Fort Worth's Storm Drain Rehabilitation Program: Exploring Artificial Intelligence For Cost-Effective Operations and Planning

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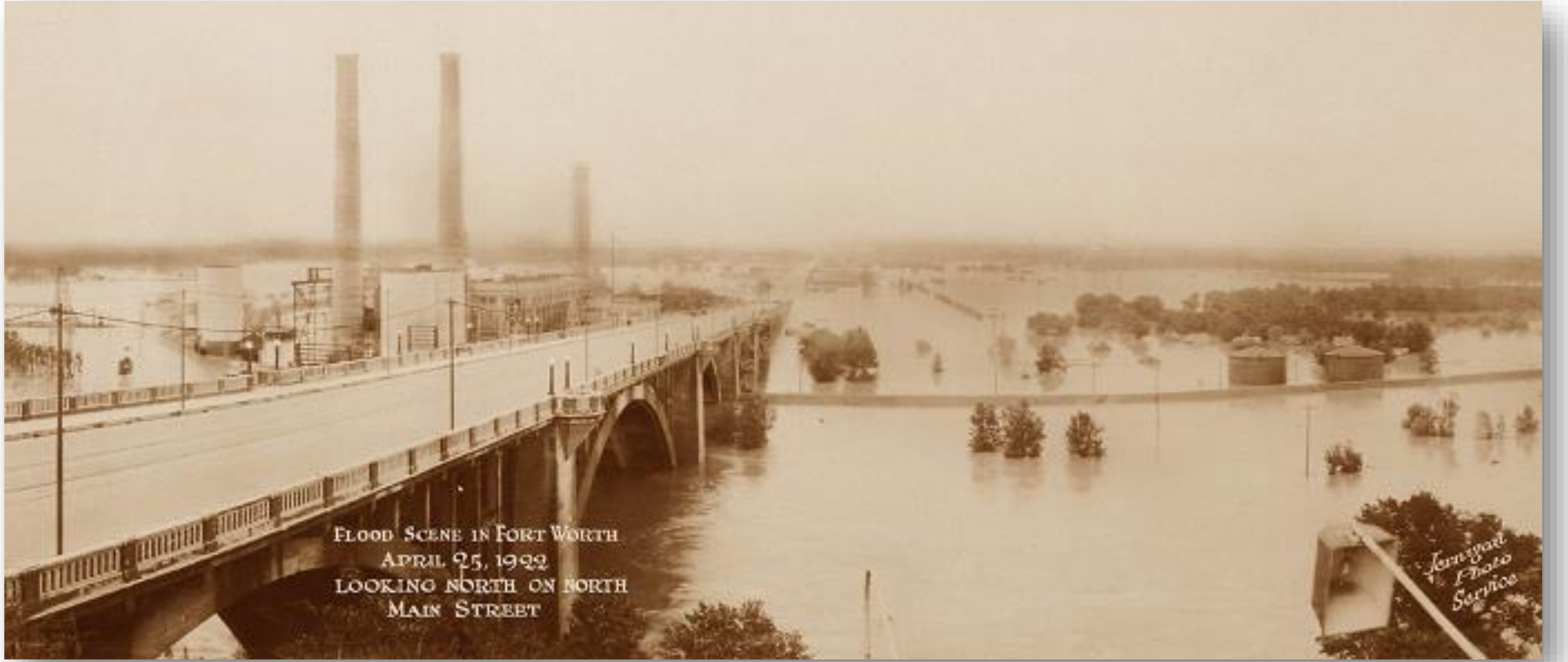
Program Drivers and Achievements

Background – Storm Drain Rehabilitation Program

1922

- One century ago, so-called “Big Flood” led to creation of TRWD



Background – Storm Drain Rehabilitation Program

1949

- Flood led to loss of life, thousands homeless, and property destruction – prompted creation of levees

Background – Storm Drain Rehabilitation Program

<u>2004</u>

- Five fatalities due to flooded roadways and significant flooding to 300 homes and businesses
- 2006 - Utility created to provide dedicated funding to address stormwater needs

Family swept off FW road

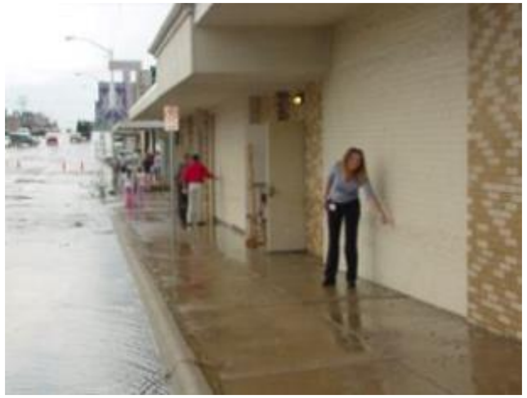
High waters swept Rosa Guerrero and her sons off a Fort Worth road Friday.

Neighbors surveyed the wreckage Saturday of a car driven by Rosa Guerrero, who drowned in this rain-swollen creek late Friday night. Ms. Guerrero's son Felipe Abrego also died in the accident in southeast Fort Worth. Her infant son Jacob Abrego was missing.

April 2004:
3 fatalities
E. Butler St. & McClure St.

June 2004:
E. Butler St. & McClure St. Flooding

June 2004:
Westcliff



June 2004:
Berry Street Urban Village

Background – Storm Drain Rehabilitation Program

Storm Drainage Level of Service and SDRP Drivers

<u>**Early 2000's**</u>

- Effective management of storm drain infrastructure + operations

<u>**2006**</u>

- Storm Water Utility established

<u>**2012 to 2016**</u>

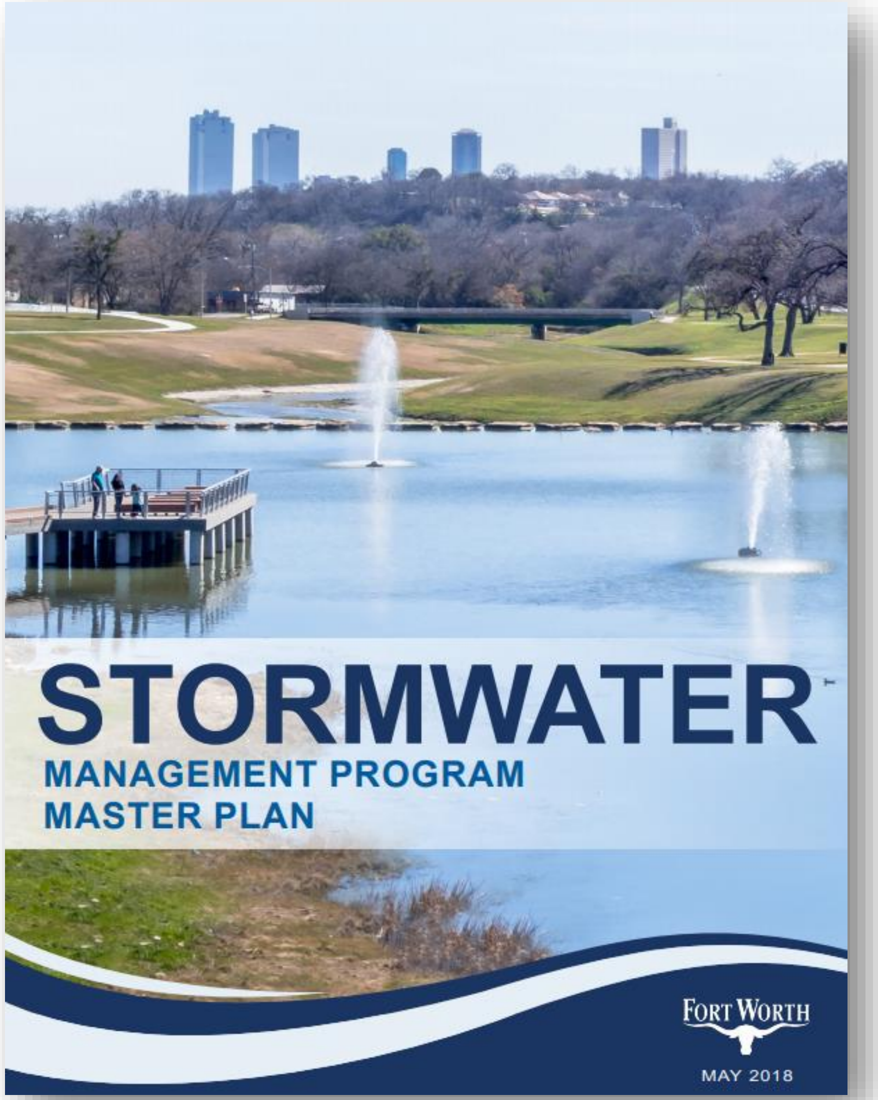
- GIS data referencing of storm drain system

