VECTREN
Live Smart

Gas Transmission Asset and Integrity Management

TIM
transmission integrity management

Risk Model

Presentation

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Vectren's Gas Footprint

Vectren Energy Delivery of Indiana – South

- 111,000 gas customers
  - 142 miles of transmission

Vectren Energy Delivery of Indiana – North

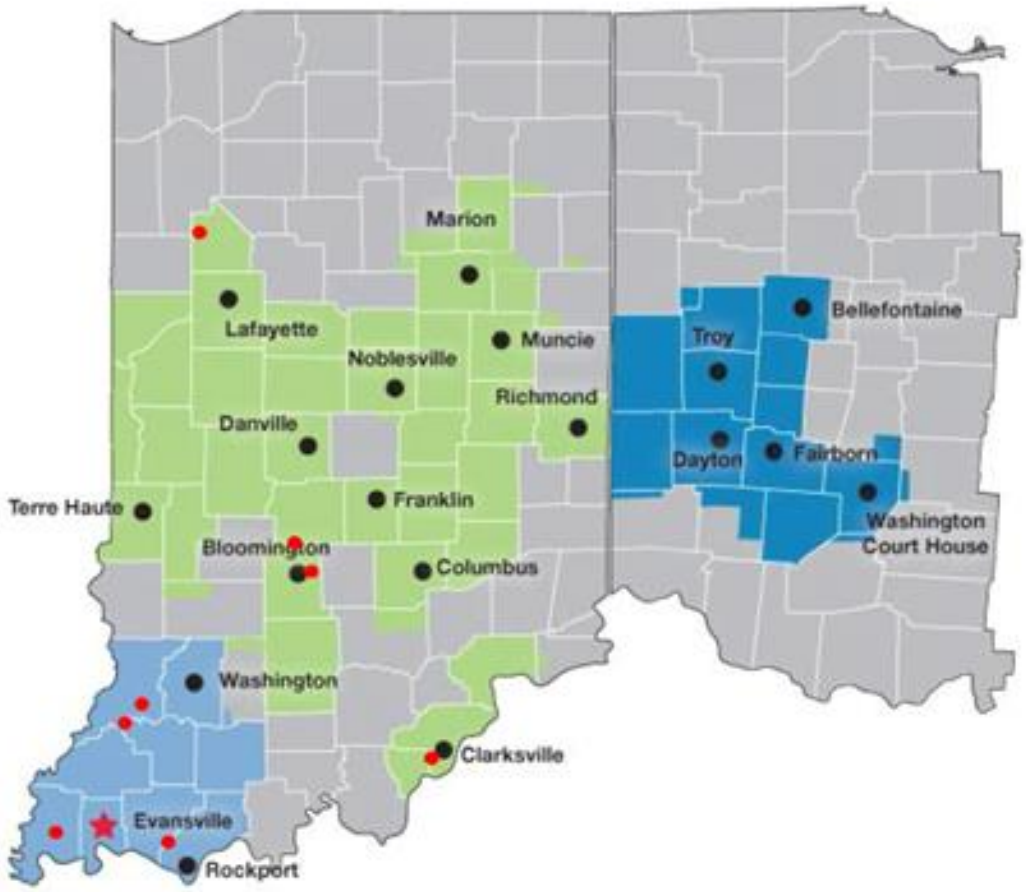
- 580,000 gas customers
  - 652 miles of transmission

Vectren Energy Delivery of Ohio

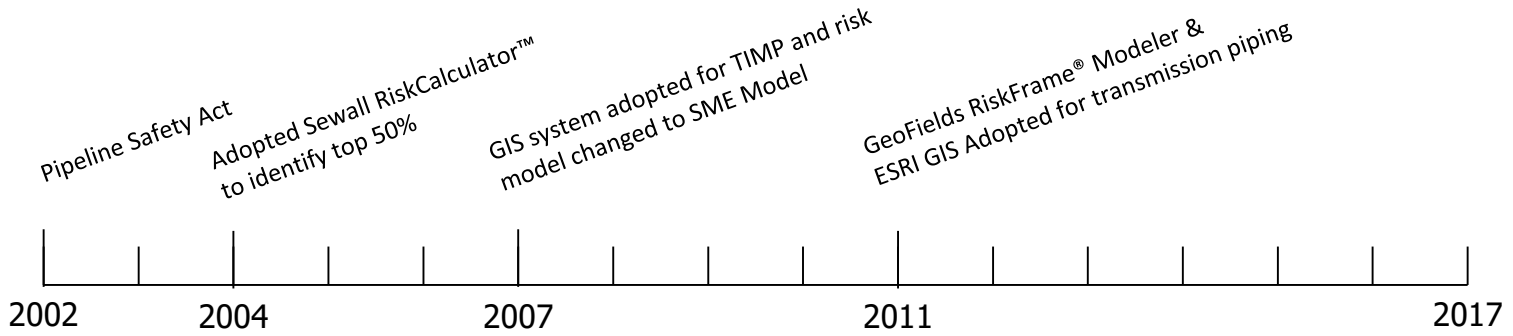
- 314,000 gas customers
  - 212 miles of transmission

Vectren Storage Fields

- 8 Storage Field Locations



Vectren Risk Model History



2004: Engaged Centerpoint Energy as a consultant to help in the development of relative risk ranking model. Subsequently used Sewall RiskCalculator™ to identify top 50% risk ranked pipelines.

2007: Adopted SmallWorld™ GIS system with a custom algorithm for automated Class and HCA identification. Also switched to Method 2 for HCA identification. The GIS system could not provide data transfer to Risk Calculator which necessitated the move to an SME style risk model with input from RiskCalculator™.

2011: Following the annual review of the Integrity Management Plan, a philosophy change in risk assessment resulted in the evaluation of several pipeline risk software packages. GeoFields RiskFrame® Modeler was chosen to evaluate risk and RiskFrame® HCA to evaluate Class and HCA.

