Colonial Pipeline Company - Managing Operational Risk

Topics

- Background information on Colonial Pipeline
- Departmental versus Enterprise GIS
- ArcGIS Pipeline Data Model (APDM) + Geodatabase as foundation for risk based asset management system
- Role of Risk Assessment in the Pipeline Integrity Management planning process
- Description of Colonial's Risk Assessment process
Colonial Pipeline Overview

Refined Petroleum Transmission Company

~5500 miles of pipeline
138 Pump Stations
15 Tank Farms
265 Terminals

Transports approximately 100 million gallons a day (2.5 million barrels) of jet fuel, diesel, heating oil and automotive fuel
Managing Operational Risk -
Good Data is Required….

Pipeline GIS/Data Management Historically….
✓ Performed on a project by project basis
✓ Developed at multiple levels within the organization (department, division, location, etc.)
✓ Typically independent data stores and processes (Data Silos)
✓ Inconsistent data collection and management
  ▪ data duplication
  ▪ accuracy differences
  ▪ which version of the truth?
  ▪ little in the way of standards or guidelines
Managing Operational Risk

Pipeline GIS/Data Management Today...

- More centrally controlled within organization
- Designed to meet enterprise-wide requirements (such as pipeline integrity management)
- Utilizes industry recognized standards and templates
  - APDM Geodatabase Model
  - data collection and maintenance standards appropriate to the enterprise
  - industry standard communication protocols (SOAP, XML, etc.)
- Easier integration with other enterprise applications
  - asset management
  - business systems
  - pipeline integrity/risk
Managing Operational Risk

Colonial Uses the Geodatabase and the APDM model as the foundation of their enterprise asset management system

- Designed as central repository for all pipeline facility information
- Particular emphasis on pipeline integrity management needs now and in the future
- Data collection at the source – the field – data flows electronically into the database
Managing Operational Risk

What is the APDM Data Model?

☑ ESRI Geodatabase model for ...
  - gas and/or liquids, onshore/offshore, gathering, transmission, or distribution pipeline systems
  - focused on pipelines that use stationed position AND XY coordinates to locate positions of features on or along the pipeline

☑ APDM → ESRI Object Model Template to handle ...
  - multiple forms of linear referencing
    - ESRI route and measure technology
  - hierarchical/geographical organization of pipeline features
  - Feature behavior during centerline editing operations
  - Links to external systems – ERP, Document Management, Work Order MS

☑ Core Feature/Object Classes

☑ Abstract Classes
Managing Operational Risk

APDM Version 4.0

✓ Abstract Classes (Core Attributes and Relationships)
  ▪ Centerline Objects, Facility Objects, Online/Offline Objects
  ▪ Response to editing the centerline
  ▪ Auditing feature/object edits

✓ Core Classes
  ▪ ControlPoint, StationSeries, AltRefMeasure, Lineloop, Subsystem, SubsystemHierarchy, LineloopHierarchy, Product, OwnerOperator, SubsystemRange, Site, Activity, ActivityHierarchy, ExternalDocument

✓ Metadata Classes
  ▪ Formal definition to describe behavior of reference modes
    ▪ Units, Basis, Type
  ▪ Listing and APDM categorization of classes within geodatabase
    ▪ Each class in the APDM will inherit from one of the APDM Abstract Classes
  ▪ Online Locations for Offline Features
    ▪ Listing of offline/online class pairs
    ▪ Listing of calculation methods for determining derivation of online locations

✓ Inline History and Auditing
Managing Operational Risk

Compliance and Interoperability

✓ The purpose of APDM is to capture the ‘behavior’ of pipeline events, features and objects within a geodatabase object model
✓ The purpose of APDM 4.0 abstract, metadata and core classes is to provide a standard for judging APDM compliance to allow true interoperability between vendor applications and data models
✓ Colonial is using the Geodatabase, APDM, and the ArcGIS software to build and manage the enterprise GIS that is the foundation for their Pipeline Integrity Management System.
Managing Operational Risk

49 C.F.R. § 195.452 - Pipeline Integrity Management in High Consequence Areas, Sub-Part (e) states:

“An operator must establish an integrity assessment schedule that prioritizes pipeline segments for assessment”

