Risk Assessment Toolbox

A Custom ArcGIS Toolbox for Wastewater Asset Management

Case Study: SJRA, The Woodlands, TX

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Agenda

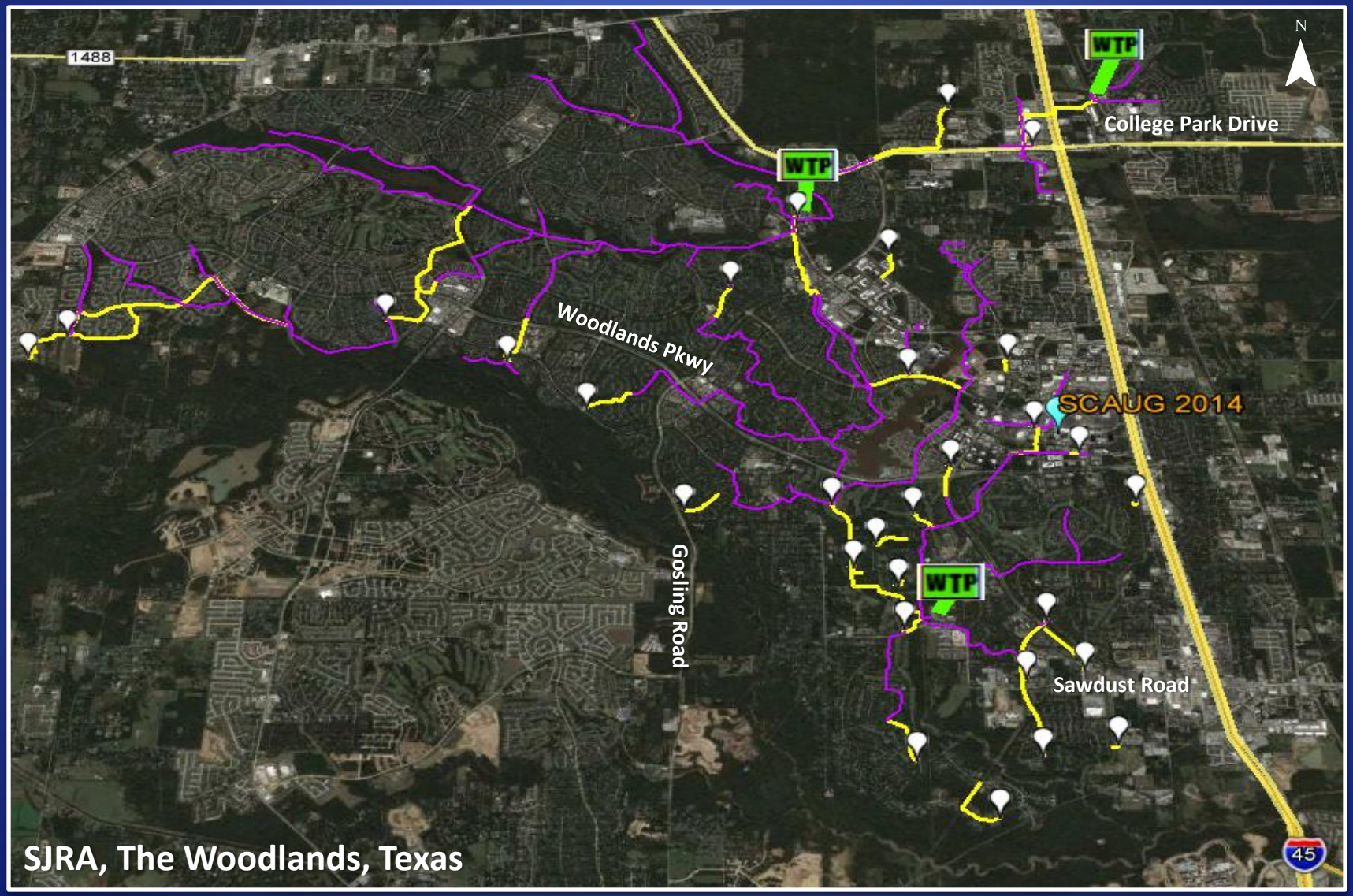
- Project Description
- Challenges and Requirements
- Tool Features
- Technical and Python Highlights
- Future Development

Project Description

- Project: Perform a business risk assessment of the SJRA, Woodlands wastewater collection and treatment system.

Asset Group	# Individual Assets	# Grouped Assets
Gravity Mains	1,128	75
Force Mains	33	33
Lift Stations	760	128
Treatment Plants	1,020	15

Project Description

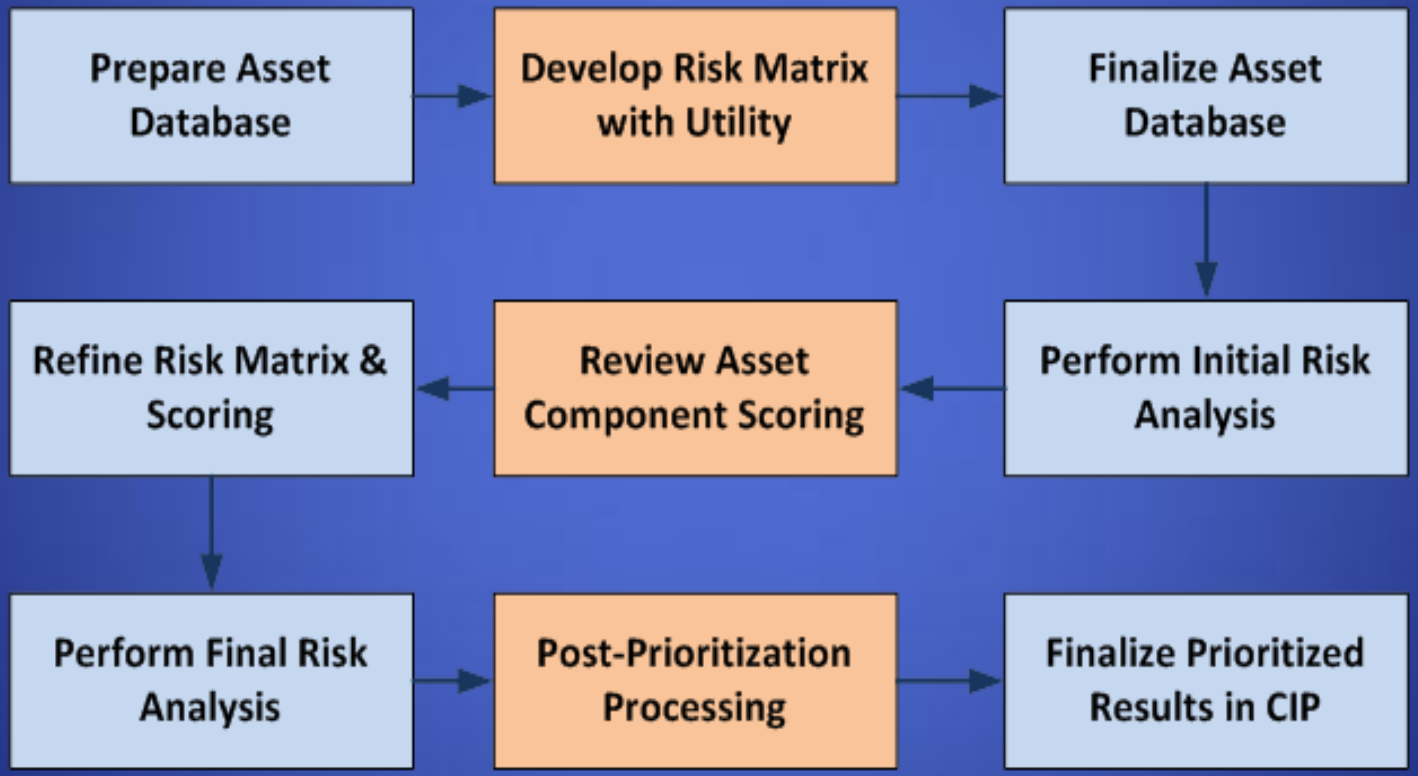


Project Description

- Scoring: Custom risk assessment criteria and scoring were developed for each asset in the system.
  - Likelihood of Failure (LOF)
  - Consequence of Failure (COF)
  - Risk of Asset Failure (ROF)
- Prioritization: ROF scores prioritized individual assets for rehabilitation in SJRA's 5 year and 10 year capital improvement plan (CIP) and to manage future asset renewal priorities.