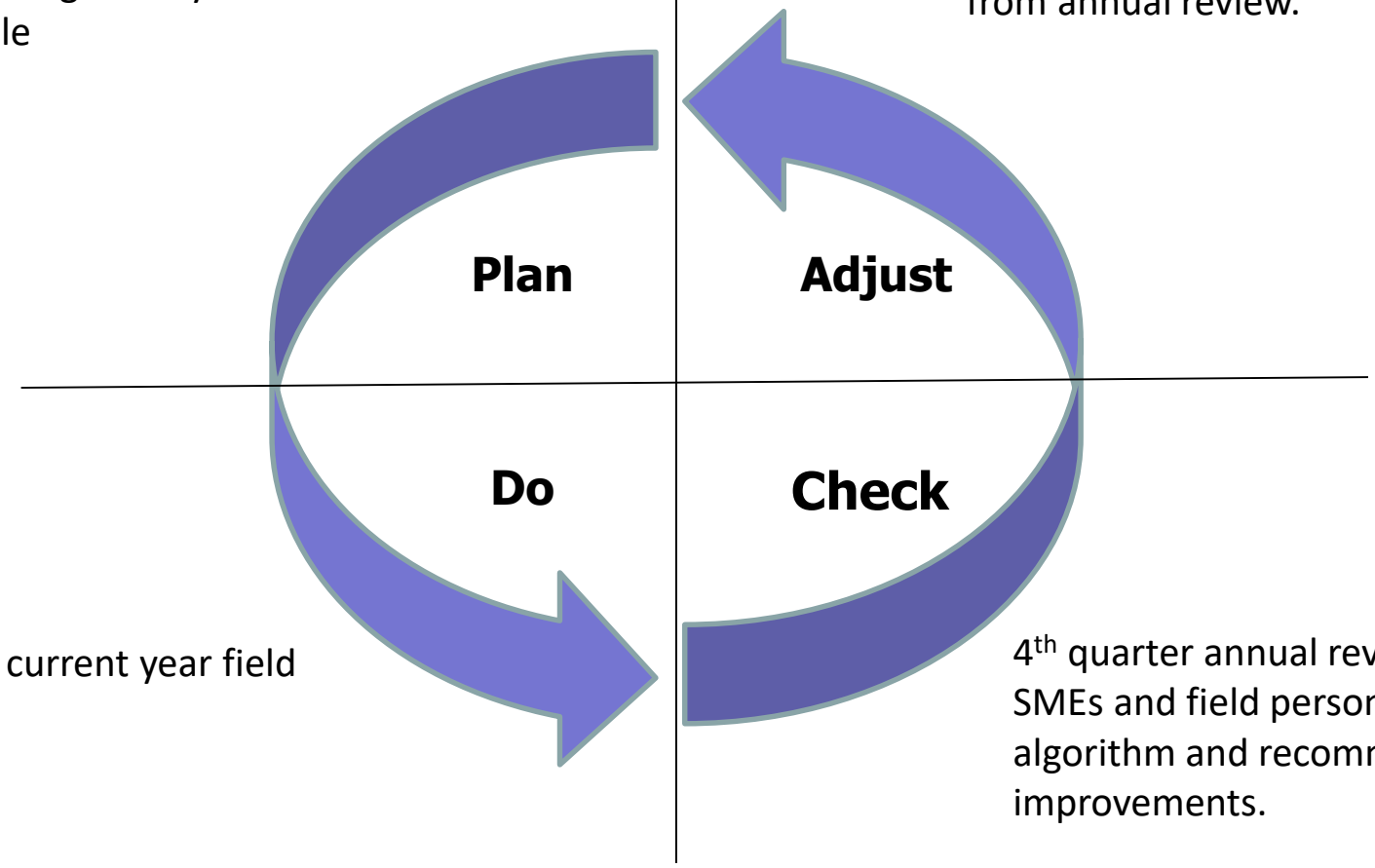
Goals of Risk Process

- Provide Management with easily understandable view of overall system risk.
- Provide Integrity Management Project Team with actionable information.
- Demonstrate effect on pipeline risk as a direct result of assessments and modernization project work.
- Demonstrate that the risk model reflects reported incidents as well as local operations observations on local pipeline risk.
- Provide Project Team with assessment options through scenarios.

Risk Model Review Process

Run risk model 1st quarter and compare against 5yr field work schedule

Modify algorithm based on input from annual review.



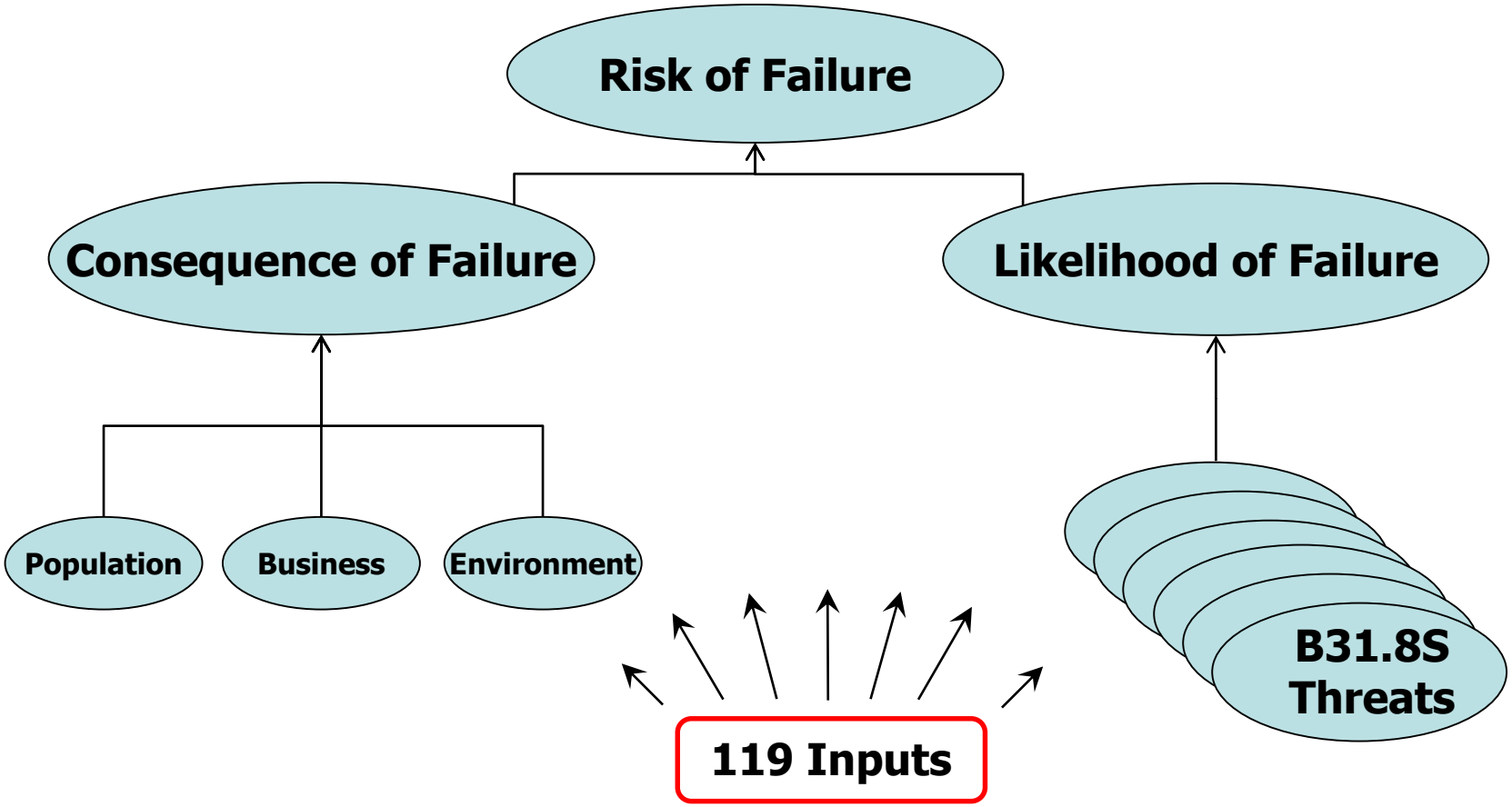
Perform current year field work.

4th quarter annual review with SMEs and field personnel to verify algorithm and recommend improvements.

Risk Scoring Process

Risk Score:

Weighted relative index score based on pipe parameters and surroundings



Risk Model Equations

Risk of Failure (ROF)

ROF= Likelihood of Failure * Consequence of Failure

Risk Model Equations

Likelihood of Failure = (10*TPD + 7*MFG + 5*IO + 5*WOF + 7*CONS +3*DS +6*EQ + 9*EC + 1*IC + 1*SCC + 5*IAT)/59

- TPD → Third Party Damage
- MFG → Manufacturing
- IO → Incorrect Operations
- WOF → Weather and Outside Forces
- CONS → Construction
- DS → Design
- EQ → Equipment
- EC → External Corrosion
- IC → Internal Corrosion
- SCC → Stress Corrosion Cracking
- IAT → Interactive Threats

ASME B31.8S Threat Categories

Risk Model Equations

Consequence of Failure = (7*COB + 1*COE + 10*COP)/18

- COB → Consequence on Business
    1. Customers out of Service
    2. Loss of Product
- COE → Consequence on Environment
    1. Environmentally Sensitive Areas
- COP → Consequence on Population
    1. Potential harm to people and/or property near pipeline

