events
- Display Route Events
- Derive From and To Measures

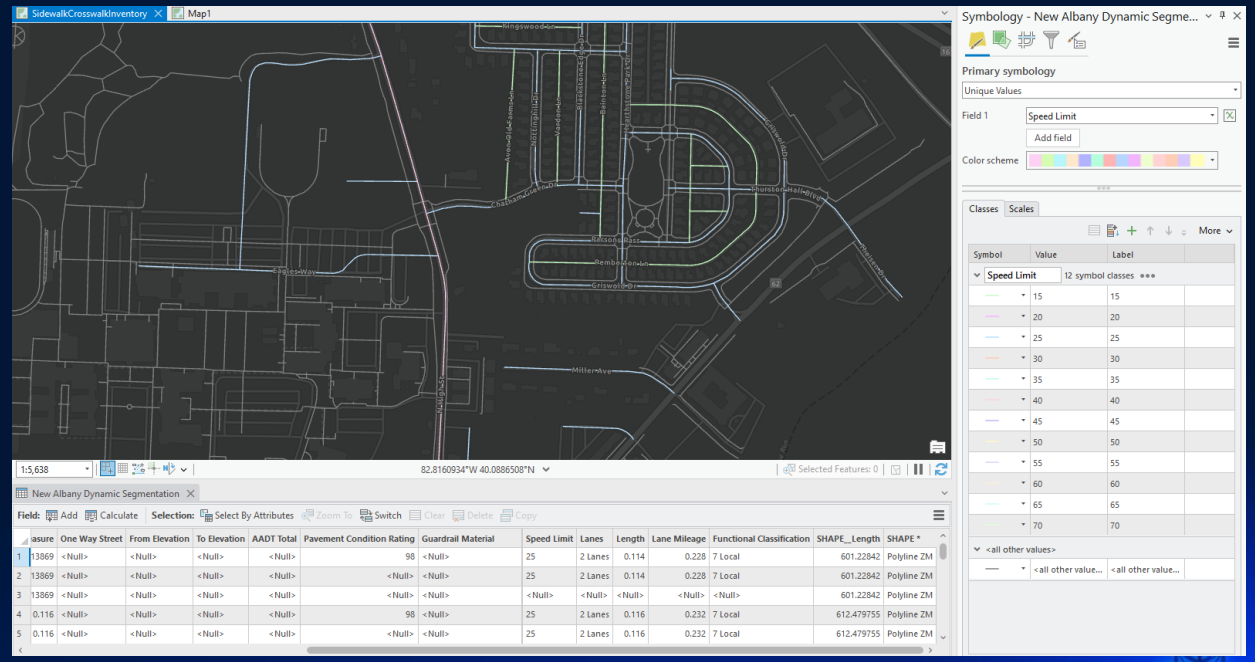




Core Linear Referencing vs ArcGIS Location Referencing

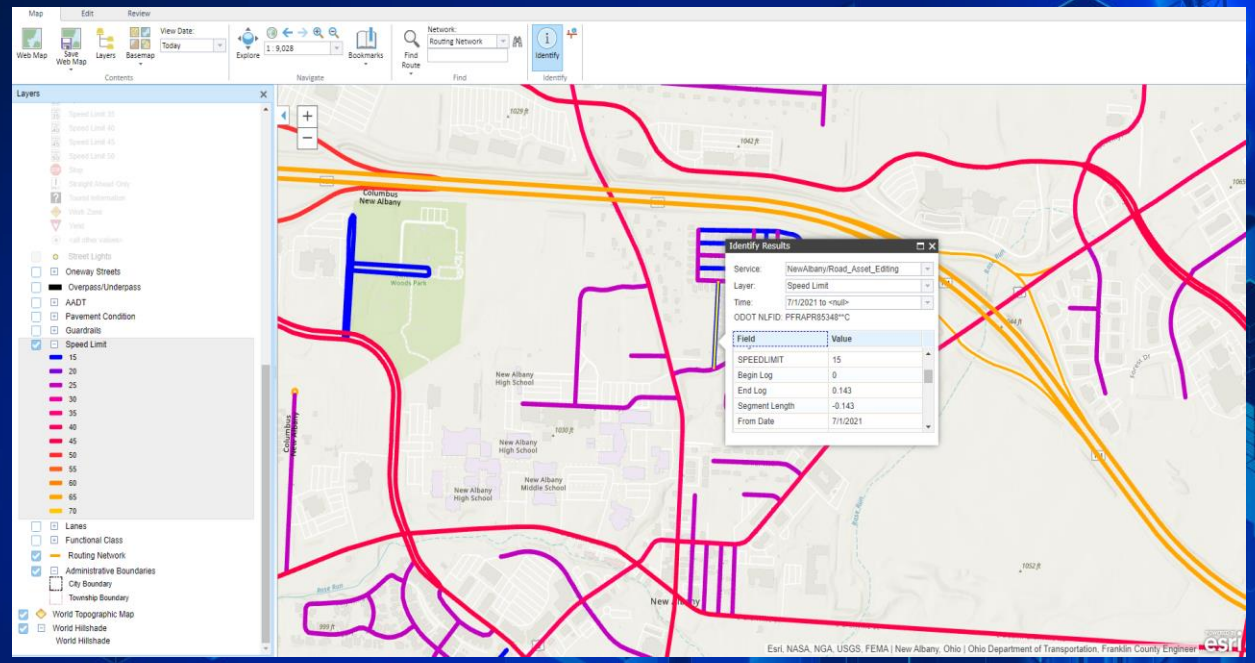
Linear Referencing

- Tabular
- Works well for fewer assets managed
- Dynamic Segmentation to visualize geometry
- Convert to Feature Class for apps and field
- Less performant/more overhead



Location Referencing

- Measurement Values based on route network
- Dynamic Segmentation
- Time Enabled
- Event Behavior
- Multiple LRM's
- Feature Service
- Utility/Pipeline Network Integration



Business Case for a Modernized LRS

MULTI-LEVEL LINEAR REFERENCING SYSTEM (MLLRS) COST/BENEFIT VALUE ANALYSIS STUDY

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)

Standing Committee on Highways

Prepared by:

Renee L. Hoekstra, CVS
RH & Associates, Inc.
Glendale, Arizona

May 2011

The information contained in this report was prepared as part of NCHRP Project 20-07, Ta
National Cooperative Highway Research Program, Transportation Research Board.

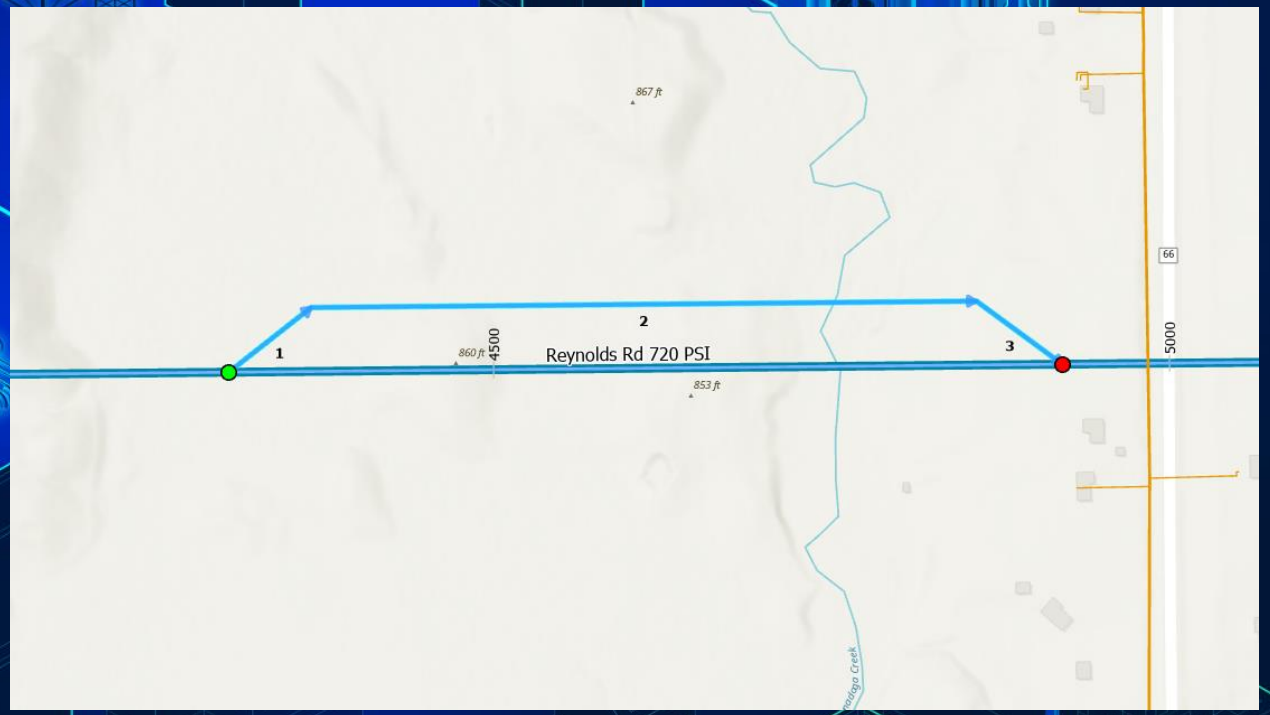
SPECIAL NOTE: This report IS NOT an official publication of the National Coopera
Highway Research Program, Transportation Research Board, National Research Council,
National Academies.

NCHRP Value Analysis Study

*onlinepubs.trb.org/onlinepubs/**nchrp**/docs/**NCHRP**20-07(302)_FR.pdf*

Multi-Level Linear Referencing System Cost/Benefit Value Analysis Study - NCHRP Project 20-07, Task 302, National Cooperative Highway Research Program, Transportation Research Board

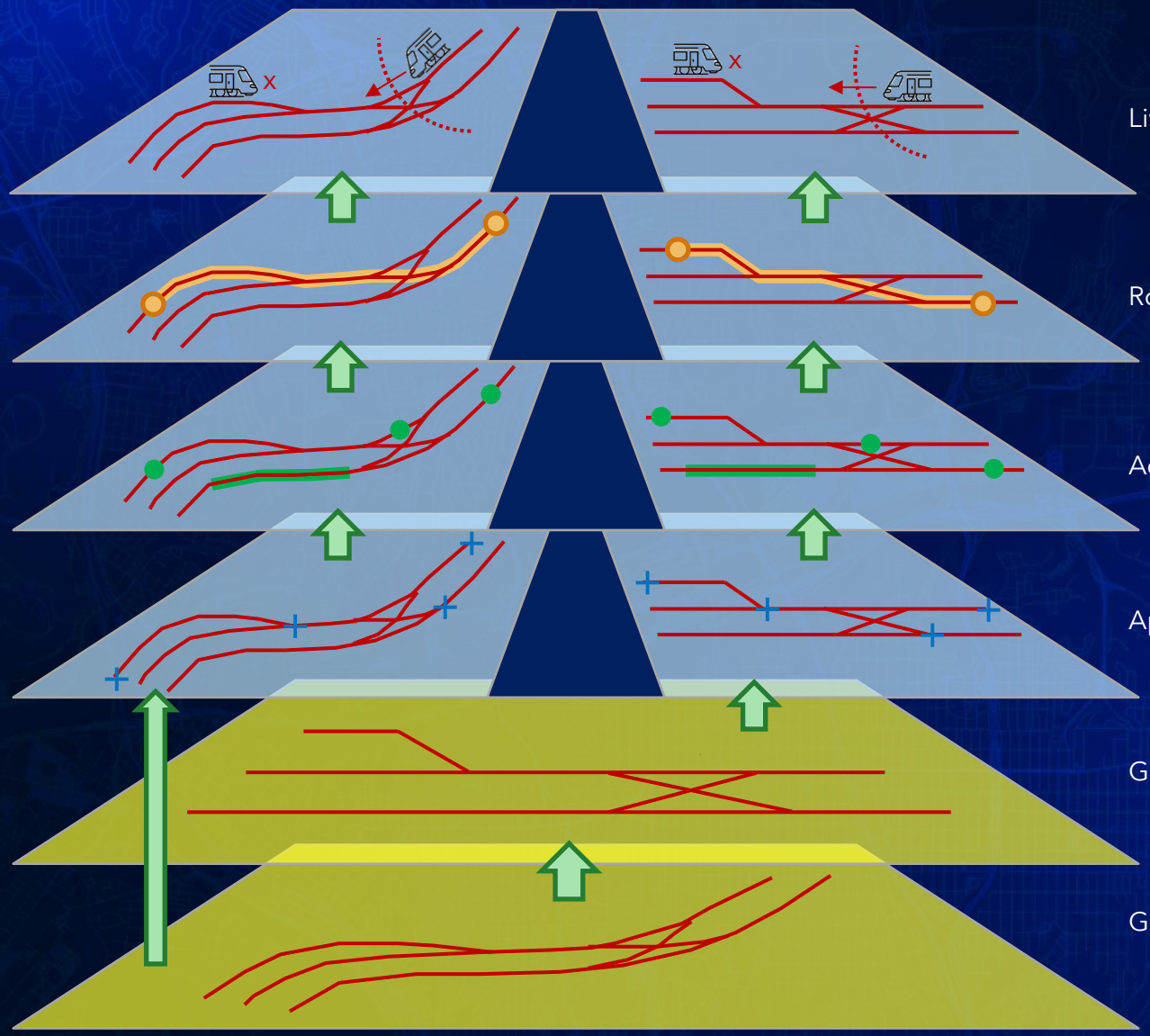
When expressed as a C/B ratio, the baseline effort yields a C/B ratio of 1.8:1 while the optional functional elements yield an aggregate 21.4:1 ratio of benefits to cost. These figures were generated from empirical values generated by several of the participating states as workshop participants. These aggregate C/B ratios are bound to be different when each particular state is analyzed separately for their own costs versus benefits using their individual operating conditions.



Linear Referencing Data Management

Jim, Tom, Hunter

Railroads and ArcGIS



Live train movement and geofences

Routing and tracing using Utility Network

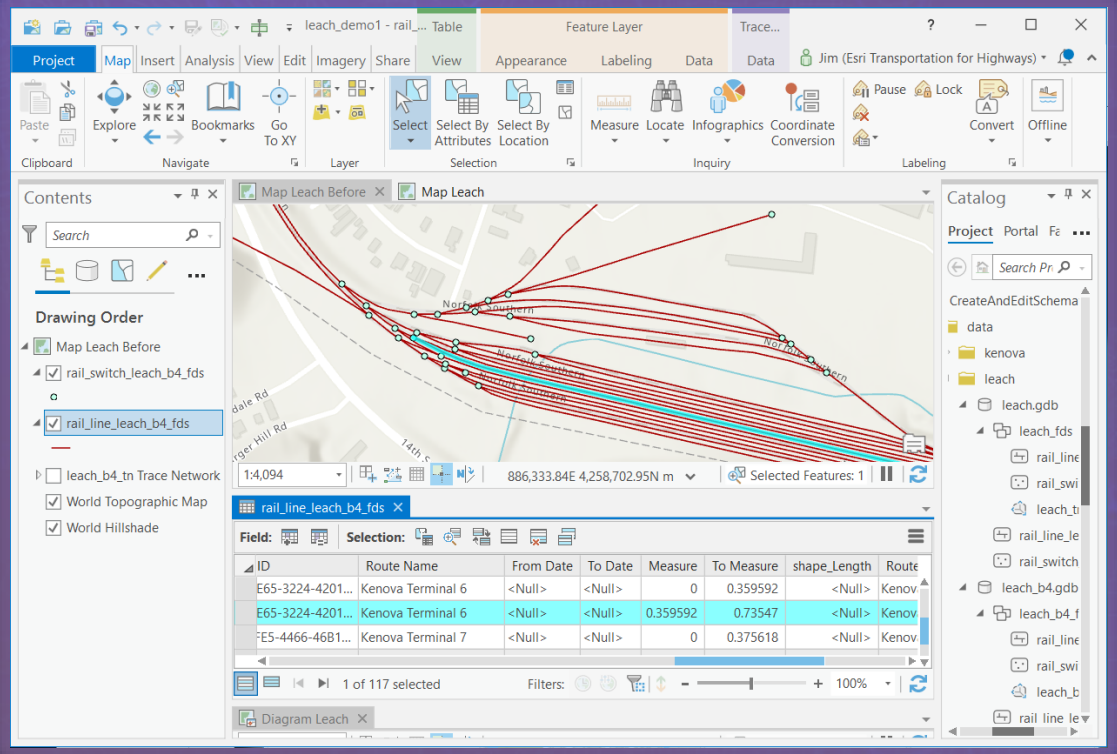
Add and manage point and linear events on the LRS

Apply and update LRS onto the Geographic and Schematic

Generate schematic diagram, using network attributes, templates

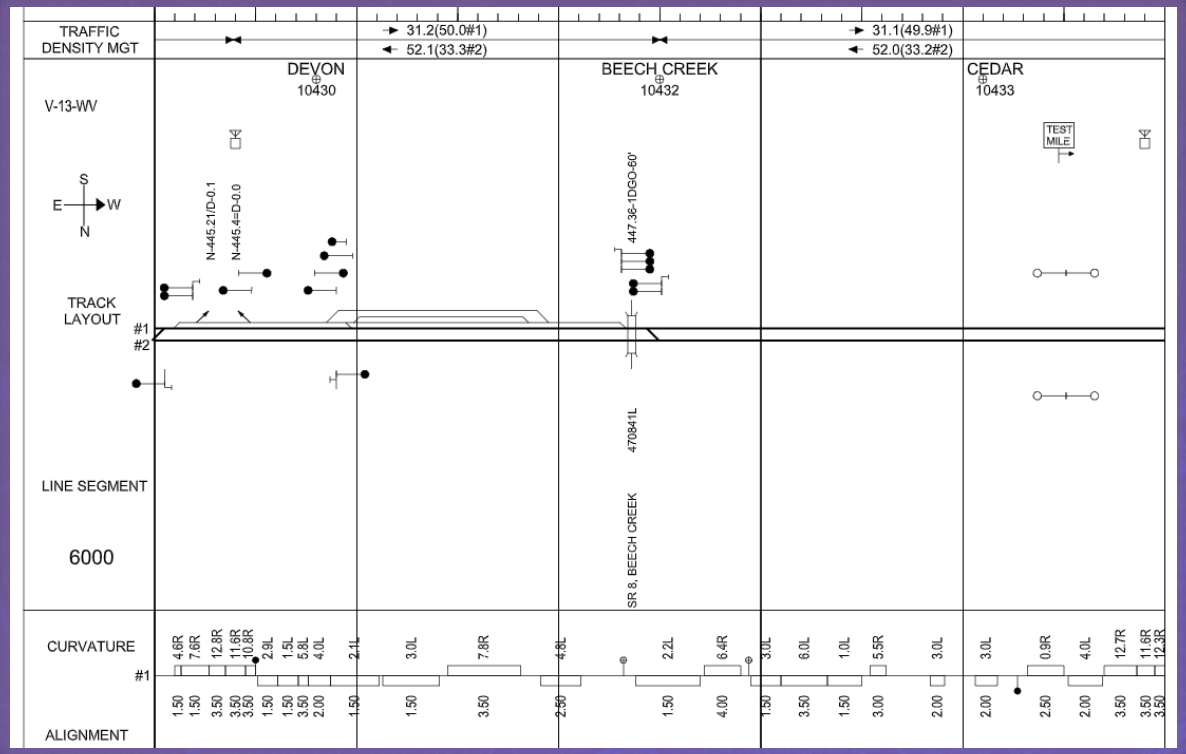
Geographic data, edit, visualize, analyze