<u>**2018**</u>

- Master Plan - expand use of data to inform programming decisions

<u>**2019 to 2020**</u>

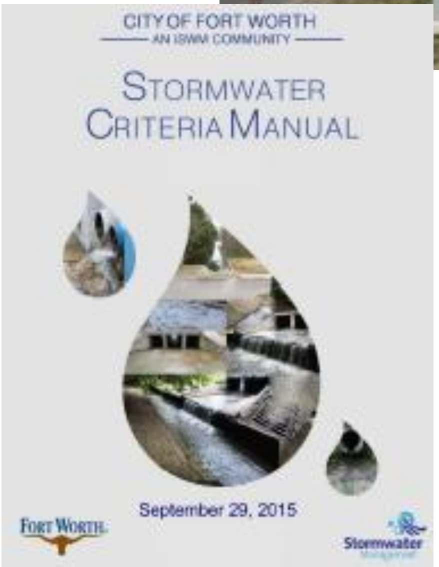
- Storm Drain Rehabilitation program developed and implemented



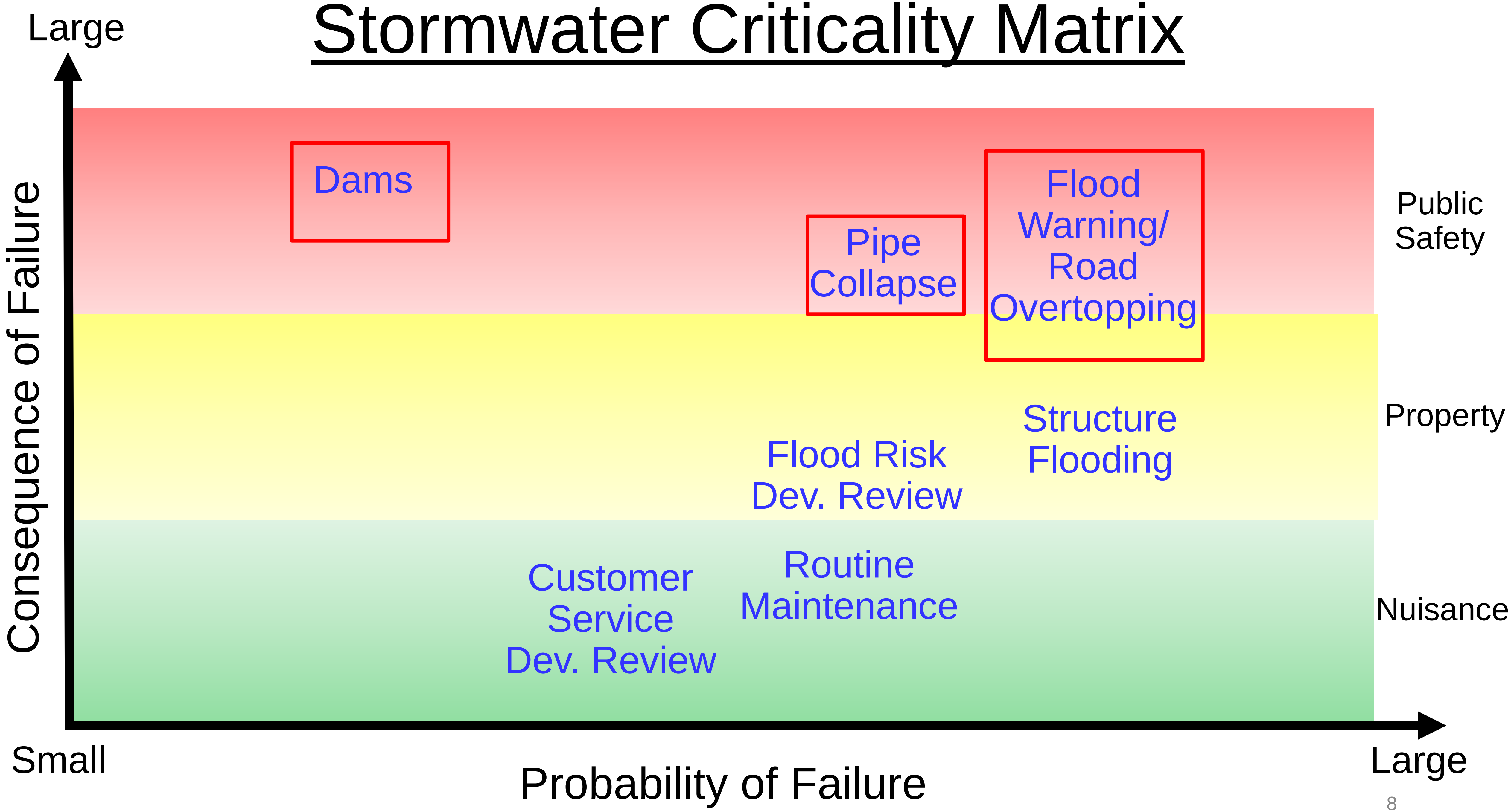
Background – Storm Drain Rehabilitation Program

Primary Functions of Stormwater Management Program

- Maintain Infrastructure (pipes, channels, etc.)
- Mitigate Hazards (flooding and erosion)
- Warn about Hazards (flooding and erosion)
- Review Development (compliance with City standards)