Range of Risk Scores

Risk of Failure

1 → Lowest Risk

100 → Highest Risk

Consequence, Likelihood, and Inputs

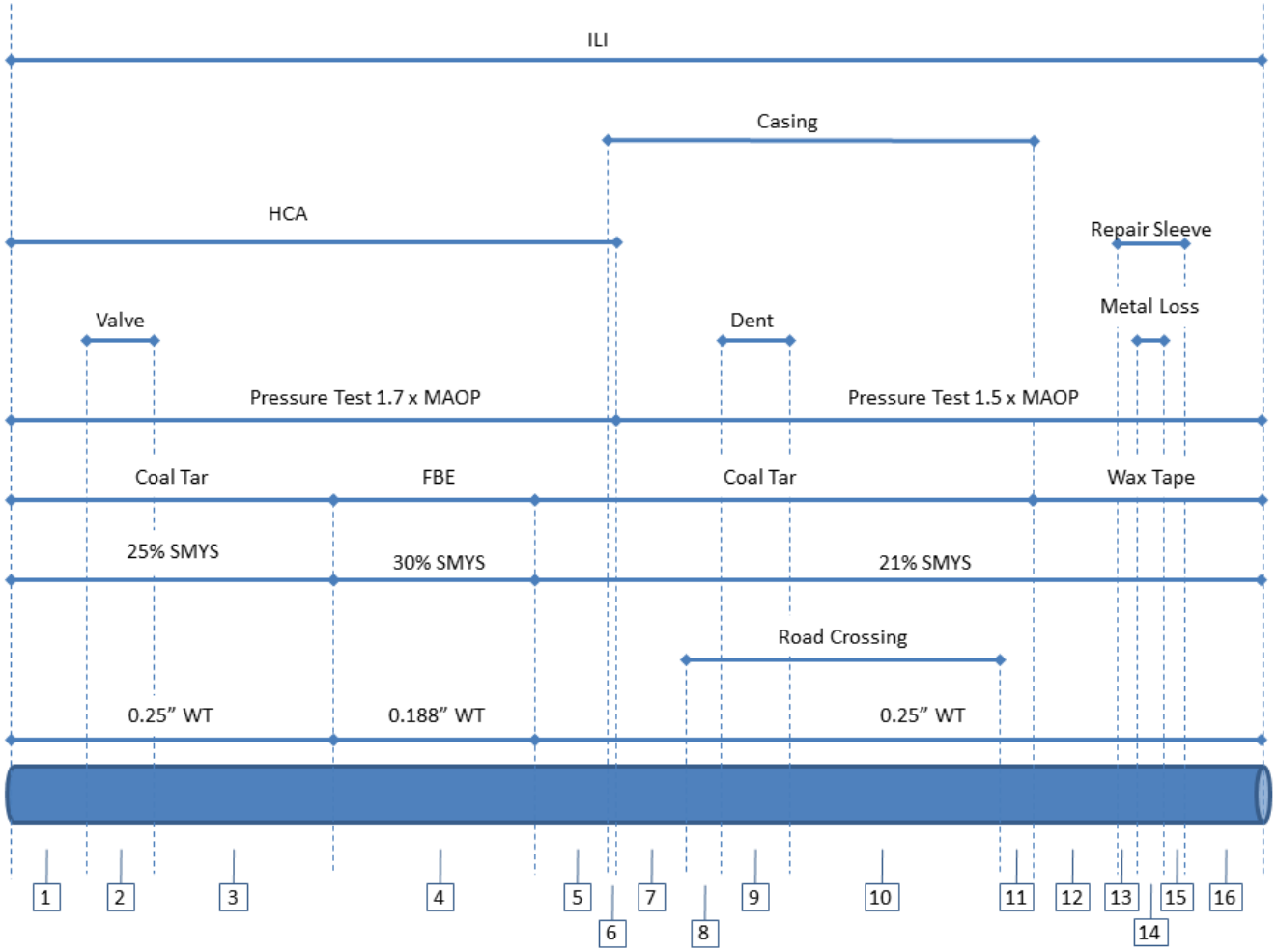
1 → Lowest Risk

10 → Highest Risk

Transmission Risk Inputs

- Consequence MAOP
- Consequence Nominal Diameter
- Single Feed Locations
- DOT Class Environment
- HCA Gas Constant
- Nominal Diameter
- Wall Thickness
- Depth of Cover
- Construction Inspection
- Construction Material
- Pressure Test
- Joint Inspection
- Wrinkle Bends
- Weld Method
- Current Year
- Install Date
- Earthquake Zones
- Land Slides
- Safety Systems
- AC Interference
- Bell Hole Inspection
- Roads
- Blasting Zones
- Exposures
- Cathodic Protection
- External Coating
- External Metal Loss
- Microbiological Induced Corrosion
- Bell Hole Soil pH
- Soil Resistivity
- Coating Condition
- Equipment Failure
- Age Failure
- O Ring Failure
- Regulator Failure
- Relief Valve
- Main Line Valves
- Remote and Non Remote-Controlled Main Line Valves
- Carbon Dioxide Content Level
- Corrosion Detection Devices
- Hydrogen Sulfide Content Level
- Internal Metal Loss
- Oxygen Content Level
- Single Family Home Density
- Encroachment Area
- High Occupancy Location
- Incorrect Operations Failures/Near Miss
- Internal Corrosion
- Water Content Level
- Storage Field
- Emergency Response Training
- Audit Findings – IM, O&M
- Operations and Training
- Pressure Control System
- Program/Procedure Review
- SCADA
- Pipe Material
- Pipe Manufacturer
- Seam Type
- Foreign Line Crossing
- Leaks
- Line Markers
- Mechanical Damage
- One-Call
- Public Awareness Program
- Patrol Frequency
- Patrol Type
- Previous Third-Party Damage
- River Crossing
- River Weights
- Frost Line
- Flood Zones

Dynamic Segmentation

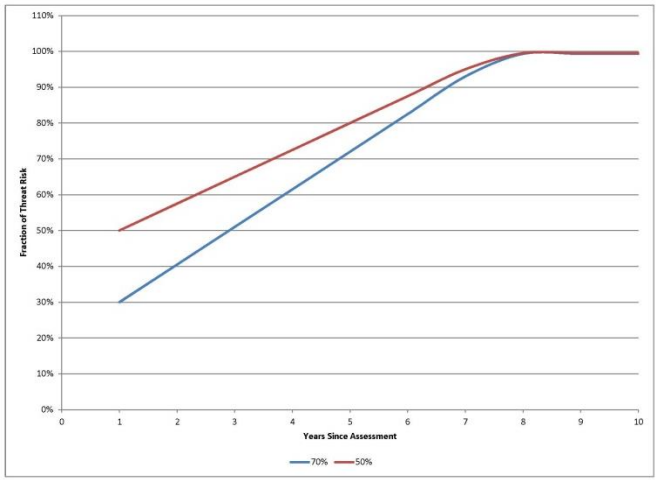


Breaks the route at every attribute change creating a new risk segment

Accounting for Assessments

Threats that can be mitigated by assessment get reduced by a diminishing factor.
Example: External Corrosion

