Reliability-Centered Device Placement at PacifiCorp

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Background

- PacifiCorp serves about 1.8 million customers across 6 states within about 136,000 sq. miles (about 14 customers/sq. mile)
- PacifiCorp developed geospatial tools in early 2003 timeframe and has used the functionality successfully
- In 2013, PacifiCorp began rewriting the geospatial tools
- PacifiCorp serves customers via an extremely diverse population of circuits ranging from 10’ long to 320 miles of exposure

Motivation

- Historic practices for installation of protective devices were widely varied and not always explicable
- Correlating reliability to “zones of protection” would enable the company to improve reliability at an optimal cost
- Without some structured method for analysis ability to develop repeatable and cost-quantifiable results would not be likely

Result

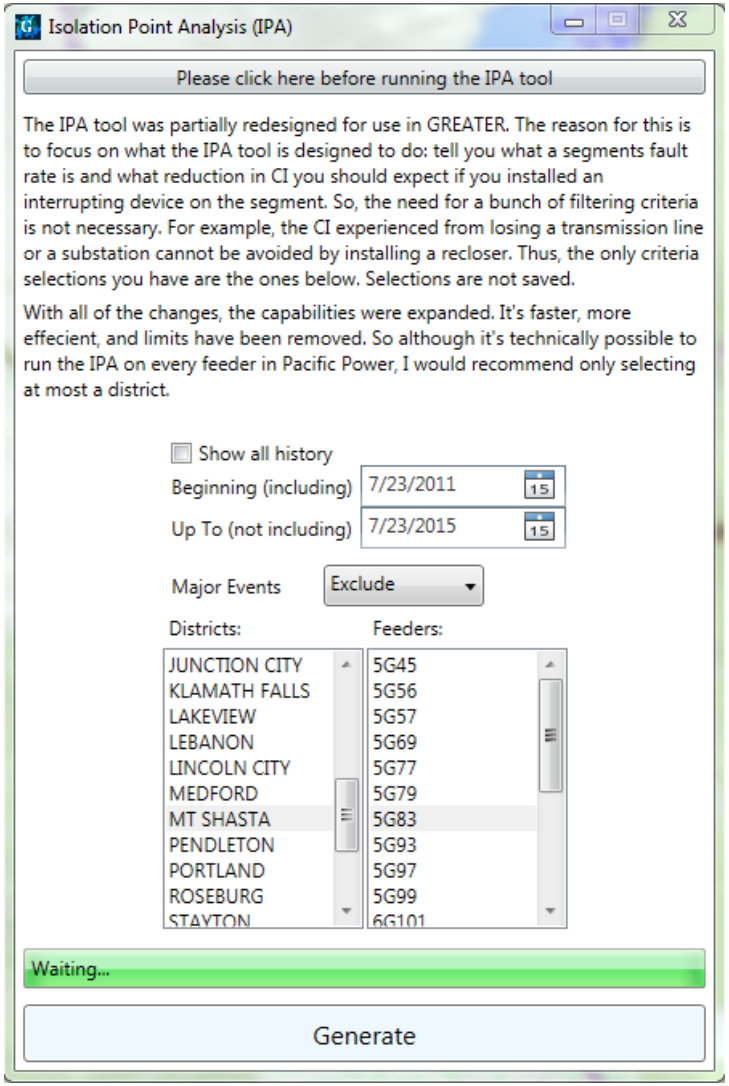
- Ergo, Isolation Point Analysis (IPA) was born
- Assume historic reliability can be used to estimate risk of future fault events
- Consider both momentary and sustained interrupting zones
- Calculate segment momentary and sustained fault rates to predict future fault probability
- Estimate customer interruptions & momentary customer interruption counts
- Model device to create new zone; recalc metrics