Project Description

- 9 Steps to a Business Risk Assessment



Project Description

- Definitions
  - **LOF**: Likelihood that an asset will fail to meet its intended use requirements.
  - **COF**: Consequence and/or severity of an asset failing. Generally related to location.
  - **ROF**: Risk of asset failure. Computed using the following equation:

$$ROF = \frac{([LOF] \times [COF])}{10}$$

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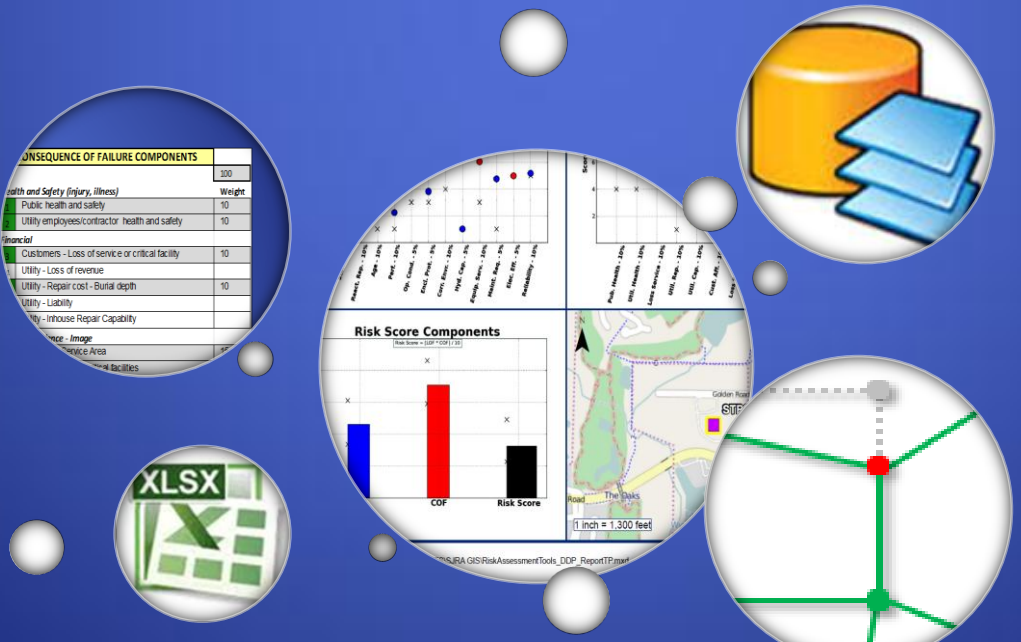
Challenges and Requirements

- Asset Management Challenges
  - Geoprocessing (location-aware analyses)
  - Efficient and accurate asset scoring, from preliminary through final iterations
  - Summary results and reporting by asset and asset group

Challenges and Requirements

- Tool Requirements
  - Import asset data and custom scoring matrices
  - Geoprocessing (point, polyline features)
  - Database processing and matrix scoring
  - Results and reports



Agenda

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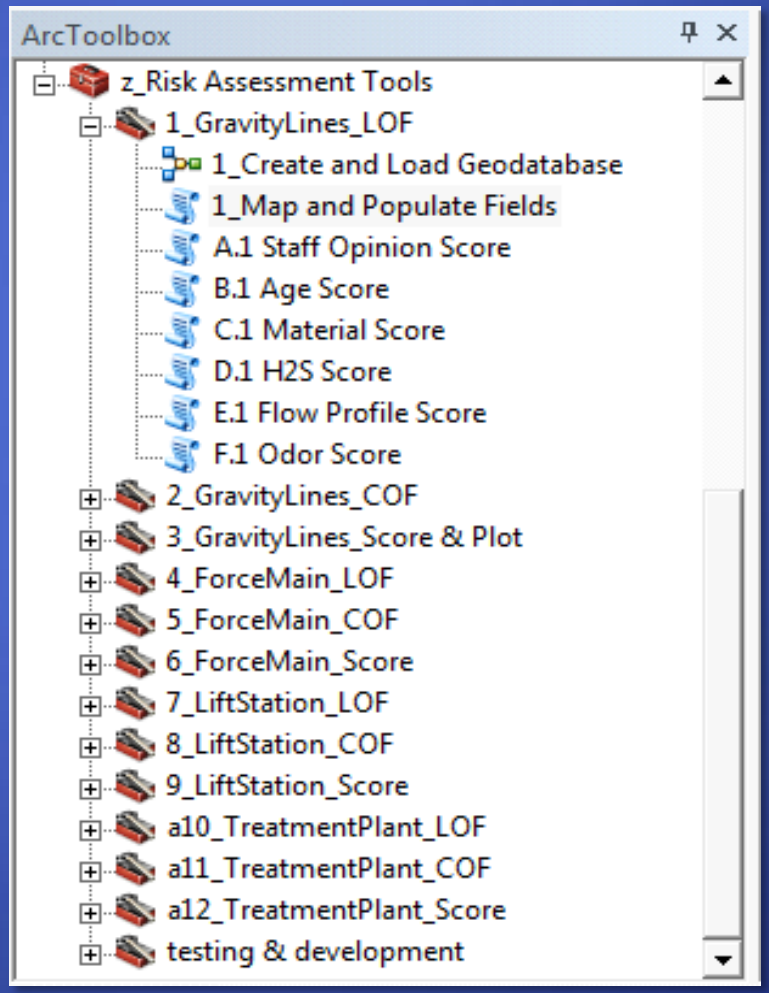
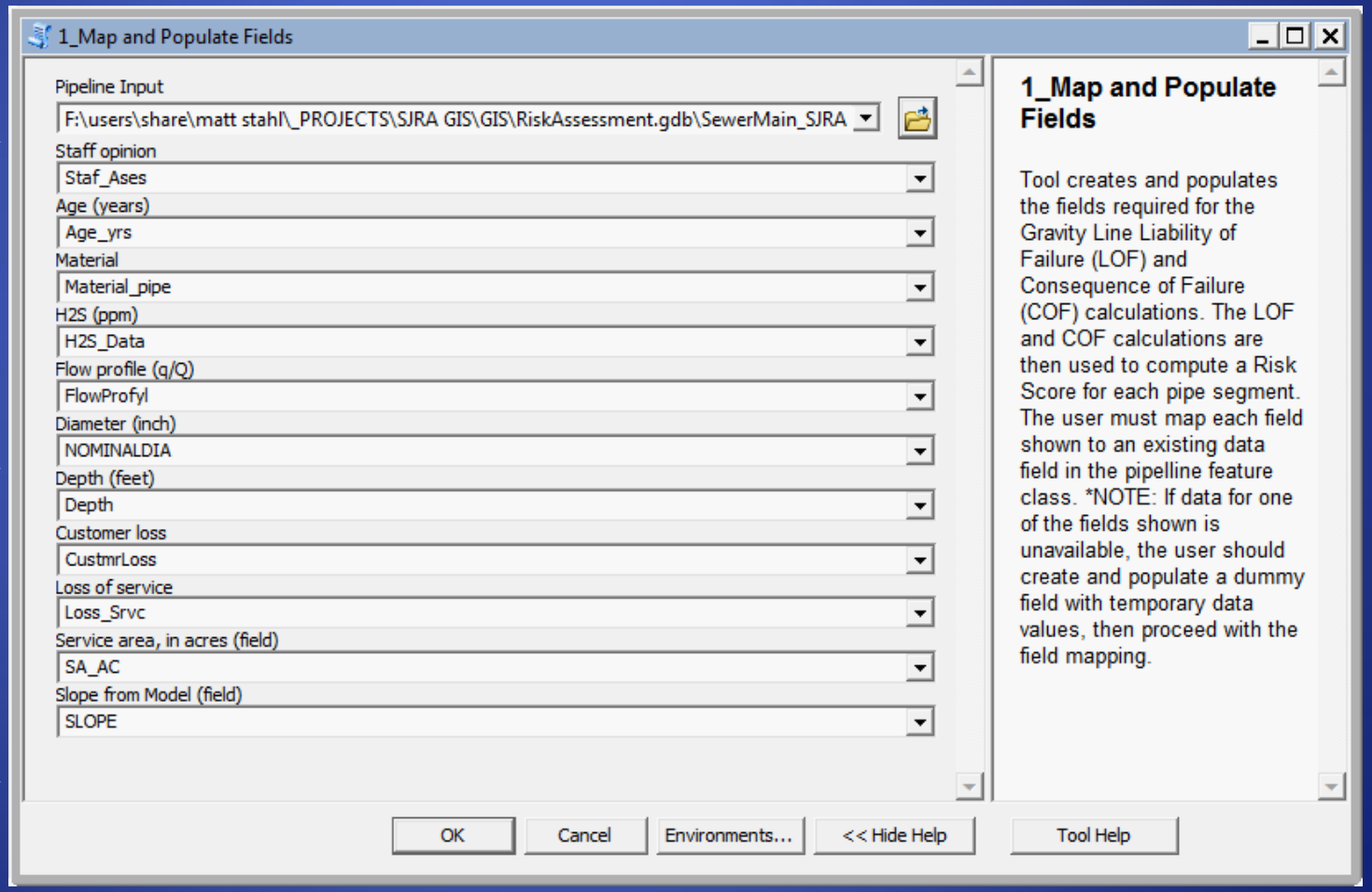
Tool Features

