

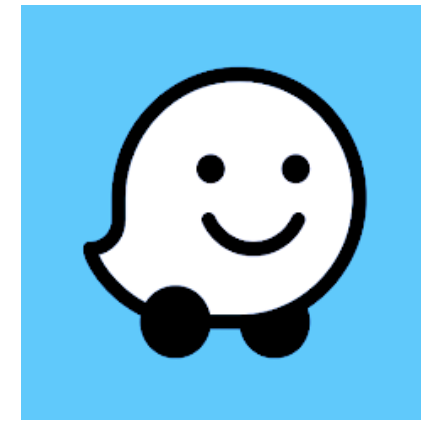


# Manage Water and Sewer Infrastructure Proactively Using AI: Case Studies

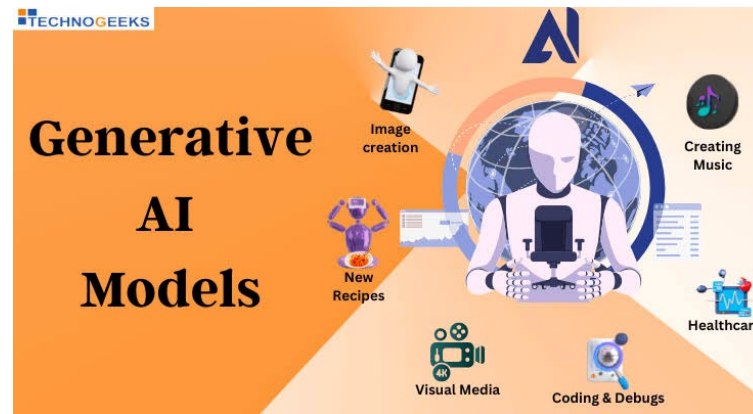
NWWC 2023

November 13, 2023

# ARTIFICIAL INTELLIGENCE IS EVERYWHERE



**WAZE**



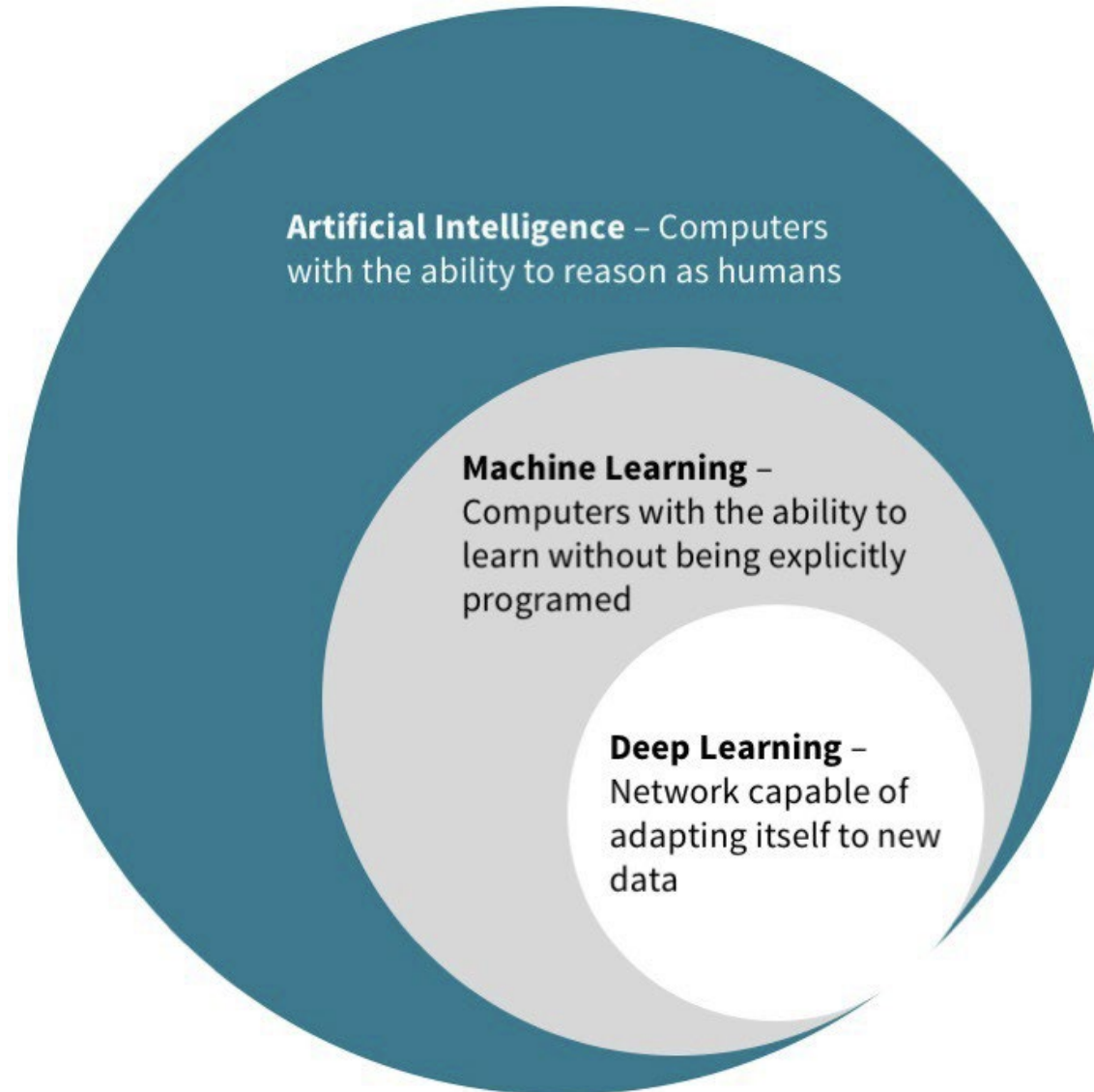
Reduce risks, improve results

# “Artificial Intelligence” (AI) is not New

- Coined at Dartmouth College in 1956
- Machines acting rationally (like most people)
- Machine Learning (ML), subset of AI, models/algorithms for improving outcomes