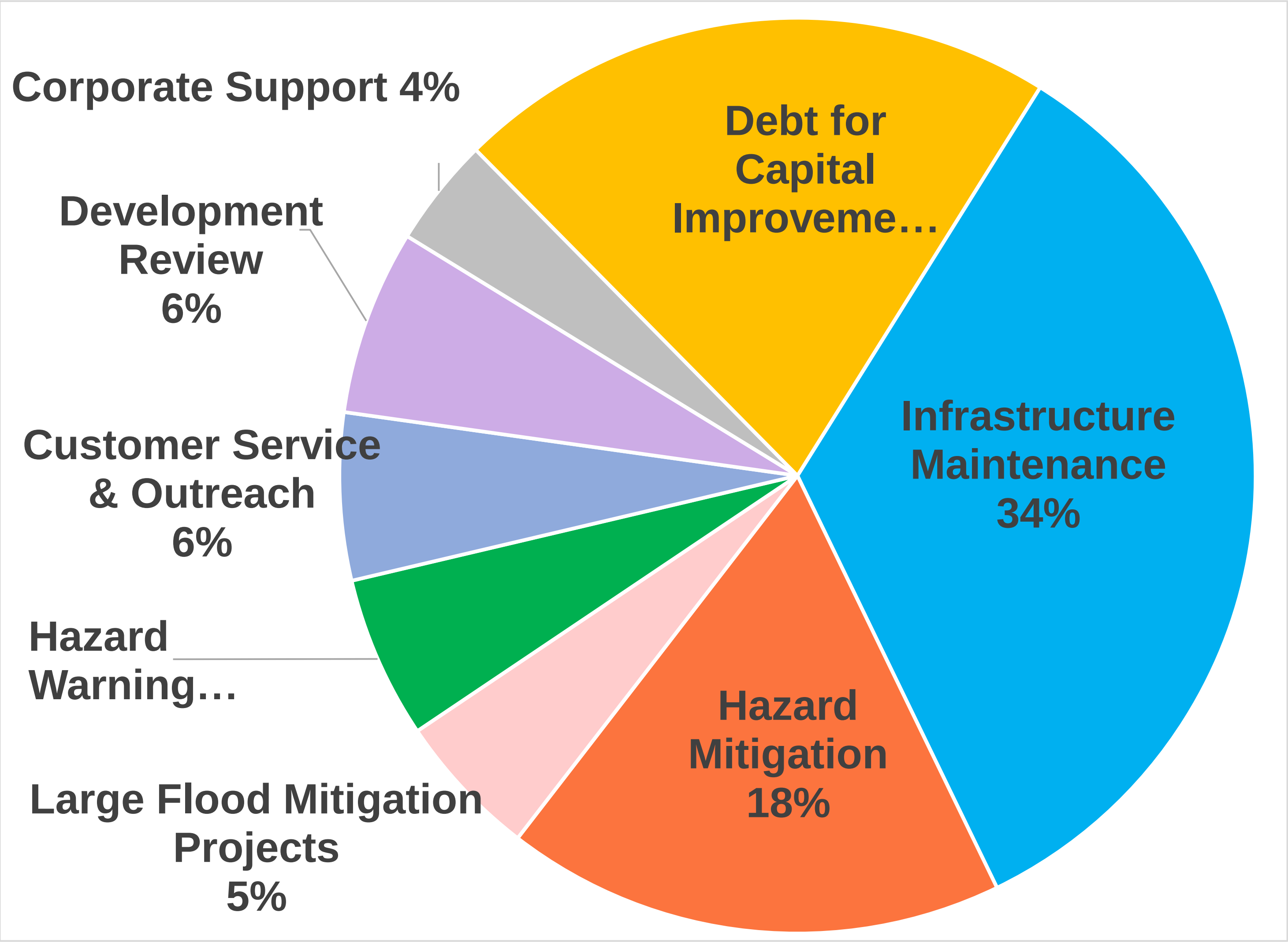


Stormwater Criticality Matrix



FY24 Adopted Budget

$58 million



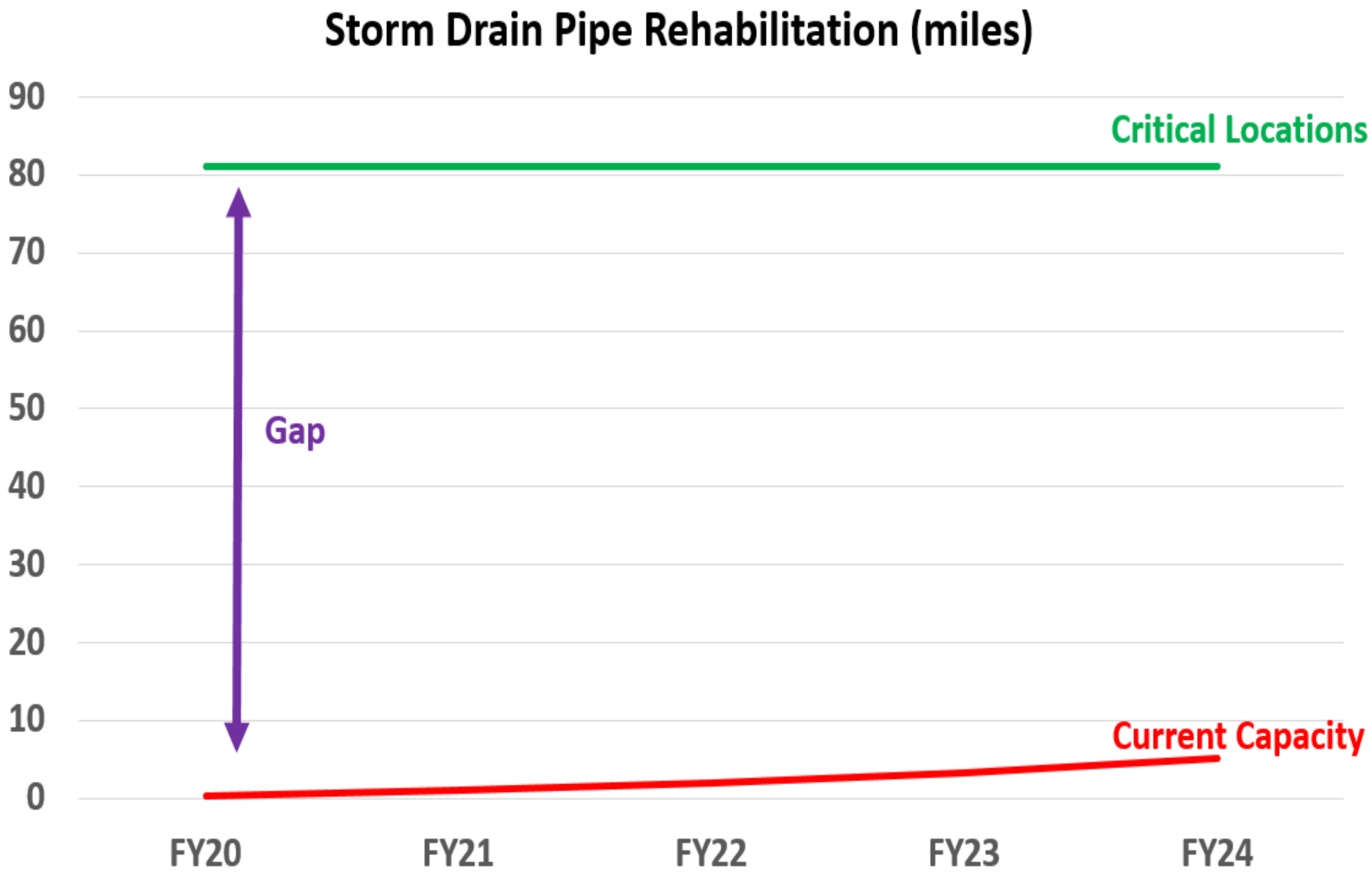
- **Reactive**
- **Proactive**
- **Decreased Cost for Proactive Programs**
  - **matt**

Note: Infrastructure Maintenance includes Storm Drain Rehab

Original Analysis of Storm Drain Rehabilitation Needs

- Current Capacity
  - 1 – 2 miles per year rehab'd
  - $2 million + per mile
  - 15 mi/year CCTV

- Unfunded backlog
  - 30 miles of pipe over 70 yr. old
    - FY 19 projected 30+ "cave in" repairs
  - $4-$6M/yr for 20-30 yr "catchup"



High-Priority Storm Drains

Challenge

Identify High-Priority Storm Drains

- Need an effective method to identify high-priority storm drains!
- Proactive inspection & rehabilitation
- Better utilize and learn from field-verified data

Challenge

Identify High-Priority Storm Drains

- Rule-based risk prioritization estimated Likelihood of Failure of storm drains
- Consequence of Failure as well
- BRE criteria – LOF and COF