“An operator must base the assessment schedule on all risk factors that reflect the risk conditions on the pipeline segment”
Managing Operational Risk

Sub-Part (e) further states that the factors an operator must consider for risk analysis include, but are not limited to:

- Results of previous assessments
- Pipe size, material, and other attributes
- Operating stress level
- Leak history, repair history, and cathodic protection history
- Existing or projected activities in the area (related to 3rd party damage)
- Local environmental factors that could affect the pipeline (e.g., corrosivity of soil, subsidence, climatic)
- Geo-technical hazards
Managing Operational Risk

An appropriately designed and implemented pipeline GIS provides the perfect environment for the collection, maintenance, and analysis of data required for pipeline risk assessment.
Managing Operational Risk

Colonial Risk Assessment Solution

- Relative risk ranking model
- Identify probability of pipe failure factors
- Identify consequence of pipe failure factors
- Determine data requirements for each
- Balance need for data against the cost to obtain data
- Total probability of failure = sum of all probability factors
- Total consequence of failure = sum of all consequence factors
- Total risk = Total probability of failure * Total consequence of failure
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

☑ Internal Corrosion
  - number of internal corrosion leaks
  - date of last ILI corrosion inspection
  - date of last hydro test
  - pipe wall thickness
  - SMYS
  - MAOP
  - flow frequency (# of days/year)
  - flow rate
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- Equipment Failure
  - number of equipment failure related leaks
  - presence of taps
  - presence of valves
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- Stress Corrosion Cracking
  - number of SCC leaks
  - number of SCC indicated ILI anomalies
  - pipe outside diameter
  - pipe wall thickness
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- Construction Problems
  - number of buckle leaks
  - pipe outside diameter
  - pipe wall thickness
  - date of last ILI deformation inspection
  - pipe install date (welding, backfill, girth weld indicator)
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- Incorrect Operations
  - number of incorrect operation related leaks
  - power and communication backup systems at stations
  - various abnormal operation incidents at stations
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

☑️ Outside Force
  - number of outside force related leaks
  - type of stream bank protection
  - pipe install date (pipe vintage – resistance to strain)
  - pipe spans
  - areas of exposed pipe
  - water crossings
  - landslide hazard
  - seismic hazard
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

✓ Manufacturing Defects
  - number of crack related leaks
  - number of ILI anomalies located on or near seams
  - date of last ILI deformation inspection
  - pipe seam type
  - pipe SMYS (Specified Minimum Yield Strength)
  - pipe install date (pre-1970 ERW)
  - pressure cycling
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- External Corrosion
  - number of external corrosion related leaks
  - number of ILI anomalies located on or near seams
  - date of last ILI corrosion inspection
  - pipe wall thickness
  - pipe SMYS (Specified Minimum Yield Strength)
  - presence of casings
  - cathodic protection exception segments
  - density of utility crossings
  - date of last CIS inspection
  - coating age
  - coating type
  - coating condition
Managing Operational Risk

Colonial Risk Assessment – Probability Factors and Data Requirements

- Third-Party Mechanical Damage
  - number of mechanical damage related leaks
  - number of mechanical damage related ILI anomalies
  - pre-1970 ERW pipe
  - pipe wall thickness
  - pipe outside diameter
  - pipe SMYS
  - pressure cycling
  - aboveground pipe
  - mechanical protection (concrete slabs/matting)
  - concrete coating
  - ROW patrolling interval
  - presence of pipeline markers
  - pipe depth of cover
  - surrounding land use
  - number of road crossings
  - number of water crossings
  - number of unauthorized encroachments
  - onecall density
Colonial Risk Assessment – Geoprocessing Requirements

- Polygon Overlay Analysis
  - seismic hazard
  - landslide hazard
  - county (One call)
  - state (general soils)
  - public lands (600 foot buffer)
  - navigable waterways (600 foot buffer)
  - NWI (600 foot buffer)
  - land use
  - aerial observation flight segment polygons
Colonial Risk Assessment – Geoprocessing Requirements