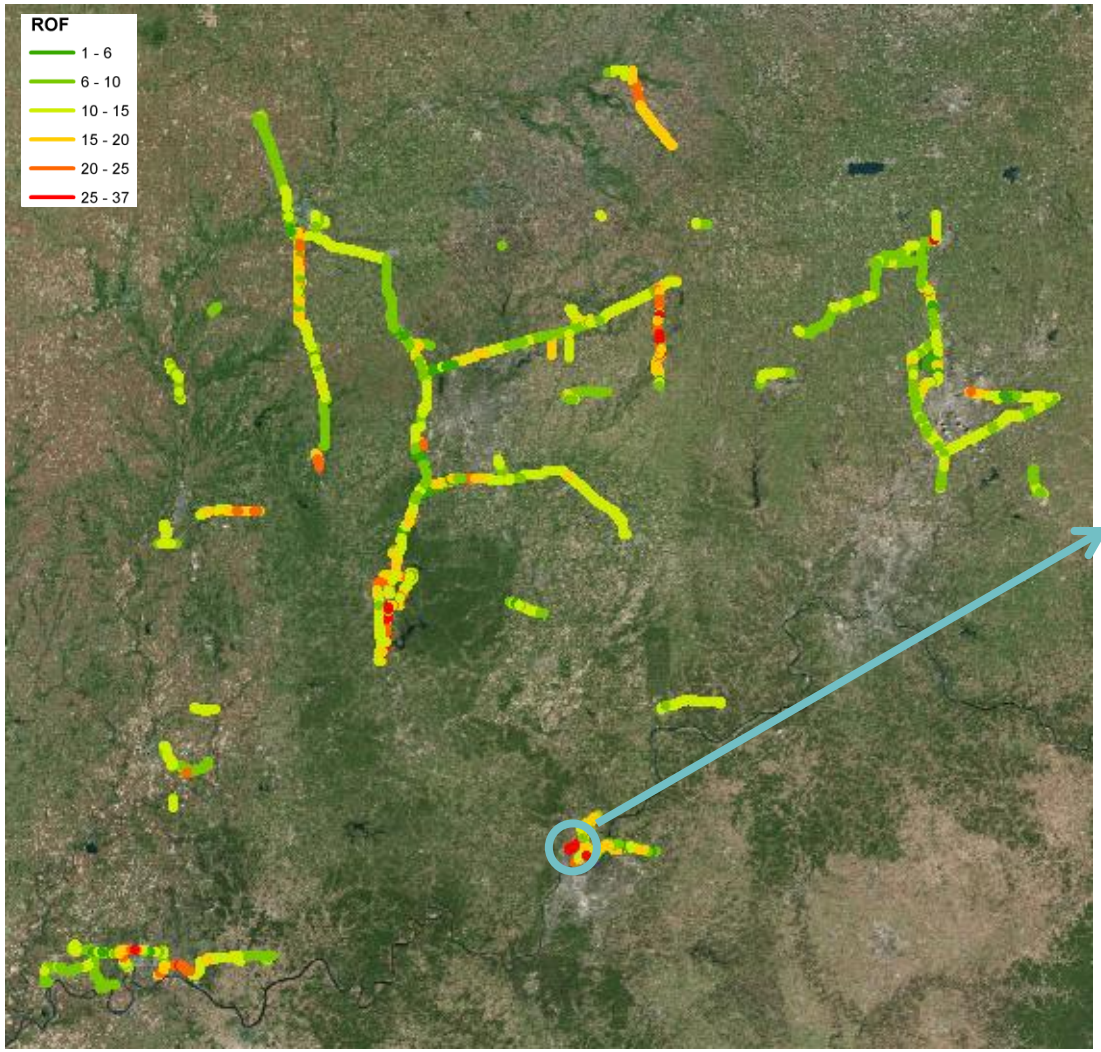
$$ECscore = ECmaxEffective*((7*InstallDateScoreEC)+(8*ExternalCoatingScoreEC)+(10*ExtCoatCondScore)+(8*ExtMLFormulaScore)+(7*WallThicknessScoreEC)+(4*NomDiaScoreEC)+(5*PctSMYSscoreEC)+(2*ECPAlogicScore)+(1*EffectiveCPFactorScore)+(9*BellHoleIECPresentScore)+(5*MICPresentScore)+(5*SoilpHScoreEC)+(8*SoilResistivityFormula)+(8*ACInterferenceScore))/87$$



While Threats that cannot mitigated by assessment are not reduced.
Example: Design

$$DSscore = ((10*PipeStrengthScore)+(0*SafetySystemsScore)+(5*DesignClassYear)*(1*PiggableScore))/16$$