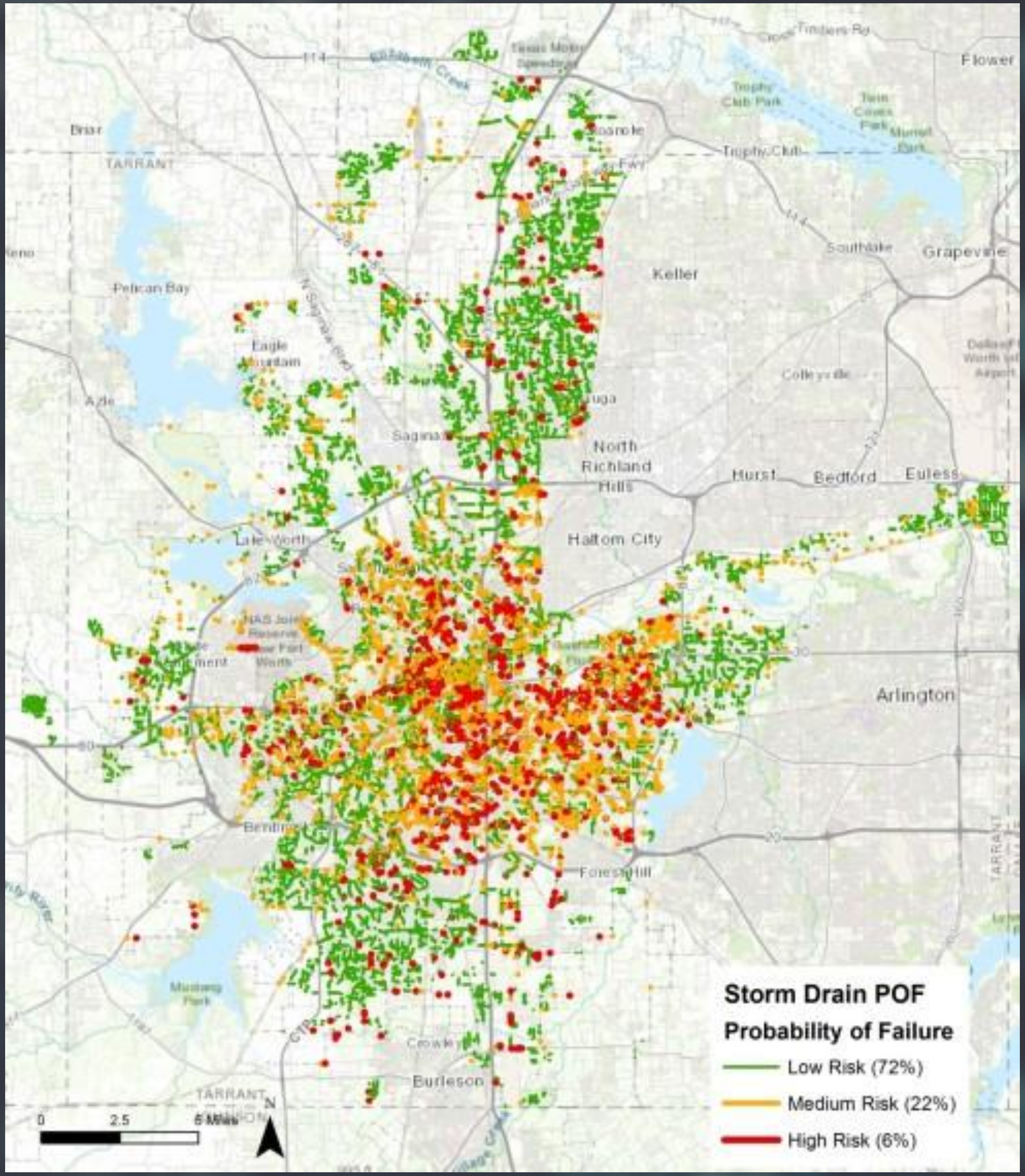
Likelihood of Failure	Weight (%)
Percent Consumed	30%
Capacity	10%
Operating Environment	20%
Material	20%
Soils	20%
TOTAL	100%

Consequence of Failure	Weight (%)
Size	40%
Buildings	15%
Roads	15%
Critical Service	15%
Sag Inlets	15%
TOTAL	100%

Challenge

Identify High-Priority Storm Drains

- Business Risk Exposure (BRE) approach
- Collected 80+ miles of CCTV Improved Level of Service (2019 to 2022)
- BRE predicted 1 out of 2 (~50%) high-priority storm drains
- Disadvantage – does not apply CCTV findings
- More decision-making insight possible!

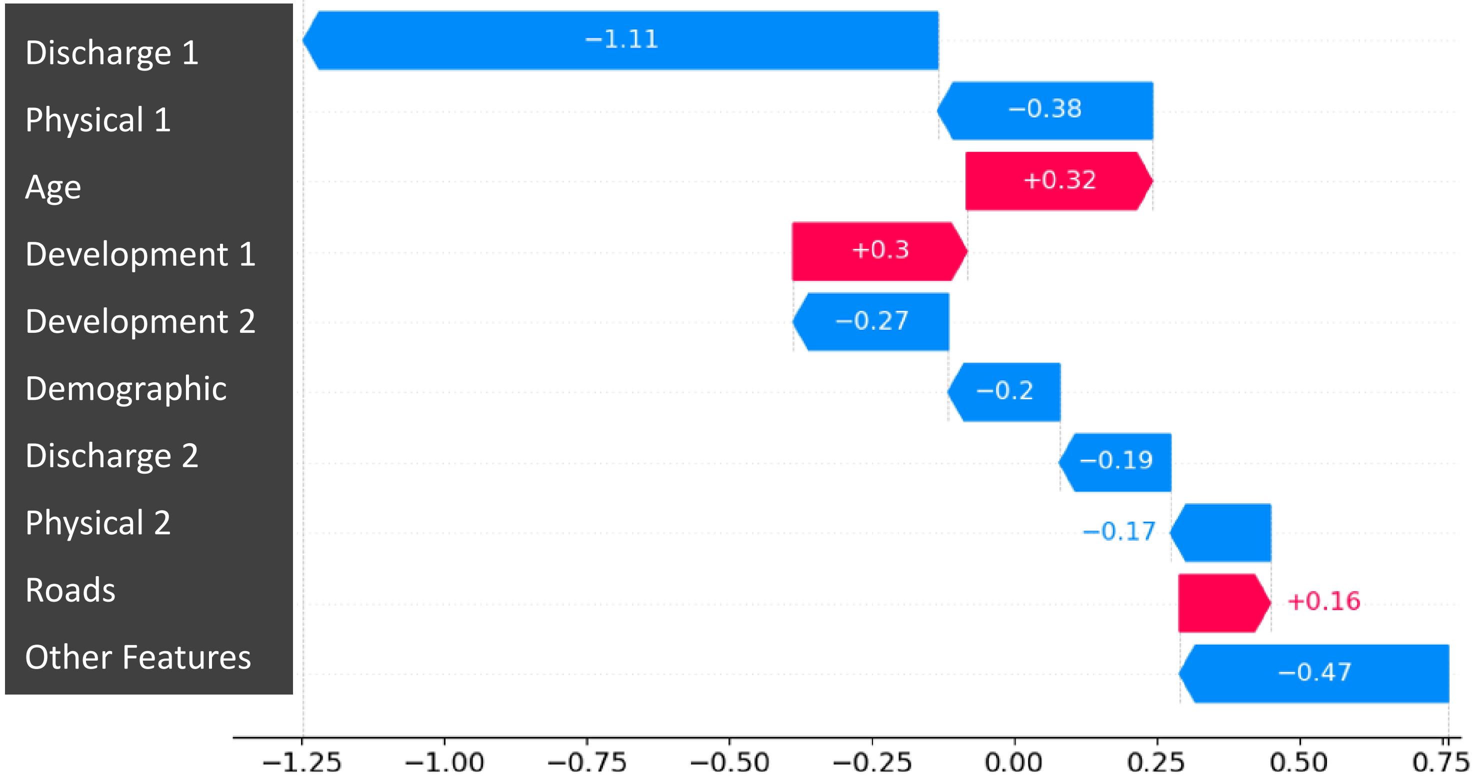


Approach

Machine Learning Model

- Basic ML model (supervised binary classification)
- Learns probability of poor condition
- Attributes associated with poor condition in storm drains given more weight
- Predicts for un-inspected assets
- Most severe problems located faster

Tree-based model: SHAP Plot sample



Approach

Overview of Modeling Process

Approach

Exploratory Data Analysis

- Initial investigations
- Data distributions
- Missing and assumed data
- Data trends
- Feature correlations

