



San Diego Gas & Electric Company

EPIC Final Report

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Attribution

This comprehensive final report documents work done in this EPIC activity.

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EXECUTIVE SUMMARY

This report summarizes project objectives, technical approach, results, and lessons learned for the EPIC-1 Project #2, Visualization and Situational Awareness Demonstration. Work on this project started with planning tasks in 2016, with most of the implementation work performed in 2017.

The role of the system operator is changing. Where distribution operators of earlier times used to deal mainly with limited information from low-bandwidth supervisory control and data acquisition (SCADA) systems and switching decisions, smart grid operations now must consider new classes of data from numerous devices. The deployment of these numerous sensors, intelligent devices, meters, and other communication nodes within the SDG&E power distribution system generates a massive amount of highly granular data, sometimes referred to as a “data tsunami”. By merely extending the existing ways of fragmented presentation of information, the data tsunami may overwhelm system operators and diminish the value of the data. However, *if presented appropriately by filtering, combining related data from different sources in line with cognitive capabilities and task related needs of users, and by adding geospatial dimension to operational, historical, and other types of data, information derived from this massive amount of data will increase the operators’ ability to process and better react to relevant information, resulting in improved grid operations and reliability.* The objectives of this project were aligned with the second approach.

Objectives (EPIC-1, Project 2)

The objective of this demonstration project was to explore how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances grid monitoring and situational awareness. In particular, this project has looked at how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators.

When transformed and presented in a visually integrated manner, this data can be invaluable for utilities to optimize grid operations as well as provide insights into the performance of the overall utility system. This visual framework also provides insights into customers’ energy consumption behavior to serve them more effectively, foster energy conservation, and reduce peak demand. The demonstrated specific visualization and situational awareness concepts will be used in the future to help SDG&E make better choices on which options should be adopted for a future visualization and situational awareness system.

Scope

The following eight use cases, addressing a wide range of SDG&E business needs within the smart grid visualization area, were selected for the project: (1) Transmission Fault Location Visualization, (2) Load Curtailment Visualization, (3) Automation of Quarterly Electric Utility Reports, (4) Visualization of Outage History Playback, (5) AMI for Operations Visualization, (6) Customer-owned DER Visualization, (7) Imagery Management, and (8) GIS Visualization infrastructure modernization.

Approach

The work on implementing each of the use cases included 1) requirements definition for the visualization and situational awareness to be provided by the use case, 2) prototyping the data integration schemes, displays, and algorithms, and 3) implementation of a testing plan.

Results

The key element of the solutions for all use cases is the use of GIS data and GIS visualization capabilities to visually and functionally integrate other types of data relevant for a use case, which, in the past, has usually been handled separately. An emphasis throughout the project was on developing solutions that are sufficiently responsive, flexible, configurable, and reusable. Therefore, a successful demonstration of these novel solutions not only addressed the current business needs of the eight use cases, but also provided a knowledge base and software artifacts that will help SDG&E find better solutions for its future visualization and situational awareness needs.

The developed solutions collectively cover a truly wide spectrum of SDG&E business areas, users, business applications, and technology topics that had to be addressed:

- **Business Areas:** Transmission Operations, Distribution Operations, Emergency Operations Center (EOC), Transmission and Distribution Engineering, Distribution Planning, Maintenance and Construction Services, Emergency Management and Aviation Services, Regulatory Compliance, Finance, and Vegetation Management
- **Business Functions:** Accurate geographic location of transmission faults, Geospatial Data Visualization for Situational Awareness, Load Curtailment Dashboard for EOC use, and Improvements in Asset Management, Operations, and GIS Maintenance afforded by new Network Model, Process improvements via automation and geospatial awareness in combination with Business Intelligence, Empowering end users via enhanced mobility and configurability to match their business needs

Recommendations

Based on the outcomes of pre-production demonstrations, the results for use cases 1 through 6 are recommended for production implementation. Results of use cases 7 and 8 (Imagery Management and GIS Visualization Infrastructure Modernization) have met the narrow objectives set for each of those use cases; however, in both instances, the efforts are just an initial step toward what is required to be a more extensive development and investigation, before the cumulative results are ready for production. For all of the other cases, the effort to transition to production is minimal – measured in fractions of FTE – and generally consists of moving the artifacts from the test to QA environments, engineering review, and customer acceptance. In one case (Visualization of Customer-owned DER), no additional work is required beyond what was necessary for the pre-production demonstration.

Conclusions

Based on the feedback from early users of the project results - which has been uniformly positive - this project has successfully achieved all of its key objectives. Through the performed work, SDG&E has demonstrated novel solutions to the selected use cases, and, in the process, has also gained reusable software artifacts and substantial experience in integrating GIS, historical, asset management, and other major SDG&E computer systems. Both aspects will provide usability well beyond the direct utility of the software components produced by the project.

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Acronyms and Definitions

AF (PI AF)	PI Asset Framework (PI AF) is a single repository for asset-centric models, hierarchies, objects, and equipment (hereafter referred to as elements) ¹ .
AMI	Advanced Metering Infrastructure
API	Application Program Interface
Basemap	Basemap contains reference geospatial information based on what the cartographer is trying to communicate. Information is added to a basemap by overlaying other information on top of basemap to create a final map.
DER	Distributed Energy Resource
EDO	Electric Distribution Operations
eGIS	Enterprise GIS
EMS	Energy Management System
EROD	Electric Reliability Operations Department (SDG&E)
ETL	A database usage process to <u>E</u> xtract, <u>T</u> ransform, and <u>L</u> oad information. Typically associated with Data Warehouse activities.
Feature (on a map)	Individual item on a map
Feature layer	A feature layer is a grouping of similar geographic features (e.g., electric circuits, poles, buildings, parcels, cities, roads, and earthquake epicenters). Features can be points, lines, or polygons (areas). Feature layers are used for visualizing data on top of basemaps. In the context of integration with PI, feature layer is a collection of AF elements based on the same AF template.
Feature service	A collection of related feature layers. Feature services are managed by Esri ArcGIS. Real time updates of feature services are done via Esri ArcGIS GeoEvent Processor (new name: ArcGIS GeoEvent Extension for Server)
FME	Feature Manipulation Engine, a Safe Software's ETL application
FFS	FME Feature Store, the FME native data format
GIS	Geographic Information System
GPU	Graphics Processing Unit
HTTP; HTTPS	Hyper Text Transfer Protocol. HTTPS is over Secure Sockets Layer (SSL) to ensure secure data transfer in transit.
ID	Identifier

¹ PI AF - Overview - OSISOFT Tech Support, <https://techsupport.osisoft.com/Products/PI-Server/PI-AF/Overview/>

IIS	Internet Information Services (formerly Server), an extensible web server created by Microsoft
IoT	Internet of Things
JSON	JavaScript Object Notation
Lat/Lon	Latitude/Longitude of a geographical point
LiDAR	Lidar (also called LIDAR, LiDAR, and LADAR) is a surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3D-representations of the target [source: Wikipedia]
LMP	Locational Marginal Price
NMS	Network Management System (SDG&E)
PNode (pnode)	CAISO pricing node, the location in the network at which LMPs are provided
PV	Photovoltaic (solar) cells for producing electricity from Sun energy
RT	Real Time
SSL	Secure Sockets Layer (SSL): uses encryption for data in transit
Widget ²	An element of a graphical user interface (GUI) that displays information or provides a specific way for a user to interact with the operating system or an application

² <http://whatis.techtarget.com/definition/widget>

1 INTRODUCTION

This report documents the demonstration work and results for EPIC-2, Project 2, Visualization and Situational Awareness Demonstration, describes key lessons learned, and identifies opportunities to provide additional value to SDG&E in the future by leveraging the insights and the specific solution patterns of this project.

Decades ago, *situation awareness* (SA) was formally defined by Endsley³ in terms of three concepts - perception, comprehension, and projection: “SA is...the perception of the elements in the environment **within a volume of time and space**, the comprehension of their meaning, and the projection of their status in the near future”. While tweaks to this definition have been suggested since, the essential elements still remain, which is that, for situational awareness, one needs to consider perceptions within the contexts of both time and space. To do this, one has to be able to readily understand the information contained in the observations, and from these two and other domain knowledge, project the status in the near future.

In the power system industry, the systems that manage and present geo-spatial and other kinds of slowly changing data (e.g., spatial data) have existed largely in separate silos from the systems that deal with operational, time-varying data. Yet, both kinds of data are essential for comprehension of the true state of the system at a point in time, especially during emergencies, and for assessing a progression of that state into the near future.

In the case of SDG&E, geo-spatial data is handled by Esri ArcGIS, and operational data eventually flows into OSISoft PI Data Historians. Each of the systems is very powerful in its own domain, and is constantly being updated and extended with new features for analysis and presentation of results. The combination of the capabilities of the two brings the situational awareness contributions that neither of the two systems can achieve alone. For this reason, several of the activities in this task are centered on the technologies used to merge the information of the two aforementioned (and other) systems (i.e., geospatial and time series data), as necessary to fulfill specific SDG&E business needs.

The third major component used in this project is Power BI from Microsoft. Out of the box, this tool brings Excel-like capabilities for end users to programmatically, or through a GUI, configure the data sources to use, perform data analytics on the collected data, and select desired built-in or newly developed visualization widgets for display. During this project, SDG&E has developed a Java-based functionality to incorporate Power BI widgets within Esri geospatial features, so the users can see and interact with the map or Power BI widgets in a coordinated fashion. For example, a selection of an element in a Power BI table highlights the corresponding element on a geospatial map, and vice versa.

A brief overview of each of these commercial building blocks is presented in the appendix.

³ Mica R. Endsley, “Toward a theory of situation awareness in dynamic systems,” *Human Factors*, 1995, Vol 37, pp. 32-64

1.1 Project Objectives

The objectives of the Visualization and Situational Awareness Demonstration project were to:

- Examine how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators
- Demonstrate how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances utility system monitoring and situational awareness

1.2 Scope of Work – Use Cases

The stated objectives of the project were realized through implementation of the following eight use cases:

1. Transmission Fault Location Visualization
2. Load Curtailment Visualization
3. Automation of Quarterly Electric Utility Reports
4. Historical Outages Playback
5. AMI for Operation Visualization
6. Customer-Owned DER Visualization
7. Imagery Management
8. GIS Visualization Infrastructure Modernization.

1.3 Main Visualization Components

Use cases were implemented by combining functionality of core components from Esri, OSISoft, and Microsoft with third party applications and custom applications developed by the SDG&E team. An overview of the SDG&E components that comprise the demonstration system, plus other interacting systems and components is shown in Figure 1-1. The GIS components are on the left side of the figure; OSISoft PI components are on the right side; Power BI is in the cloud in the middle of the figure; and Smart Grid components, T&D Operations, and AMI components complement the picture. The main end-user interactions are through the web portal (in the middle of the figure), while the developers have local access at various points throughout the system.

A brief overview of functionality of the core commercial components is provided in the appendix; the custom code developed by SDG&E is discussed in the context of specific solutions for the various use cases.

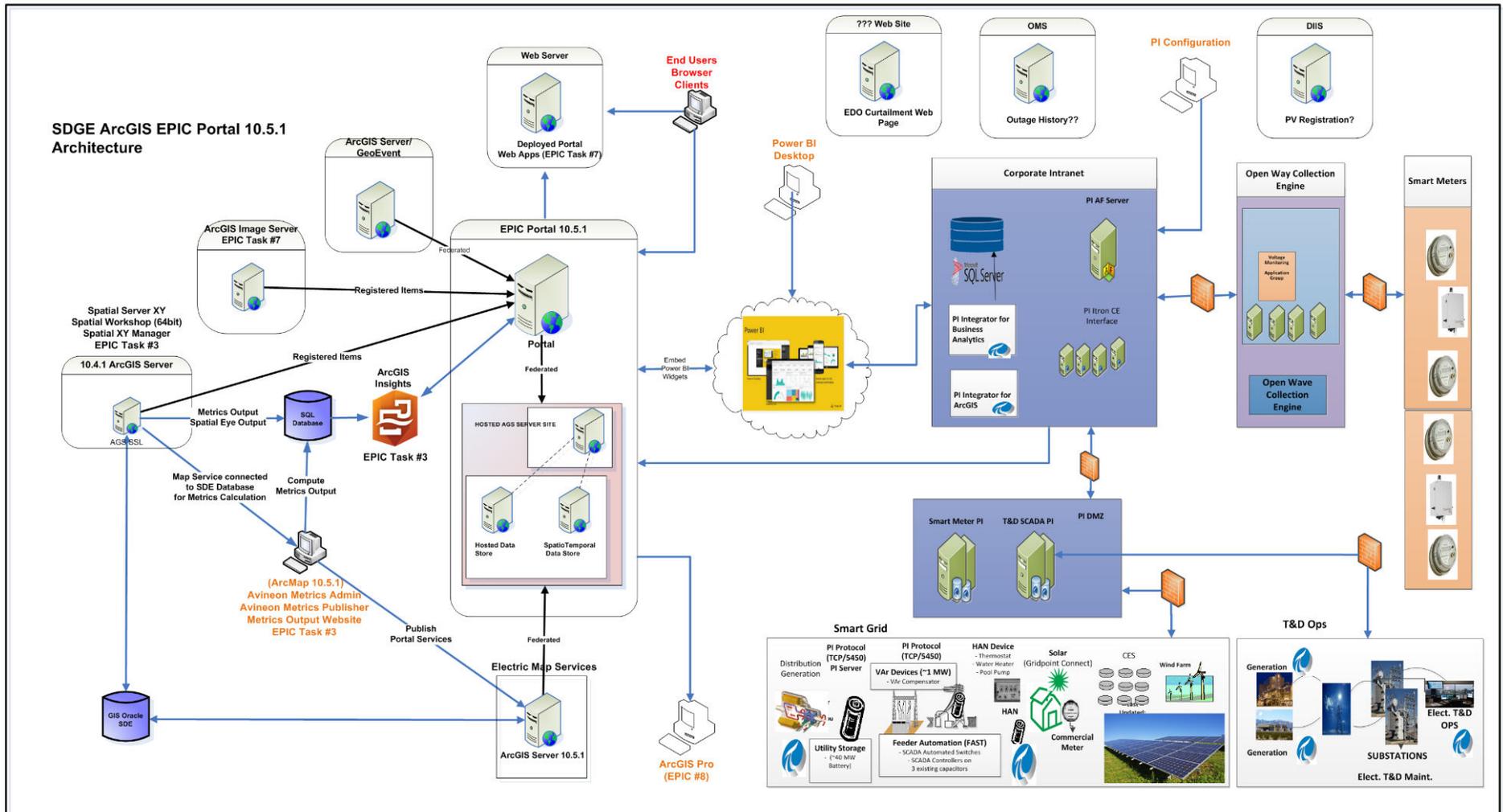


Figure 1-1. Main Components of Visualization and Situational Awareness Demonstration

2 USE CASES FOR DEMONSTRATION

This project is comprised of eight use cases covering a broad range of SDG&E smart grid business needs. The description of use cases in this section consists of the following:

- Background
- Objectives
- Users
- Solution Approach, Solution Components, and Work Flow
- Results
- Observations, Challenges, and Lessons Learned

Use-case results are demonstrated to internal SDG&E users, from among those listed for each use case.

2.1 Transmission Fault Location Visualization (UC #1)

2.1.1 Background

At SDG&E, substation relays are equipped with a function to compute a linear distance (i.e., a distance from the substation housing the relay along the line) to the line fault. When a fault occurs, relays detect it and compute the linear distance. This information eventually flows into the PI archiving system, from which an existing program called *PI Notification* sends text e-mails to relevant users with information about the fault.

The intent of Use Case #1 was to develop the Transmission Fault Location application that will enhance situational awareness about the fault by: (1) extending the e-mail message with a link to a specific web page on the ArcGIS Portal; (2) developing the functionality to generate the target web page and show a geospatial map on the page with the electric circuits and fault indicators at the exact location of the fault; and (3) showing any other geospatial layers, such as weather, fire, earthquake, etc., that may be available in the GIS system.

2.1.2 Objective

The objective of this use case was to provide the ability for end users to see fault locations and associated data on a geographical map within ArcGIS Portal.

2.1.3 Users

- Transmission operation group (Grid Operations)
- Maintenance crew - Kearny Maintenance and Ops
- System protection - System Protection and Control Engineering (SPACE)

2.1.4 Solution Approach, Solution Components, and Work Flow

Components involved in the solution:

- PI Notification: sends e-mails to users
- PI Integrator: pushes dynamic data updates to update maps
- ArcGIS Geo Processing: a service to convert linear distance to a fault obtained from PI to the latitude and longitude (Lat/Lon) of the fault by using the geometry of the asset in the geospatial database
- GeoPortal: displays geospatial maps with electric circuits overlays, along with fault indicator(s) on the affected electric circuits, and any other layers, such as weather, fire, lightning strikes, etc.

The technical solution uses two cooperating processes. The first is supported by an SDG&E custom program and by components from both the PI system and Esri GIS system. This is an event-driven process, with the event being an arrival of new fault data to PI Data Historian. When this event triggers, the custom program retrieves the description of the fault from PI Data Historian (tieline, substation, and the linear distance from the substation along the tieline) and invokes an ArcGIS Geo Processing service called ArcGIS Linear Referencing Geoprocessing service to compute the Lat/Lon of the faulted location. After receiving the results, the custom program updates PI Data Historian with this Lat/Lon data. The second process is based on leveraging the “out of the box” functionality of PI Integrator for Esri ArcGIS and is shown in a simplified form in Figure 2-1.

Data flow:

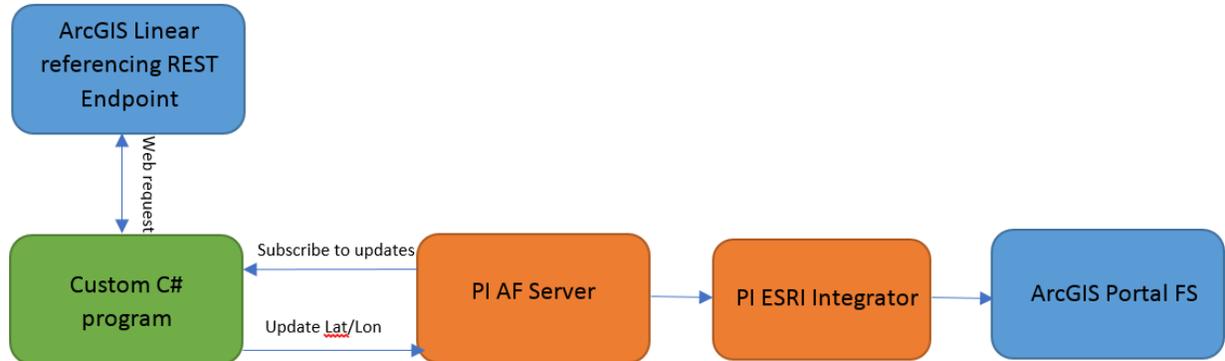


Figure 2-1. Transmission Fault Location Data Flow Diagram

The process consists of the following steps:

1. The PI Integrator for Esri ArcGIS publishes the PI Fault Distance template to ArcGIS Portal, where it gets registered as a feature service, with its own URL
2. When the feature layer is added to a map, the ArcGIS client makes a periodic request (at pre-configured intervals, e.g., every 2 seconds) to the registered PI Esri integrator URL for the Fault Distance layer data
3. The PI Integrator for Esri ArcGIS then requests the data from the PI system, specifically from the Asset Framework (AF) Server (if it is not cached) and returns the data to the client

4. The requested features are drawn on the map according to the retrieved data, including redrawing of the fault locations based on the latest retrieved Lat/Lon data

Please note that the mechanism for dynamic map feature updates described above is the same for any use case that uses PI Integrator for Esri ArcGIS. The only differences are which of the PI data templates (such as the fault Lat/Lon in this use case) drive the display.

A JavaScript Object Notation (JSON) code snippet illustrating a request from the ArcGIS of a Linear Referencing endpoint is shown in Figure 2-2.

The custom C# program automatically updates the computed Lat/Lon result in PI (Figure 2-3).

```

GET https://apwgisppit006.corp.se.sempra.com/arcgis/rest/service

Body Cookies (2) Headers (11) Tests

Pretty Raw Preview JSON

3 {
4   "paramName": "OutageOutput",
5   "dataType": "GPFeatureRecordSetLayer",
6   "value": {
7     "displayFieldName": "",
8     "geometryType": "esriGeometryPoint",
9     "spatialReference": {
10      "wkid": 4326,
11      "latestWkid": 4326
12    },
13    "fields": [
14      {
15        "name": "OBJECTID",
16        "type": "esriFieldTypeOID",
17        "alias": "OBJECTID"
18      },
19      {
20        "name": "Tieline",
21        "type": "esriFieldTypeString",
22        "alias": "Tieline",
23        "length": 15
24      },
25      {
26        "name": "Distance",
27        "type": "esriFieldTypeDouble",
28        "alias": "Distance"
29      },
30      {
31        "name": "LOC_ERROR",
32        "type": "esriFieldTypeString",
33        "alias": "LOC_ERROR",
34        "length": 50
35      }
36    ],
37    "features": [
38      {
39        "attributes": {
40          "OBJECTID": 1,
41          "Tieline": "TL 619",
42          "Distance": 38,
43          "LOC_ERROR": "NO ERROR"
44        },
45        "geometry": {
46          "x": -117.13729651999995,
47          "y": 32.784049035000066
48        }
49      }
50    ],
51    "exceededTransferLimit": false
52  }
53 },
54 "messages": []
55 }
56 }

```

Figure 2-2. Request ArcGIS Geoprocessing Service Code Fragment

Filter		
Name		Value
BreakerStatus		--
CircuitBreaker		0
CoreSightLink		0
FaultDistance		3 mi
IsBeginning		False
Latitude		-116.8695068359375
Longitude		32.833930969238281
MW		0 MW
TieLine		TL678
TieLine Length		43435.660142
TieLineID		678

Figure 2-3. PI Fault Location Template – Highlighted Item Updated by Custom C#

2.1.5 Results

2.1.5.1 Representative Results

Figure 2-4 shows two fault locations: one labeled BB23042 (near San Diego), and the other labeled AL678. In this example, the user has clicked the pin for the latter fault, and a popup display provides more details, including name (which is the name of a relay in PI comprised of a tieline ID, e.g. 678, and a substation ID, e.g., AL), circuit name, fault distance, and the exact coordinates of the fault.

However, at this level of detail, it is not possible to say if there are multiple circuits in the affected area. By zooming in (Figure 2-5), it can be seen that there are actually several circuits (at different voltage levels), and the Fault Pin pinpoints exactly the affected circuit (matching the description in the popup table of the previous figure).

Incidentally, these two figures also illustrate the useful automatic decluttering capability of the GIS software.

Legend

FaultDistanceLayer



Substation_Transmission_Operating_Map

Substation

- 138 kV
- 230 kV
- 500 kV
- 88 kV

Transmission

Conductor

- Transmission Overhead Line
 - 138 kV
 - 230 kV
 - 500 kV

- Transmission Underground Line
 - 138 kV
 - 230 kV
 - 500 kV

Transmission Overhead Line



Transmission Underground Line

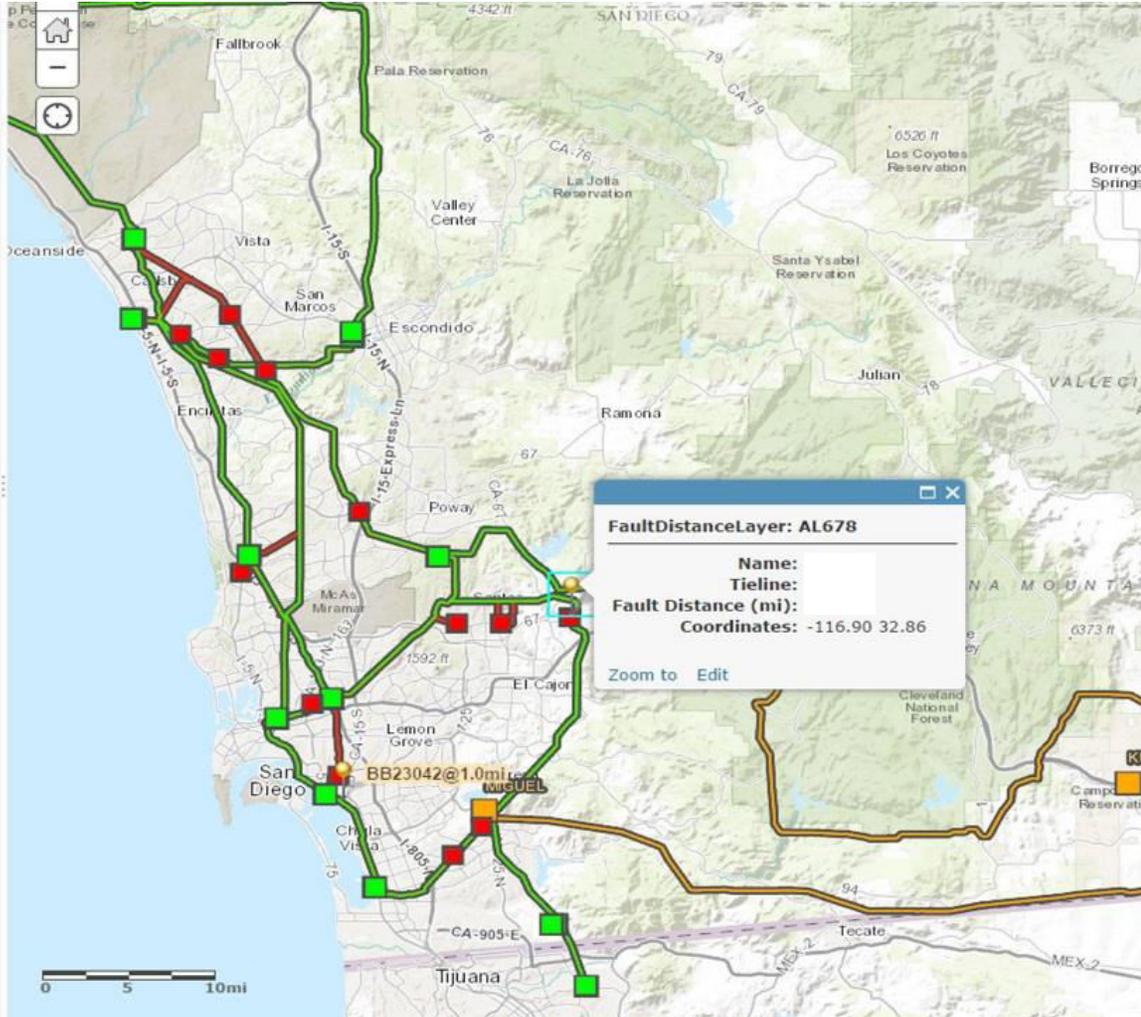


Figure 2-4. Map with Fault Location

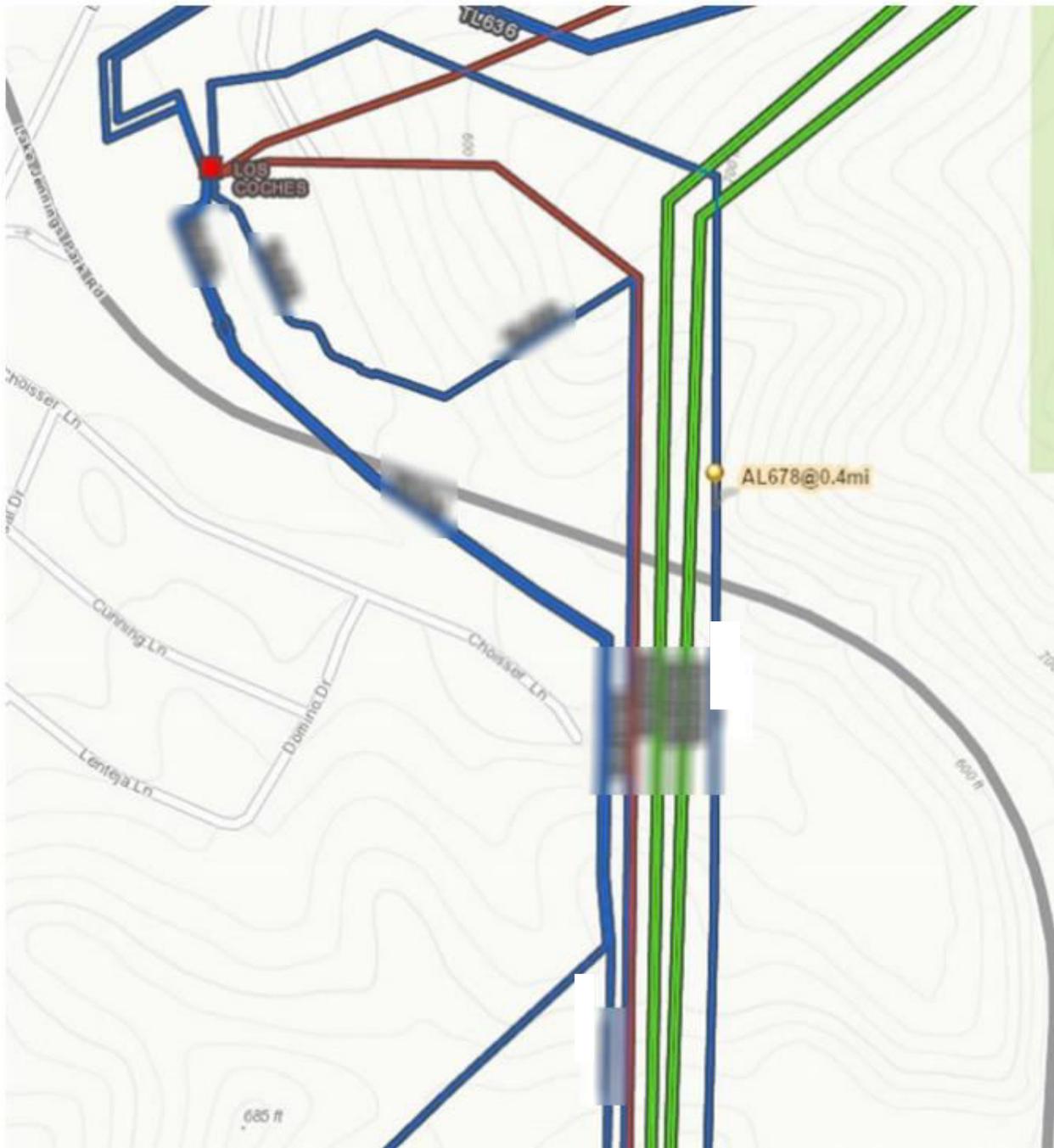


Figure 2-5. Map Detail with Fault Location (indicated by a pin)

2.1.6 Observations, Challenges, and Lessons Learned

Challenges and Resolutions

- SDG&E may eventually want to use a double-ended fault algorithm to provide even more accuracy
- Handling of faults on tapped lines is a challenge, especially when the single ended fault location algorithm is used – as for some fault locations, it is ambiguous if the fault has occurred on the main trunk or a tapped line. The work on overcoming this challenge is still in progress, with an expectation that the use of a double-ended fault algorithm will help in the resolution. Nevertheless, in the vast majority of fault location cases, the existing solution is fully functional.
- Creation of the reference layer of electrical circuits (from which the fault x-y coordinates and the x-y coordinates of the circuits themselves are derived): the GIS database may have a line asset represented as multiple line segments, each with a “from” and a “to” side and with a significant number of other attributes. ArcGIS has a service called ArcGIS Geoprocessing Service to convert a linear distance (along an asset) to the x-y coordinates of the point at the end of the linear distance. However, this service is time consuming when there are a lot of segments to peruse. To increase the ArcGIS Geoprocessing Service performance, it was necessary to perform an upfront work to appropriately concatenate line segments and create a new, simplified, composite line that always spans two substations. The line ID of this composite line needs to be provided to PI, where it serves as a key for linking the x-y information of the fault computed by ArcGIS Geoprocessing Service with operational data from PI. Any time there is a reconfiguration of a physical line, this process of so-called “digitizing” (i.e., updating of the composite line) needs to be repeated (only the very first time and after a reconfiguration). The initial effort to “digitize” all the lines, given that all 69-kV and higher voltage lines are included, was substantial. Once initially completed, an incremental effort to update after a reconfiguration is much less intensive, as such events are relatively infrequent, and the scope is much smaller (as it involves only the reconfigured lines).

Recommendations

- The labor to create the initial reference layers of electric circuits is significant and should be planned for in advance
- A process is needed to “re-digitize” lines any time there is a reconfiguration, or to digitize new lines, with an associated process to reflect the changes, if any, of the line ID in PI.

2.2 Load Curtailment Visualization (UC #2)

2.2.1 Background

Currently, SDG&E EDO updates load curtailment plans via a spreadsheet (shown later in Figure 2-7). The spreadsheet is posted on the EDO Website.

The spreadsheet shows the current total MW request for load shedding from CAISO, the amount of load already shed, as well as a list of circuits in groups according to the order in which they need to be opened to affect the load shedding. The groups are labeled Run 1, Run 2, and so on, and are arranged so that the circuits in Run 1 are opened first. Then, if there is need for more load shedding, the circuits of Run 2 are opened, and so forth. The coloring of circuits is chosen to reflect the likelihood of load shedding, with red designating the first group of circuits to open.

The information in the spreadsheet is a combination of asset names and real time load data. The intent of this use case is to display the same tabular (i.e., the spreadsheet) information but through a geospatial map, with visual cues identifying the order in which the circuits are to be opened. Examples in the results section illustrate additional options and benefits provided by the geospatial displays that in total should provide a better visual sense of when and where the load is being shed. This aspect of being able to quickly grasp the extent and location of load shedding may be very important, taking into account that load shedding is seldom required, but when it is, it is usually associated with emergency situations during which effective situation assessment is paramount.

2.2.2 Objective

The objective of Use Case #2 was to develop an ArcGIS Portal map to visualize the current SDG&E load curtailment plan.

2.2.3 Users

- Emergency Operations Center (EOC) personnel, during emergencies
- Distribution Operations

2.2.4 Solution Approach, Solution Components, and Work Flow

Components:

- Internal SDG&E Web site: the current load curtailment plan published to the site (existing functionality)
- Custom Python program periodically “scrapes” EDO Curtailment Webpage and writes the parsed curtailment results to PI
- PI Integrator for Esri ArcGIS publishes Curtailment Template to GIS Portal
- Current values of the map’s dynamic widgets (e.g., current total loads on each of the circuits marked for curtailment are updated through periodic queries from Esri portal client via PI Esri Integrator to the PI Data Historian); this can be seen later in Figure 2-7
- Esri Operations Dashboard for ArcGIS: a dashboard with the Load Curtailment map as one of its elements (example shown later in Figure 2-9)

A simplified diagram of the major data flows is shown in Figure 2-6.

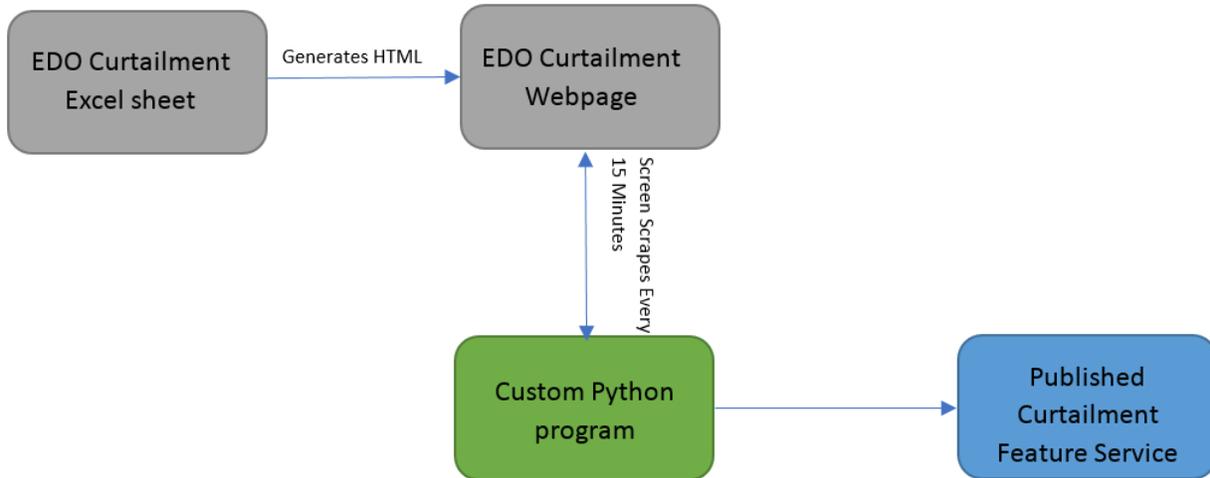


Figure 2-6. Load Curtailment Data Flow Diagram

An example of an EDO HTML Load Curtailment Page (the source of data for this use case) is shown in Figure 2-7.

An ArcGIS Portal map of load curtailment is shown in Figure 2-8. The legend on the left shows use of color to convey the status of circuits with respect to load shedding (e.g., previously or currently curtailed, early restored, or one of the exempt circuits); or it is a circuit in the first group to be curtailed (red), or in one of the later rounds (orange, light orange, yellow, etc.).

The Curtailment layer has every circuit, and each circuit has an associated Status field. When Status field is blank, the corresponding circuit is filtered out from the display.

The map is made into a dashboard using the program Esri Operations Dashboard (Figure 2-9). Multiple circuits can be selected by interactively encircling a region of interest. The widget on the lower right will then summarize the total MW dropped from the selected circuits. The list on the left side contains only the circuits that are due for curtailment.

