

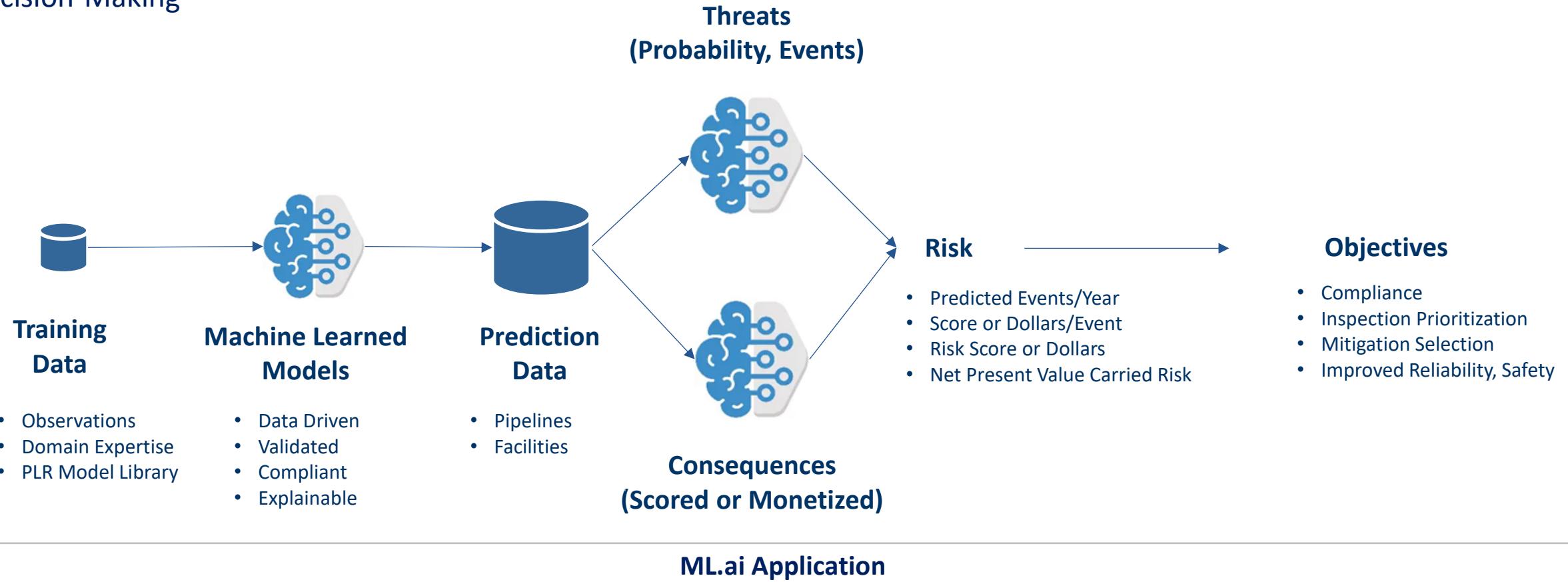
# PLR Machine Learn Based Risk Methodology

Version 3

**Michael P. Gloven, P.E.**  
**Pipeline-Risk (PLR)**  
**Engineering Solutions & Software**  
[www.pipeline-risk.com](http://www.pipeline-risk.com)

# Overview

A Data Driven Machine Learning Based Approach  
to Integrity & Risk Management Compliance &  
Decision-Making



# Overview

The purpose of this document is to explain PLR's machine-learned based risk structure for assessing the threats, consequences and risk of pipeline systems.

## Machine Learned Models

The risk structure accommodates several approaches to machine learning Individual threat & consequence models in support of integrity & risk management:

- Model learning based on actual observations of the target threat or consequence
- Model learning based on synthetic data created from PLR's model library
- Model learning based on traditional deterministic risk calculations
- Model learning based on a sampling of industry based deterministic structures & studies

Key outputs from the structure include predictions of threat and consequence risks, scored or monetized, prediction explanations and simulations.

## ML.ai Software Platform

ML.ai is PLR's secure web platform supporting pipeline & facility risk management through machine learning and advanced analytics.

## Value

ML.ai supports a data driven approach to risk, where results are transparent, explainable and can be used to support compliance and resource allocation decision-making:

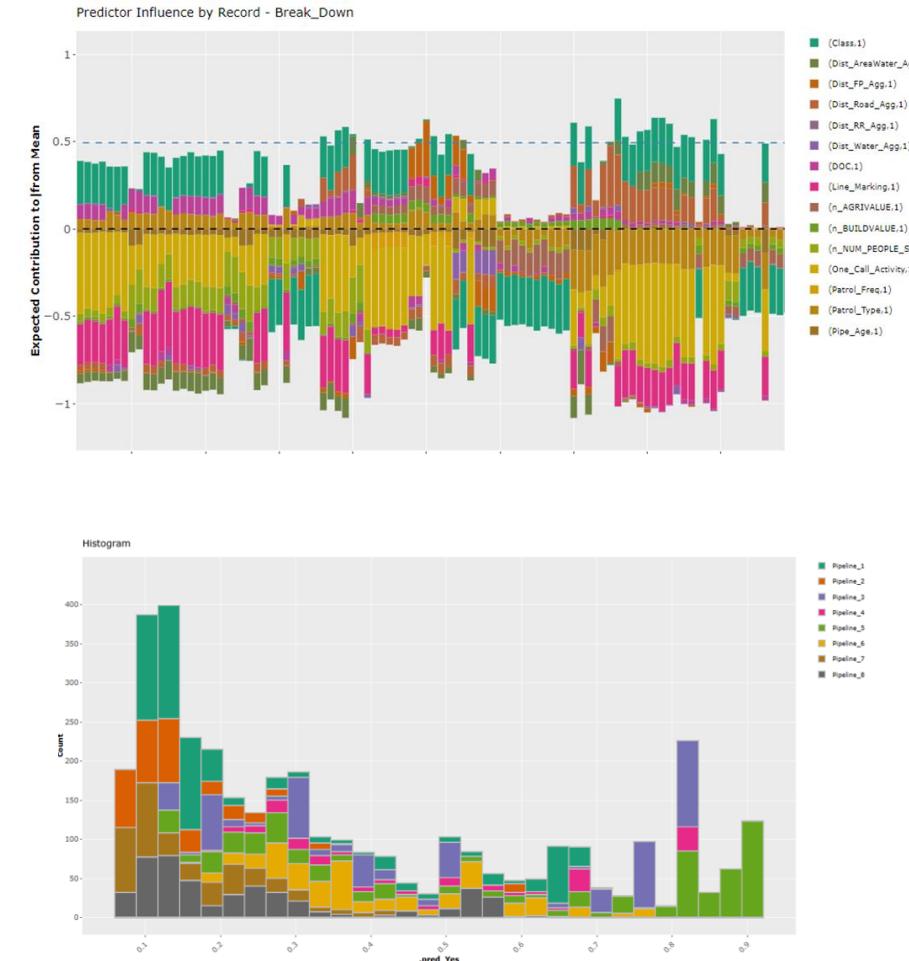
- Models are meta-data driven and can leverage existing data, PLR's geospatial data store & PLR reference models
- Results may be normalized to industry or in-house statistics in support of risk monetization
- Advanced analytics provide methods to understand and explain prediction results in support of relevant action

# Glossary of Key Concepts & Terms

# Key Concepts

Learned models are the foundation of the overall risk analysis supported by ML.ai:

- Threat models support the concept of **POER (probability of event rate)** which is a construct to calculate probabilities for different lengths of pipe or facilities depending on whether the threat is time dependent or time independent. Event rates are based on provided PHMSA statistics or asset owner assumptions, and application of POER results in predicted events per year for each pipe segment over time.
- Consequence models support **risk monetization** and are combined with the results of the threat models to generate risk values for each pipe segment over time for each threat. Risk values are then represented as net present values in support of resource allocation decision-making. Dimensionless scores can be retained if monetization is not required.
- The process provides options for inclusion of the impact of mitigations, threat resistance, recent assessments and repairs, and threat interactions as derived through advanced analytics and simulations.
- Key advantages of a machine learning approach is it is data driven, validated with actual observations, considers threat interactions and non-linearities, fully explainable, compliant and may be continuously improved as new data becomes available.



# Glossary of Terms – Time Independent Threats

Time Independent Threats		
<b>Pipe Segment Length</b>	SegLength	Segment Length (Measure_End – Measure_Start)
<b>Threat Prediction</b>	Predict	Machine Learning Prediction (Binary Classification Probability)
<b>Classification Prediction</b>	S	Probability of Threat (Susceptibility: Same as Predict)
<b>Assessment Mitigation</b>	Assess	Assessment & Repair Threat Mitigation (higher % reduces S)
<b>Threat Mitigation</b>	Mitig	Optional Additional Mitigation (higher % reduces S)
<b>Threat Resistance</b>	Resist	Optional Additional Resistance (higher % reduces S)
<b>Probability of Event Rate</b>	POER	$POER = S * (1 - Assess) * (1 - Resist) * (1 - Mitig)$
<b>Min Boundary</b>	predMin	Sets the Minimum POER Boundary for Scaling
<b>Max Boundary</b>	predMax	Sets the Maximum POER Boundary for Scaling
<b>Event Rate</b>	Event_Rate	Scaled Event Rate for Segment (#/1000 mile – yrs)
<b>Events per Year</b>	Events_yr	Length Adjusted Events per Segment per Year
<b>Analysis Years</b>	Years	Number of Years to Assess Threat

# Glossary of Terms – Dependent Threats

Time Dependent Threats		
<b>Pipe Segment Length</b>	SegLength	Segment Length
<b>Threat Prediction</b>	Predict	Machine Learning Prediction (Regression)
<b>Regression Prediction</b>	mpy	Growth Rate (Severity)
<b>Criteria</b>	Criteria	Years for WT to Exceed MAOP (Pressure) or WT Depth (Depth %)
<b>Wall Thickness</b>	WT	Current Wall Thickness of Pipe or Remaining Anomaly
<b>Wall Thickness Required</b>	WT_Req	Two Options: Minimum Pressure or Depth % Criteria
<b>Yrs to Exceed Required WT</b>	WT_Yrs	Number of Yrs to Required WT
<b>Age</b>	Age	Current Age in Years of Pipe
<b>Time to Criteria</b>	TTC	Current Age plus WT_Yrs to Exceed Required WT
<b>Probability of Event Rate</b>	Weibull	Base Probability of Event Rate based on Weibull Curve
<b>Min Boundary</b>	predMin	Sets the Minimum POER Boundary for Scaling
<b>Max Boundary</b>	predMax	Sets the Maximum POER Boundary for Scaling
<b>Assessment Mitigation</b>	Assess	Assessment & Repair Threat Mitigation (higher % reduces POER)
<b>Threat Mitigation</b>	Mitig	Optional Additional Mitigations (higher % reduces POER)
<b>Threat Resistance</b>	Resist	Optional Additional Resistance (higher % reduces POER)
<b>Probability of Event Rate</b>	POER	$POER = \text{Probability} * (1 - \text{Assess}) * (1 - \text{Resist}) * (1 - \text{Mitig})$
<b>Event Rate</b>	Event_Rate	Scaled Event Rate for Segment (#/1000 mile – yrs)
<b>Events per Year</b>	Events_yr	Length Adjusted Events per Segment per Year
<b>Analysis Years</b>	Years	Number of Years to Assess Threat

# Glossary of Terms – Consequences

## Consequences

<b>Regression Prediction</b>	Predict	Machine Learning Target (Numerical Value Regression)
<b>Min Boundary</b>	predMin	Sets the Minimum Consequence Boundary for Scaling
<b>Max Boundary</b>	predMax	Sets the Maximum Consequence Boundary for Scaling
<b>Consequence Mitigation</b>	Mitig	Optional Additional Mitigations (higher % reduces Predict)
<b>Regression Prediction</b>	Conseq	Consequence = Predict * (1 – Mitig)
<b>Scaled Consequence</b>	Conseq_Scaled	Scaled Consequence for Segment (\$)

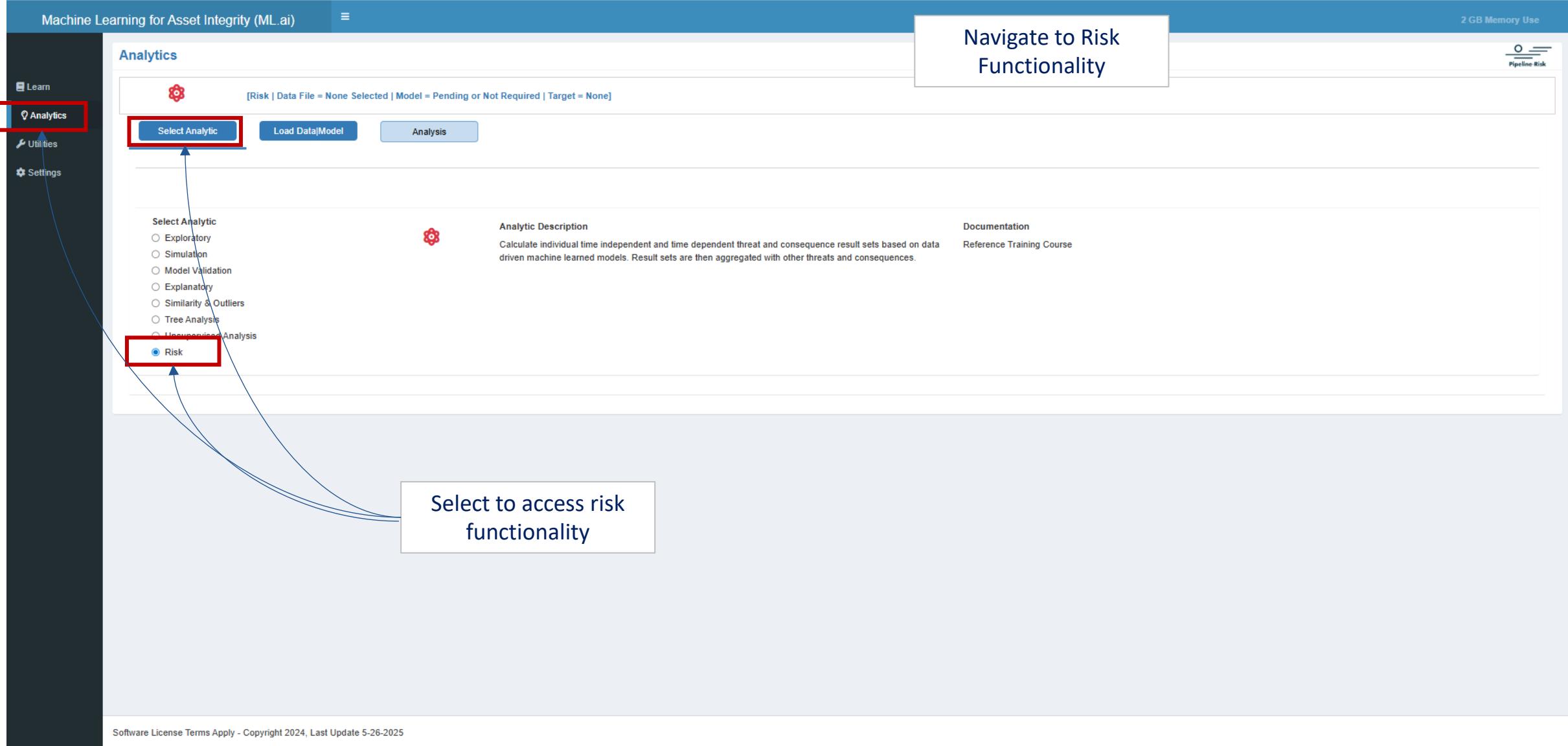
## Risk

<b>Total Events per Year</b>	Total_Events_yr	Sum of all Predicted Events
<b>Total Consequences</b>	Total_Conseq	Sum of All Consequences
<b>Total Risk</b>	Total_Risk	Total_Events_yr x Total_Conseq by Threat or All Threats (depends on selected view)
<b>Net Present Value</b>	NPV	Total_Risk discounted to Year 0
<b>Net Present Value per Mile</b>	NPV_mile	NPV Normalized by Mile

- Risk is calculated by multiplying the number of events per year times consequences for each segment and analysis year. The results will show risk for each segment and each analysis year which are then aggregated to a Net Present Value (NPV) for each segment based on an assumed discount rate and number of analysis years. NPV's are further normalized to miles shown as NPV\_mile.
- Interactions are an advanced feature, basically if interactions are set as True for a threat the threat POER is increased by the POER of the interacting threats using 1-POER math
- Ensemble model predictions are an advanced feature where the predictions from main threat are multiplied by the ensemble model predictions

# EXAMPLE

# ML.ai Navigation



The screenshot shows the ML.ai Analytics interface. On the left sidebar, the 'Analytics' option is selected and highlighted with a red box. On the main page, the 'Select Analytic' button is also highlighted with a red box. A callout box with the text 'Select to access risk functionality' points to the 'Risk' option in the 'Select Analytic' dropdown menu, which is also highlighted with a red box. Another callout box with the text 'Navigate to Risk Functionality' is positioned above the main content area.