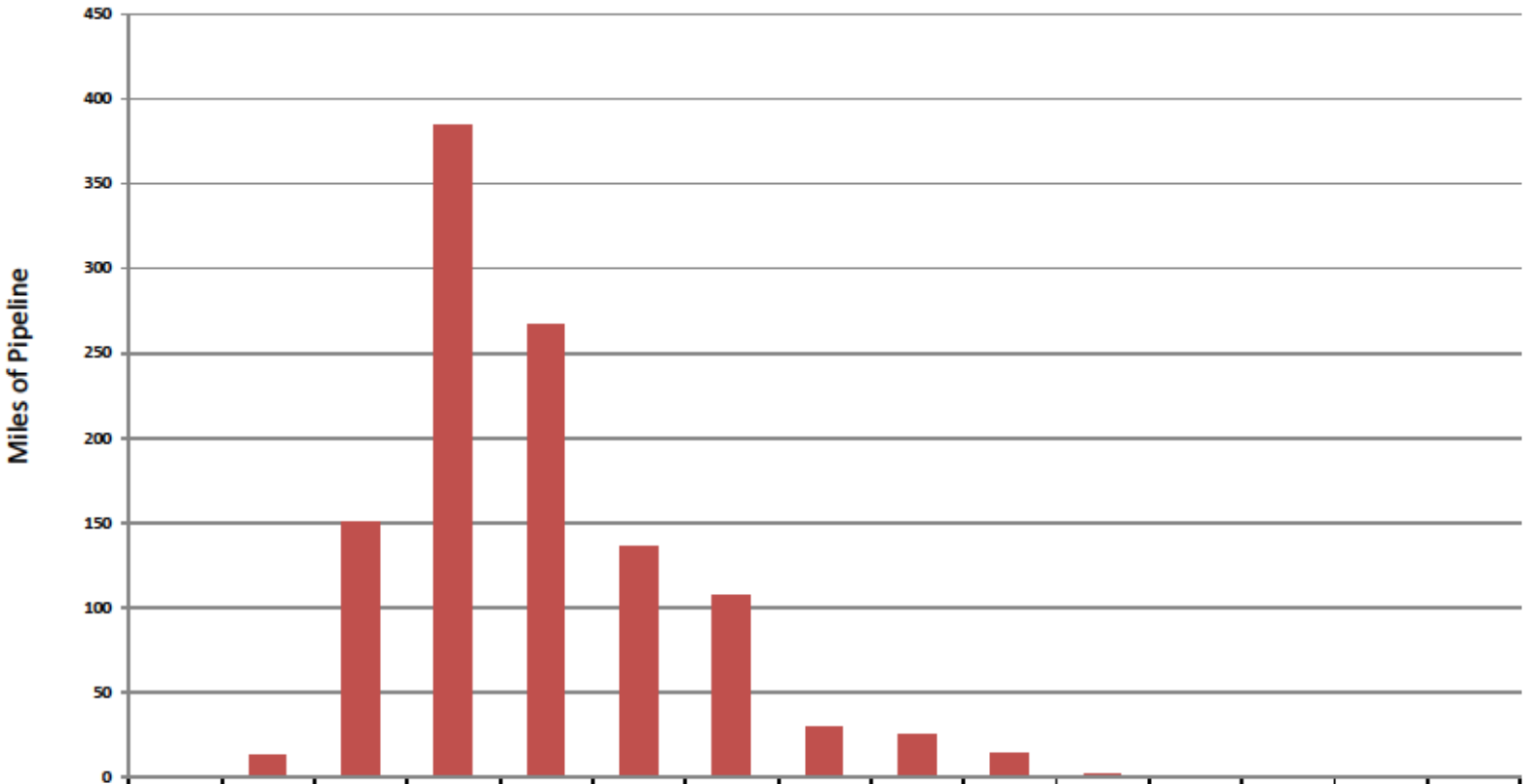
Risk Model Results



ROF	25.3	11.5
CONS	8.26	1.79
Date Installed	1965	2002

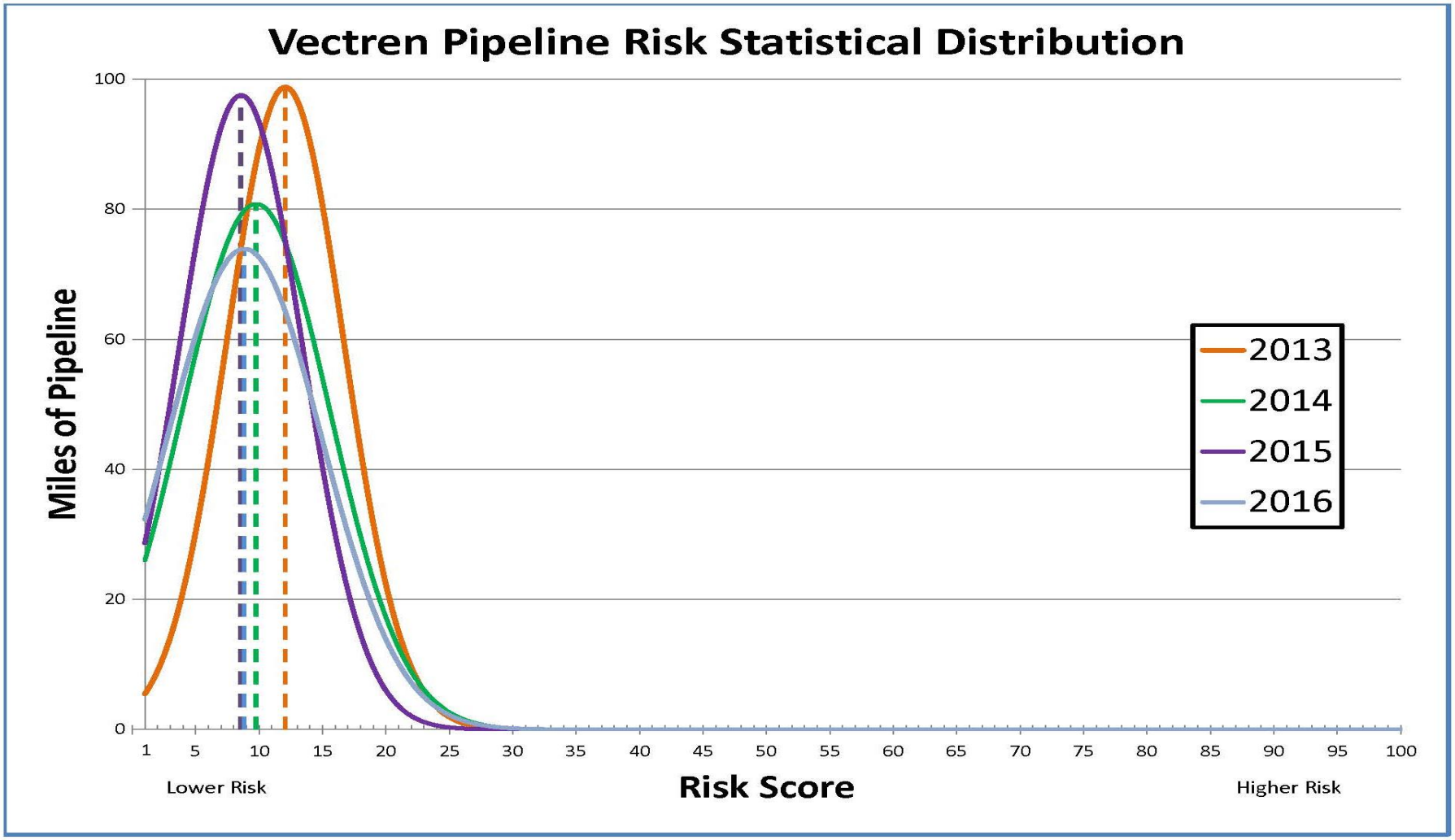
Ability to drill down on results and determine extent of threat.

Risk Model Results



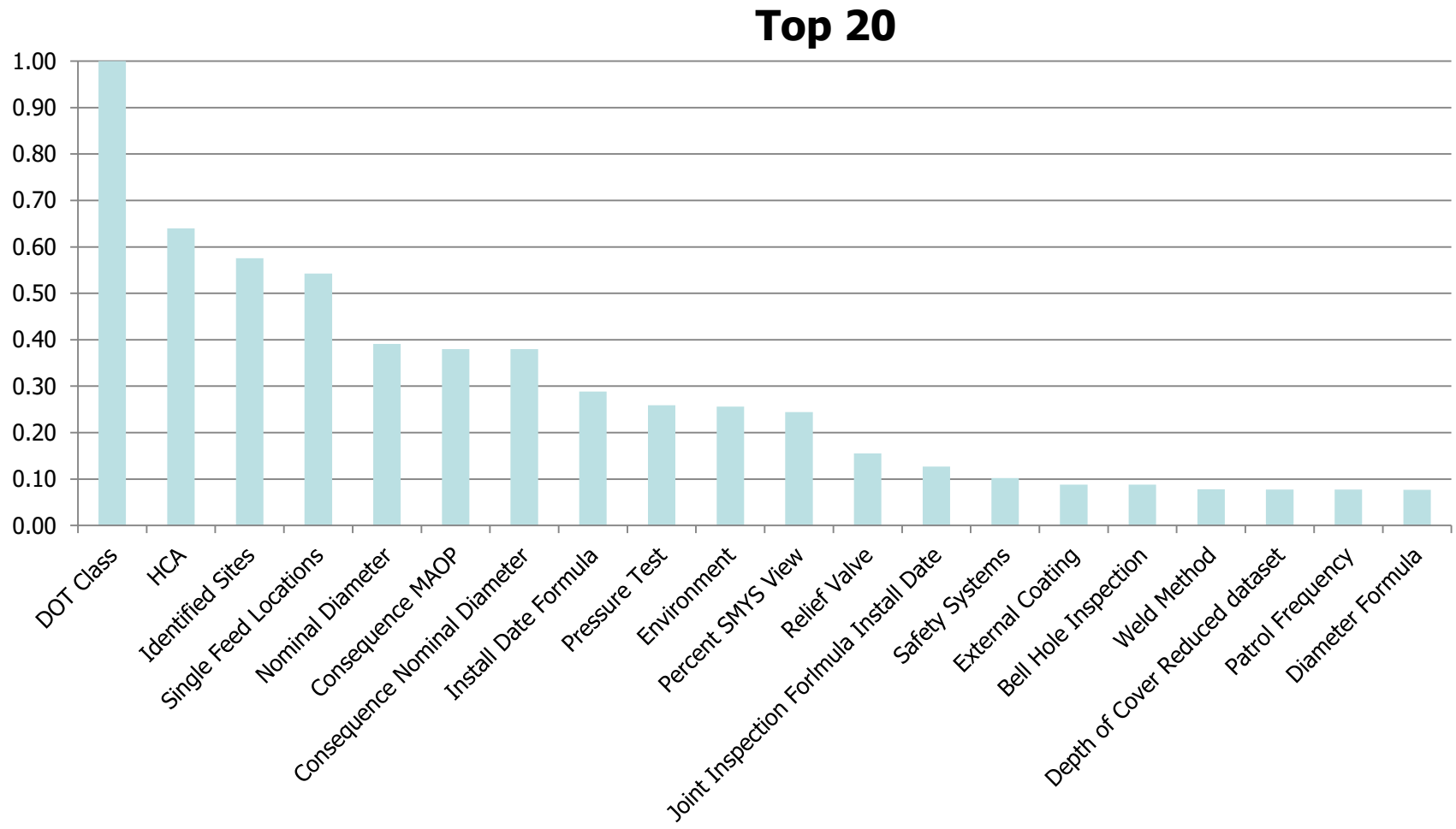
Risk Score	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Number of Segments	0	205	2,743	9,389	18,588	13,497	13,676	6,330	5,189	3,816	499	179	38	5	0
Percentage by Mileage	0.00%	1.17%	13.32%	34.02%	23.68%	12.00%	9.49%	2.65%	2.18%	1.24%	0.16%	0.09%	0.02%	0.00%	0.00%