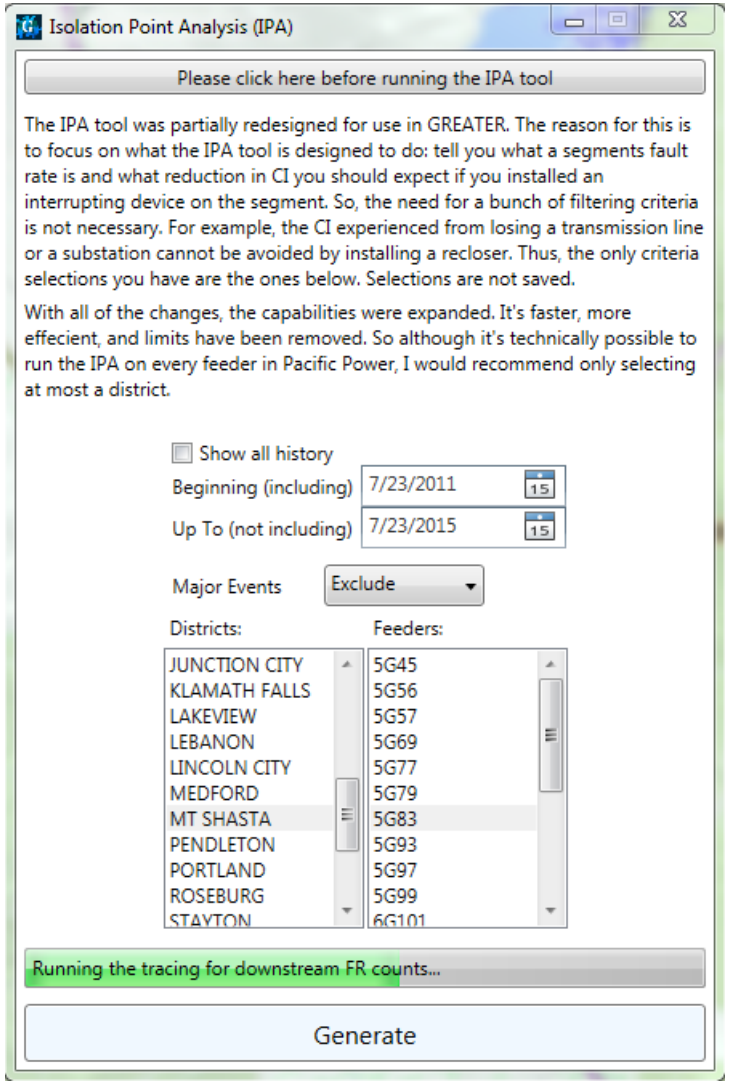
Calculated Values at Segment Level

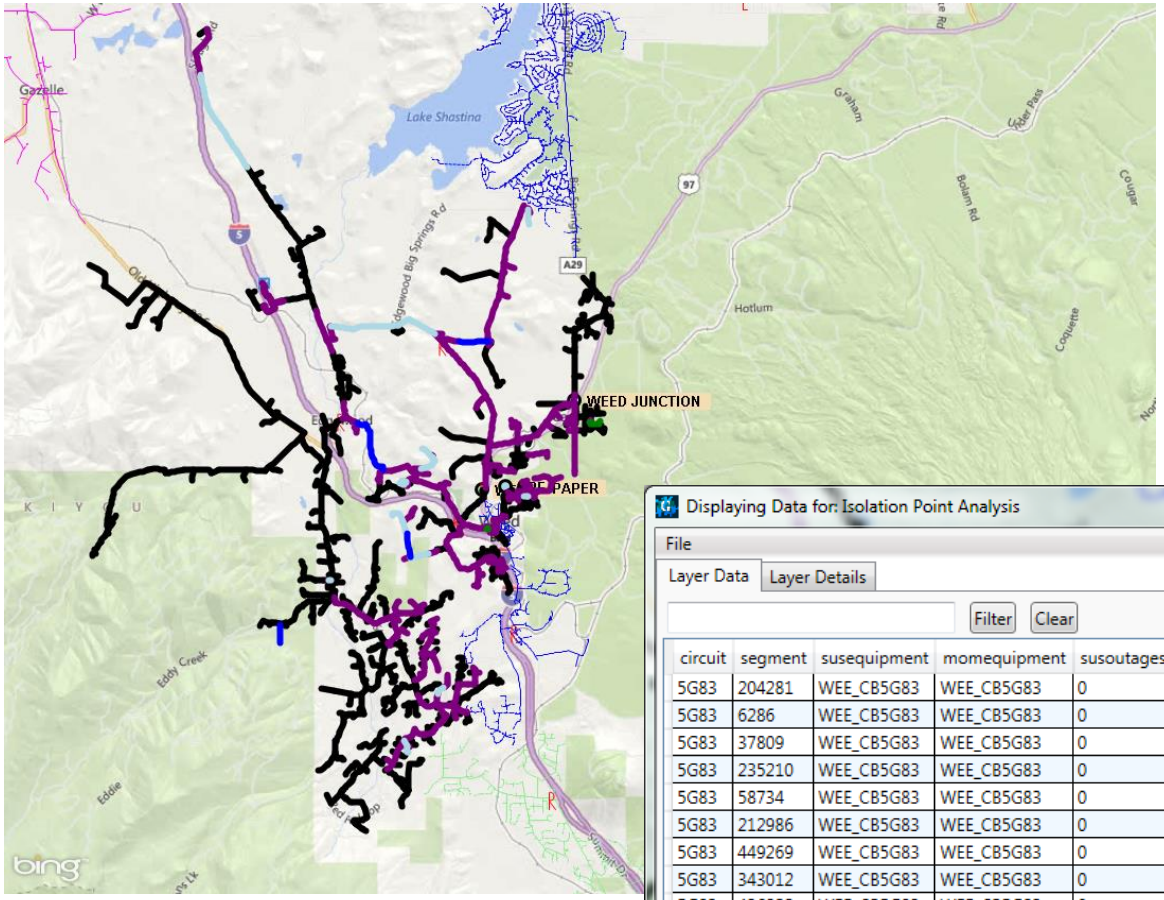
(Both Sustained and Momentary)

- The protective device
- Number of outages (either associated or distributed)
- Upstream and downstream segment orientation
- Protective zone length
- Total connected downstream customer count (DCC)
- DCC from protective device of the zone
- DCC within the protective zone (from the segment)
- CI → Customer Interruptions
- CIR → CI Rate (per year)
- FR → Fault Rate (per year)
- FM → Faults per Mile of exposure in the protective zone (per year)
- CIred → Expected CI Reduction if a device were installed on the segment (per year)

IPA's start up screen with selections and progress







Initial segment fault rate plot, and supporting data

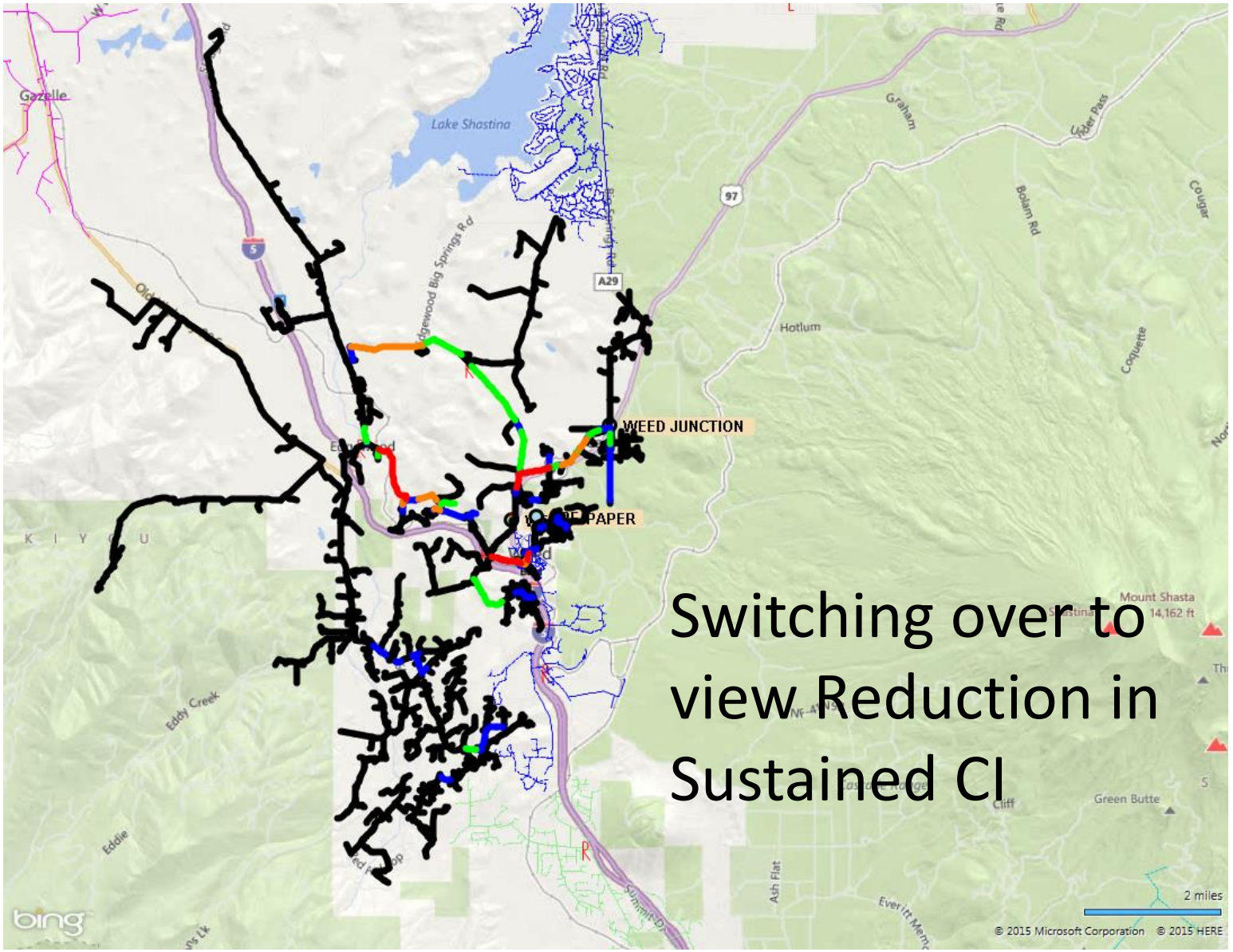
Displaying Data for: Isolation Point Analysis