Geographic

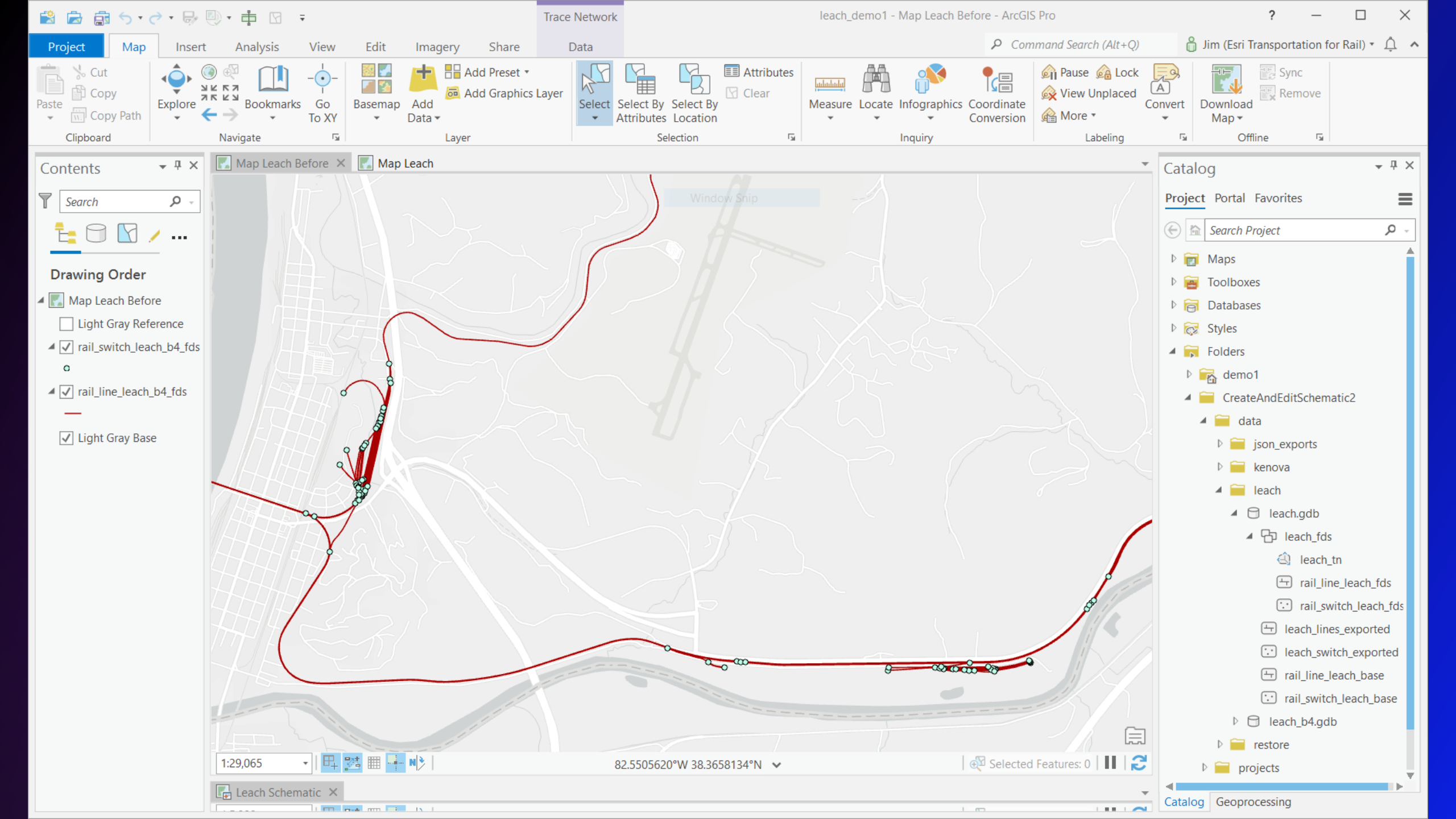


ArcGIS Pro

Schematic



Track Charts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Trace Network
Project
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Jim (Esri Transportation for Rail)
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Copy Path
Clipboard
Explore
Bookmarks
Go To XY
Navigate
Basemap
Add Data
Add Preset
Add Graphics Layer
Layer
Select
Select By Attributes
Select By Location
Attributes
Clear
Selection
Measure
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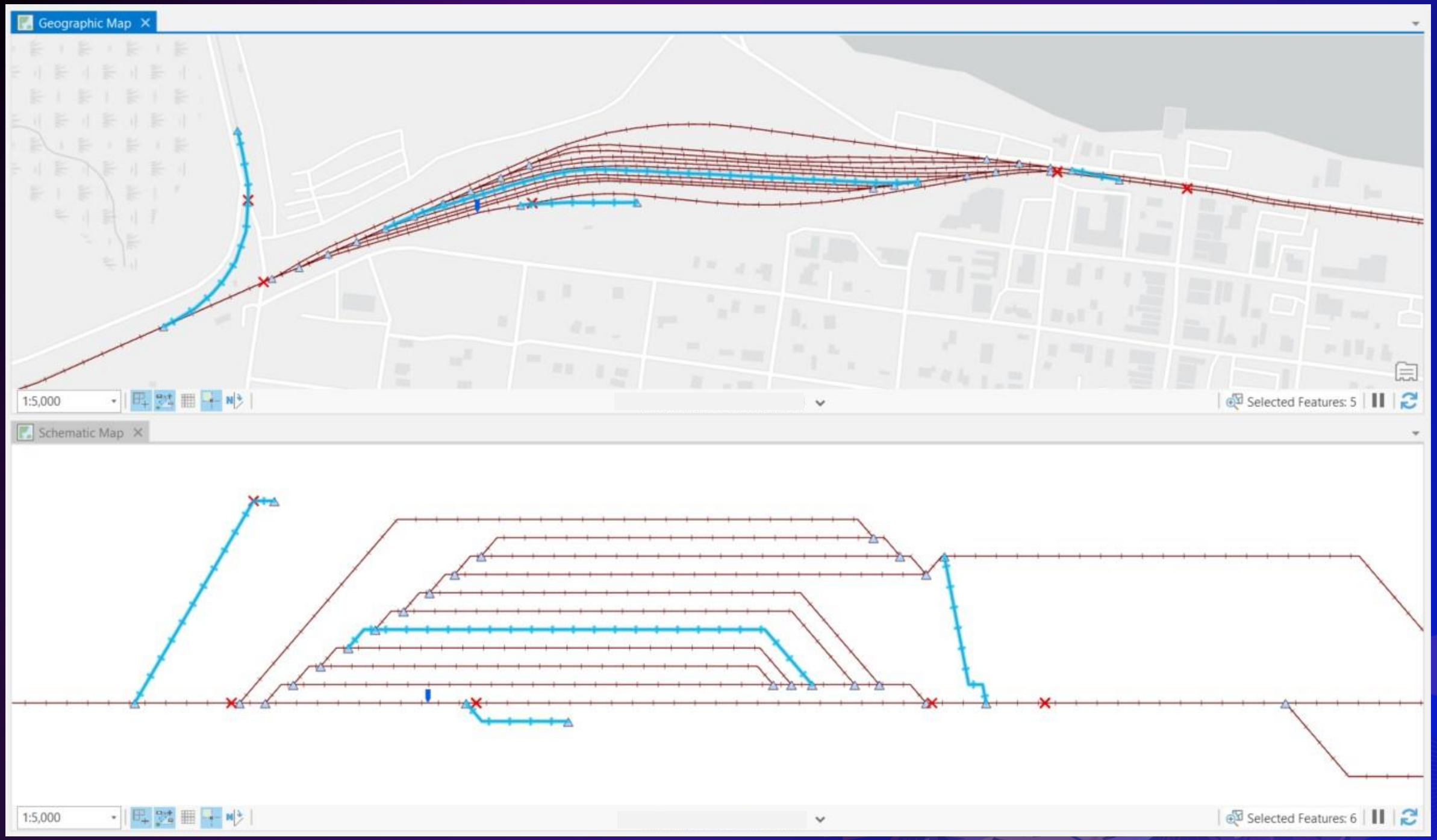
Geographic Map
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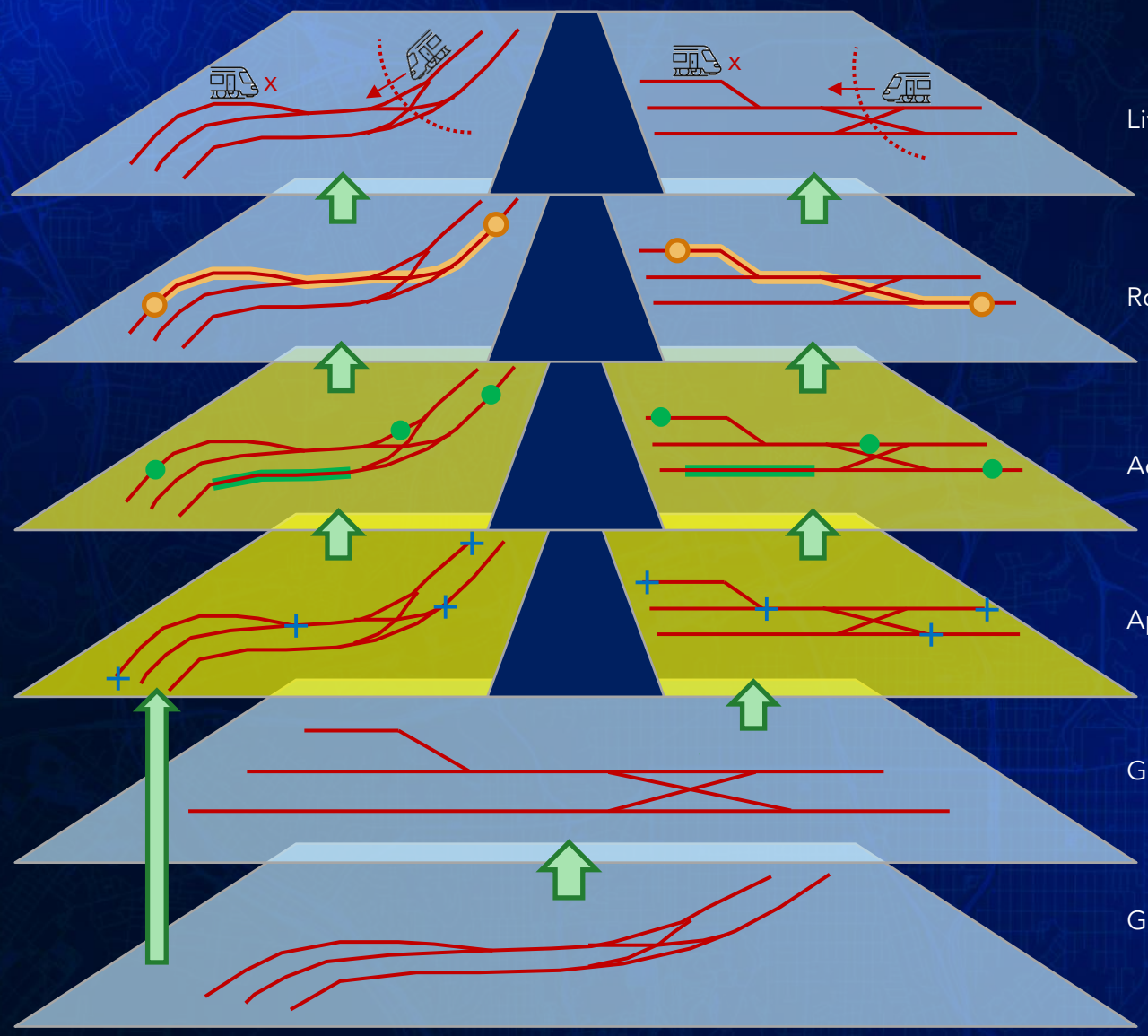
Schematic Map
1:5,000
Selected Features: 6

Railroads and ArcGIS



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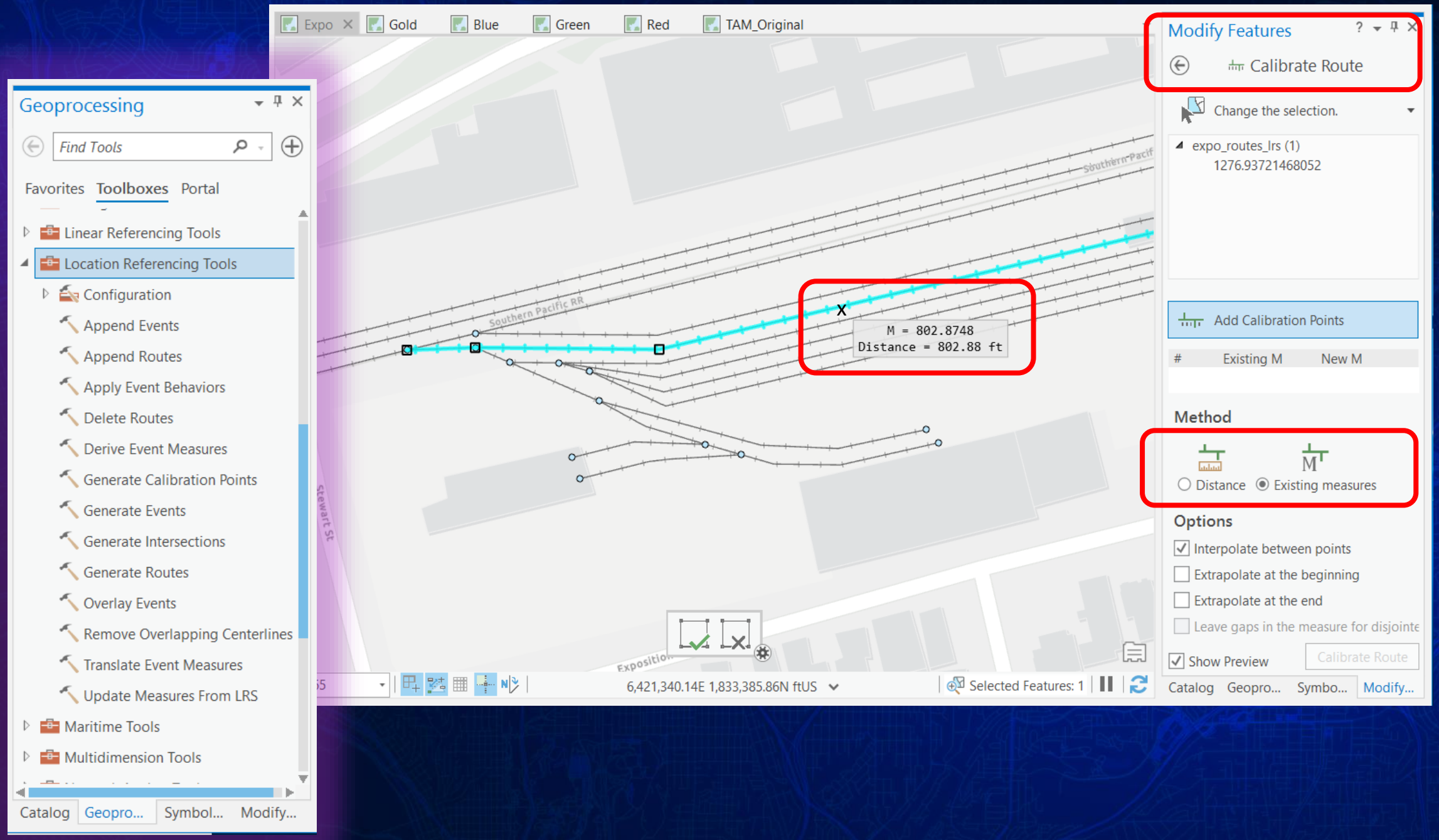
Expo
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Favorites
Toolboxes
Portal
Linear Referencing Tools
Location Referencing Tools
Configuration
Append Events
Append Routes
Apply Event Behaviors
Delete Routes
Derive Event Measures
Generate Calibration Points
Generate Events
Generate Intersections
Generate Routes
Overlay Events
Remove Overlapping Centerlines
Translate Event Measures
Update Measures From LRS
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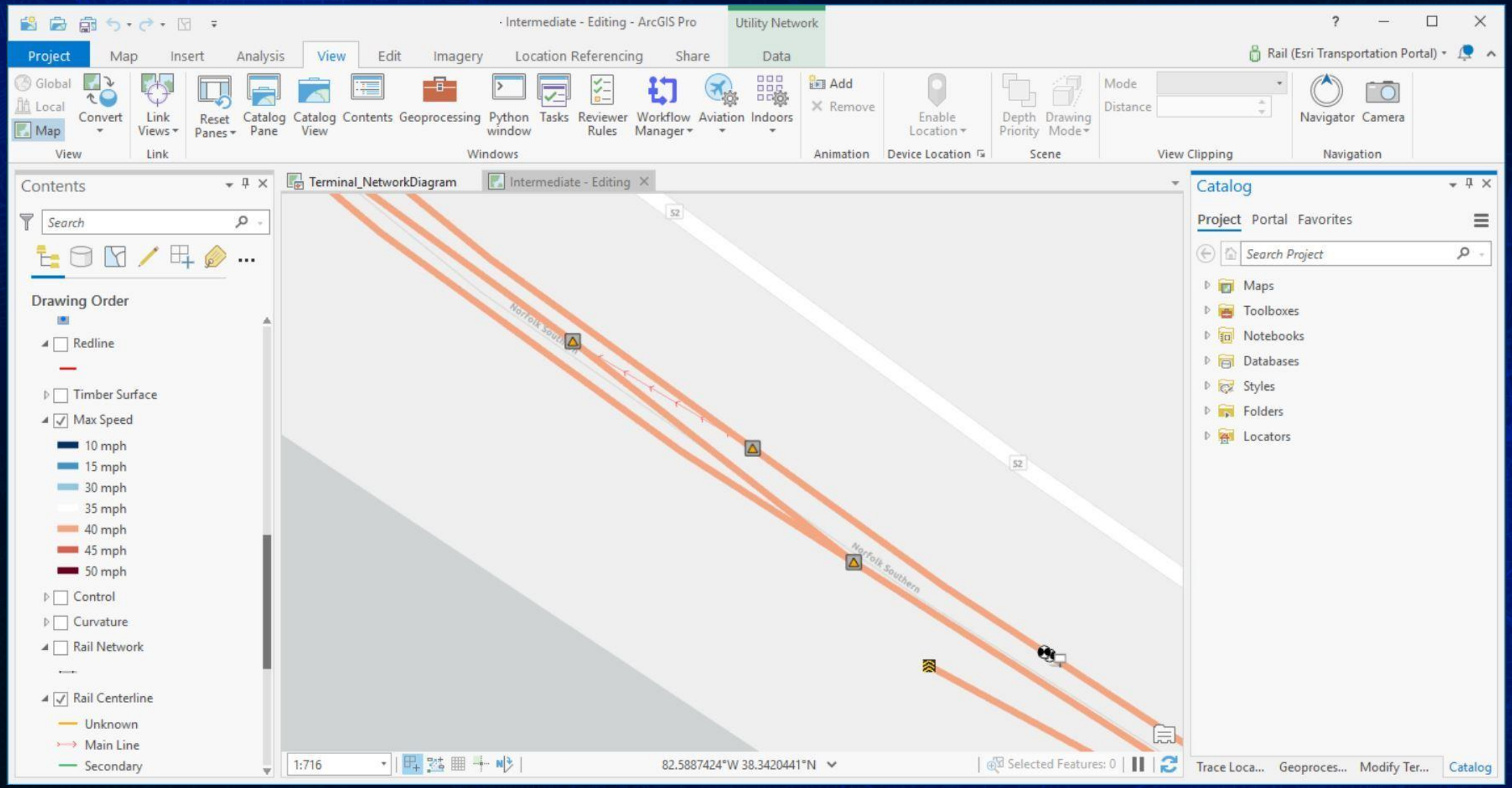
Intermediate - Editing - ArcGIS Pro
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Workflow Manager
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Modify Ter...
Catalog