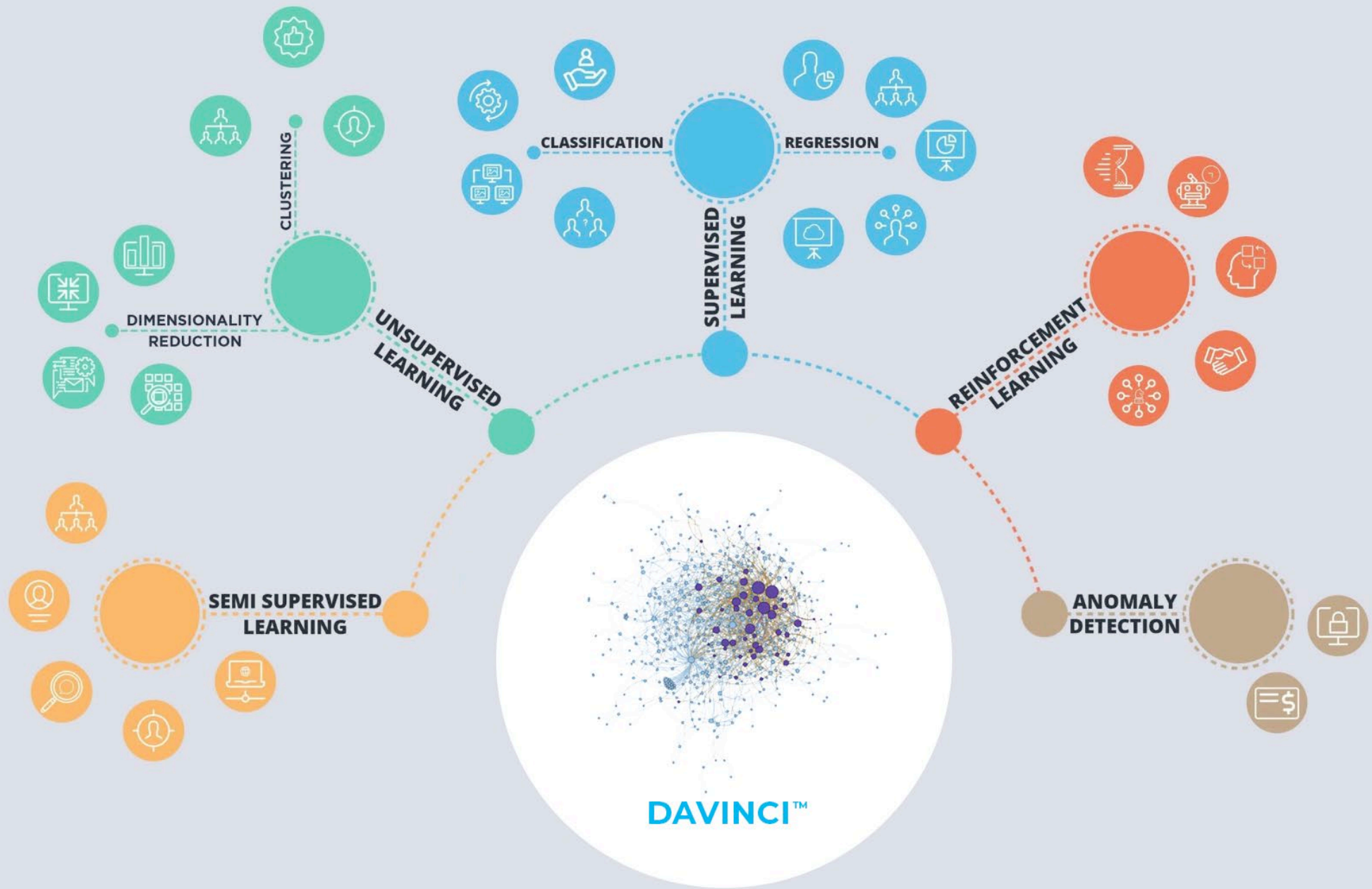


# What is Machine Learning?