- Polygon Overlay Analysis
  - overlay polygonal feature on pipe centerline
  - determine entry/exit points of centerline w/polygons
  - generates a stationed, on-centerline linear feature
  - attach specified polygon attributes
Colonial Risk Assessment – Polygon Overlay Analysis - NWI
Colonial Risk Assessment – Polygon Overlay Analysis – NWI Buffer (660 feet)
Colonial Risk Assessment –
Geoprocessing Requirements

- ILI Feature Counts
  - on one mile segments (generate empty segments)
  - corrosion defects
  - damage defects
  - seam defects
  - segment statistics to generate counts
  - input to Dynamic Segmentation
Colonial Risk Assessment –
ILI Feature Counts – Corrosion, Damage, Seam Anomalies
Colonial Risk Assessment – ILI Anomaly Feature Counts – One Mile Segments
Colonial Risk Assessment – Geoprocessing Requirements

☑ Resolve Linear Overlap

- linear feature with overlap in same pipeline range
- hydrotests and HCA segments are good examples
- split at intersections
- apply selection criteria to determine which overlapping segment to keep
  - most recent test date
  - duration \( \geq 8 \) hours
  - test pressure > 1.25 X MAOP
Colonial Risk Assessment – Geoprocessing Requirements

☑ Resolve Linear Overlap

Hydrotest 1: Date 3/4/2002, Duration 6 hours, Pressure: 1.5 X MAOP

Hydrotest 2: Date 10/9/2004, Duration 12 hours, Pressure: 2 X MAOP

Hydrotest 3: Date 12/21/2003, Duration 8 hours, Pressure: 1.5 X MAOP
Colonial Risk Assessment – Geoprocessing Requirements

- Dynamic Segmentation
  - break at any change in attribute
  - highest resolution of the input data
Colonial Risk Assessment – Geoprocessing Requirements

☑️ Dynamic Segmentation

<table>
<thead>
<tr>
<th>FBE</th>
<th>Coating</th>
<th>Wall Thickness</th>
<th>ILI Corrosion Density</th>
<th>Pipe Centerline</th>
</tr>
</thead>
<tbody>
<tr>
<td>.172”</td>
<td>2.0</td>
<td>.194”</td>
<td>1.268</td>
<td>0.0</td>
</tr>
<tr>
<td>.194”</td>
<td>1.268</td>
<td>.194”</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

DynSeg Result

Station Value

0 2544 5043 6032 8766 10000
Colonial Risk Assessment – Geoprocessing Requirements

- Generate point densities on segments resulting from Dynamic Segmentation
  - leaks by type
  - pipeline markers
  - valves
  - pipe attachments (taps)
  - line crossing by type
  - unauthorized encroachments
Colonial Risk Assessment – DynSeg Point Densities – Road Crossings
Colonial Risk Assessment –

Set Constants and Parameters

- Global variables utilized in algorithm set in one location (isolated from algorithm)
- Numerous “Max” values from Dynamic Segmentation results
  - abnormal operations variables
  - one call density
  - unauthorized encroachments
  - crossing densities
### Colonial Risk Assessment – Setting Global Variables

**Set Variable Tool Properties**

**Task Description:** Define Constants for Risk Algorithm

- **Abort Task if this process fails**

#### Variable List

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LIF_MAX</td>
<td>19.5</td>
</tr>
<tr>
<td>2</td>
<td>WTPMD</td>
<td>0.3682</td>
</tr>
<tr>
<td>3</td>
<td>WEXTCORR</td>
<td>0.3655</td>
</tr>
<tr>
<td>4</td>
<td>WMFG</td>
<td>0.1255</td>
</tr>
<tr>
<td>5</td>
<td>WOF</td>
<td>0.01</td>
</tr>
<tr>
<td>6</td>
<td>WINCOPS</td>
<td>0.0406</td>
</tr>
<tr>
<td>7</td>
<td>WCONSTR</td>
<td>0.048</td>
</tr>
<tr>
<td>8</td>
<td>WSCC</td>
<td>0.01</td>
</tr>
<tr>
<td>9</td>
<td>WEQUIP</td>
<td>0.0222</td>
</tr>
<tr>
<td>10</td>
<td>WINTCORR</td>
<td>0.01</td>
</tr>
<tr>
<td>11</td>
<td>WTPMDI</td>
<td>0.5</td>
</tr>
<tr>
<td>12</td>
<td>WTPMD</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**OK**  **Cancel**
Colonial Risk Assessment – Setting “Maximum” Variables