Event Editor

dot2.esri.com/RailUtilityNetwork

Norfolk Southern Rail Inventory - v10.8.4098 - Norfolk Southern ... rail_demo Sign Out

Map Edit Review

Web Map | Save Web Map | Layers | Basemap | Add Data | View Date: Today | Explore | 1 : 564 | Bookmarks | Find Route | Network: Rail Netw

Contents | Navigate

Layers

- AtGradeCrosssing
  - Active Warning Device
  - Passive Warning Sign
- Sign
- Insulated Joint
- Bridge
- Calibration Points
- Redline
- Timber Surface
- Max Speed
  - 10 mph
  - 15 mph
  - 30 mph
  - 35 mph
  - 40 mph

NS62 Main 1 - NS62A
Main 1 Big Sandy
Loop 1 Switch

VITA, West Virginia GIS, Esri, HER

Event Editor

dot2.esri.com/RailUtilityNetwork/

Norfolk Southern Rail Schematic Inventory - v10.8.4098 - Norfolk Southe... rail_demo Sign Out

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Web Map | Save Web Map | Layers | Basemap | Add Data | View Date: Today | Explore | 1 : 564 | Bookmarks | Find Route | Network: Rail Network

Contents | Navigate | Find

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- Active Warning D
- Passive Warning
- Sign
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- Bridge
- Calibration Poir
- Redline
- Timber Surface
- Max Speed
  - [all other values]
  - 10
  - 15
  - 30
  - 35
  - 40
  - 45
  - 50

NS62 Main 1 - NS62A
Main 1 Big Sandy
Loop 1 Switch

NS62 Main
1 Switch

NS62A Main
1 Switch

esri

Event Editor

dot2.esri.com/RailUtilityNetwork/NorfolkS

Norfolk Southern Rail Schematic Inventory - v10.8.4098 - Norfolk Southern Schematic LRS Event Editing

rail_demo Sign Out

Map | Edit | Review

Save Edits | Undo | Redo | Discard Edits — Manage Edits

Version: sde.DEFAULT — Versioning

Select | Rectangle — Layer: Max Speed — Return attribute set — Selection

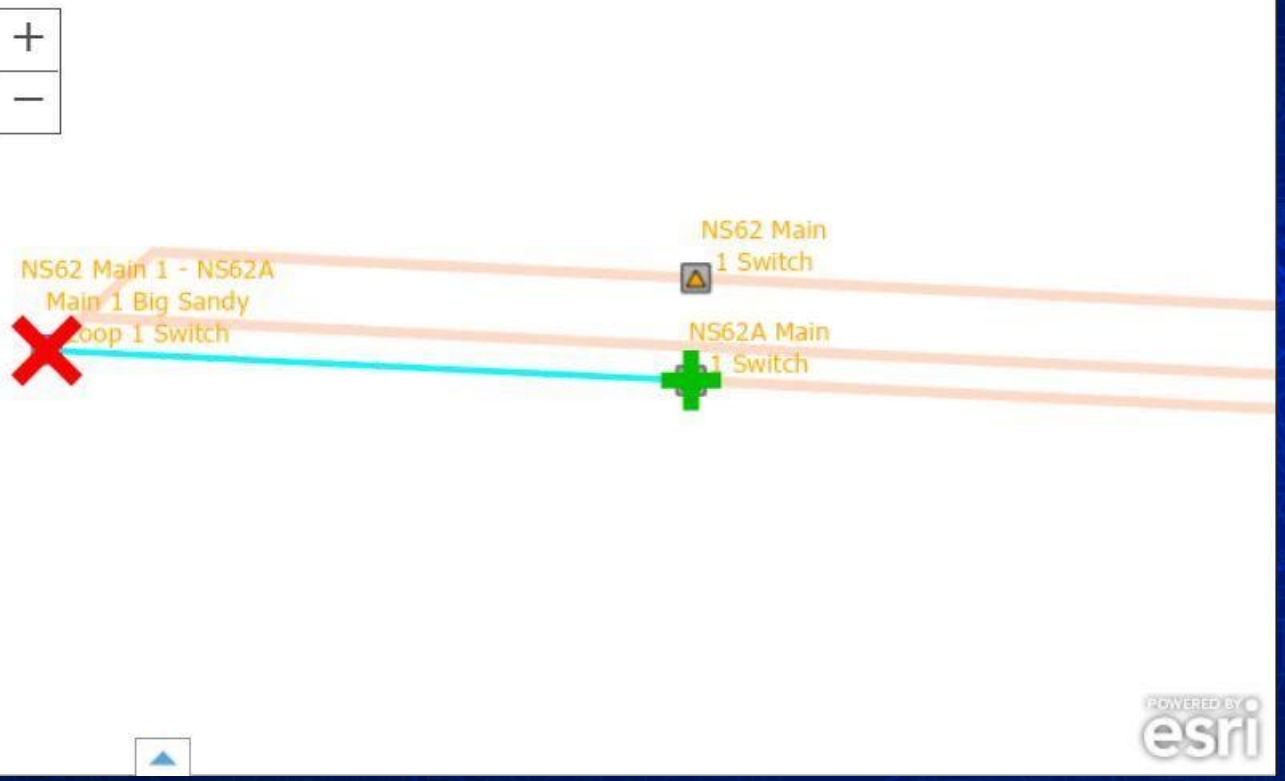
Point Events | Line Events | Event Replacement — Attribute Set: NS Schematic Route Eding — Edit Events

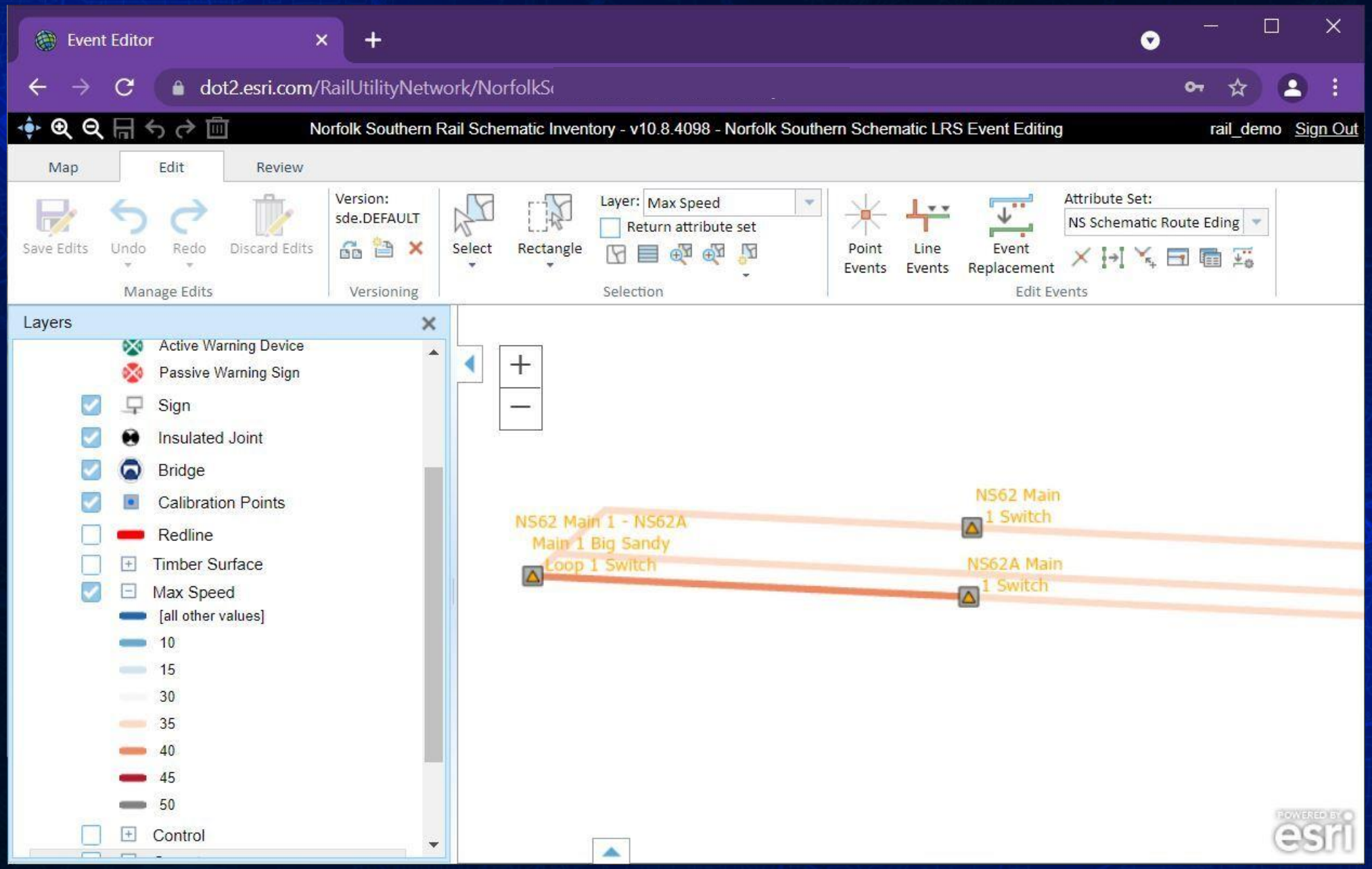
Layers

Add Linear Events

		Orientation	<null>
		Elevation	<null>
		Status	<null>
☑	Max Speed	D Curve Function	Tangent (Straight)
		D Track	001
		Speed	45 mph
		Status	<null>
☐	Timber Surface	Status	<null>
		Surface Month	<null>
		Surface Year	<null>
		Timber Surface Month	<null>

Show network names




Event Editor
dot2.esri.com/RailUtilityNetwork/NorfolkS
Norfolk Southern Rail Schematic Inventory - v10.8.4098 - Norfolk Southern Schematic LRS Event Editing
rail_demo
Sign Out
Map
Edit
Review
Save Edits
Undo
Redo
Discard Edits
Manage Edits
Version:
sde.DEFAULT
Versioning
Select
Rectangle
Layer:
Max Speed
Return attribute set
Selection
Point Events
Line Events
Event Replacement
Attribute Set:
NS Schematic Route Eding
Edit Events
Layers
Active Warning Device
Passive Warning Sign
Sign
Insulated Joint
Bridge
Calibration Points
Redline
Timber Surface
Max Speed
[all other values]
10
15
30
35
40
45
50
Control
NS62 Main 1 - NS62A Main 1 Big Sandy Loop 1 Switch
NS62 Main 1 Switch
NS62A Main 1 Switch
esri

Event Editor

dot2.esri.com/RailUtilityNetwork

Norfolk Southern Rail Inventory - v10.8.4098 - Norfolk South... rail_demo Sign Out

Map Edit Review

Web Map | Save Web Map | Layers | Basemap | Add Data | View Date: Today | Explore | 1 : 564 | Bookmarks | Find Route

Contents | Navigate

Layers

- Bridge
- Calibration Points
- Redline
- Timber Surface
- Max Speed
  - 10 mph
  - 15 mph
  - 30 mph
  - 35 mph
  - 40 mph
  - 45 mph
  - 50 mph
- Control
- Curvature
- Rail Network
- Rail Centerline
  - Unknown
  - Main Line
  - Secondary
- Norfolk Southern Project Exte
- World Topographic Map
  - Citations

NS62 Main 1 - NS62A Main 1 Big Sandy Loop 1 Switch

NS62A Main 1 Switch

VITA, West Virginia GIS, Esri, H...

aaa2.MP4

matic Inventory - v10.8.4098 - Norfolk Southern Schematic LRS Event Editing rail_demo Sign Out

Rectangle | Layer: Max Speed | Return attribute set | Point Events | Line Events | Event Replacement | Attribute Set: NS Schematic Route Eding

Selection | Edit Events

NS62 Main 1 - NS62A Main 1 Big Sandy Loop 1 Switch

NS62 Main 1 Switch

NS62A Main 1 Switch

45

50

Control

Event Editor

dot2.esri.com/RailUtilityNetwork/

Norfolk Southern Rail Inventory - v10.8.4098 - Norfolk South... rail_demo Sign Out

Map | Edit | Review

Save Edits | Undo | Redo | Discard Edits — Manage Edits

Version: sde.DEFAULT — Versioning

Select | Rectangle | Layer: Sign | Return attribute set — Selection

Point Events | Line Events

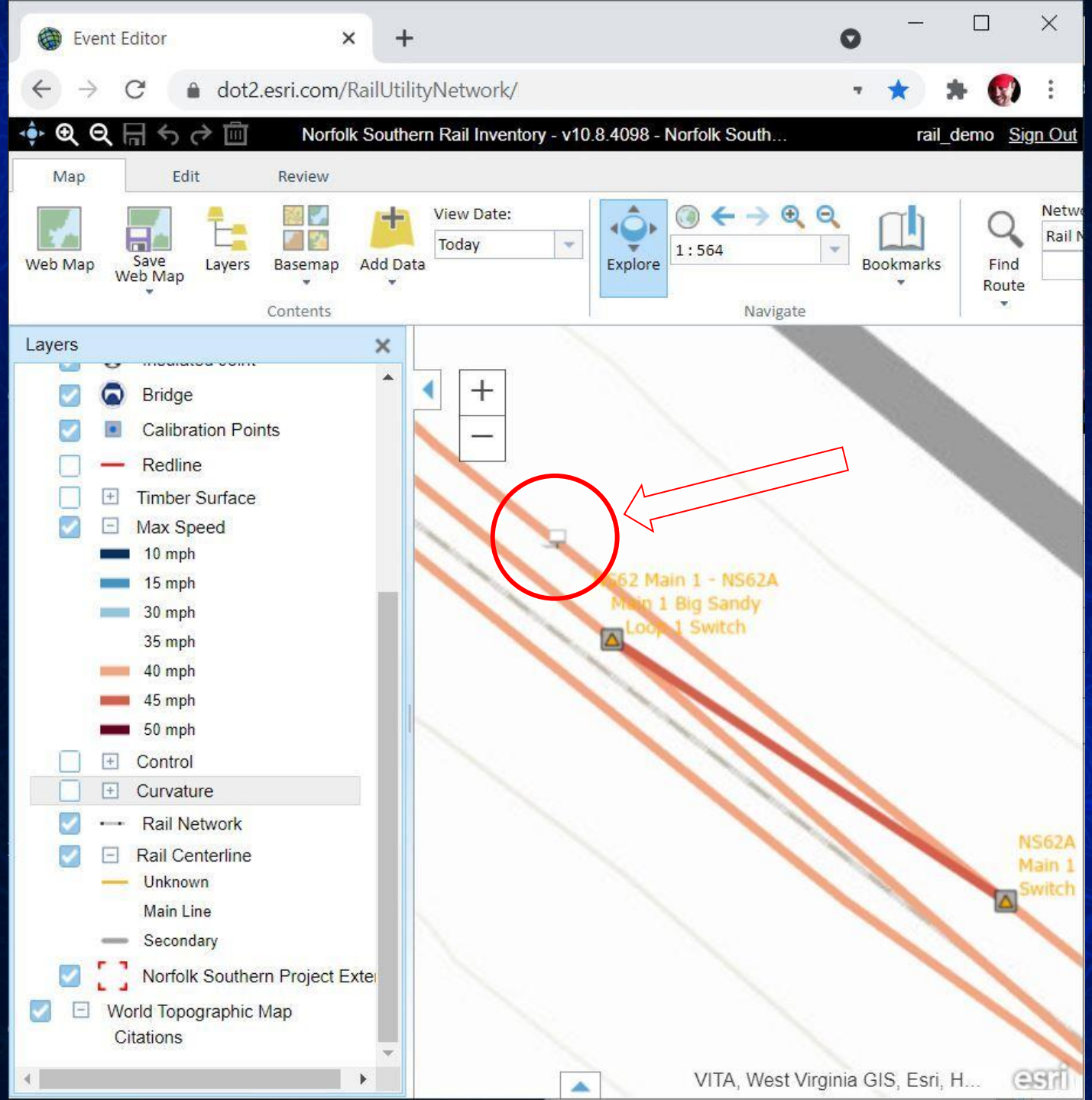
Layers

Add Point Events

Attribute	Value
Sign Type	Station Sign
Sign Text	42 Miles to Kenova Station
Synchronization Status	