- Toolbox Layout (4 asset groups)
  - LOF
  - COF
  - Score and Plot



Tool Features

- Field Mapping to Import Data to Geodatabase



Tool Features

- Custom Scoring Matrices

			LIKELIHOOD OF FAILURE COMPONENTS	
			STRUCTURAL	100
Yes	**No**		***Pipe Properties***	**Weight**
	N	1	Condition (rating via direct inspection)	
Y		2	Staff opinion of condition	15
	N	3	Repair history (# / 100 ft / yr)	
	N	4	Time since second most recent repair (yr)	
Y		5	Age (yr)	25
Y		6	Material	25
	N	7	Joint Type	
	N	8	No of connections (# /foot)	
	N	9	Installation Contractor	
			External Corrosion (Post Processing)	
	N	10	Soil resistivity (ohm-cm)	
	N	11	Soil chemistry - sulfates in soils (%)	
	N	12	Soil Moisture	
	N	13	Stray current	
	N	14	External corrosion protection	
			Internal Corrosion	
Y		16	H2S data & Some sulfate data	10
	N	17	Internal corrosion protection	
			External Stresses	
	N	18	Burial depth (ft)	
	N	19	Embedment zone backfill (quality of pipe bedding)	
	N	20	Traffic Load	
			Hydraulic	
Y		21	Flow Profile (% full - Hydraulic model)	15
	N	22	Blockage history (# / 1,000 ft / yr)	
	N	23	Surcharge conditions	
			Performance	
Y		24	Odor complaints	10
	N	25	SSO's (# / 1,000 ft / yr)	
			Others	
		26	Accessibility (monitor performance & Condition)	

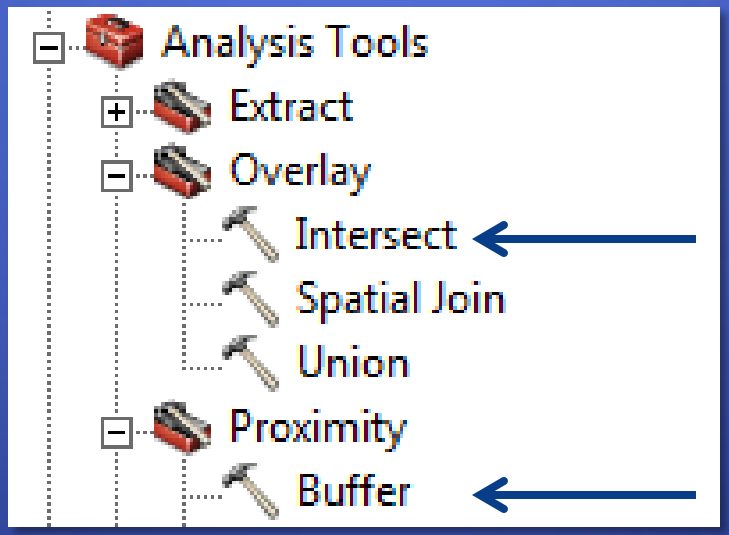
Good data available
Some data available
Little/No data available or data availability unknown

			CONSEQUENCE OF FAILURE COMPONENTS	
				100
Yes	**No**		***Health and Safety (injury, illness)***	**Weight**
Y		1	Public health and safety	10
Y		2	Utility employees/contractor health and safety	10
			Financial	
Y		3	Customers - Loss of service or critical facility	10
	N	4	Utility - Loss of revenue	
Y		5	Utility - Repair cost - Burial depth	10
	N	6	Utility - Liability	
	N	7	Utility - Inhouse Repair Capability	
			Public Confidence - Image	
Y		13	Size of the Service Area	15
Y		14	Loss of service to critical facilities	15
	N	15	Traffic Impacts	
	N	16	Probability of Media Coverage	
			Infrastructure	
Y		10	Proximity to main roads or railroads	10
			Regulatory/Environmental	
Y		11	Discharge to Sensitive Environments	10
Y		12	SSO impacts/Permit violation	10
			Other	
	N	13	Burial Depth(in cost of repair)	
	N	14	Access (In cost of repair)	
		15		
		16		
		17		

Good data available
Some data available
Little/No data available or data availability unknown

Tool Features

- Geospatial Database Processing (points, polylines)
  - The geospatial nature of the risk scoring process made it necessary to perform GIS computations involving LOF and COF components for individual pipe segments as well as lift station and wastewater treatment plant assets.

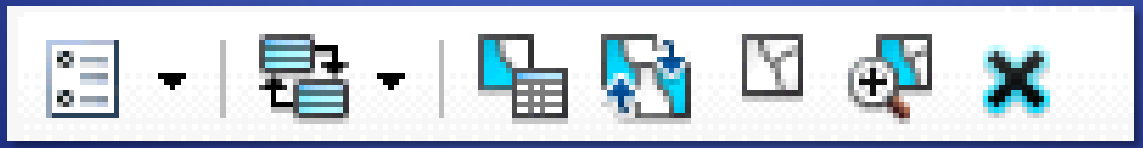


Tool Features

- Geoprocessing Components
  - Public Health and Safety (intersect of pipeline and land use)
  - Customer Loss of Service (gravity lines downstream of commercial or industrial facilities)
  - Loss of Service to Critical Facilities (gravity lines downstream of critical lift stations)
  - Proximity to Main Roads and Railroads (pipeline proximity to roads and railroads)
  - Discharge to Sensitive Environments (intersect of pipeline and sensitive environments)

Tool Features

- Data Processing Components
  - Employee Health and Safety (pipeline diameter, burial depth)
  - Cost of Repairs (pipeline diameter, burial depth)
  - Size of Service Area (size of service area, pipeline diameter)
  - Sanitary Sewer Overflows (# reported SSO's, negative pipeline slopes)
  - Matrix Scoring (all tool LOF and COF components)



Tool Features

- Data Processing Components (continued)

Diameter (in)	Road Class	UtilityRepair Score
0 to 6	FREEWAY; FRONTAGE; ACCESS	5
8 to 12		6
14 to 18		7
20 to 30		8
33 to 42		9
> 48		10
0 to 6	MAJOR	3
8 to 12		4
14 to 18		5
20 to 30		6
33 to 42		7
> 48		8
0 to 6	LOCAL	2
8 to 12		2
14 to 18		3
20 to 30		4
33 to 42		5
> 48		5

Diameter (in)	Road Class	UtilityRepair Score
0 to 6	RAILWAY	8
8 to 12		8
14 to 18		10
20 to 30		10
33 to 42		10
> 48		10
0 to 6	UNKNOWN	4
8 to 12		5
14 to 18		6
20 to 30		7
33 to 42		8
> 48		9