Risk Model Results

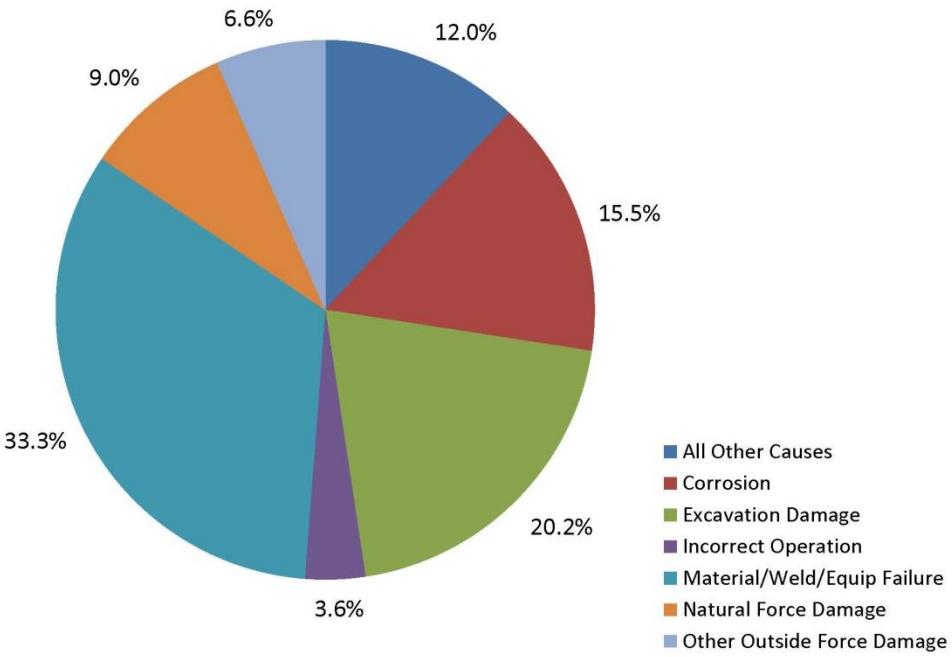


Sensitivity Study

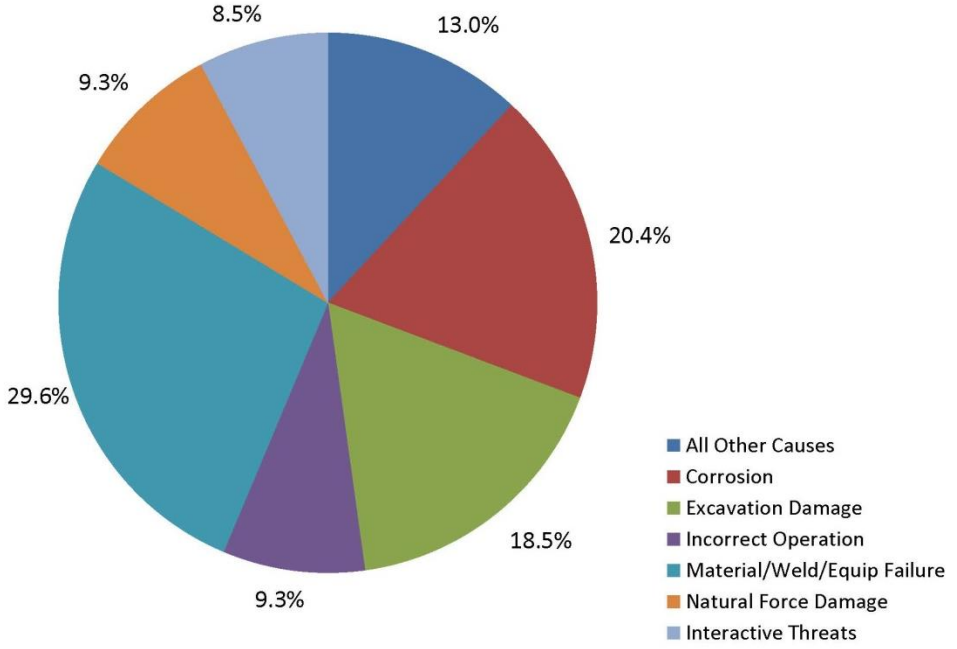
- Look at how changing one factor affects the risk score



Model Validation



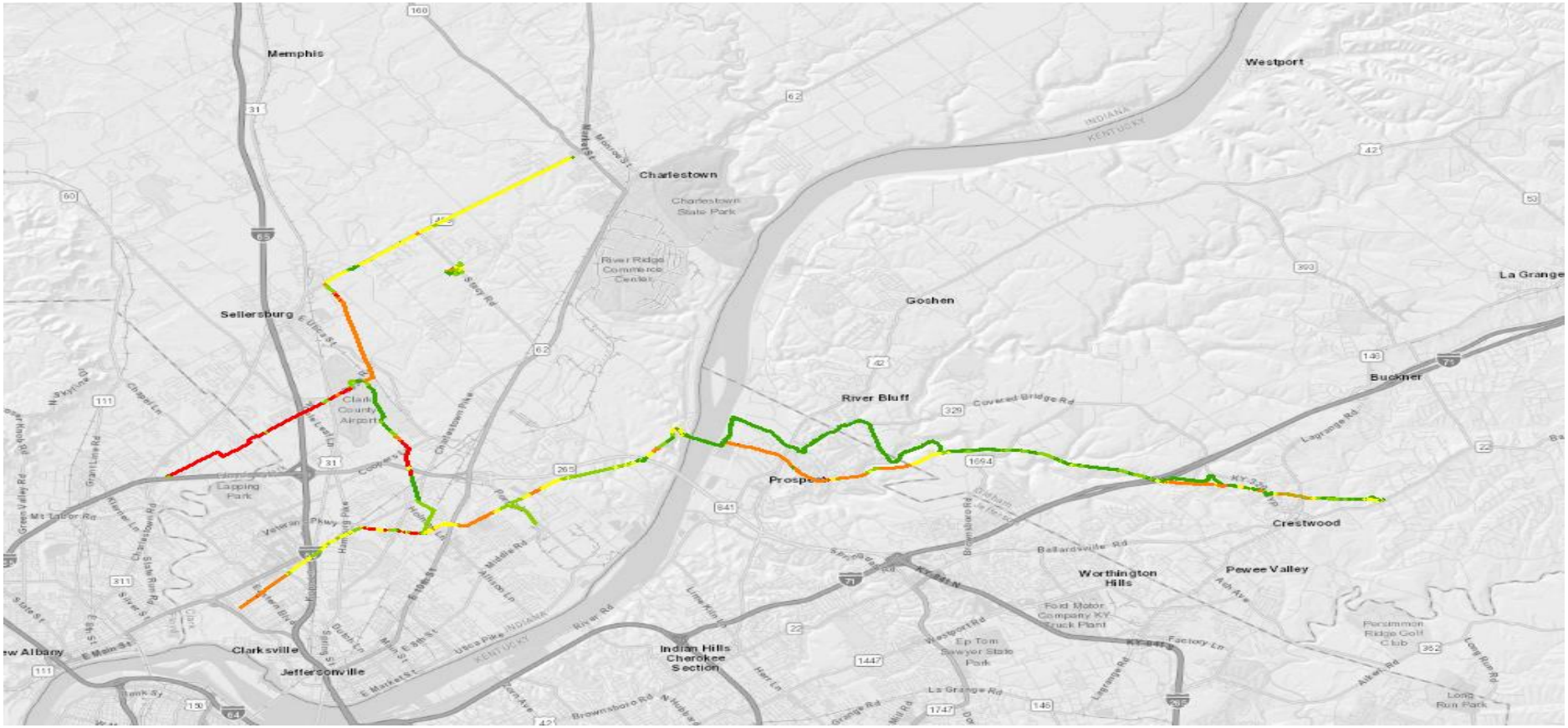
PHMSA
All Reported Incident Cause Breakdown
20 Year Average (1997-2016)