Visualization and Situational Awareness Demonstration



30 Set Refresh Rate

[Legend](#) [Manual Subs](#)

Electric Distribution Operations

Last Update: 6/1/2016 3:25:05 PM

Daily Totals **				Electric Distribution Operations																			
ISO Requested MW:	0.00	Current Run:	NONE	Run #1	25.00	Run #2	25.00	Run #3	25.00	Run #4	25.00	Run #5	25.00	Run #6		Run #7		Run #8		Run #9		Run #10	
SDG&E MW Total:	0.00	ISO Requested MW:	25.00	SDG&E Contribution:	27.51	Run #2:	27.88	Run #3:	27.03	Run #4:	25.71	Run #5:	26.32	Run #6:		Run #7:		Run #8:		Run #9:		Run #10:	
PGP MW Total:	0.00	PGP:	0	Run Start Time:	0	Run End Time:	0	Total MW Dropped:	27.51	Customers Affected:	21,465	MW Dropped	20,893	MW Dropped	12,629	MW Dropped	23,549	MW Dropped	31,641	MW Dropped		MW Dropped	
MW Dropped:	0.00	Breaker Status:		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped	
Cust Affected:	000	Community Area		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped		MW Dropped	
Index	Block	Circuit	Total Customers	Community Area	Breaker Status	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	MW Dropped	
1	1A	434	2,172	MIRA MESA	CLOSE	2.98																	
2	1A	229	1,820	MIRA MESA	CLOSE	2.18																	
3	1A	524	1,838	BARRETT LAKE, CASA DE ORO, DEHESA, JAMUL	CLOSE	1.46																	
4	2A	463	1,993	CHULA VISTA S, OTAY MESA, SAN YSIDRO	CLOSE	4.87																	
5	2A	406	2,313	ESCONDIDO E, ESCONDIDO NE	CLOSE	2.88																	
6	2A	716	1,639	MISSION VLY, NA S-MIRAMAR	CLOSE	3.92																	
7	3A	631	4,510	MIRA MESA, NORTHCITY WEST	CLOSE	4.78																	
8	3A	244	2,648	BLOSSOM VALLEY, LAKESIDE, LAKESIDE E, SAN VICENTE	CLOSE	2.34																	
9	3A	63	2,532	NORTHCITY WEST, RHO SANTA FE S, SOLANA BEACH	CLOSE	2.09																	
10	4A	83	2,365	LA MESA N, MISSION GORGE	CLOSE		0.90																
11	4A	72	2,855	ELCAJON W	CLOSE		2.08																
12	4A	382	970	MISSION VLY	CLOSE		3.74																
13	5A	988	1,267	ORTEGA	CLOSE		1.25																
14	5A	944	1,724	RHO DEL REY	CLOSE		0.74																
15	5B	177	1,440	POWAY N, POWAY S	CLOSE		0																
16	6A	500	2,835	LAKE HODGES S, RHO BERNARDO	CLOSE		1.46																
17	6A	740	2,438	PT LOMA N	CLOSE		4.40																
18	6B	258	2	CHULA VISTA W	CLOSE		0																
19	7A	850	445	VISTA S	CLOSE		5.80																
20	7A	1153	0	MIRA MESA	CLOSE		0																
21	7A	1166	321	ALPINE W, BARRETT LAKE, DEHESA, JAMUL WEST	CLOSE		0.02																
22	8A	368	1,120	ALPINE W, DEHESA, VIEJAS	CLOSE		4.37																
23	8A	291	3,140	LAKE HODGES S, RHO BERNARDO	CLOSE		2.80																
24	8A	210-172R	171	WARNER SPRINGS	CLOSE		0.31																
25	9A	443	3	SAN YSIDRO	CLOSE			2.65															
26	9A	103	1,833	BAY PARK, MISSION BAY	CLOSE			2.65															
27	9A	512	2,596	DEL MAR, NORTHCITY WEST, SOLANA BEACH	CLOSE			2.82															
28	10A	290	3,119	RHO BERNARDO	CLOSE			1.67															
29	10A	768	1,528	LAGUNA HILL S, LAGUNA NIGUEL, MISSION VIEJO	CLOSE			1.77															
30	10A	775	506	CLAIREMONT	CLOSE			3.70															
31	11A	797	2,447	LAGUNA NIGUEL	CLOSE			0.44															
32	11A	588	109	CARLSBAD	CLOSE			7.15															
33	11A	774	488	CLAIREMONT, NA S-MIRAMAR	CLOSE			4.19															
34	12A	452	3,804	ESCONDIDO E, ESCONDIDO NE, LAKE WOHLFORD	CLOSE				1.32														
35	12A	517	453	ESCONDIDO S, ESCONDIDO W	CLOSE				2.32														
36	12B	487	0	OCEANSIDE	CLOSE				0														
37	13A	745	20	TORREY PINES	CLOSE				3.65														
38	13A	986	2,526	MISSION VIEJO, ORTEGA	CLOSE				1.82														
39	13A	975	1,339	RAMONA E, SDCOUNTRY ESTATES	CLOSE				0.37														
40	14A	590	2,663	BONITA, OTAY MESA, RHO DEL REY	CLOSE				1.09														
41	14A	468	126	CENTER CITY	CLOSE				2.19														
42	14A	1117	2,866	CARLSBAD, ENCINITAS S	CLOSE				2.26														
43	15A	296	1,309	SAN MARCOS W	CLOSE				2.46														
44	15A	438	4,485	MIRA MESA	CLOSE				3.17														
45	15A	68	1,494	FAIRBANKS RCH S, NORTHCITY WEST, RHO BERNARDO	CLOSE				2.75														
46	16A	112	2	CENTER CITY	CLOSE				0.88														
47	16A	947	654	FLETCHER HILLS	CLOSE				0.19														
48	16A	510	1,808	DEL MAR, NORTHCITY WEST	CLOSE				1.25														
49	17A	951	390	MIRA MESA	CLOSE					3.90													
50	17A	502	4,427	LAKE HODGES S, RHO BERNARDO	CLOSE					2.71													
51	17A	73-14R	728	DEHESA, DESCANSO, JAPATUL, VIEJAS	CLOSE					0.49													
52	18A	410	2,148	ELCAJON W, GRANITE HILLS, SINGING HILLS	CLOSE					0.60													
53	18A	561	2,570	LAGUNA HILL S, LAGUNA NIGUEL	CLOSE					1.76													
54	18A	65	3,131	LA JOLLA N, TORREY PINES	CLOSE					2.17													
55	19A	188	1,819	ESCONDIDO NW, ESCONDIDO W, SAN MARCOS E	CLOSE					1.85													

Figure 2-7. Example EDO HTML Load Curtailment Page

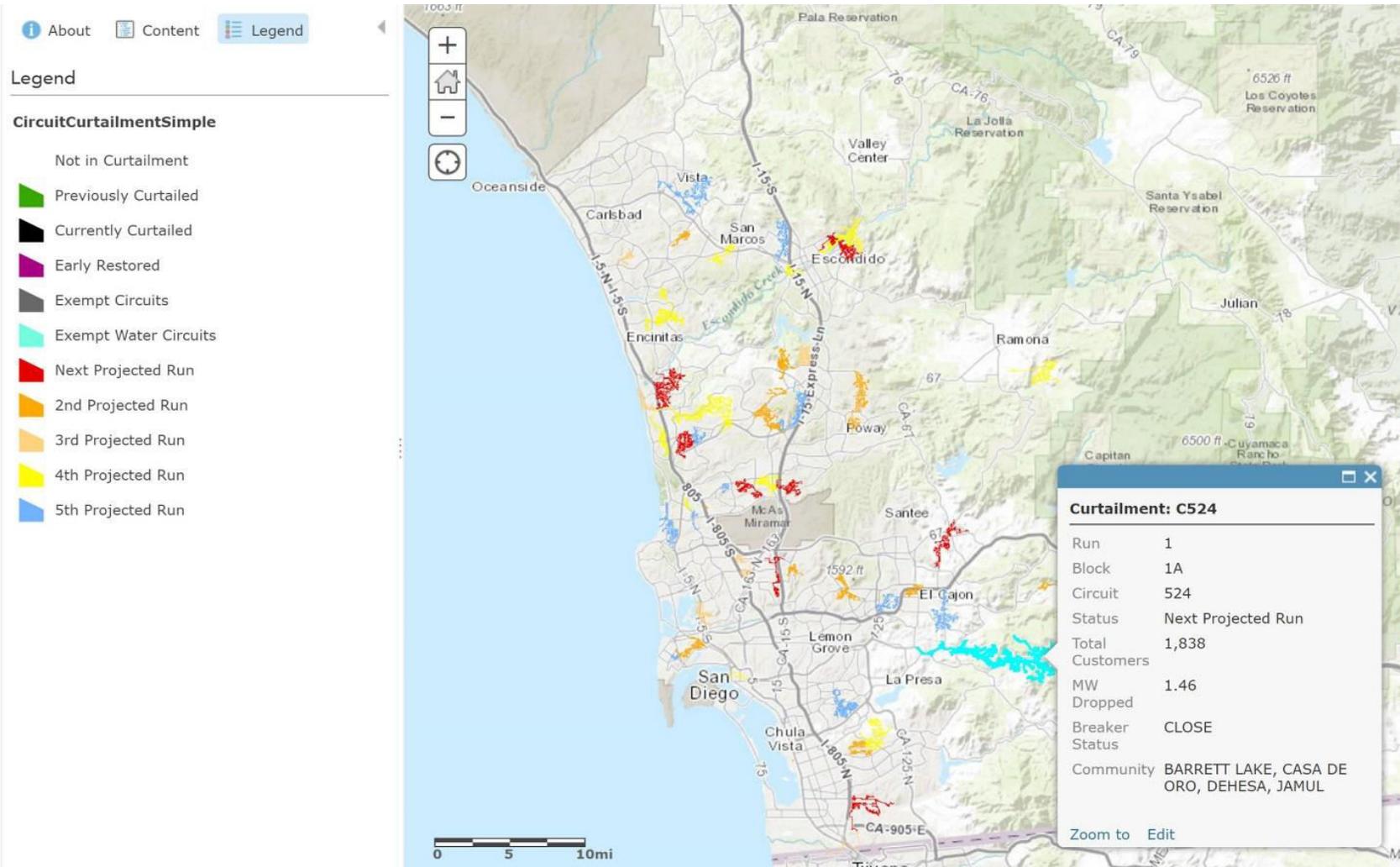


Figure 2-8. Example Load Curtailment Map

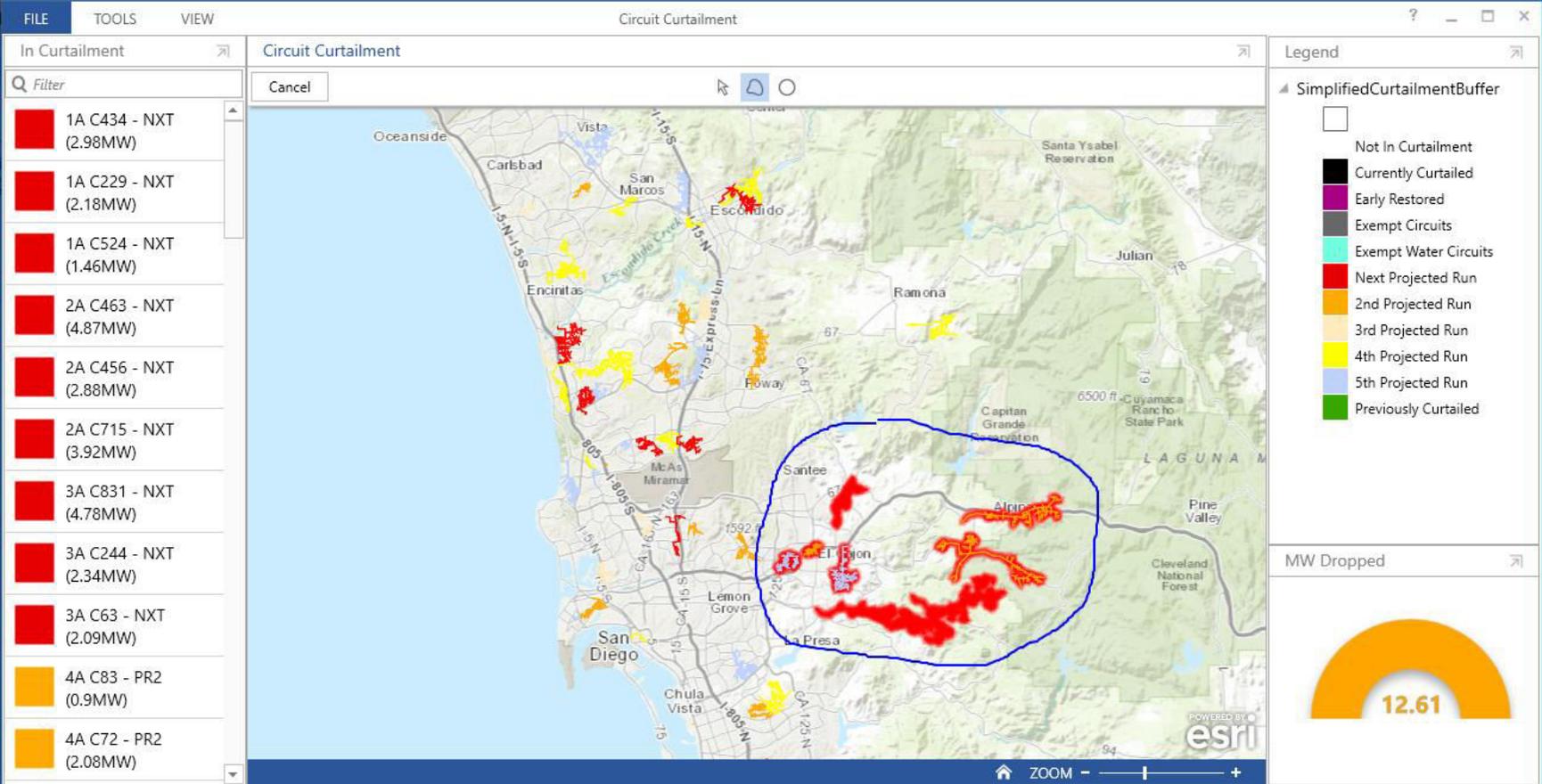


Figure 2-9. Load Curtailment Dashboard

This dashboard example illustrates how the end users are empowered by this solution – they can merely draw a boundary around a region of interest, and the display will automatically update with the total MW to be dropped within the region based on the actual load at the time of inquiry. Note that the legend adapts to the selected region of interest. This example also illustrates how the solution enables a user to get information of interest very quickly and in an intuitive way.

2.2.5 Results

2.2.5.1 Features

- Geospatial maps show the circuits for load shedding (either just finished, in progress, or planned)
- Color coding used to indicate both the (near) real time and the planned load shedding status
- Automatic decluttering of circuits that are not involved in load shedding
- Built in capabilities of GIS system can be leveraged to quickly create load shedding dashboard, which further extend usability of the displays by empowering users to make ad-hoc inquiries about load shedding amounts in any region of interest

2.2.5.2 Representative Results

The figures shown above illustrate the basic functionality and features of the load shedding use case.

2.2.6 Observations, Challenges, and Lessons Learned

Challenges and Resolutions

- In the absence of available APIs to interface with the SDG&E Web legacy system where the load curtailment schedules are posted, an interface to this system was implemented by scraping the site's web pages. Such technology is inferior to an interface based on a dedicated API.
- The electrical line circuits' information used for GIS visualization is rebuilt nightly to ensure the circuits' layer is a good reference for all the uses in need of this information. A coordination with PI data (at the level of line ID updates where new lines are created, or existing lines are retired) is also required any time the electrical circuit layout and connectivity change.
- Initially, the circuit layer visualization on the map was very slow. Significant improvements were made by using the Esri "generalization" tool to remove extreme details such as a lot of vertices. The result is circuit representation without a visually perceptible loss of information, yet enabling a substantial speedup of rendering. For example, it originally took upward of 20 seconds to render the electric circuit layers; it now takes a fraction of a second. When zooming in, the circuit layout is still sufficiently accurate.

Recommendations

- From a development perspective, it is recommended to replace scraping of web pages with an interface via a dedicated API
- From a usage standpoint, the development team will seek further feedback from the managers of EOC after a planned demonstration of the function is presented to them in the near future

2.3 Automation of Quarterly Electric Utility Reports (UC #3)

2.3.1 Background

SDG&E regularly has to prepare various reports (typically quarterly) about its assets in 1) **Full** Distribution, 2) Primary Equipment, 3) Substations, and 4) Transmission, based on a combination of GIS criteria such as:

- Features (e.g., wood poles)
- Attributes (e.g., characteristics like length of poles)
- Polygons (e.g., high risk fire area)
- Networks (e.g., by circuit)

The process to prepare the reports is quite laborious and lengthy (several weeks) and involves the analysis and computation of around 1500 analytics.⁴ It involves a GIS/Business Analyst to perform data reconciliation of active circuits, manual editing and execution of many scripts/queries, and manual entry of each individual result into Microsoft Excel reporting templates. Figure 2-10 illustrates the steps involved, and Figure 2-11 provides a sample of one of many scripts used in the process.

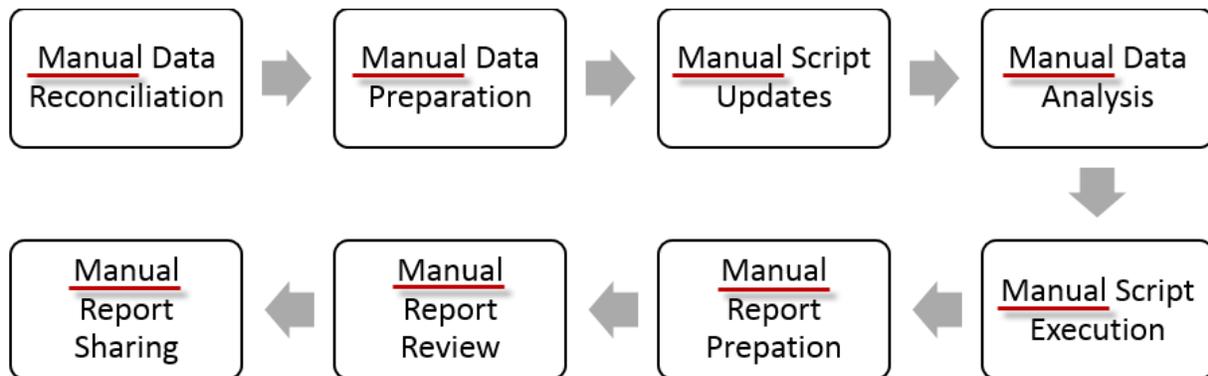


Figure 2-10. "As-Is" Report Creation Process

```

CONSTRUCTIONSTATUS IN ('A','R') AND (SUBTYPECD IN (1,2) OR (SUBTYPECD IN (4,5) AND
DISTRIBUTIONIDC = 'Y' AND TRANSLIFECYCLECD IN (2,3,4))) AND MATERIAL = 'WOOD' AND (GlobalID IN
(SELECT StructureGUID FROM SEU_GIS_ELEC.OHStruct_PriOH WHERE PriOHGUID IN (SELECT GlobalID
FROM SEU_GIS_ELEC.PriOHConductor WHERE NOMINALVOLTAGE = 12 AND FeederID NOT IN
('11','218','484','1246','MC1','NC1','SCE','DEAD','NEUT'))) OR (GlobalID IN (SELECT StructureGUID FROM
SEU_GIS_ELEC.OHStruct_PriUG WHERE PriUGGUID IN (SELECT GlobalID FROM
SEU_GIS_ELEC.PriUGConductor WHERE NOMINALVOLTAGE = 12 AND FeederID NOT IN
('11','218','484','1246','MC1','NC1','SCE','DEAD','NEUT'))))
  
```

Figure 2-11. Example Legacy Script Used for Generating Reports

⁴ **Analytics** [Wikipedia] is the discovery, interpretation, and communication of meaningful patterns in **data**. In the context of this use case, analytics is any data transformation from the source data into a reportable item (a cell) in any of the reports, or an intermediate result from which the reportable items are composed.

The aim of Use Case #3 is to utilize advanced GIS technologies (spatial analytics) to substantially automate the process, and, at the same time, to provide flexibility to end users to configure the reports' content to their specific needs. The specific objectives for the use case are presented in the next section.

2.3.2 Objective

The objectives of Use Case #3 were:

- To evaluate an option for a self-service Electric eGIS reporting tool and demonstrate a chosen method to provide a flexible, intuitive self-service reporting application using the eGIS and/or other databases. The focus was on providing functionality to explore the data, ease of use, and achievement of high performance.
- In selecting the solution, to address reporting performance and consider the use of third-party software options (e.g., Spatial Eye, Metrics Extension to ArcGIS) as well as integration of the existing Esri GIS Portal technology, while also leveraging the SDG&E existing product licensing.
- In developing the solution, identify a methodology that is repeatable for other types of spatial reports from GIS. The methodology should be resilient to changes and cost effective in addressing changes with data model, analysis functions, and business rules.

2.3.3 Users

Electric eGIS users

- T&D engineering group
- Asset management group
- Land management
- Regulatory and compliance group
- Tax group

2.3.4 Solution Components and Work Flow

2.3.4.1 Solution Components

- **Metrics Extension:** An extension to ArcGIS for Server from Avineon is used to define, compute, and store asset statistics and trends from GIS databases.
- **Spatial Eye Workshop:** Advanced software tool from Spatial Eye is used for designing spatial analytics from data in complex data models. It is used to integrate data easily and to modernize manual scripts, analysis, and processes into spatial analytics models.
- **Spatial Eye XY Server:** Server software from Spatial Eye to schedule the execution of spatial analytics models and store the results in spatial data warehouse, data marts, and export to Microsoft Spreadsheets.
- **ArcGIS Insights:** Web application from Esri to visualize and analyze raw data in GIS or results precomputed by server tools such as Spatial Eye XY Server, or ArcGIS GeoAnalytics, or ArcGIS GeoEvents server.

- **ArcGIS Portal:** Web foundation from Esri to implement role-based access to GIS content for self-service reports.

2.3.4.2 Solution Approach and Work Flow

The use case core reporting requirements are based on the current GIS report requirements. This includes the ability to create reports via a user input, such as lists of all wood poles over 60 feet in length within a High Risk Fire Area. The execution of such requests would typically consist of selecting features, attributes, polygons, and electric networks (circuits) from valid domains.

The technologies illustrated in Figure 2-12 were reviewed as potential solution candidates for this use case. A closer review of the workflow and the GIS data model illustrated the need to choose a spatial analytics tool that can simplify the data joining, analysis, and aggregation of spatial and non-spatial data sets for a Business Analyst.

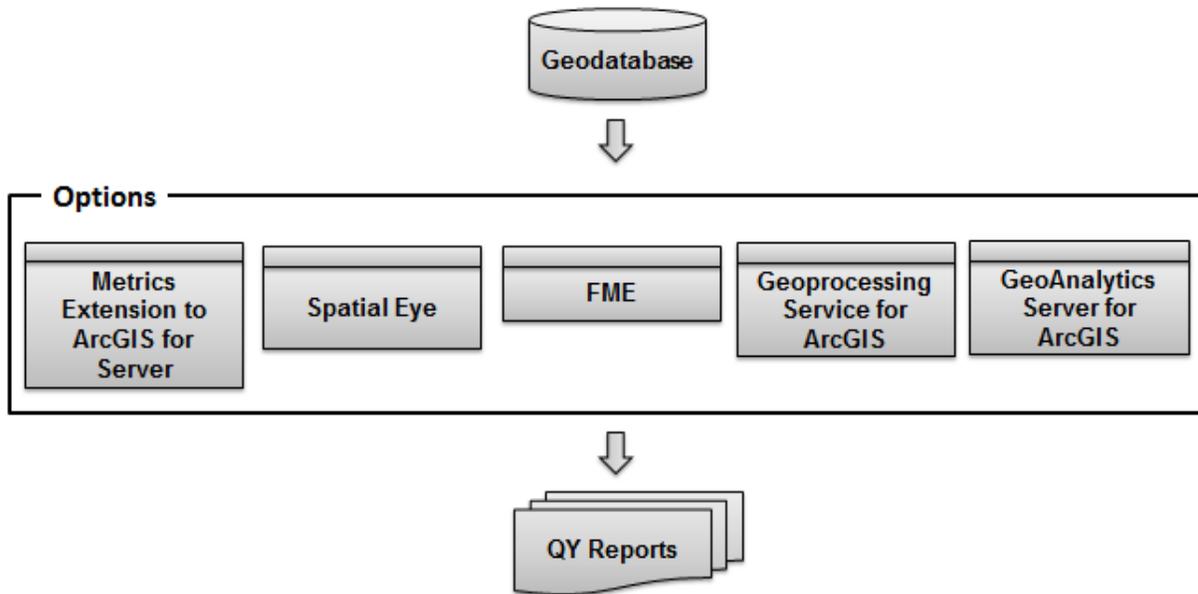


Figure 2-12. Options to Support Reports Creation

Figure 2-13 illustrates a solution architecture selected for in-depth research and feasibility analysis within this use case.

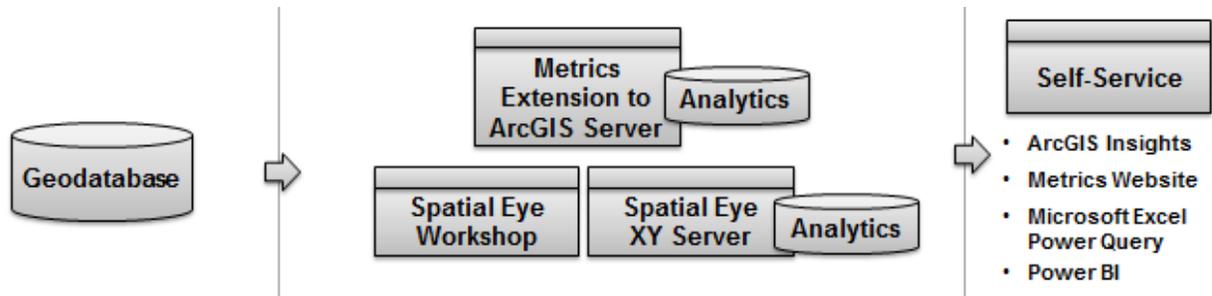


Figure 2-13. Selected Architecture for Reports Generation

The solution component (Metric Extension) was installed on an SDG&E server and configured to generate reporting data for visualization using ArcGIS Insights (Figure 2-14). Metrics Extension was tested for its ability to define, compute, and schedule metrics for this purpose. The results were visualized using ArcGIS Insights (see Figure 2-15 for an example of the output and the user selection choices).

The Spatial Eye Workshop and Spatial Eye XY server software components were installed and configured on the SDG&E Server (see Figure 2-16 and Figure 2-17). The queries, business rules, and manual analytics steps currently used for QY reporting were carefully analyzed and translated as business collections in a spatial analytics model. This analytics model was executed using the XY server and the results that were written to a) Spatial Eye Analytics data and b) Microsoft Excel files. These were visualized using Workbooks and Cards within ArcGIS Insights, as well as a Microsoft Excel reporting template currently used by Business Analysts.

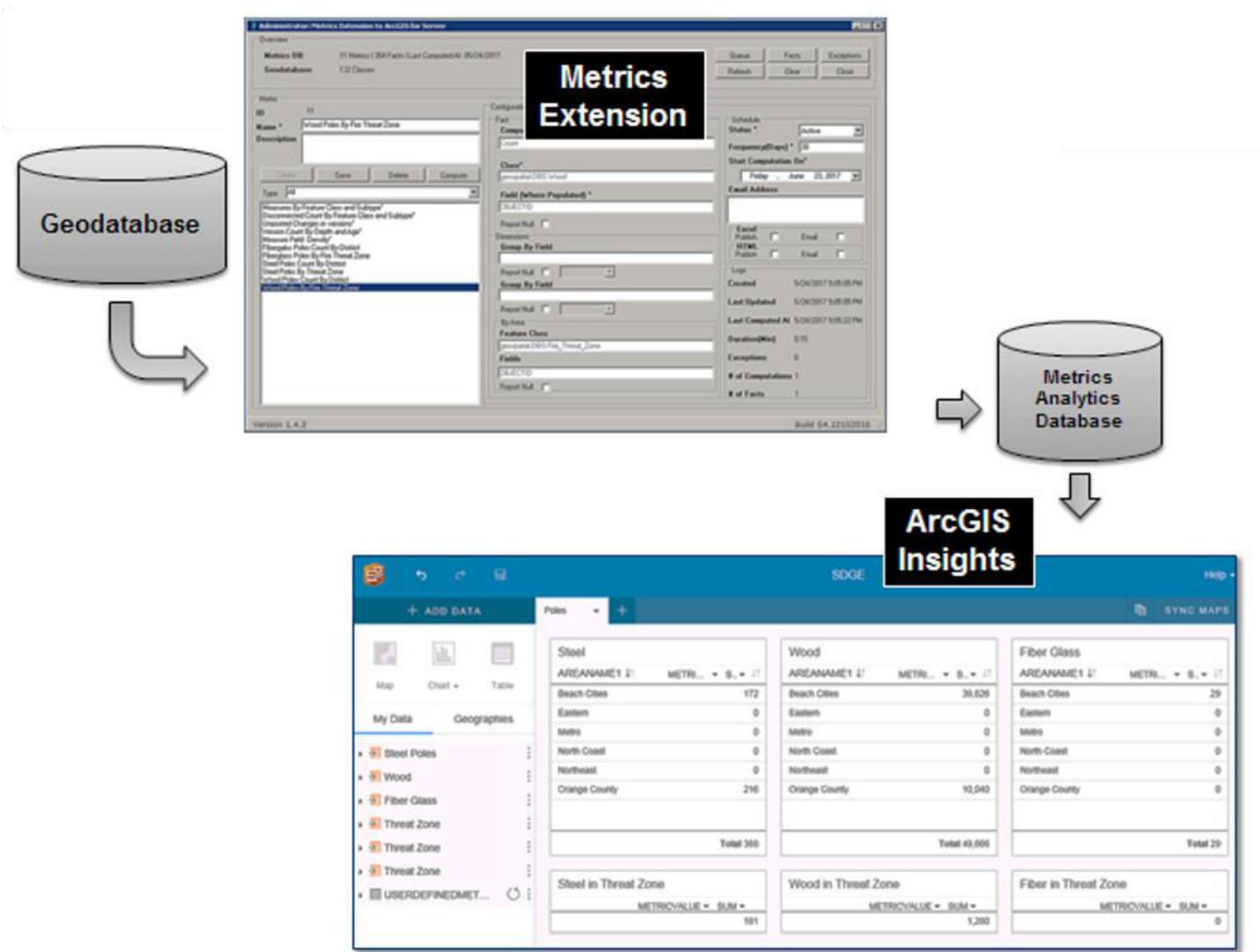


Figure 2-14. Metrics Extension and ArcGIS Insights-Based Process

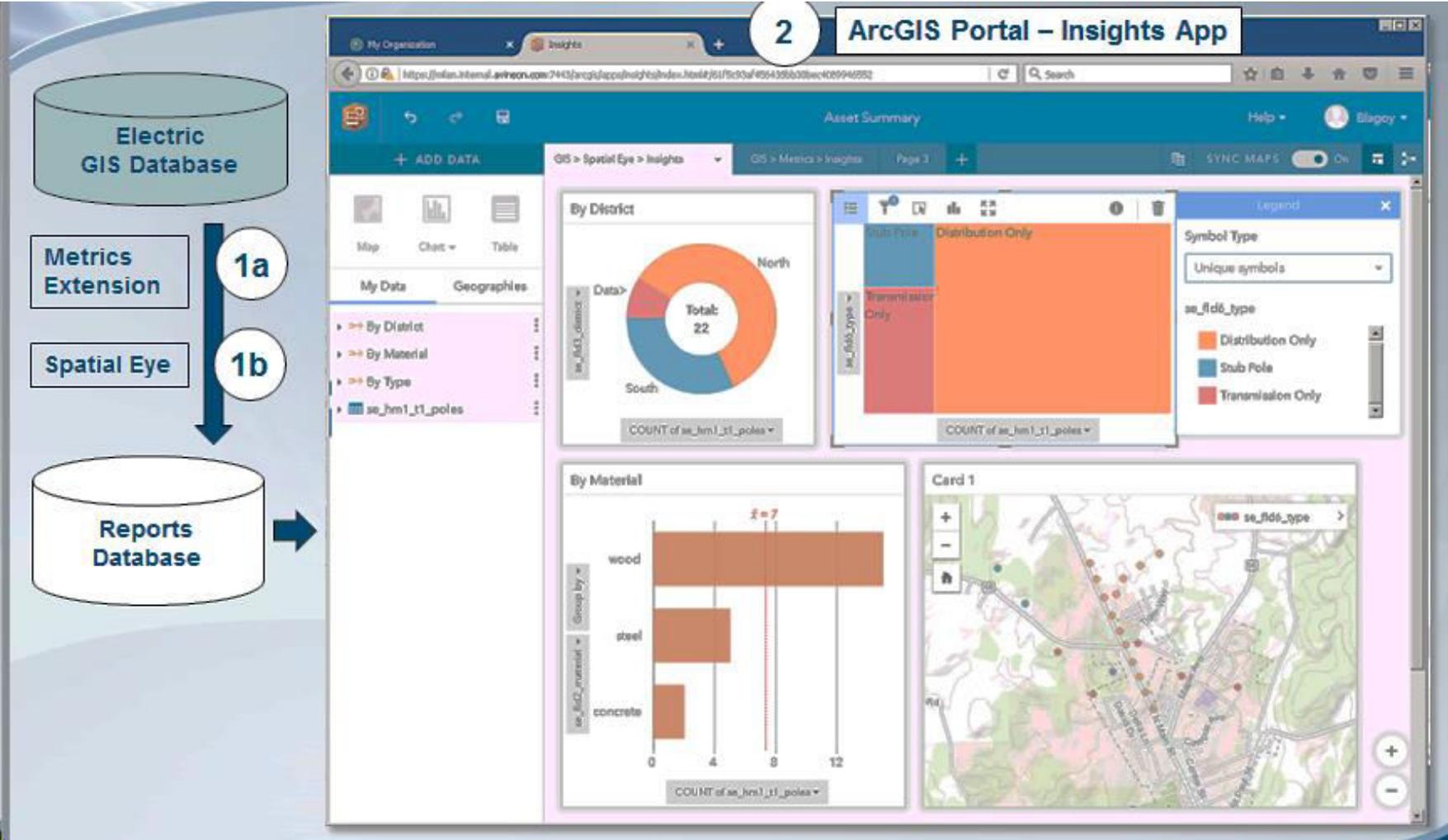


Figure 2-15. Schematic of the Report Generation Process Using Insights and Sample Results

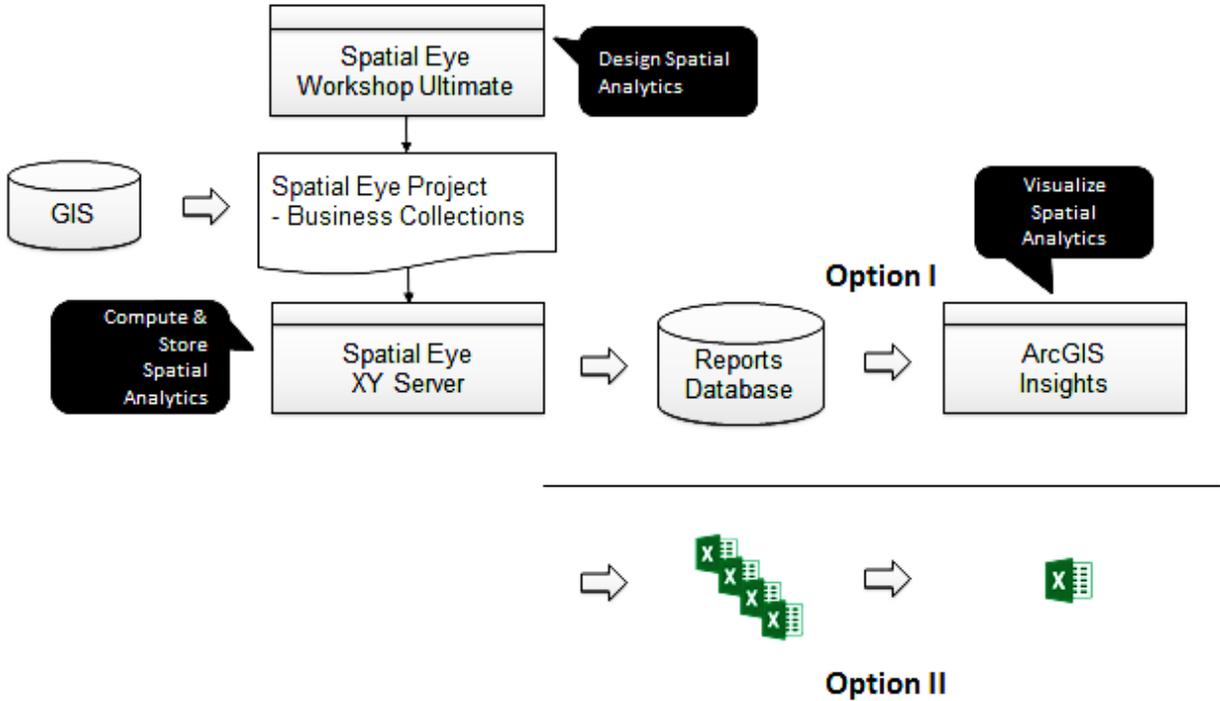


Figure 2-16. Spatial-Eye-Based Work Flow

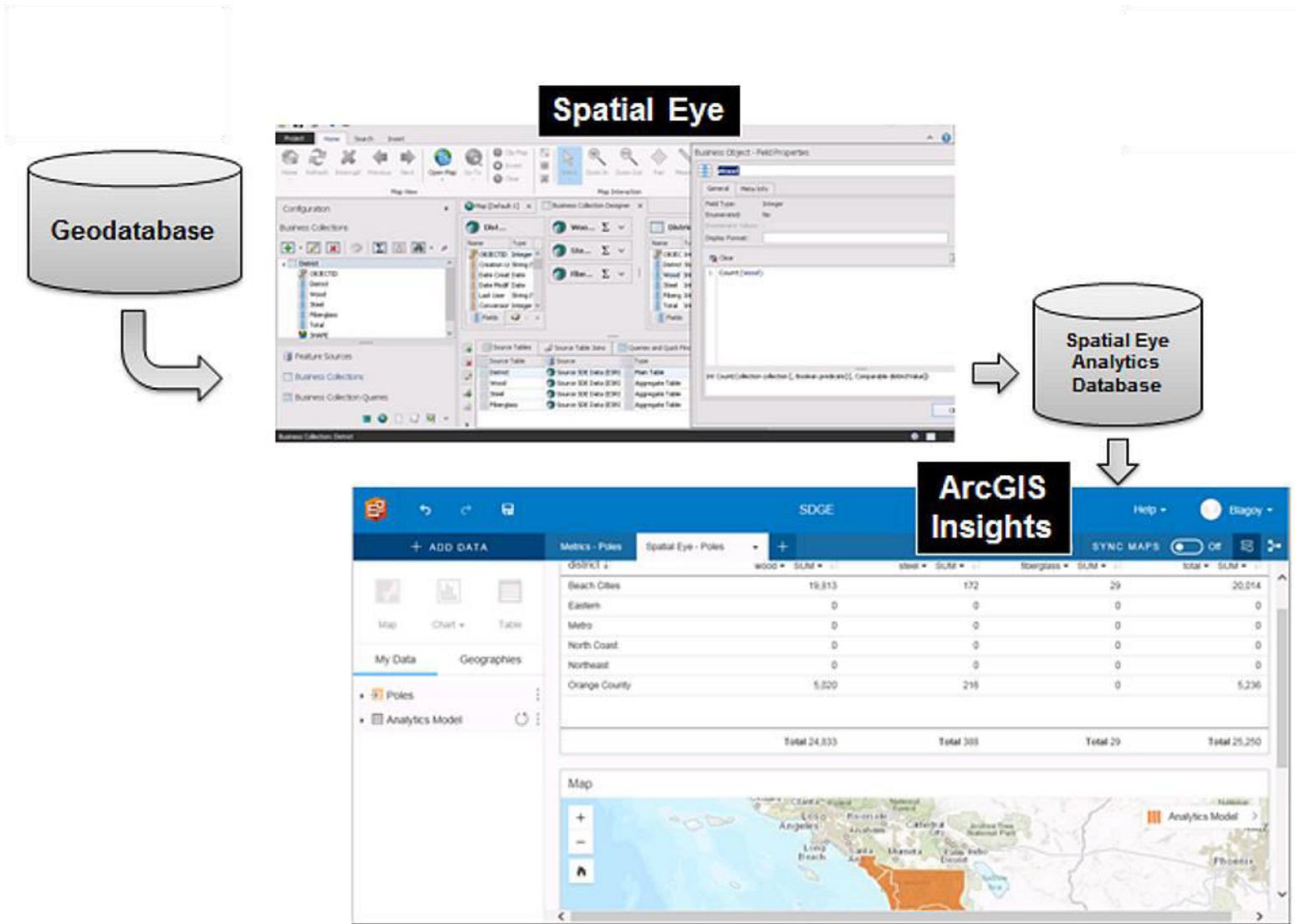


Figure 2-17. Spatial-Eye-Based and ArcGIS-Insights-Based Process and Sample Result

2.3.5 Results

2.3.5.1 Features

The research resulted in the identification of a repeatable and scalable methodology for spatial analysis and self-service reporting. The methodology was successfully verified to automate the computation of spatial analytics, and the results were compared with manual computation methods for Q2 2017 reporting period. This was done for 1) Full Distribution; 2) Primary and Equipment, and 3) Substations. The methodology for transmission reporting, however, was not included for in-depth analysis due to budget and timeline constraints.

The application of the solution components to this use case has demonstrated between 80% to 100% automation within various tasks of the reporting process, as illustrated in Figure 2-18 (the “blue” processes are ~80% automated, and the “green” processes – which used to be manual – were fully automated. The only remaining manual sub-process is “Report Review”, which was, indeed, intended to stay that way.

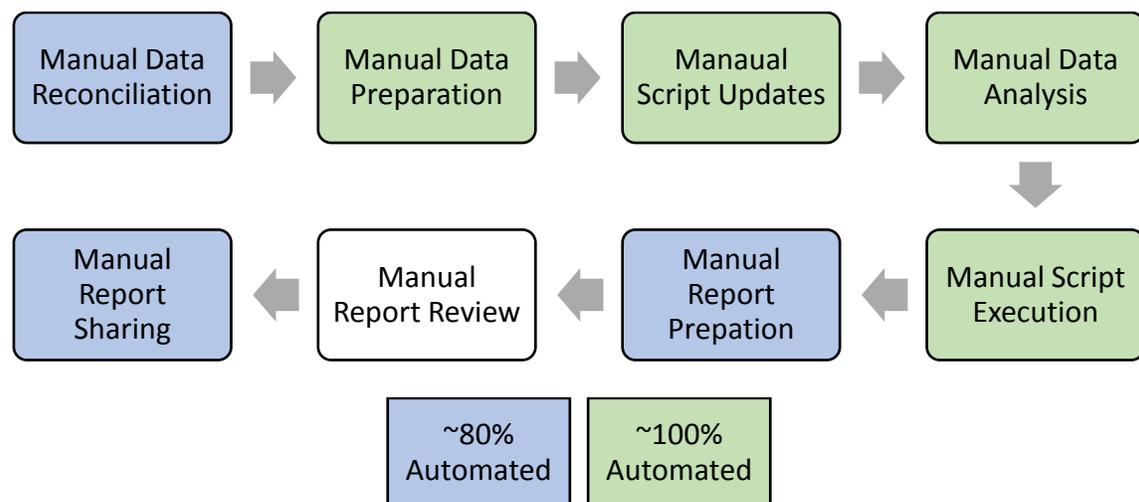


Figure 2-18. New, Largely-Automated Process

Thanks to this automation, the resulting work flow greatly simplifies the original multi-week process to a multi-day process comprised of the following steps:

1. Copy active circuits spreadsheet into designated folder
2. Verify and update business collections in Spatial Eye Workshop to verify the join-with-active-circuits spreadsheet
3. Click Run button in XY Server to compute analytics and write them to a) database and b) spreadsheets
4. Verify cards in ArcGIS Insights and formulas in the reporting template spreadsheet

2.3.5.2 Representative Results

Sample screenshots of the options available to end users are presented in Figure 2-19 through Figure 2-26.