- Variable List
  - Variable: ILL CORROSION_DENSITY_MAX
    - Expression: GPT_MAX:ILL_CORROSION_DENSITY
  - Variable: ILL DAMAGE_DENSITY_MAX
    - Expression: GPT_MAX:ILL DAMAGE_DENSITY
  - Variable: AOP2YR_MAX_US
    - Expression: GPT_MAX:AOP2YR_US
  - Variable: AOP2YR_MAX_DS
    - Expression: GPT_MAX:AOP2YR_DS
  - Variable: AOPYR_MAX_US
    - Expression: GPT_MAX:AOPYR_US
  - Variable: AOPYR_MAX_DS
    - Expression: GPT_MAX:AOPYR_DS
  - Variable: AOPJ23_MAX_US
    - Expression: GPT_MAX:AOPJ23_US
  - Variable: AOPJ23_MAX_DS
    - Expression: GPT_MAX:AOPJ23_DS
  - Variable: AOPJ50_MAX_US
    - Expression: GPT_MAX:AOPJ50_US
  - Variable: AOPJ50_MAX_DS
    - Expression: GPT_MAX:AOPJ50_DS
  - Variable: AOPJ11_MAX_US
    - Expression: GPT_MAX:AOPJ11_US
  - Variable: AOPJ11_MAX_DS
    - Expression: GPT_MAX:AOPJ11_DS
  - Variable: AOP120_MAX_US
    - Expression: GPT_MAX:AOP120_US
Colonial Risk Assessment –

“Lookup” of Risk Weighting Values

- Translate variable values to weighting values
- String variables – examples
  - external coating type
  - bank protection quality
- Numeric variables (range lookups) – examples
  - number of years since last CIS survey
  - depth of cover
### Colonial Risk Assessment – Lookup – Risk Weighting Values