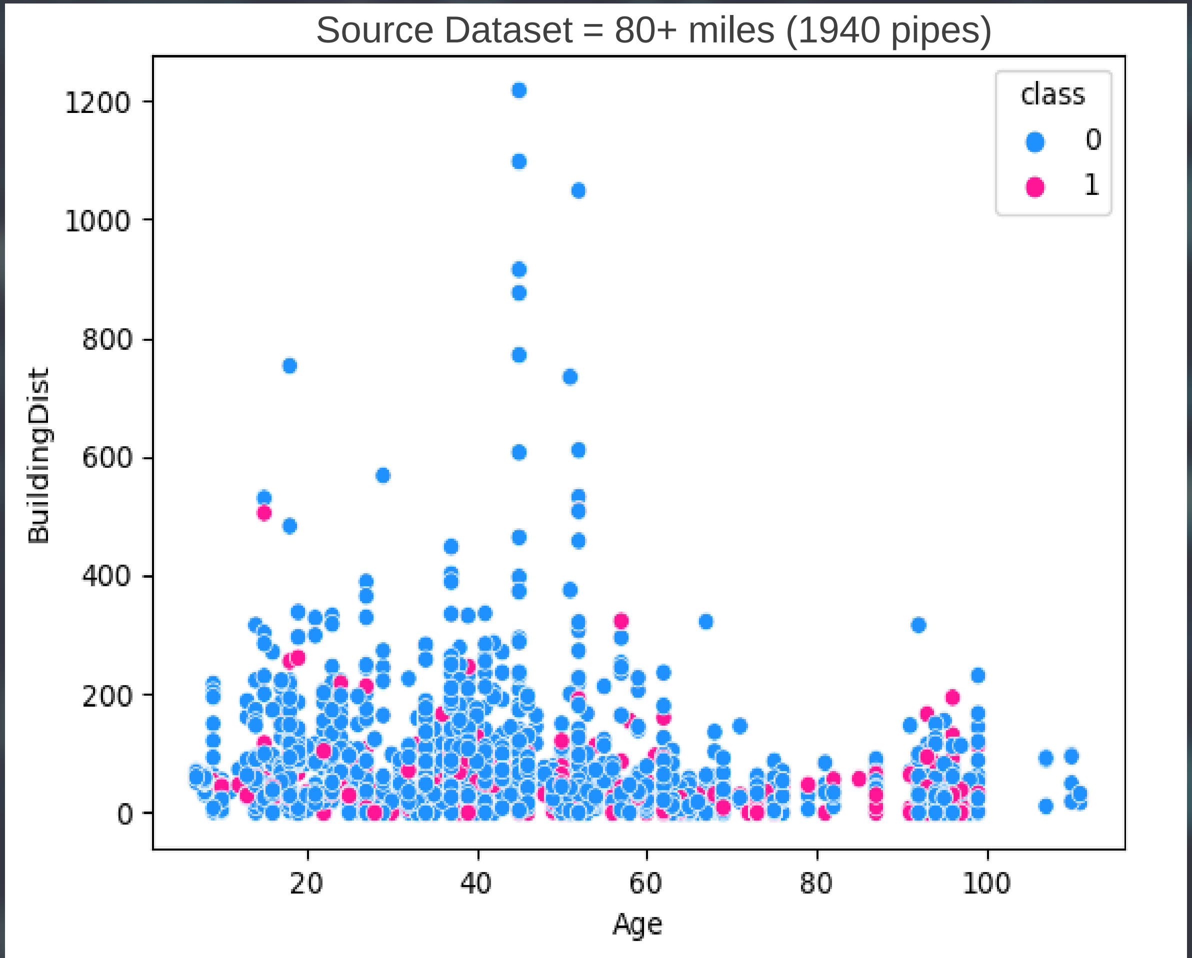
Feature Engineering

Machine Learning Model Attribute	Type
Pipe physical characteristics	Independent
Demographics	Independent
Spatial	Independent
Pipe condition	Dependent

Approach

Model Assumptions

- Source dataset = 80+ inspected miles (1940 pipes) – see figure
  - Utility intrusions removed
- Class imbalance = 1 to 6
  - 1: PACP Grade = 5
  - 6: PACP Grade <= 4
- Training dataset (balanced) = 30 miles (680 pipes)
- Train/Test split = 80/20
  - Train set (balanced) = 24 miles (543 pipes)
  - Test set (balanced) = 6 miles (137 pipes)
    - 10-fold cross-validation
- Recall "True Positive Rate"



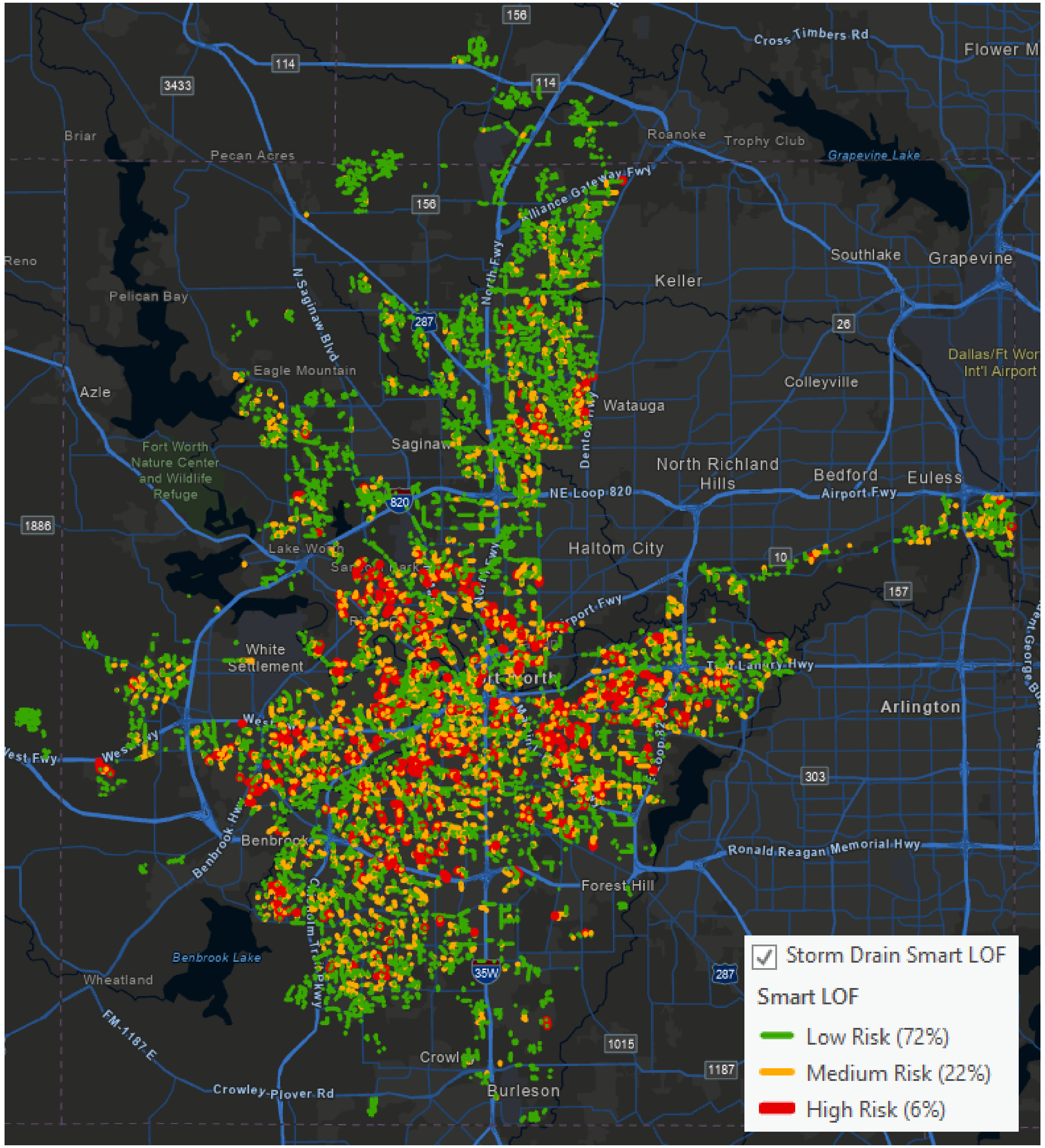
Solution

ML Identification of High-Priority Storm Drains

- Identifies 4 out of 5 known storm drains in poor condition i.e. PACP=5
- Recall median value = 80%
- Cross validation
  - Recall min = 76%
  - Recall max = 85%
- Trained model predicts for unseen pipes
- Model results will improve over time