File

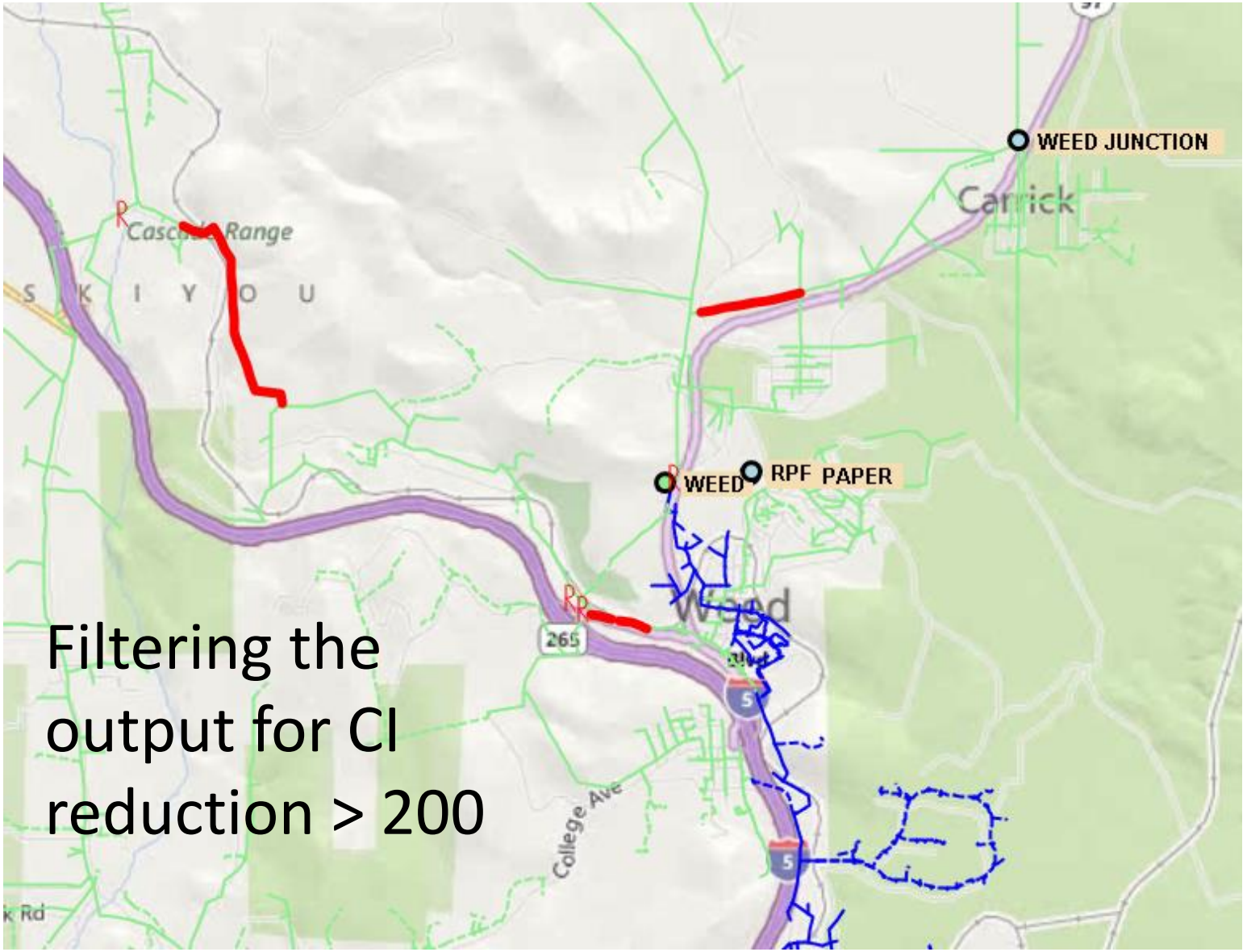
Layer Data | Layer Details

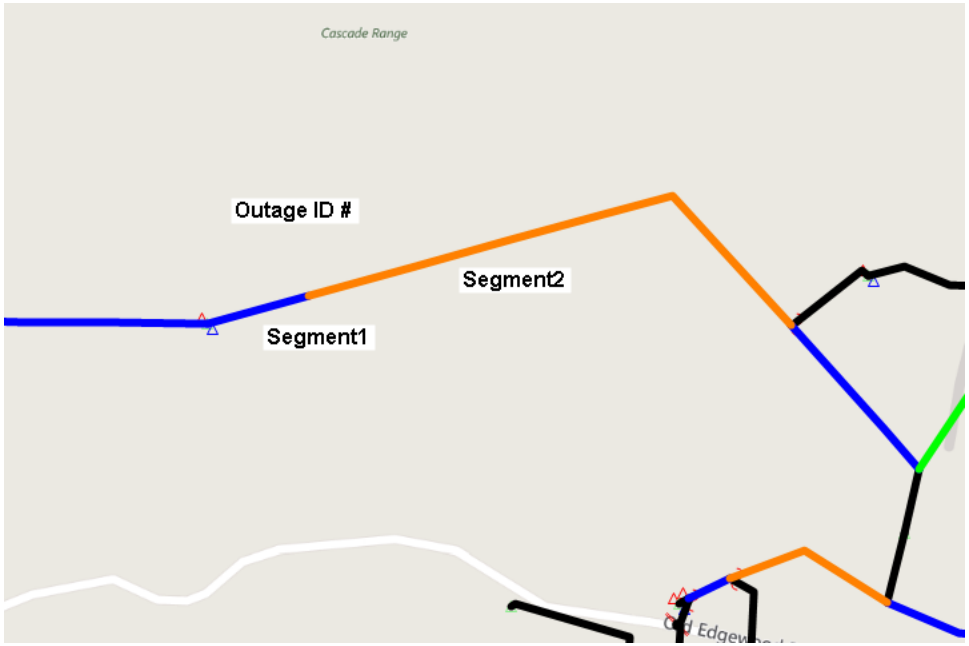
Filter | Clear

circuit	segment	susequipment	momequipment	susoutages	momoutages	CI	CIR	FR	FM	CIred	MCI	MCIR	MI
5G83	204281	WEE_CB5G83	WEE_CB5G83	0	1.6275257	0	0	0	0	0	3240.4036687	810.100917175	0.4
5G83	6286	WEE_CB5G83	WEE_CB5G83	0	1.5493674	0	0	0	0	0	3084.7904934	771.19762335	0.3
5G83	37809	WEE_CB5G83	WEE_CB5G83	0	0.792287	0	0	0	0	0	1577.443417	394.36085425	0.1
5G83	235210	WEE_CB5G83	WEE_CB5G83	0	1.1231033	0	0	0	0	0	2236.0986703	559.024667575	0.2
5G83	58734	WEE_CB5G83	WEE_CB5G83	0	0.7701629	0	0	0	0	0	1533.3943339	383.348583475	0.1
5G83	212986	WEE_CB5G83	WEE_CB5G83	0	0.407044	0	0	0	0	0	810.424604	202.606151	0.1
5G83	449269	WEE_CB5G83	WEE_CB5G83	0	0.8596141	0	0	0	0	0	1711.4916731	427.872918275	0.2