Machine Learning for Asset Integrity (ML.ai)

Analytics

[Risk | Data File = None Selected | Model = Pending or Not Required | Target = None]

Select Analytic

Load Data|Model Analysis

Select Analytic

- Exploratory
- Simulation
- Model Validation
- Explanatory
- Similarity & Outliers
- Tree Analysis
- Unsupervised Analysis
- Risk**

Analytic Description

Calculate individual time independent and time dependent threat and consequence result sets based on data driven machine learned models. Result sets are then aggregated with other threats and consequences.

Documentation

Reference Training Course

Software License Terms Apply - Copyright 2024, Last Update 5-26-2025

# Prerequisites – Models

Threat and consequence models are required for the risk process. The example shows three typical model types, learned as part of PLR's industry-based reference model library:

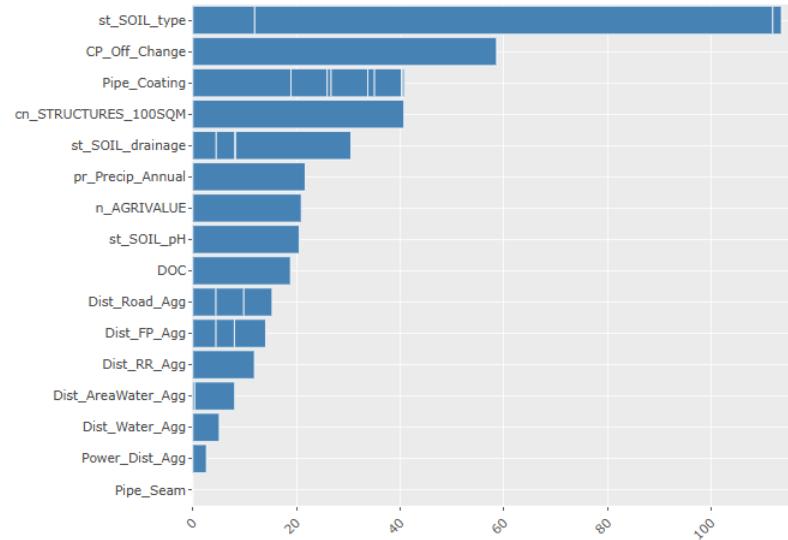
**EC\_mpy** – external corrosion growth rate model (time dependent)

**TPD** – third party damage susceptibility model (time independent)

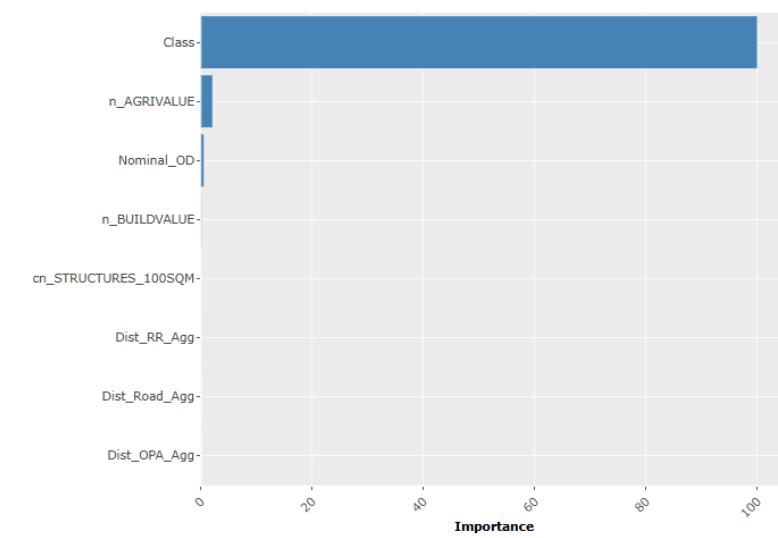
**Consequence** – impact on population model (consequence)

- Additional models may be added to the process
- The model learning process is automated through ML.ai and is not presented in this document
- The models used in this example are simply previously learned digital objects loaded into the risk process to demonstrate the different types of models

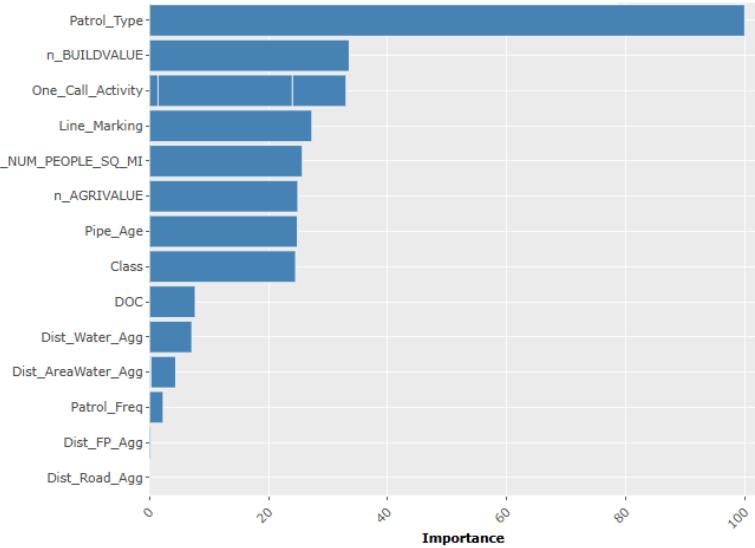
**EC\_mpy Predictors & Weights**



**Consequence Predictors & Weights**



**TPD Predictors & Weights**



**Saved Model Files:**

 M_Consequence.RDS
 M_EC_mpy_tune.RDS
 M_TPD.RDS

# Prerequisites – Prediction Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

**Select Analytic** **Load Data/Model** **Analysis**

**Load** **Table** **Plots** **Quality** **Variance** **Correlation** **Levels** **Models** **Predictors** **Model Info**

**Source File**  
 C\_vwTransmission.RDS

**Model (RDS)**  
 M\_TPD.RDS

Up/DownSample Data  
 Create Unique Rec\_ID  
 Check Data for Special Characters  
 Skip Model (Data Analysis Only)

Use Ensemble

Target = TPD  
Task = Binary Classification  
Learn Date = Thu Oct 23 11:09:18 AM 2025  
Units = probability  
Model = Model5  
Pos Class = Yes

**Load Prediction Data**

**Level 1**  
**Assets**  
Pipeline\_1  
Pipeline\_2  
Pipeline\_3  
Pipeline\_4  
Pipeline\_5  
Pipeline\_6  
Pipeline\_7  
Pipeline\_8

**Level 2**  
**Fields**  
Class  
cn\_AreaLand  
cn\_AreaWater  
cn\_PEOPLE\_100SQM  
cn\_STRUCTURES\_100SQM  
Consequence  
CP\_Off\_Change  
Cum\_Sum  
Dist\_AreaWater  
Dist\_AreaWater\_Agg  
Dist\_Comp  
Dist\_FP  
Dist\_FP\_Agg  
Dist\_OPA  
Dist\_OPA\_Agg  
Dist\_Road  
Dist\_Road\_Agg  
Dist\_RR  
Dist\_RR\_Agg  
Dist\_Water  
Dist\_Water\_Agg  
Dist\_Waterway\_rev  
DOC  
Dyn\_Seg\_ID

Enable Search & Select Option  
 Use File to Pre-Select Assets

**Pre-Select Fields**  
Model Predictors (Load Model)

**Load Model**

**Load Optional Ensemble Model**

**Prediction data and models are loaded one model at a time, where each model is a risk element (threats or consequences) used in the process.**

**Guidance**

**Data Sets**  
Learn - Model Learn Data  
Analysis - Data of Interest

**Load** **Clear Data**

Loaded Assets = 8  
Loaded Fields = 59  
Loaded Records = 3,650  
Filtered Assets = 8  
Filtered Fields = 54  
Filtered Analysis Records = 1,951  
Filtered Learning Records = 1,699  
 Inc. Model Learning Data in Analysis

- Data Loaded
- Data Table in State
- Valid Model Loaded
- Data Table Filtered
- All Predictors Present
- Minimum Fields = 2
- Valid Column Names
- Field Classes Match
- Excludes Reserved Fields
- All Records Complete
- Measures Present
- Size Load < 200000
- Field Count < 50
- File is Dataframe

**Loaded prediction data is verified for consistency with the loaded model**

# Prerequisites – Prediction Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Select Analytic   Load Data/Model   Analysis

Load   Table   Plots   **Quality**   Variance   Correlation   Levels   Models   Predictors   Model Info

Update   Analysis Data

Select Fields

Rec_ID
Level1
Level2
Comp_ID
Comp_Name
Data_Set
TPD
Class
cn_PEOPLE_100SQM
cn_STRUCTURES_100SQM
Consequence
CP_Off_Change
Dist_AreaWater_Agg
Dist_FP_Agg
Dist_OPA_Agg
Dist_Road_Agg
Dist_Water_Agg

Missing Only Fields

Exclude References

Drop Zero Levels

Zero Variance Fields

Convert Factors to Character

Show Field Type

All

Levels

3

Trim Strings

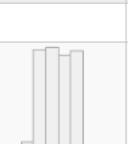
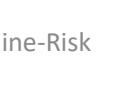
20

Guidance

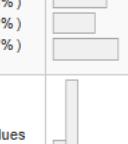
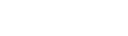
**Quality**

Analysis Data

Learn Data from Model

No	Variable	Stats / Values	Freqs (% of Valid)	Graph	Missing
1	Record Count = 1951				
6	CP_Off_Change [numeric]	Mean (sd) : -0.002 (0.017) min ≤ med ≤ max: -0.08 ≤ -0.001 ≤ 0.04 IQR (CV) : 0.022 (-8.064)	49 distinct values		
2	Class [numeric]	Mean (sd) : 1.772 (0.852) min ≤ med ≤ max: 1 ≤ 1 ≤ 3 IQR (CV) : 2 (0.481)	1 : 980 (50.2%) 2 : 435 (22.3%) 3 : 536 (27.5%)		0 (0.0%)
5	Consequence [numeric]	Mean (sd) : 30205023 (43112839) min ≤ med ≤ max: 1000000 ≤ 1000000 ≤ 100000000 IQR (CV) : 99000000 (1.427)	1000000 : 980 (50.2%) 10000000 : 435 (22.3%) 100000000 : 536 (27.5%)		0 (0.0%)
13	DOC [numeric]	Mean (sd) : 26.818 (12.237) min ≤ med ≤ max: 12 ≤ 24 ≤ 128 IQR (CV) : 12 (0.456)	60 distinct values		
7	Dist_AreaWater_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	1059 (54.3%) 632 (32.4%) 260 (13.3%)		0 (0.0%)
8	Dist_FP_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	1005 (51.5%) 750 (38.4%) 196 (10.0%)		0 (0.0%)
9	Dist_OPA_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	42 ( 2.2%) 1887 (96.7%) 22 ( 1.1%)		0 (0.0%)

Quality report shows data summary statistics and comparison of prediction data (analysis data) to learning data

No	Variable	Stats / Values	Freqs (% of Valid)	Graph	Missing
1	Record Count = 1699				
2	Class [numeric]	Mean (sd) : 2.074 (0.857) min ≤ med ≤ max: 1 ≤ 2 ≤ 3 IQR (CV) : 2 (0.413)	1 : 566 (33.3%) 2 : 442 (26.0%) 3 : 691 (40.7%)		0 (0.0%)
9	DOC [numeric]	Mean (sd) : 27.759 (11.551) min ≤ med ≤ max: 12 ≤ 24 ≤ 124 IQR (CV) : 12 (0.416)	43 distinct values		0 (0.0%)
3	Dist_AreaWater_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	998 (58.7%) 574 (33.8%) 127 ( 7.5%)		0 (0.0%)
4	Dist_FP_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	879 (51.7%) 725 (42.7%) 95 ( 5.6%)		0 (0.0%)
5	Dist_OPA_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	26 ( 1.5%) 1670 (98.3%) 3 ( 0.2%)		0 (0.0%)
7	Dist_RR_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	97 ( 5.7%) 1598 (94.1%) 4 ( 0.2%)		0 (0.0%)
6	Dist_Road_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	475 (28.0%) 1174 (69.1%) 50 ( 2.9%)		0 (0.0%)
8	Dist_Water_Agg [factor]	1. Limited_Impact 2. Out_Of_Range	950 (55.9%) 12 ( 0.7%)		0 (0.0%)

## **Third Party Damage - TPD (Time Independent Threat)**

# Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.

Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Select Analytic **Load Data/Model** Analysis

Load Table Plots Quality Variance Correlation Levels Models Predictors Model Info

Source of Analytical Data: RDS Data Frame

Source File: C\_vwTransmission.RDS **Upload complete**

Model (RDS): M\_TPD.RDS **Upload complete**

Target = TPD  
Task = Binary Classification  
Learn Date = Thu Oct 23 11:09:18 AM 2025  
Units = probability  
Model = Model5  
Pos Class = Yes

Use Ensemble

Level 1: Assets: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Level 2: Fields: Class, cn\_AreaLand, cn\_AreaWater, cn\_PEOPLE\_100SQM, cn\_STRUCTURES\_100SQM, Consequence, CP\_Off\_Change, Cum\_Sum, Dist\_AreaWater, Dist\_AreaWater\_Agg, Dist\_Comp, Dist\_FP, Dist\_FP\_Agg, Dist\_OPA, Dist\_OPA\_Agg, Dist\_Road, Dist\_Road\_Agg, Dist\_RR, Dist\_RR\_Agg, Dist\_Water, Dist\_Water\_Agg, Dist\_Waterway\_rev, DOC, Dyn\_Seg\_ID

Guidance: Data Sets, Learn - Model Learn Data, Analysis - Data of Interest

Load Clear Data

Loaded Assets = 8  
Loaded Fields = 59  
Loaded Records = 3,650  
Filtered Assets = 8  
Filtered Fields = 54  
Filtered Analysis Records = 1,951  
Filtered Learning Records = 1,699  
 Inc. Model Learning Data in Analysis

Pre-Select Fields: Model Predictors (Load Model)

Loaded prediction data is verified it is consistent with the loaded model

Data Loaded  
 Data Table in State  
 Valid Model Loaded  
 Data Table Filtered  
 All Predictors Present  
 Minimum Fields = 2  
 Valid Column Names  
 Field Classes Match  
 Excludes Reserved Fields  
 All Records Complete  
 Measures Present  
 Size Load < 200000  
 Field Count < 50  
 File is Dataframe

# Apply TPD Model to Data

Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Select Analytic   Load Data/Model   Analysis

Configure   Normalize   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Map Model

Type: Time\_Independent Threat

Prediction Units: Probability or Score

Use Configuration File

Target = TPD  
Task = Binary Classification  
Learn Date = Thu Oct 23 11:09:18 AM 2025  
Units = probability  
Pos Class = Yes

Map General Fields

Asset Type: Pipe

Measurement System: Standard

Analysis Years: 5

Current Year: 2025

Measure Start: Measure\_Start

Measure End: Measure\_End

Assessment Mitigation (opt): None

Addit. Mitigations (opt): None

Addit. Resistance (opt): None

Update

Loaded Records = 3,650  
Calculation Years = 5  
Calculation Records = 18,250

Mapping Valid

Guidance

- Each Model Generates Risk Results
- Results Calculated for Each Model
- Configure Each Threat Model
- Configure Each Consequence Model
- Minimize Use of Missing Data
- Configure File Persists Mapping
- All Fields Require Mapping
- Results Aggregated Later in Process
- Aggregated Results Use Same Data

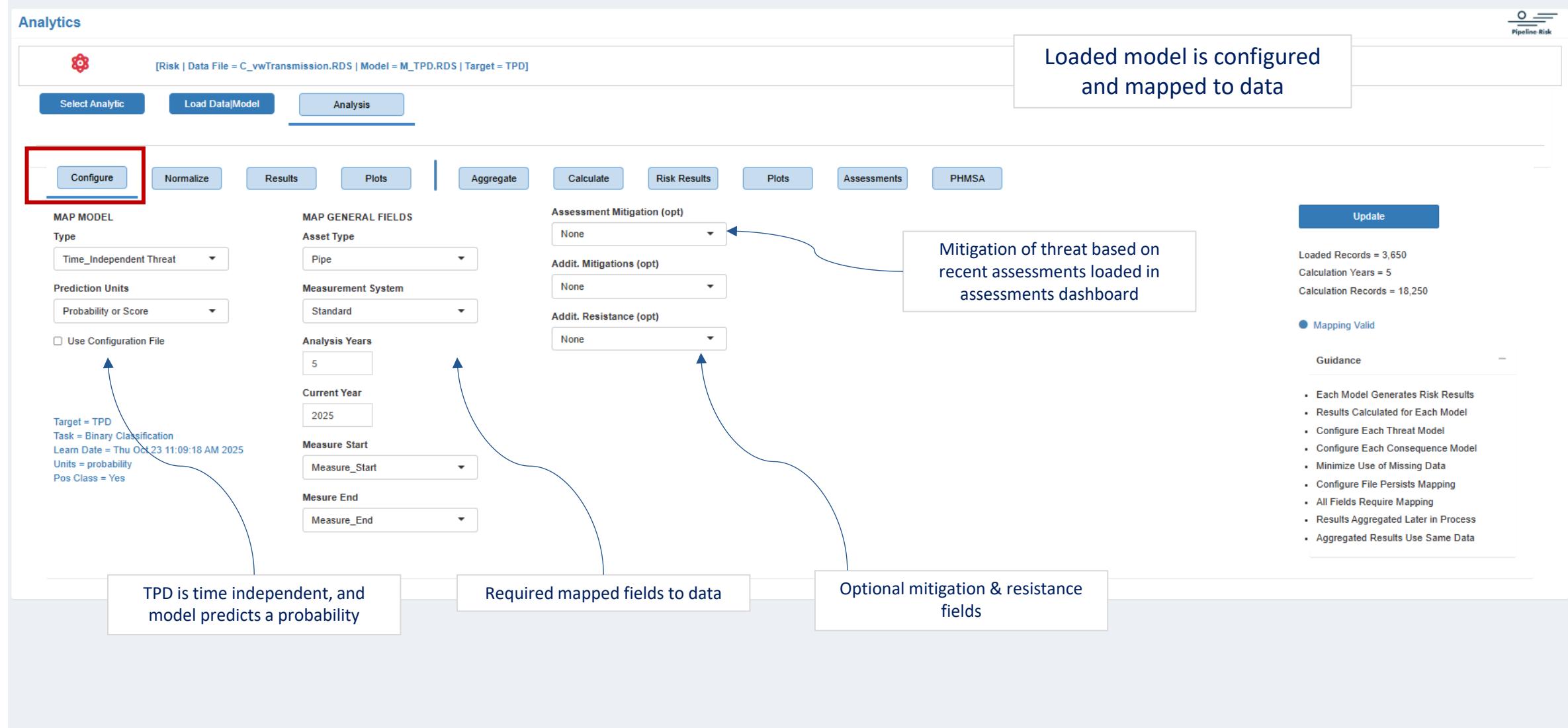
Loaded model is configured and mapped to data

Mitigation of threat based on recent assessments loaded in assessments dashboard

TPD is time independent, and model predicts a probability

Required mapped fields to data

Optional mitigation & resistance fields



# Apply TPD Model to Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Select Analytic   Load Data|Model   **Analysis**

Configure   **Normalize**   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

**PREDICTION RESULTS**

Histogram Type: Regular   Results: Time Independent Predictions

Position: Stack   Minimum = 0.29, Maximum = 0.65, Mean = 0.42, Standard Deviation = 0.08

Persist Range   Range Min: 0   Range Max: 1

Set these to model range

**Model Prediction Results (Year 1) - Predict**

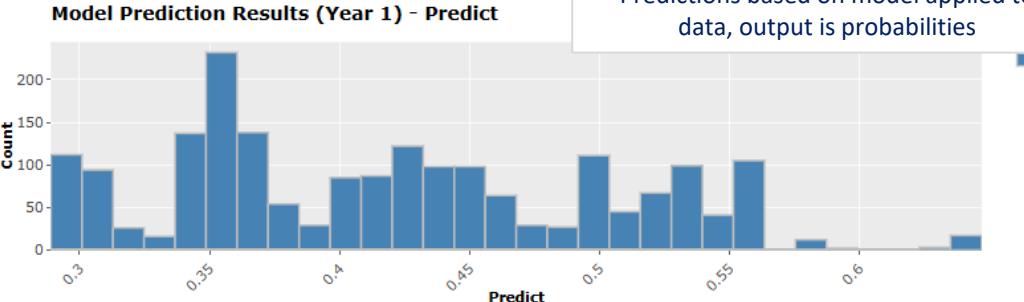
Predictions based on model applied to data, output is probabilities

Count

Legend: All

Bins: 30   Intervals: 3

Constant = All



**NORMALIZATION STATISTICS**

Distribution Type Fit: uniform   Select normalization distribution type

Min Scale to Value: 0.0001   Max Scale to Value: 1

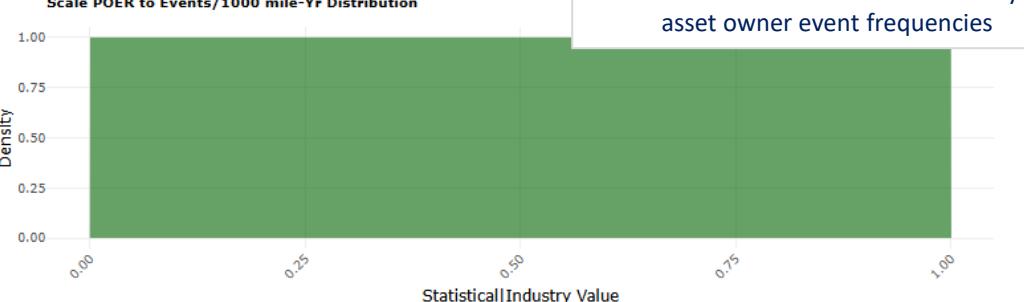
Save Configuration

**Scale POER to Events/1000 mile-Yr Distribution**

Predictions are normalized to industry or asset owner event frequencies

Density

Statistical|Industry Value



**Normalize or convert model predictions to TPD event rates**

**Calculate**

Analysis Records = 1,951   Calculation Years = 5   0.06 Estimated Run Time (min)

Model Exists   Records > 0   Results Complete

**Create Normalized Results**

Guidance

- Results Exclude Learning Data
- Persist Range Sets Scale to Transform
- Transform is to Normalization Range
- Transform Scales POER to Event Rates
- Transform Scales Consequences to Dollars

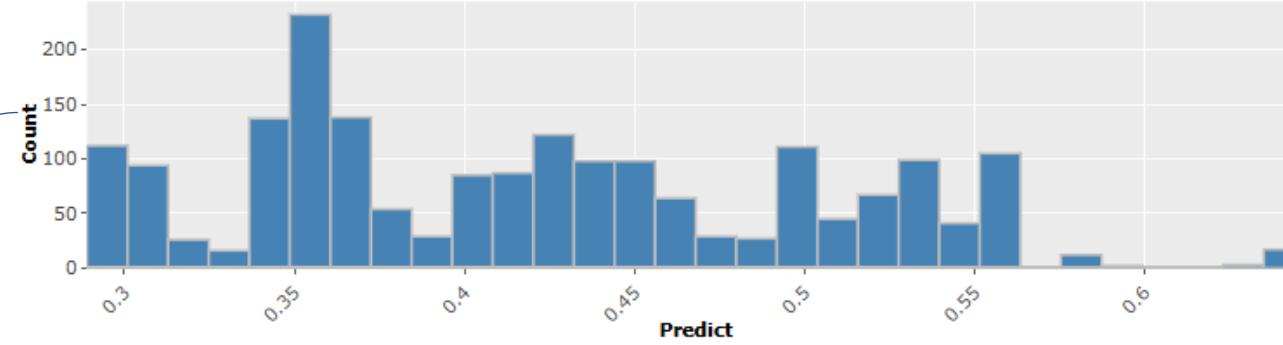
# Normalization Concept

Predicted Probability of Event



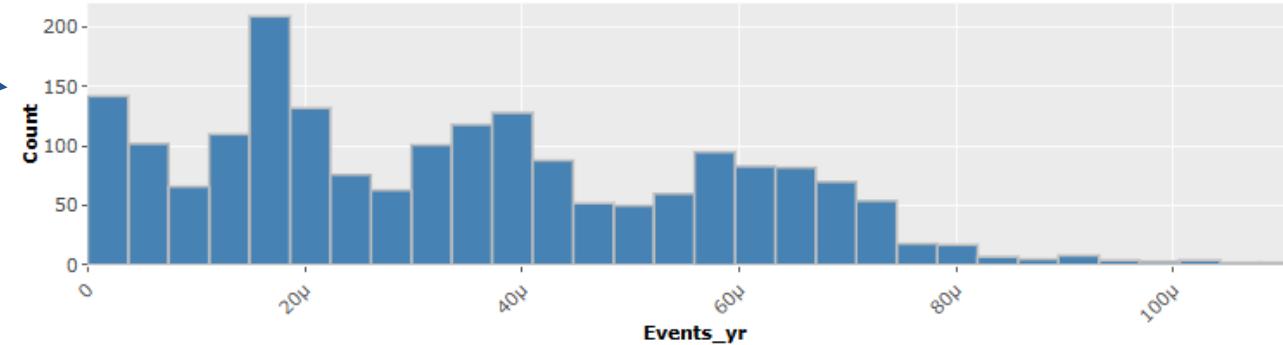
Predicted Events per Year

Model Prediction Results (Year 1) - Predict



Machine Learned Predictions

Model Prediction Results (Year 1) - Events\_yr



Statistical Normalized Predictions

# Results

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Analysis

Configure Normalize **Results** Plots | Aggregate Calculate Risk Results Plots Assessments PHMSA

Filter by Year: 1 | Update | Clear | Excel | RDS | **RDS (All Results, Data, Models)**

Download and save TPD risk element results for later use

Risk\_Consequence.RDS

Risk\_EC\_mpy.RDS

**Risk\_TPD.RDS**

Search:

Level1	Level2	Comp_Name	SegLength	Rec_ID	yr	POER	Event_Rate	Events_yr	Comp_ID				
Level1	Level2	Pipeline_1	410.00	1	1.00	0.372	0.37	0.00	0.00	0.372	0.37236277	0.000028914533	1
Level1	Level2	Pipeline_1	436.00	16	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000028807802	1
Level1	Level2	Pipeline_1	619.00	26	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000040899149	1
Level1	Level2	Pipeline_1	401.00	40	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000026495249	1
Level1	Level2	Pipeline_1	459.00	46	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000030327479	1
Level1	Level2	Pipeline_1	645.00	51	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000042617046	1
Level1	Level2	Pipeline_1	527.00	53	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000034820439	1
Level1	Level2	Pipeline_1	501.00	59	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000033102543	1
Level1	Level2	Pipeline_1	495.00	71	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000032706105	1
Level1	Level2	Pipeline_1	209.00	78	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000013809244	1
Level1	Level2	Pipeline_1	755.00	83	1.00	0.391	0.39	0.00	0.00	0.391	0.39066094	0.000055861555	1
Level1	Level2	Pipeline_1	460.00	88	1.00	0.36	0.36	0.00	0.00	0.36	0.36056395	0.000031412768	1
Level1	Level2	Pipeline_1	499.00	97	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000032970397	1
Level1	Level2	Pipeline_1	343.00	110	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000022663018	1
Level1	Level2	Pipeline_1	670.00	113	1.00	0.349	0.35	0.00	0.00	0.349	0.34886512	0.000044268869	1

Reference glossary of terms for definitions and calculations

# Results

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_TPD.RDS | Target = TPD]

Select Analytic   Load Data/Model   Analysis

Configure   Normalize   Results   **Plots**   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Update

Graph: Histogram   X (numeric): Predict   Legend: Comp\_Name   Intervals: 3   Plot Height: 800

Special Plots:  None    Profile Base Predictions (Probability)    Profile Probability of Event Rate (POER)    Profile Event-Rate (Mile-Year)    Profile Events (per Segment-Year)    PHMSA Incidents (Industry 2010-23)

Position: Stack   Histogram Type: Regular   Log10 Y: identity   X Numeric Format: comma   Y Numeric Format: comma

Use Axis Tics & Disable Format    Show Stats   Bins: 50

**Perform interactive analysis of results data**

**Histogram**

Count

Predict

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Legend: Pipeline\_1 (teal), Pipeline\_2 (orange), Pipeline\_3 (purple), Pipeline\_4 (pink), Pipeline\_5 (green), Pipeline\_6 (yellow), Pipeline\_7 (brown), Pipeline\_8 (grey)

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## External Corrosion Growth Rate – EC\_mpy (Time Dependent Threat)

# Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.

Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_EC\_mpy\_tune.RDS | Target = EC\_mpy]

Select Analytic Load DataModel Analysis

Load Table Plots Quality Variance Correlation Levels Models Predictors Model Info

Source of Analytical Data: RDS Data Frame

Source File: C\_vwTransmission.RDS (Upload complete)

Model (RDS): M\_EC\_mpy\_tune.RDS (Upload complete)

Level 1: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Level 2: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Assets: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Fields: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8, cn\_AreaLand, cn\_AreaWater, cn\_PEOPLE\_100SQM, cn\_STRUCTURES\_100SQM, Consequence, CP\_Off\_Change, Cum\_Sum, Dist\_AreaWater, Dist\_AreaWater\_Agg, Dist\_Comp, Dist\_FP, Dist\_FP\_Agg, Dist\_OPA, Dist\_OPA\_Agg, Dist\_Road, Dist\_Road\_Agg, Dist\_RR, Dist\_RR\_Agg, Dist\_Water, Dist\_Water\_Agg, Dist\_Waterway\_rev, DOC, Dyn\_Seg\_ID

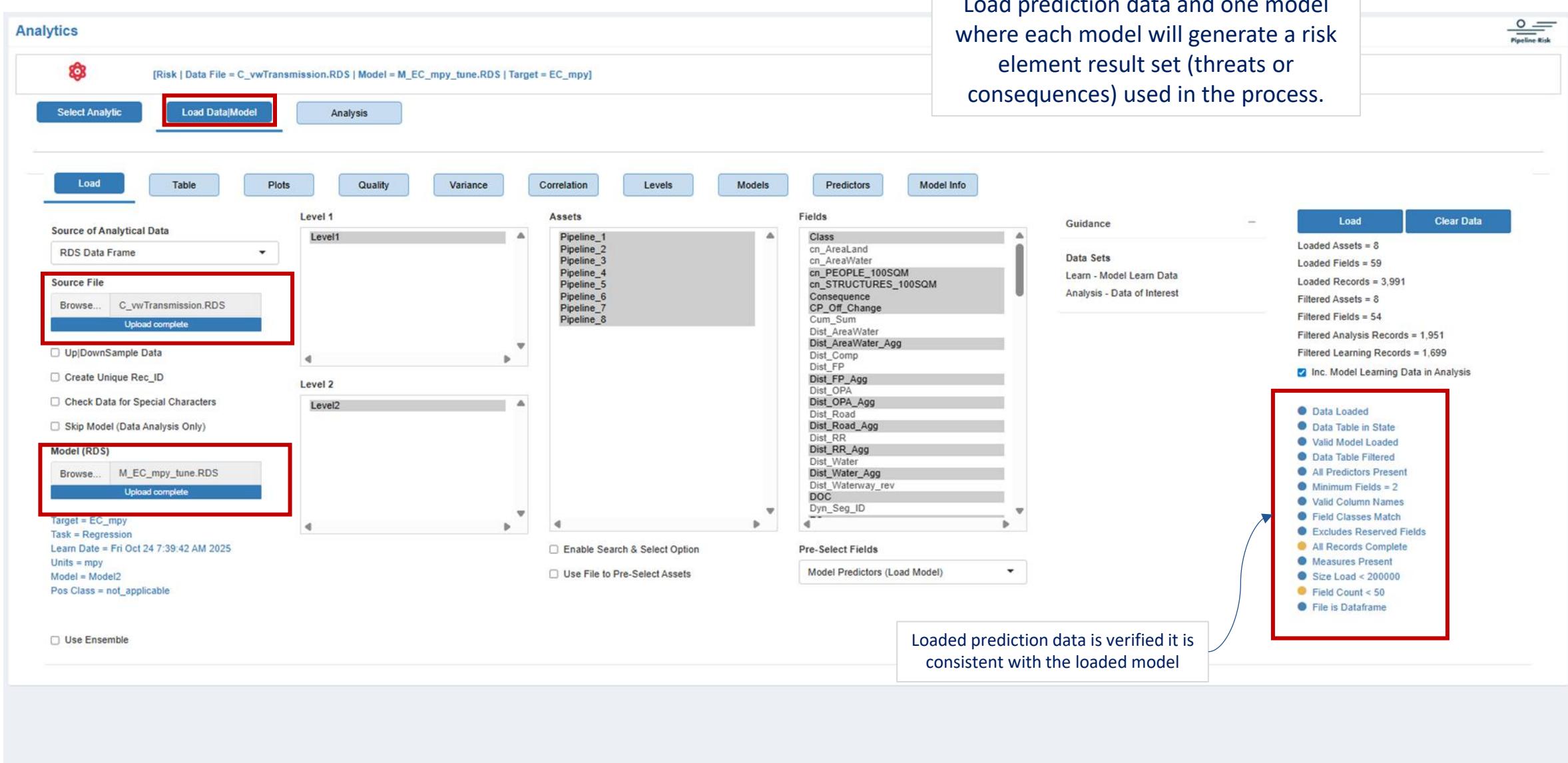
Guidance: Data Sets, Learn - Model Learn Data, Analysis - Data of Interest

Load Clear Data

Loaded Assets = 8, Loaded Fields = 59, Loaded Records = 3,991, Filtered Assets = 8, Filtered Fields = 54, Filtered Analysis Records = 1,951, Filtered Learning Records = 1,699, Inc. Model Learning Data in Analysis

Data Loaded, Data Table in State, Valid Model Loaded, Data Table Filtered, All Predictors Present, Minimum Fields = 2, Valid Column Names, Field Classes Match, Excludes Reserved Fields, All Records Complete, Measures Present, Size Load < 200000, Field Count < 50, File is Dataframe

Loaded prediction data is verified it is consistent with the loaded model



# Apply EC\_mpy Model to Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_EC\_mpy\_tune.RDS | Target = EC\_mpy]

Select Analytic   Load Data|Model   **Analysis**

**Loaded model is configured and mapped to data**

**Configure**   Normalize   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA   **Update**

**MAP MODEL**

Type: Time\_Dependent Threat   Asset Type: Pipe   Time to Criteria (TTC|Scale): Pressure   Pressure Criteria: MAOP   Weibull - Shape: 3   Max Years: 200   Wall Thickness: Nominal\_WT   Grade: Pipe\_SMYS   Diameter: Nominal\_OD   Install Year: Pipe\_InstallYr   Assessment Mitigation (opt): None   Addit. Mitigations (opt): None   Addit. Resistance (opt): None

**MAP GENERAL FIELDS**

Prediction Units: mpy   Measurement System: Standard   Analysis Years: 5   Current Year: 2025   Measure Start: Measure\_Start   Measure End: Measure\_End

**EC\_mpy is time dependent, and model predicts an mpy**

**Required mapped fields to data**

**Application calculates a time to criteria (TTC) in years which is used to convert predicted mpy to a probability using a Weibull 2 parameter method**

**Mitigation of threat based on recent assessments loaded in assessments dashboard**

**Optional mitigation & resistance fields**

Loaded Records = 3,991   Calculation Years = 5   Calculation Records = 19,955

● Mapping Valid

Guidance

- Each Model Generates Risk Results
- Results Calculated for Each Model
- Configure Each Threat Model
- Configure Each Consequence Model
- Minimize Use of Missing Data
- Configure File Persists Mapping
- All Fields Require Mapping
- Results Aggregated Later in Process
- Aggregated Results Use Same Data

# Apply EC\_mpy Model to Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_EC\_mpy\_tune.RDS | Target = EC\_mpy]

Select Analytic   Load Data|Model   **Analysis**

Configure   **Normalize**   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

**PREDICTION RESULTS**

Histogram Type: Regular   Results: Weibull Probability (%)

Position: Stack   Minimum = 0, Maximum = 0.27, Mean = 0.09, Standard Deviation = 0.07, Pipe Segments = 1,951, Total Length ft = 969,658

Persist Range   Range Min: 0   Range Max: 1

Legend: All   Bins: 30, Intervals: 3

**Model Prediction Results (Year 1) - Weibull**

Count

Weibull

**Predictions based on model applied to data, output is probabilities**

Constant = All

**NORMALIZATION STATISTICS**

Distribution Type Fit: uniform   Select normalization distribution type

Min Scale to Value: 0.0001   Max Scale to Value: 1

Save Configuration

**Scale POER to Events/1000 mile-Yr Distribution**

Density

Statistical|Industry Value

**Predictions are normalized to industry or asset owner event frequencies**

Normalize or convert model predictions (mpy probabilities) to External Corrosion event rates

**Calculate**

Analysis Records = 1,951   Calculation Years = 5   0.06 Estimated Run Time (min)

Model Exists   Records > 0   Results Complete

**Create Normalized Results**

**Guidance**

- Results Exclude Learning Data
- Persist Range Sets Scale to Transform
- Transform is to Normalization Range
- Transform Scales POER to Event Rates
- Transform Scales Consequences to Dollars

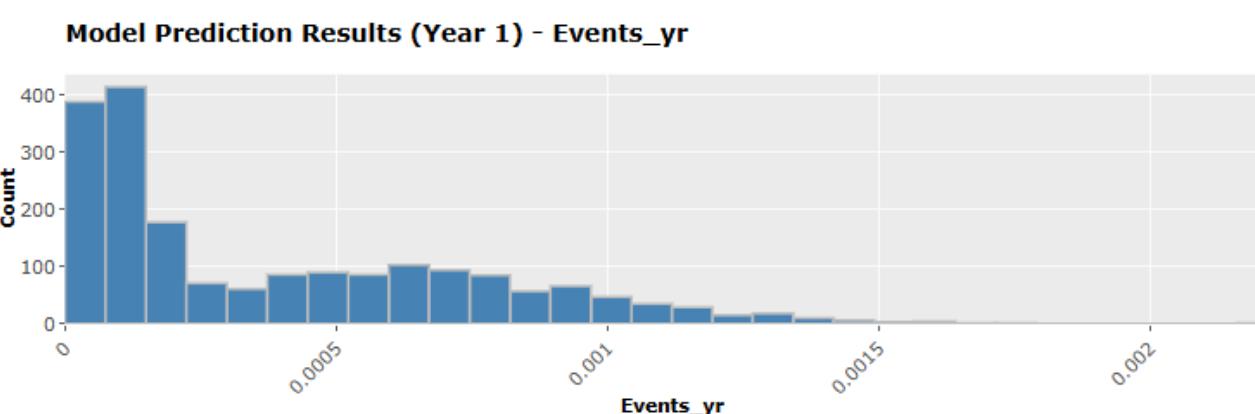
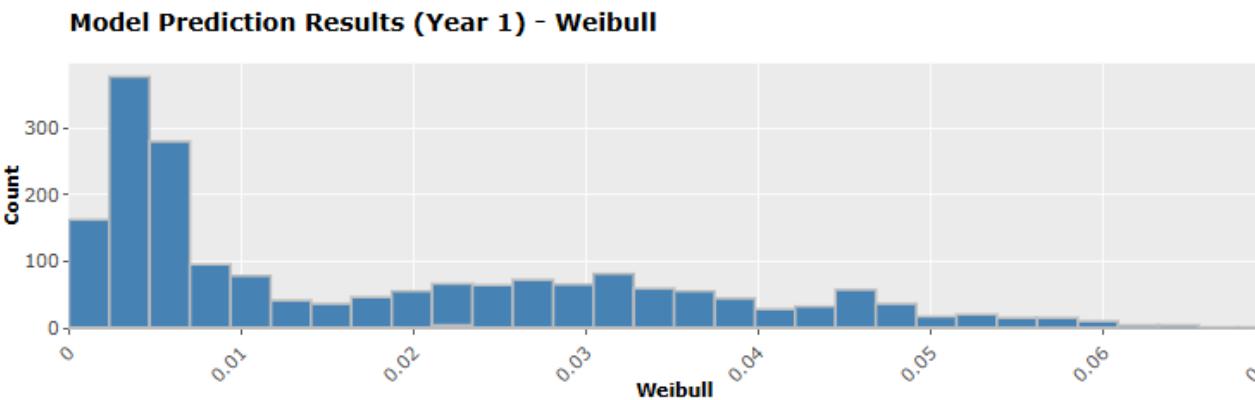
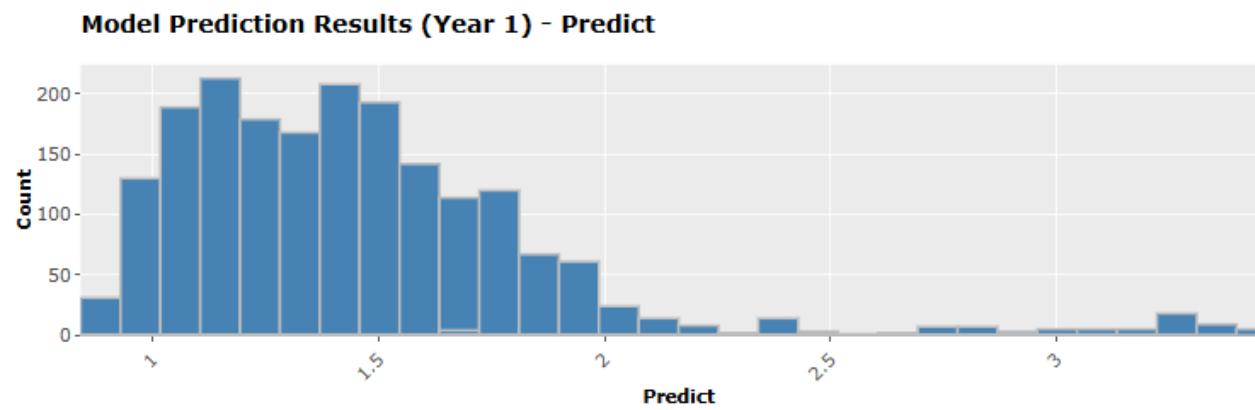
# Normalization Concept

Predicted Corrosion Growth Rate



Probability of Exceeding Criteria (Pressure, % Depth)

Predicted Events per Year



Machine Learned Predictions (mpy)

Reliability Curve

Statistically Normalized Predictions

# Results

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_EC\_mpy\_tune.RDS | Target = EC\_mpy]

Results of Model Application

Select Analytic   Load Data|Model   Analysis

Configure   Normalize   **Results**   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Filter by Year: 1   Update   Clear     **RDS (All Results, Data, Models)**

Only Show Results    Load Results File

Options: Show Selected Fields   Include Models on Save   Round: 2   Grid Size: 800   Relocate Columns   Guidance

Download and save EC\_mpy risk element results for later use

Risk\_Consequence.RDS   Risk\_EC\_mpy.RDS   Risk\_TPD.RDS

Search:

Level1	Level2	Comp_Name	SegLength	Rec_ID	yr	Predict	WT	Pressure	780.00	0.20	74.77	62.00	136.77	0.09	0.00	0.00	0.00	0.093	0
Level1	Level2	Pipeline_1	410.00	1	1.00	1.076	0.28	Pressure	780.00	0.20	74.77	62.00	136.77	0.09	0.00	0.00	0.00	0.034	0
Level1	Level2	Pipeline_1	436.00	16	1.00	1.218	0.56	Pressure	1,619.00	0.40	129.08	61.00	190.08	0.03	0.00	0.00	0.00	0.034	0
Level1	Level2	Pipeline_1	619.00	26	1.00	1.213	0.56	Pressure	1,619.00	0.40	129.68	61.00	190.68	0.03	0.00	0.00	0.00	0.034	0
Level1	Level2	Pipeline_1	401.00	40	1.00	1.001	0.56	Pressure	1,619.00	0.40	157.16	61.00	218.16	0.02	0.00	0.00	0.00	0.023	0
Level1	Level2	Pipeline_1	459.00	46	1.00	1.213	0.56	Pressure	1,619.00	0.40	129.68	61.00	190.68	0.03	0.00	0.00	0.00	0.034	0
Level1	Level2	Pipeline_1	645.00	51	1.00	1.001													0.047
Level1	Level2	Pipeline_1	527.00	53	1.00	1.001													0.047
Level1	Level2	Pipeline_1	501.00	59	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.40	61.00	170.40	0.05	0.00	0.00	0.00	0.047	0
Level1	Level2	Pipeline_1	495.00	71	1.00	1.002	0.39	Pressure	1,126.00	0.28	109.28	61.00	170.28	0.05	0.00	0.00	0.00	0.047	0
Level1	Level2	Pipeline_1	209.00	78	1.00	1.213	0.47	Pressure	1,351.00	0.34	108.24	61.00	169.24	0.05	0.00	0.00	0.00	0.048	0
Level1	Level2	Pipeline_1	755.00	83	1.00	1.018	0.39	Pressure	1,126.00	0.28	107.53	61.00	168.53	0.05	0.00	0.00	0.00	0.049	0
Level1	Level2	Pipeline_1	460.00	88	1.00	1.04	0.39	Pressure	1,126.00	0.28	105.26	61.00	166.26	0.05	0.00	0.00	0.00	0.051	0
Level1	Level2	Pipeline_1	499.00	97	1.00	1.01	0.39	Pressure	1,126.00	0.28	108.46	61.00	169.46	0.05	0.00	0.00	0.00	0.048	0
Level1	Level2	Pipeline_1	343.00	110	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.36	61.00	170.36	0.05	0.00	0.00	0.00	0.047	0
Level1	Level2	Pipeline_1	670.00	113	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.39	61.00	170.39	0.05	0.00	0.00	0.00	0.047	0

Reference glossary of terms for definitions and calculations

# Results

## Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_EC\_mpy\_tune.RDS | Target = EC\_mpy]

Select Analytic   Load Data|Model   Analysis

Configure   Normalize   Results   **Plots**   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Perform interactive analysis of results data

Update

Graph: Box Plot

X (numeric): POER

Y (character): Comp\_Name

Legend: Level1

Intervals: 3

Plot Height: 800

None

Profile Base Predictions (mpy)

Profile Probability of Event Rate (POER)

Profile Event-Rate (Mile-Year)

Profile Events (per Segment-Year)

Profile Weibull

PHMSA Incidents (Industry 2010-23)

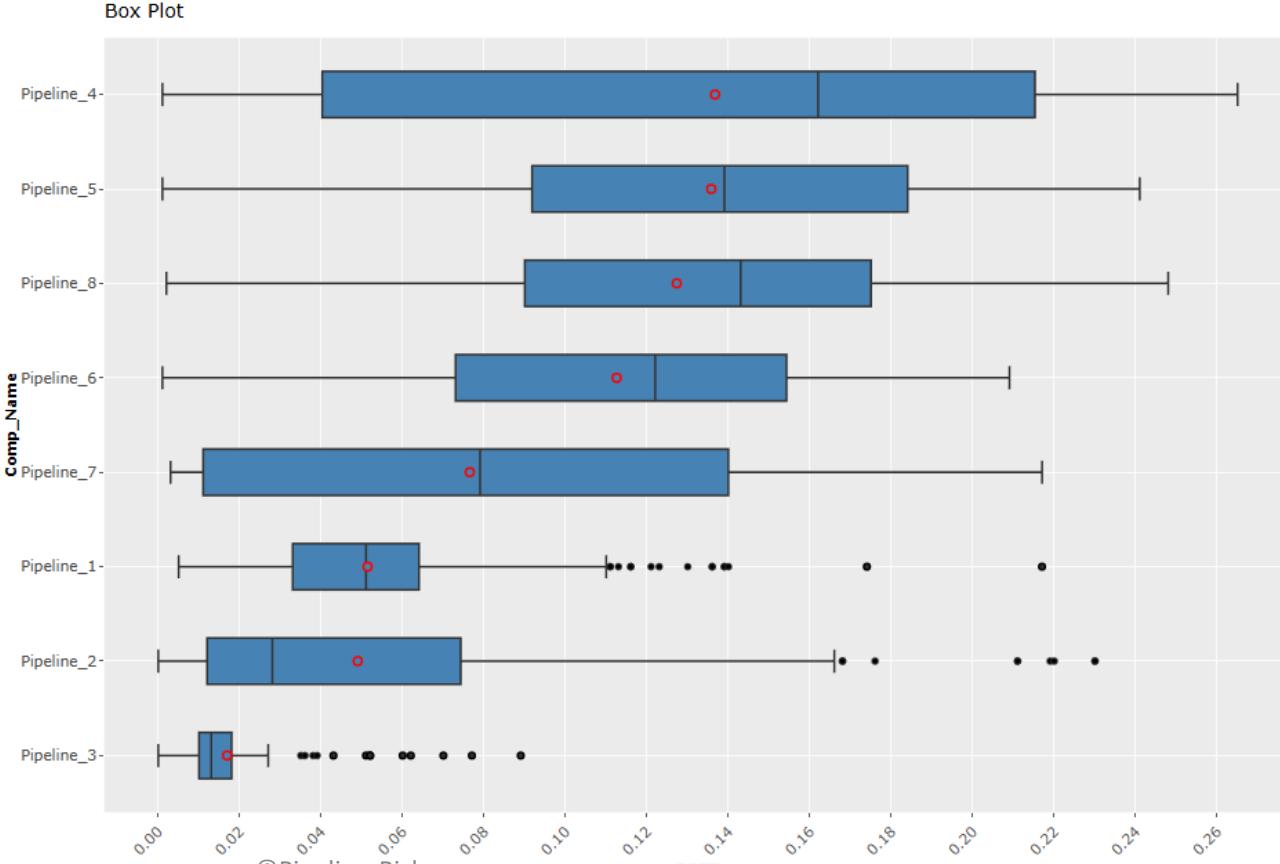
Flip Coordinates

Y Numeric Format: comma

Show Violin

Box Plot

Legend: Constant = Level1



POER

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# Impact on Population (Consequences)

# Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.

Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic Load Data|Model Analysis

Load Table Plots Quality Variance Correlation Levels Models Predictors Model Info

Source of Analytical Data: RDS Data Frame

Source File: C\_vwTransmission.RDS (Upload complete)

Model (RDS): M\_Consequence.RDS (Upload complete)

Level 1: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Level 2: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Assets: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

Fields: Class, cn\_AreaLand, cn\_AreaWater, cn\_PEOPLE\_100SQM, cn\_STRUCTURES\_100SQM, Consequence, CP\_Offset\_Change, Cum\_Sum, Dist\_AreaWater, Dist\_AreaWater\_Agg, Dist\_Comp, Dist\_FP, Dist\_FP\_Agg, Dist\_OPA, Dist\_OPA\_Agg, Dist\_Road, Dist\_Road\_Agg, Dist\_RR, Dist\_RR\_Agg, Dist\_Water, Dist\_Water\_Agg, Dist\_Waterway\_rev, DOC, Dyn\_Seg\_ID

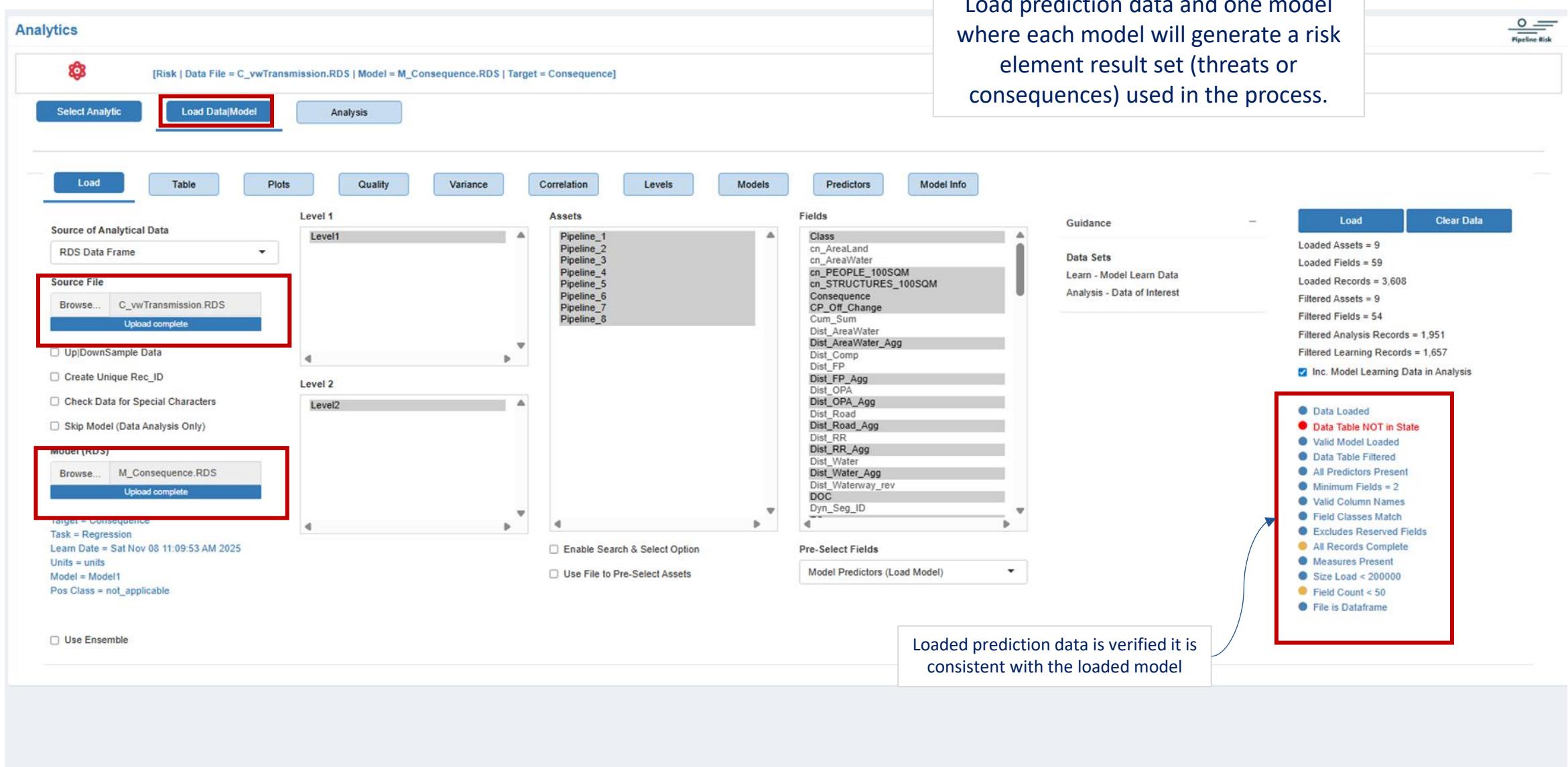
Guidance: Data Sets, Learn - Model Learn Data, Analysis - Data of Interest

Load Clear Data

Loaded Assets = 9, Loaded Fields = 59, Loaded Records = 3,608, Filtered Assets = 9, Filtered Fields = 54, Filtered Analysis Records = 1,951, Filtered Learning Records = 1,657, Inc. Model Learning Data in Analysis

Data Loaded, Data Table NOT in State, Valid Model Loaded, Data Table Filtered, All Predictors Present, Minimum Fields = 2, Valid Column Names, Field Classes Match, Excludes Reserved Fields, All Records Complete, Measures Present, Size Load < 200000, Field Count < 50, File is Dataframe

Loaded prediction data is verified it is consistent with the loaded model



# Apply Consequence Model to Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

**Loaded model is configured and mapped to data**

**Configure**   Normalize   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA   **Update**

**MAP MODEL**

Type: Consequence

Prediction Units: Numerical Value

Use Configuration File

Target = Consequence  
Task = Regression  
Learn Date = Sat Nov 08 11:09:53 AM 2025  
Units = units  
Pos Class = not\_applicable

**MAP GENERAL FIELDS**

Asset Type: Pipe

Measurement System: Standard

Current Year: 2025

Measure Start: Measure\_Start

Measure End: Measure\_End

Addit. Mitigations (opt): None

Optional mitigation field

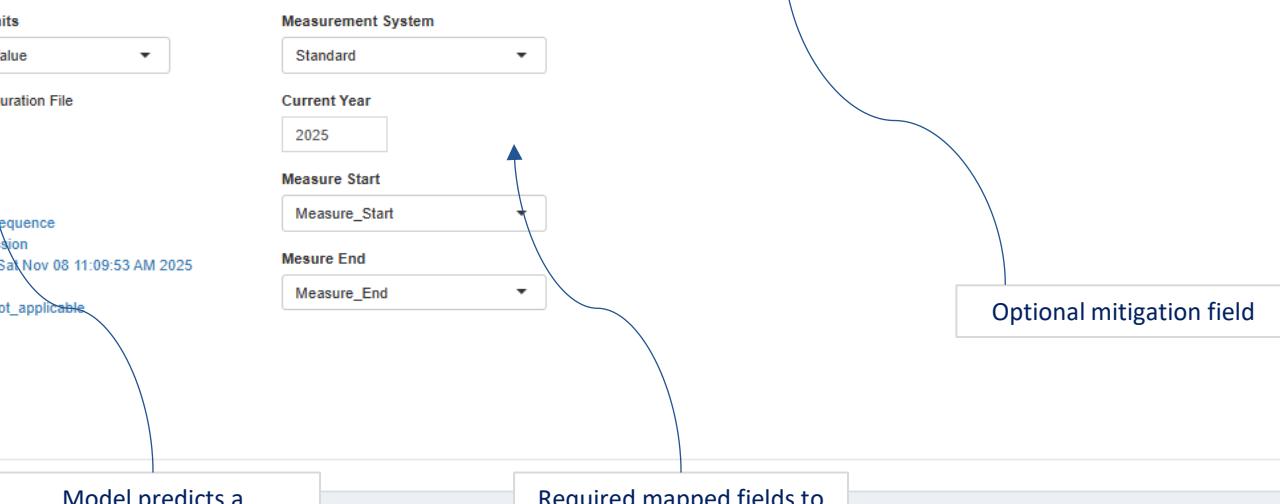
Loaded Records = 3,608  
Calculation Years = 5  
Calculation Records = 18,040

● Mapping Valid

**Guidance**

- Each Model Generates Risk Results
- Results Calculated for Each Model
- Configure Each Threat Model
- Configure Each Consequence Model
- Minimize Use of Missing Data
- Configure File Persists Mapping
- All Fields Require Mapping
- Results Aggregated Later in Process
- Aggregated Results Use Same Data

Model predicts a consequence   Required mapped fields to data



# Apply Consequence Model to Data

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

Configure   **Normalize**   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