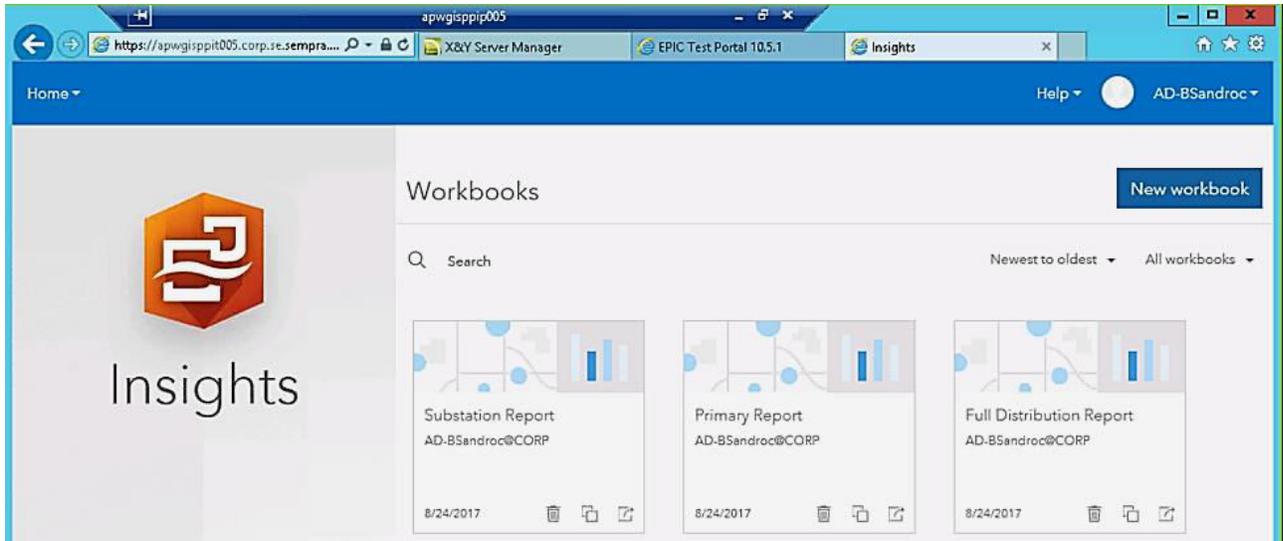


Figure 2-19. Report Options Using Insights

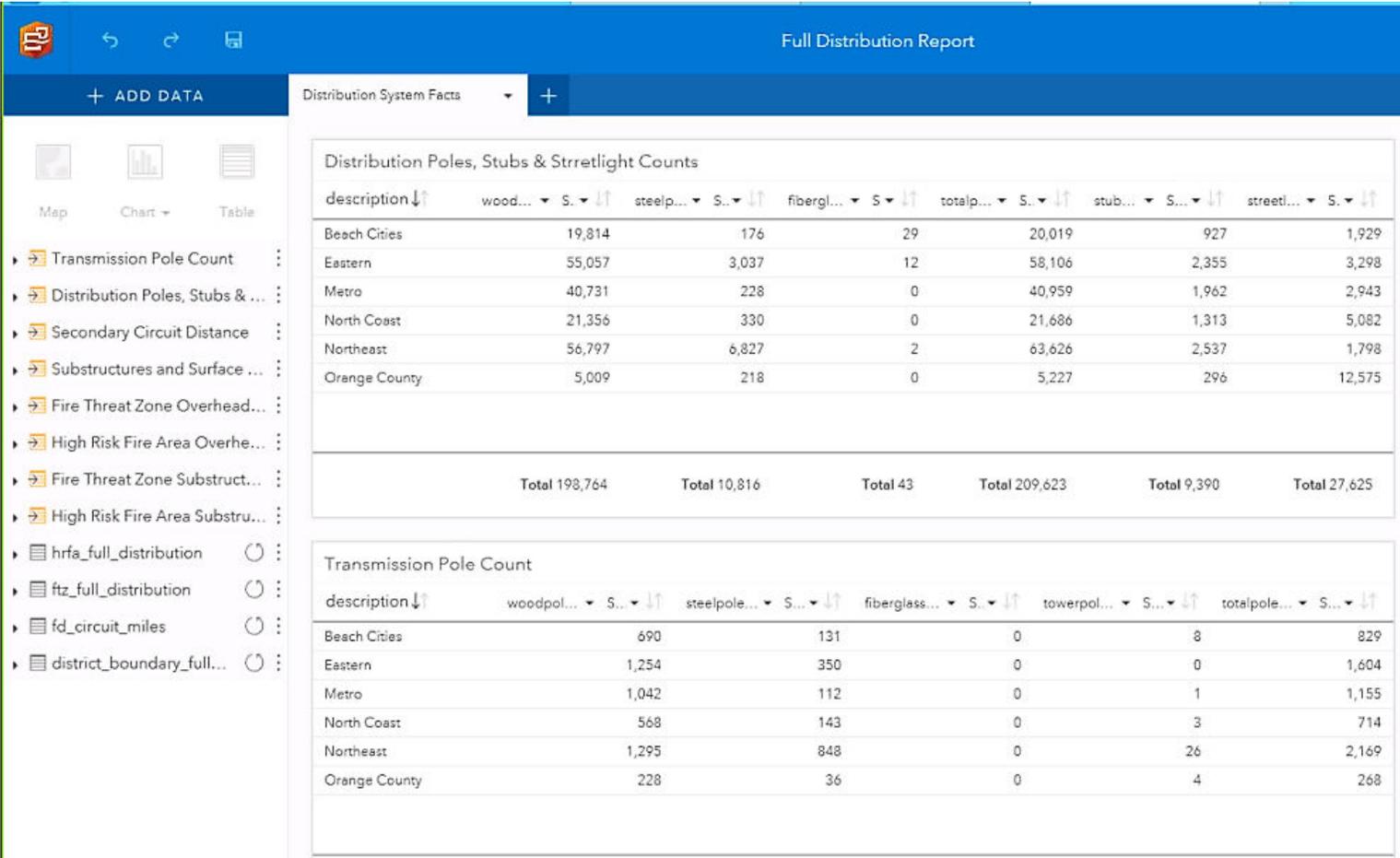


Figure 2-20. Distribution System Facts Report

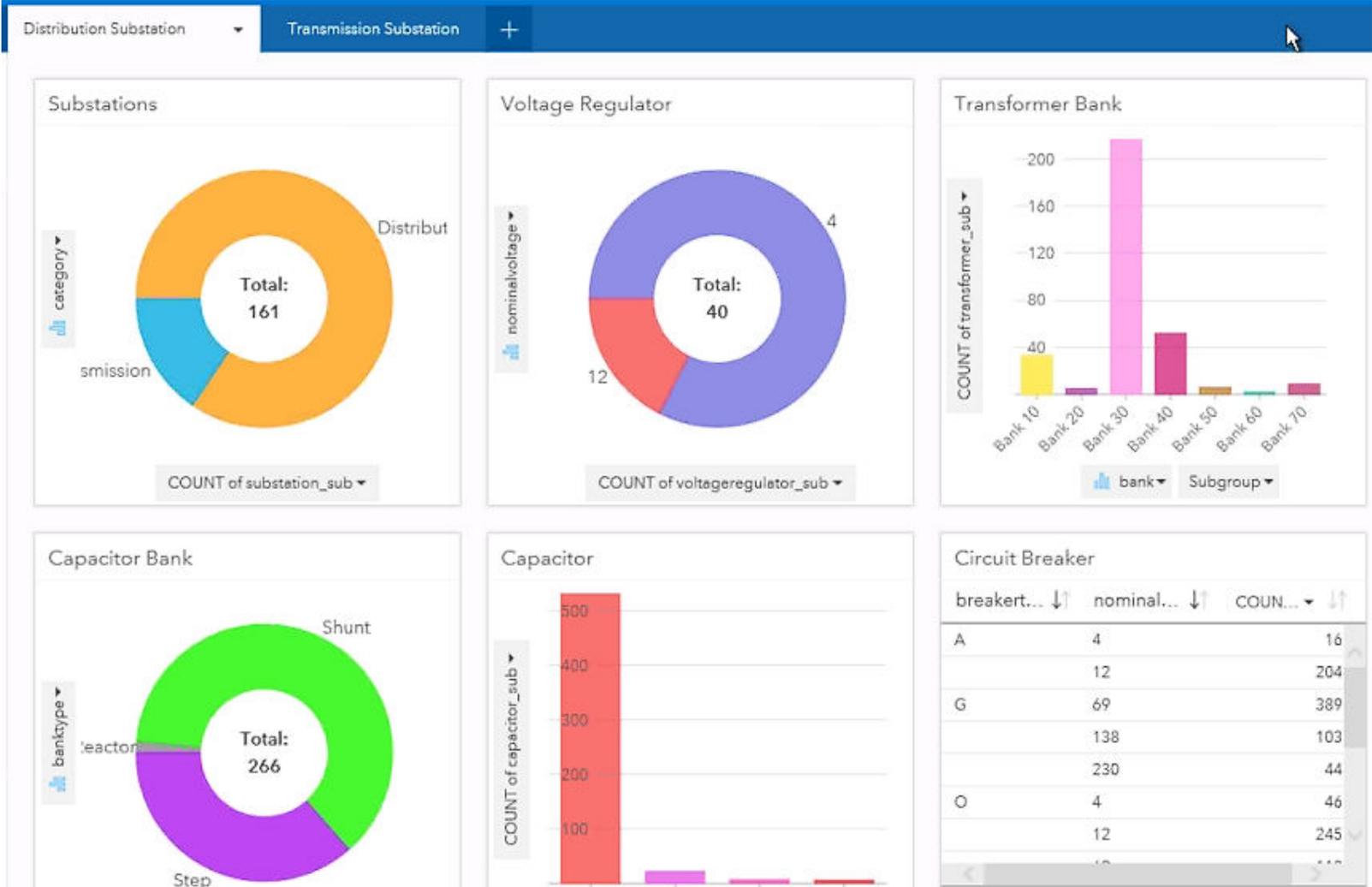


Figure 2-21. Distribution Substation Report

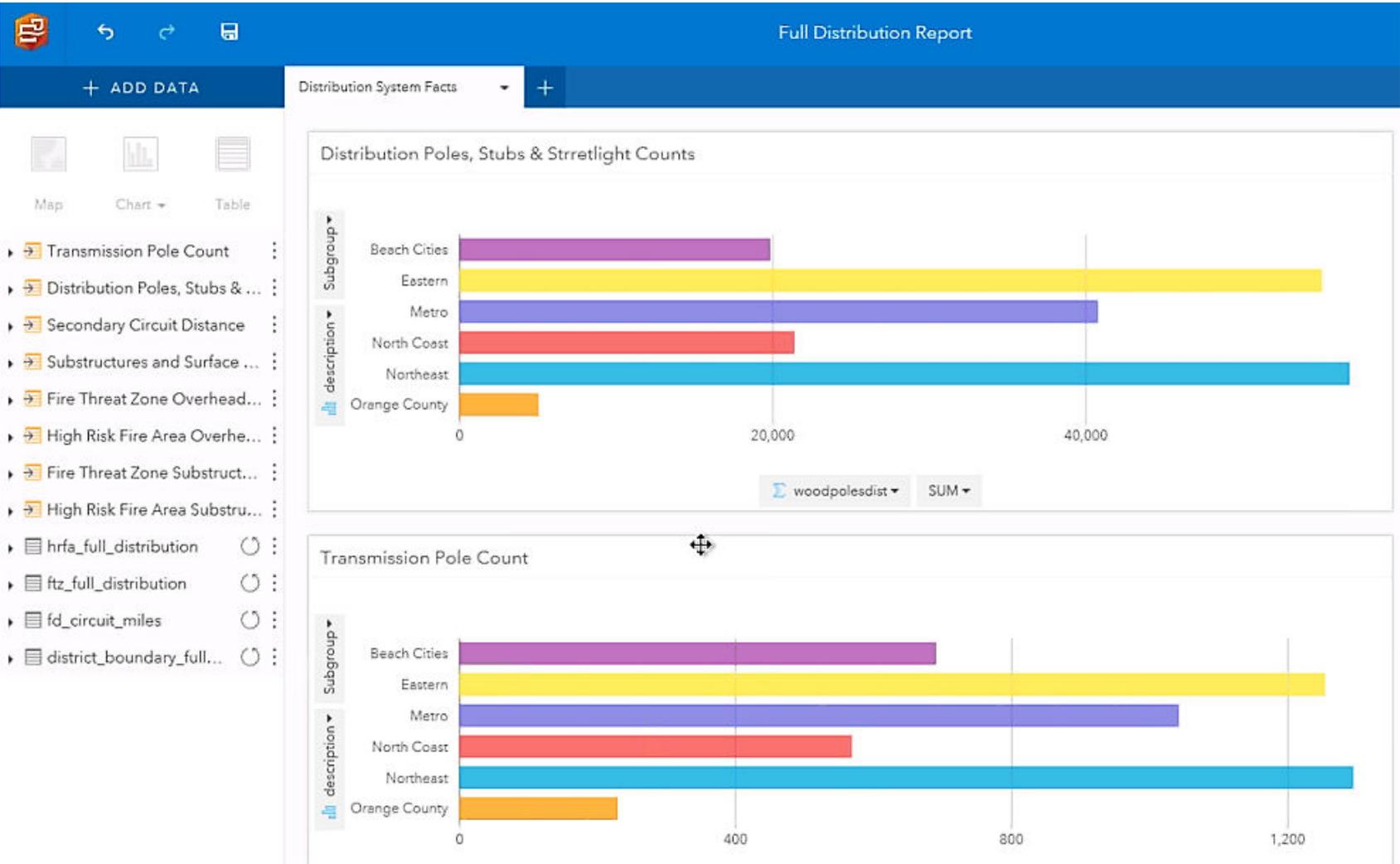


Figure 2-22. Distribution and Transmission Pole Count by District

Overhead	Distribution only				Transmission Underbuild				Stub Pole	UG Streetlight
	Wood	Steel	Fiberglass	Total	Wood	Steel	Fiberglass	Total		
BC	20,154	149	2	20,305	713	112	0	825	1,144	1,999
CM	41,547	184	0	41,731	1,073	83	0	1,156	2,892	3,130
EA	56,308	2,016	8	58,332	1,303	305	0	1,608	2,805	3,300
NC	21,569	298	0	21,867	572	141	0	713	1,588	5,445
NE	60,027	3,693	2	63,722	1,329	813	0	2,142	3,002	2,594
OC	5,193	130	0	5,323	231	31	0	262	365	12,641
Total	204,798	6,470	12	211,280	5,221	1,485	0	6,706	11,796	29,109
FTZ	73,004	5,490	9	78,503	1,654	981	0	2,635	3,222	3,924
HRFA	34,187	3,276	2	37,465	819	299	0	1,118	1,298	179

Figure 2-23. Tabular Report of SDG&E Distribution System Facts

Surface/Underground	Substructures						Surface	
	Manhole	Subsurf. Enclosure	Vault	Primary Handhole	Secondary Handhole	Handhole Total	Pad	Enclosure
BC	1,493	5	166	6,153	19,576	25,729	17,924	14
CM	1,245	1	548	6,270	25,108	31,378	18,010	7
EA	305	31	110	4,669	19,697	24,366	14,993	8
NC	568	24	46	8,289	30,521	38,810	24,680	6
NE	447	10	37	9,862	33,672	43,534	29,018	4
OC	417	191	32	5,017	24,876	29,893	13,325	1
Total	4,475	262	939	40,260	153,450	193,710	117,950	40
FTZ	150	9	100	5,817	20,302	26,119	19,968	6
HRFA	30	8	50	900	3,053	3,953	3,599	1

Figure 2-24. Tabular Report of Substructures

SDG&E PRIMARY DISTRIBUTION SYSTEM FACTS

Quantity of Distribution Circuits	Total/kV
12kV	804
4kV	224
Total Quantity:	1,028

Primary Distribution Infrastructure		Miles			Poles*				Substructures*			Surface*	
		OH Conductor	UG Cable	Total	Wood	Steel	Fiberglass	Total	Handholes	Manholes	Vaults	Pads	Enclosures
BC	12kV	459	1,579	2,038	15,304	243	1	15,548	5,909	1,439	67	17,699	13
	4kV	95	58	153	2,368	15	1	2,384	103	223	5	338	2
CM	12kV	576	1,540	2,116	28,335	230	0	28,565	6,029	1,136	429	17,817	0
	4kV	195	73	268	7,657	62	0	7,719	133	112	57	382	0
EA	12kV	1,715	1,102	2,817	44,535	2,133	8	46,676	4,599	295	16	14,909	6
	4kV	97	17	114	3,339	9	1	3,349	47	14	0	194	1
NC	12kV	517	2,160	2,677	16,746	416	0	17,162	8,101	550	5	24,549	5
	4kV	105	58	163	3,179	45	0	3,224	171	74	1	679	2
NE	12kV	2,516	2,466	4,982	51,877	4,302	2	56,181	9,696	431	1	28,885	4
	4kV	89	15	104	2,142	177	0	2,319	45	4	0	206	2
OC	12kV	188	1,278	1,466	4,426	157	0	4,583	5,060	410	5	13,264	1
	4kV	11	15	26	391	1	0	392	77	58	1	102	0
Total	12kV	5,971	10,125	16,096	161,223	7,481	11	168,715	39,394	4,261	523	117,123	29
	4kV	592	236	828	19,076	309	2	19,387	576	485	64	1,901	7
FTZ	12kV	3,287	1,718	5,005	64,240	6,125	9	70,374	5,705	140	0	19,857	5
	4kV	85	17	102	1,952	172	0	2,124	54	4	0	220	2
HRFA	12kV	1,629	299	1,928	30,496	3,403	2	33,901	895	29	0	3,576	1
	4kV	43	5	48	958	130	0	1,088	11	0	0	72	0

*Structures that have both 12kV and 4kV are counted as 12kV

Figure 2-25. Primary Distribution System Facts

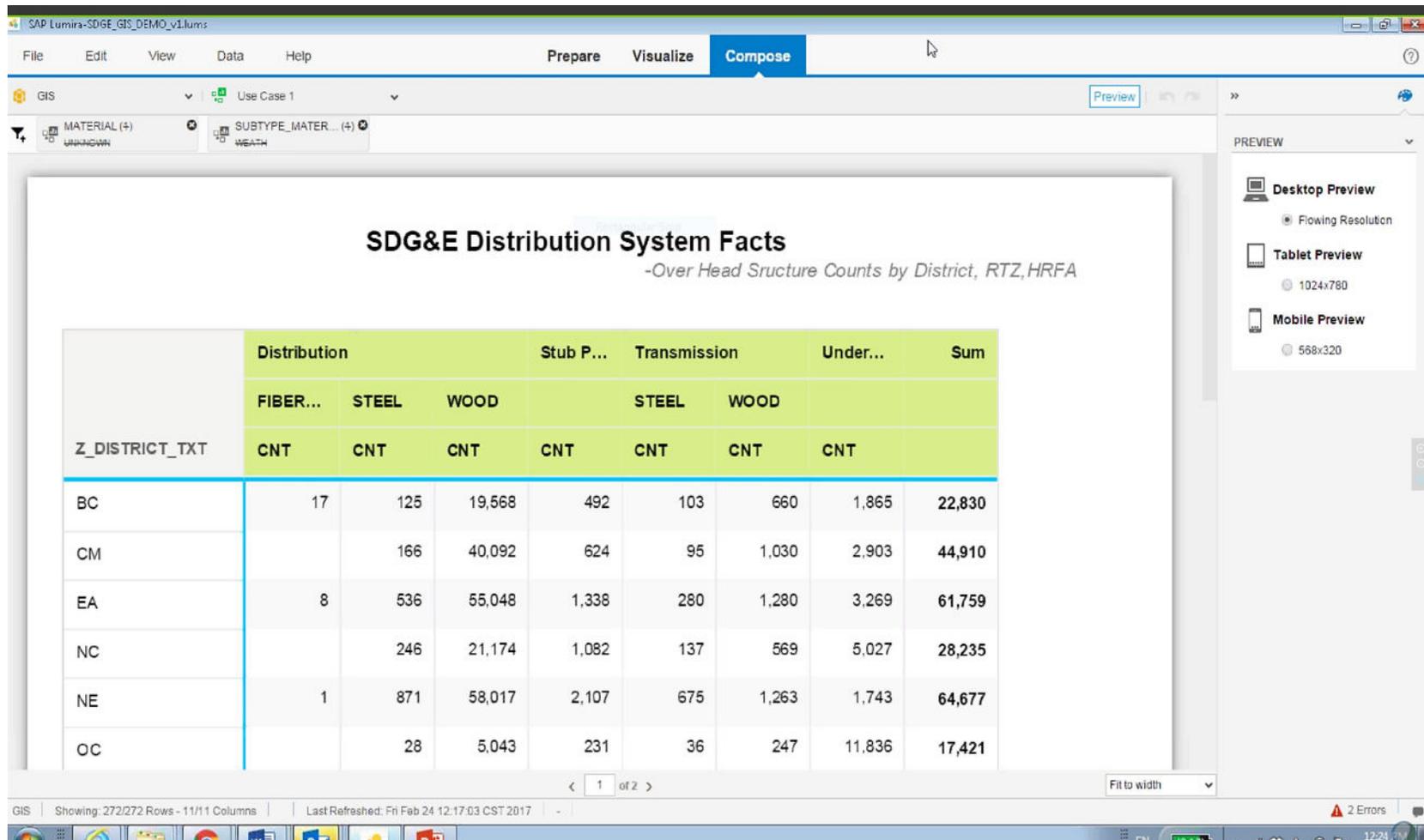


Figure 2-26. Overhead Structure Count by District

2.3.6 Observations, Challenges, and Lessons Learned

Metrics, with its zero-programming ease-of-use approach, was able to generate ~25% of the analytics within SDG&E QY report. Spatial Eye was more complex to use, but it was able to generate 100% of the analytics within SDG&E QY report.

While ArcGIS Insights provided better visuals (charts, maps, etc.) with interactive experience, the views did not match exactly the Excel reporting template currently used by SDG&E. The alternative is to export this analytics as Excel spreadsheets and reference them within the SDG&E's Microsoft Excel reporting template. This provides a viable path with minimal changes to the end users of the report.

Challenges and Resolutions

- Biggest hurdle was translating the needed SQL queries to the Spatial Eye language (once queries are translated, they can be reused without needing to manually translate them for each use).
- There is a significant learning curve to master Spatial Eye queries and to setup Spatial Eye projects.
- Automating the process is the key to process speed improvement (many steps could be done overnight); once the circuit/subs list is up to date, the users can run queries at any time.

Recommendations

- An investment in terms of time, effort, and training is needed to master Spatial Eye queries and the setup of Spatial Eye projects.

2.4 Historical Outages Playback (UC #4)

2.4.1 Background

The goal of this task was to provide an ability to visually represent historical electrical outages up to 5 years in the past as points on a geographical map, with a user being able to interactively specify the history duration and to select additional geospatial layers to display. The core information needed to accomplish this goal are the Lat/Lon of each outage of interest. However, such information is not readily available in one place. For example, the database of assets contains exact geographical locations of all facilities and equipment, but does not have information about outages. Likewise, a database of outages does not have the Lat/Lon of the outaged facilities.

An ability to look at historical outage data in the context of the exact geographical location and other data that might have had some impact on the outages is of great value to both Operations and T&D Engineering. Prior to this effort, various pieces of the overall outage picture were scattered among different SDG&E systems. The aim of Use Case #4 was to develop a GIS-based application for replaying outages along with other kinds of related data in order to get a better grasp of the potential causes and of the outage restoration performance. It is hoped that the insights from these replays might help improve outage restoration performance in the future.

2.4.2 Objective

In technical terms, the goal of this task was to integrate information from the systems of record for the outage data, build appropriate applications for associating outages with the Lat/Lon, and to provide

needed support to end users to enable them to interactively peruse outage information on a geographical map.

2.4.3 Users

- T&D Engineering
- Distribution Operation

2.4.4 Solution Approach, Solution Components, and Work Flow

2.4.4.1 Solution Components

- Outage Management System: source of outage data
- Postgres DB: the store for the extracted outage data
- Esri Web AppBuilder: a development tool for creating custom widgets for ArcGIS
- GIS Portal

2.4.4.2 Work Flow

Prior to this use case, SDG&E did not have all the needed information required to draw an outage location on a geographical map within one data source. Relevant data is spread across three main data sources, as follows:

- **FP_PROD** – Oracle database instance which receives outages from Network Management System (NMS) in a near real-time. This source does not contain the Lat/Lon of the outage facilities and equipment.
- **PRO_VAQ_ELEC** – Oracle instance storing electric GIS assets (structures, devices) in an Esri ArcSDE geodatabase. This is the source of Lat/Lon data, but this source does not have outage data.
- **EROD.xlsx** – Excel spreadsheet supplied by the Electric Reliability Group with 5 years' worth of scrubbed (validated and accepted) outage data. This source is supplied on a monthly basis and refreshed in the Electric Reliability web application by the FME process depicted in the workflow diagrams that follow. This source does not contain the outage Lat/Lon data.

In the diagrams that follow, the source data stores are shown as yellow shapes. The data sources are utilized within a multi-step process to produce an outage point feature that can be represented geospatially on a map. To accomplish this, the source EROD data needs to be matched to another source that can provide these coordinates for the outage through a two-step approach: in the first step, an attempt is made to match the existing GIS features (structures, devices) stored in PRO_VAQ_ELEC to the EROD records (the historical outage data). When a match cannot be found, then, in the second step, an attempt is made to match the EROD records to NMS data via an Oracle database view to EROD records. If neither of these sources can provide a location, an error is raised requiring manual intervention to establish a location.

An overview of the overall workflow is shown in Figure 2-27, followed by a more detailed description of its sub-processes.

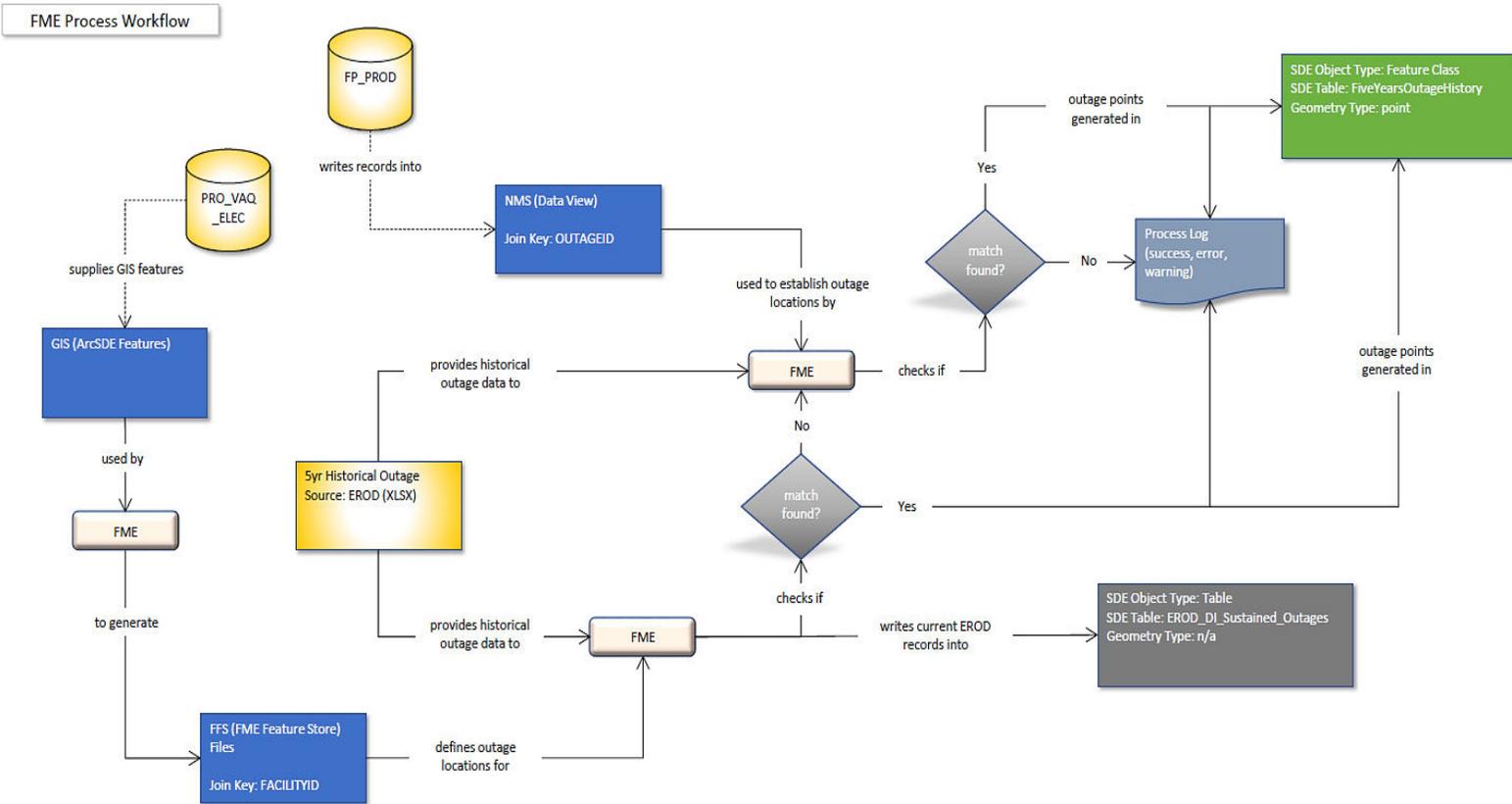


Figure 2-27. Work Flow for Generating Outage Features

The following workflow describes in more detail how the process illustrated in Figure 2-27 is carried out.

1. To prepare for matching EROD records to the asset location data stores, there is a preliminary step to read 1.3 million features found in 10 different feature classes, and transform this information using the Safe Software’s ETL application FME (Feature Manipulation Engine) into a format that greatly improves the performance of the matching process. The results are stored in a single file in FME’s native format FFS (FME Feature Store), as shown in Figure 2-28.

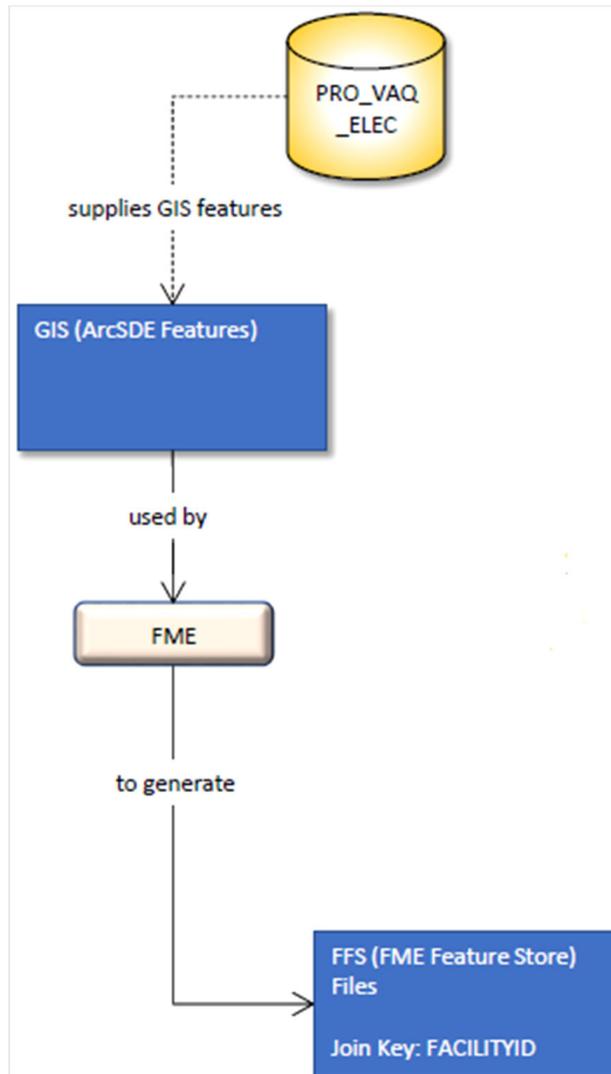


Figure 2-28. Transformation of GIS Features into FME Feature Store Native Format

2. The secondary source for a given outage location consists of records read from NMS. A database view is created from FP_PROD and is made available to FME if required (see Figure 2-29).

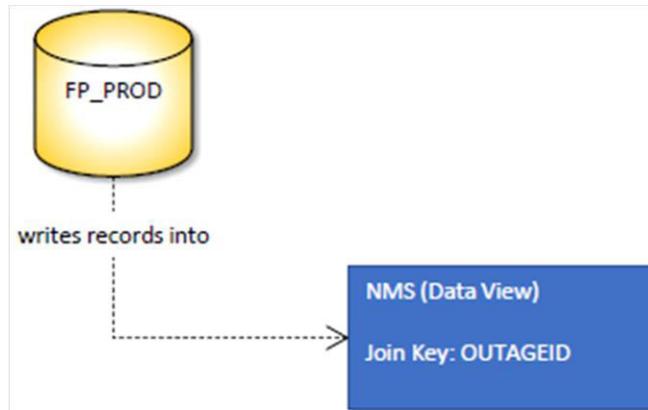


Figure 2-29. Matching of Outage Data with NMS Data

3. With these two data sources available, an FME process is then used to attempt the 2-step matching process. First match is attempted between the source EROD data and the GIS data (see Figure 2-30).

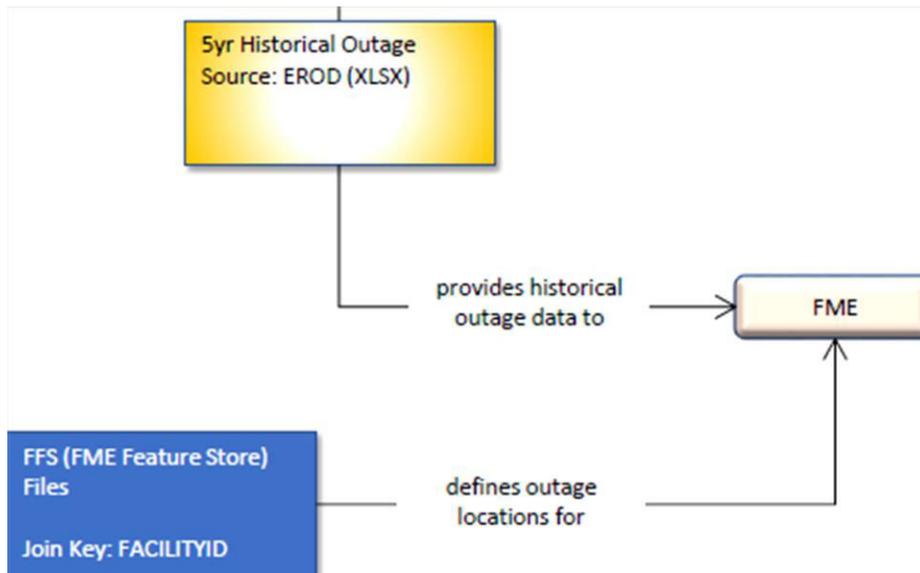


Figure 2-30. Matching of EROD Data and GIS Data

4. If a match is found, then a point feature is generated in a geodatabase. A record is also written into a process log for reference (see Figure 2-31).

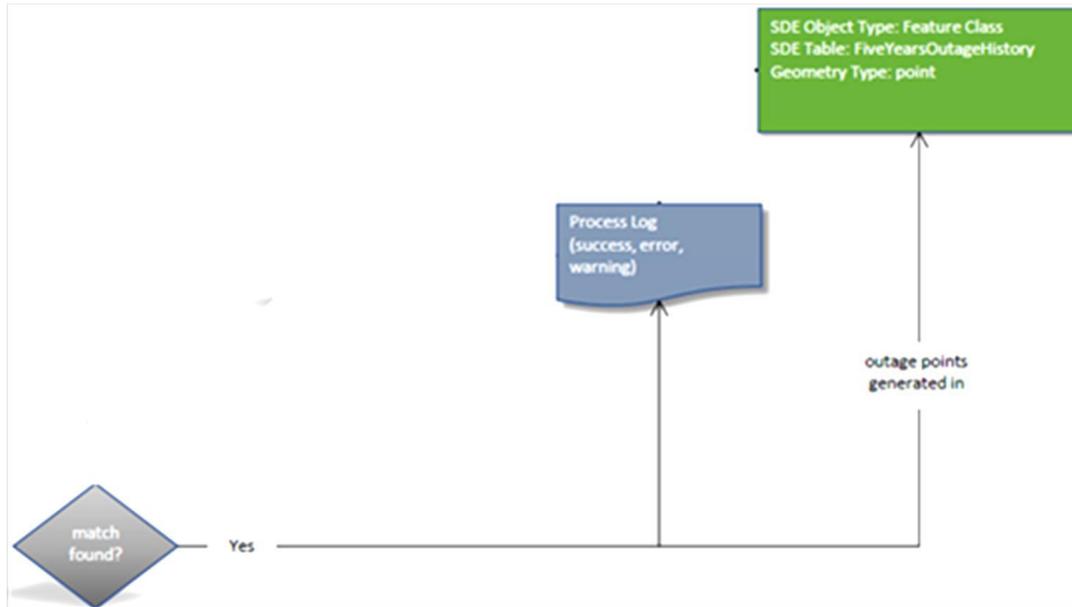


Figure 2-31. Matching Process Main Output

5. At the same time, a table is populated with the source EROD data for possible future reference (see Figure 2-32).

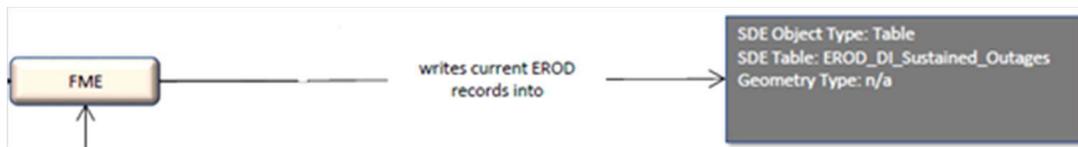


Figure 2-32. Matching Process: Additional Output Table

6. If a match to the GIS could not be found, the second step is to match EROD data to NMS records (see Figure 2-33).

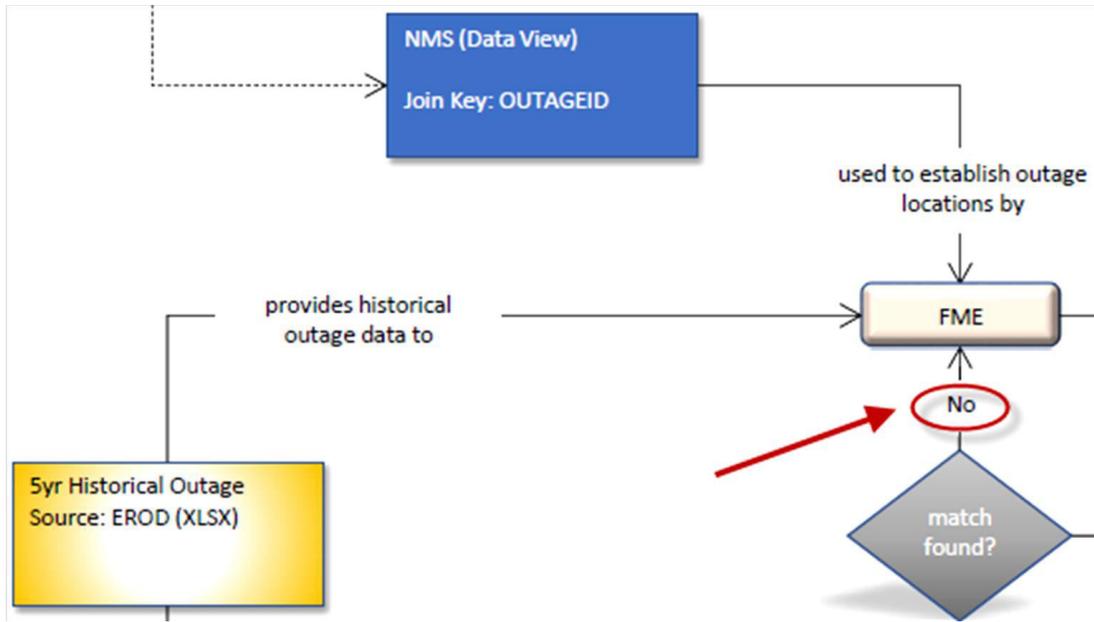


Figure 2-33. Matching Outage Data with NMS Data

7. If a match is found, a point feature is generated in the output feature class that will be presented within the Electric Reliability web application (see Figure 2-34).

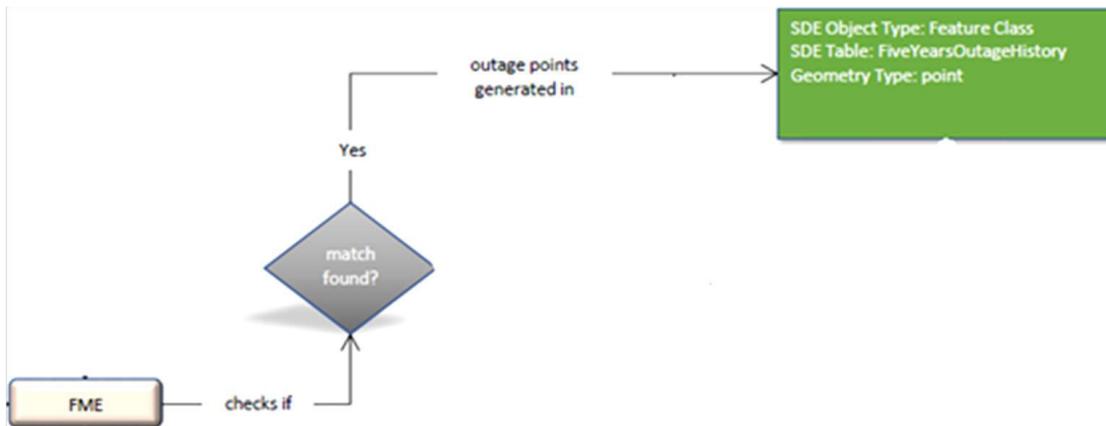


Figure 2-34. Output of Second Step Matching

8. If a match cannot be established from NMS, an error is produced in the output processing log file (see Figure 2-35). These EROD records need to be manually researched to establish an actual geographic location.