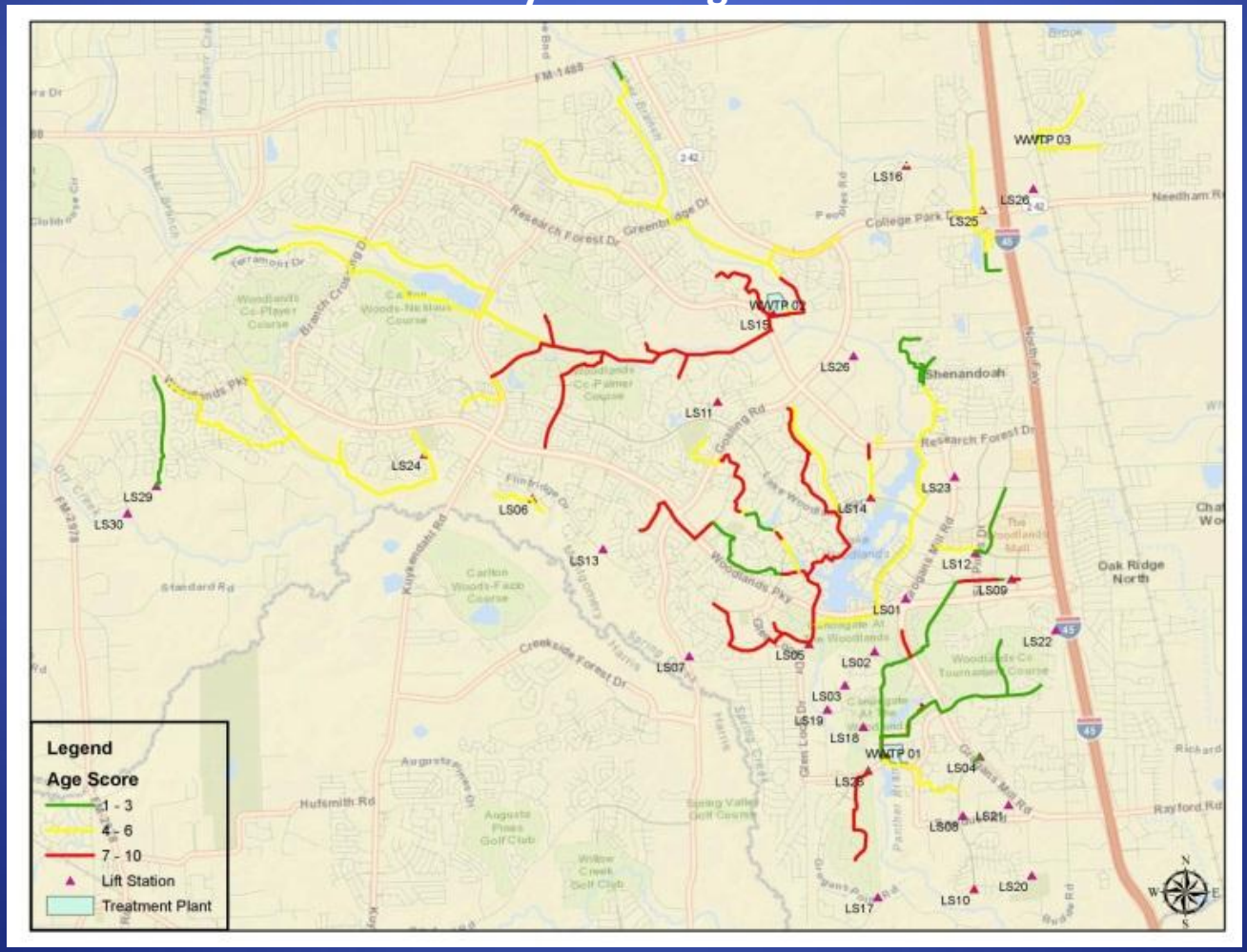
Tool Features

- Results Generation
  - Preliminary iterations of LOF, COF, and Risk scores
  - Matrices and rankings refined through sensitivity review workshops with the Client
  - Final LOF, COF, and Risk scores for each of the 4 asset groups used to rank and prioritize assets for renewal projects
- Results Outputs
  - Map Exhibits (ArcGIS)
  - Summary Reports (Matplotlib)

Tool Features

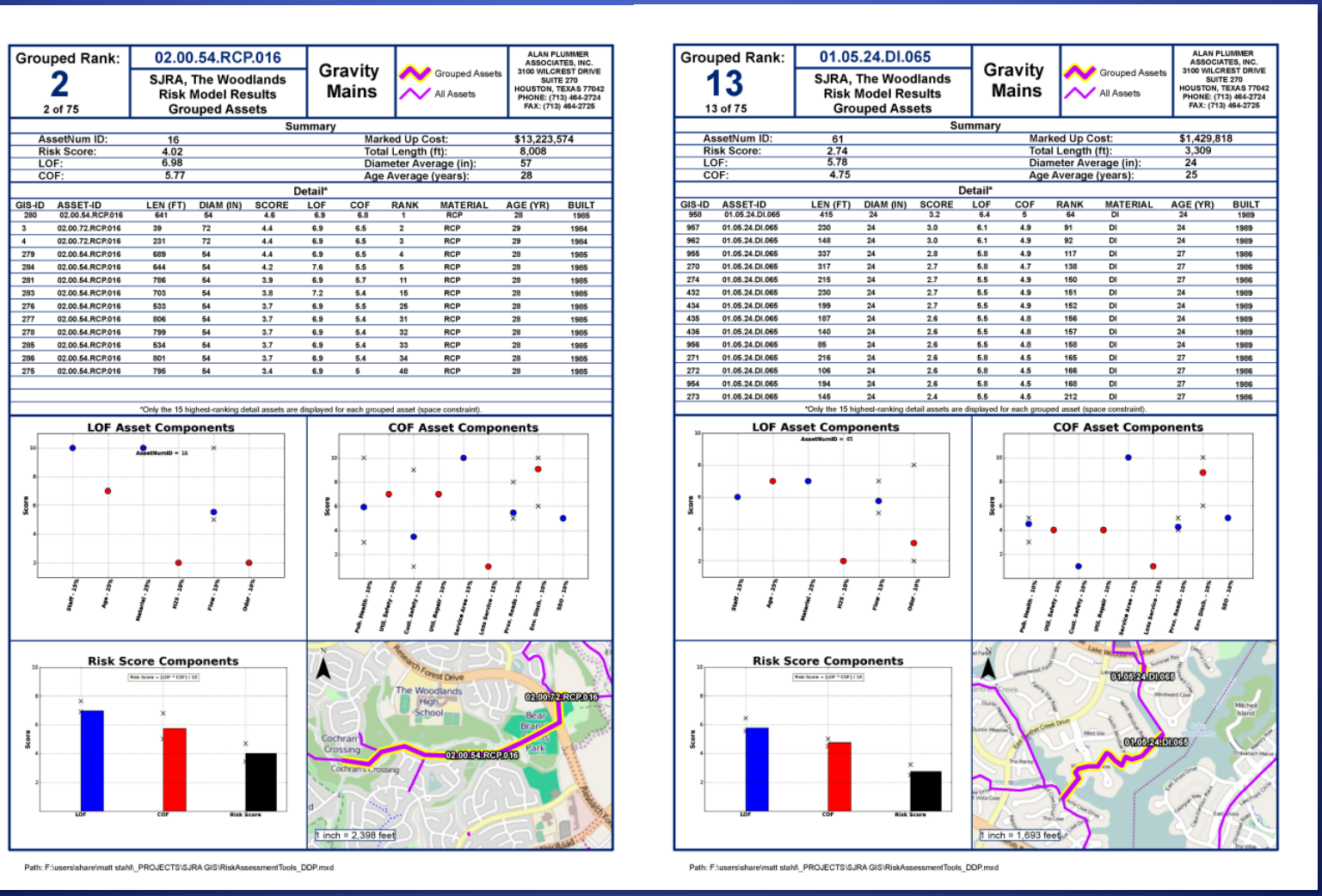
- Results Output: Map Exhibits (ArcGIS)

Gravity Mains Age Score



Tool Features

- Results Output: Reports (Matplotlib, ArcGIS DDP)



Grouped Rank: 2 (2 of 75) | 02.00.54.RCP.016 | SJRA, The Woodlands Risk Model Results Grouped Assets | Gravity Mains | Grouped Assets / All Assets | ALAN PLUMMER ASSOCIATES, INC. 3100 WILCREST DRIVE SUITE 270 HOUSTON, TEXAS 77042 PHONE: (713) 464-2724 FAX: (713) 464-2725

Summary

AssetNum ID:	16	Marked Up Cost:	$13,223,574
Risk Score:	4.02	Total Length (ft):	8,008
LOF:	6.98	Diameter Average (in):	57
COF:	5.77	Age Average (years):	28

Detail*

GIS-ID	ASSET-ID	LEN (FT)	DIAM (IN)	SCORE	LOF	COF	RANK	MATERIAL	AGE (YR)	BUILT
280	02.00.54.RCP.016	641	54	4.6	6.9	6.8	1	RCP	28	1985
3	02.00.72.RCP.016	39	72	4.4	6.9	6.5	2	RCP	29	1984
4	02.00.72.RCP.016	231	72	4.4	6.9	6.5	3	RCP	29	1984
279	02.00.54.RCP.016	689	54	4.4	6.9	6.5	4	RCP	28	1985
284	02.00.54.RCP.016	644	54	4.2	7.6	5.5	5	RCP	28	1985
281	02.00.54.RCP.016	786	54	3.9	6.9	5.7	11	RCP	28	1985
283	02.00.54.RCP.016	703	54	3.8	7.2	5.4	15	RCP	28	1985
276	02.00.54.RCP.016	533	54	3.7	6.9	5.5	25	RCP	28	1985
277	02.00.54.RCP.016	806	54	3.7	6.9	5.4	31	RCP	28	1985
278	02.00.54.RCP.016	799	54	3.7	6.9	5.4	32	RCP	28	1985
285	02.00.54.RCP.016	534	54	3.7	6.9	5.4	33	RCP	28	1985
286	02.00.54.RCP.016	801	54	3.7	6.9	5.4	34	RCP	28	1985
275	02.00.54.RCP.016	796	54	3.4	6.9	5	48	RCP	28	1985

*Only the 15 highest-ranking detail assets are displayed for each grouped asset (space constraint).