**PREDICTION RESULTS**

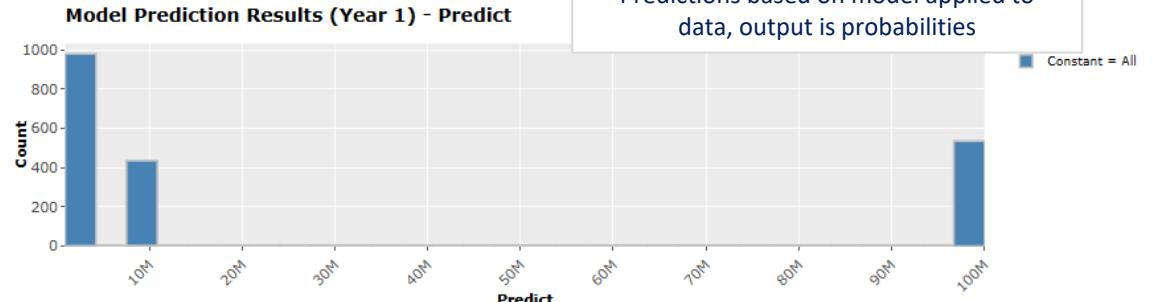
Histogram Type: Regular   Results: Consequence Predictions

Position: Stack   Minimum = 944487, Maximum = 100032248, Mean = 30192638.81, Standard Deviation = 43096365.79, Pipe Segments = 1,951, Total Length ft = 969,658

Persist Range   Range Min: 10000   Range Max: 1000000

Legend: All   Bins: 30, Intervals: 3

**Model Prediction Results (Year 1) - Predict**



Predictions based on model applied to data, output is probabilities

Constant = All

**NORMALIZATION STATISTICS**

Distribution Type Fit: uniform   Select normalization distribution type

Min Scale to Value: 10000   Max Scale to Value: 1000000

Save Configuration

**Normalize or convert model predictions to consequence values (monetized or score)**

**Calculate**

Analysis Records = 1,951   Calculation Years = 5   0.06 Estimated Run Time (min)

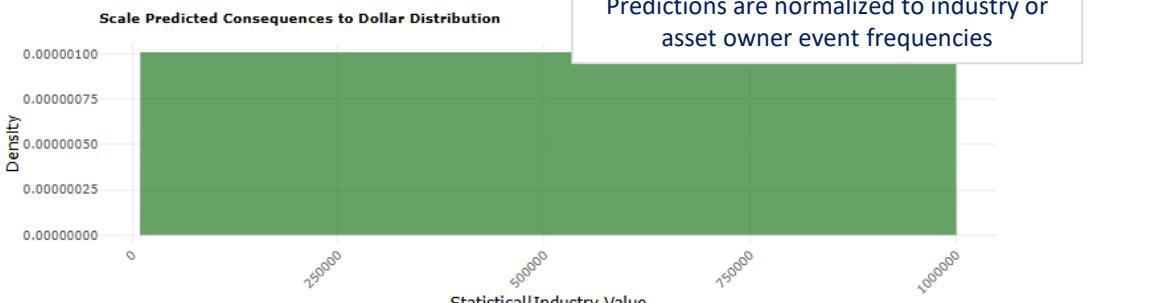
Model Exists   Records > 0   Results Complete

**Create Normalized Results**

Guidance

- Results Exclude Learning Data
- Persist Range Sets Scale to Transform
- Transform is to Normalization Range
- Transform Scales POER to Event Rates
- Transform Scales Consequences to Dollars

**Scale Predicted Consequences to Dollar Distribution**



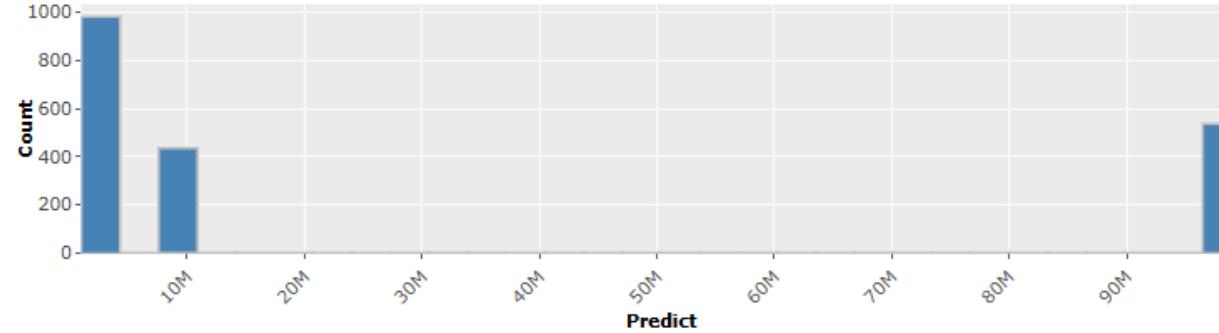
Predictions are normalized to industry or asset owner event frequencies

# Normalization Concept

**Predicted Consequence  
(Score or Monetized)**

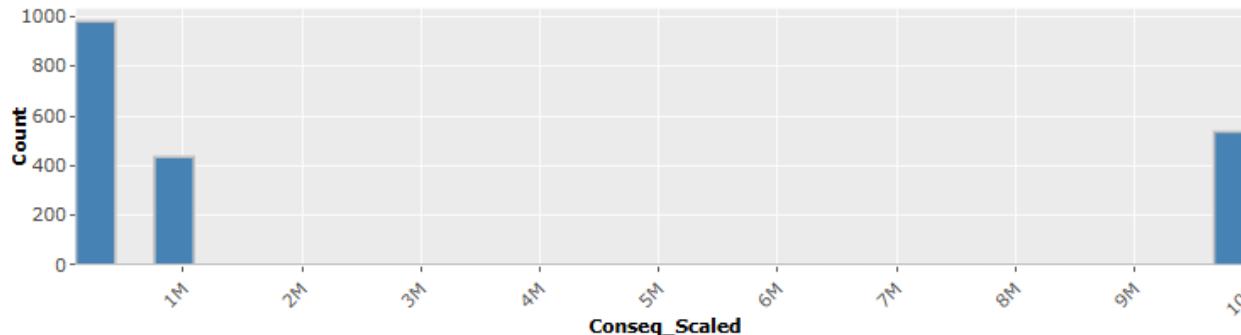


**Model Prediction Results (Year 1) - Predict**



**Consequences  
(per Event)**

**Model Prediction Results (Year 1) - Conseq\_Scaled**



**Machine Learned  
Predictions**

**Statistically  
Normalized  
Predictions**

# Results

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

Configure   Normalize   **Results**   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Filter by Year: 1   Update   Clear   [Excel](#)   [RDS](#)   [RDS \(All Results, Data, Models\)](#)

Only Show Results   Load Results File

Options: Show Selected Fields, Include Models on Save, Round: 2, Grid Size: 800, Relocate Columns, Guidance

Download and save Consequence risk element results for later use

Risk_Consequence.RDS	Search:
Risk_EC_mpy.RDS	
Risk_TPD.RDS	

Reference glossary of terms for definitions and calculations

Level1	Level2	Comp_Name	SegLength	Rec.	1	1.00	991327	0.00	991327	991327.375	1
Level1	Level2	Pipeline_1	410.00	1	1.00	991327	0.00	991327	991327.375	1	
Level1	Level2	Pipeline_1	436.00	16	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	619.00	26	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	401.00	40	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	459.00	46	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	645.00				0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	527.00				0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	501.00	59	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	495.00	71	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	209.00	78	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	755.00	83	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	460.00	88	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	499.00	97	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	343.00	110	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	670.00	113	1.00	998207	0.00	998207	998206.625	1	
Level1	Level2	Pipeline_1	580.00	120	1.00	1000557	0.00	1000557	1000000	1	

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# Results

## Analytics

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   Analysis

Configure   Normalize   Results   **Plots**   Aggregate   Calculate   Risk Results   Plots   Assessments   PHMSA

Update

Graph: Histogram

X (numeric): Predict

Legend: Comp\_Name

Intervals: 3

Plot Height: 800

Use Axis Tics & Disable Format

Special Plots:  None

- Base Predictions (Numerical Value)
- Scaled Consequences (dollars)
- PHMSA Consequences (Industry 2010-23)

Position: Slack

Histogram Type: Regular

Log10 Y: identity

X Numeric Format: comma

Y Numeric Format: comma

Show Stats

Bins: 50

Count

Predict

Histogram showing the distribution of Predict values for eight pipelines. The x-axis represents Predict values from 0 to 100,000,000, and the y-axis represents the count from 0 to 1,000. The distribution is highly right-skewed, with the highest frequency occurring at 0. The data is stacked by pipeline: Pipeline\_1 (green), Pipeline\_2 (orange), Pipeline\_3 (purple), Pipeline\_4 (pink), Pipeline\_5 (light green), Pipeline\_6 (yellow), Pipeline\_7 (brown), and Pipeline\_8 (grey).

Perform interactive analysis of results data

Legend: Pipeline\_1, Pipeline\_2, Pipeline\_3, Pipeline\_4, Pipeline\_5, Pipeline\_6, Pipeline\_7, Pipeline\_8

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# Aggregate Risk Elements to Overall Risk

# Aggregate Risk Elements

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

Configure   Normalize   Results   Plots   **Aggregate**   Calculate   Risk Results   Plots   Assessments   PHMSA

**Select & add risk element threat and consequence files**

Aggregate Individual Threat & Consequence Results

Load Threat Result Files

Browse... 2 files  
Upload complete

Add Files   Remove Row Selected File

Assign Interactions to Selected Row

Update Interactions

Optional addition of interactions (increases POER if interaction is True)

Load Consequence Result Files

Browse... Risk\_Consequence.RDS  
Upload complete

Add Files   Remove Row Selected File

**Aggregate**  
Result Records = 1,951

**Aggregate files & results**

Data Aligns  
Guidance

**Navigate to threat risk files, select & add to table**

**Navigate to consequence risk files, select & add to table**

Target	MType	EC_mpy	TPD	FileName	RecordCount
EC_mpy	TD			Risk_EC_mpy.RDS	9,755.00
TPD	TI			Risk_TPD.RDS	9,755.00

Target	MType	FileName	RecordCount
Consequence	C	Risk_Consequence.RDS	1,951.00

This feature of the application combines all threat and consequence models together

# Calculate Risk

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

Configure   Normalize   Results   Plots   Aggregate   **Calculate**   Risk Results   Plots   Assessments   PHMSA

Show Results    Threats    Consequences

Update   Clear       **Calculate Risk**

All Unfiltered Data Passes to Risk Calculations & Results

Search:

Target	Rec_ID	yr	Predict	WT	Criteria	Crit_Value	WT_Req	WT_Yrs	Age	TTC	Weibull	Assess	Mitig	Resist	POER	Event_Rate	Events_yr	SegLength			
					All	All	A	A									All	All			
EC_mpy	1	1.00	1.076	0.28	Percent_Depth	0.20	0.06	208.97	62.00	270.97	0.01	0.00	0.00	0.00	0.013	0.178062678100	0.000013826800	4			
TPD	1	1.00	0.372												0.00	0.00	0.00	0.372	0.232543922900	0.000018057388	4
EC_mpy	16	1.00	1.218	0.56	Percent_Depth	0.20	0.11	369.06	61.00	430.06	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000003528900	4			
TPD	16	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000013781043	4
EC_mpy	26	1.00	1.213	0.56	Percent_Depth	0.20	0.11	370.77	61.00	431.77	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000005010000	6			
TPD	26	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000019565288	6
EC_mpy	40	1.00	1.001	0.56	Percent_Depth	0.20	0.11	449.35	61.00	510.35	0.00	0.00	0.00	0.00	0.002	0.025641025600	0.000001947400	4			
TPD	40	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000012674766	4
EC_mpy	46	1.00	1.213	0.56	Percent_Depth	0.20	0.11	370.77	61.00	431.77	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000003715000	4			
TPD	46	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000014508024	4
EC_mpy	51	1.00	1.001	0.39	Percent_Depth	0.20	0.08	312.50	61.00	373.50	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000008004700	6			
TPD	51	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000020387093	6
EC_mpy	53	1.00	1.001	0.39	Percent_Depth	0.20	0.08	311.71	61.00	372.71	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000006540300	5			
TPD	53	1.00	0.349												0.00	0.00	0.00	0.349	0.166889689900	0.000016657361	5
EC_mpy	59	1.00	1.001	0.39	Percent_Depth	0.20	0.08	312.50	61.00	373.50	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000006217600	5			

Calculate risk - combines threats & consequences outputs Total Risk, \$ NPV and \$ NPV/Mile

# Risk Results

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load DataModel   Analysis

Configure   Normalize   Results   Plots   |   Aggregate   Calculate   **Risk Results**   Plots   Assessments   PHMSA

View Results  
 Summary  
 Results by Threat (Stacked)  
 Results by Threat (Interactions)

Update   Clear        **RDS (All Results)**

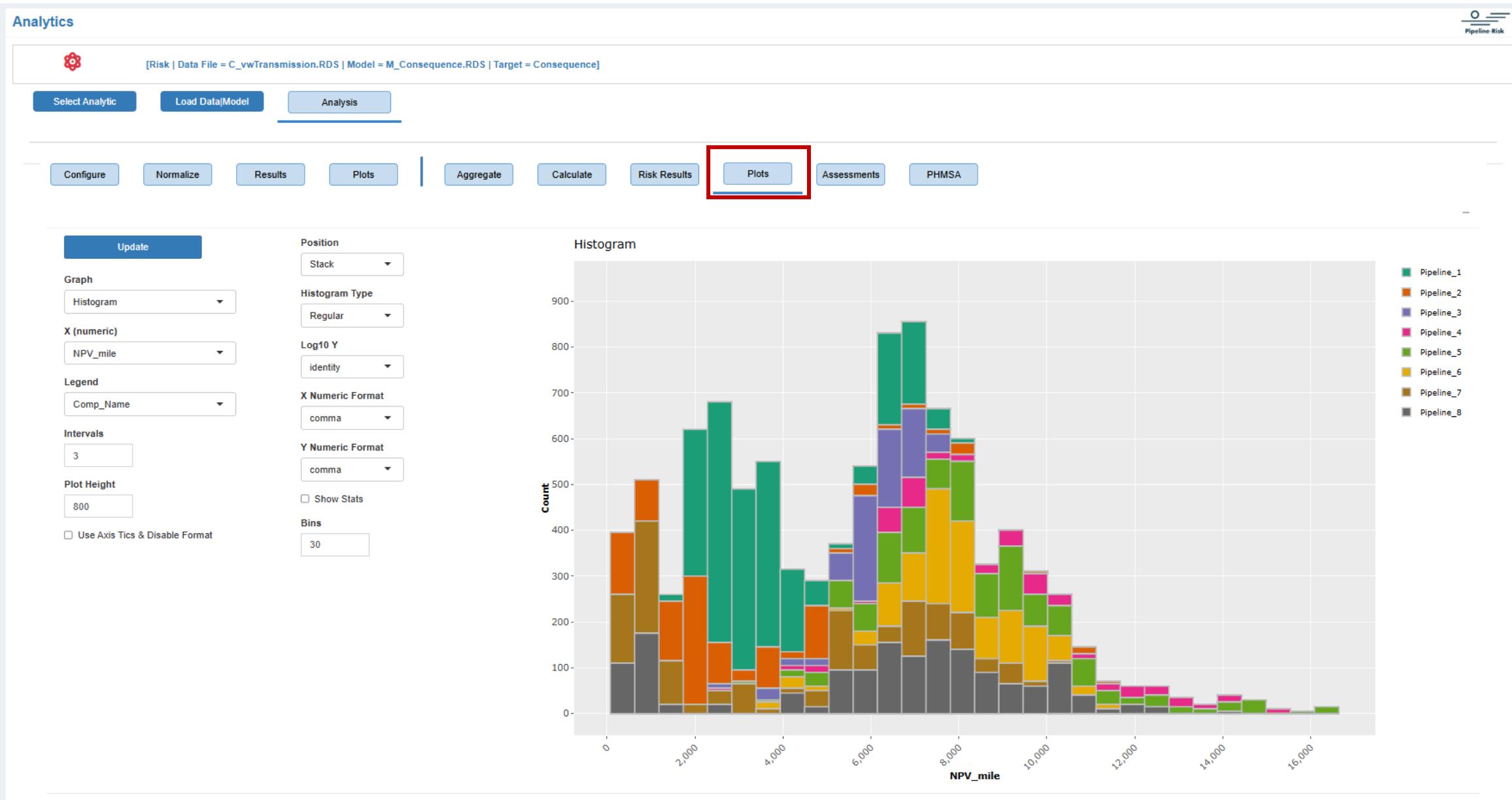
Filtered Data Passes to Plots & Download