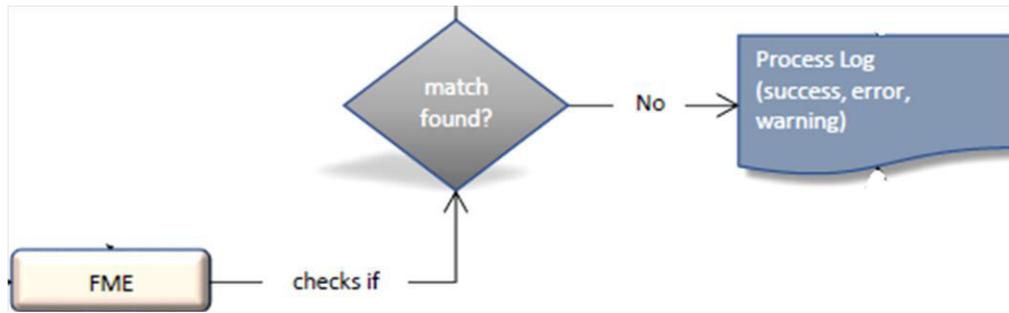


Figure 2-35. Second Step Matching Log

9. As noted previously, both match processes write out success or failure into a process log (see Figure 2-36).

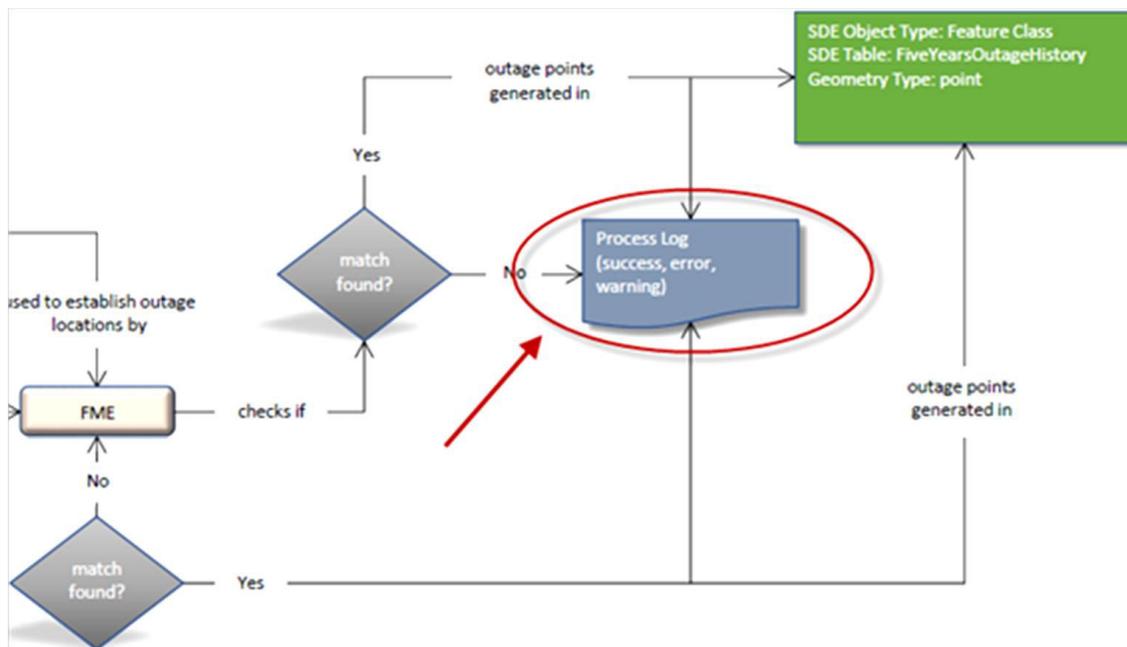


Figure 2-36. Matching Process Log

With the outage data assigned to the geographical location through the above processes, the resulting features could be presented alone or in combination with other geo-enabled features like SCADA data and weather at the time of the outage. Updates to the SCADA data on maps are accomplished with the help of PI Integrator for Esri ArcGIS, through a mechanism explained in more detail within the Use Case #1 description.

Figure 2-37 provides an example of how to configure an outage playback on a map and what options are available for displaying additional, complementary data. More details and examples of the application capability for replaying outages is also available in the Results section.

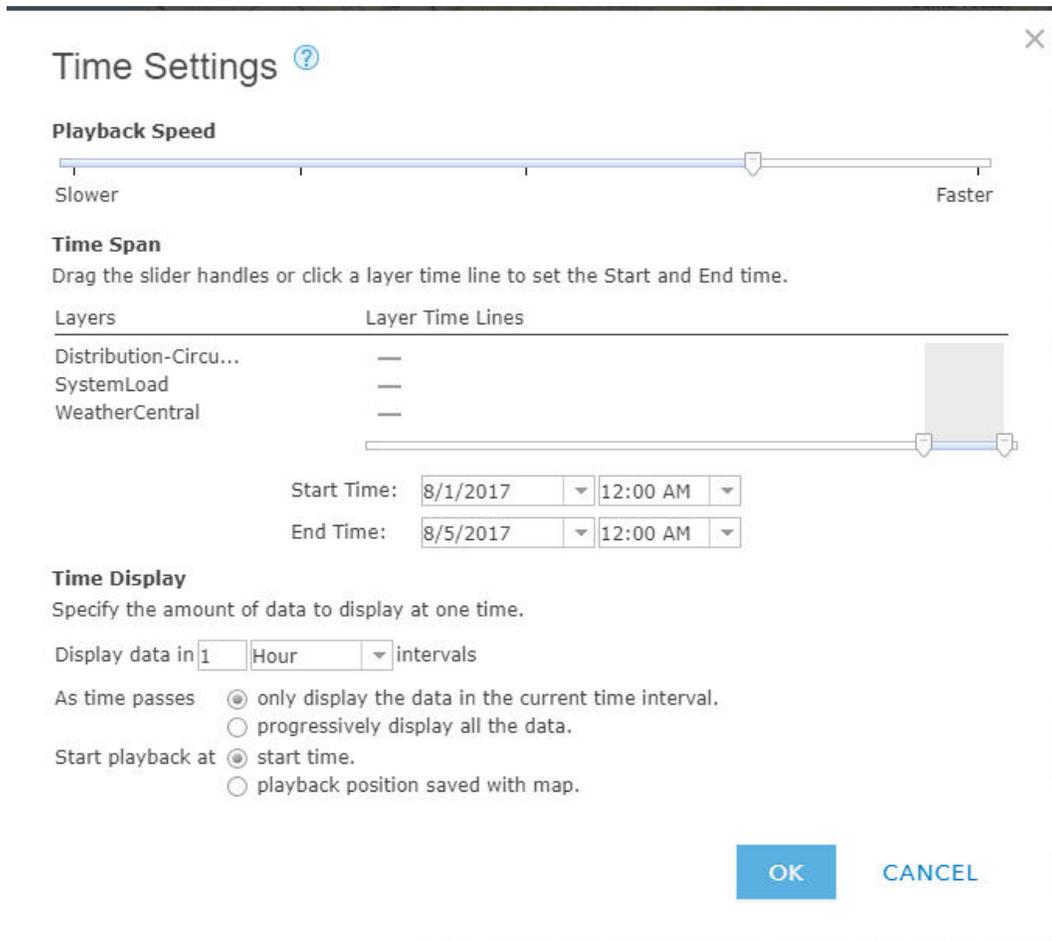


Figure 2-37. Setup for History Playback

2.4.5 Results

An ArcGIS Web app builder widget, called Outage Filter, has been created to enable a user to select and display Electric Reliability Outages based on the criteria in the following groups (see Figure 2-38):

1. Feeder or District ID
2. Time Interval
3. Additional Outage Parameters

Outage Filter

Feeder ID/District Search....

Feeder ID

District

Time Selection....

Time Period:

Date:

From Date:

To Date:

Additional Outage Parameters....

- Crew Contact
- Foreign Object
- Maintenance
- Miscellaneous
- Tree Contact
- Undetermined
- Weather
- Equipment

Figure 2-38. Configuration of Outages to Display

1. Feeder ID or District

In this category, the user can choose either a Feeder ID or a District. For example, Figure 2-39 shows outages for a feeder ID 214.

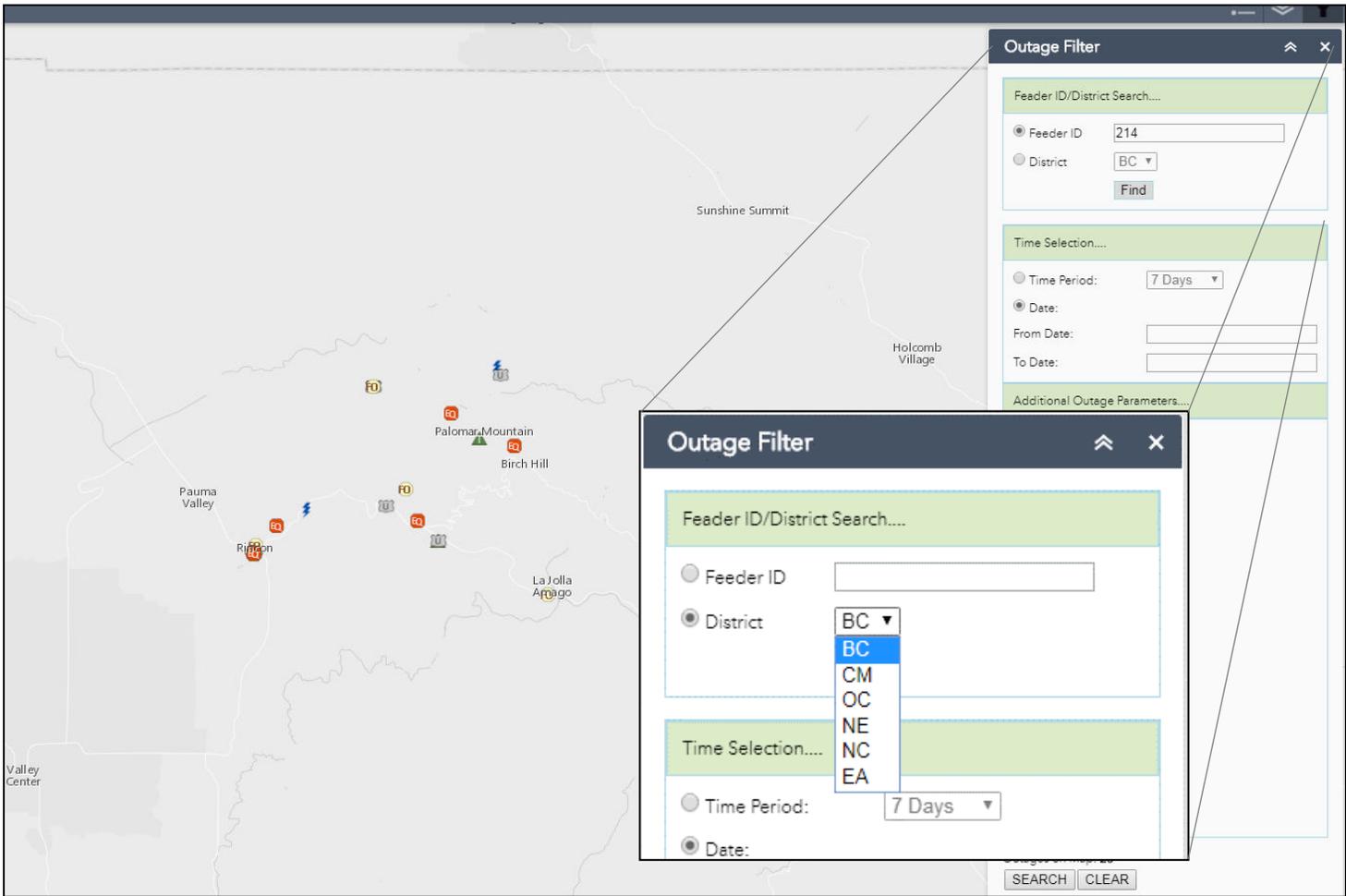


Figure 2-39. Outages for a Selected Feeder and Date Range

Similarly, when a user selects a district code (inset in Figure 2-39 above), the resulting map shows the outages in that district, including that district’s boundary.

2. Time Selection:

Users can specify the time interval of interest in one of two ways, relative and absolute. In the relative method, invoked by selecting the “Time Period” radio button, the choices are the number of days prior to today (e.g., All Days, 5 Days, etc., as seen in Figure 2-40).

The screenshot shows a web interface with two main sections. The top section, titled "Feeder ID/District Search....", contains two radio buttons: "Feeder ID" (unselected) and "District" (selected). Next to "District" is a dropdown menu showing "BC" and a "Find" button. The bottom section, titled "Time Selection....", contains two radio buttons: "Time Period:" (selected) and "Date:". The "Time Period:" dropdown menu is open, showing a list of options: "7 Days", "All Days", "5 Days", "7 Days", "1 Months", "3 Months", "6 Months", "1 Year", "2 Year" (highlighted in blue), "3 Year", "4 Year", and "5 Year". Below the "Time Selection...." section is a section titled "Additional Outage Param" with a list of checkboxes and labels: "Crew Contact", "Foreign Object", "Maintenance", "Miscellaneous", "Tree Contact", "Undetermined", "Weather", and "Equipment".

Figure 2-40. Selection of History Interval

In the absolute method, the user chooses “Date” radio button and is given an option to enter “From Date” and “To Date”, as shown in Figure 2-41 below. The dates can be entered by typing in the date fields or by using the calendar widget.

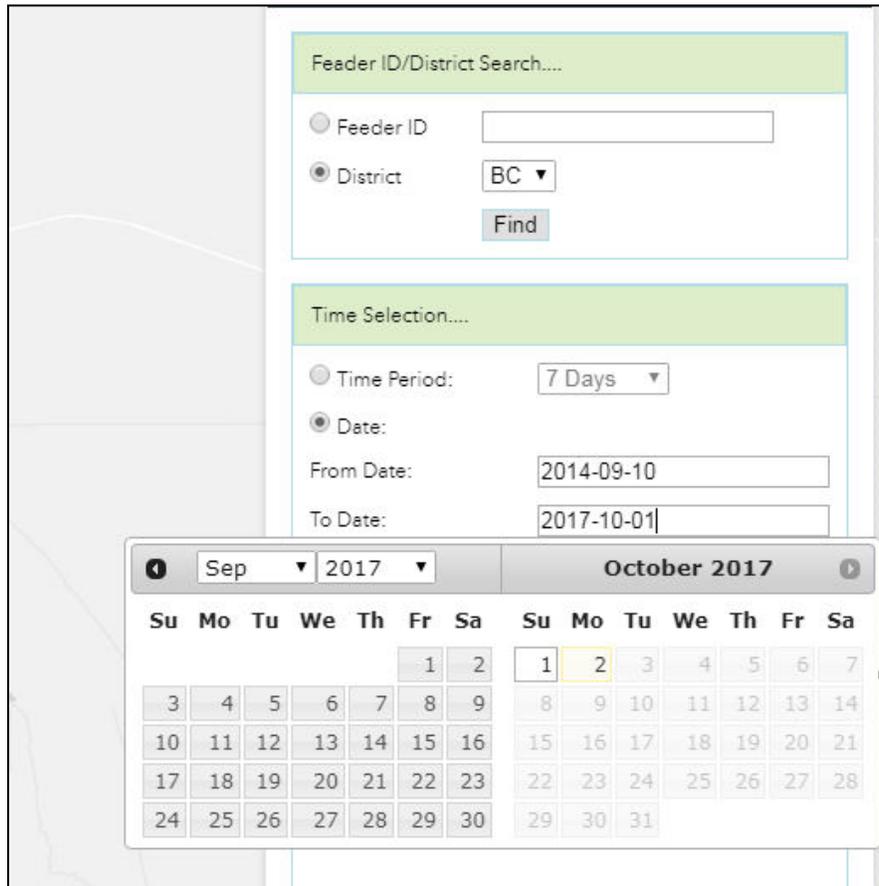


Figure 2-41. Specifying Date Range

3. Additional Outage Parameters

In the Filter widget, Outage Parameters are selected from groups of related outage-cause categories. The current list of outage-cause categories contains the following:

- Crew Contact
- Foreign Object
- Maintenance
- Miscellaneous
- Tree Contact
- Undetermined
- Weather
- Equipment

Each of the categories may contain additional subcategory items that the user can reveal and choose from. For example, Figure 2-42 shows Crew Contact and Foreign Object categories revealed.

The screenshot shows a 'Outage Filter' dialog box with the following sections:

- Feeder ID/District Search....**
 - Feeder ID:
 - District: District:
- Time Selection....**
 - Time Period: Time Period:
 - Date: Date:
 - From Date:
 - To Date:
- Additional Outage Parameters....**
 - Crew Contact
 - SDG&E Contr. Line fault/tree trimming
 - SDG&E Crew Line fault/tree trimming
 - SDG&E Crew error
 - SDG&E Contr. Personnel contact
 - SDG&E Crew Personnel contact
 - SDG&E Crew Vehicle Contact
 - SDG&E Contr. Heavy equip contact/dig in
 - SDG&E Contr. Vehicle contact
 - SDG&E Crew Heavy equip contact/dig in
 - SDG&E Contr. Crew error
 - SDG&E Contr. Line fault/hot wash
 - Foreign Object
 - Flashover/vegetation
 - Bird contact
 - Damage by gunshot
 - Foreign object in distribution line
 - Animal contact
 - Aircraft
 - Vandalism
 - Maintenance
 - Line-xfmr deenerg/maint/const/tap chg
 - Miscellaneous
 - Tree Contact
 - Undetermined
 - Weather
 - Equipment

Outages on Map: Loading...

Figure 2-42. Additional Outage Criteria

The following series of figures illustrates what the user sees by selecting different outage categories: Figure 2-43 shows Crew Error-caused outages (within Crew Contact category); Figure 2-44 shows all weather-related outages (including all sub-cause categories); and Figure 2-45 shows outages due to two cause types – specifically, Cable Fault (from Equipment category) and Line Fault/Hot Wash (from Tree Contact category).

As indicated earlier, the user can select to display any combination of outage data, circuit loading, and weather data. For example, Figure 2-46 presents the weather and circuit loading information at a particular point in time, in this case at 3 PM on August 1, 2017. Weather station colors on the map are light orange/gray. According to the legend on the left side of the screen snapshot, the temperatures are in the upper 80s. Also, according to the legend for percent of rating, the orange system load symbols (the squares) indicate loading >50% of their rating.

By adding loading and weather condition data, the user can draw useful conclusions about the possible cause of the outage and the progress of restoration, which, lacking this capability, would be much harder to accomplish.

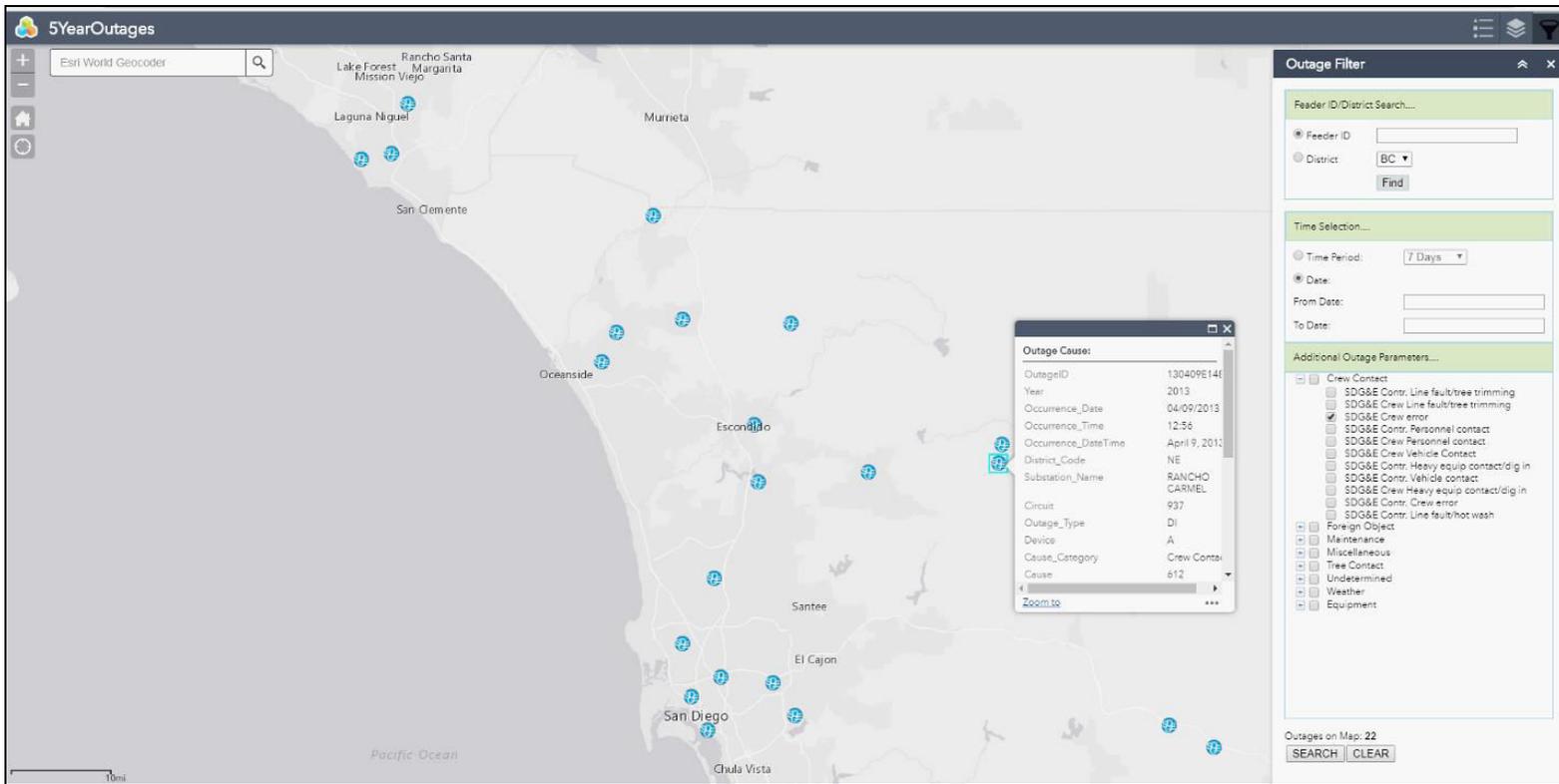


Figure 2-43. Crew Error-Caused Outages (within Crew Contact category)

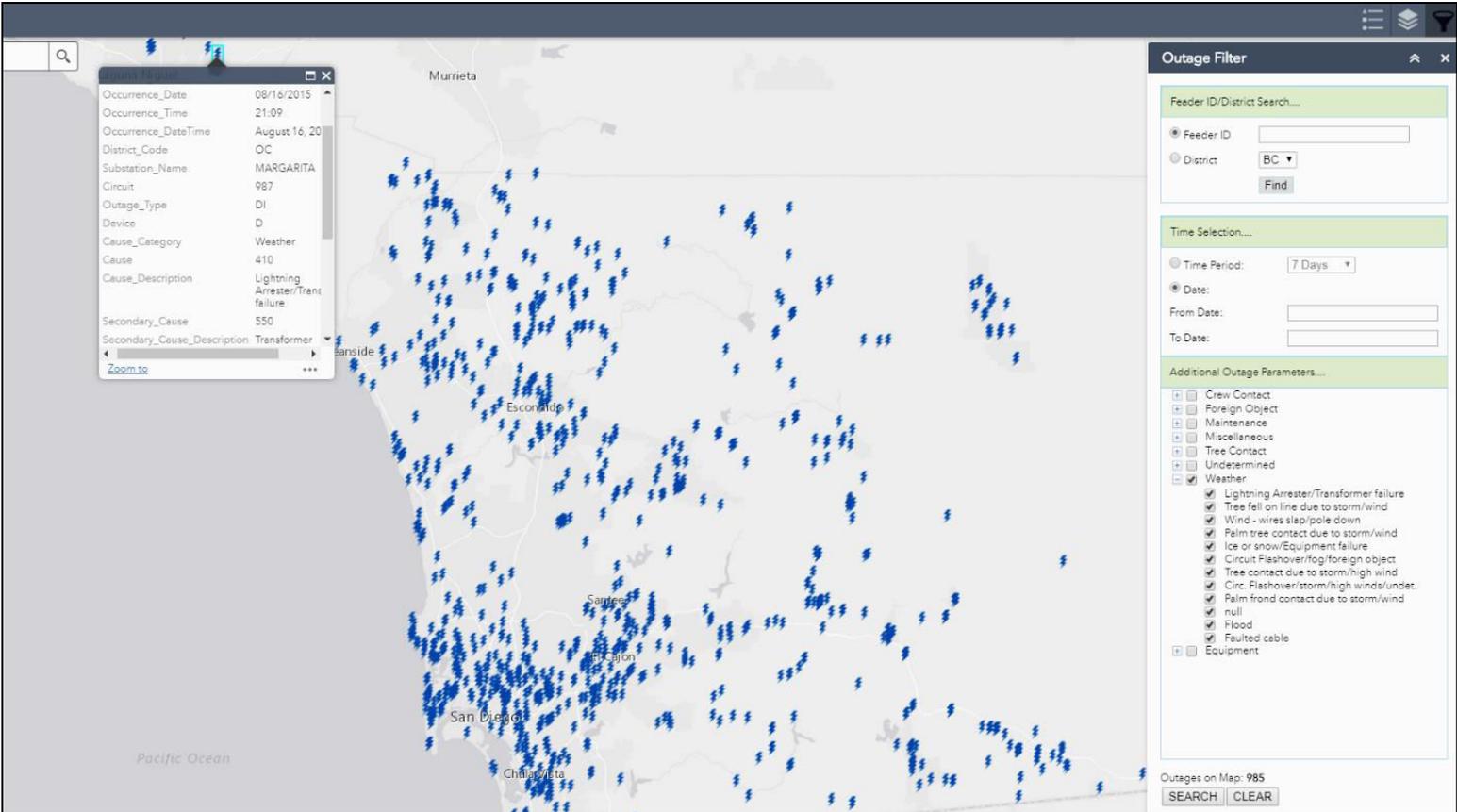


Figure 2-44. All Weather-Related Outages

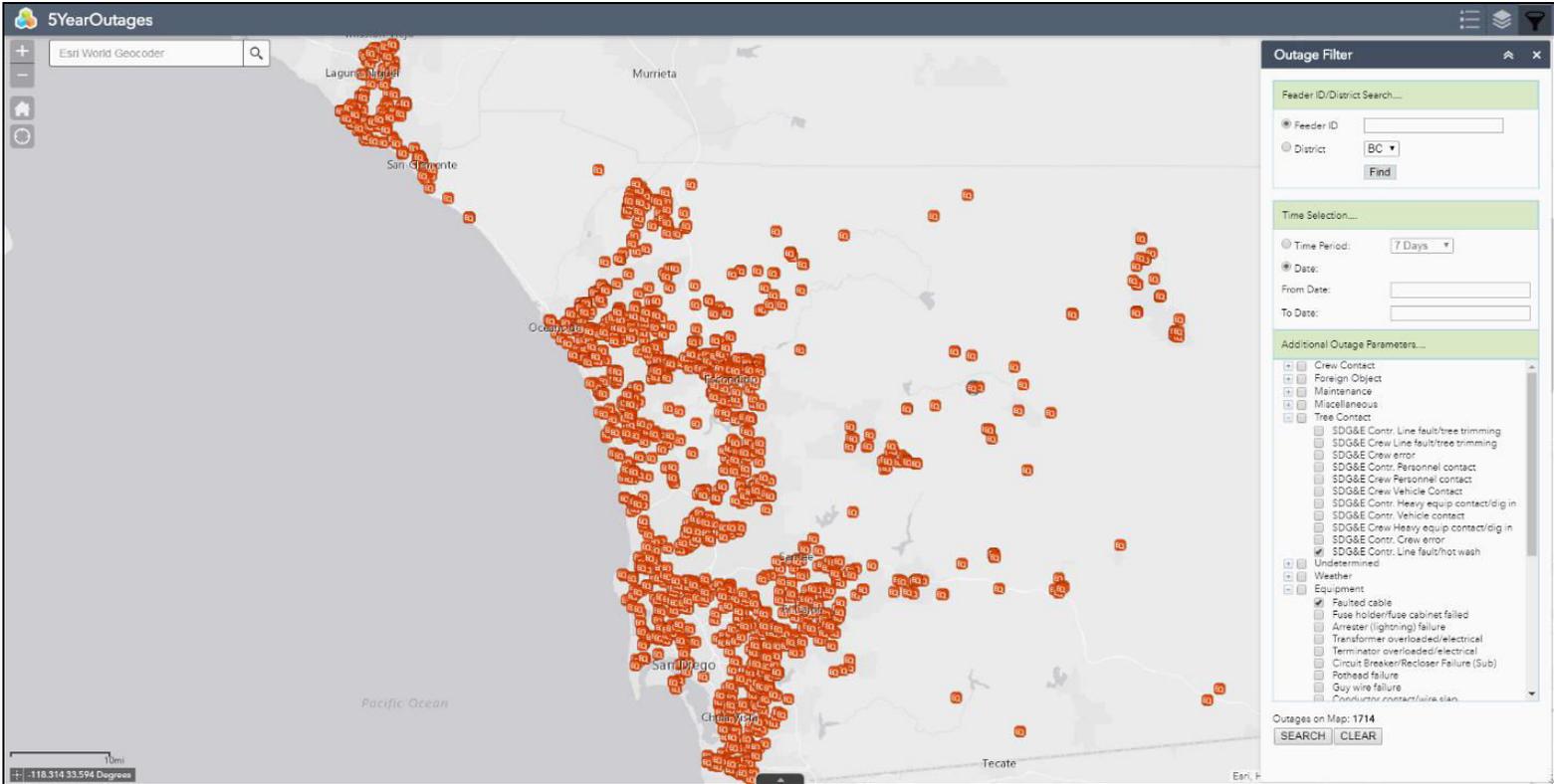


Figure 2-45. Outages Due to Two Cause Types

2.4.6 Observations, Challenges and Lessons Learned

Challenges and Resolutions

- Sources of outage data were in different systems of record (for example, the current outage management system does not yet have the full 5 years of history). As a result, the collection, transformation, and validation of the transformed outage data required significant effort on the part of SDG&E staff. Also, before this project, outage data was not geographically enabled. As part of this use case process, all relevant outage data for the rolling 5-year history is brought into one place, is geo enabled, and is made current on a daily basis.
- One of the challenges was identifying the appropriate data owners.
- The design of custom widgets required careful analysis and development, as the goal was to make general components that can be reused; the need for generality added to the challenge.

Recommendations

- The most important starting point is to collect and formulate solid user requirements
- There is a need to continuously communicate with various stakeholders and data owners, to affirm requirements and share results
- Continue developing widgets to serve the evolving needs of end customers.

2.5 AMI for Operations (UC #5)

2.5.1 Background

A widespread availability of AMI data provides an opportunity to get a clearer real-time picture of the voltage situation across the SDG&E network. The purpose of Use Case #5 is to overlay the AMI and SCADA voltage data onto a GIS map containing the electrical circuit topology and to create a heat map that shows the voltage swell and swag data. This visualization capability is expected to assist during emergency operations under various scenarios, such as the following:

- Storm
- Red Flags (e.g., Wind – Santa Ana)
- Earthquake
- Wildfire

After the fact, the historical playback capability should allow analysis of voltage behavior during different situations and, thus, provide a valuable insight about the need for system upgrades.

2.5.2 Objective

The objective of this task was to overlay the AMI and SCADA voltage data onto a GIS map with circuit topology and create a heat map that shows the voltage swell and swag data on the GIS map.

2.5.3 Users

- Electric T&D Engineering

- Electric Distribution Planning
- Electric Distribution Operation

2.5.4 Solution Approach, Solution Components, and Work Flow

Solution components:

- Smart Meter PI
- DMZ PI
- Power BI
- PI Event Frame: detect voltage changes that constitute an event (e.g., voltage above 1.05%)
- ArcGIS picks up 10 years' worth of the events captured by PI Event frame
- Esri Webapp application builder to integrate Power BI widgets and other customizations for GIS Portal
- GIS Portal

An ability to show the substation SCADA data and the field devices' power quality data as map layers is created by the PI Integrator for Esri ArcGIS, and custom components indicated in green in Figure 2-47.

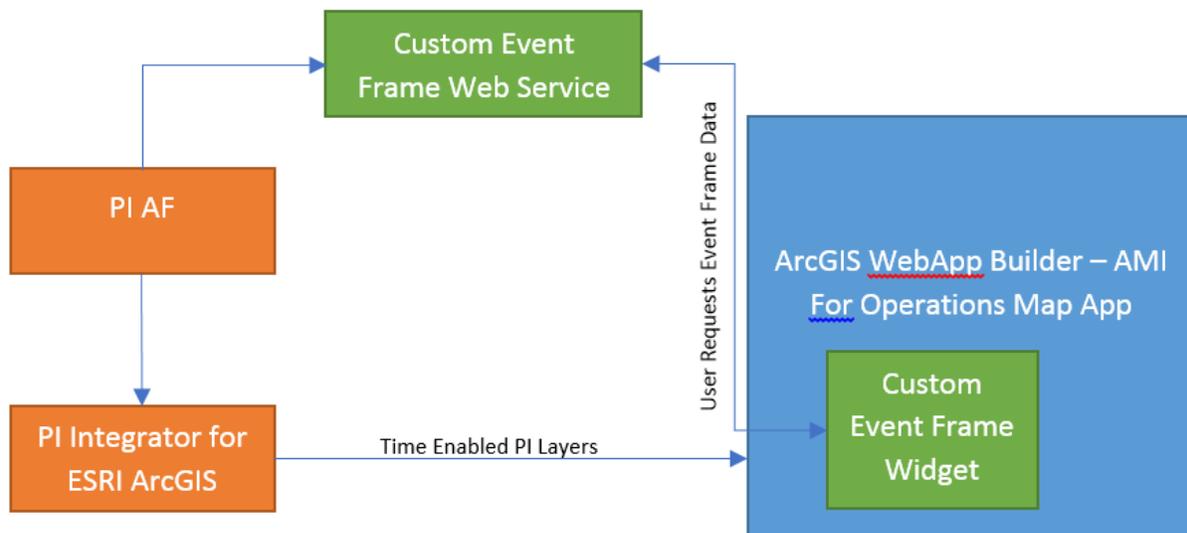


Figure 2-47. AMI for Operations Data Flow Diagram

2.5.5 Results

2.5.5.1 Features

- Voltage for primary distribution circuits with visual indicator % of nominal voltage and Visualization display for additional parameters available in Historian (PF, THD, voltage & load unbalance, etc.).

- Trending granular distribution circuit voltage analysis based on AMI data with the intent to identify possible future problem areas.
- Visualizations for other Intelligent Electronic Device (IED) data beyond typical SCADA such as microprocessor controlled circuit breakers, relays, transformers, regulators, and capacitors. The System Protection and Control group can provide detail.
- Visualizations for emergency operations various scenarios:
- Storm, Red Flag (Wind – Santa Ana), Earthquake, Wildfire

2.5.5.2 Representative Results

Figure 2-48 through Figure 2-51 illustrate (self-explanatory) custom widgets for configuring various display attributes for this use case.

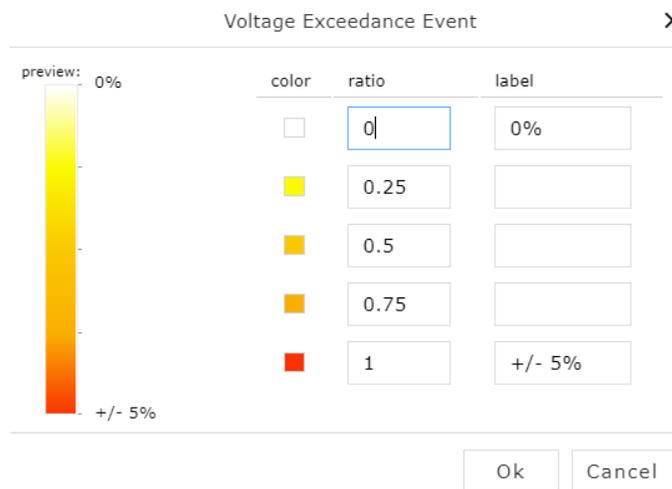


Figure 2-48. Custom Widget: Customizable Heat Map Colors

Visualization and Situational Awareness Demonstration

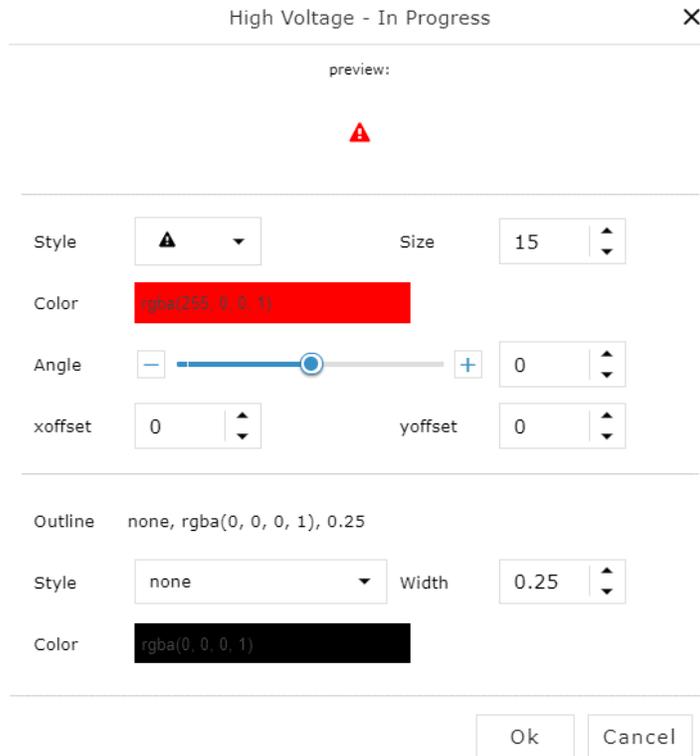


Figure 2-49. Custom Widget: Customizable Symbols

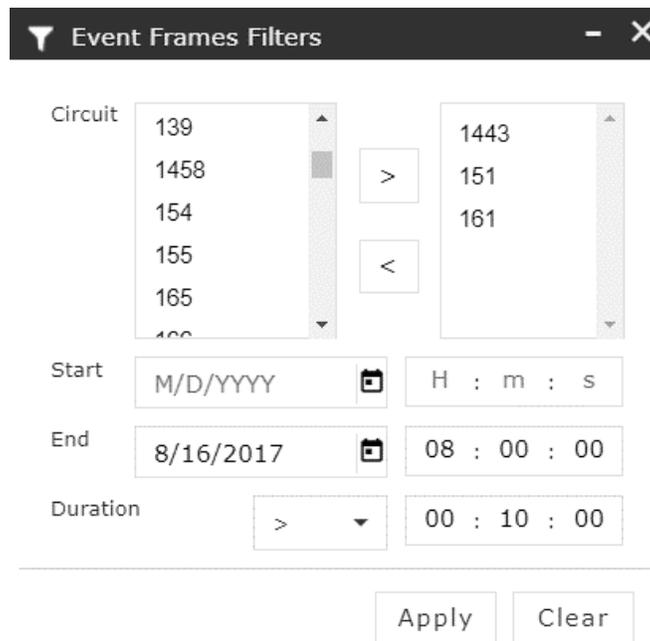


Figure 2-50. Custom Widget: Selecting Facilities of Interest

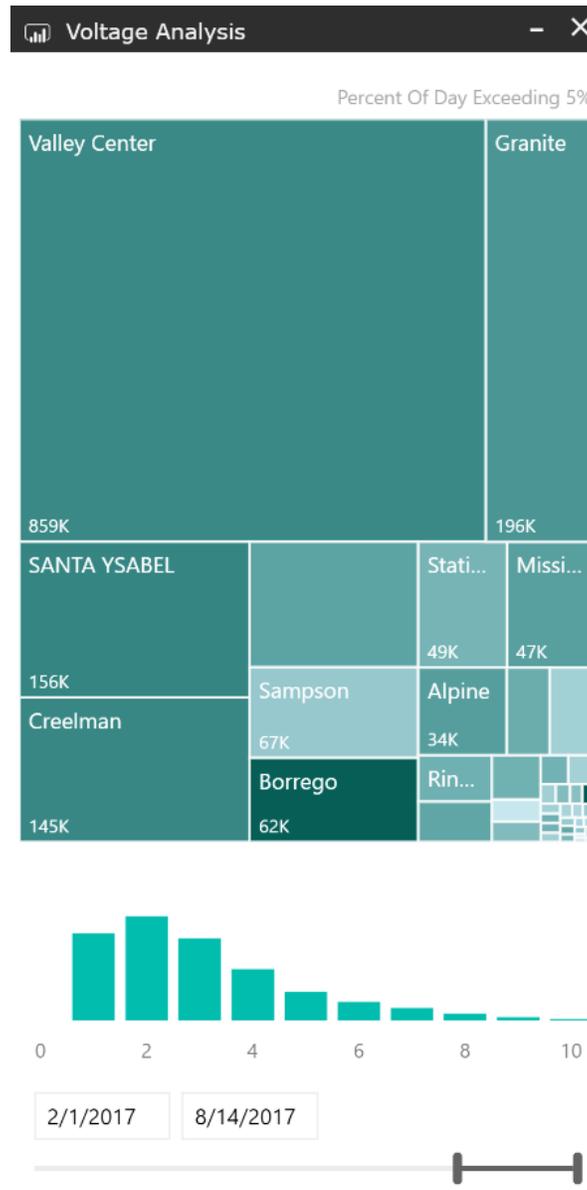


Figure 2-51. Power BI Display of Voltage Exceedance Events (tile size proportional to # of events)

The histogram at the bottom is the distribution of metering errors over the time horizon indicated in the timeline at the bottom of figure (from 2/1/2017 to 8/14/2017).

Selecting any of the boxes is akin to zooming in. For example, by “clicking” on Valley Center, the display will update to show the counts on meters within that station only, and the histogram will also update to show exceedance by all meters in the Valley Center substation.

By a further zoom-in action, one can get to a breaker of interest shown in the left-hand side of Figure 2-52; details on the number of exceedances as shown by tile size on the right; the histogram of metered deviations below the tiles; and the timeline bar at the very bottom.