Cross Validation

Recall	CV
85%	11
82%	20
81%	101
81%	105
80%	95
80%	43
79%	5
79%	71
78%	120
76%	89



Takeaways

- ML Smart LOF model +30% improvement over BRE approach
- TPW adopted AI-based mapshed prioritization in FY23
- Multiple severe defects identified
- Savings of 15-25% estimated for proactive, planned repairs
- Examples below = value-added

Examples - AI-prioritized defects/mapsheds

Semi-Automated CCTV Defect QC

Challenge

QA/QC of Storm Drain CCTV

Longitudinal cracking

Deformation

Utility intrusion

Collapsed wall

Challenge

QA/QC of Storm Drain Defects

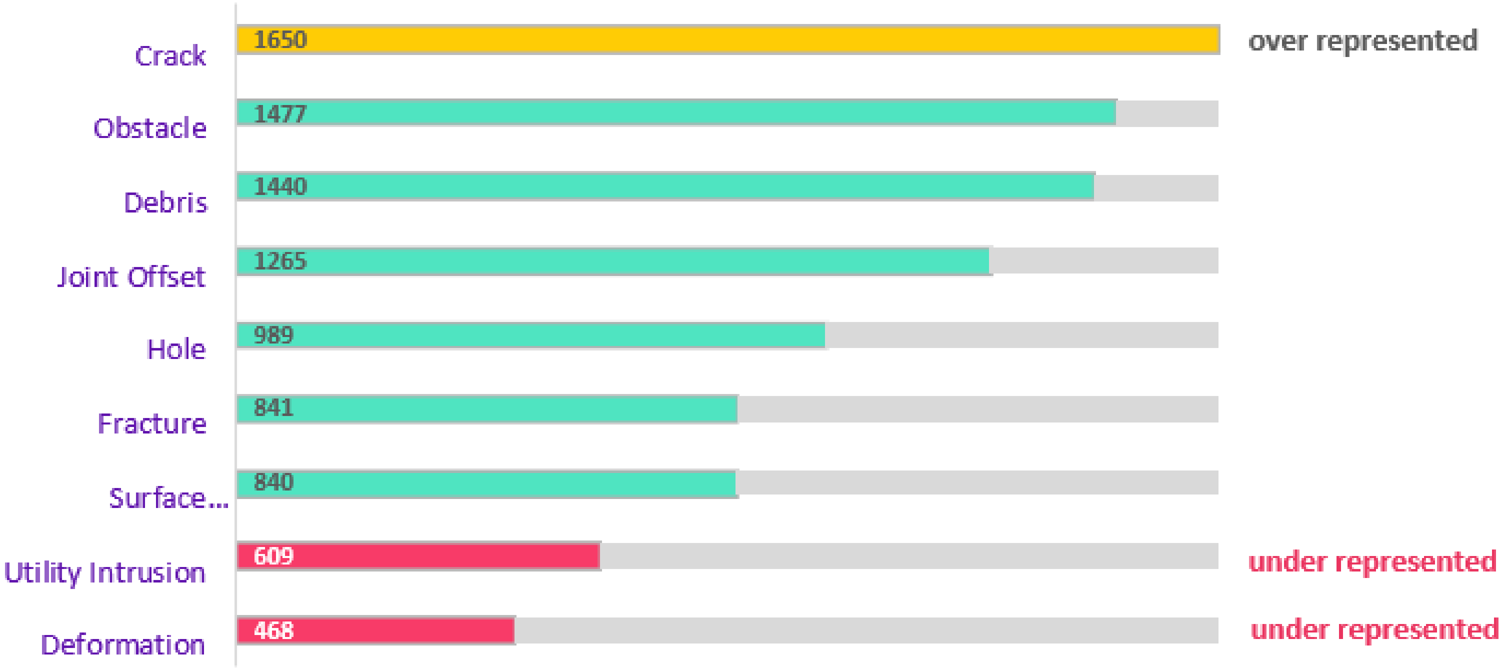
- April 2020, Linwood area pipe with significant defects overlooked during CCTV
- Flagged during 15-20% QC
- Risk of partial QC
- How to supplement partial CCTV review/QC?

Approach

Semi-automated CCTV Defect QC

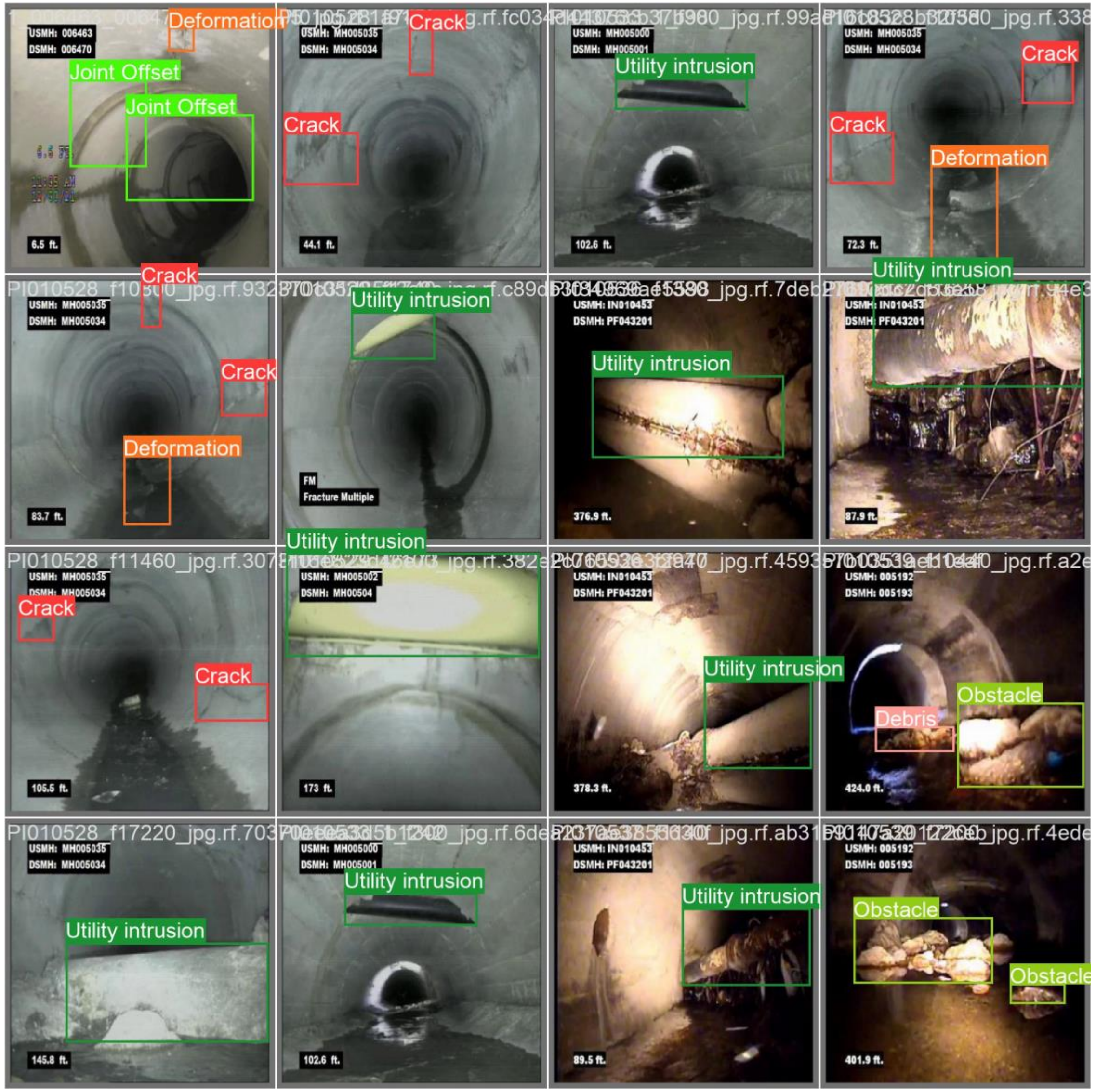
- Computer vision, object detection technology for QC
- Deep learning model trained & evaluated
- 9500 training objects
- 9 broad defect classes