LOF Asset Components | COF Asset Components | Risk Score Components

1 inch = 2,398 feet

Path: F:\users\share\matt stahl_PROJECTS\SJRA GIS\RiskAssessmentTools_DDP.mxd

Grouped Rank: 13 (13 of 75) | 01.05.24.DI.065 | SJRA, The Woodlands Risk Model Results Grouped Assets | Gravity Mains | Grouped Assets / All Assets | ALAN PLUMMER ASSOCIATES, INC. 3100 WILCREST DRIVE SUITE 270 HOUSTON, TEXAS 77042 PHONE: (713) 464-2724 FAX: (713) 464-2725

Summary

AssetNum ID:	61	Marked Up Cost:	$1,429,818
Risk Score:	2.74	Total Length (ft):	3,309
LOF:	5.78	Diameter Average (in):	24
COF:	4.75	Age Average (years):	25

Detail*

GIS-ID	ASSET-ID	LEN (FT)	DIAM (IN)	SCORE	LOF	COF	RANK	MATERIAL	AGE (YR)	BUILT
958	01.05.24.DI.065	415	24	3.2	6.4	5	64	DI	24	1989
957	01.05.24.DI.065	230	24	3.0	6.1	4.9	91	DI	24	1989
962	01.05.24.DI.065	148	24	3.0	6.1	4.9	92	DI	24	1989
955	01.05.24.DI.065	337	24	2.8	5.8	4.9	117	DI	27	1986
270	01.05.24.DI.065	317	24	2.7	5.8	4.7	138	DI	27	1986
274	01.05.24.DI.065	215	24	2.7	5.5	4.9	150	DI	27	1986
432	01.05.24.DI.065	230	24	2.7	5.5	4.9	151	DI	24	1989
434	01.05.24.DI.065	199	24	2.7	5.5	4.9	152	DI	24	1989
435	01.05.24.DI.065	187	24	2.6	5.5	4.8	156	DI	24	1989
436	01.05.24.DI.065	140	24	2.6	5.5	4.8	157	DI	24	1989
956	01.05.24.DI.065	85	24	2.6	5.5	4.8	158	DI	24	1989
271	01.05.24.DI.065	216	24	2.6	5.8	4.5	165	DI	27	1986
272	01.05.24.DI.065	106	24	2.6	5.8	4.5	166	DI	27	1986
954	01.05.24.DI.065	194	24	2.6	5.8	4.5	168	DI	27	1986
273	01.05.24.DI.065	148	24	2.4	5.5	4.5	212	DI	27	1986

*Only the 15 highest-ranking detail assets are displayed for each grouped asset (space constraint).

LOF Asset Components | COF Asset Components | Risk Score Components

1 inch = 1,693 feet

Path: F:\users\share\matt stahl_PROJECTS\SJRA GIS\RiskAssessmentTools_DDP.mxd

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Technical and Python Highlights

- Field Mapping

Define Variables

```python
#Import modules
import arcpy

#Define variables, these are for data mapping inputs
FC = arcpy.GetParameterAsText(0) #feature class - Lift station ASSETS
P1_fld = arcpy.GetParameterAsText(1) #parameter source field
P2_fld = "StaffOp"
P3_fld = arcpy.GetParameterAsText(2) #parameter source field
P4_fld = "RepairsRWO"
```

Add Fields

```python
##A. DATA Fields Generate and Populate - For ASSET Scoring
#Add LOF fields to attribute table (for parameter data and score calculation)
if 'StaffOp' not in [f.name for f in arcpy.ListFields(FC)]:
    arcpy.AddField_management(FC, 'StaffOp', 'DOUBLE') #create parameter field
if 'StaffOpScore' not in [f.name for f in arcpy.ListFields(FC)]:
    arcpy.AddField_management(FC, 'StaffOpScore', 'DOUBLE') #create score fie
```

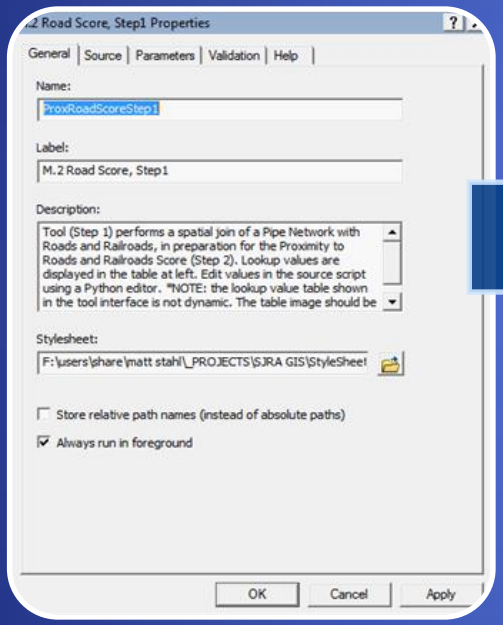
Data Cursor

```python
#Update fields with existing data, where 1st field (new) set equal to 2nd field (existing
#Parameter 1
cur = arcpy.UpdateCursor(FC)
for row in cur:
    row.setValue(P2_fld, row.getValue(P1_fld))
    cur.updateRow(row)
del row, cur
```

Technical and Python Highlights

- Tool Customization

Description



Stylesheet (XML)

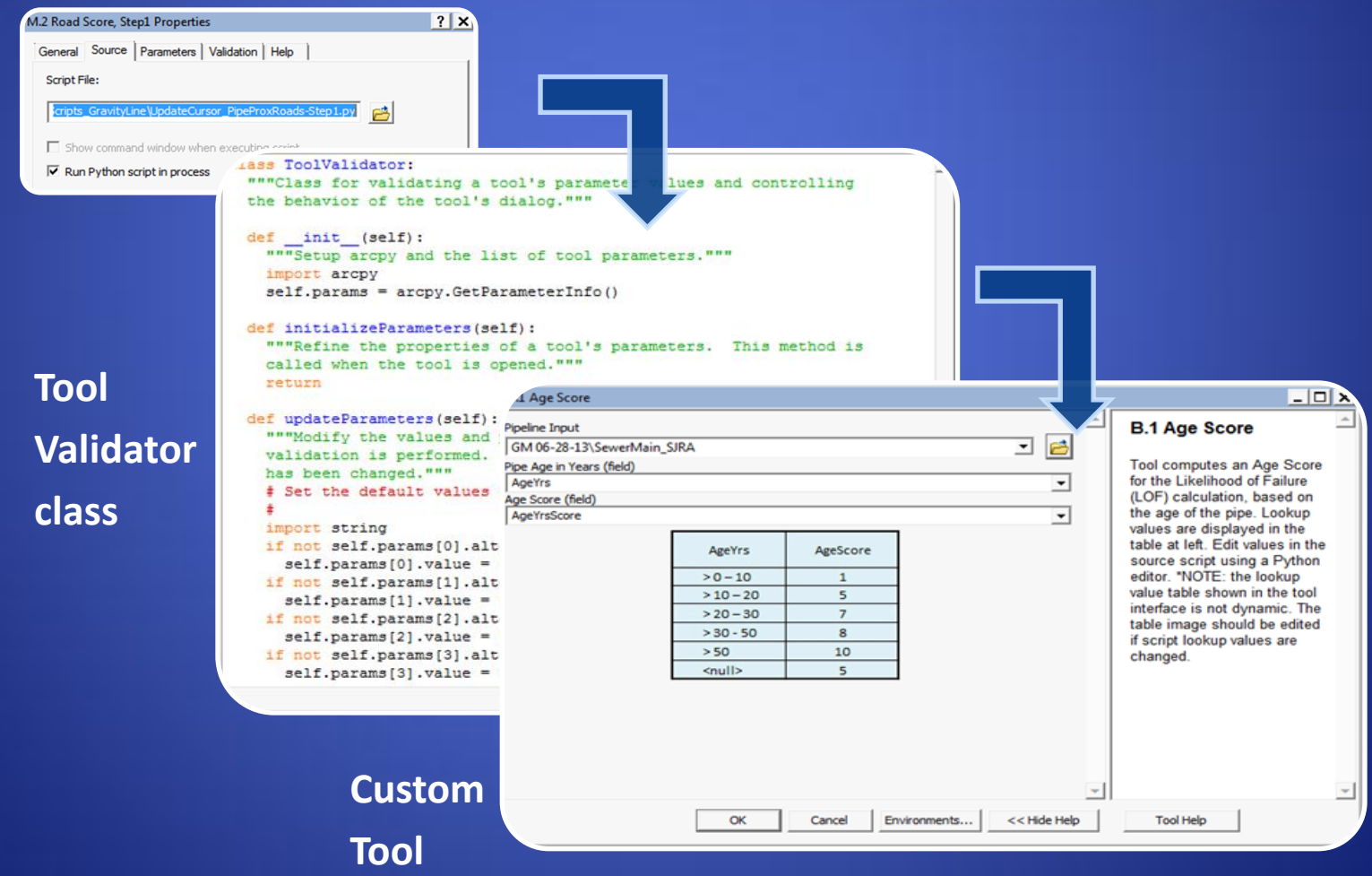
```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
                version="1.0">

<xsl:output method="html"/>

<!-- ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ -->
<!--                    Variable Definitions                    -->
<!-- ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ -->

<xsl:variable name="BackgroundColor">buttonface</xsl:variable>
<xsl:variable name="BackgroundImage">url(F:\users\share\matt stahl\_PROJECTS\SJRA GIS\Sty
<xsl:variable name="BackgroundPosition">center bottom</xsl:variable>
<xsl:variable name="BackgroundRepeat">no-repeat</xsl:variable>

<xsl:variable name="ButtonHeight">20px</xsl:variable>
```