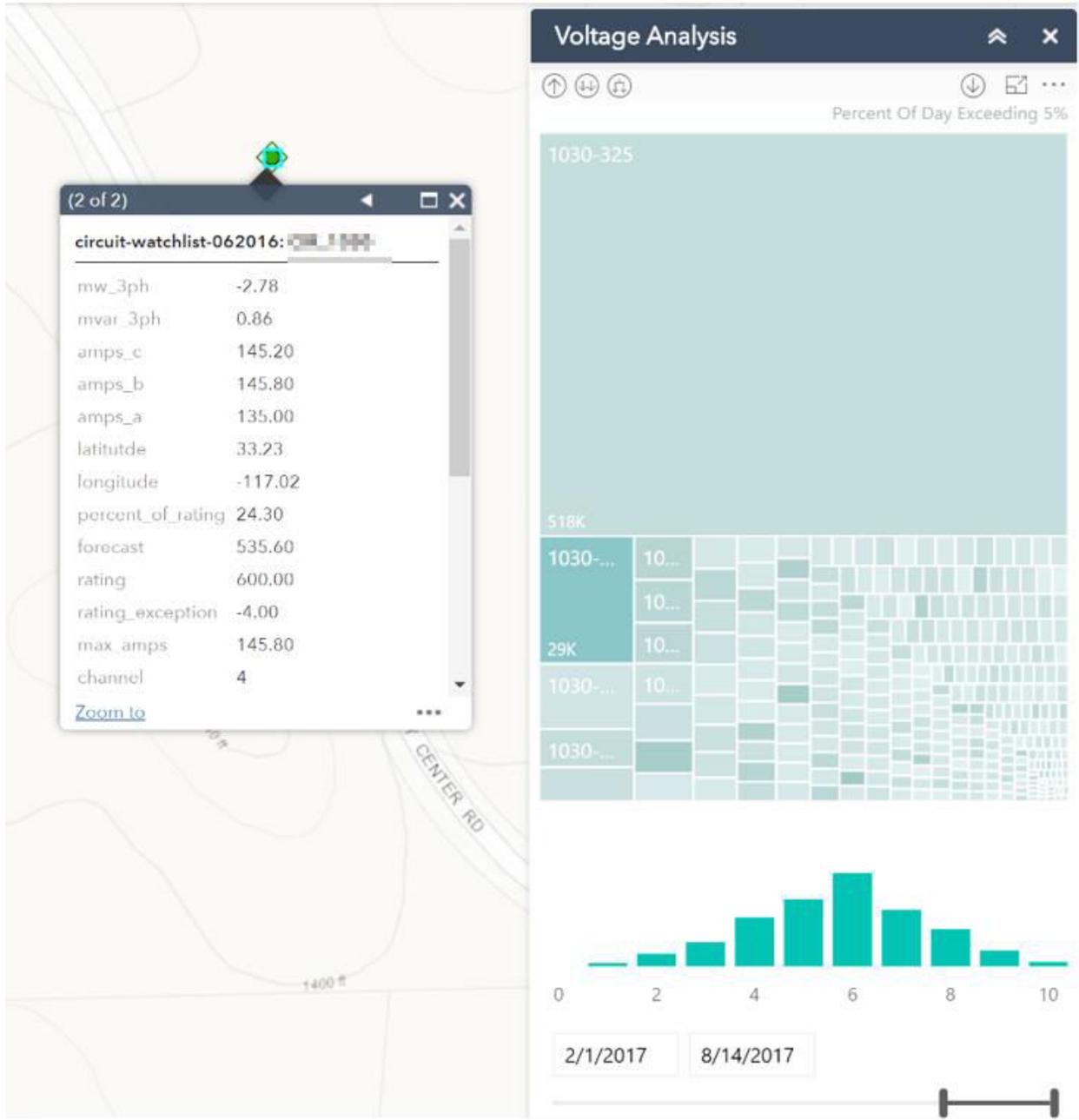


Figure 2-52. Breaker CIR_1030 Events

Figure 2-53 shows an event loader configured to retrieve and display events for a given date, and an interval relative to that date specified by the values in the “From” and “To” fields. The asterisk (*) in the date field means current time; solid icon colors mean the event is still in effect at the end of the selected interval; hollow icons mean the event occurred and completed prior to the end of the specified interval.

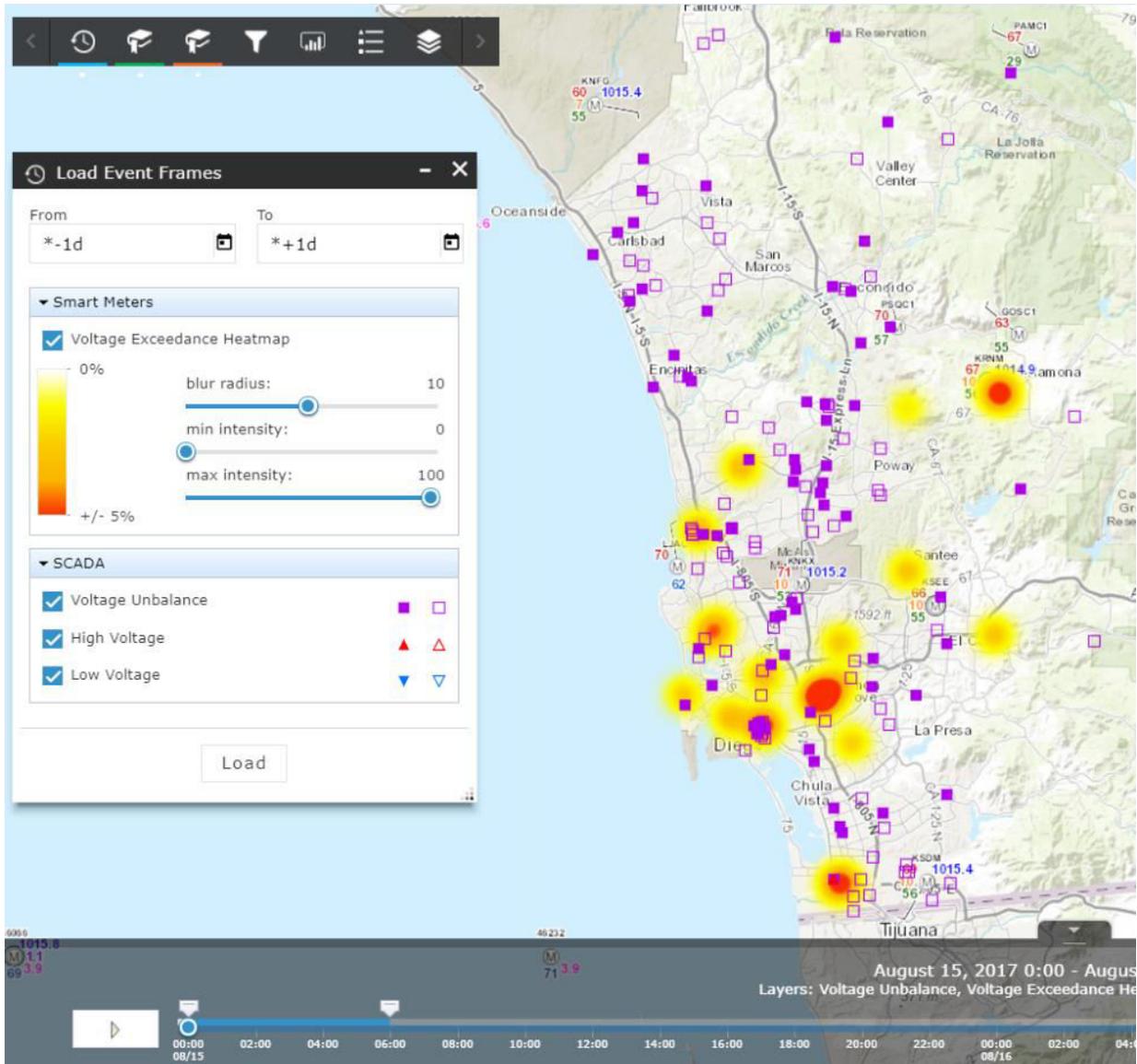


Figure 2-53. Custom Widget: Dynamic Heat Map of Voltage Exceedances over a Specified Time Interval

By “clicking” on an event, one gets additional details. For example, Figure 2-54 shows a, b, and c phase currents from SCADA at the event time. This illustrates a still ongoing event; hence, the square is filled with color, and End date/time is not filled in.

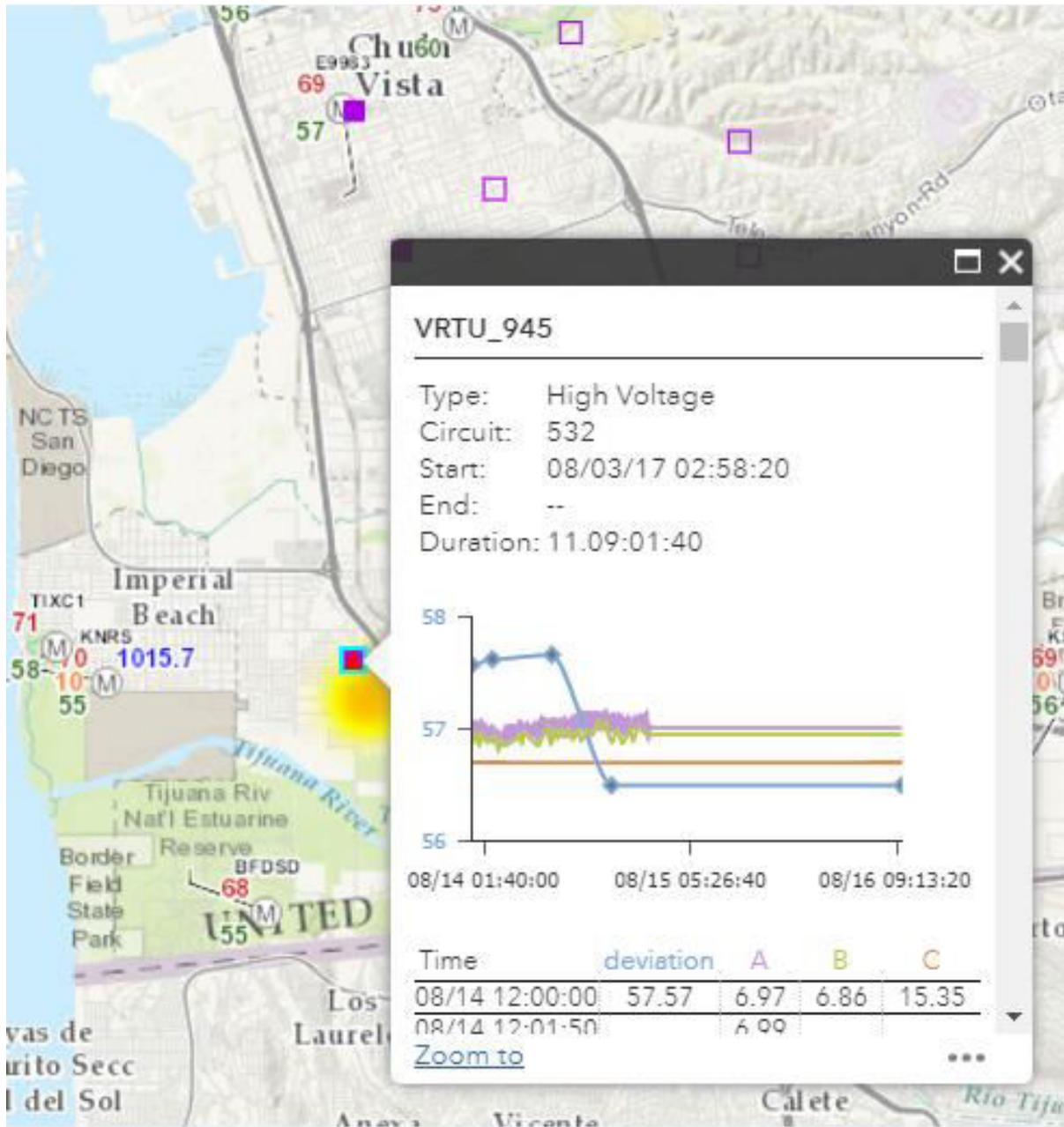


Figure 2-54. Event Detail: Voltage Chart

Figure 2-55 is a Power BI custom widget in conjunction with a geospatial display, showing tabular details of the events configured according to Figure 2-53. Due to the integration of Power BI with geospatial visualization, by selecting any element in the table, the corresponding element on the map is identified.

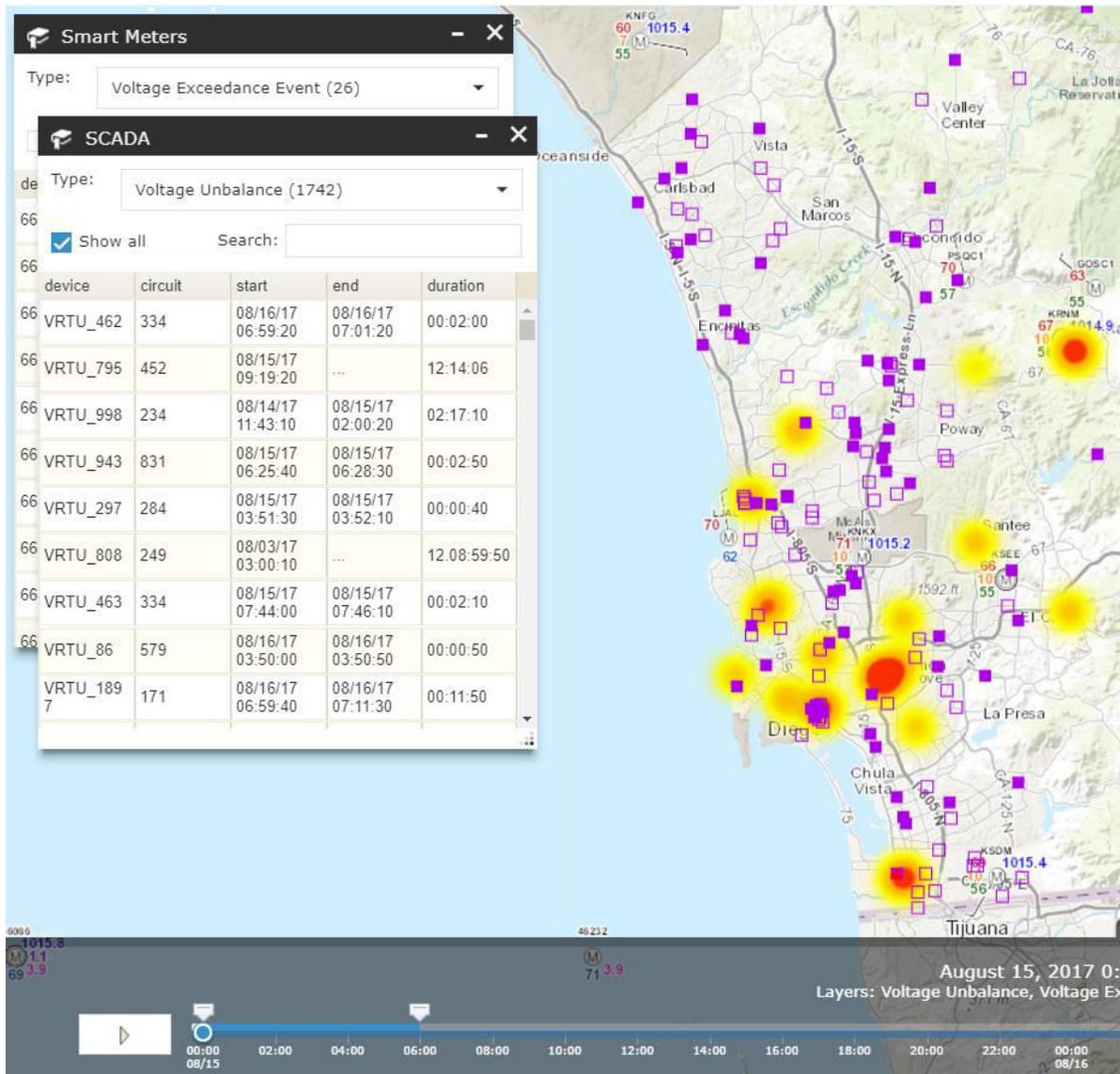


Figure 2-55. Custom Widget: Power BI Showing Voltage Exceedance

2.5.6 Observations, Challenges and Lessons Learned

Challenges and Resolutions

- Coming up with a solution to integrate Power BI and ArcGIS, with the solution that is configurable so it can be reused. The task has been successfully solved with a custom program.
- Customizing Power BI widgets.
- Esri has a component for integrating Power BI with Esri maps, but that solution requires Power BI to also be on premises. In this case, Power BI was a cloud based solution, and hence, SDG&E needed to develop an alternative solution for integrating Power BI widgets within Esri maps.

- An early user's feedback indicated a need for customizable widgets, such as different symbols for the items that can be displayed on maps. As a result, the team developed a customizable widget for configuring symbols by the end user.
- Authenticating users with MS OAUTH (used by Power BI users) was a challenge: Power BI is a cloud-based application, the rest of the needed applications are on premises. The challenge was to implement a single sign-on in this hybrid environment due to a lack of templates (for accomplishing this task) and due to terse documentation. After a good deal of trial and error, the hurdle was overcome.

Recommendations

- It is suggested to design custom widgets to be as generic as possible. In this project, that approach has proven to be very helpful, and it is expected that it will continue to be helpful in future projects.
- Applications should be designed to be customizable by end-users, which helps with usability, and ultimately, with adoption of the function.

2.6 Customer-Owned DER Visualization (UC #6)

2.6.1 Background

Given the significant installed capacity of DERs, it is becoming important to be able to incorporate into GIS maps a representation of customer-owned energy resources' name-plate data, with an ability to group by transformer, circuit, and substation. Specifically, the desired features are:

- Visualizing customer-generated load via the transformers to the circuits in ArcGIS portal.
- Real time visualization of DER (generators and storage) data for dispatch (30 kW or more).

2.6.2 Objective

The objectives of Use Case #6 were to incorporate a representation of customer-owned Energy Resources' nameplate data by transformer, circuit, and substation data presentments.

2.6.3 Users

- T&D Engineering
- Electric System Planning and Grid Modernization
- Electric Distribution Operation
- DER (part of Growth and Technology Integration)

2.6.4 Solution Approach, Solution Components, and Work Flow

Solution components:

- DIIS: system of record for registration data of DER devices
- Esri Web AppBuilder: Esri custom application to retrieve data from DIIS and develop custom geo-features
- GIS Portal

For this use case, a layer displaying all customer generation systems was created with many attributes, including nameplate rating. The layer is symbolized with circles, with their size representing nameplate ratings (see Figure 2-56).

Also, an advanced energy storage dashboard is created as part of this use case (Figure 2-57). This dashboard contains pricing data for different large battery storage systems along with relevant CAISO locational marginal pricing data.

The top half of the dashboard shows the two battery systems EC and ES that can be selected to view individually. It shows instantaneous MW data, along with a Discharge + Charge trend. The discharge and charge trend begin at zero for the start of the time period selected and increase from there. That way, one can easily see total charge and discharge values for any point in the selected time range without doing any additional calculations.

The lower half of the dashboard contains pricing data. CAISO_LMP shows the current price per MWh in the real-time market. Revenue shows revenue from the batteries discharging based on CAISO_LMP, and Cost shows cost from the batteries charging based on LMP. Calculations are done per battery system based on their respective CAISO PNode pricing data. The Net trend shows net for the period (Revenue minus Cost). The very bottom of the display has the time range selector to adjust the period the dashboard is displaying.

There is also an Advanced Energy Storage dashboard created for this use case (see Figure 2-58). This Power BI dashboard contains pricing data for different large battery storage systems along with relevant CAISO pricing data. The architecture for the display is shown in Figure 2-59.

The top half of the dashboard shows the two battery systems EC and ES that can be selected to view individually. It shows instantaneous MW data, along with a Discharge + Charge trend. The discharge and charge trend begin at zero for the start of the time period selected and increase from there. That way, one can easily see total charge and discharge values for any point in the selected time range without doing any additional calculations.

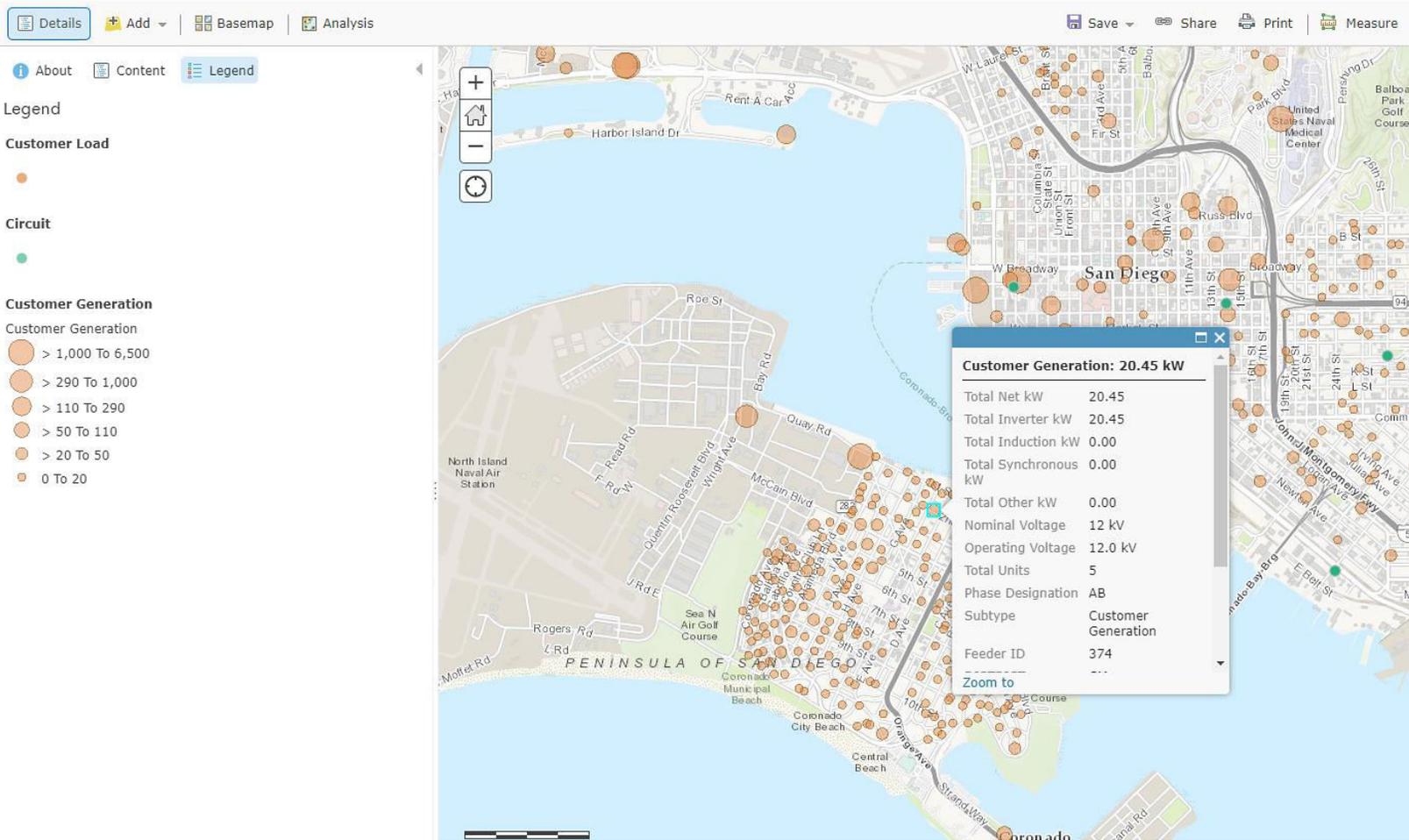


Figure 2-56. Customer Generation Location and Size

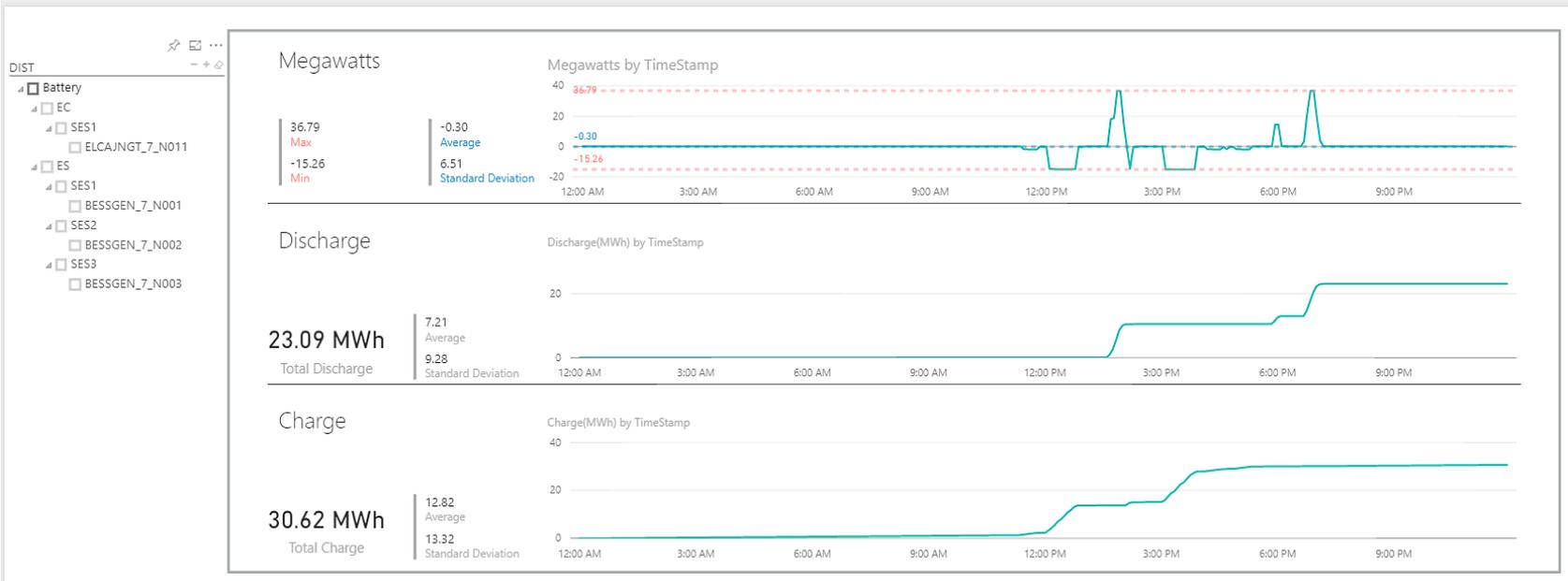


Figure 2-57. Battery Charge and Discharge Charts

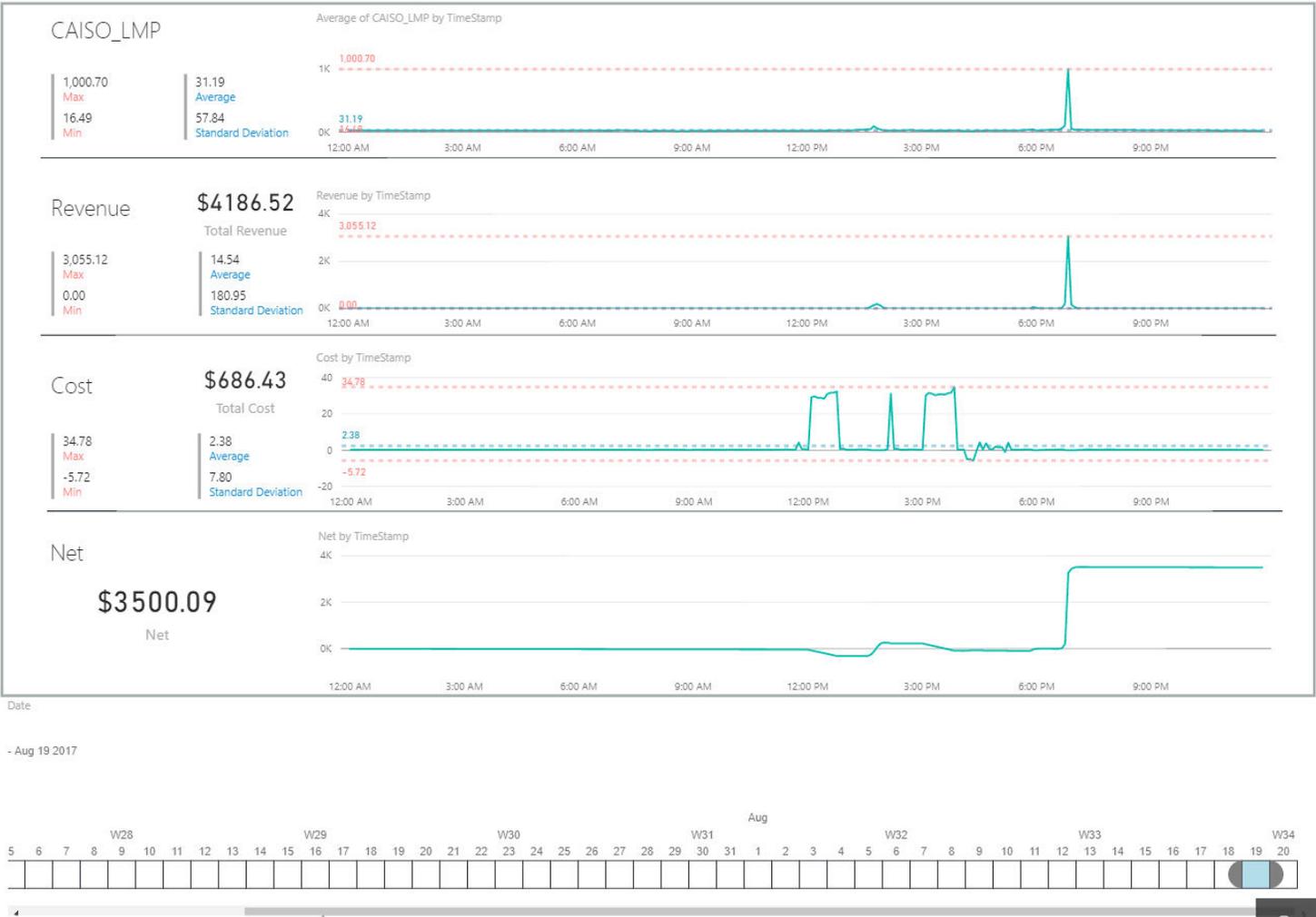


Figure 2-58. CAISO LMP, Battery Revenue and Cost

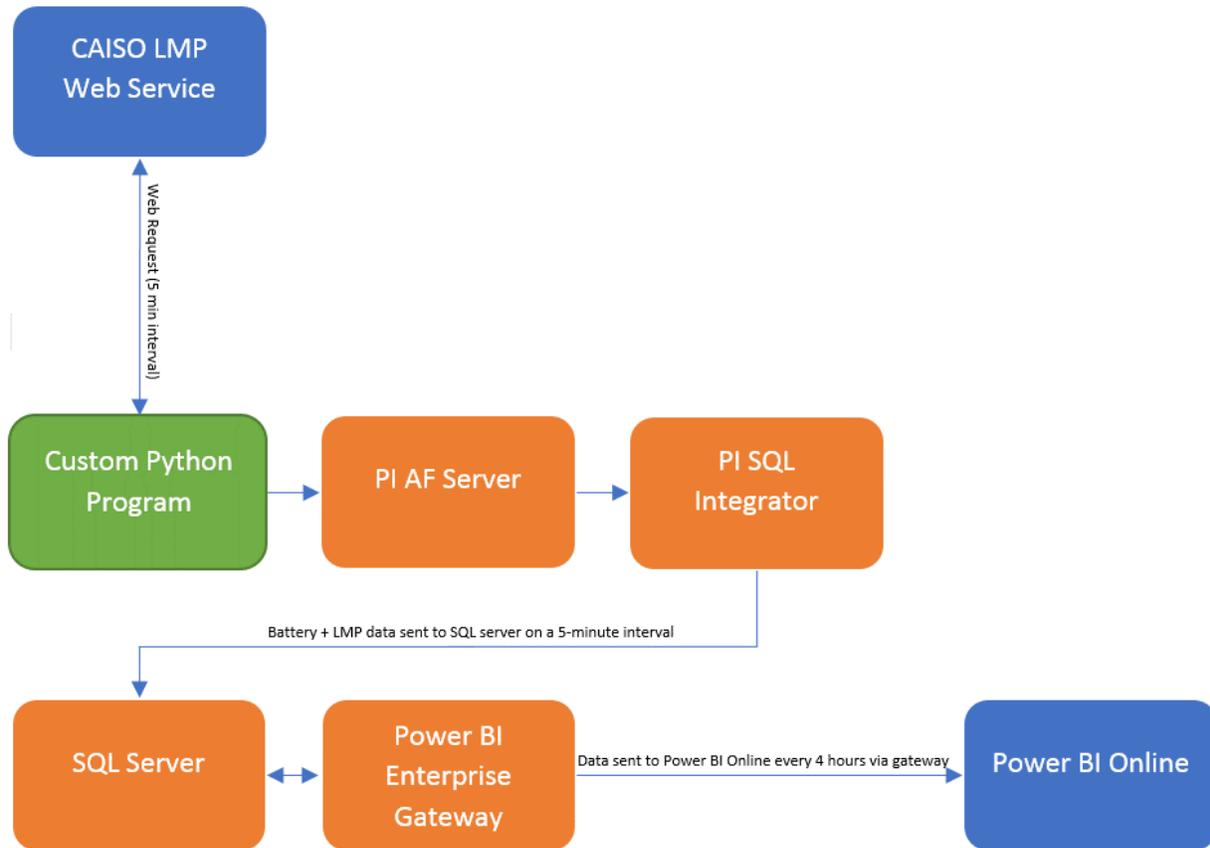


Figure 2-59. UC 6 Data Flow Diagram

2.6.5 Results

Major results of this use case are standardization of battery models in PI, real time visualization of DER (generators and storage) data for dispatch (30 MW or more), and geospatial presentation of customer generation based on the nameplate data (e.g., household or industrial PVs).

2.6.6 Observations, Challenges, and Lessons Learned

Challenges and Resolutions

- For operations, actual PV output is important, whereas the registration system used as the source of the production data for DER visualization records only nameplate data. SDG&E is still evaluating options for converting nameplate data to operational data. Some of those thoughts are listed in the Recommendation section.
- For batteries, a challenge was combining within SDG&E the PI battery model and operational data with CAISO pricing data. This required the development of an interface to retrieve the CAISO data and an application to store this data within PI (see Figure 2-59).

- Battery systems are from different vendors with different data models and different naming conventions (i.e., there are no standards for modeling batteries). This resulted in the SDG&E team having to spend quite a bit of time to analyze and develop an SDG&E standard model for representing batteries in order to accommodate all the different battery manufacturers.
- Design and development of the battery dashboard (selection of items to display).

Recommendations

- Ideas for converting PV nameplate data to actual real time output: use an existing, nearby solar plant for which there is real time data, and apply the same scaling factor between the nameplate capacity and the actual output to rooftop PV outputs in the vicinity of the PV plant. Also, consider use of models that produce kW output for given solar conditions.
- For batteries, it would be ideal to have a dashboard similar to the one currently used with real time prices to display Day-ahead market prices

2.7 Imagery Management (UC #7)

2.7.1 Background

An anticipated increase in the amount and variety of data from drones, imagery, video, and 3D sources necessitates a comprehensive image data management strategy. This use case aims to explore and demonstrate technologies for integration and management of LiDAR, imagery, and 3D data, with the goal to learn how to manage multidimensional data information efficiently, and how to use previously collected drone data with existing GIS data to improve data quality.

More specifically, the aim is to be able to see the data sources visually, in a geographic context, as opposed to searching for the data via file and folder names. This should save time and effort in organizing huge amounts of data. Additionally, the aim is to provide historic references for source data to help understand the data acquisition patterns. The specific objectives to support these aims are presented in the next section.

2.7.2 Objective

The objective of Use Case #7 was to prepare an image catalog to search and find data through a user-provided area extent on a geographical map. A custom search should also be supported to allow for a search through the data catalog using date/time, pole, tieline, circuit, or facility ID.

2.7.3 Users

- Construction Services
- Electric Transmission and Distribution Engineering
- Substation and Corporate Security

2.7.4 Solution Approach, Solution Components, and Work Flow

2.7.4.1 Solution Components

The following components were used to implement the use case:

- Esri Web AppBuilder 2.5: the application builder is used to deploy the 'Image Discovery' widget⁵
- ArcPro and ArcGIS
- Esri ArcGIS portal 10.5.1

2.7.4.2 Data Formats Used for this Project

- LiDAR
- Oblique imagery (JPEG, GeoTIFF, ECW, JP2)
- Video files from UAV

2.7.4.3 Work Flow

1. Data is organized on a NAS folder.
 - a. Collected from different departments, through FTP site or folders on a server.
 - b. The data is cleaned to reflect only imagery formats and associated metadata (e.g., PDF files with accuracy report, weather data excel files, circuit diagrams, or any QA/QA reports for the data).
 - c. The data is organized by circuits, tielines, type of data, and year obtained.
2. Each type of data is ingested into ArcGIS or ArcPro in different workflows.
3. Publish datasets to portal as mosaic dataset to accommodate the search.
4. Application is created using the Web AppBuilder 2.5 and the Image Discovery widget to find the data in an area extent or an area specified. The Image Discovery widget with the area extent selection icon circled can be seen later in Figure 2-62.

A similar tool called GOSI was developed at PG&E. GOSI uses PG&E Operational Mesoscale Modeling System, or POMMS, which has similar aims, but goes deeper than the scope of this project could accommodate. Furthermore, SDG&E leveraged the available Esri products, which were covered by the existing SDG&E licenses.

2.7.5 Results

Examples of different representations of datasets are shown in Figure 2-60 (data by LiDAR extent) and Figure 2-61 (LiDAR data in 3D). The user starts image discovery by selecting an area of interest. In Figure 2-62, the circled icon designates the user is choosing an area extent method, after which the user can place on a map a rectangle of a desired size at a desired location.

When a user specifies an area of interest (via a rectangle in this example), the image data files available for the selected area are listed on the right-side pane of Figure 2-63.

⁵ Esri custom widget, developed through an open source process, and copyrighted to Esri.