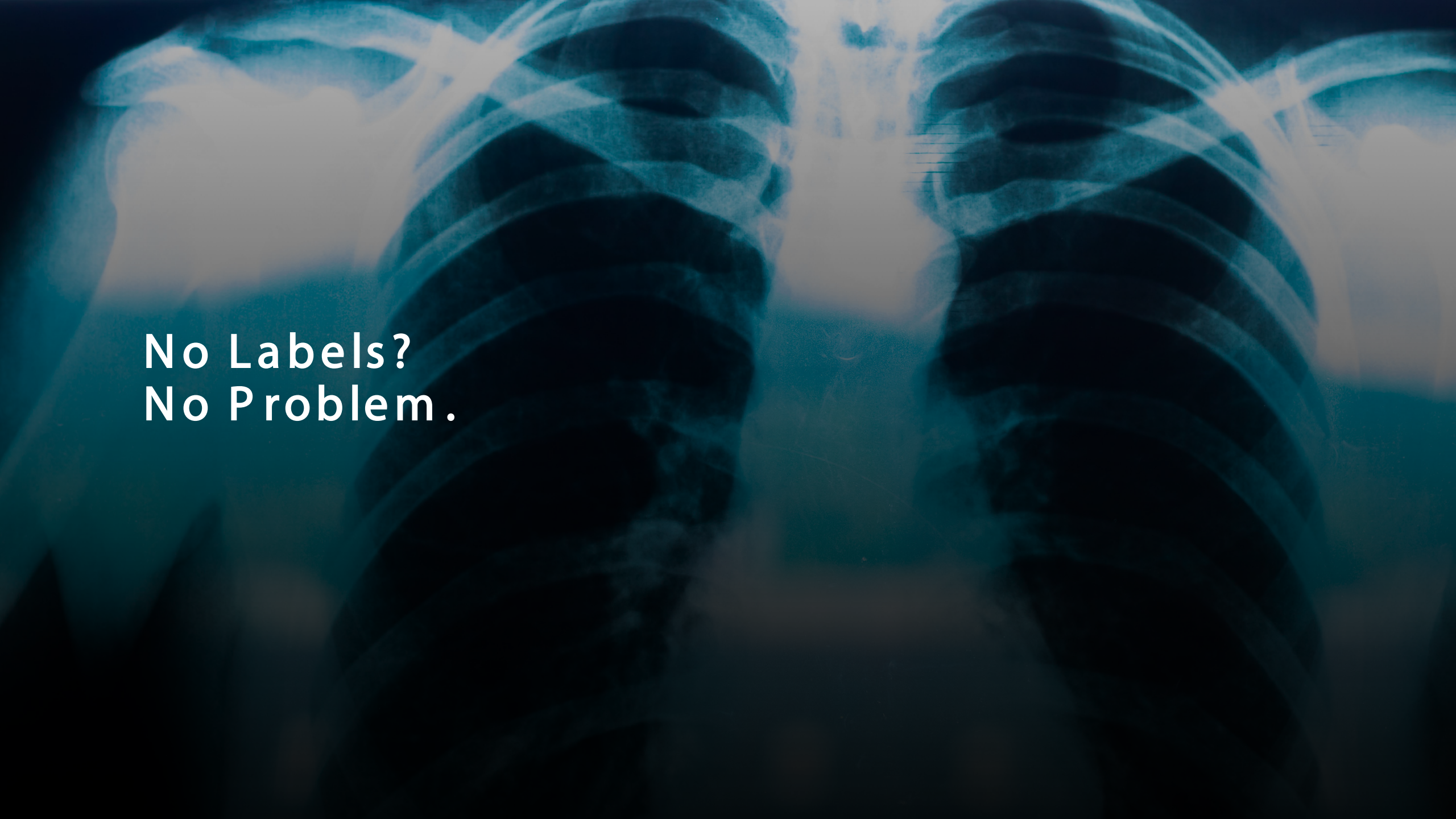
# Why Machine Learning Today?