Custom Graphics

AgeYrs	AgeScore
> 0 – 10	1
> 10 – 20	5
> 20 – 30	7
> 30 - 50	8
> 50	10
<null>	5

Technical and Python Highlights

- Tool Customization (continued)



Technical and Python Highlights

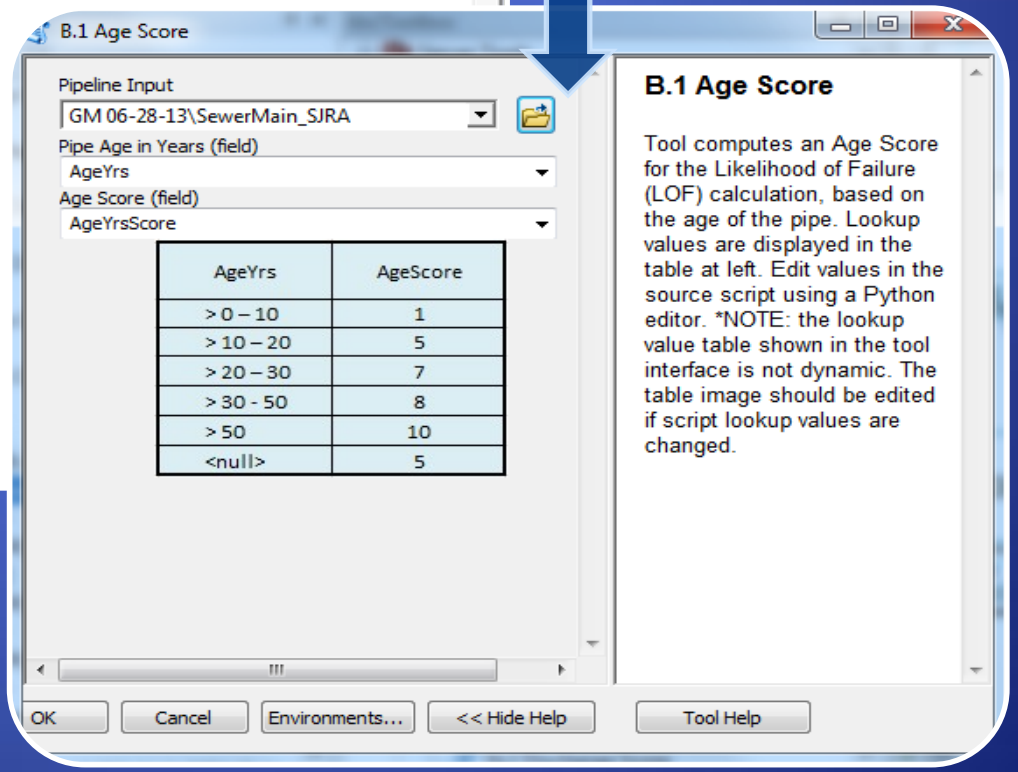
- Arcpy Cursors – Ex 1: Data Processing (Pipe Age)

Variables

Cursor scores data

```python
#Import modules
import arcpy

#Variables
FC = arcpy.GetParameterAsText(0) #feature class
P_fld = arcpy.GetParameterAsText(1) #parameter field to score
S_fld = arcpy.GetParameterAsText(2) #score output field

#Update cursor for parameter
cur = arcpy.UpdateCursor(FC)

#Lookup value loop
for row in cur:
    if 0 <= row.getValue(P_fld) <= 10:
        val = 1
    elif 10 < row.getValue(P_fld) <= 20:
        val = 5
    elif 20 < row.getValue(P_fld) <= 30:
        val = 7
    elif 30 < row.getValue(P_fld) <= 50:
        val = 8
    elif row.getValue(P_fld) > 50:
        val = 10
    elif row.getValue(P_fld) == 'Unknown':
        val = 5
#Default value
    else:
        val = 5
    row.setValue(S_fld, val)
    cur.updateRow(row)

#Delete cursors to avoid schema locks
del row, cur
```

Pipe Age tool



Technical and Python Highlights

- Arcpy Cursors – Ex 2: Geoprocessing (Road Prox)

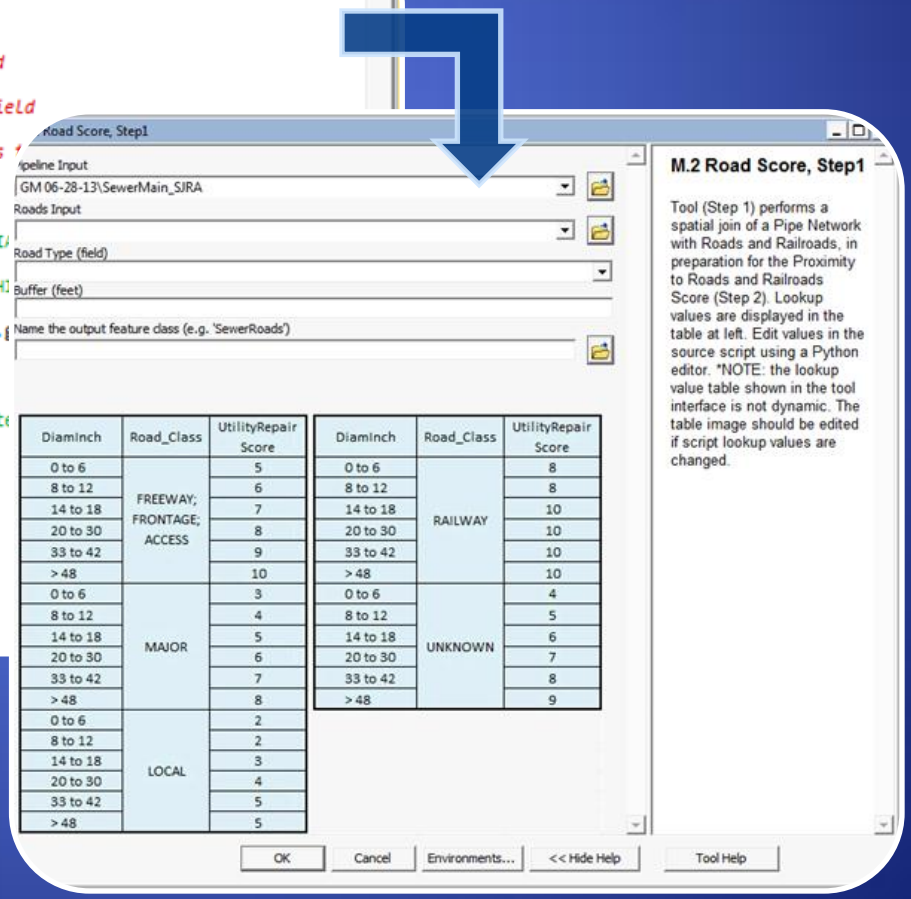
Variables

Layer creation

Spatial selection by roads

Cursor assigns values

```
#Import modules
import arcpy

#Variables
FC = arcpy.GetParameterAsText(0) #FC
S_fld = arcpy.GetParameterAsText(1) #score output field
SPATIALSELECT = arcpy.GetParameterAsText(2) #Poly
P_fld = arcpy.GetParameterAsText(3) #parameter input field
Buffer = arcpy.GetParameterAsText(4) #"100 feet"
## NOTE: WITHIN_A_DISTANCE used instead of INTERSECT as

##Select Category 1 = FREEWAY
#Make a layer, then select pipes in FREEWAY
arcpy.MakeFeatureLayer_management(SPATIALSELECT, 'SPATI
arcpy.MakeFeatureLayer_management(FC, 'FC_lyr1')
arcpy.SelectLayerByLocation_management('FC_lyr1', 'WITH
#Update cursor for parameter
matchcount1 = int(arcpy.GetCount_management('FC_lyr1').
cur = arcpy.UpdateCursor('FC_lyr1')
for row in cur:
    if matchcount1 == 0:
        print('no features matched spatial and attribut
    else:
        val = 'FREEWAY'
    row.setValue(S_fld, val)
    cur.updateRow(row)
try: del row
except NameError: pass
del cur

##Select Category 2 = FRONTAGE
#Make a layer, then select pipes in FRONTAGE
```