Show network name

< Back | Save


Event Editor
dot2.esri.com/RailUtilityNetwork/
Norfolk Southern Rail Inventory - v10.8.4098 - Norfolk South...
rail_demo
Sign Out
Map
Edit
Review
Web Map
Save Web Map
Layers
Basemap
Add Data
View Date:
Today
Contents
Explore
1 : 564
Bookmarks
Find Route
Navigate
Layers
Bridge
Calibration Points
Redline
Timber Surface
Max Speed
10 mph
15 mph
30 mph
35 mph
40 mph
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50 mph
Control
Curvature
Rail Network
Rail Centerline
Unknown
Main Line
Secondary
Norfolk Southern Project Exte
World Topographic Map
Citations
NS62A Main 1
Switch
VITA, West Virginia GIS, Esri, H...
esri

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dot2.esri.com/RailUtilityNetwork

Norfolk Southern Rail Inventory - v10.8.4098 - Norfolk South... rail_demo Sign Out

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Web Map | Save Web Map | Layers | Basemap | Add Data | View Date: Today | Explore | 1 : 564 | Bookmarks | Find Route

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- Redline
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NS62A Main 1 Switch

VITA, West Virginia GIS, Esri, H...

aaa2.MP4

matic Inventory - v10.8.4098 - Norfolk Southern Schematic LRS Event Editing rail_demo Sign Out

Rectangle | Layer: Max Speed | Return attribute set | Point Events | Line Events | Event Replacement | Attribute Set: NS Schematic Route Eding

Selection | Edit Events

NS62 Main 1 Switch

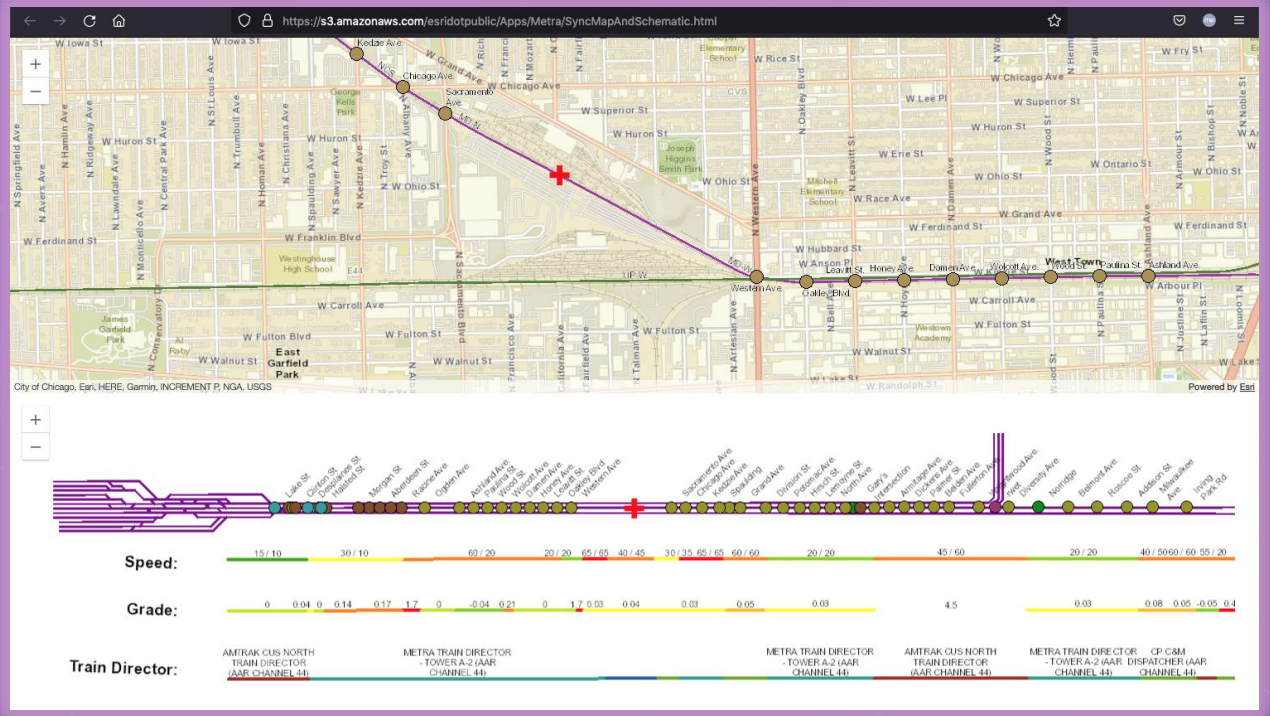
NS62 Main 1 - NS62A Main 1 Big Sandy Loop 1 Switch

NS62A Main 1 Switch

45

50

Control

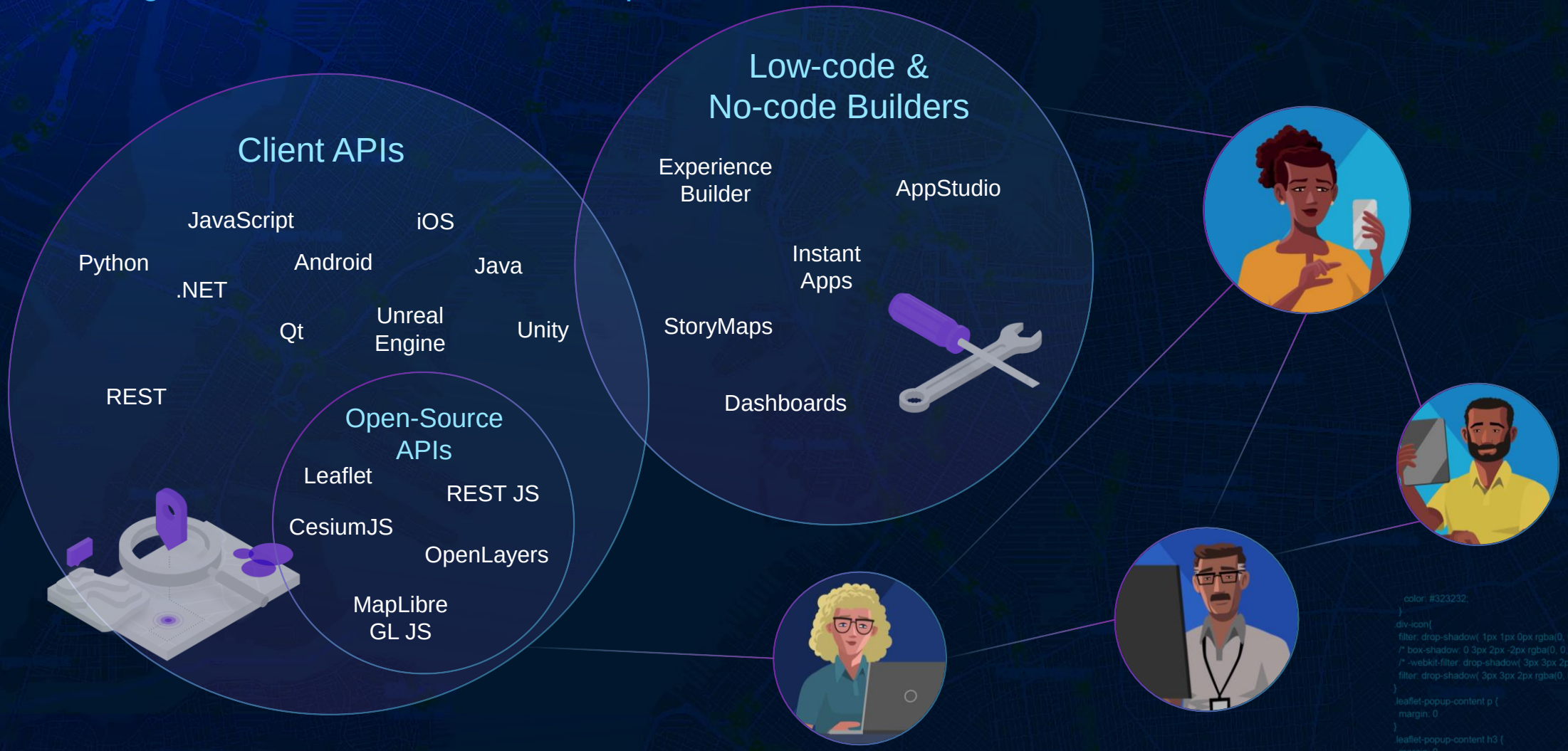


LRS for Developers

Jim Barry

Variety of Development Choices

Use the Right Tools for Your Skills and Requirements



Variety of Development Choices

Use the Right Tools for Your Skills and Requirements

ArcGIS REST API

Web

ArcGIS Maps SDK for JavaScript ›

Native

ArcGIS Maps SDK for .NET ›
ArcGIS Maps SDK for Kotlin ›
ArcGIS Maps SDK for Swift ›
ArcGIS Maps SDK for Java ›
ArcGIS Maps SDK for Qt ›

Game engines

ArcGIS Maps SDK for Unity ›
ArcGIS Maps SDK for Unreal Engine ›

Scripting and services

ArcGIS API for Python ›
ArcGIS REST JS ›
ArcGIS REST APIs ›

Open source

Esri Leaflet ›
MapLibre GL JS ›
OpenLayers ›

Calcite design system

Overview ›
Components ›
Colors ›
Icons ›

App builders and templates

ArcGIS AppStudio ›
ArcGIS Experience Builder ›
ArcGIS Survey123 ›
ArcGIS Web AppBuilder ›

ArcGIS Pro

ArcGIS Pro SDK for Microsoft .NET
ArcPy

ArcGIS Enterprise

ArcGIS Enterprise SDK ›
ArcGIS Workflow Manager ›
Chef for ArcGIS Enterprise
GeoEvent Server SDK

Reference topics

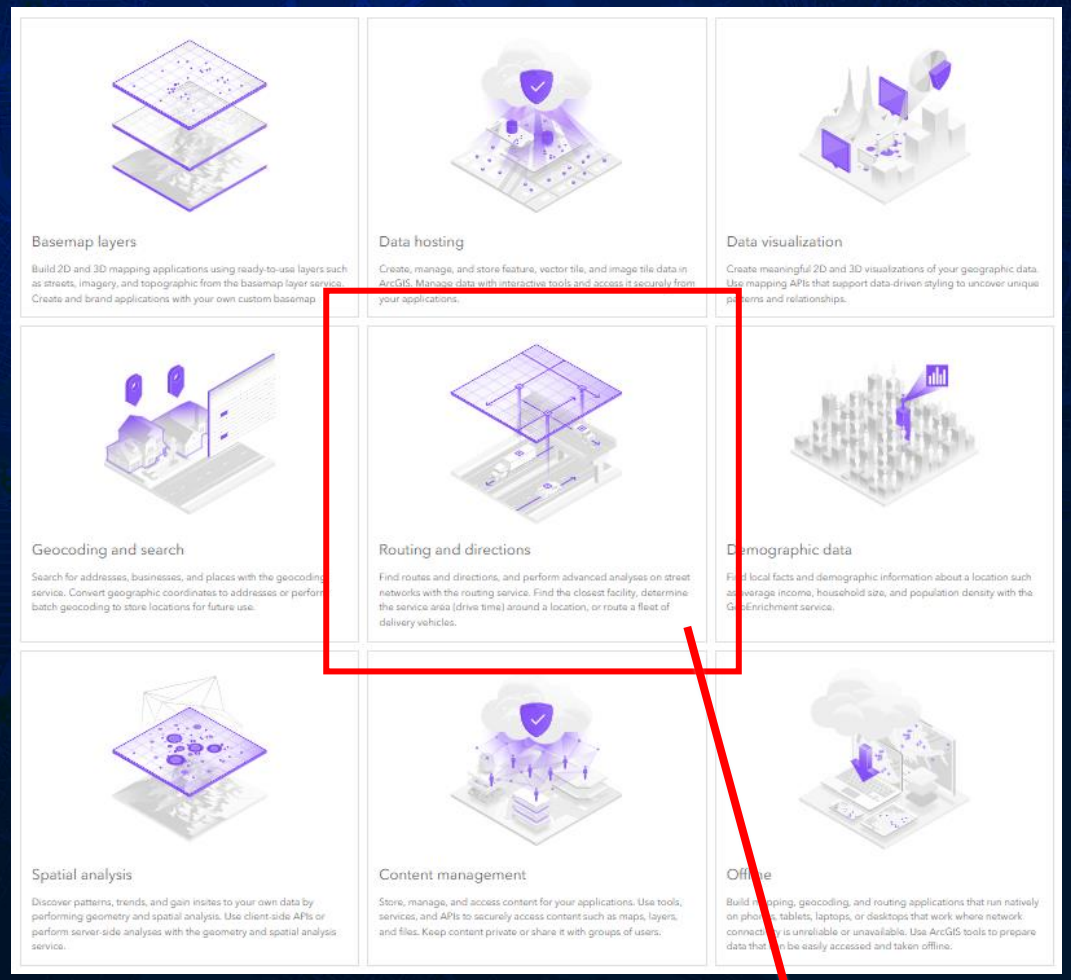
Arcade ›
Cartographic Information Model Specification
Common data types ›
Developer glossary ›
Indexed 3D Scene Layers
Spatial references ›
Tile package specification
Web Map Specification ›
Web Scene Specification ›

ArcObjects

ArcObjects SDK for C++
ArcObjects SDK for Java
ArcObjects SDK for .NET

Other documentation

ArcGIS API for JavaScript (legacy 3.x) ›
ArcGIS Developer release notes ›
ArcGIS Earth Automation API ›
ArcGIS GeoAnalytics Engine ›
ArcGIS Urban API ›
ArcGIS CityEngine SDK ›
ArcGIS Velocity gRPC Feeds (Beta) ›
Frequently asked questions (FAQ) ›
Vector Tile Style Editor



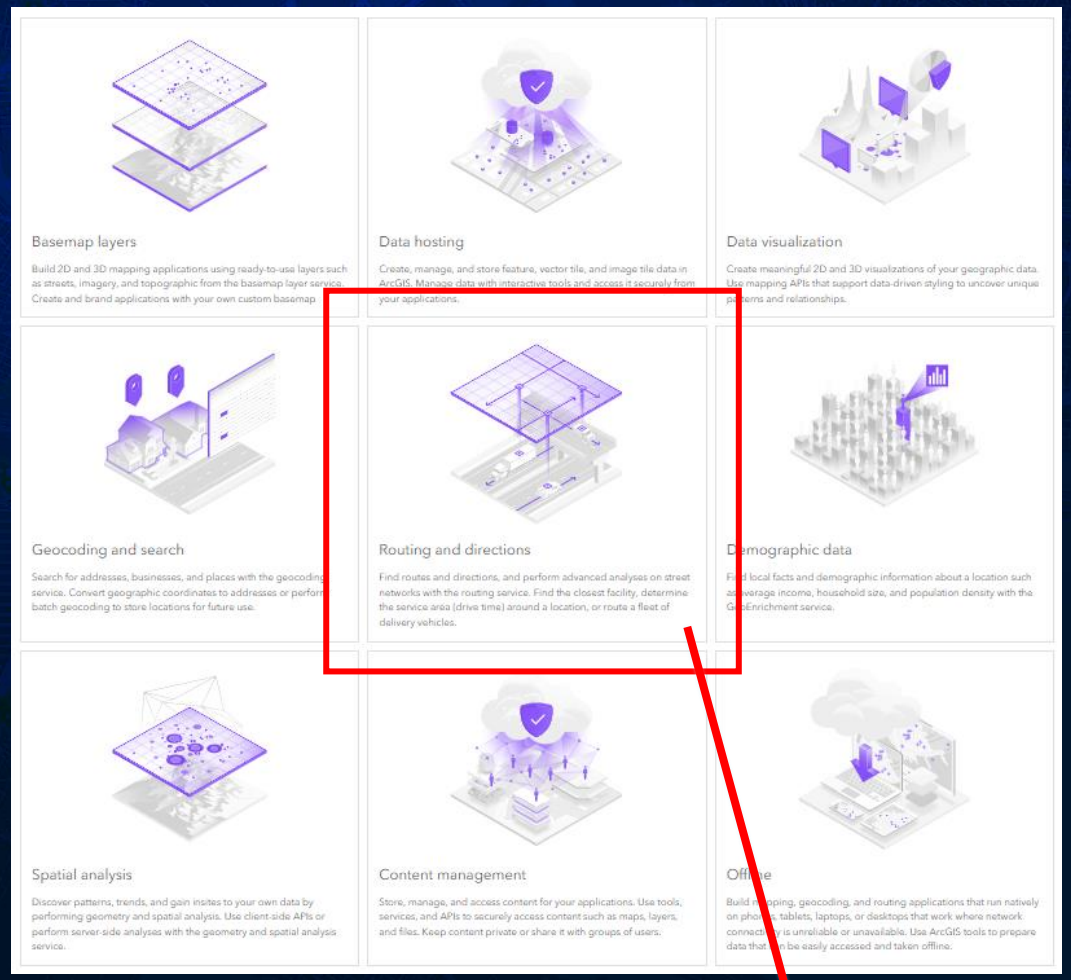
What is the REST API?

Collection of methods, accessible as HTTPS requests, that return results.