Vectren
Risk Model Threat Weightings

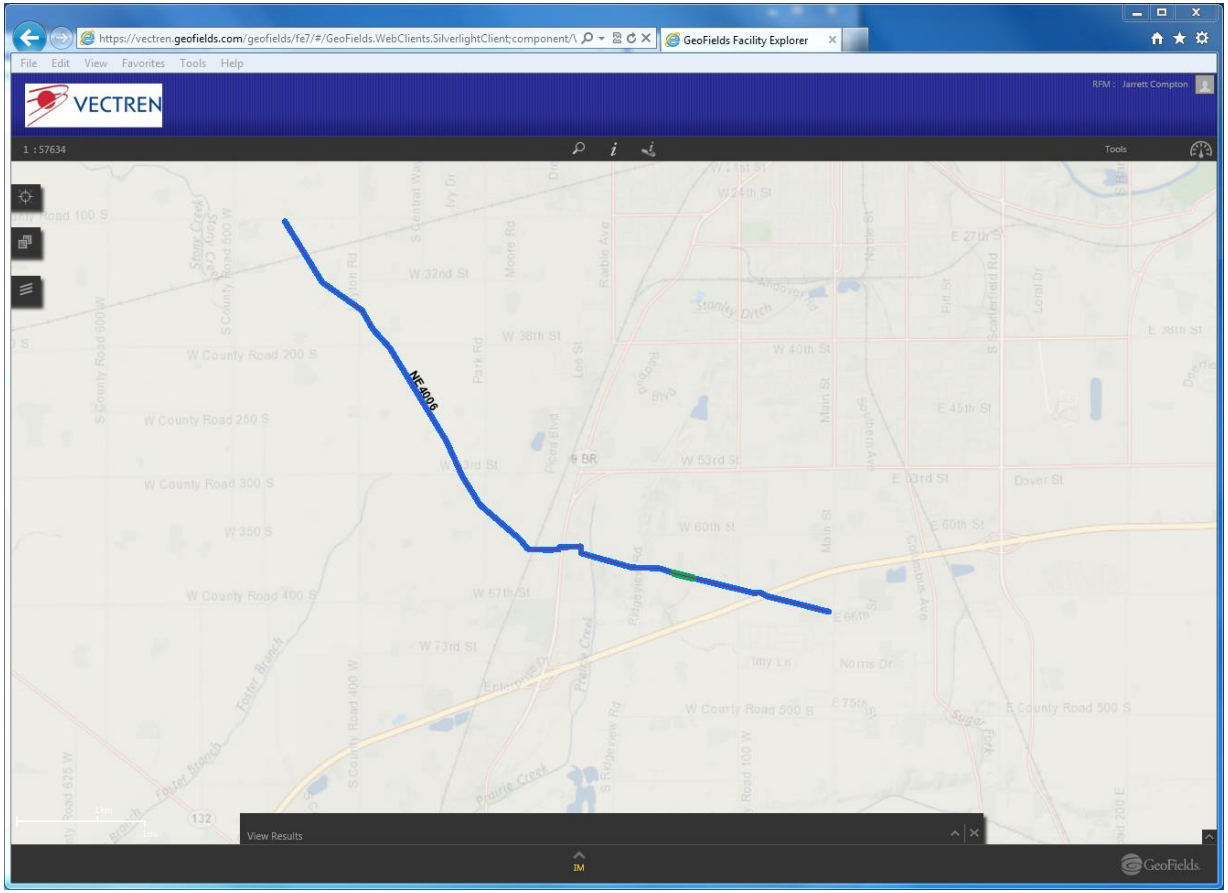
Model Validation

The results are also presented to local operations to solicit feedback as to the relative risk of the pipelines in the operations center.



Scenarios

Scenarios allow for the simulation of assessment activity to study the effect on risk by changing an attribute value or group of values.



This particular pipeline has a moderate risk score due to construction threats. The pipeline has the installation pressure test from 1971.

We can run a scenario to determine the effect or the risk score by simulating a new qualifying hydrotest.

For the hydrotest scenario, we have reviewed what threats would be affected and when the model is ran it will tell you how it will affect risk.

Scenarios

Scenarios allow for the simulation of assessment activity to study the effect on risk by changing an attribute value or group of values.
Below is shown the result of performing a pressure test on a pipeline.

Route_Name	Begin_Measure	End_Measure	SegLength	ROF	LOFscore	COFscore	SCCscore	COBscore	COEscore	COPscore	CONSscore	DSscore	EQscore	ECscore	ICscore	MFGscore	TPDscore	WOFscore	IncOpsScore	Create_Date
NE4006	0.00	7.07	7.07	13.39	4.07	3.29	0.86	2.91	1.00	3.78	7.08	16.25	0.41	3.39	3.56	5.67	1.85	1.92	4.33	5/11/2017
NE4006	0.00	7.07	7.07	9.57	2.91	3.29	1.00	2.91	1.00	3.78	4.95	16.25	0.41	2.37	2.49	3.97	0.55	0.19	4.33	5/25/2017
NE4006	7.07	104.97	97.90	13.09	3.98	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.85	1.92	4.33	5/11/2017
NE4006	7.07	104.97	97.90	9.38	2.85	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.55	0.19	4.33	5/25/2017
NE4006	104.97	131.65	26.68	13.65	4.15	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	2.87	1.92	4.33	5/11/2017
NE4006	104.97	131.65	26.68	9.48	2.88	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.76	0.19	4.33	5/25/2017
									00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
									00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
									00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.77	1.92	4.33	5/11/2017
									00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.54	0.19	4.33	5/25/2017
									00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
									00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
									00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.77	1.92	4.33	5/11/2017
									00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.54	0.19	4.33	5/25/2017
									00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
									00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
NE4006	828.04	997.96	169.92	13.06	3.97	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.77	1.92	4.33	5/11/2017
NE4006	828.04	997.96	169.92	9.34	2.84	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.54	0.19	4.33	5/25/2017
NE4006	997.96	1257.63	259.67	12.96	3.94	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.62	1.92	4.33	5/11/2017
NE4006	997.96	1257.63	259.67	9.34	2.84	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.51	0.19	4.33	5/25/2017
NE4006	1257.63	1439.62	181.99	13.06	3.97	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.77	1.92	4.33	5/11/2017
NE4006	1257.63	1439.62	181.99	9.34	2.84	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.54	0.19	4.33	5/25/2017
NE4006	1439.62	1446.69	7.07	12.77	3.88	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.26	1.92	4.33	5/11/2017
NE4006	1439.62	1446.69	7.07	9.31	2.83	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.44	0.19	4.33	5/25/2017
NE4006	1446.69	1494.65	47.96	12.53	3.81	3.29	0.86	2.91	1.00	3.78	5.69	16.25	0.41	3.39	3.56	5.67	1.26	1.92	4.33	5/11/2017
NE4006	1446.69	1494.65	47.96	9.11	2.77	3.29	1.00	2.91	1.00	3.78	3.98	16.25	0.41	2.37	2.49	3.97	0.44	0.19	4.33	5/25/2017
NE4006	1494.65	2270.96	776.31	12.83	3.90	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
NE4006	1494.65	2270.96	776.31	9.31	2.83	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
NE4006	2270.96	3568.83	1297.87	13.06	3.97	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.77	1.92	4.33	5/11/2017
NE4006	2270.96	3568.83	1297.87	9.34	2.84	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.54	0.19	4.33	5/25/2017
NE4006	3568.83	3663.14	94.31	12.83	3.90	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
NE4006	3568.83	3663.14	94.31	9.31	2.83	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
NE4006	3663.14	3705.15	42.01	13.39	4.07	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	2.41	1.92	4.33	5/11/2017
NE4006	3663.14	3705.15	42.01	9.44	2.87	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.67	0.19	4.33	5/25/2017
NE4006	3705.15	4446.36	741.21	12.83	3.90	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
NE4006	3705.15	4446.36	741.21	9.31	2.83	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017
NE4006	4446.36	4505.54	59.18	13.39	4.07	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	2.41	1.92	4.33	5/11/2017
NE4006	4446.36	4505.54	59.18	9.44	2.87	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.67	0.19	4.33	5/25/2017
NE4006	4505.54	4556.15	50.61	12.83	3.90	3.29	0.86	2.91	1.00	3.78	6.31	16.25	0.41	3.39	3.56	5.67	1.38	1.92	4.33	5/11/2017
NE4006	4505.54	4556.15	50.61	9.31	2.83	3.29	1.00	2.91	1.00	3.78	4.42	16.25	0.41	2.37	2.49	3.97	0.46	0.19	4.33	5/25/2017