5G83	343012	WEE_CB5G83	WEE_CB5G83	0	0.3476487	0	0	0	0	0	692.1685617	173.042140425	0.0
5G83	436822	WEE_CB5G83	WEE_CB5G83	0	0.1596776	0	0	0	0	0	317.9181016	79.4795254	0.0
5G83	117966	WEE_CB5G83	WEE_CB5G83	0	0.1322824	0	0	0	0	0	263.3742584	65.8435646	0.0
5G83	169829	WEE_CB5G83	WEE_CB5G83	0	0.3449131	0	0	0	0	0	686.7219821	171.680495525	0.0
5G83	448920	WEE_CB5G83	WEE_CB5G83	0	0.2186864	0	0	0	0	0	435.4046224	108.8511556	0.0
5G83	384934	WEE_CB5G83	WEE_CB5G83	0	0.2641851	0	0	0	0	0	525.9925341	131.498133525	0.0
5G83	262665	WEE_CB5G83	WEE_CB5G83	0	0.3232348	0	0	0	0	0	643.5604868	160.8901217	0.0
5G83	101648	WEE_CB5G83	WEE_CB5G83	0	0.1609602	0	0	0	0	0	320.4717582	80.11793955	0.0

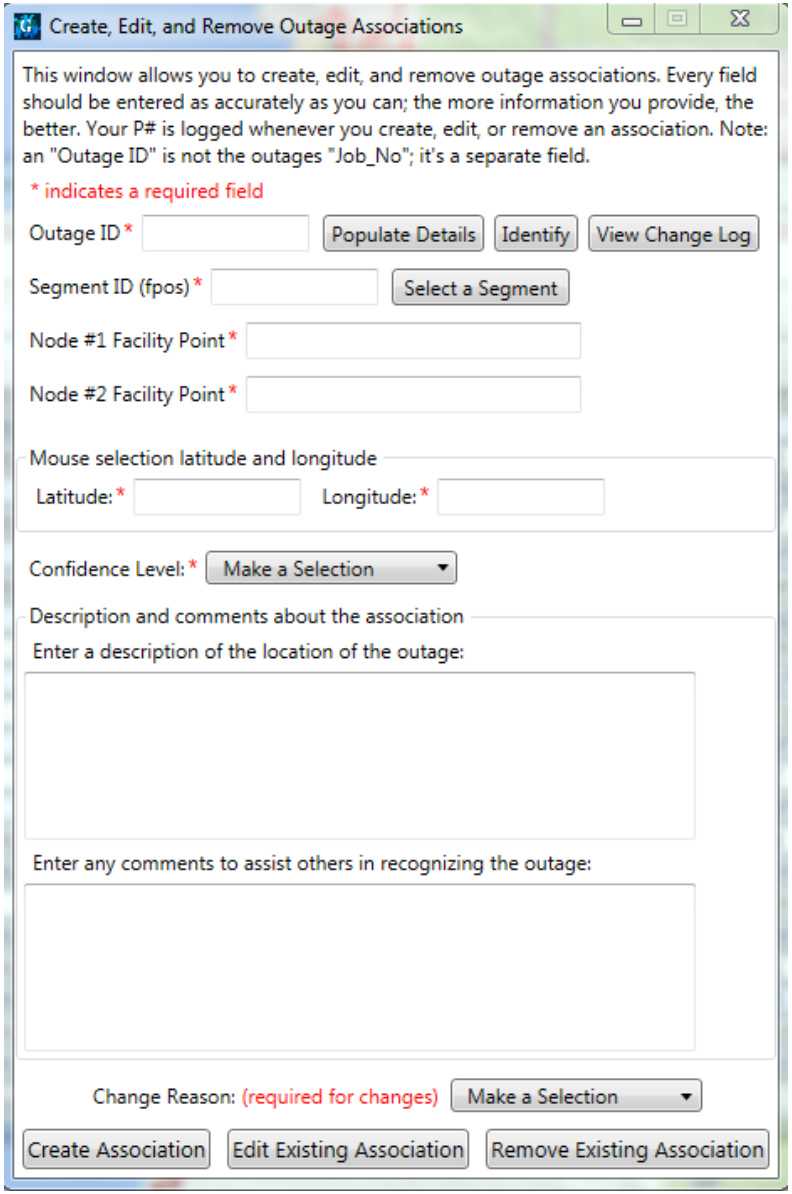


Switching over to view Reduction in Sustained CI


WEED JUNCTION
Carrick
Cascade Range
S K I Y O U
WEED
RPF PAPER
Weed
265
5
5
College Ave
Filtering the output for CI reduction > 200