Class Balance*

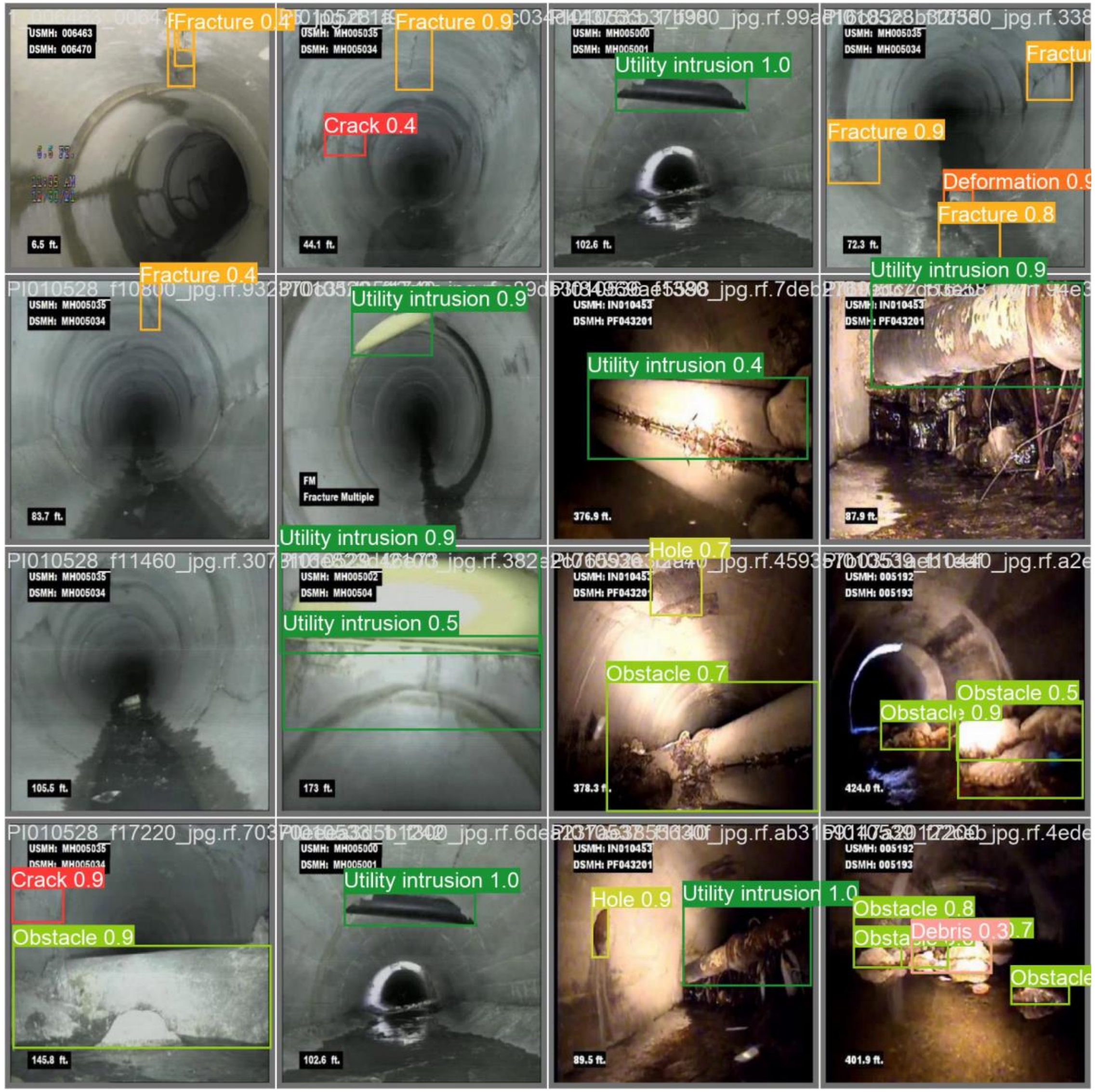


* 9,579 training objects identified from ~1,500 storm drain inspections

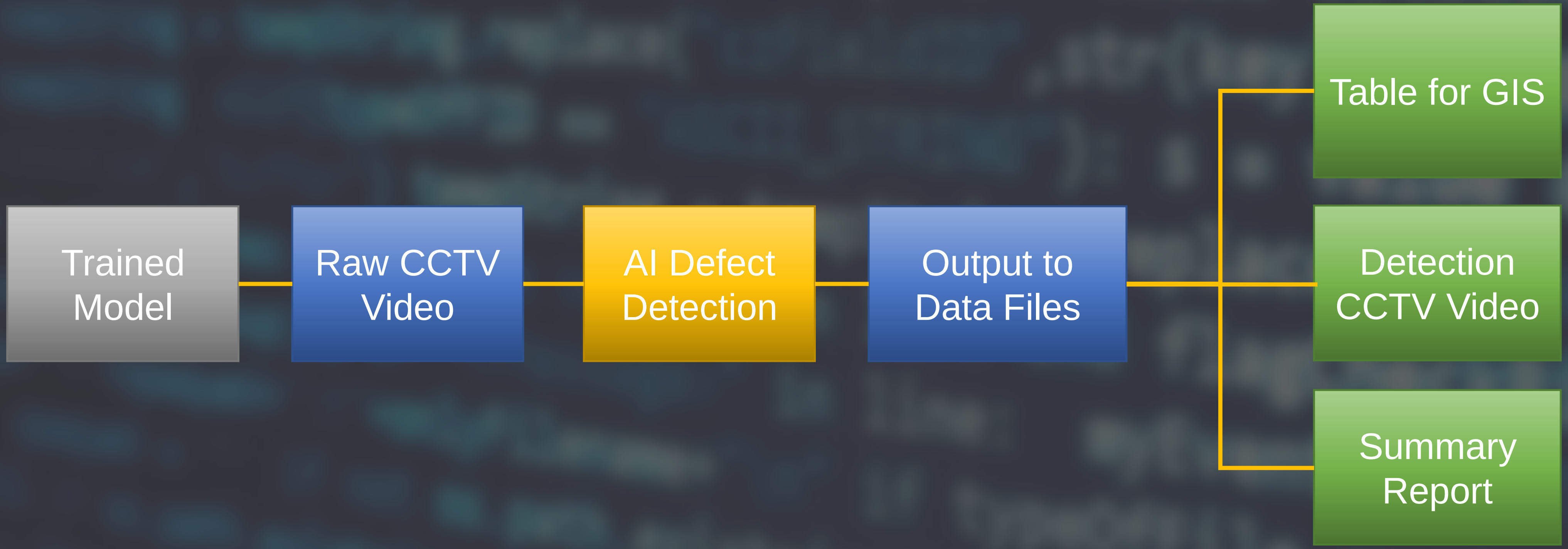
Labeling/Training



Defect Detection



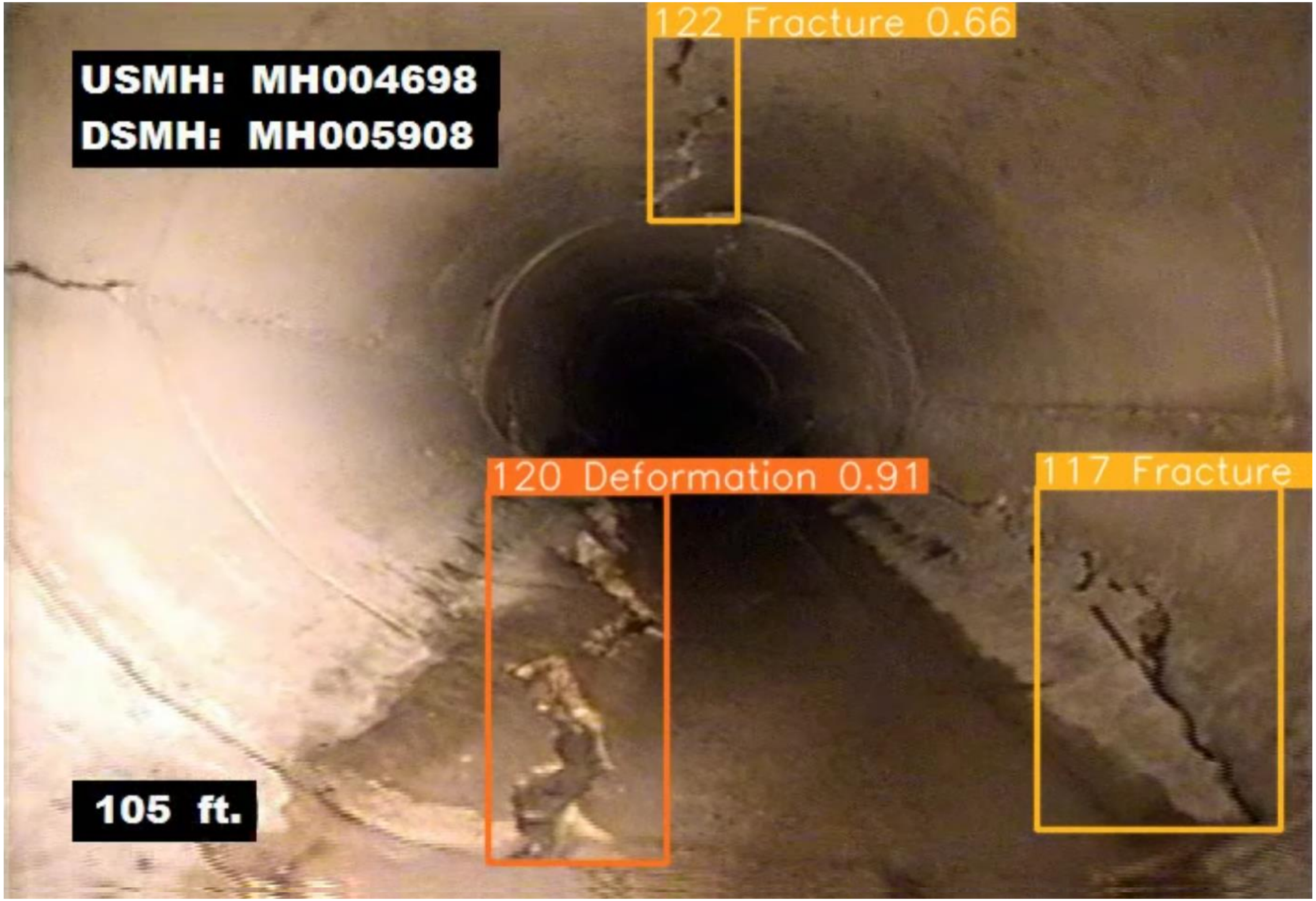
Model Application and Deliverables



Solution

100% Baseline QA/QC of Storm Drain Inspections

- Comparison, Linwood pipe that was missed
- Tabular and PDF report outputs also generated
- Cost comparison under evaluation in FY23



Solution

Video clip

Where Can We Improve?

- Active flow – sometimes mistaken for utility intrusion

- Joints – sometimes detected as offsets

- Laterals/taps – occasionally classified as holes

- Text overlay impacts tabular results
- Class balance is important!