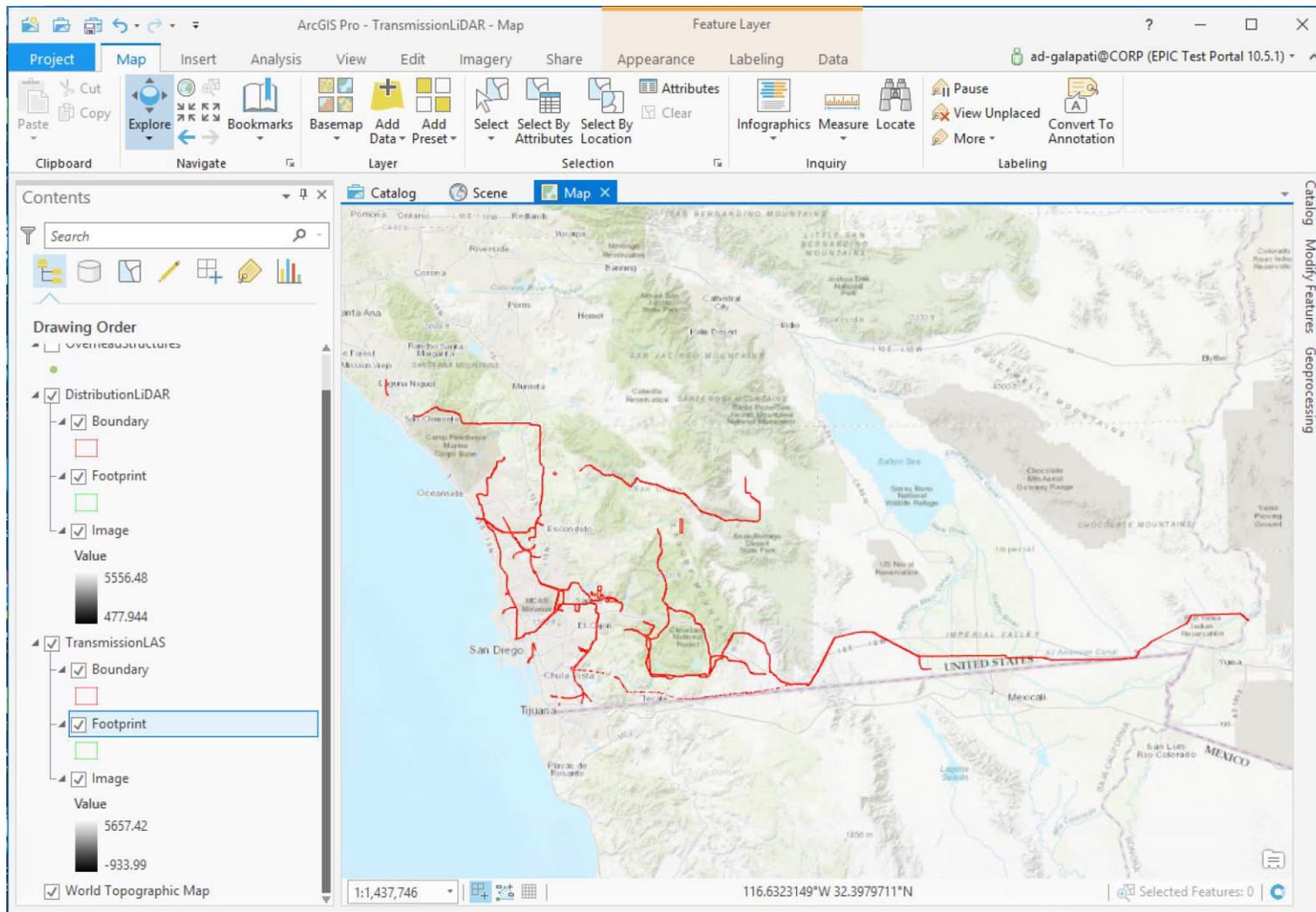


Figure 2-60. LiDAR Data Extent (red lines are boundaries of LiDAR extent)

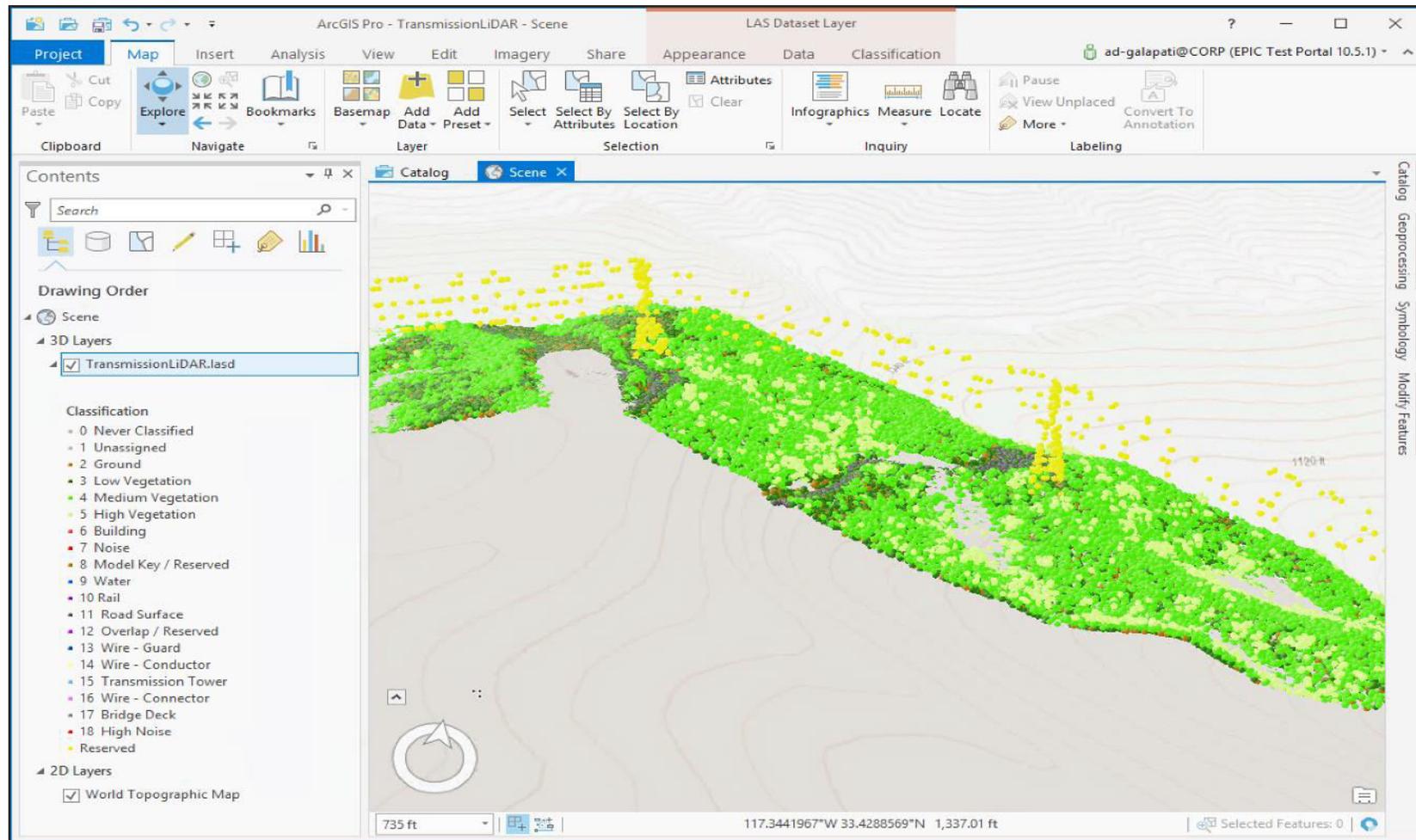


Figure 2-61. LiDAR Data in 3D in ArcPro

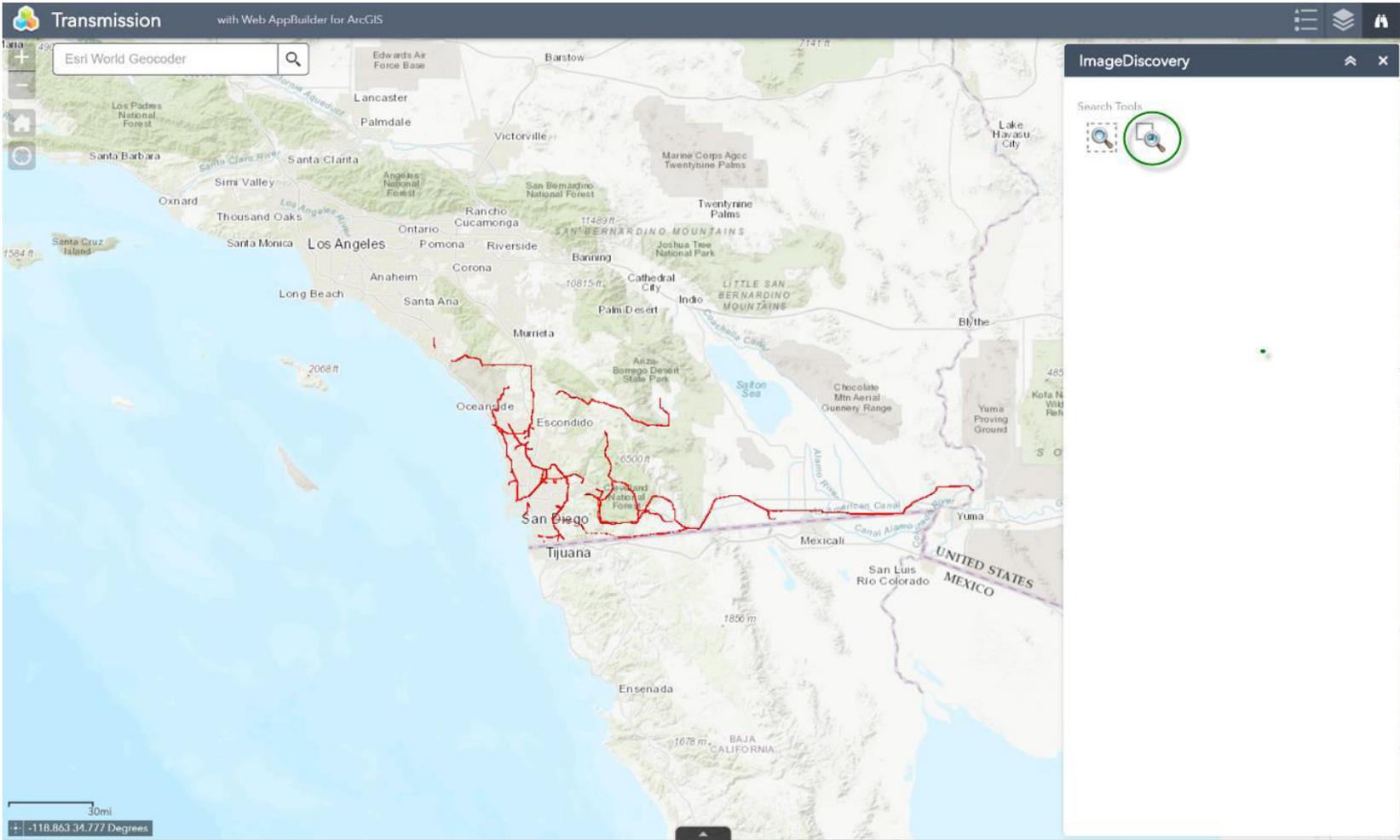


Figure 2-62. Search Tool with Search by Area Extent Circled

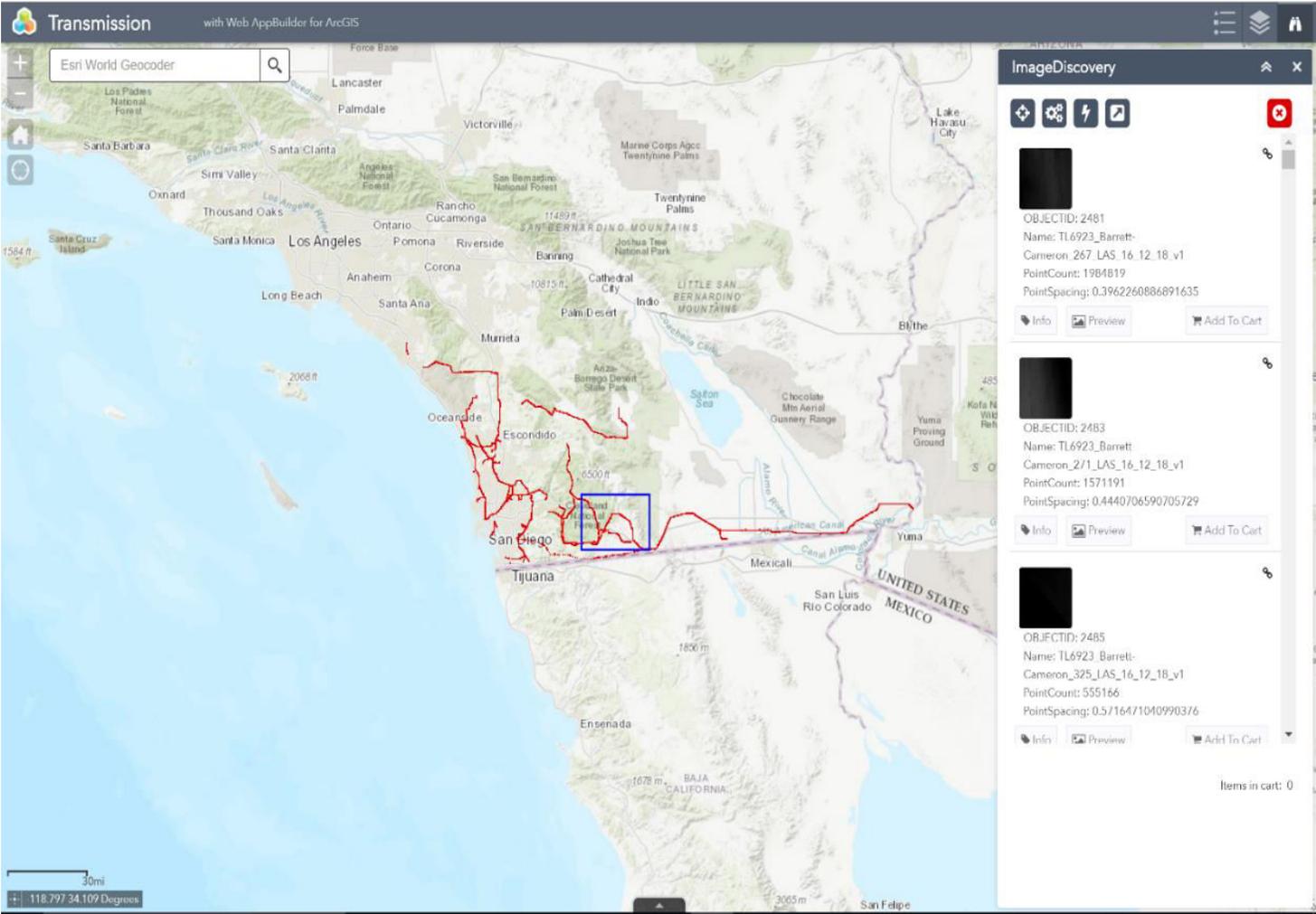


Figure 2-63. Selection of Image Files Based on Area of Interest

From here, the user can preview and download a file of interest by clicking on the file icon of interest.

In addition, the capability to search by Facility, Tipline, or Circuit ID, as well as filter output on specific dates or date ranges, is also provided, all with a look and feel similar to the other query forms.

2.7.6 Observations, Challenges, and Lessons Learned

Challenges and Resolutions

- Multiple vendors (five) work with different SDG&E departments and use about 20 different image data types. Metadata for images is not standard for all the vendors (or across departments). Development of a way to visualize through a consistent interface is a challenge
- Data cleanup is necessary to use the data in a GIS workflow. This is a laborious process. Also, the archived data obtained from different vendors often does not have labels or any references between the Image and the Transmission data. Where missing, this type of data needs to be constructed to achieve better performance, which, again, is a laborious process.
- Obtaining data access and finding the right data owners and data took significant time. Processing the imagery datasets requires dedicated hours for the task, anywhere from 5 to 12 hours, depending on the size of data. If the datasets are not processed properly, the downloads cannot be accomplished.

2.7.6.1 Current Limitations for Data Access

- Looking for new image data in source folders takes significant amount of time.
- Permissions to add all users to secured data locations does involve potential risks

2.7.6.2 Solved Issues

- Having data on a common NAS drive and accessing it through a website application mitigates the risks associated with granting permissions for access. In this case, the portal website is the only place to track access and downloads.
- Although the data is in a common NAS folder, different applications can be spawned to use the same data according to the specific requirements, which simplifies the task of managing what application can be shared with which user groups. For example, it is possible to have Distribution data and Transmission data accessible via two different applications; similarly, it is possible to have LiDAR and TIFF data in one application, and JPG and imagery in another application. By managing which applications are being shared by what users, one manages the permissions for data access.
- PDF, CSV, Excel, and all metadata supporting the imagery can be attached and viewed as attachments to the GIS features that serve as reference for Images.
- The application does not allow anyone to access bulk amounts of data; a user can only download a few files at a time depending on the size of data. The application limits the download size of data. The limit can be varied when needed.

2.7.6.3 Future Work

- Add more data and data types within the set supported by Esri
- Maintenance of applications and development enhancements as required by the users

Recommendations

- Identify the right data owners
- Develop an SDG&E standard for image metadata

2.8 GIS Visualization Infrastructure Modernization (UC #8)

2.8.1 Background

The GIS technologies currently implemented for visualizing assets and electrical connectivity as 2D circuit maps and schematics are over 10 years old. Over the same time span, the visualization infrastructure used at SDG&E has seen only incremental improvements through patches and upgrades, with no major changes in the core software stack and data components. Furthermore, the underlying electrical circuits connectivity models and the corresponding data currently supporting various SDG&E visualization needs are physically separated by domains such as transmission, distribution, structural, telecom, and others; in addition, the models have a limitation on the amount of asset details they can capture.

Meanwhile, and especially over the last several years, the GIS-specific technologies, but also broader technologies with a potential to impact GIS visualization, have seen significant transformation. The most notable of these changes are:

- More expressive utility network modeling capabilities that allow for a more comprehensive details capture, as well as more powerful and functional engines that process these models
- Hardware virtualization
- GPU processing
- Software component interfaces via Web Service architecture
- Web browser functionality for viewing, editing, and tracing electric networks
- 3D maps that can support augmented and mixed reality consumption
- Real-time data from drones, Internet of Things (IoT), and smart devices
- Open source technologies
- Machine learning

It is inevitable that at least some of these advancements will find a way to improve GIS visualization capabilities in the industry at large, and at SDG&E in particular. With a view toward inevitability of improvements in the SDG&E GIS capabilities through accommodations of more advanced GIS and GIS-related technologies, SDG&E envisions a need to research and identify those modernizations in the industry (including hardware, software, data model, connectivity, and databases) that can help to better support SDG&E visualization of asset maps and schematic diagrams, both in the office and in the field. The specific modernizations of interest are:

- **Hardware:** Modernize CPU with GPU processor
- **Virtualization:** Modernize Citrix with VM Ware
- **Software:** Modernize 32-bit ArcMap with 64-bit ArcGIS Pro
- **Architecture:** Modernize direct database transactions with services-based transactions

- **Data Model:** Modernize the current Electric data model with Utility Network data model
- **Data Content:** Modernize asset content by reducing abstraction from field and as-built conditions
- **Connectivity:** Modernize Geometric Network with Utility Network
- **Database:** Modernize Oracle with Postgres
- **Apps:** Modernize front-end Web technology with Node.JS-based technology

These examinations will require significant effort, spread over time. Examinations within this use case constitute a beginning of this examination effort, and have as its objective a subset of the required activities as listed in the next section.

2.8.2 Objective

The objective of Use Case #8 is to conduct an initial investigation of hardware and GPU virtualization, as well as options to modernize the front-end Web technology.

2.8.3 Users

- GBS – GIS Business Solutions
- T&D Engineering
- Electric T&D Construction

2.8.4 Solution Components, and Approach

2.8.4.1 Solution Components

- Three widgets
 - Display Manger
 - URL Navigator
 - Net Explorer
- GIS Portal

2.8.4.2 Solution Approach

As part of the EPIC technology demonstration, SDG&E used ArcGIS Pro and Esri beta Utility Network (UN) together with a Hypervisor hardware/software appliance equipped with NVIDIA GRID technology. In other words, a virtual desktop and virtual application approach was used to provision the new GIS and network utility model.

The Hypervisor is a powerful server that is used for running Virtual Machines (VM) to deliver the ArcGIS Pro application to the end users. At SDG&E, desktop GIS users use the VMware ESXi 6.0. At the Hypervisor Operating System level, the VMware ESXi is an operating system running its own kernel that manages the desktop VM. A VMware product known as vSphere allows for an administrator to provision and manage the VM. In vSphere, administrators can configure and allocate vGPU (virtual Graphics Processing Unit) for the VM pool.

For the EPIC demonstration project, SDG&E is acquiring two Tesla M60s to make up the NVIDIA GRID GPU portion of the Hypervisor appliance, allowing for a total of 16 GB of DDR5 VRAM (Video RAM) (8 GB's per GPU). NVIDIA's GRID vGPU Manager allows administrators to create 1-GB, 2-GB, 4-GB, or 8-GB vGPU's for the Virtual Desktop pools.

For load testing, the following ratios are estimated: 1 GB = 16 Virtual Machines, 2 GB = 8 Virtual Machines, 4 GB = 4 Virtual Machines and 8 GB = 2 Virtual Machines. Using the various profiles, SDG&E plans to obtain performance metrics to help understand user density optimizations. For the EPIC demonstration, the configuration applies to the VMware products ESXi, vSphere, and Horizon View.

At a high level, the diagram (Figure 2-64) from NVIDIA illustrates how it works.

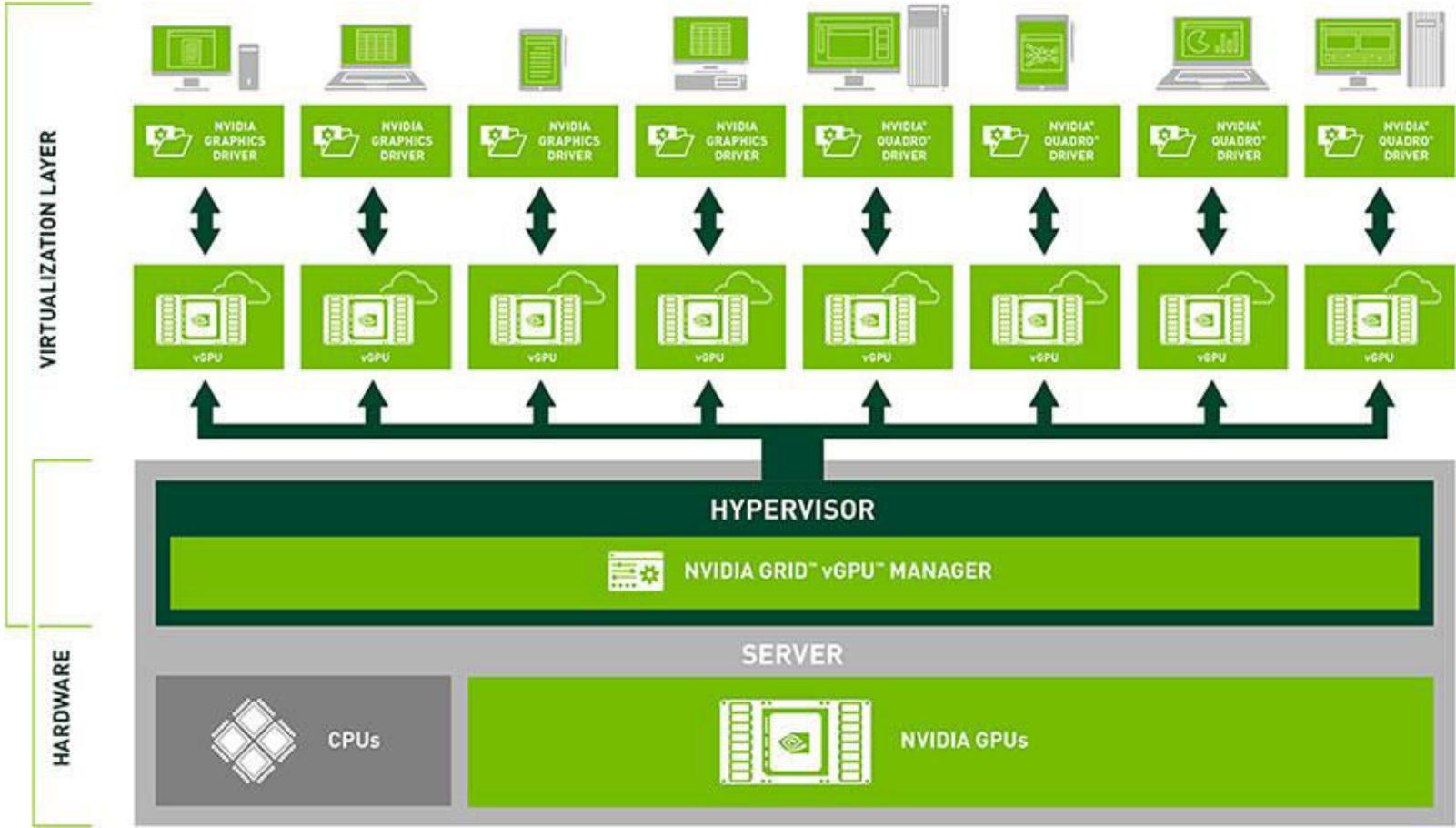


Figure 2-64. Virtualization of GPUs

VDI versus Terminal Services Discussion

As noted, the GPU server Hypervisor servers can also be supported on the VMware or the comparable Citrix environments (XenServer and XenDesktop). Currently at SDG&E, the electric GIS desktop is deployed using a Citrix XenApp (terminal services) approach. From the business user's perspective, they are accustomed to using several applications at the same time. For productivity, their preference is to access multiple applications using the same virtual desktop window. To satisfy this need, using the XenDesktop approach would require the various applications that would require a different Virtual Desktop images. Additionally, they would need different Virtual Desktop pool deployments to support the different application licensing. With XenApp, it is not possible to simply add all applications into one image to meet each of the user needs.

From an IT perspective, the preference is also to deploy a desktop using the Citrix XenApp application virtualization rather than XenDesktop (VDI). The XenApp allows the teams to rapidly deploy GIS updates. From the Citrix administration standpoint, dealing with the client image management and non-GIS applications users' need is of less of concern.

For the EPIC technology demonstration, the focus was on VDI deployment. Via discussions with the technology vendors, it was found that using XenApp paired with ArcPro resulted in reduced application performance. This was not a Citrix limitation or an issue with ArcGIS Pro but rather the Server Operating System (Microsoft Windows). In a XenApp scenario, one typically assigns a vGPU to a Virtual Server. When a user launches an instance of ArcGIS Pro via XenApp, a session is created on the Virtual Server with no resource allocation guarantee for users. Essentially, what ends up happening is, as users spin up sessions on the Virtual Server via XenApp, the Frame Buffer (a portion of the VRAM for storing bitmaps which make up screen display to the user) runs out of memory. After about 4 users, XenApp Server reaches a state of not-so-great performance.

This will be something that SDG&E needs to consider in the future because the current deployment relies on XenApp. With the expected production deployment of ArcPro and Esri Utility Network several years away, it is hoped that there will be sufficient time to design a strategy to deliver Virtual Desktops to GIS users that present them with a good experience.

2.8.4.3 New Widgets

The three widgets from Avineon that demonstrate an opportunity to modernize Silverlight technology as a part of this effort are *Display Manager*, *URL Navigator*, and *Net Explorer*. A brief description of each follows:

1. Display Manager

The DisplayManager™ widget (Figure 2-65) provides functionality to easily filter map content across multiple layers for user-specified values. This widget also provides capability to apply filters on related features such as feature linked annotation. The typical use of this widget is to display all features associated with a work order or perhaps of a particular status. The widget configuration screen provides the ability to choose the layers and fields to apply the filter on. Figure 2-65 illustrates the display of features for a selected facility (in this case Facility ID = P235245). Figure 2-66 illustrates the use of Display Manager to display features filtered by Owner (SDG&E). An example of what details can be selected are shown in Figure 2-67.

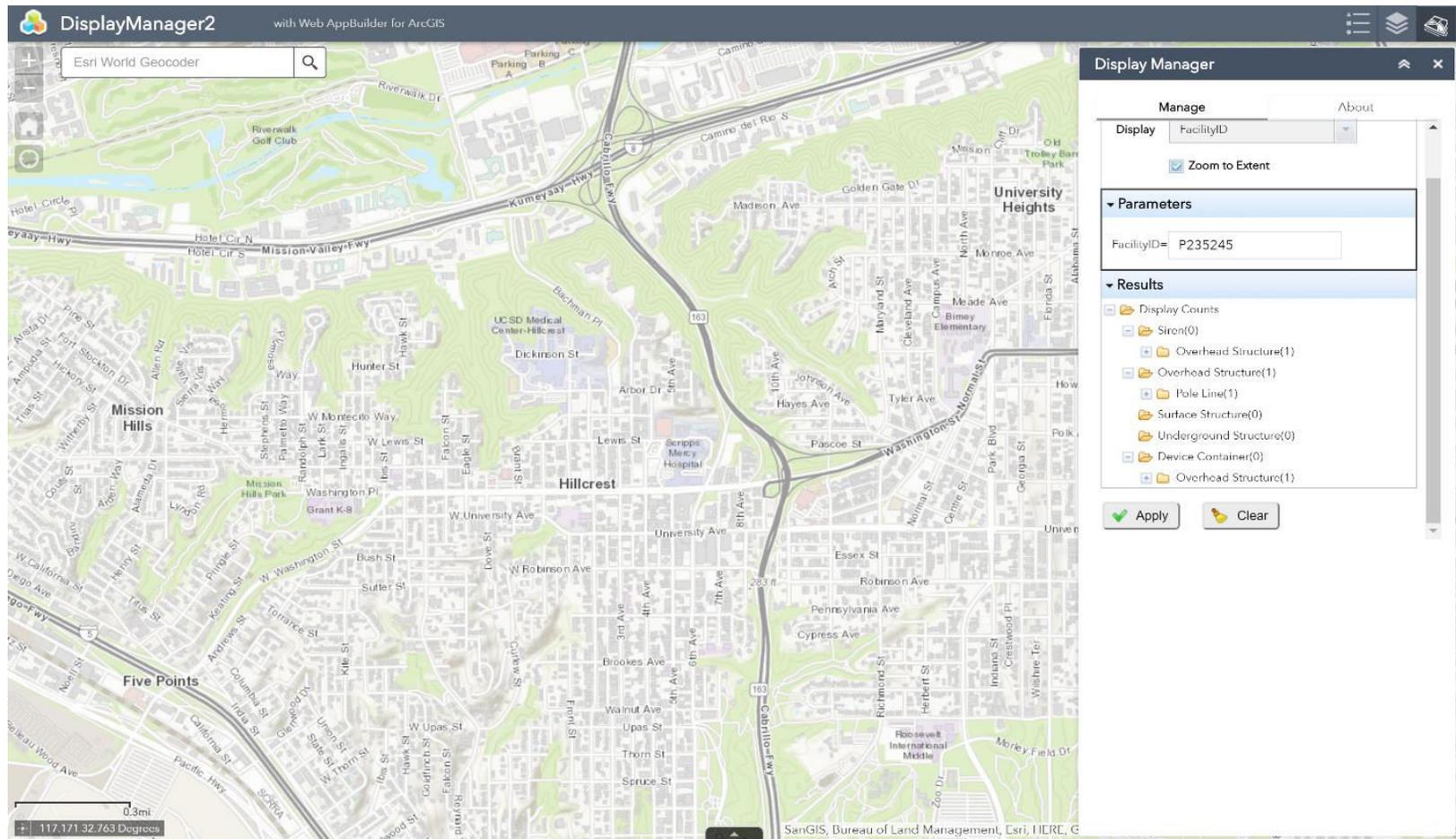


Figure 2-65. Custom Widget: Display Manager, Selection by Parameter

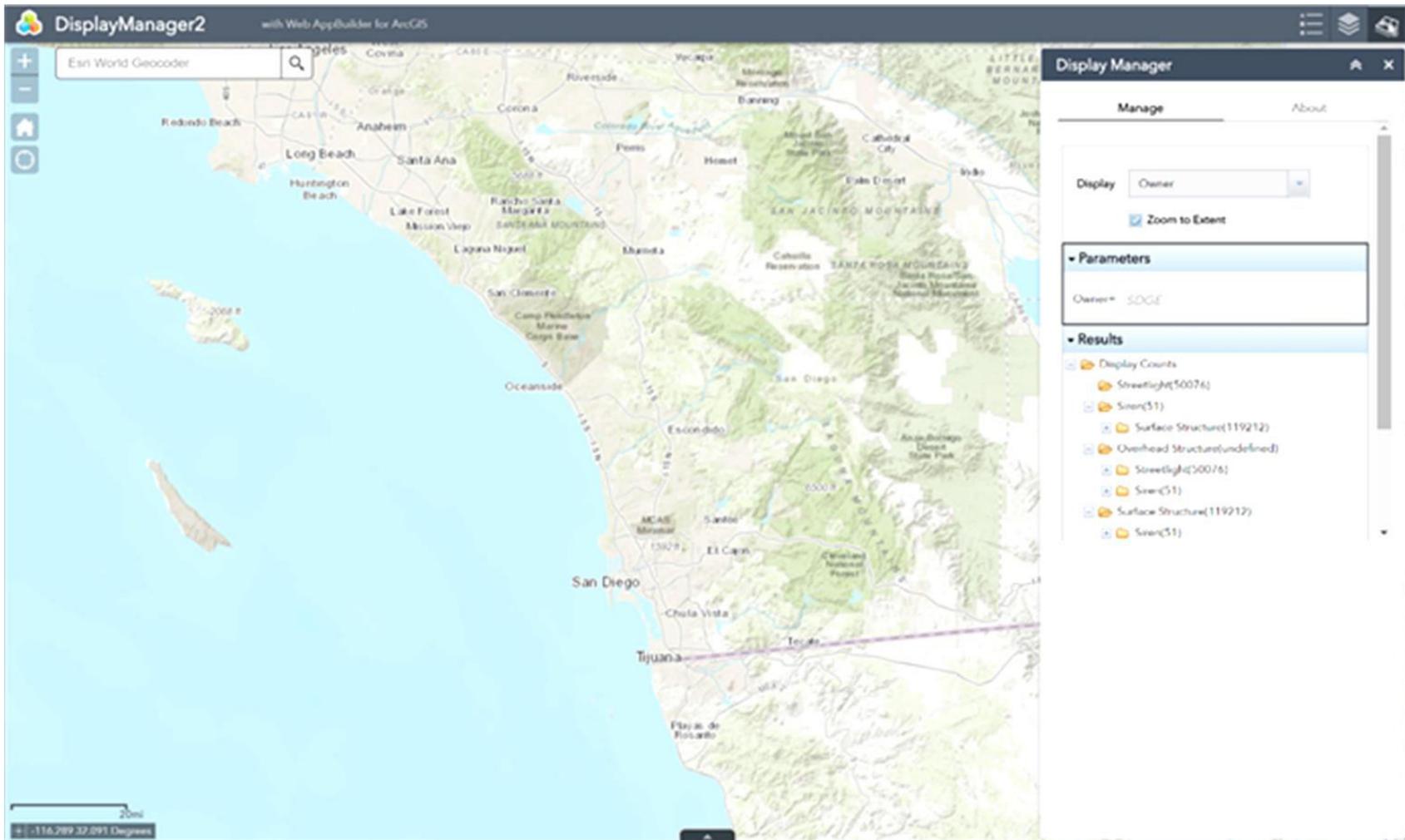


Figure 2-66: Custom Widget: Display Manager, Selection by Owner (SDG&E)

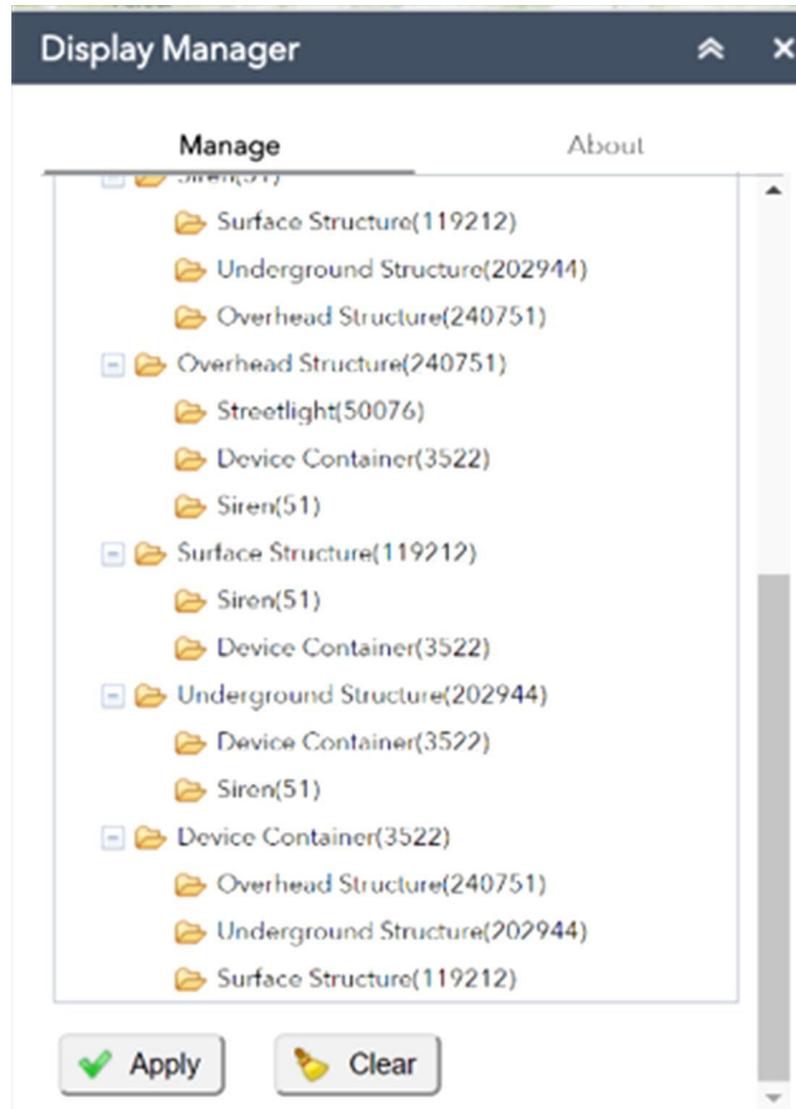


Figure 2-67: Features Available when Owner Selected

2. URL Navigator

The URL Navigator widget displays clickable links for features selected in the map. By clicking on these links, users can open the target web pages either in a new tab or new browser window. The links (URLs) to target pages are constructed by the widget based on the features class, fields, and values specified in the widget configuration and selection screens.

The key capabilities of this widget are:

- i) Add New URL Navigator (the URL links for the selected features are displayed in the URL Navigator widget)
 - (1) Parameter Details
 - (2) Types of Parameters
 - (a) Add Parameter
 - (i) Parameter with Text
 - (ii) Parameter with Field Value
 - (iii) Parameter with Subtype/Domain
 - (iv) Parameter with Coordinates
 - (3) Edit Parameter
 - (4) Delete Parameter
 - ii) Edit URL Navigator
 - iii) Delete URL Navigator

An example of the LiveStreet link is shown in Figure 2-71; the Google Maps example link is shown in Figure 2-72.