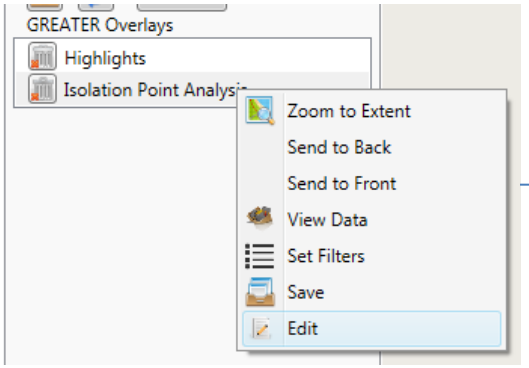


Manually associating outages for more precise analysis. By default, all outages are evenly distributed throughout the device's protection zone.

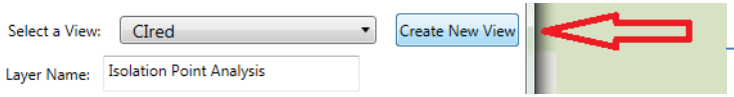


Creating and Changing the View

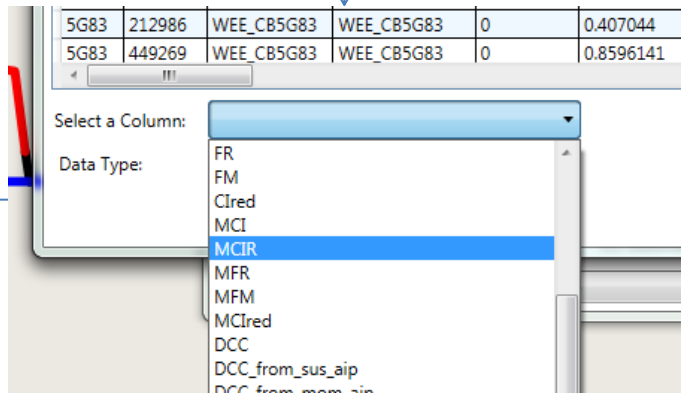
(Momentary Reduction in CI)