Takeaways

- Computer vision for 100% baseline pipe review
- Technical expert in the loop is essential!
- Manual review is still performed and is necessary
- Focuses effort on review of high-priority defects

Examples - AI-flagged defects that would have been missed

Conclusion

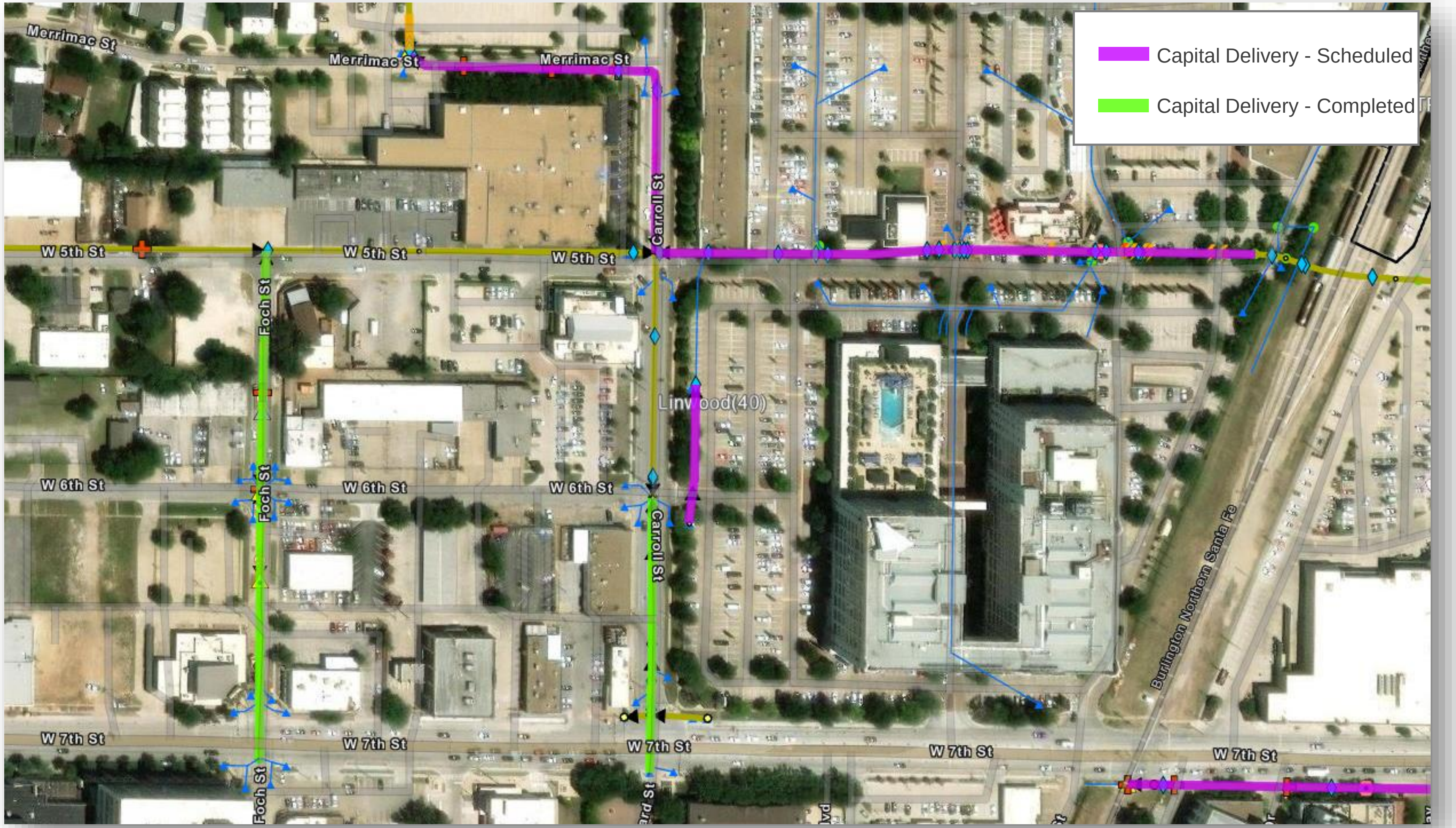
Background – Storm Drain Rehabilitation Program

SDRP Achievements 2020 to early 2024

- 145+ miles CCTV
- In-house CCTV
- 73 miles evaluated for corrective actions
- 47 sinkhole concerns evaluated
- TPW collaborative efforts
- State and national-level recognition (ACEC 2022)

ACEC ENGINEERING Excellence AWARDS

Linwood area rehabilitation projects



Final Takeaways

Q & A

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