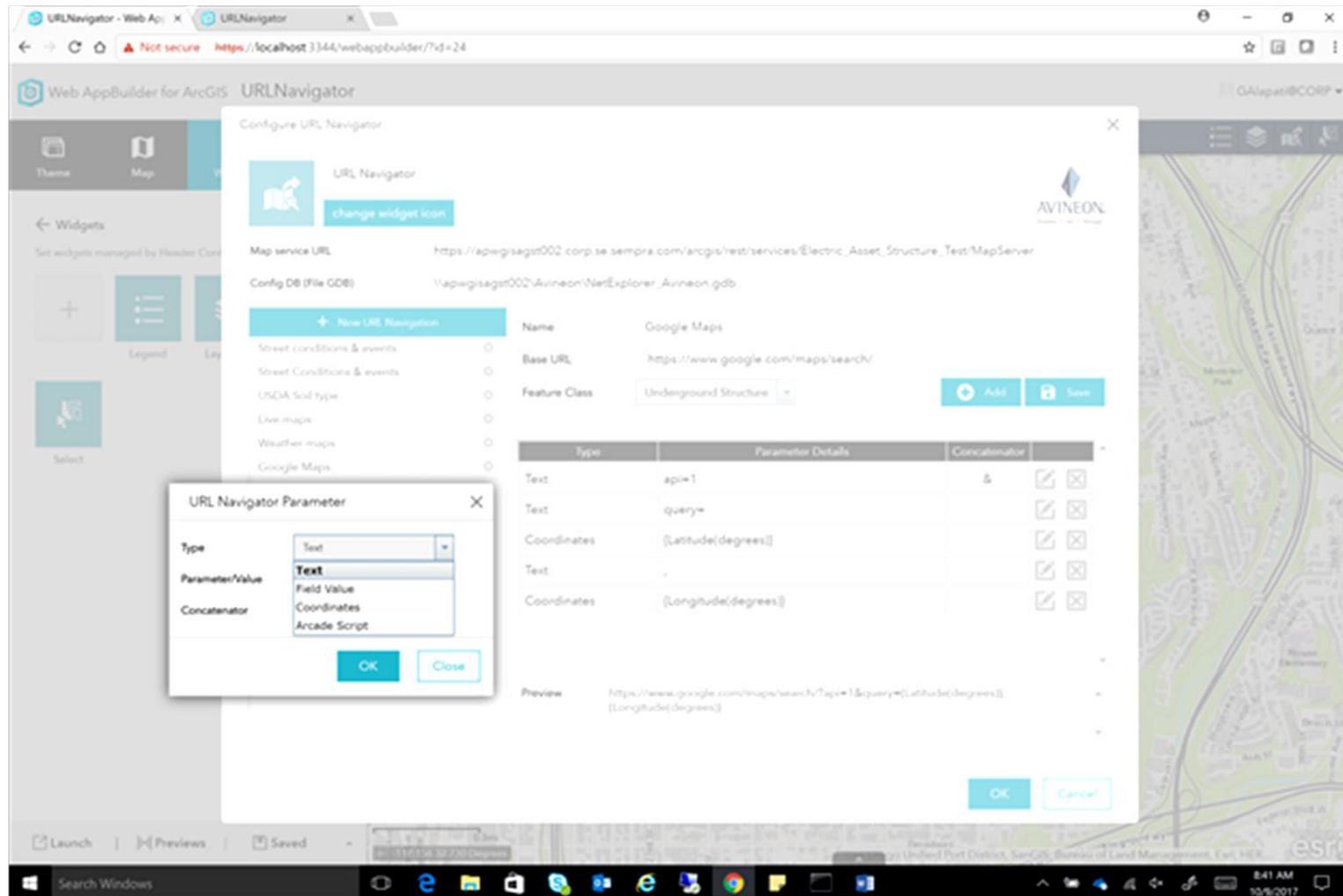


Figure 2-68. UI for URL Formation

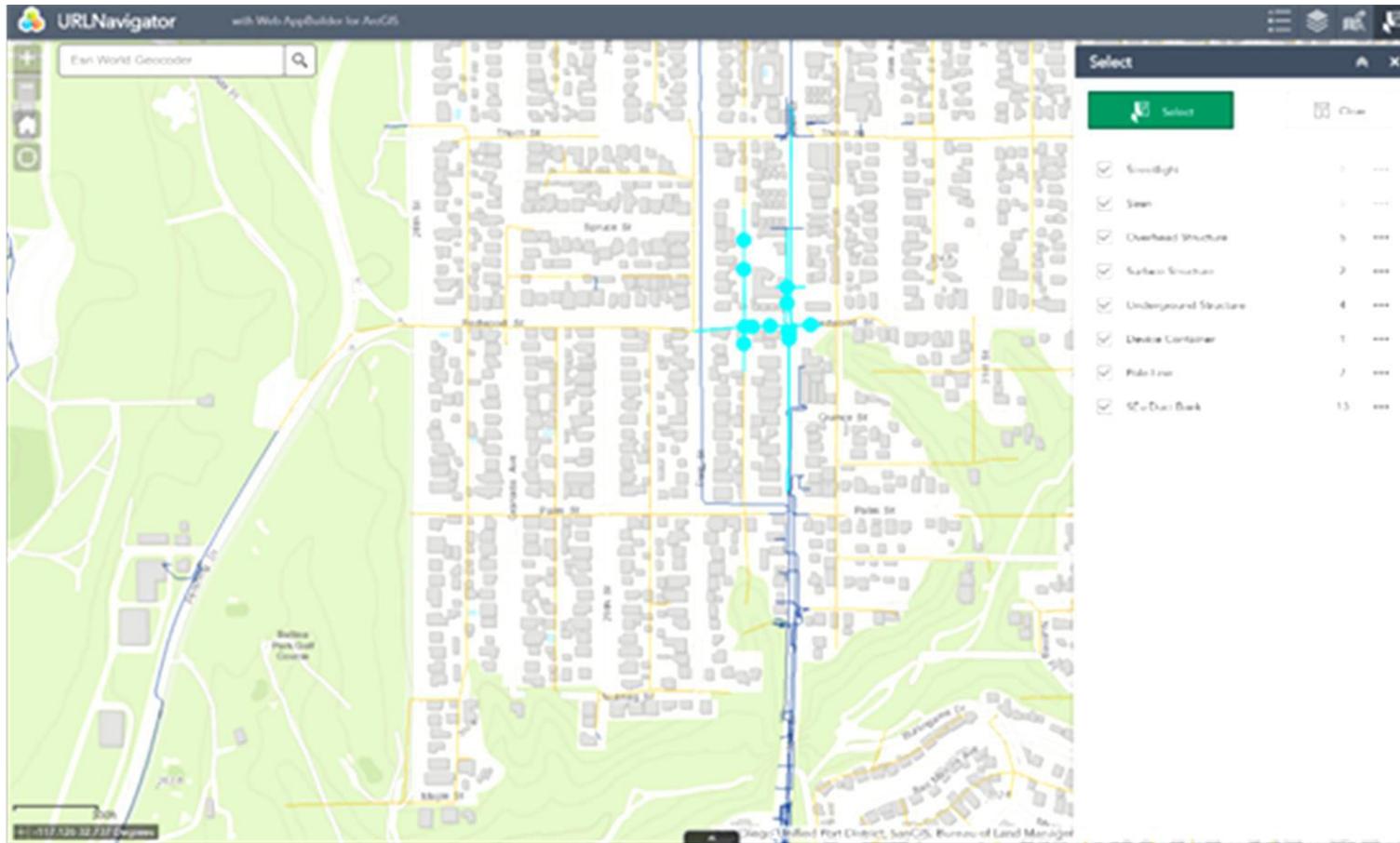


Figure 2-69. Select Desired Features to Display via URL

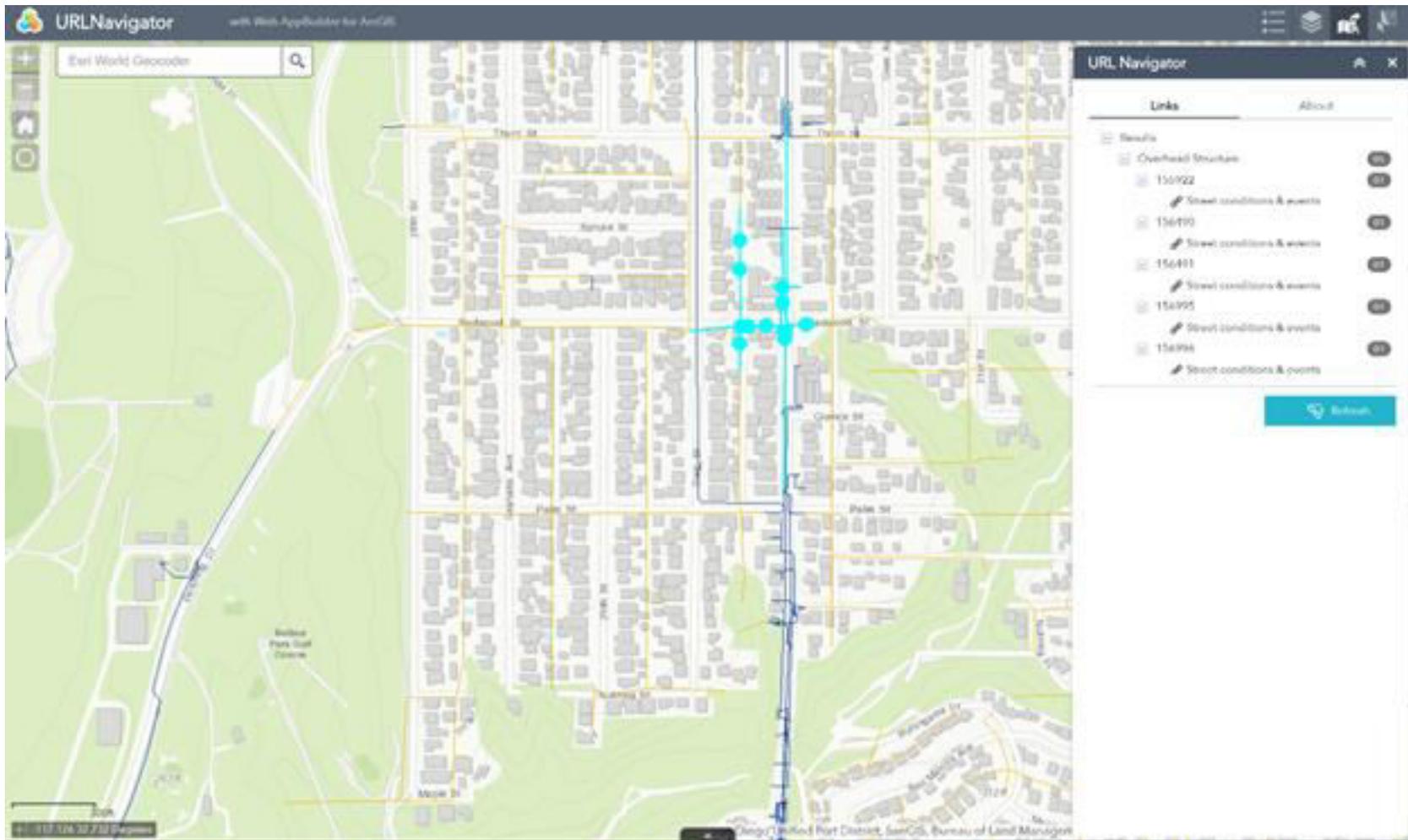


Figure 2-70. Example of Created URLs

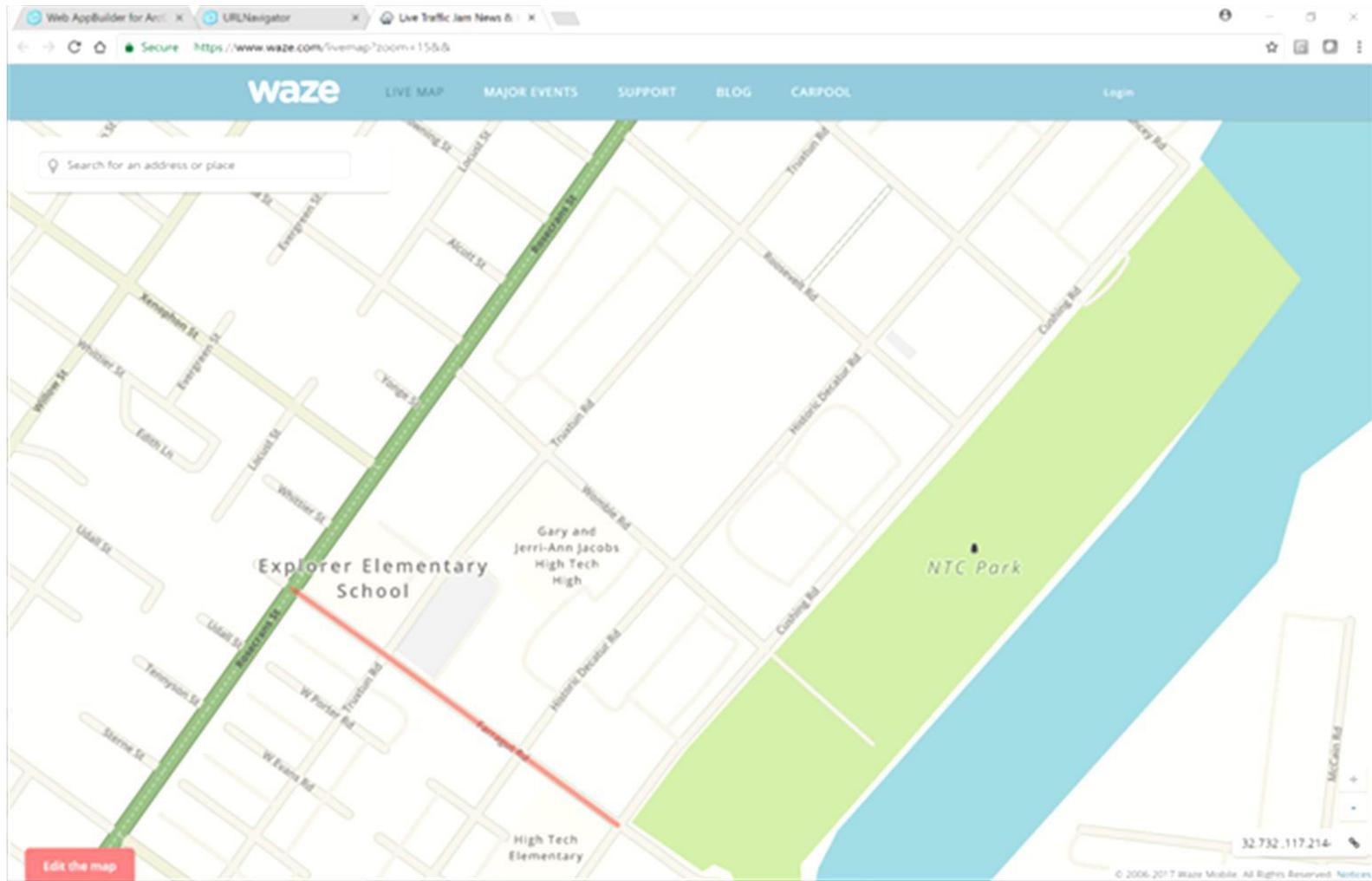


Figure 2-71. Example URL to LiveStreet

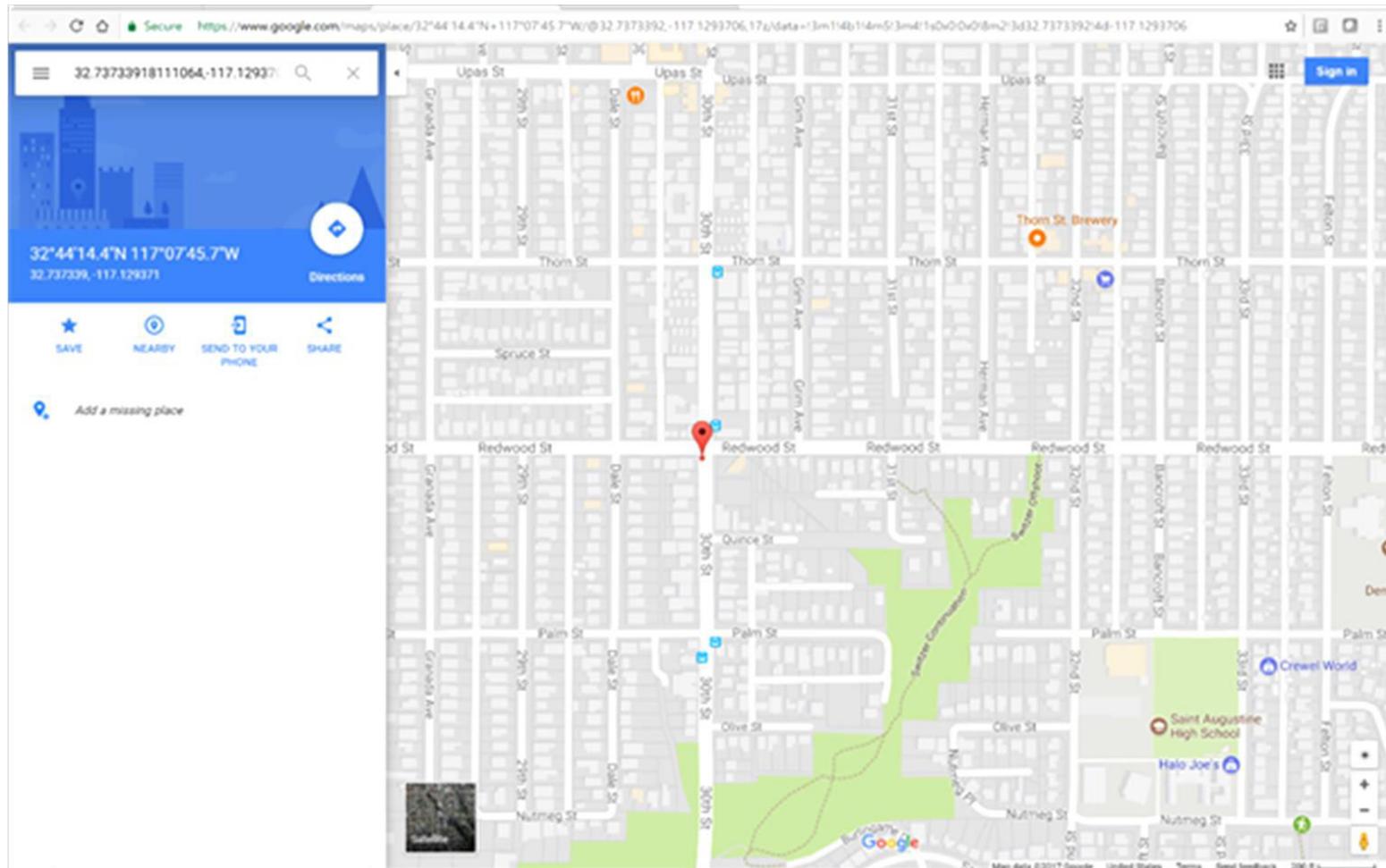


Figure 2-72. Example URL to Google Maps

3. Net Explorer

NetExplorer is an easy-to-use widget to trace and report on electric networks within GIS using a web browser.

Similar to the tracing functionality available in desktop GIS, this web widget provides intuitive functionality for users to specify starting points and stopping points (optional), run traces, and report on asset connectivity. Users can see trace results displayed on the map and also summarized by each GIS layer. The trace results are also available for deeper interrogation and analysis. This configurable widget can be made available to end users in **Basic** and **Advanced** modes. The basic mode is highly suitable for GIS end users and requires little-to-no training.

The key capabilities of this widget are:

1. Select Trace to Run
2. Key In Parameters
3. Select Stopping Points (optional)
4. Run the Trace
5. View Summary of Trace Results
6. Summarize Trace Results By Fields of Interest
7. Interact with Trace Results
8. Save Trace Inputs for Reuse

The advanced mode is suitable for business analysts and users that need more choices and flexibility when tracing networks and provides following additional capabilities:

1. Select Network to Trace
2. Specify Trace Task
3. Specify Starting Points for the Trace
4. Specify Trace Options

An example of a display to configure Trace to run is shown in Figure 2-73, and the results are shown in Figure 2-74 and Figure 2-75. Show Related on Output tab shows customer information for the selection.

In the “Details” tab, there is an option to display related records by features. When selected, an output, like that shown in Figure 2-76, will be obtained, where customer information is part of features.

The results can be saved with a name and shared with other users. This particular trace is saved as ‘AssetsOffSwitch’.

The ‘Exclude’ option on Input can be used to exclude certain features from the trace results. A difference between including and excluding certain features is illustrated by Figure 2-77 and Figure 2-78.

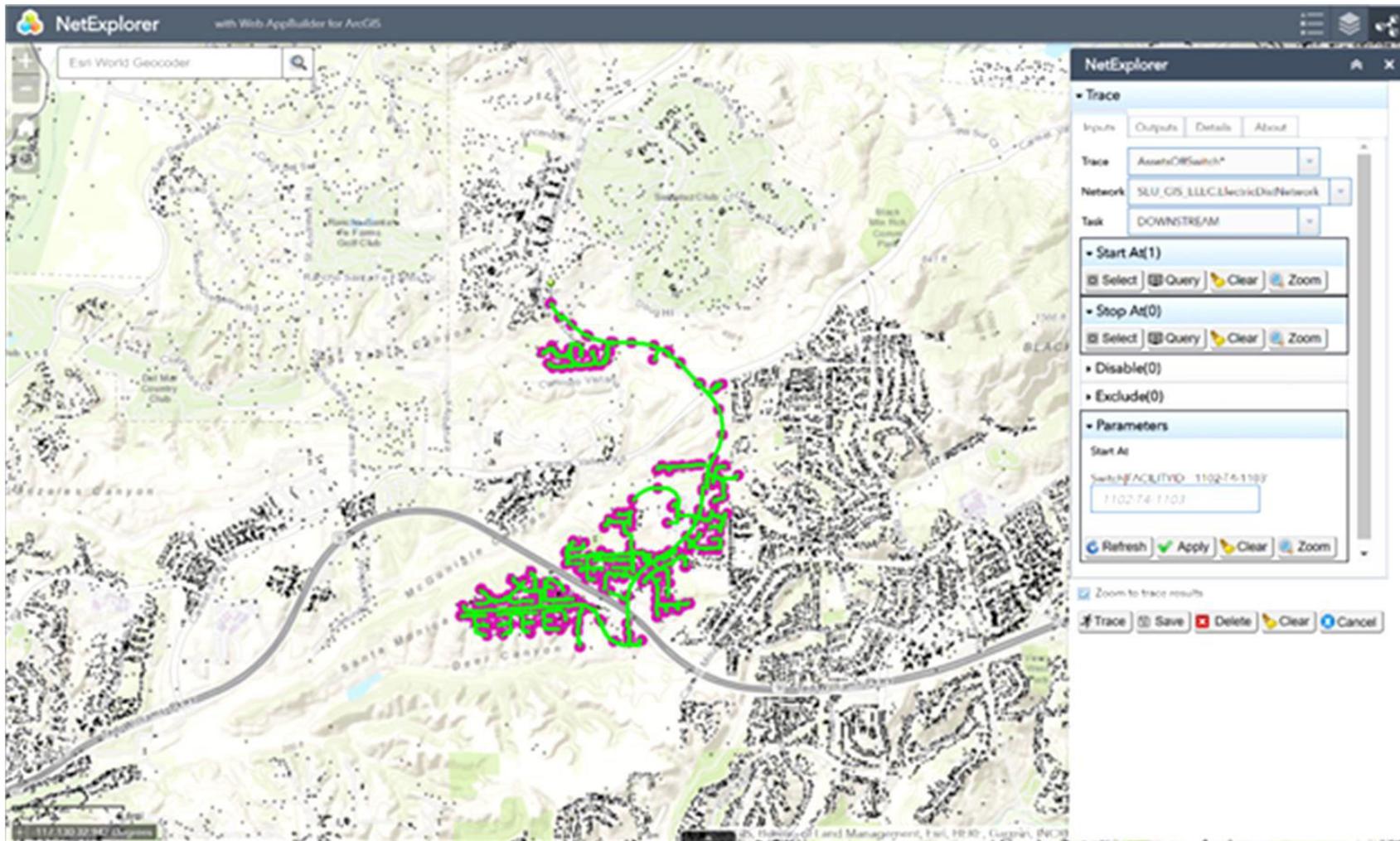


Figure 2-73. NetExplorer Trace Configuration Display

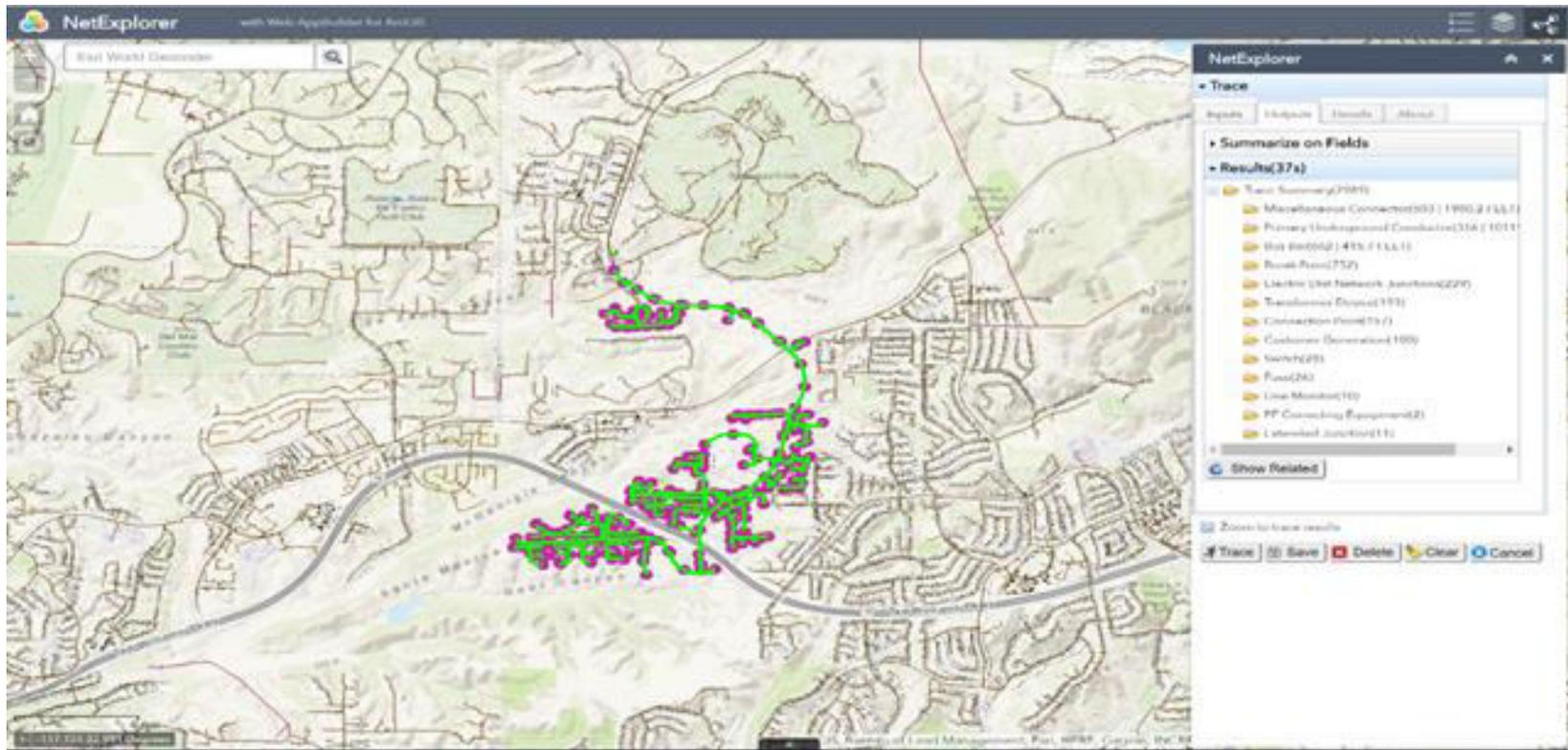


Figure 2-74. A NetExplorer Trace Output

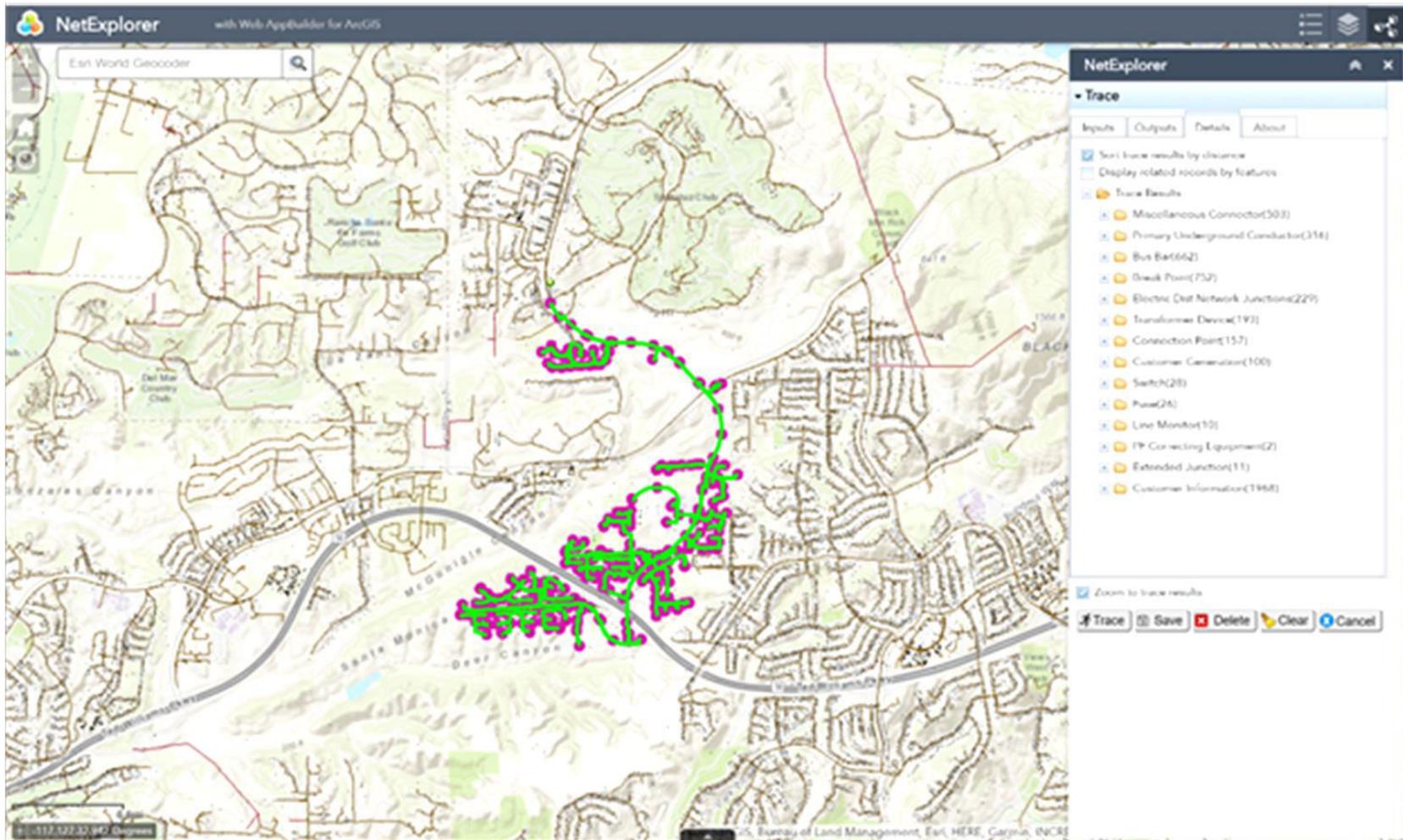


Figure 2-75. Details of the Trace (on Details tab)

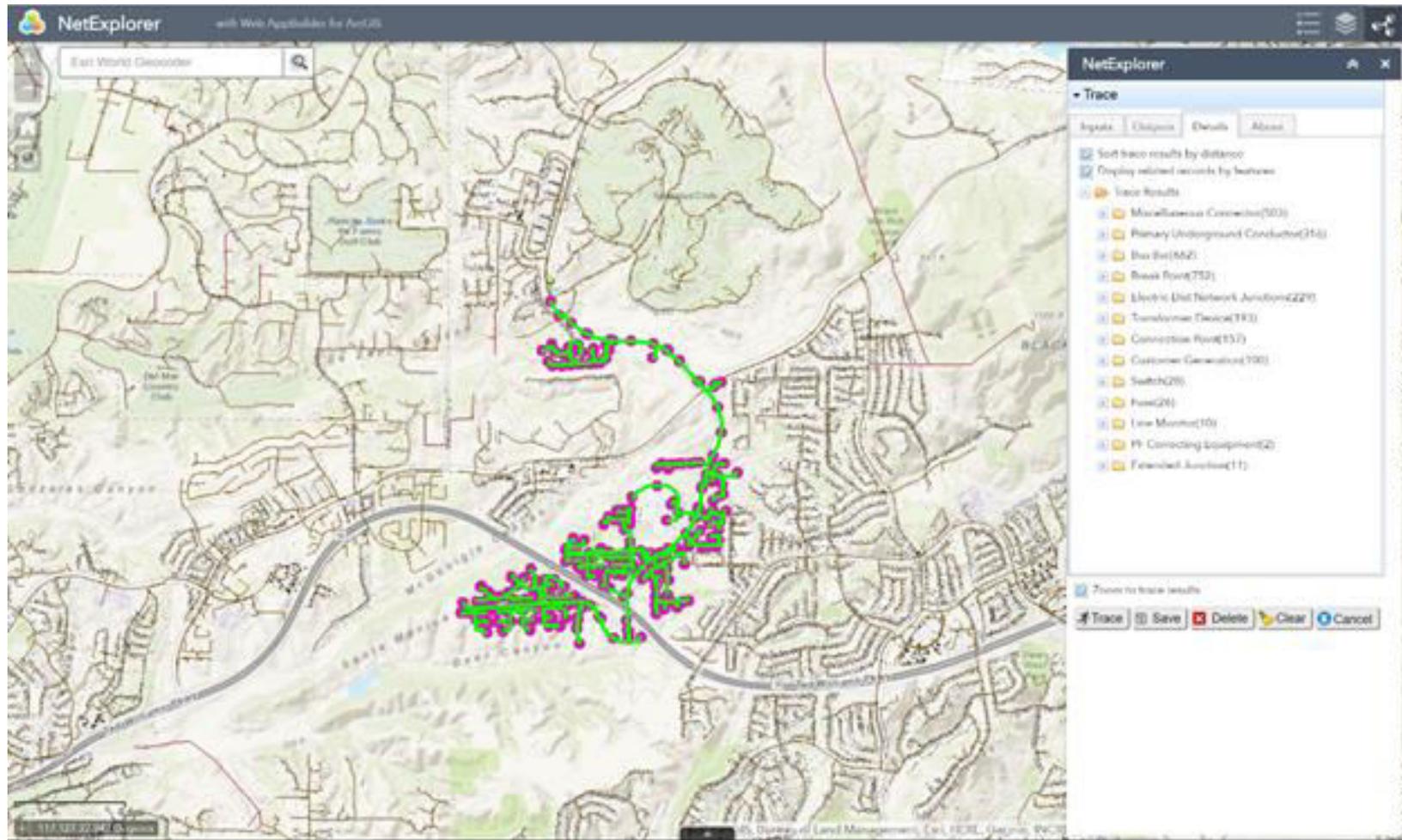


Figure 2-76. Display Related Records by Features

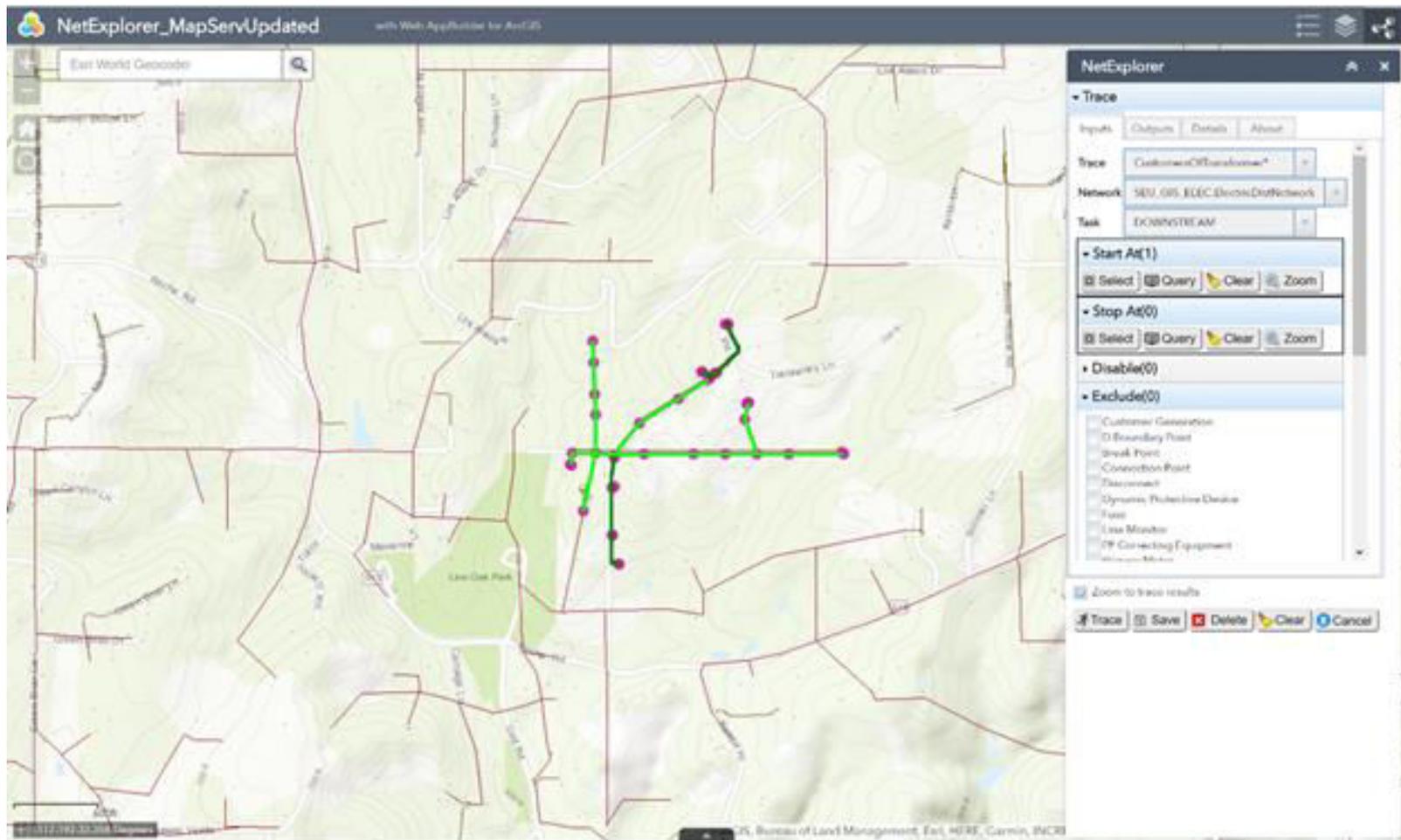


Figure 2-78. Same Display with Included Features (no exclusions)

While saving the trace results (for sharing with other users), the 'Exclude' options are also saved.

'Basic' users can view trace results created and saved in 'Advanced' mode. In the 'Basic' mode, the users can select start/stop by clicking on a map and view the trace results, but cannot apply advanced filters and exclude and disable feature classes.

The available Input, Output, and Detail options for 'Basic' mode users are illustrated by Figure 2-79, Figure 2-80, and Figure 2-81.

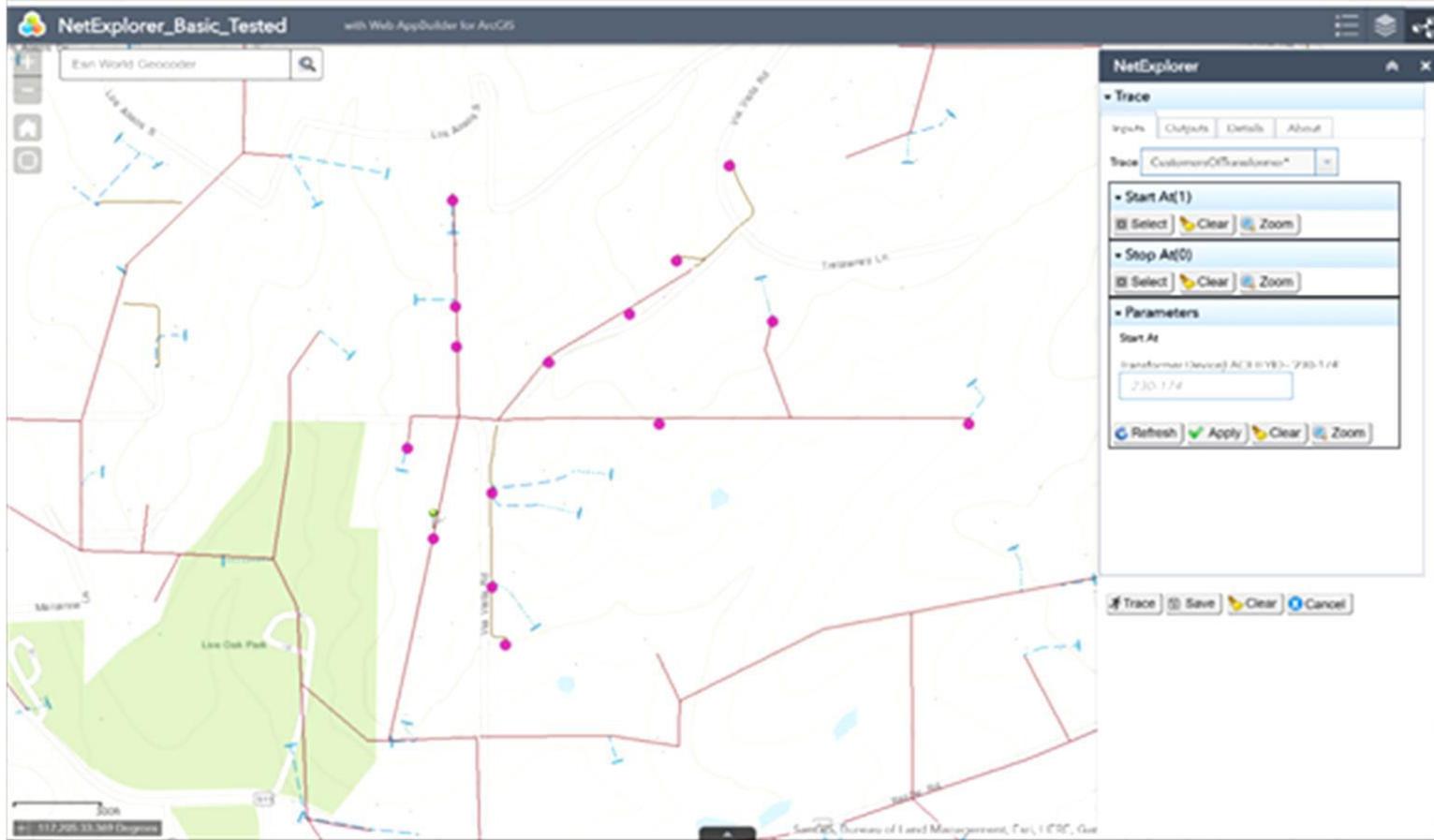


Figure 2-79. Basic Mode Trace Input Options

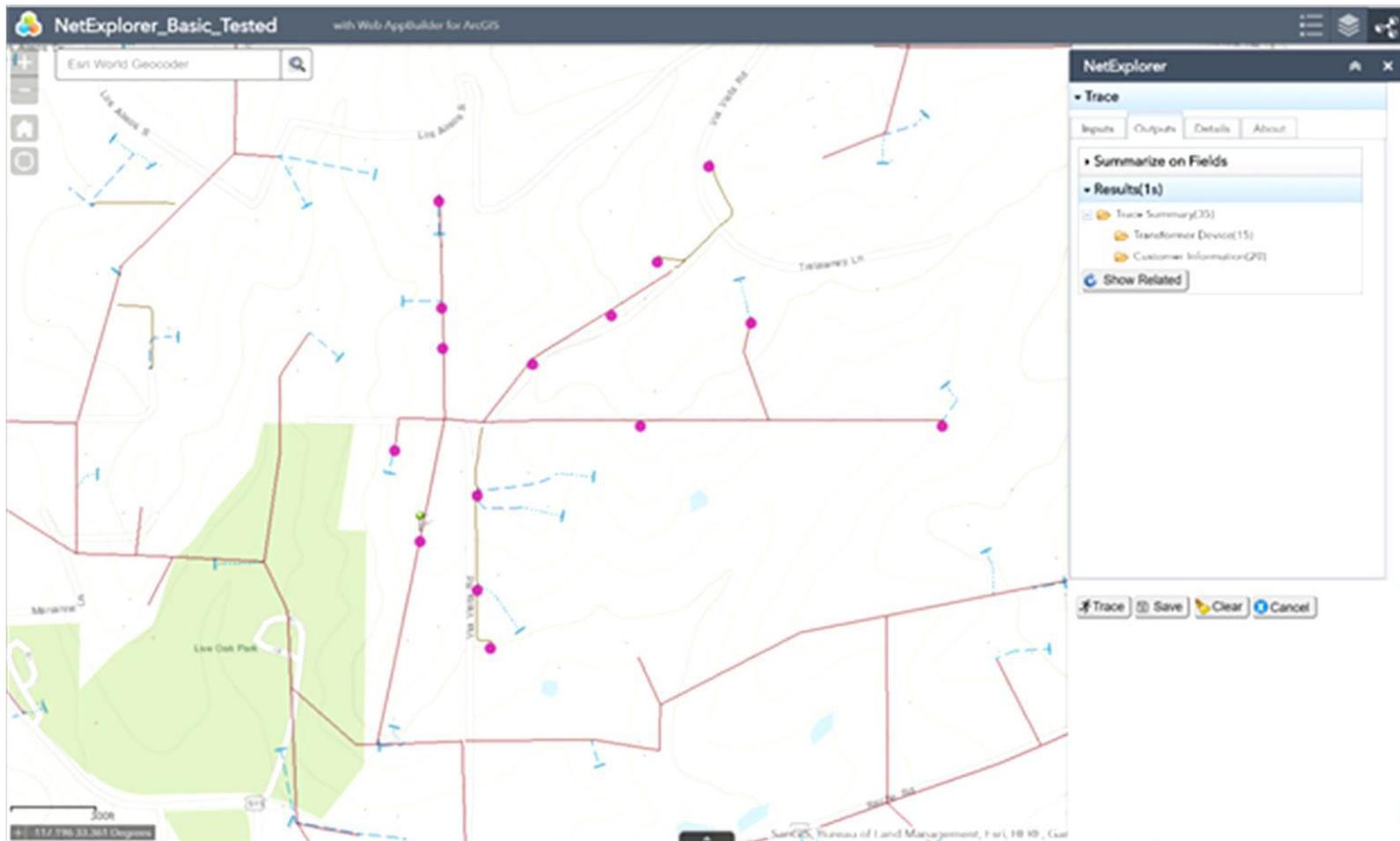


Figure 2-80. Basic Mode Trace Output Options

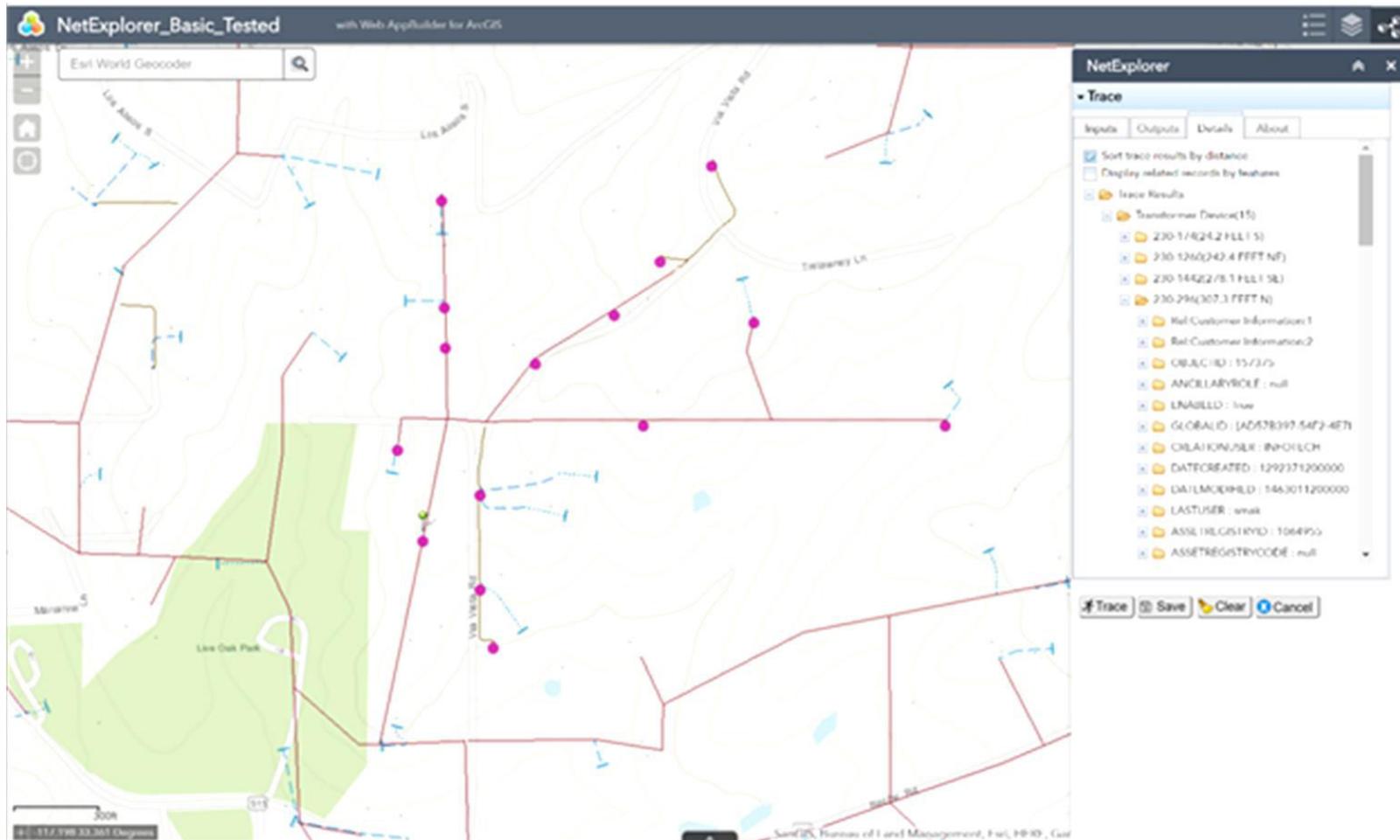


Figure 2-81. Basic Mode Trace Details Options

2.8.5 Observations, Challenges, and Lessons Learned

Challenges and Resolutions

- Extracting data from the existing system and converting the existing models into the new model by both leveraging the capabilities of the new (and different) modeling structure while maximizing the reuse of the useful information from the existing models. This process is time consuming and involves an assessment of whether there are benefits to reformulating the network model within the new framework; the performed work marks only the beginning of what will be a long and an ongoing process to carefully evaluate all aspects of this process on a few pilot circuit implementations before undergoing a full scale transition.
- Currently, geoprocessing is slow when the new full-facility models are used (some other use cases within this project even used simplifications of the existing, old asset models to speed up rendering to an acceptable level for those use cases, and the new models are significantly more complex, with the corresponding effect on rendering speed). Therefore, an objective of this use case was to assess if and what new virtualization-based HW platform improvements are required to be able, in the future, to configure an environment for SDG&E users with sufficient performance for GIS rendering of new models.
- The solutions exercised in this use case are based on brand new components (e.g., some of the components are in beta release), with little experience in the industry to draw from.
- This is still a work in progress relative to the larger scope of modernizing SDG&E GIS infrastructure, but the completed results of this use case have produced initial observations and experiences that will be leveraged in the ongoing efforts on this subject.