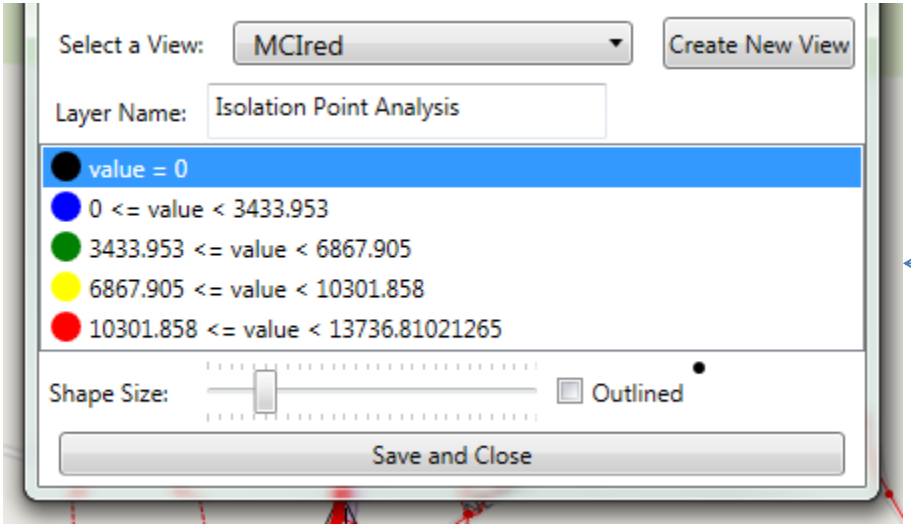
Select to edit the layer



Click to create a View



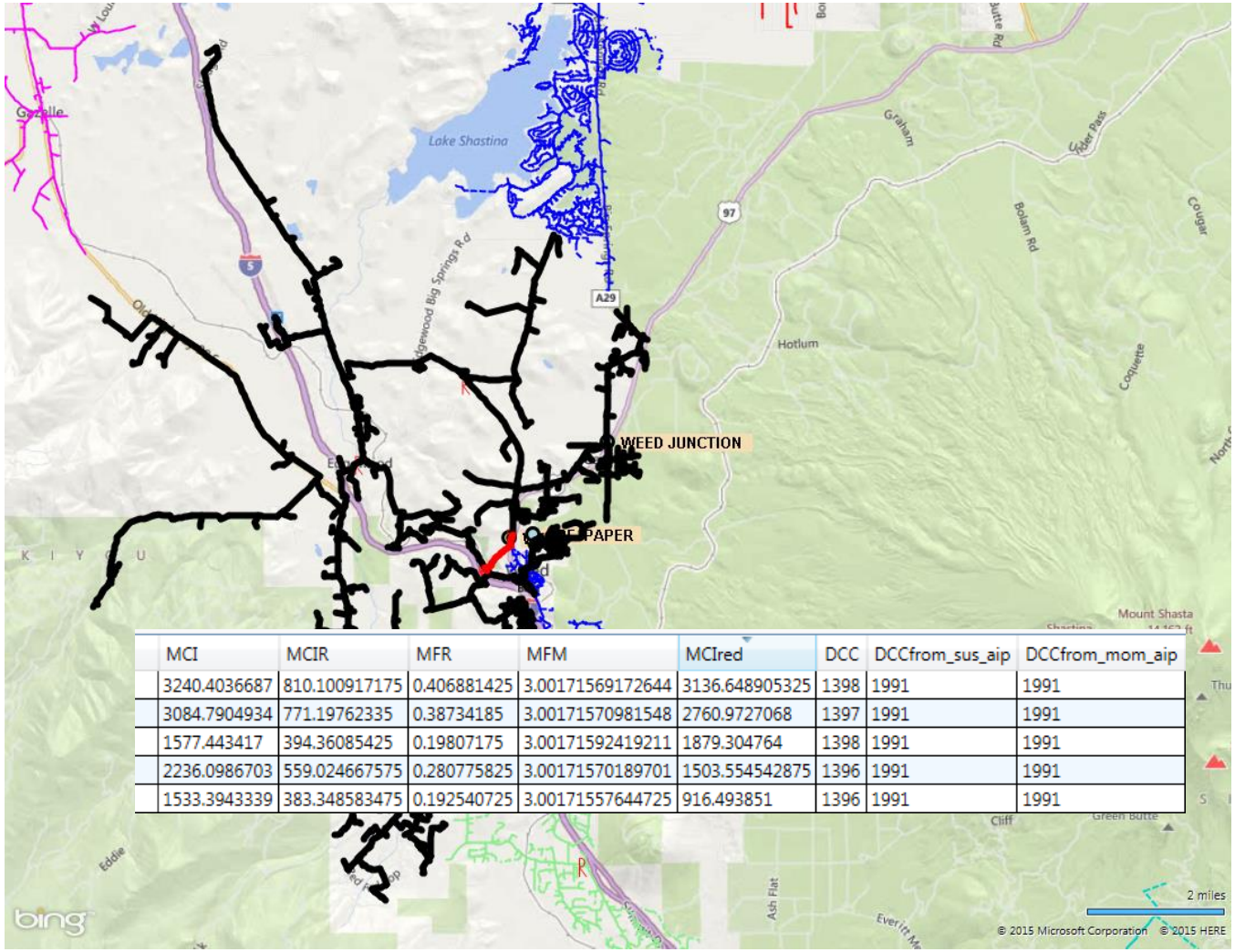
Select an available column



Create a custom range and Save

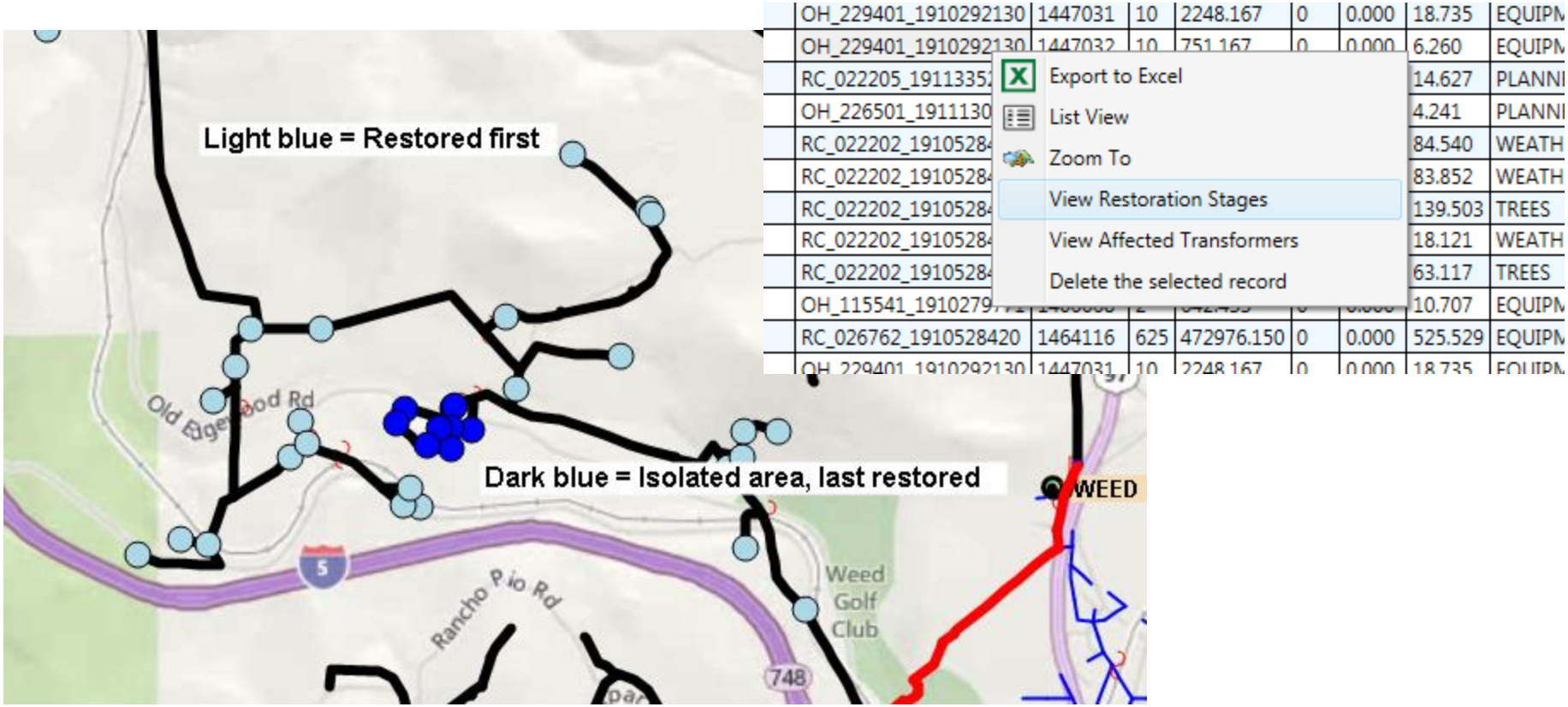
Momentary Reduction in CI

- Identify areas where momentary outages are affecting lots of customers
- Typically only momentary breaker operations are readily available



MCI	MCIR	MFR	MFM	MCIred	DCC	DCCfrom_sus_aip	DCCfrom_mom_aip
3240.4036687	810.100917175	0.406881425	3.00171569172644	3136.648905325	1398	1991	1991
3084.7904934	771.19762335	0.38734185	3.00171570981548	2760.9727068	1397	1991	1991
1577.443417	394.36085425	0.19807175	3.00171592419211	1879.304764	1398	1991	1991
2236.0986703	559.024667575	0.280775825	3.00171570189701	1503.554542875	1396	1991	1991
1533.3943339	383.348583475	0.192540725	3.00171557644725	916.493851	1396	1991	1991