Download and save all results for later upload

Search:

Rec_ID	yr	Level1	Level2	Comp_Name	Measure_Start	Measure_End	Total_Events_yr	Total_Conseq	Total_Risk	NPV	NPV_mile	Threat	Data_Set	Predict	WT	Criteria	
1	1	Level1	Level2	Pipeline_1	0	410	0.00003188	99132	31.61	283.94	3656.59	All	All	Analysis	1.076	0.281	Percent_D
1	2	Level1	Level2	Pipeline_1	0	410	0.00003205	99132	31.77	283.94	3656.59	All	All	Analysis	1.076	0.281	Percent_D
1	3	Level1	Level2	Pipeline_1	0	410	0.00003219	99132	31.91	283.94	3656.59	All	All	Analysis	1.076	0.281	Percent_D
1	4	Level1	Level2	Pipeline_1	0	410	0.00003229	99132	32.01	283.94	3656.59	All	All	Analysis	1.076	0.281	Percent_D
1	5	Level1	Level2	Pipeline_1	0	410	0.00003249	99132	32.21	283.94	3656.59	All	All	Analysis	1.076	0.281	Percent_D
16	1	Level1	Level2	Pipeline_1	410	846	0.00001731	99820	17.28	154.36	1869.31	All	All	Analysis	1.218	0.562	Percent_D
16	2	Level1	Level2	Pipeline_1	410	846	0.0000173	99820	17.27	154.36	1869.31	All	All	Analysis	1.218	0.562	Percent_D
16	3	Level1	Level2	Pipeline_1	410	846	0.0000174	99820	17.37	154.36	1869.31	All	All	Analysis	1.218	0.562	Percent_D
16	4	Level1	Level2	Pipeline_1	410	846	0.00001738	99820	17.35	154.36	1869.31	All	All	Analysis	1.218	0.562	Percent_D
16	5	Level1	Level2	Pipeline_1	410	846	0.00001746	99820	17.43	154.36	1869.31	All	All	Analysis	1.218	0.562	Percent_D
26	1	Level1	Level2	Pipeline_1	846	1465	0.00002458	99820	24.53	219.15	1869.32	All	All	Analysis	1.213	0.562	Percent_D
26	2	Level1	Level2	Pipeline_1	846	1465	0.00002456	99820	24.52	219.15	1869.32	All	All	Analysis	1.213	0.562	Percent_D
26	3	Level1	Level2	Pipeline_1	846	1465	0.0000247	99820	24.66	219.15	1869.32	All	All	Analysis	1.213	0.562	Percent_D
26	4	Level1	Level2	Pipeline_1	846	1465	0.00002468	99820	24.63	219.15	1869.32	All	All	Analysis	1.213	0.562	Percent_D
26	5	Level1	Level2	Pipeline_1	846	1465	0.0000248	99820	24.75	219.15	1869.32	All	All	Analysis	1.213	0.562	Percent_D
40	1	Level1	Level2	Pipeline_1	1465	1866	0.00001462	99820	14.6	130.52	1718.57	All	All	Analysis	1.001	0.562	Percent_D

# Risk Results



# Special Features

# Assessments

Practitioner can upload an .xlsx with historical assessments to then make this data available to the risk process as an “assessment” credit (managed for each threat element)

Load Assessment Results

Comp_Name	Comp_ID	Assessment_Type	Year	Life	Mitig_EC	Mitig_IC	Mitig_SCC	Mitig_TPD	Mitig_GEO	Mitig_WOF	Mitig_MFG	Mitig_CON	Mitig_IO	Mitig_EQ	Comments
Pipeline_1	1	ILI	2024	10	0.9	0.9	0.2	0.2			0.5	0.5			
Pipeline_2	2	ILI	2024	10	0.9	0.9	0.2	0.2			0.5	0.5			

Estimated impact of assessment on mitigation of threat, decayed over life of assessment

Concept is asset owner will mitigate all critical defects for a threat(s) after an assessment and the risk for that threat would be expected to be impacted over some time (straight line decay) during the life of the assessment

**Analytics**

[Risk | Data File = C\_vwTransmission.RDS | Model = M\_Consequence.RDS | Target = Consequence]

Select Analytic   Load Data|Model   **Analysis**

Configure   Normalize   Results   Plots   Aggregate   Calculate   Risk Results   Plots   Assessments   **PHMSA**

PHMSA - Event Rates   PHMSA - Consequences

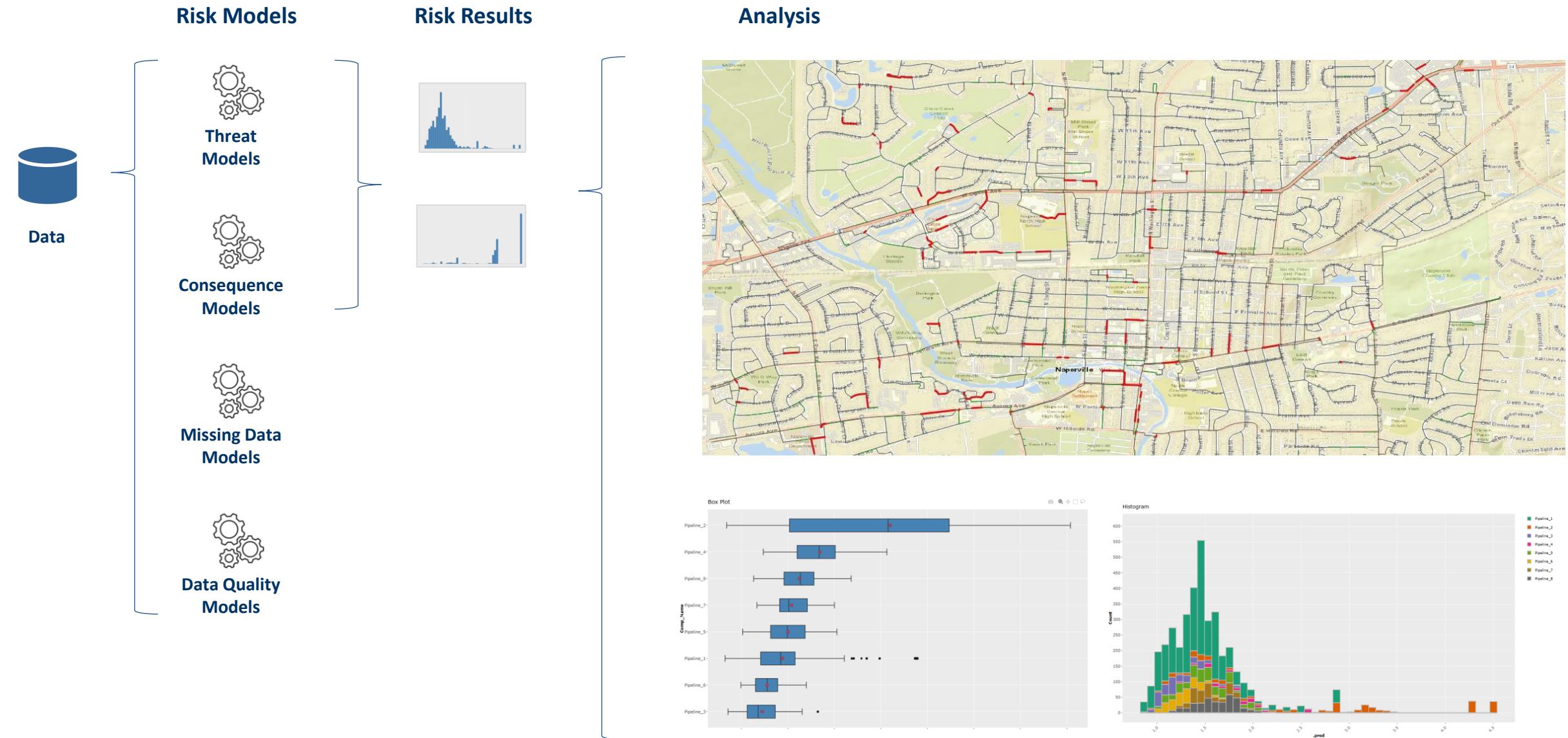
Copy   CSV   Excel   Print   Search:

All	Category	System_Type	Asset_Item	Map_Cause	Ext_Int	Events	Freq_E1000myr	Miles_2023	Report_Yrs	Conversion	Rec_ID
All	All	All	All	All	All	All	All	All	All	All	All
All	GasTransmission	GG (Gas Gathering)	FLANGE ASSEMBLY	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	1
All	GasTransmission	GG (Gas Gathering)	OTHER	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	2
All	GasTransmission	GG (Gas Gathering)	PIPE	ALL OTHER CAUSES		4	0.00253505409425179	111118	14.2	1000	3
All	GasTransmission	GG (Gas Gathering)	SCRAPER/PIG TRAP	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	4
All	GasTransmission	GG (Gas Gathering)	TUBING	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	5
All	GasTransmission	GG (Gas Gathering)	WELD/FUSION, INCLUDING HEAT-AFFECTED ZONE	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	6
All	GasTransmission	GG (Gas Gathering)	PIPE	EXCAVATION DAMAGE		6	0.00380258114137769	111118	14.2	1000	7
All	GasTransmission	GG (Gas Gathering)	COMPRESSOR	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	8
All	GasTransmission	GG (Gas Gathering)	FLANGE ASSEMBLY	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	9
All	GasTransmission	GG (Gas Gathering)	REGULATOR/CONTROL VALVE	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	10
All	GasTransmission	GG (Gas Gathering)	SCRAPER/PIG TRAP	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	11

**PLR curated PHMSA threat and consequence data which can be used to normalize model predictions**

# Conceptual

# Risk Management - Distribution



# Risk Management - Transmission

## Risk Models



Threat  
Models



Consequence  
Models

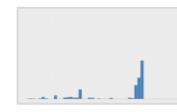
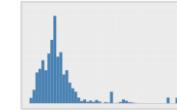


Missing Data  
Models

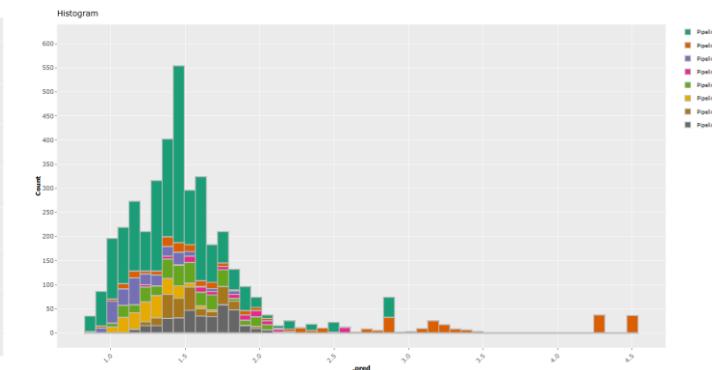
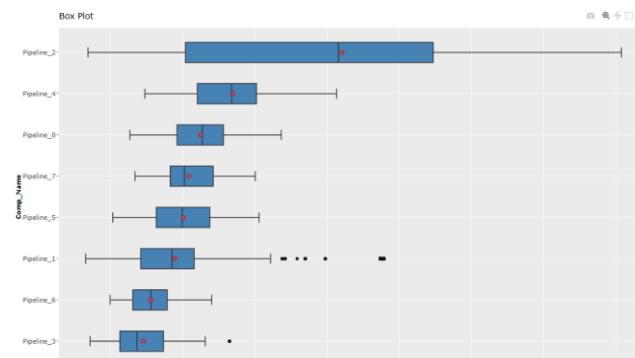
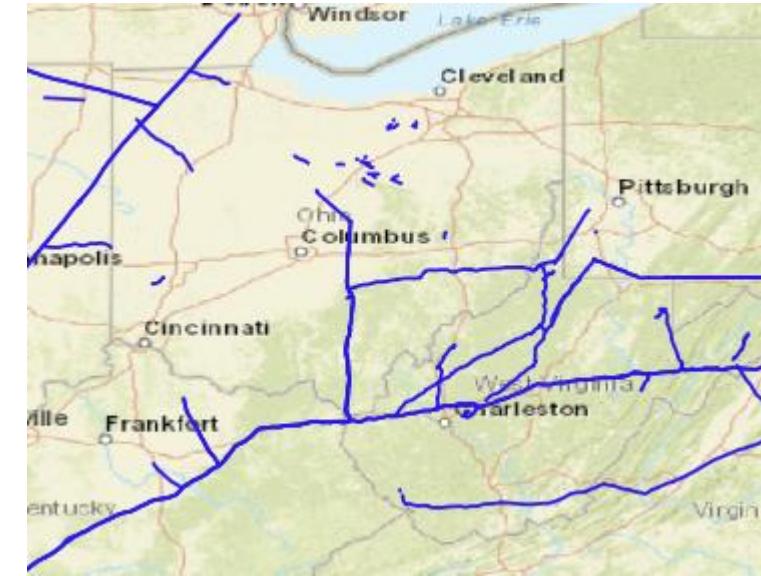