<table>
<thead>
<tr>
<th>OBJECTID</th>
<th>EVENTID</th>
<th>LOOKUPNAME</th>
<th>MEMBERVALUE</th>
<th>RISKVALUE</th>
<th>MEMBERTYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>214</td>
<td>4FAD8870-91AC-41B3-B100-44A103298AFCA</td>
<td>AboveGround</td>
<td><em>ISNULL</em></td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>191</td>
<td>32416B27-5265-3F45-E147-74D0D0E2C24D</td>
<td>AboveGround</td>
<td>No</td>
<td>0</td>
<td>String</td>
</tr>
<tr>
<td>89</td>
<td>6A9953CE-38DF-1848-C9F7-77A47C4EED0</td>
<td>AboveGround</td>
<td>Unknown</td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>122</td>
<td>6E6EEA0-845B-F24C-2797-789A9BFD169D</td>
<td>AboveGround</td>
<td>Yes</td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>207</td>
<td>700089F9-4B0B-48B9-AC1F-9E8C56A25C65</td>
<td>BankProtection</td>
<td><em>ISNULL</em></td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>91</td>
<td>B250F90-99E2-40B1-D193-8E284418</td>
<td>BankProtection</td>
<td>Excellent</td>
<td>2</td>
<td>String</td>
</tr>
<tr>
<td>117</td>
<td>5E8BE574-CCAF-245B-43C2-209316639637</td>
<td>BankProtection</td>
<td>Fair</td>
<td>6</td>
<td>String</td>
</tr>
<tr>
<td>12</td>
<td>6F426D1E-CE87-DB45-10E9-9C11091C3965</td>
<td>BankProtection</td>
<td>Good</td>
<td>4</td>
<td>String</td>
</tr>
<tr>
<td>164</td>
<td>1BB04A19-861F-D741-561S-598884A7E3F7</td>
<td>BankProtection</td>
<td>N/A</td>
<td>0</td>
<td>String</td>
</tr>
<tr>
<td>60</td>
<td>BE111D0A-8E16-A24B-3D5B-8750E6137469</td>
<td>BankProtection</td>
<td>None</td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>98</td>
<td>D17C4FFE-EB25-2494-0715-5057C290478E</td>
<td>BankProtection</td>
<td>Poor</td>
<td>8</td>
<td>String</td>
</tr>
<tr>
<td>29</td>
<td>6067789D-9CCA-BE4B-03F7-7B5CB7F243FB</td>
<td>BankProtection</td>
<td>Unknown</td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>209</td>
<td>4E22CABA-1D08-40F8-9676-987AFAF093869</td>
<td>Casing</td>
<td><em>ISNULL</em></td>
<td>0</td>
<td>String</td>
</tr>
<tr>
<td>160</td>
<td>8AAAB237E-6B98-5C04-A030-30178ACC70DF</td>
<td>Casing</td>
<td>No</td>
<td>0</td>
<td>String</td>
</tr>
<tr>
<td>171</td>
<td>3986606C-33F2-564C-4FB5-5868914E5C51</td>
<td>Casing</td>
<td>Yes</td>
<td>10</td>
<td>String</td>
</tr>
<tr>
<td>136</td>
<td>3AFCCDB1-12CE-B347-466E-6F107EDEC3D</td>
<td>CisAge</td>
<td>0</td>
<td>1</td>
<td>Numeric</td>
</tr>
<tr>
<td>60</td>
<td>C1D395AB-DD46-3F4E-EB41-19C09001F082</td>
<td>CisAge</td>
<td>1</td>
<td>1.05</td>
<td>Numeric</td>
</tr>
<tr>
<td>111</td>
<td>70CBA17H-45C6-924D-96C7-758ABB90958D5</td>
<td>CisAge</td>
<td>10</td>
<td>1.5</td>
<td>Numeric</td>
</tr>
<tr>
<td>32</td>
<td>6B58C21-73F0-D140-4F52E13A44</td>
<td>CisAge</td>
<td>2</td>
<td>1.1</td>
<td>Numeric</td>
</tr>
<tr>
<td>139</td>
<td>A0621A2B-1612-9A46-E10A-A374A49B233</td>
<td>CisAge</td>
<td>3</td>
<td>1.15</td>
<td>Numeric</td>
</tr>
<tr>
<td>192</td>
<td>79C632A-26F7-154A-C91C-C3566F32C87</td>
<td>CisAge</td>
<td>4</td>
<td>1.2</td>
<td>Numeric</td>
</tr>
</tbody>
</table>
Colonial Risk Assessment –

Algorithm Expressions

- Utilize enhanced “CalcField” tool
- Calculates multiple fields simultaneously
- Dynamically adds the field to the output theme if necessary
- Dynamically replaces VBA or Calc expressions with variables created elsewhere
- Ultra-fast ADO2 calculation method
### Calculate Field Tool