Digging into the Outages

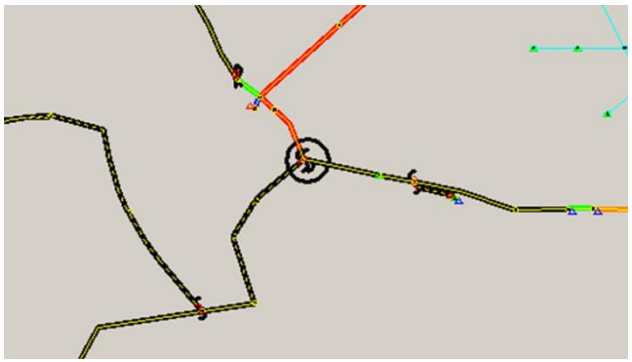


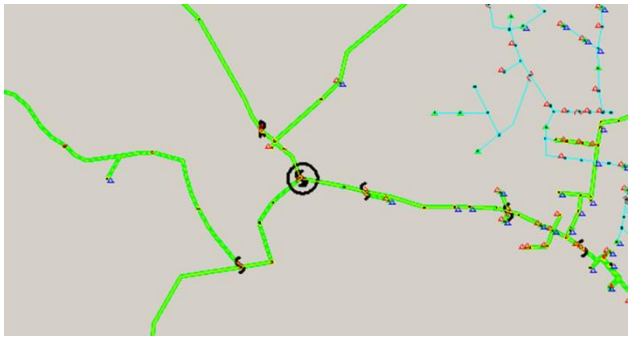
OH_229401_1910292130	1447031	10	2248.167	0	0.000	18.735	EQUIPM
OH_229401_1910292130	1447032	10	751.167	0	0.000	6.260	EQUIPM
RC_022205_1911335						14.627	PLANNI
OH_226501_1911130						4.241	PLANNI
RC_022202_1910528						84.540	WEATH
RC_022202_1910528						83.852	WEATH
RC_022202_1910528						139.503	TREES
RC_022202_1910528						18.121	WEATH
RC_022202_1910528						63.117	TREES
OH_115541_1910279						10.707	EQUIPM
RC_026762_1910528420	1464116	625	472976.150	0	0.000	525.529	EQUIPM
OH_229401_1910292130	1447031	10	2248.167	0	0.000	18.735	EQUIPM

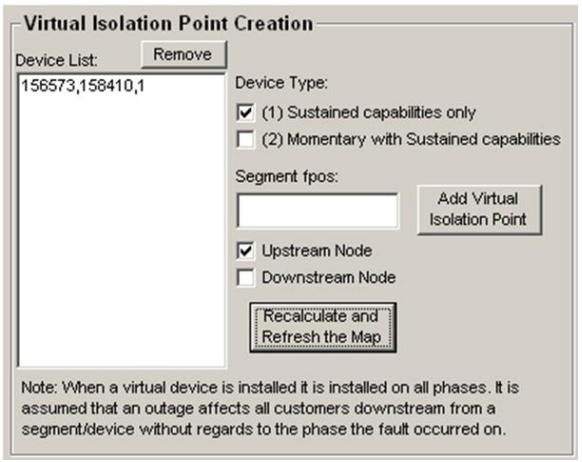
Viewing the restoration stages is another way of determining where outages may have occurred to improve your analysis.

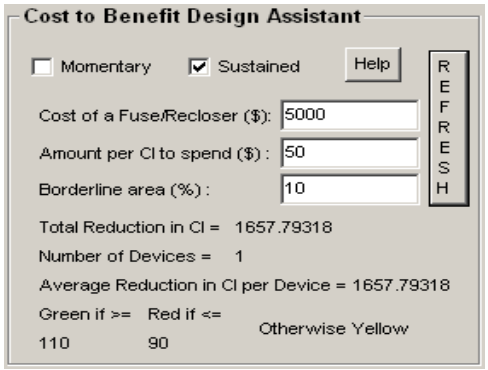
Virtual Device Placement (part 1)

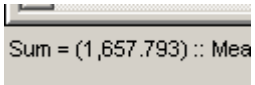
The original IPA (in GREAT) was capable of placing virtual devices on the feeder to demonstrate the expected reduction. It would also perform cost to benefit analysis.









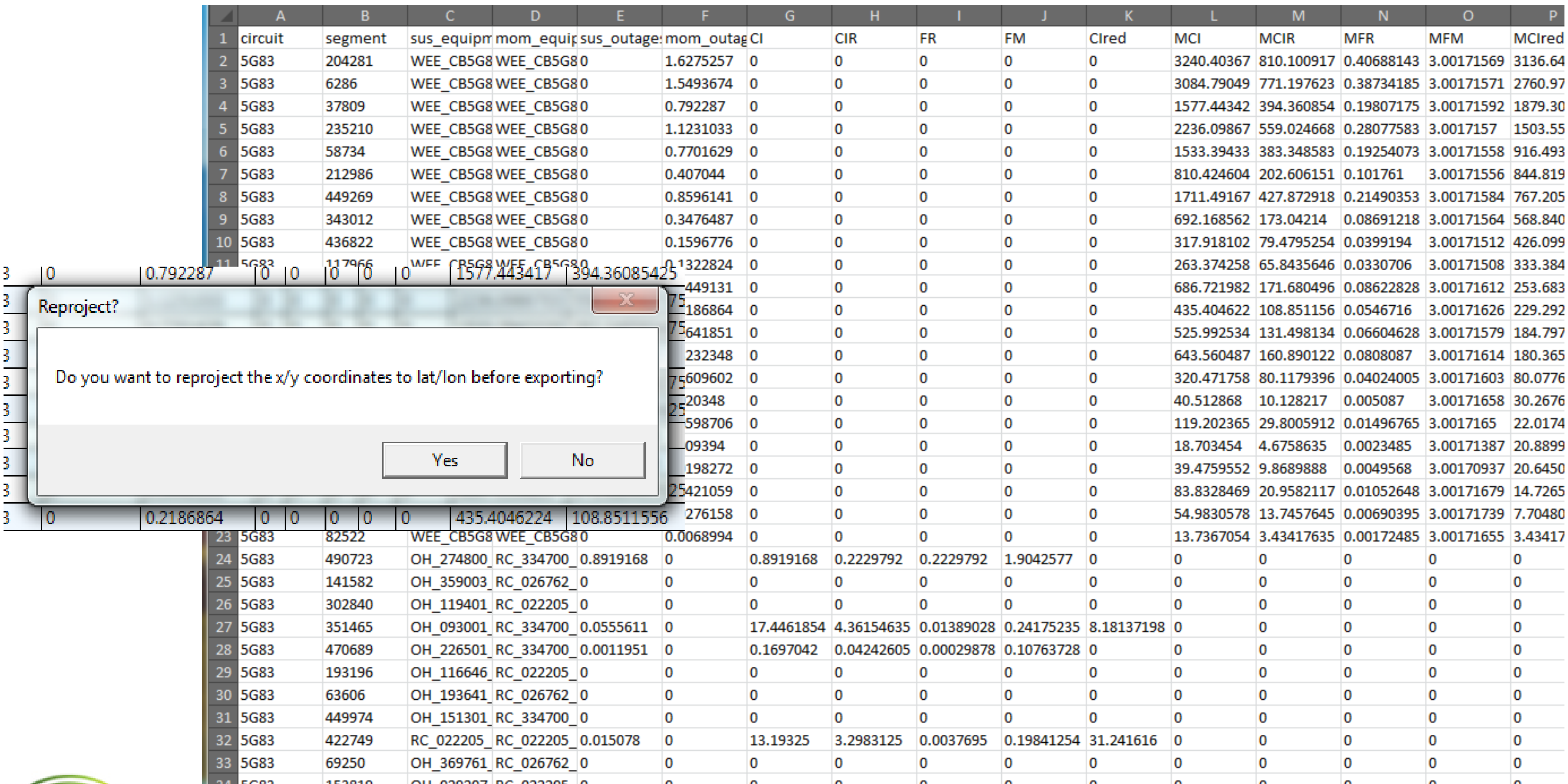


Virtual Device Placement (part 2)