Supports GET and POST

Return data is often JSON, but could also be images or other kinds of data.

https://route.arcgis.com/arcgis/rest/services/World/Route/NAServer/Route_World/solve
?stops=-74.068398,40.418693;-74.067576,40.417070&token=*[your_token]***&f=pjson**



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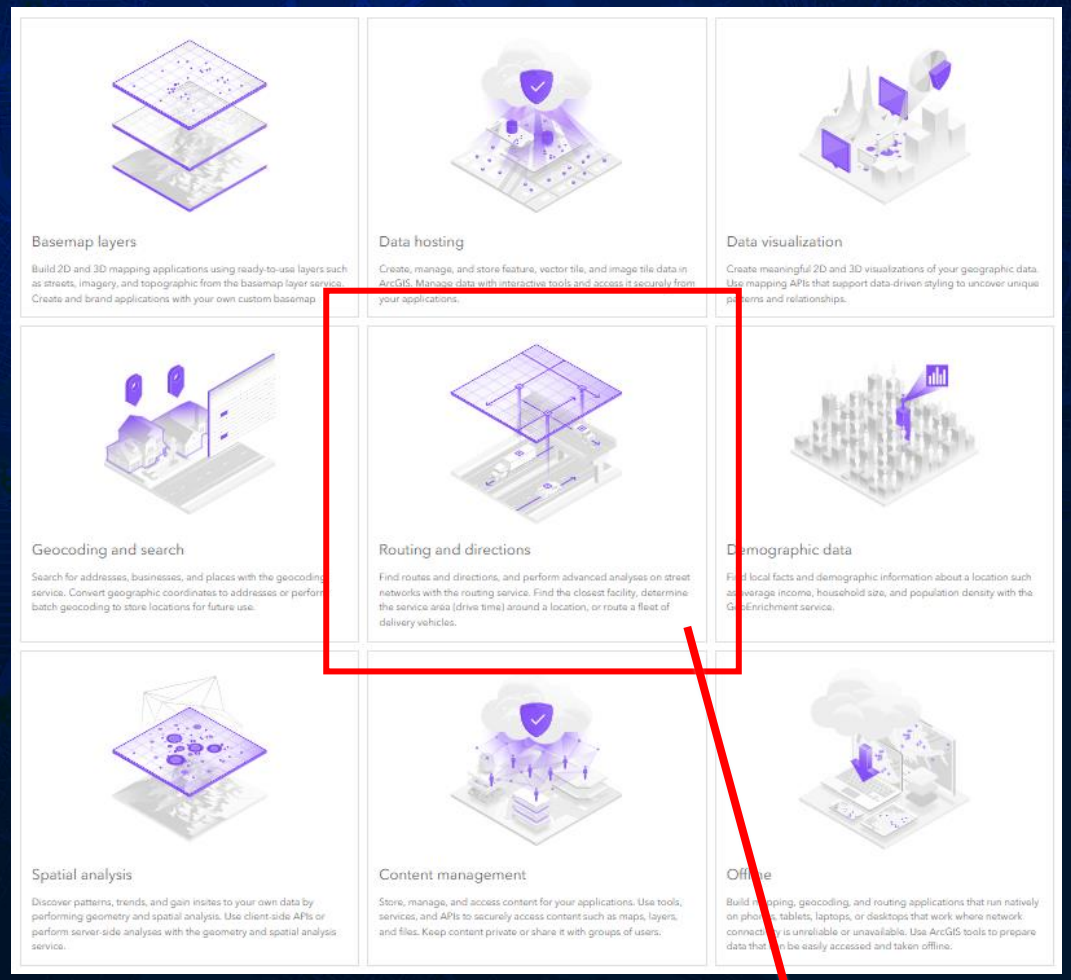
?stops=-74.068398,40.418693;-74.067576,40.417070&token=[your_token]&f=pjson
```



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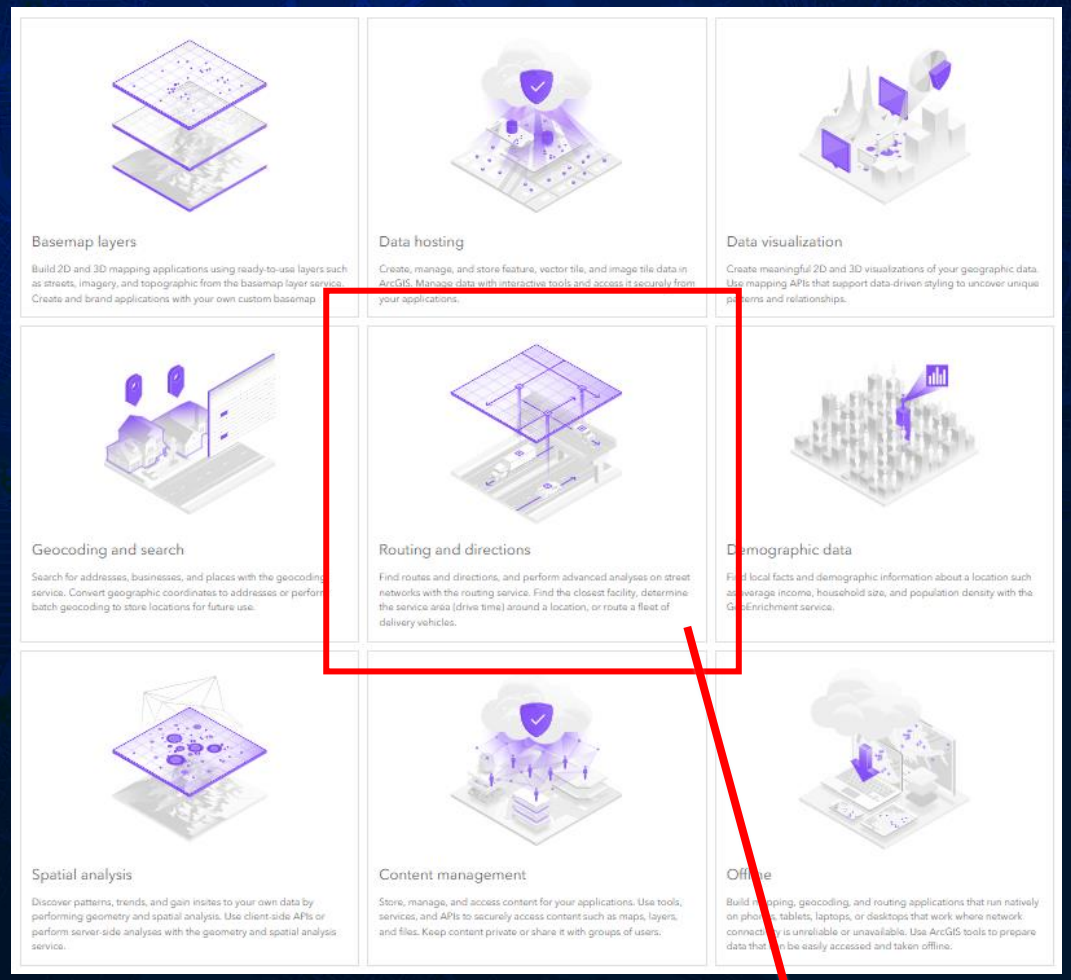

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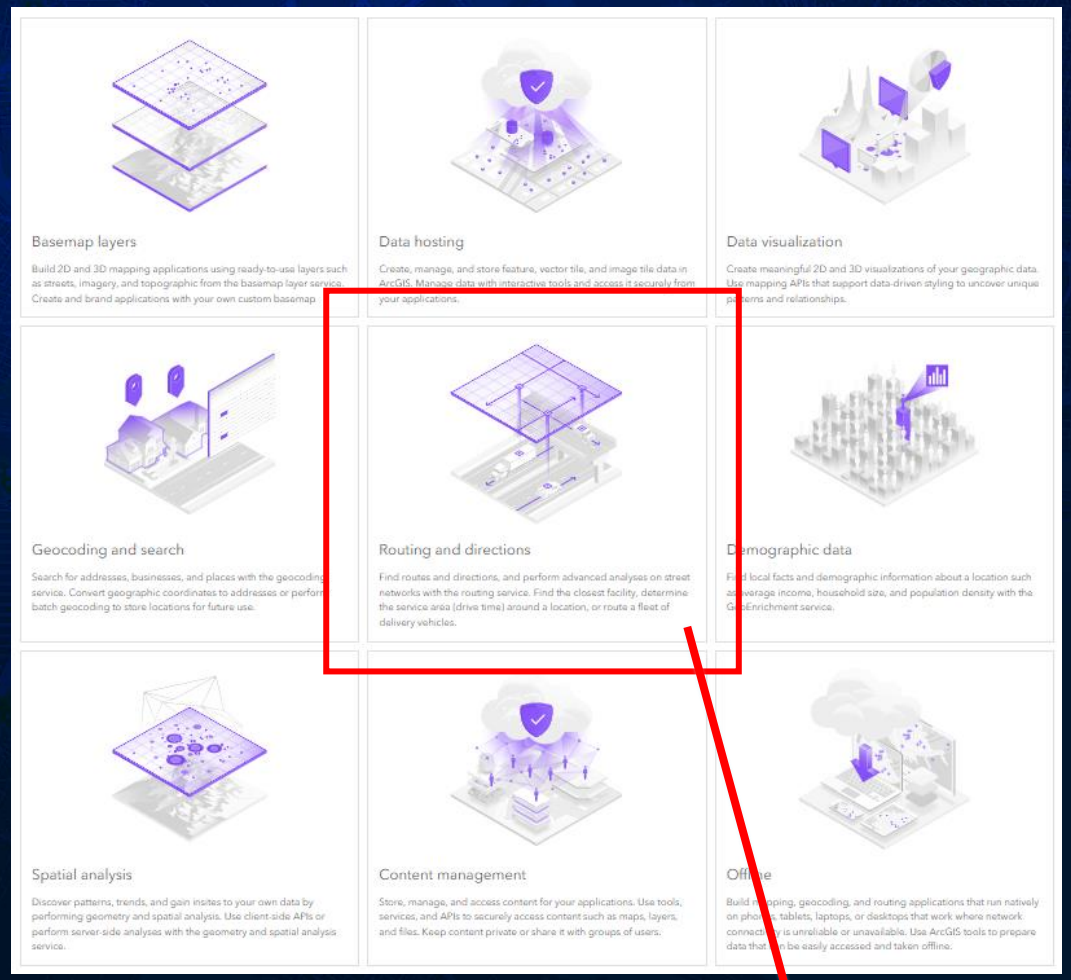

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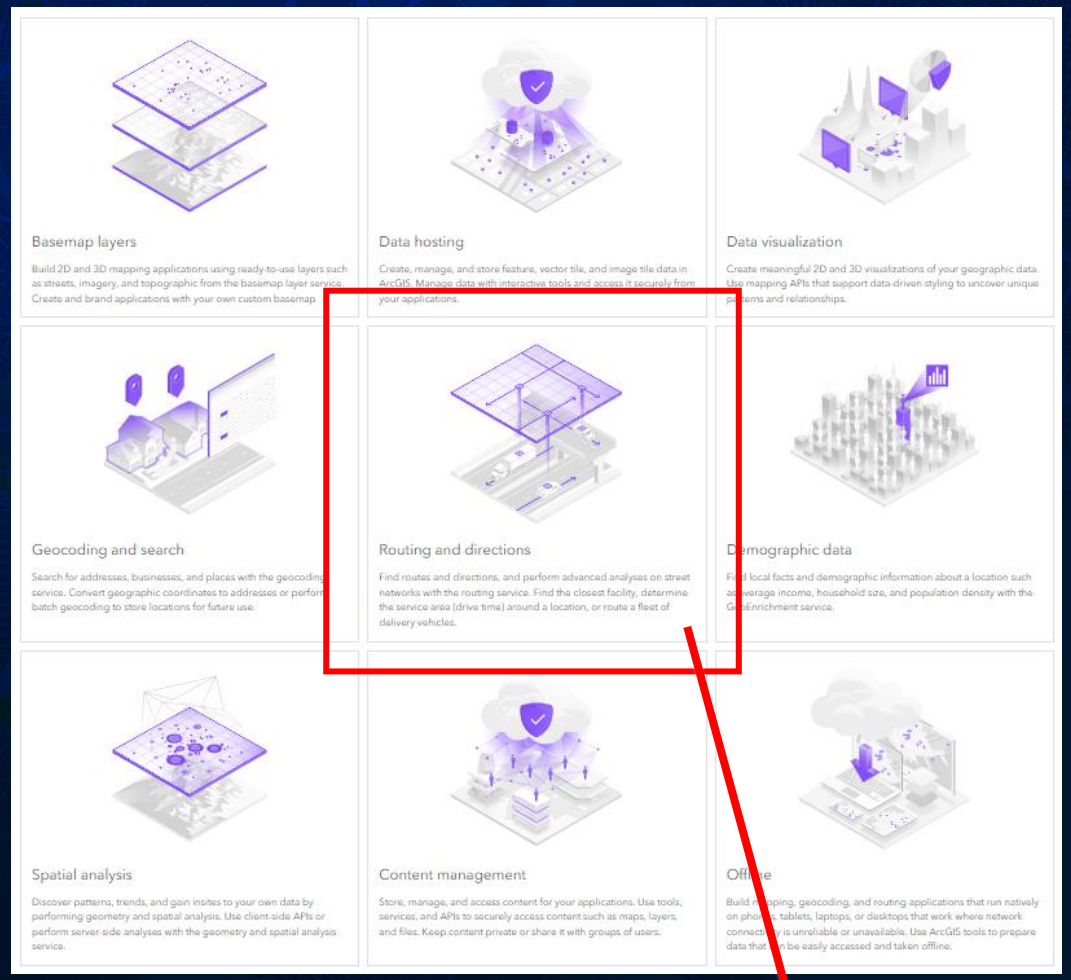

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?stops=-74.068398,40.418693;-74.067576,40.417070&token=*[your_token]***&f=pjson**

Home Workspaces API Network Explore Search Postman Upgrade

[CONFLICT] GET route_with POST createRe GET https://s POST generate GET NS_route_ GET FindAdc GET SolveRo login_stuff

Routing / **SolveRoute_wToken** Save

GET https://route.arcgis.com/arcgis/rest/services/World/Route/NAServer/Route_World/solve?stops=-74.068398, 40.418693;-74.067576, 40.417... Send

Params

Query Params

KEY	VALUE	DESCRIPTION
stops	-74.068398, 40.418693;-74....	
token	AAPKbd4e54318a1a4070be...	
f	json	
Key	Value	Description

Body 200 OK 748 ms 1.64 KB Save Response

Pretty Raw Preview Visualize JSON