DiamInch	Road_Class	UtilityRepair Score
0 to 6	FREEWAY; FRONTAGE; ACCESS	5
8 to 12		6
14 to 18		7
20 to 30		8
33 to 42		9
>48		10
0 to 6	MAJOR	3
8 to 12		4
14 to 18		5
20 to 30		6
33 to 42		7
>48		8
0 to 6	LOCAL	2
8 to 12		2
14 to 18		3
20 to 30		4
33 to 42		5
>48		5

DiamInch	Road_Class	UtilityRepair Score
0 to 6	RAILWAY	8
8 to 12		8
14 to 18		10
20 to 30		10
33 to 42		10
>48		10
0 to 6	UNKNOWN	4
8 to 12		5
14 to 18		6
20 to 30		7
33 to 42		8
>48		9

Pipe Proximity to Roads tool

Technical and Python Highlights

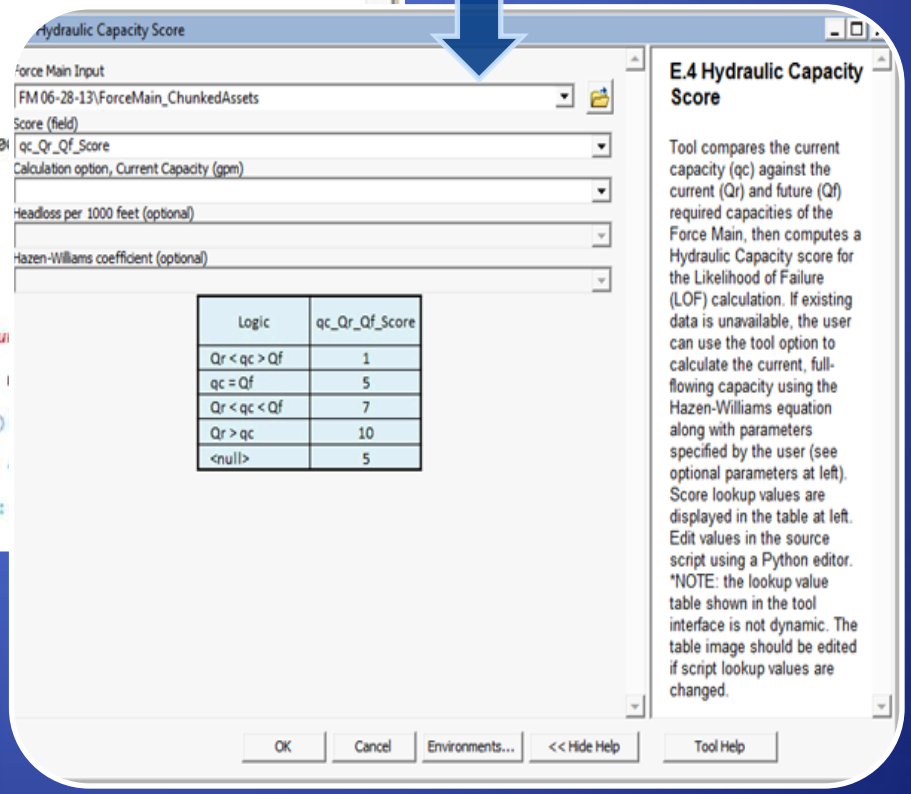
- Arcpy Cursors – Ex 3: Calculations (Hydr Capacity)

Variables

Calcs

Cursor assigns values

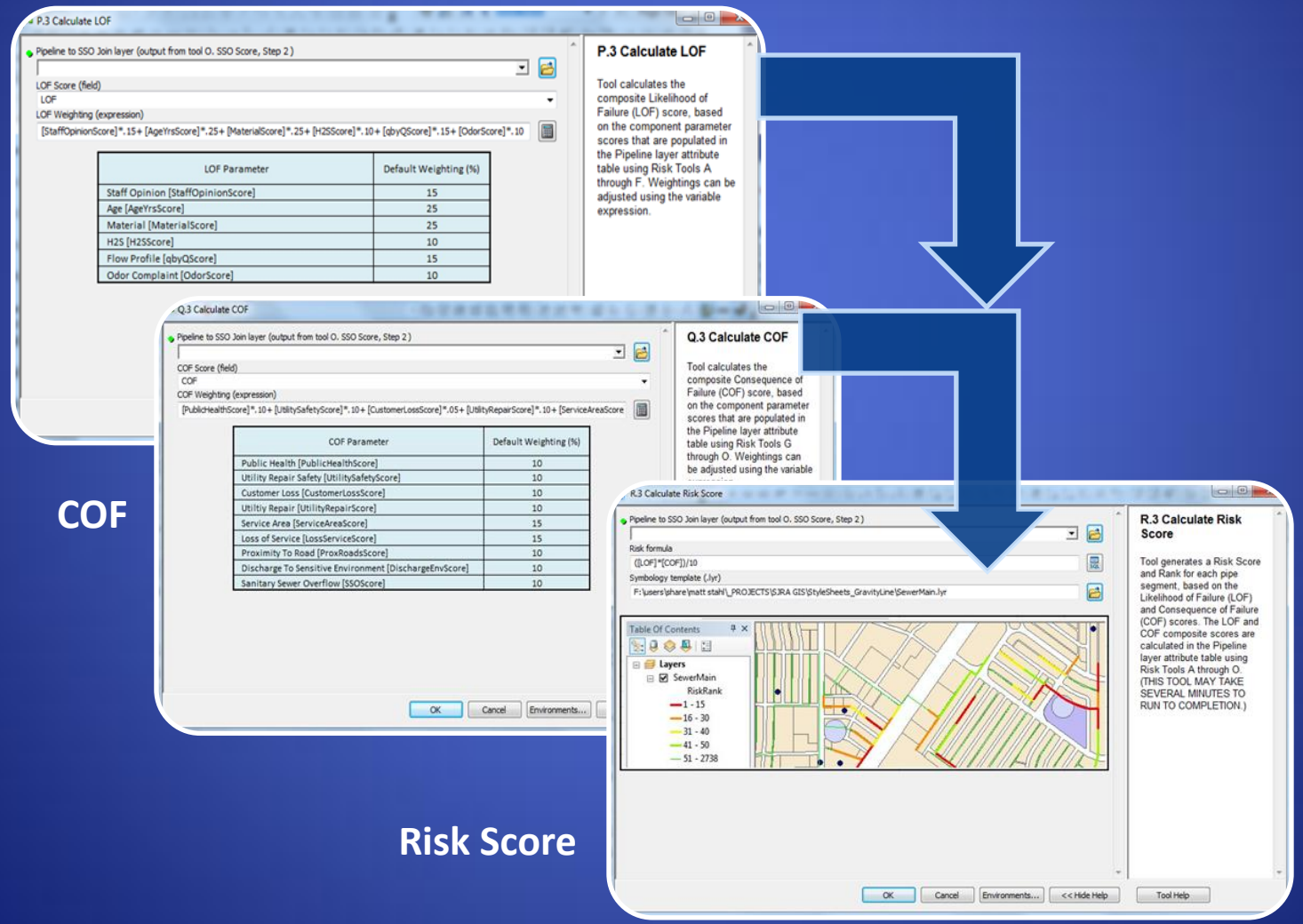
```
#Variables
FC = arcpy.GetParameterAsText(0) #feature class
S_fld = arcpy.GetParameterAsText(1) #scoring field
option = arcpy.GetParameterAsText(2) #option string, for dropdown menu calculation choic
HL1000 = arcpy.GetParameterAsText(3) #HL per 1000 ft
HW = arcpy.GetParameterAsText(4) #Hazen Williams coefficient

#Update cursor: Hazen-Williams capacity (in gpm)
if option == "Hazen-Williams":
    cur = arcpy.UpdateCursor(FC)
    for row in cur:
        Chw = float(HW)
        D = row.getValue('DiamInch')
        HL = float(HL1000)
        capacity = 1.318*Chw*(((D/12)/4)**0.63)*((HL/10
        row.setValue('qcGPM', int(capacity))
        cur.updateRow(row)
    #Delete cursors to avoid schema locks
    del row, cur

#Update cursor for scoring
cur = arcpy.UpdateCursor(FC)

#Lookup value loop, for qc(=current capacity) vs Qr(=cu
for row in cur:
    if row.getValue('QrGPM') < row.getValue('qcGPM') >
        val = 1
    elif row.getValue('qcGPM') == row.getValue('QfGPM')
        val = 5
    elif row.getValue('QrGPM') < row.getValue('qcGPM')
        val = 7
    elif row.getValue('qcGPM') < row.getValue('QrGPM'):
        val = 10
```