In this case, there is a 25% reduction in risk score by performing a pressure test

Missing Inputs and Nulls

- **Missing and Null Value data are handled on an individual basis**
- **Where practical, conservative values are used to assess risk in pipe segments with missing data**
- **Missing data that is deemed vital to the safe operation of the system is actively collected**
  - **Pipe grade and Wall Thickness**
    - **667 pipe segment analyzed**
    - **2,315 Specimens Tested**
  - **Documented Test Pressure**
    - **All HCA gaps remediated by end of 2016**
    - **All Transmission gaps remediated by end of 2020**

Wins

- Standardized scoring makes explaining the model and the results easier.
- Visual output has been effective in demonstrating reasoning for project prioritization.
- Annual reviews have received good participation.

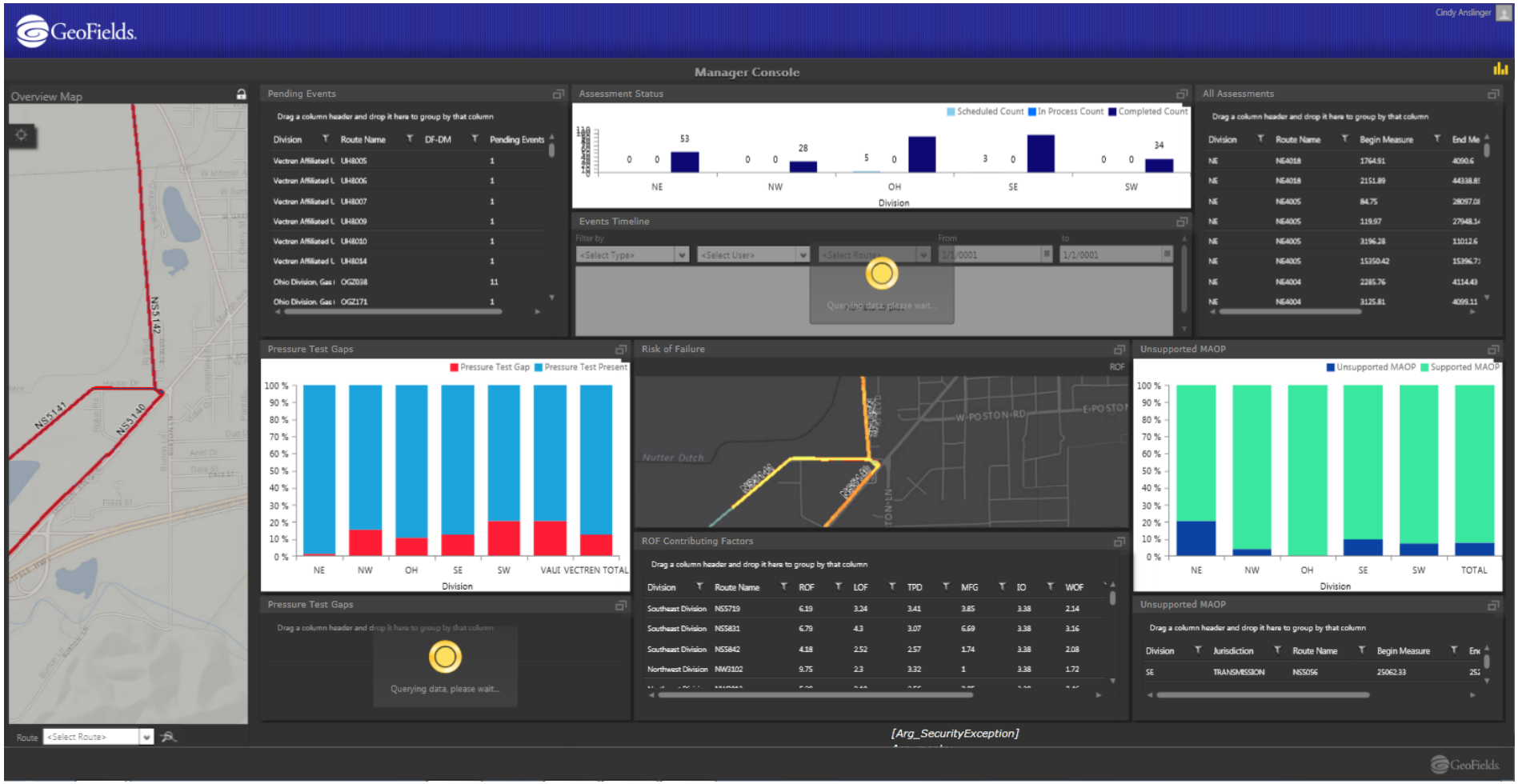
Lessons Learned

- The ROF=LOF * COF format over emphasizes the consequence portion which is generally static and difficult to influence.
- Large number of risk segments makes prioritizing individual segments difficult.
- Need to account for cost of remediation activities outside of the risk model for project prioritization.

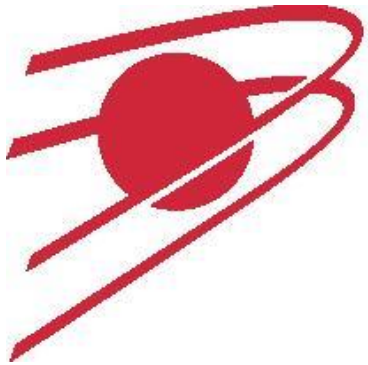
Continuing Improvements

- Prioritizing activities based on likelihood scores which are more directly affected by field work.
- Modifying model to better show how remediation and assessment lowers risk.
- Modifying model to better utilize the risk range.
- Modifying the system for improved views aligned with the role of the person

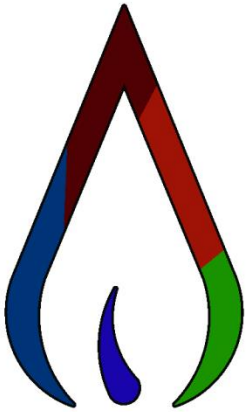
Transmission GIS Dashboard



Questions?



VECTREN



GAIM