Data Quality  
Models

## Risk Results

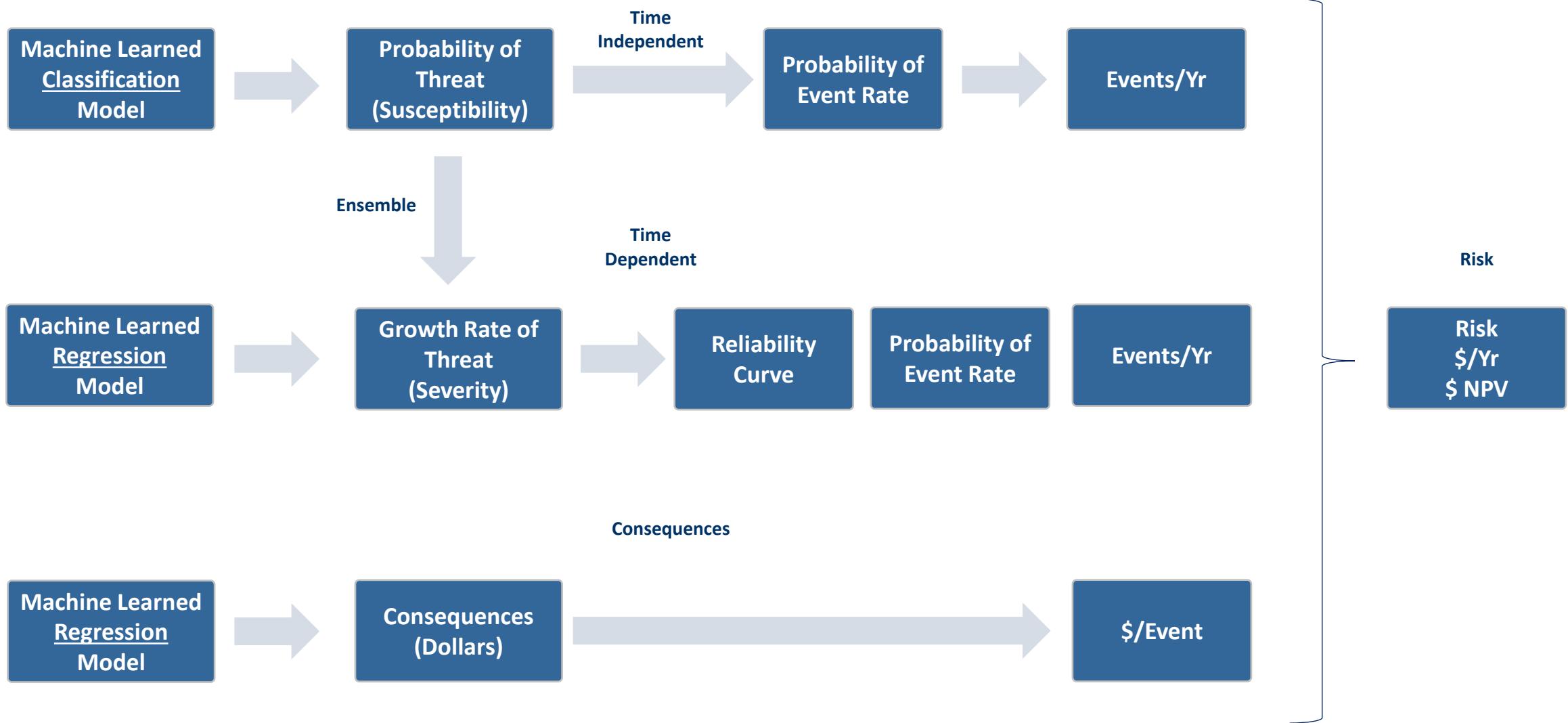


## Analysis



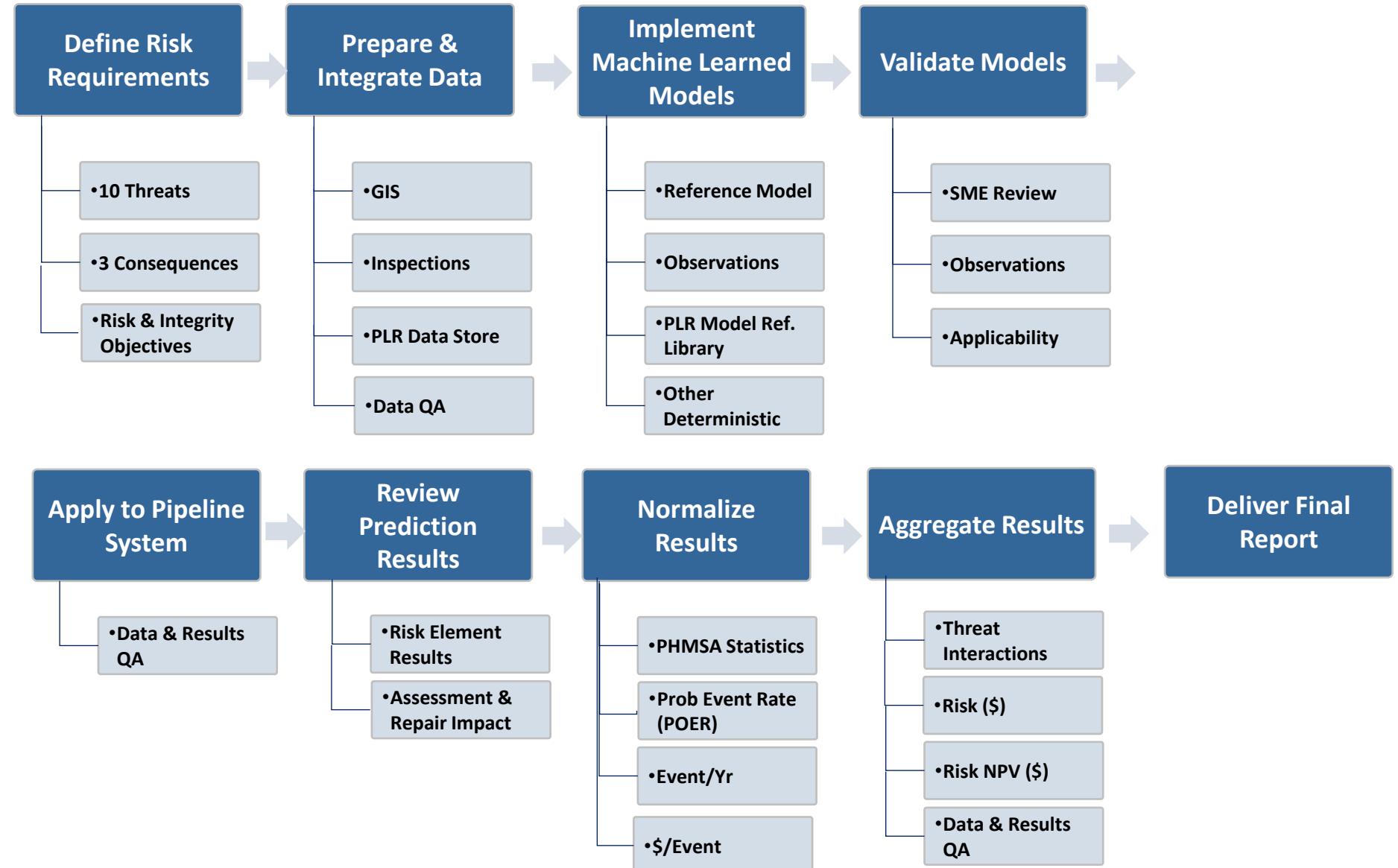
# Work-Flows & Structures

Threats



# Process

- Data-Driven Machine Learned Based Risk Assessment Process
- Leverage Existing Client Data & PLR Geospatial Data Store
- Manages 10 Threats & 3 Consequences (flexible depending on use case)
- Supports Risk Monetization thru Use of Industry Statistics



# Details

## Threat Analysis

- Initial data driven machine learned models are based on PLR reference & other client learned models
- Models are then tuned to Client observations & domain expertise
- Primary output is a **POER (Probability of Event Rate)** for each segment of pipe
- Time independent threats have stable POER over time
- Time dependent threats have changing POER over time based on predicted growth rates & exceedance criteria
- Results are fully traceable to raw input data
- POERs are normalized to industry event rates to arrive at potential events per yr per segment of pipe

## Consequence Analysis

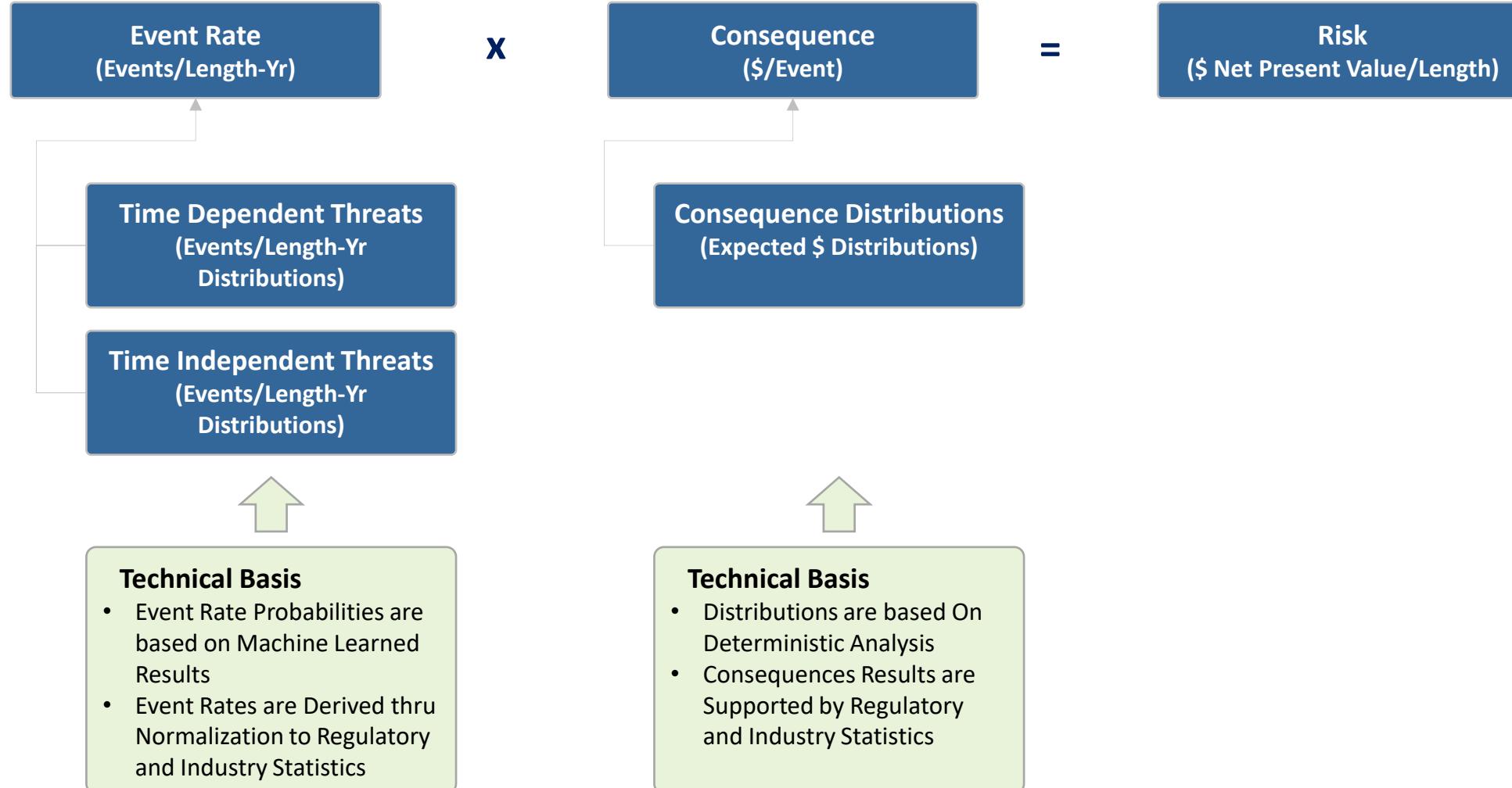
- Initial data driven machine learned models are based on PLR reference & other client learned models
- Models are then tuned to Client observations & domain expertise
- Results are fully traceable to raw input data
- Result is a scaled Consequence number (monetized) normalized to Industry statistics in terms of potential **\$/event**

## Risk Analysis

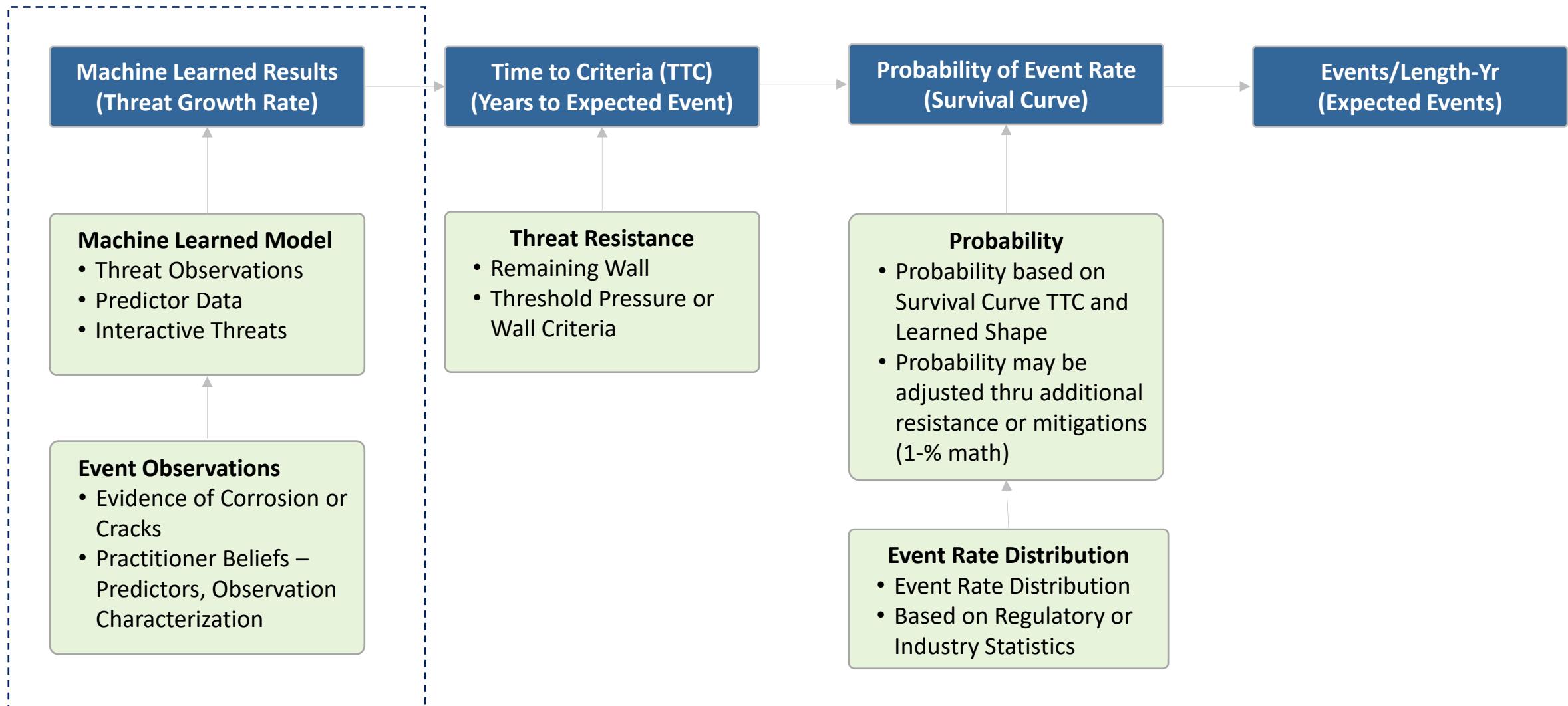
- Predicted Events/Yr x \$/Event outputs \$ Risk for each pipe segment per yr
- Risk is reduced by assessment & repair activity
- Interactive threats are considered
- Outputs include potential **\$ Risk, \$ Net Present Value and \$ Net Present Value/mile for each segment of pipe**

- Risk is calculated by multiplying the number of events per year times consequences for each segment and analysis year. The results will show risk for each segment and each analysis year which are then aggregated to a Net Present Value (NPV) for each segment based on an assumed discount rate and number of analysis years. NPV's are further normalized to miles shown as NPV\_mile.
- Interactions are an advanced feature, basically if interactions are set as True for a threat the threat POER is increased by the POER of the interacting threats using 1-POER math
- Ensemble model predictions are an advanced feature where the predictions from main threat are multiplied by the ensemble model predictions

# Risk Structure - Monetization



# Risk Structure – Time Dependent Threats



# Risk Structure – Time Independent Threats