#### Task Description:
Risk Algorithm 2

- **Abort Task if this process fails**

#### Source Theme Type:
Risk Dynamic Segment

#### Output Theme Type:

- Within tool
- Dynamically Linked

### Add Calculated Fields

<table>
<thead>
<tr>
<th>Step</th>
<th>Field Name</th>
<th>Field Type</th>
<th>Calc Type</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LENGTH</td>
<td>Number</td>
<td>AD02</td>
<td>[ENDSTATION] - [BEGINSTATION]</td>
</tr>
<tr>
<td>2</td>
<td>LEAK_INTCORR_PTS</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([LEAK_INTCORR] &gt; 0, 2, 1)</td>
</tr>
<tr>
<td>3</td>
<td>INTCORR_INDICATORS</td>
<td>Number</td>
<td>AD02</td>
<td>LEAK_INTCORR_PTS</td>
</tr>
<tr>
<td>4</td>
<td>ILL_CORROSION_PROT</td>
<td>Number</td>
<td>AD02</td>
<td>IIF(ISNULL([ILL_CORROSION_INSPE_DATE]), 1, IIF(([MODEL_YEAR] - YEAR([ILL_CORROSION_PROT]) &gt; 0, 0, 1))</td>
</tr>
<tr>
<td>5</td>
<td>EXCORR_PROTECTION</td>
<td>Number</td>
<td>AD02</td>
<td>ILL_CORROSION_PROT</td>
</tr>
<tr>
<td>6</td>
<td>HYDRO_PROTECTION</td>
<td>Number</td>
<td>AD02</td>
<td>IIF(ISNULL([HYDRO_TEST_DATE]), 1, IIF(([MODEL_YEAR] - YEAR([HYDRO_TEST_DATE]) &lt; 1, 0, 1))</td>
</tr>
<tr>
<td>7</td>
<td>INT_PRO</td>
<td>Number</td>
<td>AD02</td>
<td>((INTPC) * [ILL_CORROSION_PROT]) + ((INTCPH) * [HYDRO_PROTECTION])</td>
</tr>
<tr>
<td>8</td>
<td>INTCORR_PPREFERENCE</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([INT_PRO] = 0, 1, IIF([INT_PRO] &lt; 1, [INT_PRO], 1))</td>
</tr>
<tr>
<td>9</td>
<td>PCT_SMYS_FTS</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([CEMOP] / [SMYS] = (SMYS1, 10, IIF([CEMOP] / [SMYS] = (SMYS2, 8, 1))</td>
</tr>
<tr>
<td>10</td>
<td>INTCORR_RESISTANCE</td>
<td>Number</td>
<td>AD02</td>
<td>((INTCRS) * IIF([[PCT_SMYS_PTS] / 10] + 0.15 &lt; 1, [[PCT_SMYS_PTS] / 10] + 0.15, 1) + (INTCRS))</td>
</tr>
<tr>
<td>11</td>
<td>INTCORR_DRIVERS</td>
<td>Number</td>
<td>AD02</td>
<td>((INTCDR) * [FLOWRATE_PTS]) + (INTCDR) + (FLOWFREQ_PTS)</td>
</tr>
<tr>
<td>12</td>
<td>INTCORR</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([INTCORR_DRIVERS] + [INTCORR_RESISTANCE] + [INTCORR_PROTECTION] + [INTCORR]</td>
</tr>
<tr>
<td>13</td>
<td>LEAK_EQUIPMENT_PTS</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([LEAK_EQUIPMENT] &gt; 0, 2, 1)</td>
</tr>
<tr>
<td>14</td>
<td>EQUIP_INDICATORS</td>
<td>Number</td>
<td>AD02</td>
<td>LEAK_EQUIPMENT_PTS</td>
</tr>
<tr>
<td>15</td>
<td>ATTACHMENTS_PTS</td>
<td>Number</td>
<td>AD02</td>
<td>IIF([ATTACHMENTS] &gt; 0, 10, 0)</td>
</tr>
</tbody>
</table>
Colonial Risk Assessment – Results Rollup

- Summarize risk results to various levels
  - 1,000 foot segments
  - piggable segments
  - HCA Segments

- Define rollup expression
  - Length Weighted formula
  - \( \text{SUM}(((\text{EndStation} - \text{BeginStation}) / \text{SEG\_LENGTH}) \times \text{RISK}) \)
### Colonial Risk Assessment – Geoprocessing Requirements

#### Length Weighted Risk

\[ \text{SUM}(((\text{EndStation} - \text{BeginStation}) / \text{SEG_LENGTH}) \times \text{RISK}) \]

<table>
<thead>
<tr>
<th>Station Value</th>
<th>DynSeg Result</th>
<th>1,000 Foot Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>(254 - 0) / 1000 * 747.23 = 189.79</td>
<td>Risk = 747.23</td>
<td>189.79</td>
</tr>
<tr>
<td>(504 - 254) / 1000 * 3012.61 = 753.15</td>
<td>Risk = 3012.61</td>
<td>753.15</td>
</tr>
<tr>
<td>(603 - 504) / 1000 * 2423.93 = 239.97</td>
<td>Risk = 2423.93</td>
<td>239.97</td>
</tr>
<tr>
<td>(876 - 603) / 1000 * 248.74 = 67.91</td>
<td>Risk = 248.74</td>
<td>67.91</td>
</tr>
<tr>
<td>(1000 - 876) / 1000 * 545.97 = 67.70</td>
<td>Risk = 545.97</td>
<td>67.70</td>
</tr>
</tbody>
</table>

\[ \text{Length Weighted Risk:} \quad 1318.52 \]