```
126            {
127                "attributes": {
128                    "length": 0.1067529323196411,
129                    "time": 0.4986114501953125,
130                    "text": "Turn right on Ocean Blvd",
131                    "ETA": -2209161600000,
132                    "arriveTimeUTC": -2209161600000,
133                    "maneuverType": "esriDMTTurnRight"
134                },
135                "compressedGeometry": "+rkq95-1vvvuqk
                       +12tj4v5-92-j83-92-jq8-i4-4q1",
136                "strings": [
                       {
                           "string": "Ocean Blvd",
                           "stringType": "esriDSTStreetName"
                       }
                   ]
               },
               {
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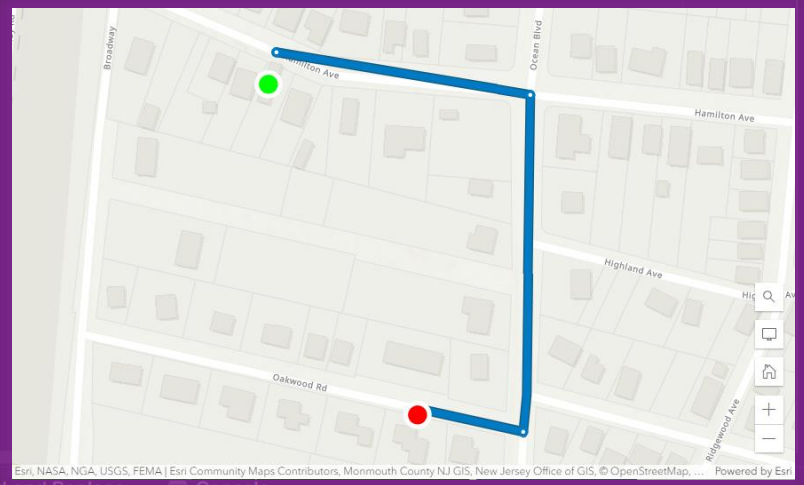
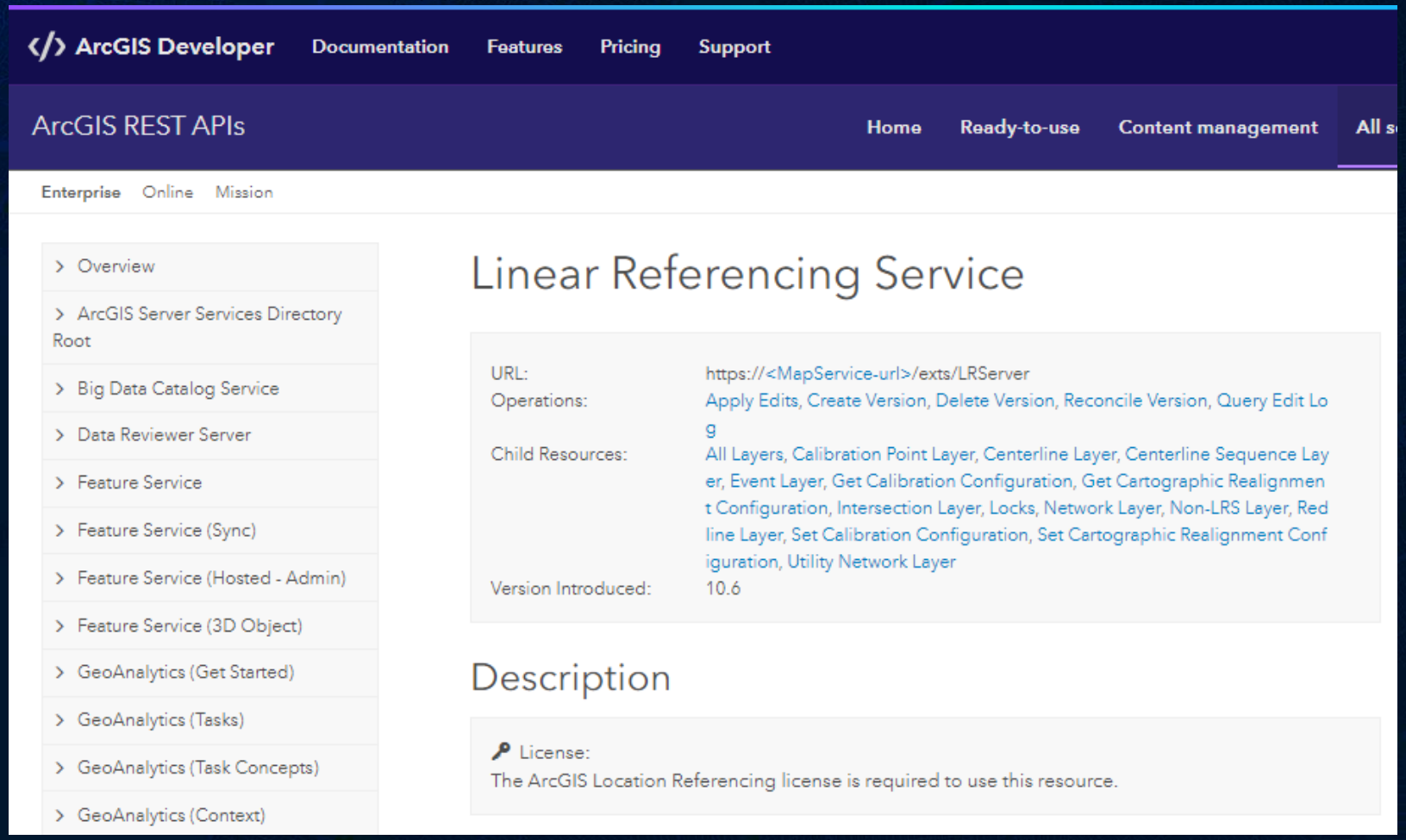
                       "time": 0.29912211675002376,
                       "text": "Turn right on Oakwood Rd",
                       "ETA": -2209161600000,
                       "arriveTimeUTC": -2209161600000,
                       "maneuverType": "esriDMTTurnRight"
```

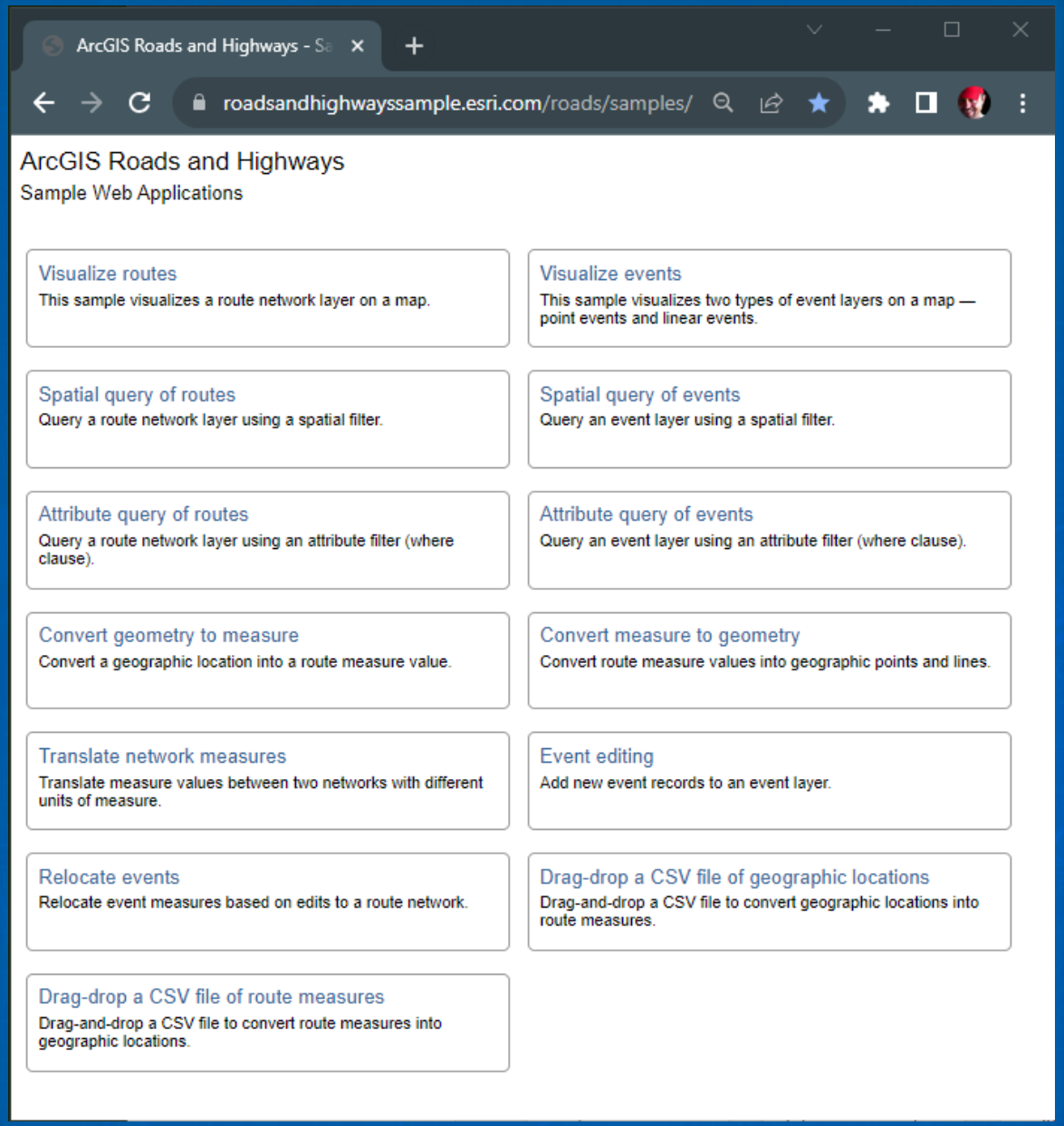



Online Find and Replace Console Cookies Capture requests Runner Trash

Linear Referencing Service

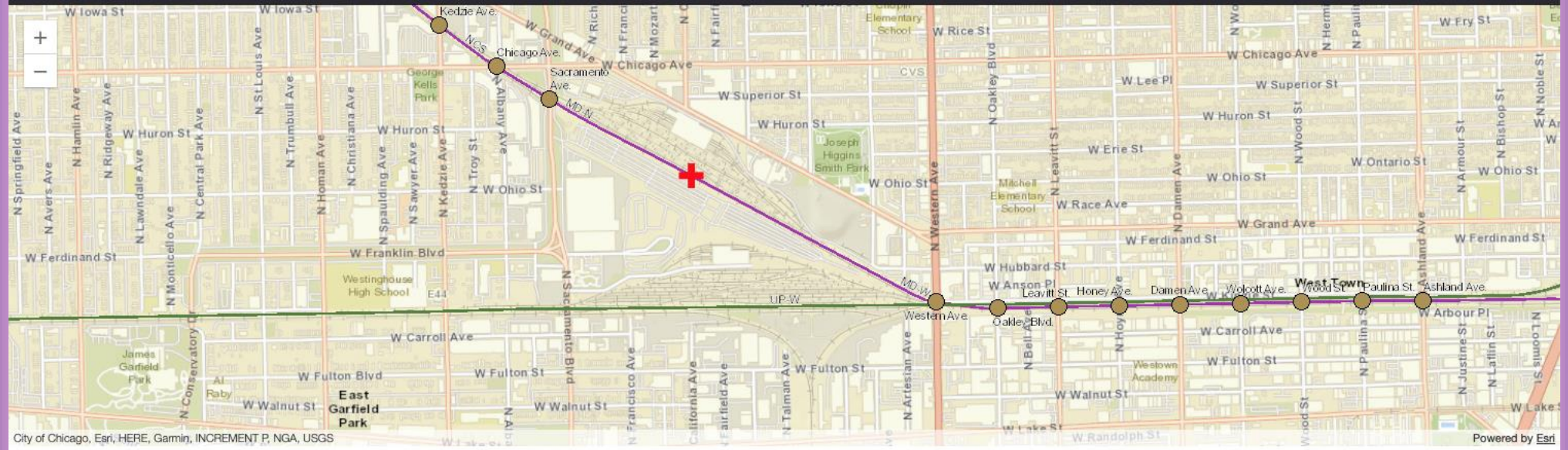


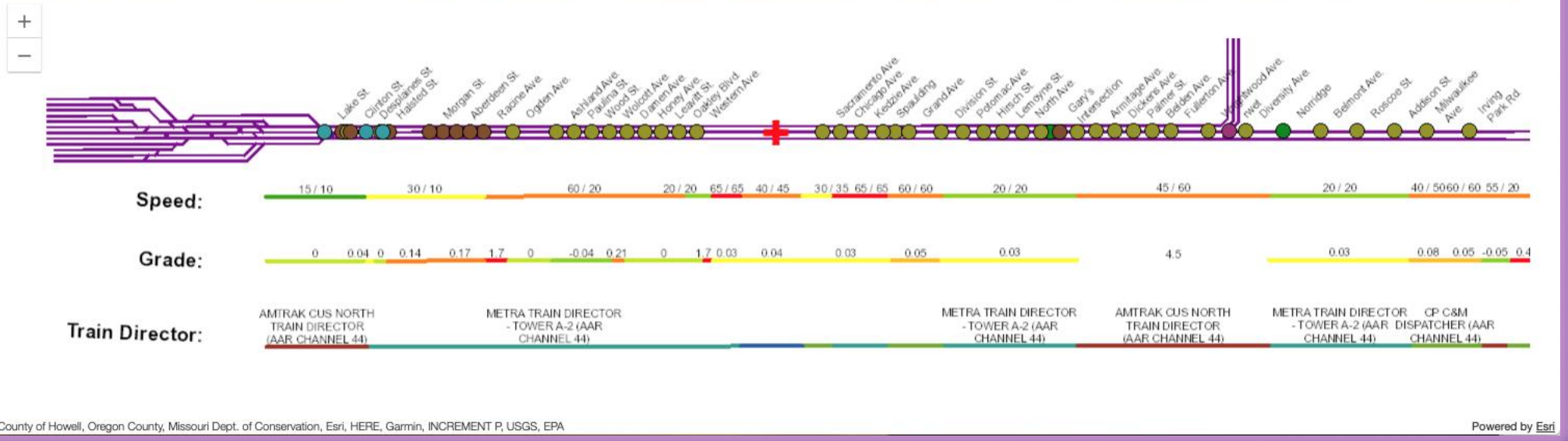
roadsandhighwayssample.esri.com/roads/samples



Metra LRS Rail Demo

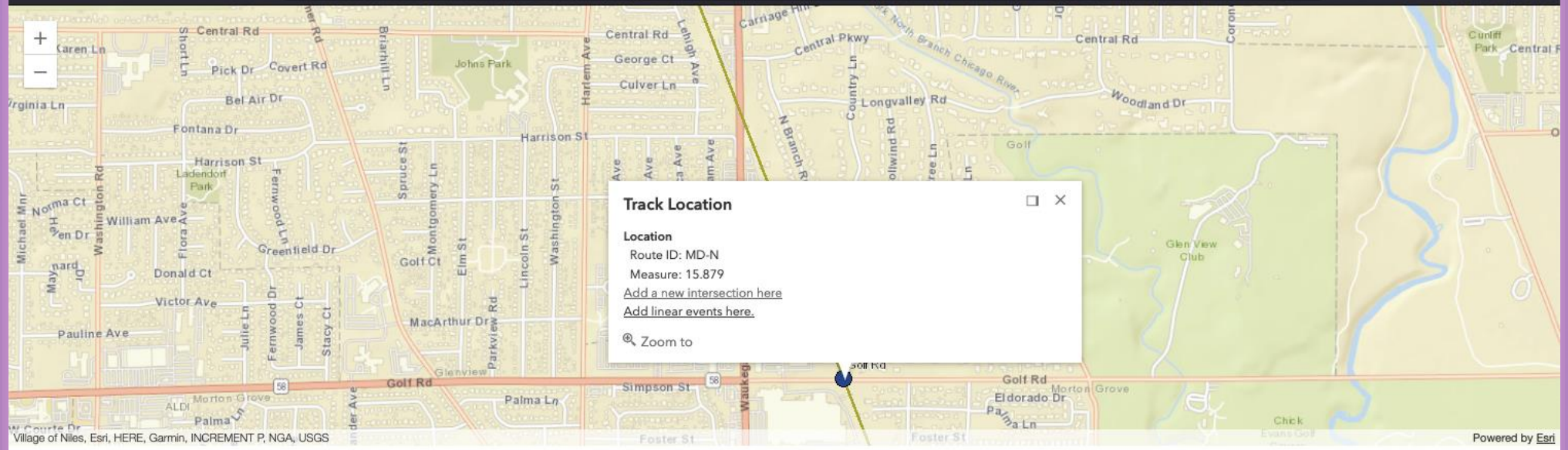
https://s3.amazonaws.com/esridotpublic/Apps/Metra/SyncMapAndSchematic.html

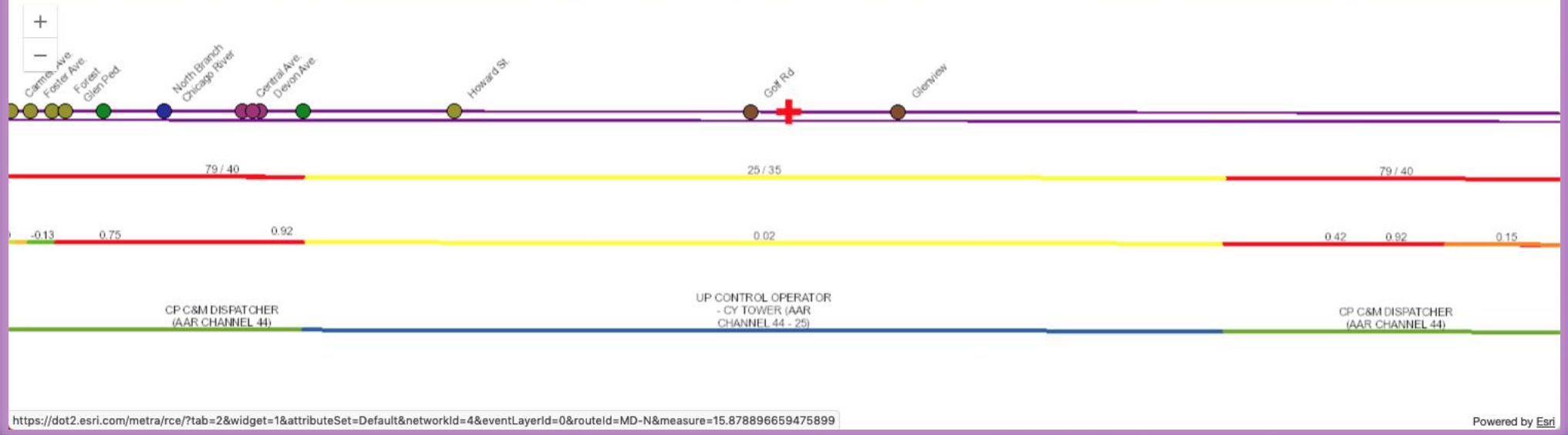




Metra LRS Rail Demo | Event Editor

https://s3.amazonaws.com/esridotpublic/Apps/Metra/SyncMapAndSchematic.html





Metra LRS Rail Demo | Event Editor | Event Editor

https://dot2.esri.com/metra/rce/?tab=2&widget=1&attributeSet=Default&networkId=4&eventLayerId=0&routeId=MD-N&measure=15.8788966

Rail Event Editor - v10.7.1.3052 - Metra LRS Event Editor Map

jimba@esri.com Sign Out

Map | Edit | Review

Reconcile | Version: | Select | Rectangle | Layer: Grade | Return attribute set | Point Events | Line Events | Event Replacement | Attribute Set: Default

Versioning | Selection | Edit Events

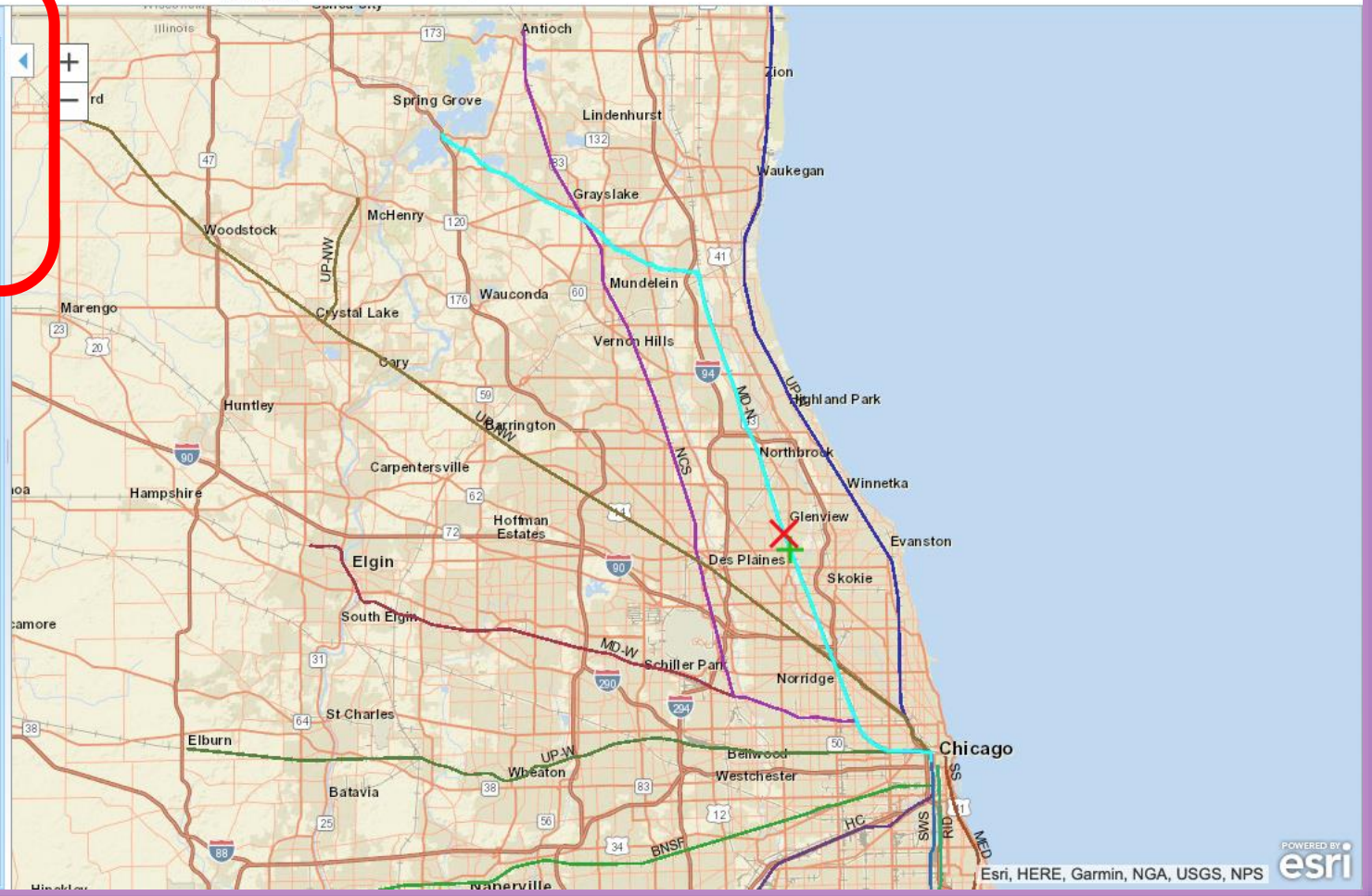
Add Linear Events

All Attributes

	Attribute	Value
☑	Grade	0.9
☑	Speed_Other	50
	Speed_Passenger	40
☑	Train_Director	AMTRAK CUS NORTH

☐ Show network names
☐ Show layer names
☑ Go to next measure upon save

< Back | Save



Metra LRS Rail Demo | Event Editor

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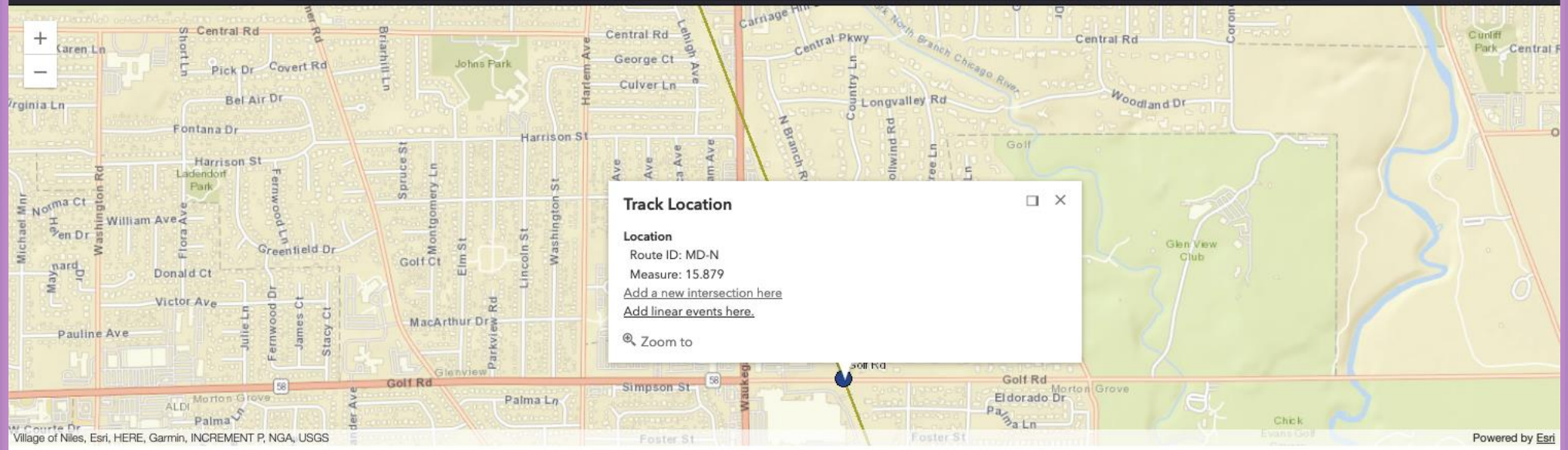
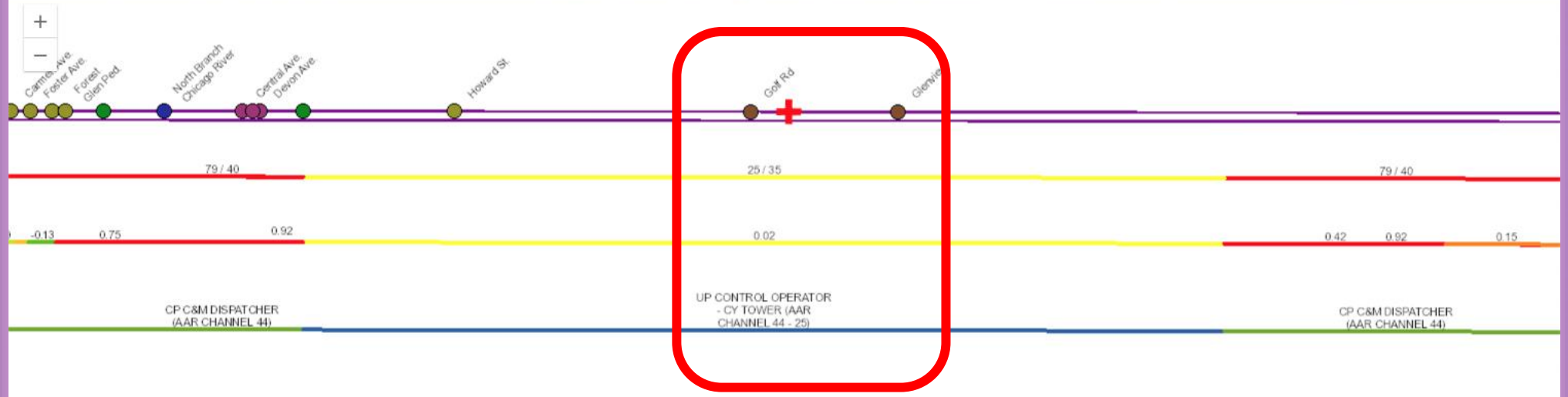


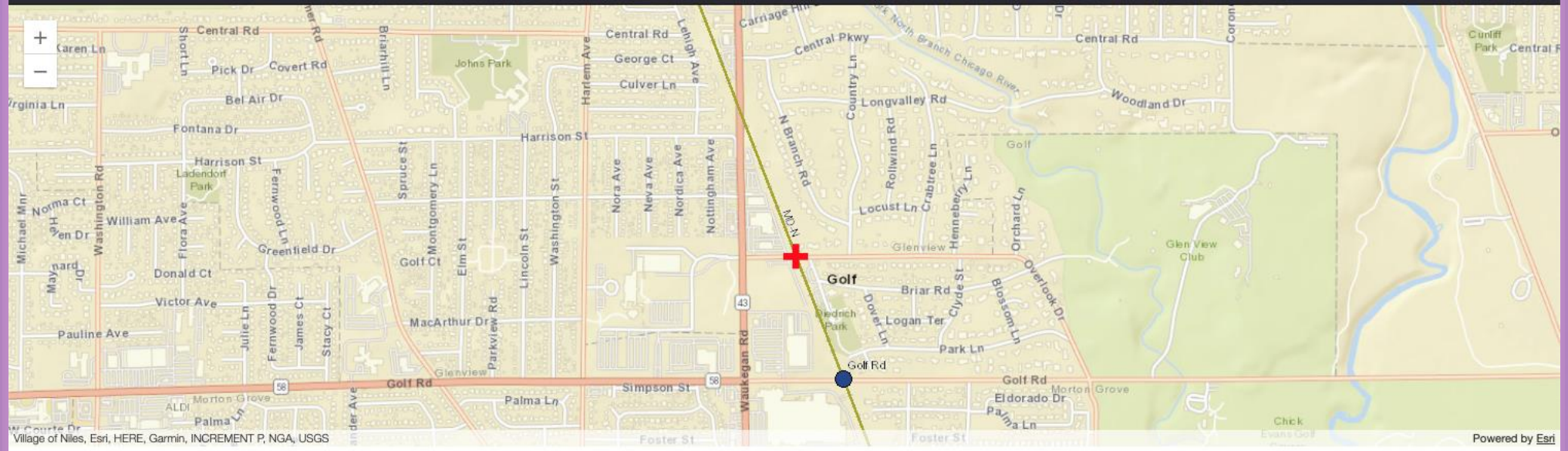


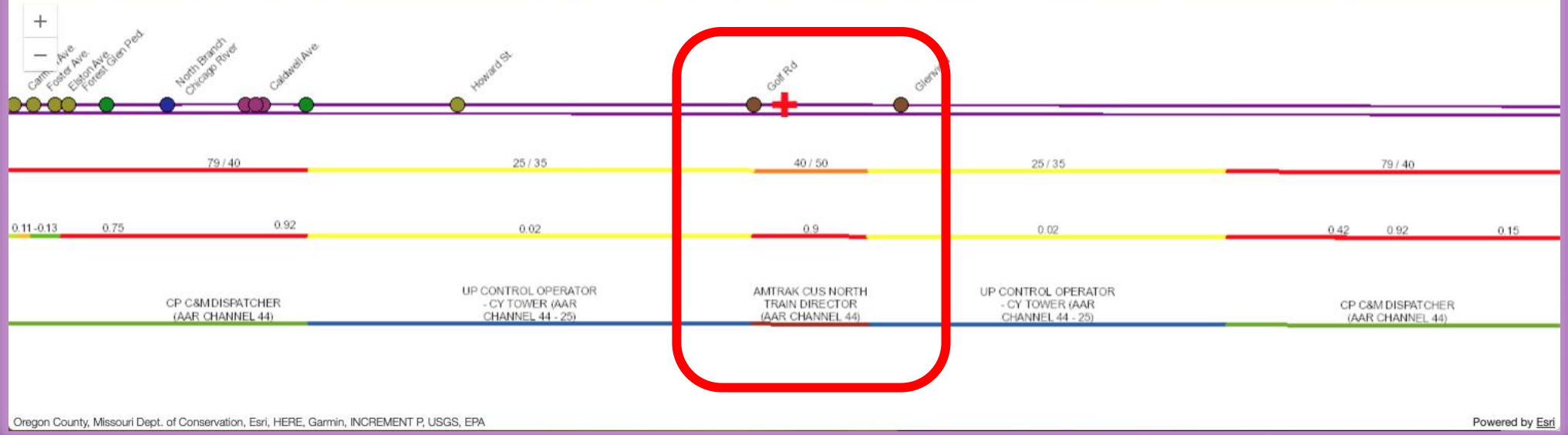