- IPA in GREATER was altered for faster and broader analysis. This translates to removing analysis restrictions such as only viewing analysis for one feeder at a time.
- GREATER is optimized to show you where problems areas are, not design a new protection scheme.
  - Associate outages and calculate segment fault rates
  - Colorful layers
  - View the data: it'll tell you the expected reduction
  - A cost to benefit analysis can be performed from the data
- We are hoping to utilize third party applications the company is already using to perform more complex analysis such as virtual devices and new protection schemes.
  - Ability to place a fuse or recloser and perform power flow analysis, coordination, etc.
  - Use the outage data from GREATER

Exporting the Results

Easily export to excel (.xlsx format) for further analytic capabilities and report generation. GREATER will ask you if you want the coordinates re-projected before exporting.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	circuit	segment	sus_equipm	mom_equip	sus_outage	mom_outag	CI	CIR	FR	FM	CIred	MCI	MCIR	MFR	MFM	MCIred
2	5G83	204281	WEE_CB5G8	WEE_CB5G8	0	1.6275257	0	0	0	0	0	3240.40367	810.100917	0.40688143	3.00171569	3136.64
3	5G83	6286	WEE_CB5G8	WEE_CB5G8	0	1.5493674	0	0	0	0	0	3084.79049	771.197623	0.38734185	3.00171571	2760.97
4	5G83	37809	WEE_CB5G8	WEE_CB5G8	0	0.792287	0	0	0	0	0	1577.44342	394.360854	0.19807175	3.00171592	1879.30
5	5G83	235210	WEE_CB5G8	WEE_CB5G8	0	1.1231033	0	0	0	0	0	2236.09867	559.024668	0.28077583	3.0017157	1503.55
6	5G83	58734	WEE_CB5G8	WEE_CB5G8	0	0.7701629	0	0	0	0	0	1533.39433	383.348583	0.19254073	3.00171558	916.493
7	5G83	212986	WEE_CB5G8	WEE_CB5G8	0	0.407044	0	0	0	0	0	810.424604	202.606151	0.101761	3.00171556	844.819
8	5G83	449269	WEE_CB5G8	WEE_CB5G8	0	0.8596141	0	0	0	0	0	1711.49167	427.872918	0.21490353	3.00171584	767.205
9	5G83	343012	WEE_CB5G8	WEE_CB5G8	0	0.3476487	0	0	0	0	0	692.168562	173.04214	0.08691218	3.00171564	568.840
10	5G83	436822	WEE_CB5G8	WEE_CB5G8	0	0.1596776	0	0	0	0	0	317.918102	79.4795254	0.0399194	3.00171512	426.099
11						1322824	0	0	0	0	0	263.374258	65.8435646	0.0330706	3.00171508	333.384
						449131	0	0	0	0	0	686.721982	171.680496	0.08622828	3.00171612	253.683
						186864	0	0	0	0	0	435.404622	108.851156	0.0546716	3.00171626	229.292
						641851	0	0	0	0	0	525.992534	131.498134	0.06604628	3.00171579	184.797
						232348	0	0	0	0	0	643.560487	160.890122	0.0808087	3.00171614	180.365
						609602	0	0	0	0	0	320.471758	80.1179396	0.04024005	3.00171603	80.0776
						20348	0	0	0	0	0	40.512868	10.128217	0.005087	3.00171658	30.2676
						598706	0	0	0	0	0	119.202365	29.8005912	0.01496765	3.0017165	22.0174
						09394	0	0	0	0	0	18.703454	4.6758635	0.0023485	3.00171387	20.8899
						198272	0	0	0	0	0	39.4759552	9.8689888	0.0049568	3.00170937	20.6450
						421059	0	0	0	0	0	83.8328469	20.9582117	0.01052648	3.00171679	14.7265
						276158	0	0	0	0	0	54.9830578	13.7457645	0.00690395	3.00171739	7.70480
23	5G83	82522	WEE_CB5G8	WEE_CB5G8	0	0.0068994	0	0	0	0	0	13.7367054	3.43417635	0.00172485	3.00171655	3.43417
24	5G83	490723	OH_274800_	RC_334700_	0.8919168	0	0.8919168	0.2229792	0.2229792	1.9042577	0	0	0	0	0	0
25	5G83	141582	OH_359003_	RC_026762_	0	0	0	0	0	0	0	0	0	0	0	0
26	5G83	302840	OH_119401_	RC_022205_	0	0	0	0	0	0	0	0	0	0	0	0
27	5G83	351465	OH_093001_	RC_334700_	0.0555611	0	17.4461854	4.36154635	0.01389028	0.24175235	8.18137198	0	0	0	0	0
28	5G83	470689	OH_226501_	RC_334700_	0.0011951	0	0.1697042	0.04242605	0.00029878	0.10763728	0	0	0	0	0	0
29	5G83	193196	OH_116646_	RC_022205_	0	0	0	0	0	0	0	0	0	0	0	0
30	5G83	63606	OH_193641_	RC_026762_	0	0	0	0	0	0	0	0	0	0	0	0
31	5G83	449974	OH_151301_	RC_334700_	0	0	0	0	0	0	0	0	0	0	0	0
32	5G83	422749	RC_022205_	RC_022205_	0.015078	0	13.19325	3.2983125	0.0037695	0.19841254	31.241616	0	0	0	0	0
33	5G83	69250	OH_369761_	RC_026762_	0	0	0	0	0	0	0	0	0	0	0	0
34	5G83	153819	OH 029207	RC 022205	0	0	0	0	0	0	0	0	0	0	0	0