### Calculation Details

1. **189.79**
   - (254 - 0) \(/\) 1000 \* 747.23
2. **753.15**
   - (504 - 254) \(/\) 1000 \* 3012.61
3. **239.97**
   - (603 - 504) \(/\) 1000 \* 2423.93
4. **67.91**
   - (876 - 603) \(/\) 1000 \* 248.74
5. **67.70**
   - (1000 - 876) \(/\) 1000 \* 545.97

\[ \text{Length Weighted Risk:} \quad 1318.52 \]
Colonial Risk Assessment – Symbolized Risk Results – 1,000 foot segments
Colonial Risk Assessment – Results

Line XX Weighted Risk - 1,000 Foot Segments

Weighted Risk vs. Stationing
### Average and Length Weighted Risk

*by 1,000 Foot Segment*

<table>
<thead>
<tr>
<th>SERIESNAME</th>
<th>BEGINSTATION</th>
<th>ENDSTATION</th>
<th>AVG RISK</th>
<th>WEIGHTED RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINE XX</td>
<td>0</td>
<td>1000</td>
<td>380.518599918791</td>
<td>399.896473481664</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>2000</td>
<td>380.458971036278</td>
<td>401.623506585802</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>3000</td>
<td>380.545618612975</td>
<td>400.170782022568</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>4000</td>
<td>380.570382150798</td>
<td>409.135093643418</td>
</tr>
<tr>
<td></td>
<td>4000</td>
<td>5000</td>
<td>380.570375917737</td>
<td>413.005389419658</td>
</tr>
<tr>
<td></td>
<td>5000</td>
<td>6000</td>
<td>356.97319033288</td>
<td>362.079643656187</td>
</tr>
<tr>
<td></td>
<td>6000</td>
<td>7000</td>
<td>356.282841887101</td>
<td>365.323380741634</td>
</tr>
<tr>
<td></td>
<td>7000</td>
<td>8000</td>
<td>396.027313613528</td>
<td>383.811765475527</td>
</tr>
</tbody>
</table>
Colonial Risk Assessment – Results

Top Scoring Segments - Length Weighted Risk
by 1,000 Foot Segment

<table>
<thead>
<tr>
<th>SERIESNAME</th>
<th>BEGINSTATION</th>
<th>ENDSTATION</th>
<th>WEIGHTED RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINE XX</td>
<td>166000</td>
<td>167000</td>
<td>5942.47212168976</td>
</tr>
<tr>
<td></td>
<td>167000</td>
<td>168000</td>
<td>5801.88657918426</td>
</tr>
<tr>
<td></td>
<td>168000</td>
<td>169000</td>
<td>5424.15217823648</td>
</tr>
<tr>
<td></td>
<td>178000</td>
<td>179000</td>
<td>3604.83847961627</td>
</tr>
<tr>
<td></td>
<td>175000</td>
<td>176000</td>
<td>3432.81162189647</td>
</tr>
<tr>
<td></td>
<td>176000</td>
<td>177000</td>
<td>3345.19844133042</td>
</tr>
<tr>
<td></td>
<td>177000</td>
<td>178000</td>
<td>3330.99466171044</td>
</tr>
<tr>
<td></td>
<td>174000</td>
<td>175000</td>
<td>3207.29611642876</td>
</tr>
<tr>
<td></td>
<td>179000</td>
<td>179366</td>
<td>2892.46814270678</td>
</tr>
<tr>
<td></td>
<td>172000</td>
<td>173000</td>
<td>2653.74911316636</td>
</tr>
<tr>
<td></td>
<td>169000</td>
<td>170000</td>
<td>2545.06563665665</td>
</tr>
<tr>
<td></td>
<td>170000</td>
<td>171000</td>
<td>2496.84120520078</td>
</tr>
</tbody>
</table>