https://dot2.esri.com/metra/rce/?tab=2&widget=1&attributeSet=Default&networkId=4&eventLayerId=0&routeId=MD-N&measure=15.878896659475899

Powered by Esri

Metra LRS Rail Demo | Event Editor | Event Editor

https://s3.amazonaws.com/esridotpublic/Apps/Metra/SyncMapAndSchematic.html



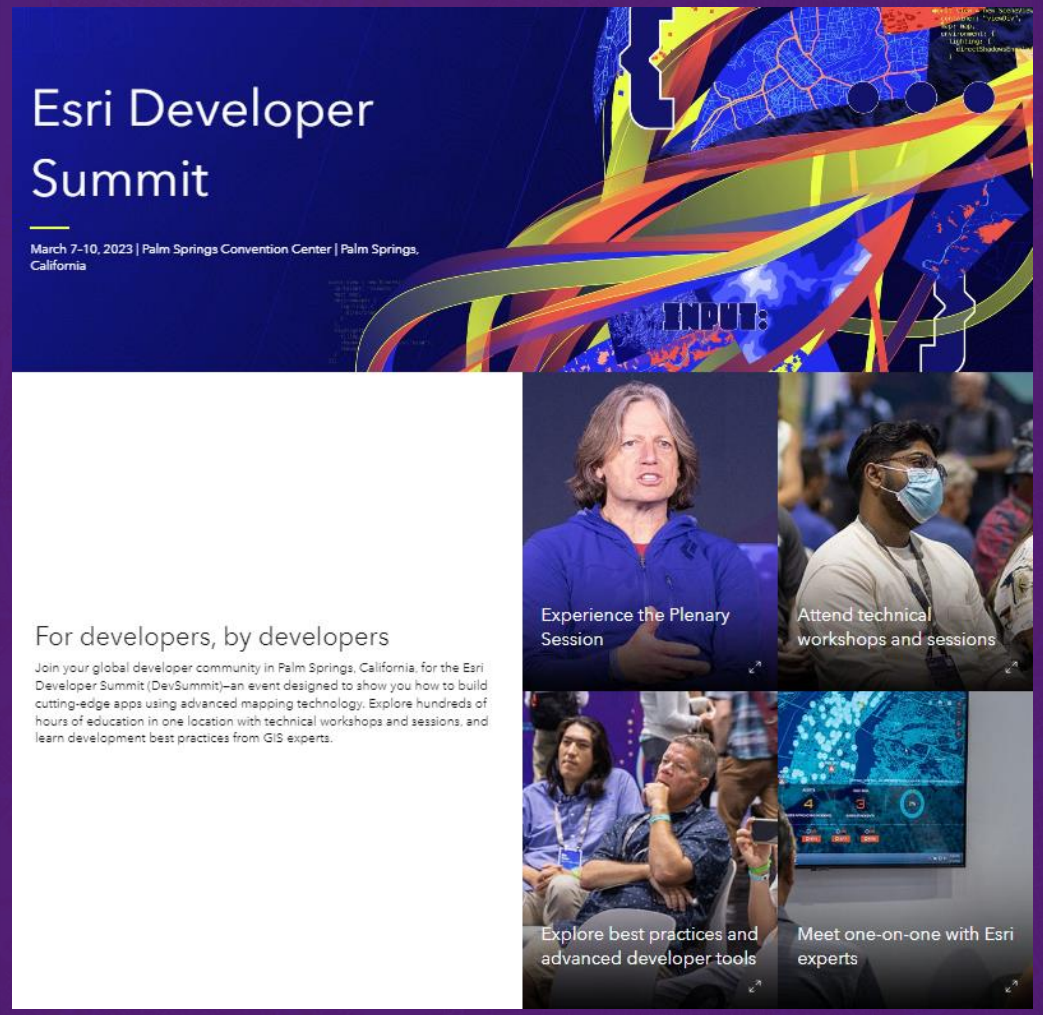


DevSummit

For Developers, By Developers

- Berlin *14-16 November 2023*

- Palm Springs *12-15 March 2024*
  - *tech sessions, demo theaters*
  - *hundreds recorded*
  - *dozens live-streamed*



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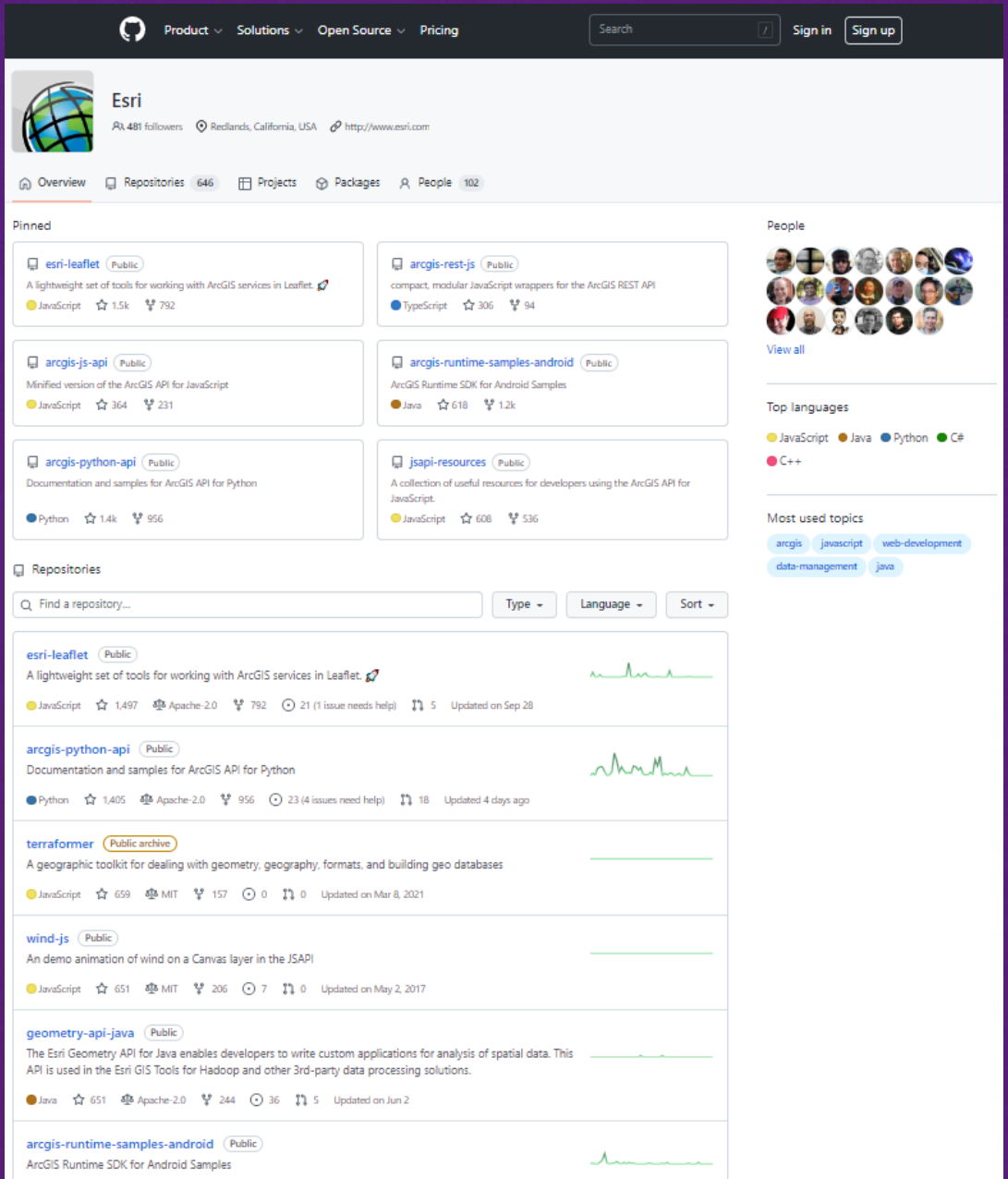
  - What's new, what's next
- Breakout tech sessions
- Pool social

Github.com/Esri

600+ repos

- Apps
- Libraries
- Widgets
- Extensions
- Documents
- …and more



Resources

Where can I learn more about Location Referencing

community.esri.com

(formerly "GeoNet")

- Q&A Forums
- Blog articles
- Videos
- Code samples
- …and more

esri Community

Railways

esri Community

Gas and Pipeline

esri Community

Roads and Highways

Deleting many but not all routes from the same line in LRS Line Network
0 1 531
While trying to implement a workaround suggested at Re: Creating Route to fill gap in Line of LRS Line... - Esri Comm...
POST by GraemeBrowning_Aurizon • Occasional Contributor II
in Roads and Highways Questions • Last Updated 01-23-2023

Extend Route appears to ignore Attribute Rules
0 4 871
This is related to Realigning route confuses Attribute Rules - Esri Community and probably has the same underlying ca...
POST by GraemeBrowning_Aurizon • Occasional Contributor II
in Roads and Highways Questions • Last Updated 11-08-2022

Realign Route appears to ignore Attribute Rules
0 3 842
Before looking at the complex example in the spoiler below, I think you should review the simpler example at Extend R...
POST by GraemeBrowning_Aurizon • Occasional Contributor II
in Roads and Highways Questions • Last Updated 11-08-2022

Creating Route to fill gap in Line of LRS Line Network
0 4 828
I suspect that I am encountering the same issue that @MasaoMatsuoka reported at Cannot create a route at the start or...
POST by GraemeBrowning_Aurizon • Occasional Contributor II
in Roads and Highways Questions • Last Updated 11-03-2022

ds symbology level to topology road
0 0 452
eryone,Recently I encounter a problem related to topology and cartography.I got ers of different class of r...
by WANNILIN • New Contributor
in Roads and Highways Questions • Last Updated 09-04-2022

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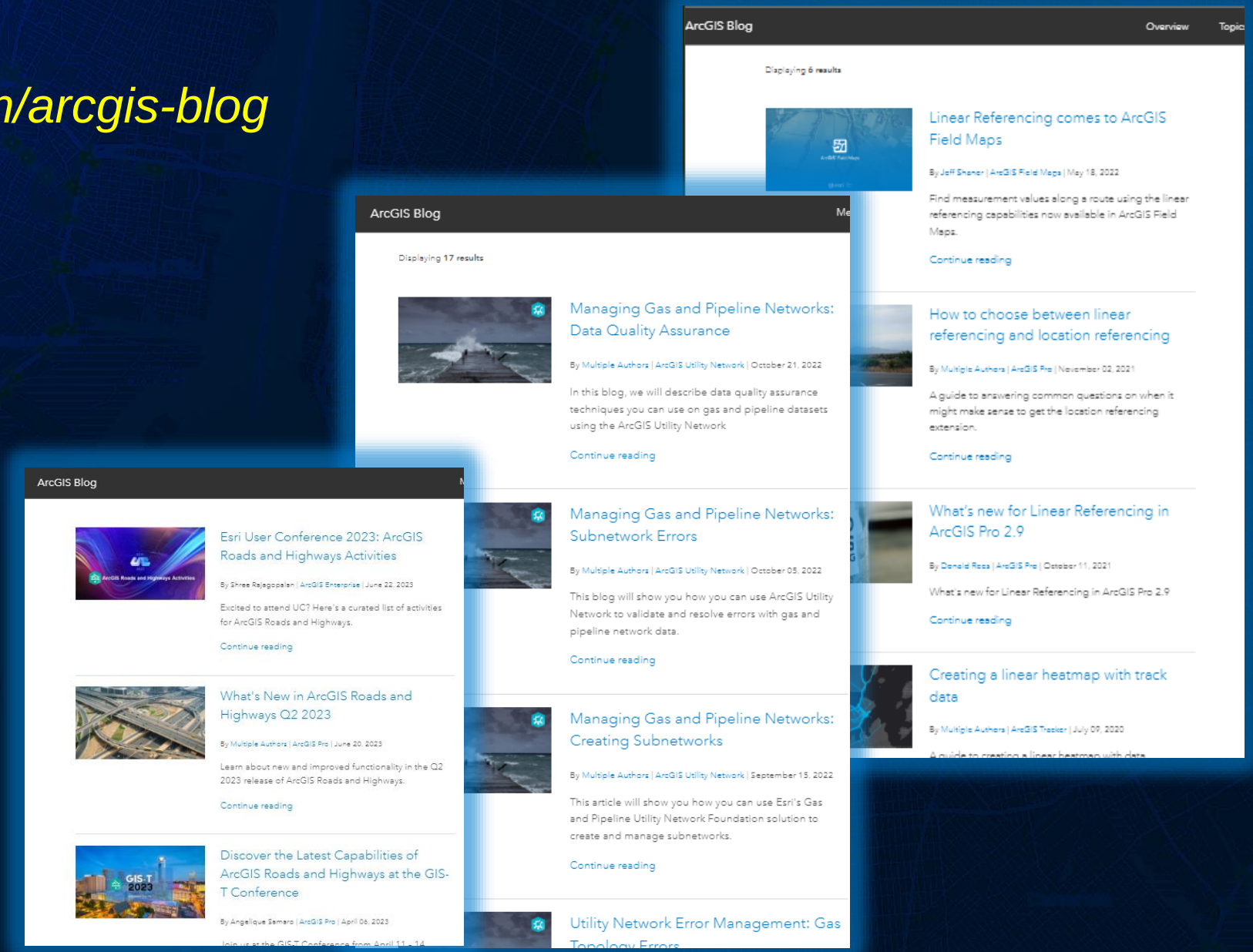
- Build Mobile Apps
- Build Web Apps
- Script and Automate

- Documents
- E-Learning
- Instructor-Led
- Learning Plans
- MOOCs
- Story Maps