Hydraulic Capacity tool

Technical and Python Highlights

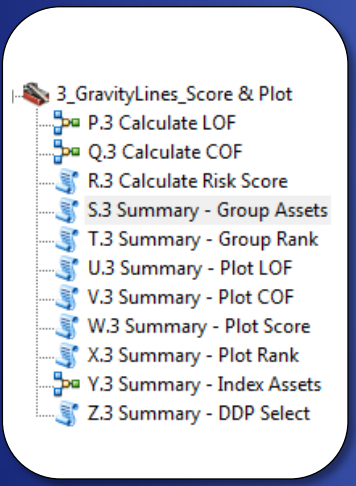
- Risk Calculation



Technical and Python Highlights

- Summary Reports (Matplotlib, ArcGIS DDP)

Report/Plot Tools

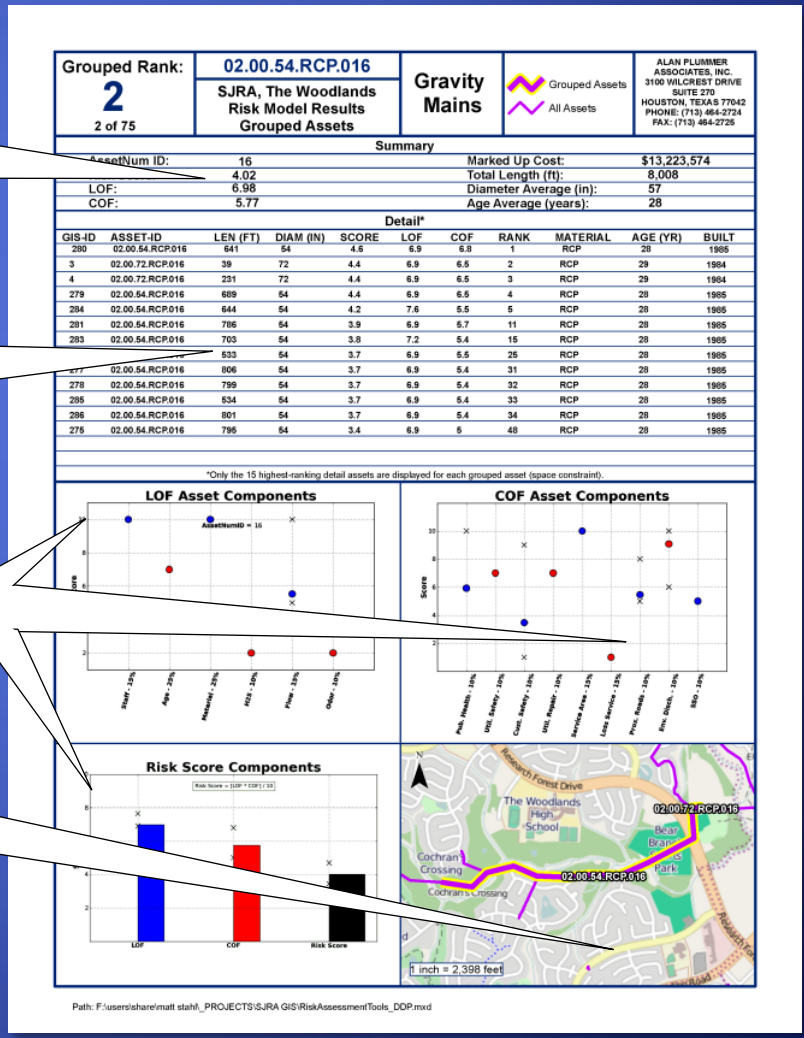


Summary Statistics (ArcGIS table)

Individual Values (ArcGIS table)

Summary Plots (Matplotlib jpegs via Raster Catalog)

Locator Map (ArcGIS DDP)

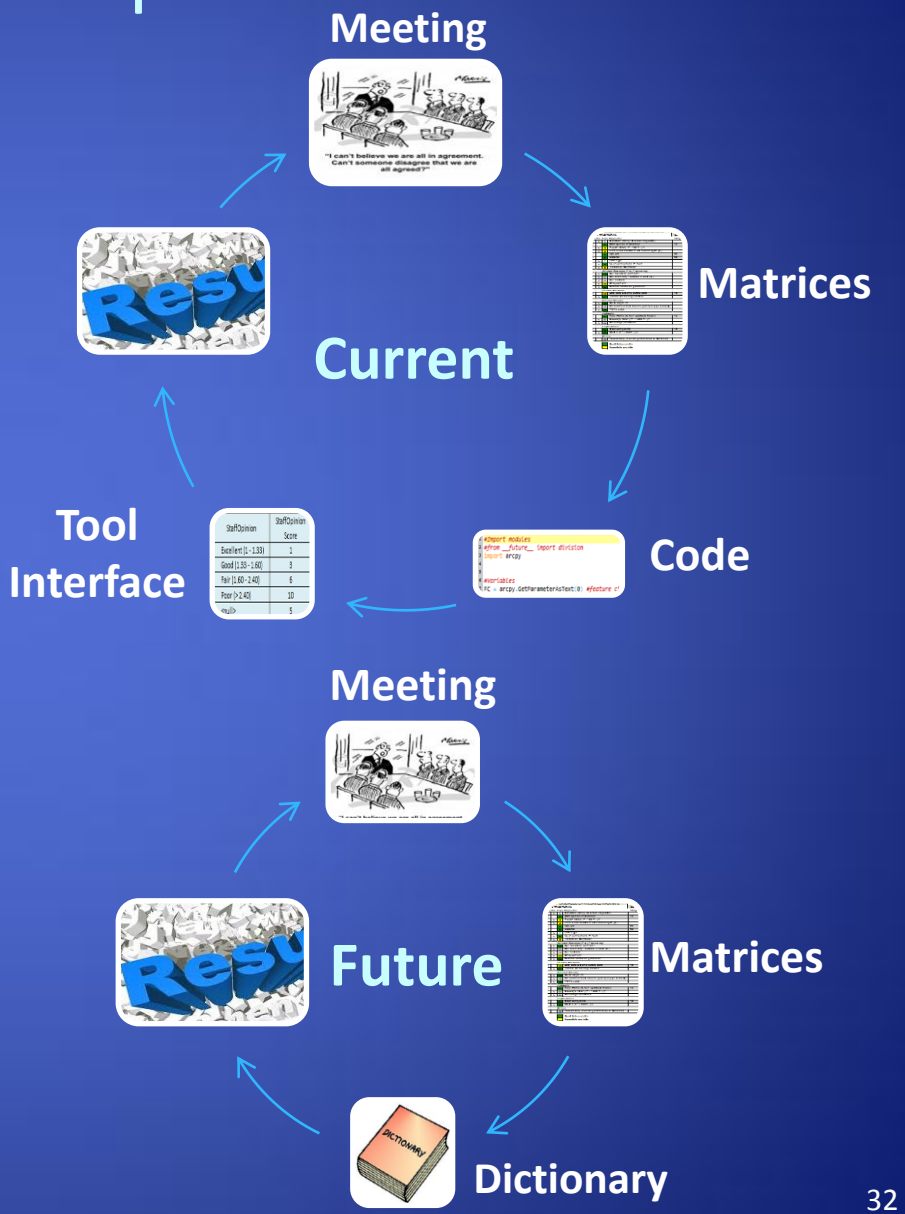


Agenda

- Project Description
- Challenges and Requirements
- Tool Features
- Technical and Python Highlights
- Future Development

Future Development

- Scoring Matrix Interface/Editing
  - Weights currently edited within Model-Builder tool dialog
  - Python dictionaries as lookup tables to improve ease of matrix editing & transfer to new projects



Questions?

- Useful References
  - ESRI.com
  - Python.org
  - Matplotlib.org
  - Stackoverflow.com
- Contact Information

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