3 KEY ACCOMPLISHMENTS AND RECOMMENDATIONS

3.1 Key Accomplishments

With the solutions demonstrated in the project, the SDG&E project team has made significant improvements over the state-of-the-art approaches at SDG&E in each of the areas addressed by the eight use cases. The following lists some of the key accomplishments of these efforts:

- Real-time feature updates on maps based on the time varying data from PI has been successfully resolved by the use of OSISoft PI Integrator for Esri ArcGIS and Esri GeoEvent Extension for Server products. This mechanism is reusable and has been extensively used across multiple use cases.
- The team has successfully integrated standard and custom PowerBI widgets within various maps, in combination with other feature layers. In the course of the widget development, the emphasis was placed on the widgets' reuse, resulting in a reuse on multiple use cases.
- Electrical circuits layers are extensively used in some of the use cases. The team has found a way of simplifying the asset models of electrical circuits for an improved (better than an order of magnitude) rendering speed of electrical circuits' layers. Where it was taking in excess of 20 seconds to render circuit layers at the beginning of the project, it now takes an acceptable (sub-seconds) time for the same task.
- All use cases have solutions that produce map updates at speeds compatible with expectations of interactive users.
- SDG&E has successfully used GIS processing technologies and GIS analytics to aid in preparation of certain SDG&E mandatory and ad-hoc reports. The process has led to a substation automation of previously manually intensive steps, with savings in the overall processing time measured in days. It is expected that the approach will be extended in the future to cover additional reports.
- SDG&E has completed an initial set of GIS-based applications to help with SDG&E imagery management. Consolidation (in terms of access) of the many imagery sources should help with more effective use and management of these valuable resources in the future.
- SDG&E has begun explorations of 3D utility network modeling for SDG&E and of the associated computing infrastructures needed to support eventual widespread use of this more advanced modeling approach. This new modeling approach has the potential to unify some of the stove pipes GIS models necessitated by the capabilities of the previous GIS technology.

SDG&E is planning to continue with further refinements and extensions of the developed solutions, especially in response to feedback from operational use. Although the basic architectural solutions are believed to be solid, future developments will need to include periodic assessments of the architecture, a search for more robust implementations where possible, and training of future users.

3.2 Recommendations and Insights

Based on the outcomes of pre-production demonstrations, the results for use cases 1, 2, 4, 5, and 6 are recommended for production implementation. Results of use cases 7 and 8 (Imagery Management and GIS Visualization Infrastructure Modernization) have met the narrow objectives set for each of those use cases; however, in both instances, the efforts are just an initial step towards what is required for a more extensive development and investigation (i.e., the cumulative results of use cases 7 and 8 are not ready for production).

Use Case #3 has successfully demonstrated the capability of third-party analytics, in combination with the core GIS system, to substantially automate the process of producing certain time-consuming quarterly reports. Furthermore, the approach is such that it can be generalized, with additional work, to the production of other reports. Ultimately, SDG&E has decided, based on licensing, installation, and training considerations, that a similar outcome can be achieved using products SDG&E already has a license for, and its developers have more familiarity. It is on this basis that the team does not recommend a production implementation at SDG&E at this time.

For the use cases recommended for production implementation, the effort to transition to production is minimal, measured in fractions of FTE, and generally consists of moving the artifacts from the test to QA environments, engineering review, and customer acceptance. In one case (Visualization of Customer-owned DER), no additional work is required beyond what was necessary for the pre-production demonstration.

In the course of implementation, each of the use case teams had to overcome certain challenges, and each has gained valuable insights from doing so. The most notable insights for each use case follow.

UC 1: Transmission Fault Location

- The labor to create the initial reference layers of electric circuits is pretty significant and should be planned for.
- There is a need to setup a process to “re-digitize” electrical circuit lines any time there is a reconfiguration, or to digitize new lines, with an associated process to reflect the changes in PI.

UC 2: Load Curtailment

- From a development perspective, a replacement for the scraping of web pages with a more direct interface would be desirable.
- From a usage standpoint, the development team is expecting quite a bit of feedback from the managers of Emergency Operations Center after a planned demonstration of the function is presented in the near future.

UC 3: Self Service EGI BI Reports

- An investment in terms of time, effort, and training is needed to master Spatial Eye queries and setup of Spatial Eye projects.

UC 4: History Playback

- This insight underscores one of the basic tenets of effective software development – the most important starting point is to collect and formulate solid user requirements
- For effective integration of dispersed data, there is a need to continuously communicate with various stakeholders and data owners
- Widget development is envisioned as a continuous process in order to serve the evolving needs of end customers

UC 5: AMI for Operations

- Design custom widgets to be as generic as possible. In this project, that approach has proven to be very helpful, and such an approach is expected to continue to be helpful in future projects

- Allowing the application to be customizable by end-users helps better match system functionality with user needs, and ultimately it helps with adoption of the function

UC 6: Customer-Owned DER Visualization

- Ideas for converting PV nameplate data to actual data: use an existing nearby solar plant for which there is a real-time data, and apply the same scaling factor between the nameplate capacity and the actual output to rooftop PV outputs in the vicinity of the PV plant. Also, consider use of models, nameplate capacity and metered irradiation data in the vicinity of PVs.
- For batteries, a dashboard similar to the one currently used (e.g., with real time prices to display Day-ahead market prices).

UC 7: Imagery Management

- With data sources spread out over many data owners and locations, one of the key challenges of this use case was identification of the correct data owners
- One of the key efforts to systematize access to imagery is development of an SDG&E standard for image metadata

UC 8: Visualization Infrastructure Modernization

- The experiences gained through the project, due to the novel nature of what was being demonstrated, should be very useful both for SDG&E and the industry at large.

3.3 Technology Transfer Plan for Applying Results into Practice

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within SDG&E and across other IOUs and the CEC, and the wider industry. In order to facilitate this knowledge sharing, SDG&E has been sharing the results of the EPIC SDG&E Visualization and Situational Awareness Demonstrations project at suitable industry workshops and conferences.

The project team believes that visualization and situational awareness solutions developed in this project will be useful beyond SDG&E, and, therefore, the solution ideas and lessons learned will continue to be shared with other stakeholders, to promote further advancements of the integration and visualization solutions initiated in this project.

This final report and all other public papers and presentations on this project will continue to be posted on SDG&E's EPIC public website at www.sdge.com/epic.

4 CONCLUSIONS

This project examined how data currently unexploited and separately processed at SDG&E can be integrated and visually presented for strategic use by system operators. The project also demonstrated technical solutions at a pre-commercial level for how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances grid monitoring and situational awareness.

Enhanced monitoring and situational awareness is achieved by providing a geospatial context for a wide variety of operational, historical, and metering data. Consequently, through the numerous use cases undertaken within this project, it has illustrated how the data commonly used to support diverse business needs at SDG&E can be combined with geospatial data to significantly enhance insights and situational awareness.

The project has successfully achieved all of its key objectives. In the process, the project team and other SDG&E stakeholders have gained valuable experience and a solution framework that can be reused to speed up future developments in the area of situational awareness and integration of real-time and geospatial data.

5 METRICS AND VALUE PROPOSITION

5.1 Project Metrics

The project tracking metrics included the milestones in the project plan. Technical project metrics included the completion of the initial specification for a visualization and situational awareness system, the demonstration of a system display mock-up, and the specifications and recommendations regarding adoption by SDG&E.

Also, major project results were submitted in technical papers and presentations for consideration by major technical conferences and publications.

This section provides more information about the metrics and benefits of the project. The most important benefits are in areas of:

Safety, power quality, and reliability

- a. Ability to monitor, visualize, and analyze visualization information can help reduce number of outages, as well as their frequency and duration. Transmission fault location use case is particularly useful for this purpose.
- b. Public safety improvement and hazard exposure reduction can also be accomplished by advanced visualization tools.
- c. Utility worker safety improvement and hazard exposure reduction

Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy

- a. Description of the issues, project(s), and the results or outcomes
- b. Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360)
- c. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services (PU Code § 8360)

Effectiveness of information dissemination

- a. The visualization platform enables the creation of numerous reports and fact sheets for various users, not only within SDG&E but also on a wider basis, via preparation of conference presentations, papers, and other relevant material.

Adoption of EPIC technology, strategy, and research data/results by others

- a. The technology developed and demonstrated during the course of the project provides a promising basis for building upon and for development of a production version of the monitoring and visualization platform that can be effectively utilized by various stakeholders both at SDG&E and beyond.

After further development of all presented use cases and additional testing, it would be beneficial to prepare a comprehensive description and documentation of the technology that could help with obtaining approvals from the California Energy Commission for further proposals, thereby enabling wide-spread adoption of the technology, first at California IOUs and, eventually, beyond.

5.2 Value Proposition: Primary and Secondary Guiding Principles

The value proposition is to address how the project met the EPIC principals.

Table 1.1 summarizes the specific primary and secondary EPIC Guidelines Principles advanced by the Visualization and Situational Awareness Project.

Table 5.1: EPIC Primary and Secondary Guiding Principles

Primary Principals			Secondary Principals				
Reliability	Lower Costs	Safety	Loading Order	Low-Emission Vehicles / Transportation	Safe, Reliable & Affordable Energy Sources	Economic Development	Efficient Use of Ratepayers Monies
✓	✓	✓					

The Visualization and Situational Awareness Project covers the following primary EPIC principals:

- Reliability:** This project developed tools that give the ability to monitor, visualize, and analyze information which help reduce number of outages, as well as their frequency and duration, giving a higher reliability. Transmission fault location use case is particularly useful for this purpose.
- Lower Costs:** Given the ability to visualize occurring events in near real time to operators, helps deploy maintenance crews more efficiently and effectively. The imagery management use case, for example, aim is to be able to see the data sources visually, in a geographic context, as opposed to searching for the data via file and folder names. This should save time and effort in organizing huge amounts of data.
- Safety:** As mentioned, the ability to monitor events and historical trends, like transmission faults or voltage issues, gives the departments and crews that depend on this information, to have a better assessment on how to approach an occurring issue, or based on trends, evaluate on how to safely plan a future activity.

6 APPENDIX: FOUNDATIONAL COMPONENTS

6.1 Esri GIS Components

This section provides very basic information about the Esri GIS components that have been used in this project. The source of the information is largely from Esri's extensive web-help site <http://resources.arcgis.com/en/help/> (following the contained links).

Esri provides various solutions to meet its clients' GIS needs. Figure 6-1 shows the main components of ArcGIS Enterprise, which is the version used by SDG&E in this project. The diagram shows the main functional groups of components. Subsequent sections contain a brief summary of these groups.

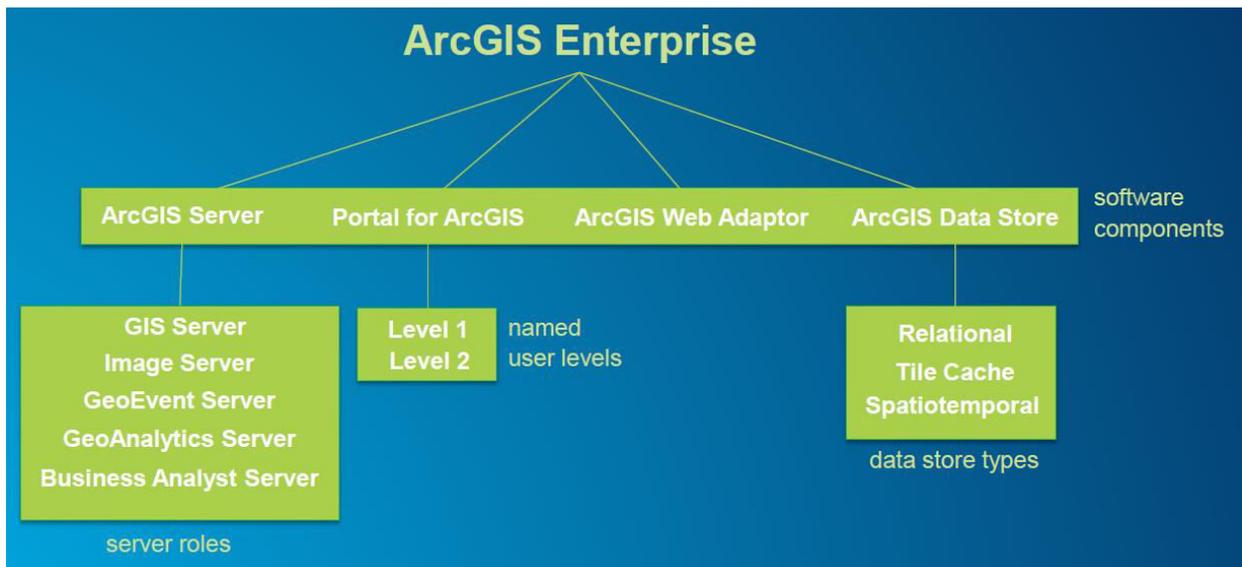


Figure 6-1. Esri ArcGIS Enterprise Components

In the following subsections, each of the functional groups of the ArcGIS Enterprise suite of applications is briefly overviewed based on the information provided on the Esri Web Site.

6.1.1 ArcGIS Servers

There are five different kinds of servers: GIS Server, Image Server, GeoEvent Server, GeoAnalytics Server, and Business Analyst Server. A brief overview of each of these servers is provided in the following subsections.

6.1.1.1 Image Server

ArcGIS Image Server provides serving, processing, analysis, and extracting business value from collections of imagery, rasters, and remotely sensed data. Figure 6-2 shows, pictorially, Esri's depiction of the main roles of its Image Server. In this project, Image Server is primarily used to support Use Case #7, Imagery Management.



Figure 6-2. Esri Image Server

6.1.1.2 GeoEvent Server

The main role of GeoEvent Server (Figure 6-3) is to facilitate updates of geospatial feature of GIS maps based on dynamic data. Within this project, the role of providing dynamic data updates is filled by OSISoft PI Esri Integrator for the dynamic data that resides in PI Historians, and by GeoEvent Server for all other kinds of dynamic data (e.g., weather, fire, etc.).

6.1.1.3 GeoAnalytics Server and Insights

GeoAnalytics Server (Figure 6-4) supports Big Data analytics on the server side.

Insights (Figure 6-5) provides visual programming capabilities to end-users, allowing them to specify sophisticated data analysis and display results on maps within portal for ArcGIS. Insights blends spatial and non-spatial data to bring together spreadsheets, databases, and ArcGIS data.

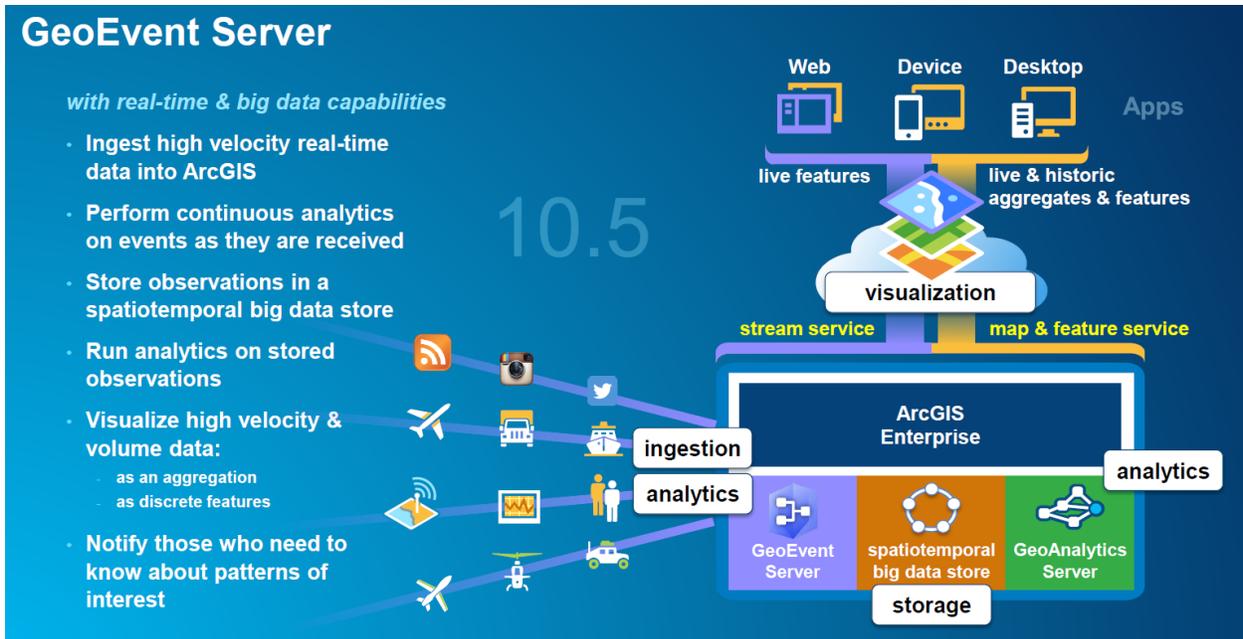


Figure 6-3. Esri GeoEvent Server

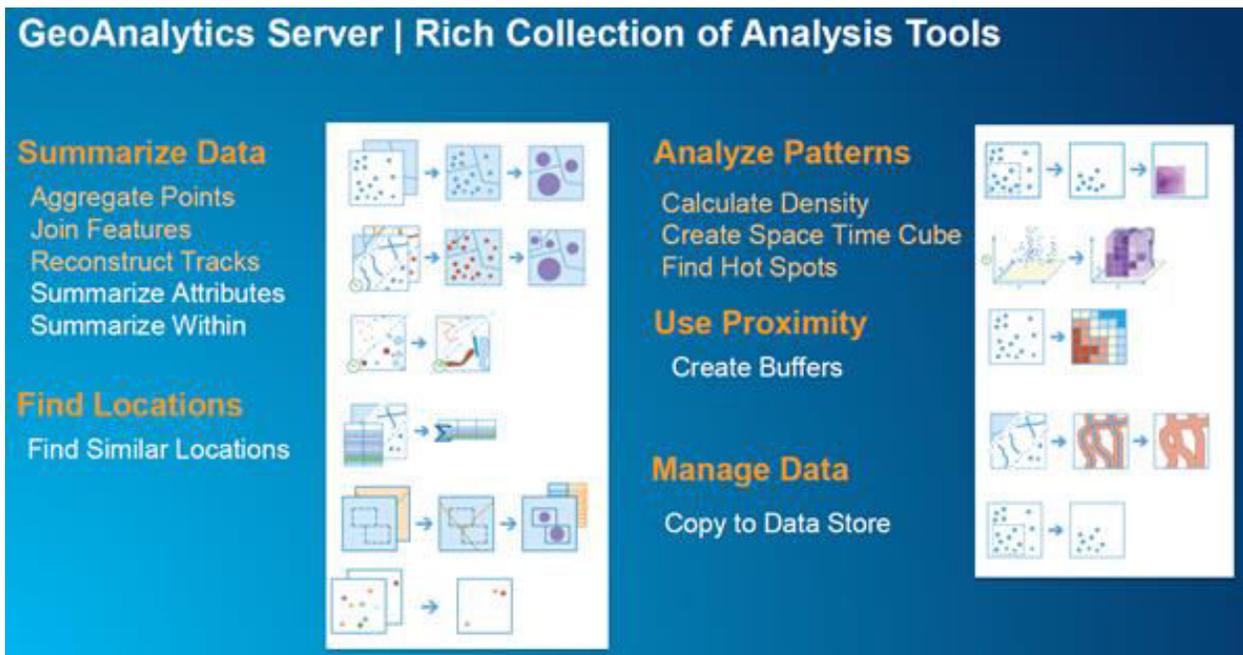


Figure 6-4. Esri GeoAnalytics Server

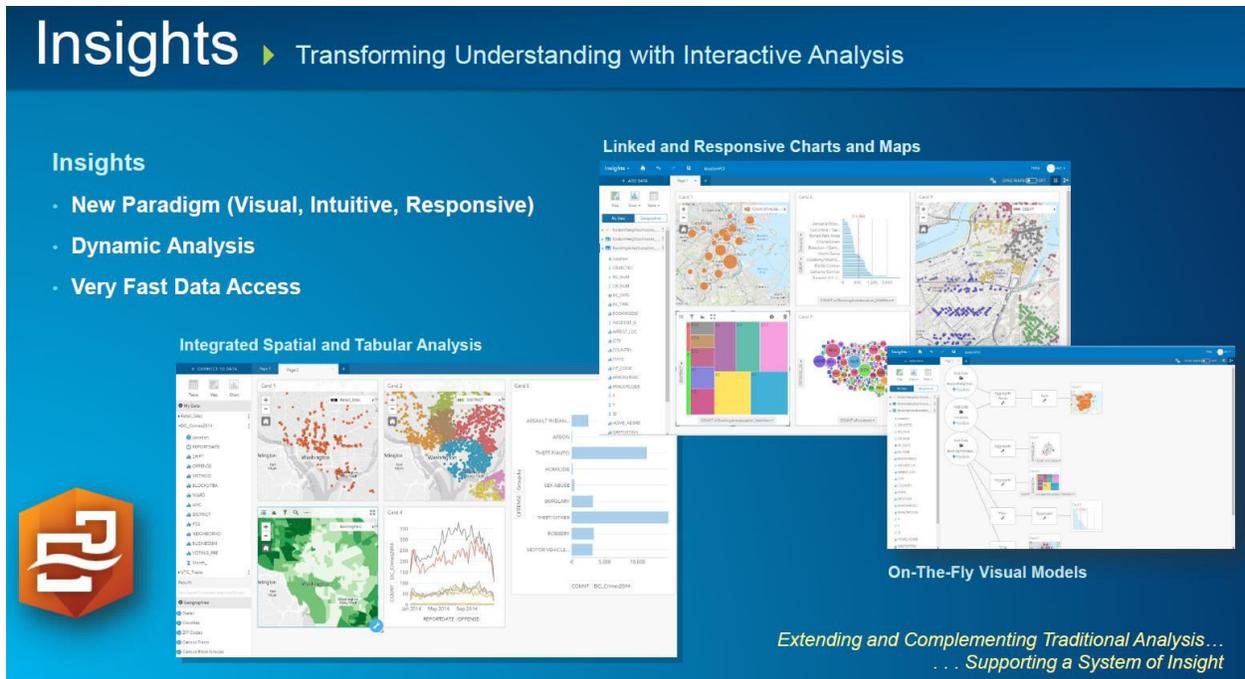


Figure 6-5. Esri Insights

6.1.2 Portal for ArcGIS

This component was heavily used in this project. Portal for ArcGIS allows sharing of maps, scenes, apps, and other geographic information with other people in the organization. The shareable content is delivered through a website. The website can be customized to the organization's visual standards.

Portal for ArcGIS brings together all the geographic information in the ArcGIS platform, and it shares it throughout the organization. For example, with Portal for ArcGIS it is possible to:

- Create, save, and share web maps and scenes.
- Create and host web mapping apps.
- Search for GIS content within the organization.
- Create groups for sharing GIS information with coworkers.
- Share links to GIS apps.
- Share map and layer packages to use in ArcGIS Desktop.

Portal for ArcGIS includes geographic viewers designed for those who are just beginning with GIS. Experienced GIS users can connect to Portal for ArcGIS from ArcGIS Desktop, developer APIs, and other applications.

6.1.3 ArcGIS Web Adapter

The Web Adaptor provides the following features:

- Allows integration of *Portal for ArcGIS* with the organization's existing web server. Inclusion of a web server with ArcGIS Web Adapter provides the ability to host web applications that use GIS services.
- The organization's identity store and security policies can be used at the web-tier level. For example, when using IIS, it is possible to use Integrated Windows Authentication to restrict who enters the portal. It is also possible to use Public Key Infrastructure (PKI) or any other identity store for which the web server has built-in or extensible support. This allows provision of a single sign-on or other custom authentication experience when logging in to use services, web applications, and Portal for ArcGIS.
- Portal for ArcGIS functions can be exposed through a site name other than the default ArcGIS.

The Web Adaptor is platform independent of Portal for ArcGIS, and hence, the Web Adaptor does not have to match the operating system platform of the portal. For example, if the portal is running on Linux, it is possible to deploy ArcGIS Web Adaptor (IIS) or (Java Platform) to work with Portal for ArcGIS. Conversely; if the portal is running on Windows, an ArcGIS Web Adaptor (Java Platform) on Linux can work with the Portal for ArcGIS.

After installing and configuring the Web Adaptor, the URL used to access the portal will be in the format <https://webadapter.domain.com/arcgis/home>. For example, if the machine hosting the Web Adaptor is named *webadapter* with the domain *sdgeorg.net*, and the portal is named *arcgisportal*, the portal is accessed using the URL <https://webadapter.sdgeorg.net/arcgisportal/home>.

6.1.4 ArcGIS Desktop and Server

ArcGIS for Desktop – Comprehensive software used by GIS professionals on Windows PCs for a range of GIS activities including data compilation, mapping, modeling, spatial analysis, and geoprocessing. ArcGIS for Desktop extensions provide additional functionality such as 3D visualization, network analysis, schematics, and geostatistics. Desktop is the starting point and foundation for deploying GIS in organizations. It is used by professional GIS staff for desktop mapping, reporting, and analysis. It is also used by data compilation staff to create and maintain critical foundational data layers that fuel other GIS applications. This role for data stewardship is quite significant.

ArcGIS for Server – GIS back-office software that enables centralized, enterprise-level geodatabase management and server-based publication of maps and geographic information services throughout the enterprise and on the Internet as web services. ArcGIS Server supports the leading enterprise database management systems (DBMS): Oracle, SQL Server, DB2, Informix, and PostgreSQL. It is available on Windows or Linux servers on-site or in cloud configurations. This project uses on premises installations.

ArcGIS Server provides the core technology for implementing large-scale GIS in organizations and businesses worldwide.

6.1.5 ArcGIS Data Store

ArcGIS Data Store is an application supporting configuration of data stores for hosting and for federated servers used with the Portal. The following different types of data stores can be configured:

- Relational data store: stores Portal's hosted feature layer data, including hosted feature layers created as output from spatial analysis tools running in the portal
- Tile cache data store: stores caches for Portal's hosted scene layers

- Spatiotemporal big data store: archives real-time observation data that can be used with an ArcGIS Server running ArcGIS GeoEvent Server that is federated with the portal; also stores the results generated using ArcGIS GeoAnalytics Server tools

A more comprehensive list of ArcGIS Data Store features includes:

- Publish large numbers of hosted feature layers.
- When publishing large numbers (thousands) of feature layers to Portal, it is recommended to use ArcGIS Data Store to create a relational data store. Hosted feature layers that rely on the relational data store require a smaller memory footprint to run, making it possible to publish many services with fewer hardware resources.
- Publish hosted scene layers to the Portal.
- When the Portal's hosting server is registered with a Tile Cache Data Store, it is possible to publish hosted scene layers from ArcGIS Pro to Portal.
- Publishing hosted scene layers also creates a hosted feature layer. Esri recommends use of ArcGIS Data Store to create a relational data store to support this functionality; other managed databases registered with the hosting server can be used instead if preferred.
- Archiving
- High volume, real-time observation data
- When using ArcGIS GeoEvent Extension to stream high volumes of real-time data, it is possible to create a Spatiotemporal Big Data Store to archive the GeoEvent observation data in it
- Create automatic backups of relational data stores
- Backups support recovery of feature data in the event of a disaster such as data corruption or hardware failure
- Configure a failover data stores for feature layer data and scene caches
- ArcGIS Data Store allows a setup of primary and standby relational data store machines, and primary and standby tile cache machines. Hosted feature layer and hosted scene layer tile cache data is replicated from the primary machines to the standby machines
- Configure highly available spatiotemporal Big Data stores
- Configure multiple spatiotemporal big data stores to balance data loads over multiple machines and ensure availability of spatiotemporal data in the event of a machine failure.
- Analyze the Portal for ArcGIS map viewer
- Spatial analysis functionality in Portal requires that the portal hosting servers use an ArcGIS Data Store relational data store
- GeoAnalytics Tools require the hosting server to be configured with a spatiotemporal big data store.

6.2 OSIssoft PI

OSIssoft PI was originally developed to efficiently capture and store real-time data, especially time series data. Through addition of functions, and a widespread deployment in the industry, it has grown to now include a comprehensive set of functions to capture, process, analyze, store, and visualize any form of real-time data. PI is used extensively at SDG&E.

The key elements of the PI platform are shown in Figure 6-6. A standard installation is shown in Figure 6-7.

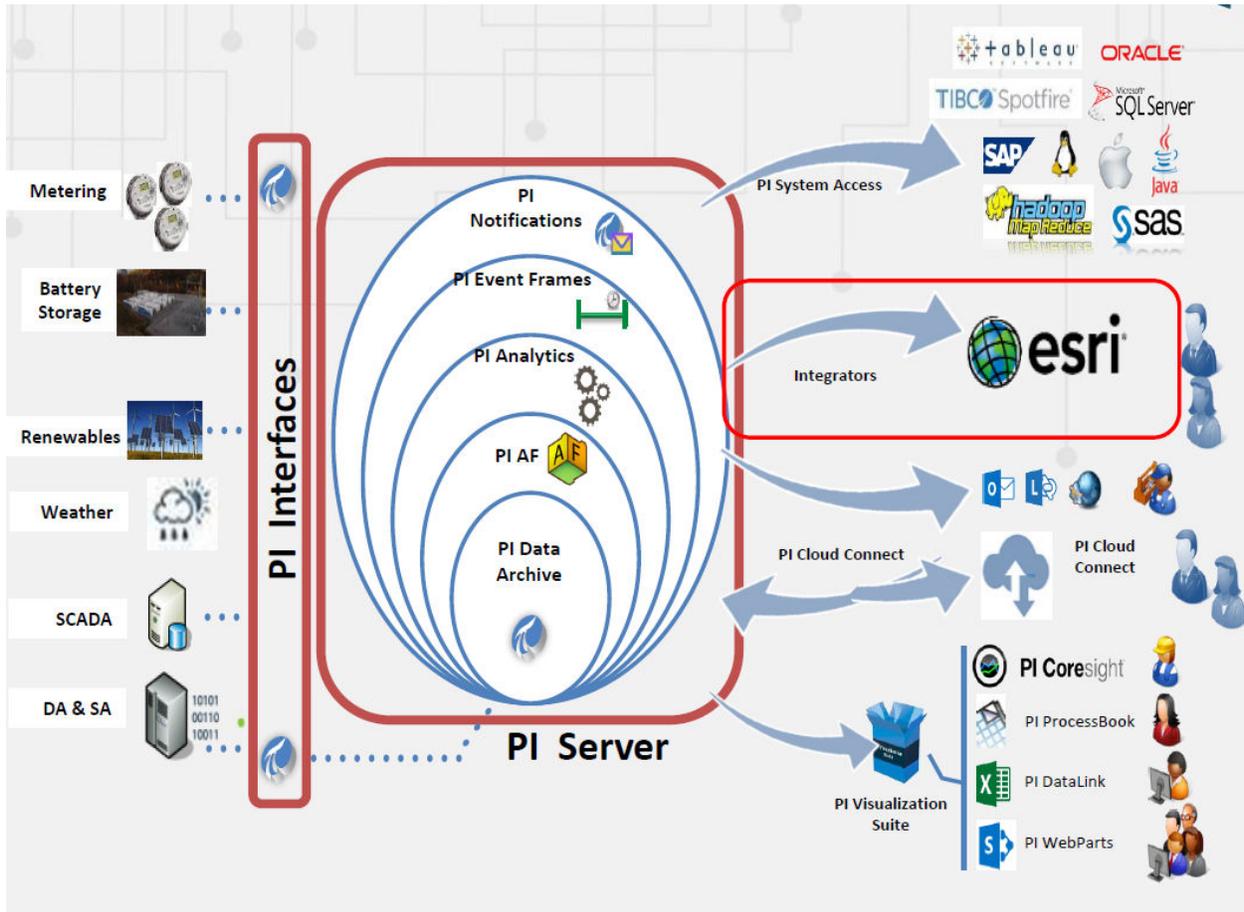


Figure 6-6. OSIsoft PI System Components

Standard PI Architecture

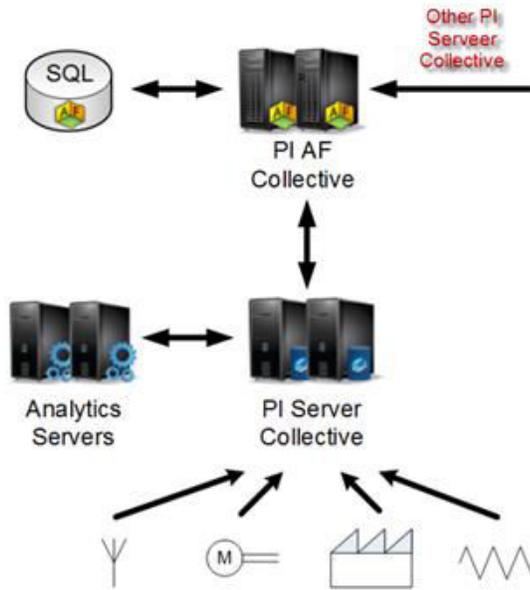


Figure 6-7. OSISoft Standard PI Architecture

A generic on-premises installation of PI systems in combination with ArcGIS is shown in Figure 6-8, and the specific configuration at SDG&E is shown towards the beginning of this document in Figure 1-1.

On Premises Architecture

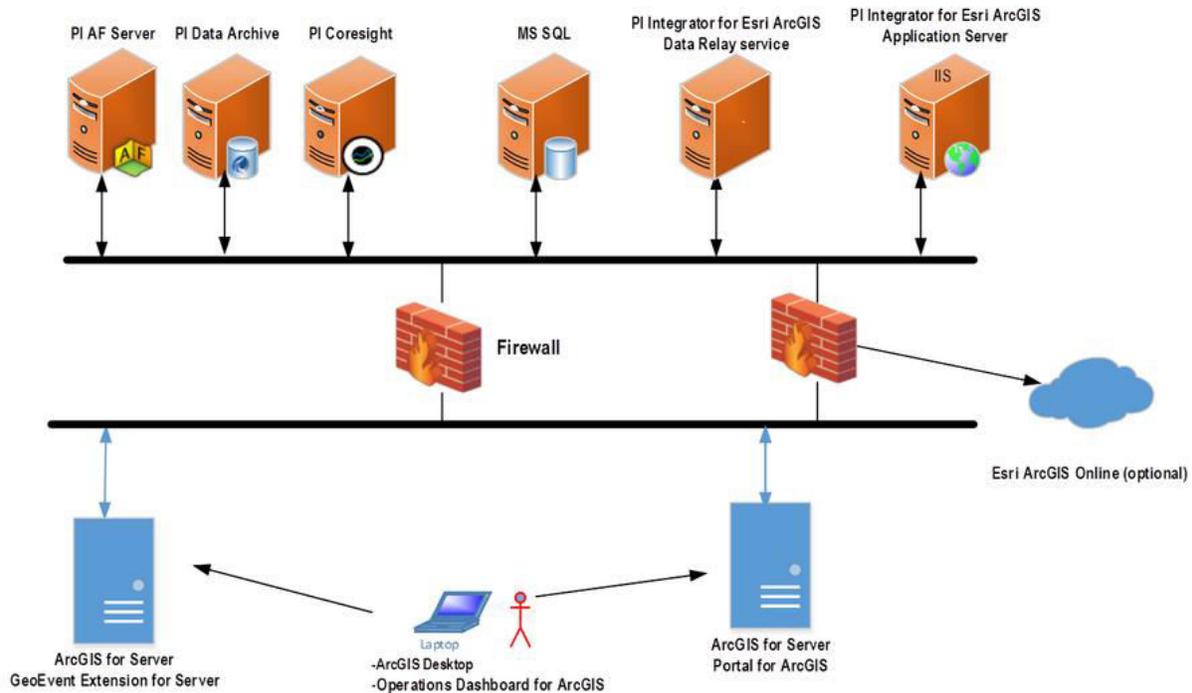


Figure 6-8. OSISoft Generic On-Premises Architecture

6.2.1 PI Integrator for Esri® ArcGIS® Overview

PI Integrator for Esri® ArcGIS® is the OSISoft product that enables a PI System to be connected with an ArcGIS Platform to first define geospatial feature services and layers in ArcGIS, and once defined, to dynamically update these with the data from PI.⁶ The whole process of dynamically updating ArcGIS feature services and layers requires two components from Esri and two components from OSISoft:

- Esri
 - Esri ArcGIS for Server: manages feature services and layers
 - GeoEvent Extension for Server: provides GeoEvent Service to update real-time data, as well as Input and Output (the difference between the input and output is that additional processing can be performing on Input data within the GeoEvent Service, e.g., filtering, processing, geofencing, to produce Output)
- OSISoft
 - PI Server, containing PI Data Archive and PI Asset Framework data stores
 - PI Integrator for Esri ArcGIS, containing Application Server and Data Relay

⁶ <https://www.youtube.com/watch?v=7iTPdVHZkWM>

The integration process starts by using Application Server wizards to setup GeoEvent Services and Inputs and Outputs in GeoEvent Extension for Server. A simple setup is when Output = Input, but manual changes in GeoEven Extension for Server can be made to institute additional transformation of Input data to Output. Here, one service is defined for each PI AF Template used.

Once the GeoEven Service is defined, at certain periodicity, the service issues HTTP (or HTTPS) to Application Server, which in turn relies on Data Relay to retrieve data from PI Data Archive referenced by an AF Template, provides it to Application Server, which in turn responds to GeoEvent Service with the requested data, which then traverses through Input to Output within GeoEvent Extension for Server, and finally updates the Feature Service on ArcGIS for Server.

The Data Relay component sends metadata and real-time information to Application Server of Esri ArcGIS.

6.3 Power BI

Power BI is a Microsoft suite of tools for efficient data analysis, which enables users to connect with many data sources to extract, analyze, and visualize the extracted data in many different ways. Once a connection to data sources is established, even the end users – without any programming skills – can specify through a Graphical User Interface (GUI) the type of analysis to be performed, and how to visualize the data and the results. Enhanced capabilities for these tasks are also available through high-level languages supported by the various Power BI sub-components.

Esri provides a component that enables display of Power BI results on geo-spatial maps, giving additional options for presenting results in addition to Excel-like tables and graphs that are available in the Power BI itself. This component, however, does not work in mixed environments, where EsriArc products run on premises and PowrBI in the cloud, as is the case at SDG&E. To overcome this difficulty, SDG&E resorted to writing its own Java-based code to allow Power BI widgets to be displayed on geospatial maps.

Major sub-components of Power BI (with yes/no indication of if used in this project):

- Power Query (yes): Data mash up and transformation tool.
- Power Pivot (yes): In-memory tabular data modelling tool
- Power View (yes): Data visualization tool
- Power Map (no): 3D Geo-spatial data visualization tool
- Power Q&A (no): Natural language question and answering engine
- Power BI Desktop (yes): A development tool for building Power BI reports and dashboards

There are other components, such as PowerBI.com Website that is used to share Power BI data analysis as cloud services; and Power BI Mobile Apps on Android, Apple, and Windows mobile devices.