- Teacher Resources
- Training Seminars
- Tutorials
- Videos
- Web Courses

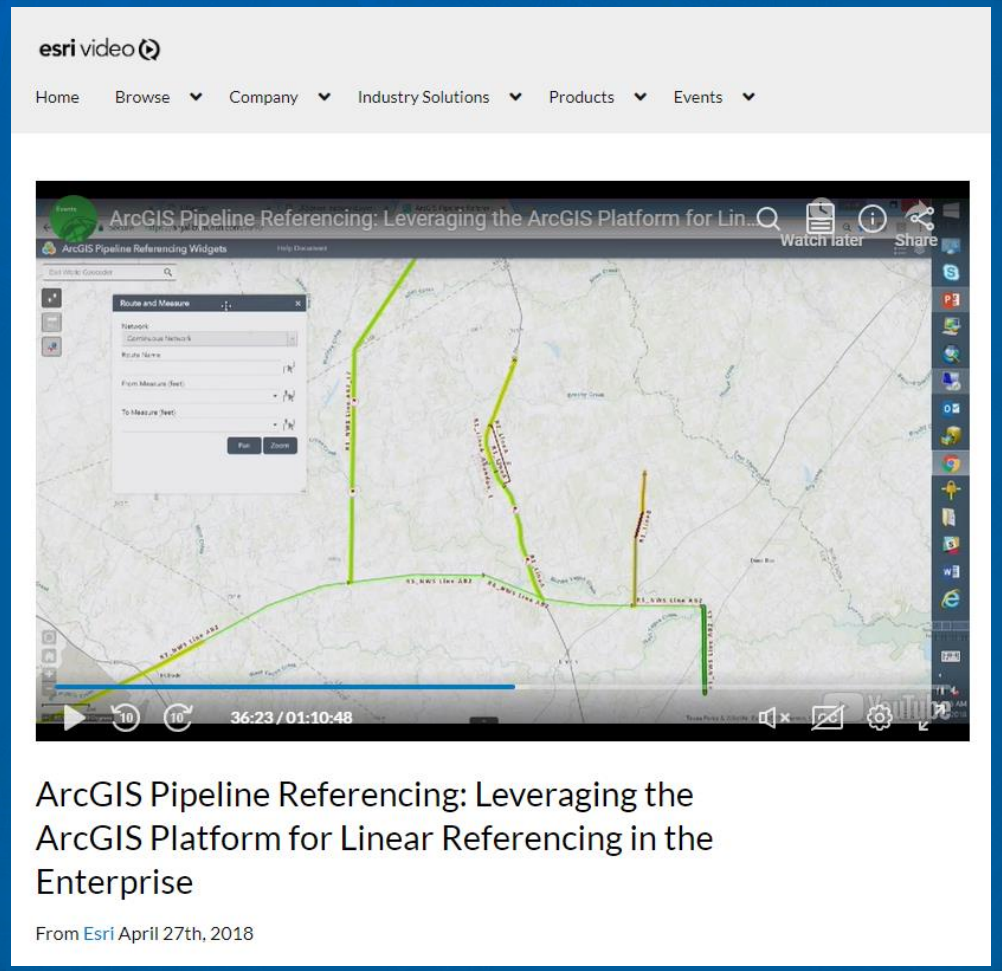
WEB COURSE Getting Started with Linear Referencing	4 Hours, 15 Minutes	Requires Maintenance Subscription
WEB COURSE Linear Referencing Using ArcGIS	3 Hours, 45 Minutes	Requires Maintenance Subscription
INSTRUCTOR-LED Introduction to ArcGIS Pipeline Referencing	2 Days (16 Hours)	
WEB COURSE ArcGIS Roads and Highways: Preparing and Sharing an LRS Using ArcGIS Enterprise	3 Hours, 55 Minutes	Requires Maintenance Subscription
LEARNING PLAN ArcGIS Roads and Highways Fundamentals Added by Esri on March 14, 2023	3 Courses	
WEB COURSE ArcGIS Roads and Highways: Introduction to Modeling and Data Management in a Desktop Environment	3 Hours, 45 Minutes	Requires Maintenance Subscription
WEB COURSE ArcGIS Roads and Highways: Editing an LRS	5 Hours, 50 Minutes	Requires Maintenance Subscription
WEB COURSE Referencing Data to Real-World Locations Using ArcGIS	3 Hours, 15 Minutes	Requires Maintenance Subscription

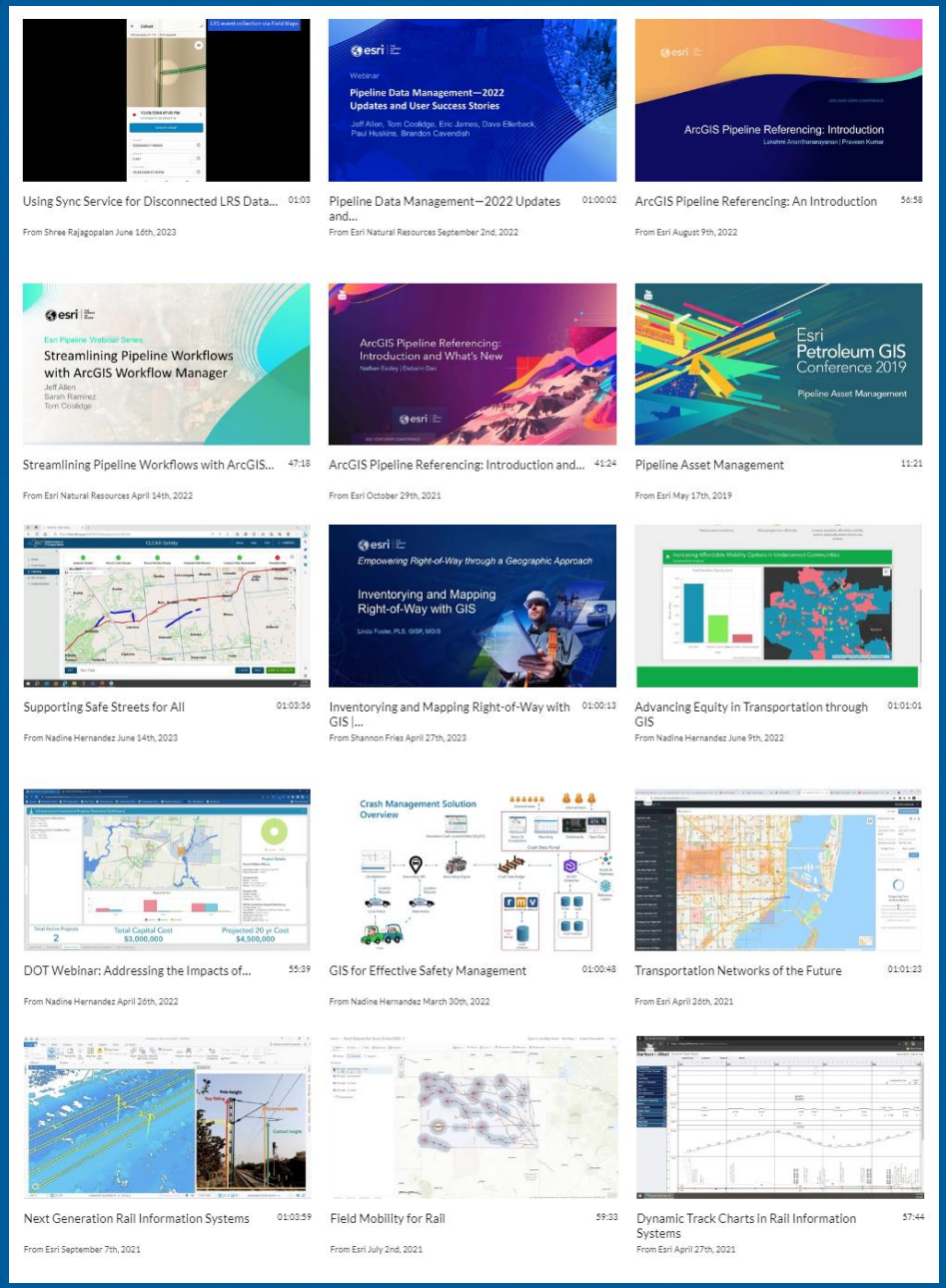
ArcGIS Blog *esri.com/arcgis-blog*

- News, announcements
- Release notes
- Tips, tricks, techniques
- Sample code
- Case studies
- Video
- Discussion



Videos *mediaspace.esri.com*





Linear/Location Referencing

What’s New and The Road Ahead

What’s New

- Event Replacement
  - Create attribute sets and retire or replace events on routes
- Dynamic Segmentation
  - Edit events from multiple event layers in a single table. Edits will be pushed to the edited event features
- Merge Events
- Translate Tool
  - Translate between RouteID and RouteName, LineID and LineName, and also coincident or intersecting measures of routes either in the same network or different networks
- Rename Route Tool
  - Rename a route across time slices
- Sync Service for ArcGIS Field Maps
  - Event editing in a disconnected environment in ArcGIS Field Maps

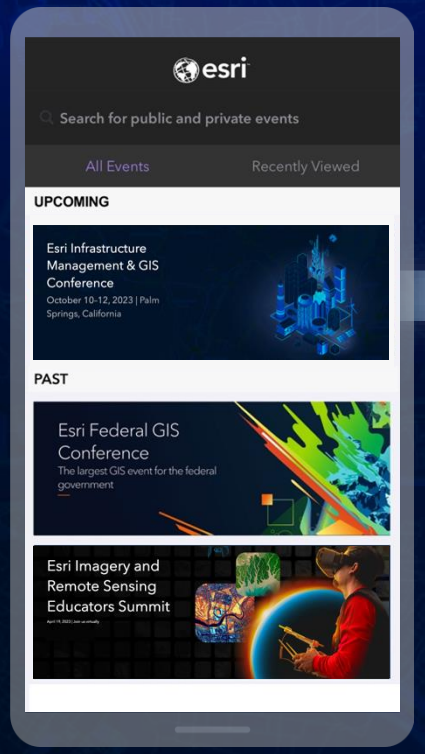
Road Ahead

- Near-Term (Enterprise 11.2 and Pro 3.2):
  - enhancement to reassign routes for an enhanced user experience
  - reverse stationing support
  - next-gen web based LRS event editing experience using ArcGIS Experience Builder
- Medium term – Later 2024
  - usability enhancements to editing workflows
  - more analytic and reporting capabilities
- Long-Term – 2025, 2026
  - enhancing referent support

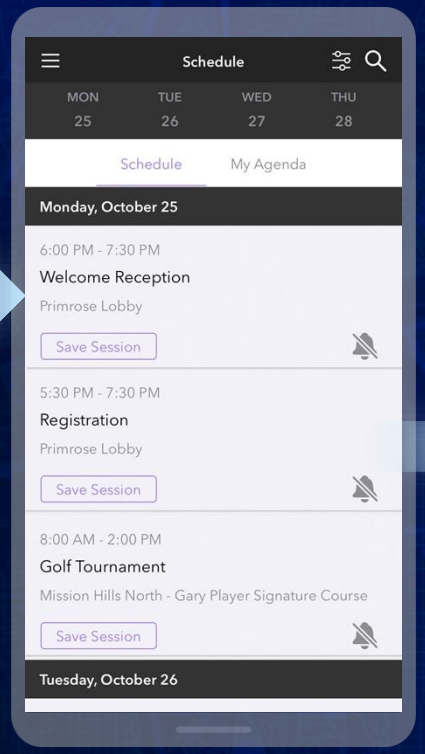
Questions

Please Share Your Feedback in the App

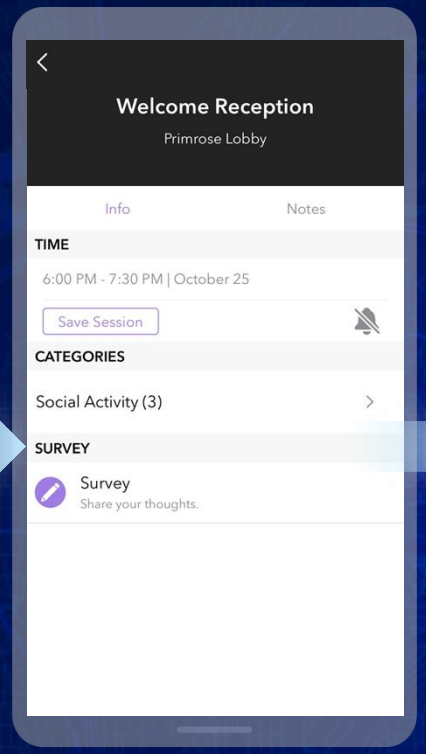
Download the Esri Events app and find your event



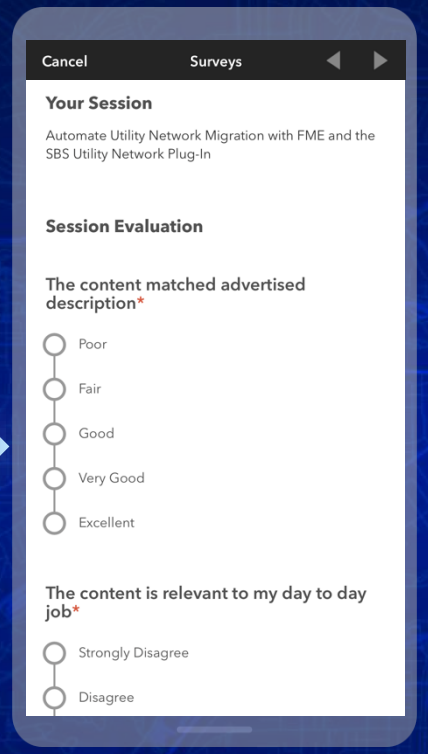
Select the session you attended



Scroll down to "Survey"



Log in to access the survey



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