- Increased computing power
- Access to more data
  - Volume
  - Variety
  - Velocity
- New research



# Multiple Algorithms/Models Optimize Results

- Decision trees
- Bagging
- Boosting
- Random forest
- k-NN
- Linear regression
- Naive Bayes
- Artificial neural networks
- Logistic regression
- Relevance vector machine
- Support vector machine
- Supervised learning
- Unsupervised learning
- Deep learning
- Clustering
- Dimensionality reduction
- Structured prediction
- Anomaly detection
- Artificial neural network
- Reinforcement learning
- Human collaboration



No Labels?  
No Problem.





## Detect Emotions.

ML consistently detects 37 emotions from facial expressions.

# Benefits of ML



Data-driven  
decision making



Optimize scarce  
resources



Enhance  
outcomes



Find patterns  
we can't see

# Applications of ML

Autonomous vehicles



Weather forecasts

Chess and GO

Speech Recognition

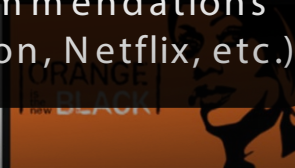
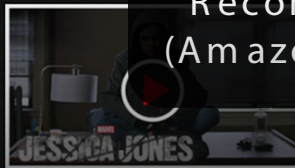
Credit assessment

NETFLIX

Because you watched shows about Anti-Heroes and Moral Ambiguity >



Because you watched shows with Sharp Humor and Strong Female Leads >



Because you watched shows about Dangerous Worlds and Complex Conse

OpenAI

ChatGPT: Optimizing Language Models for Dialogue

We've trained a model called ChatGPT which interacts in a conversational way. The dialogue is that makes it possible for us to answer followup questions, admit its mistakes, correct premises, and reject inappropriate requests. We're releasing this model to InstructGPT, which is a prompt and provide a

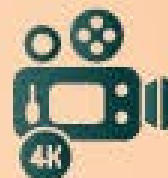
# Generative AI Models



Image  
creation



New  
Recipes



Visual Media



Coding & Debugs



Creating  
Music



Healthcare



# Generative AI

- Fraud Detection
- Customer Experience
- Supply Chain Optimization
- Optimized Operations
- Content Creation
- Training and Development
- Risk Management
- Predictive/Proactive Maintenance
- Enhance Customer Service
- Targeted Advertising

OK...

So how is AI/ML relevant to utilities?



**850**

Water main breaks just from today

\$ 1 Trillion in total corrosion costs

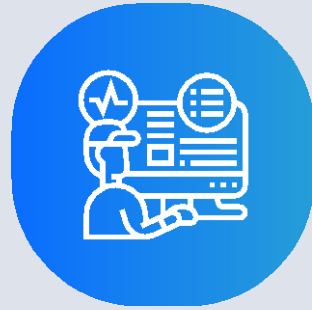
Do you proactively assess and  
manage water mains?



# How do you choose which ones to



Inspect?



Monitor?



Repair or  
Replace?



Exercise  
Valves?



Install  
Sensors?

# Traditional Methods to Predict Issues

**CLUSTER AREAS**

**INTUITION**

**FAILURE HISTORY**

**PIPE AGE**

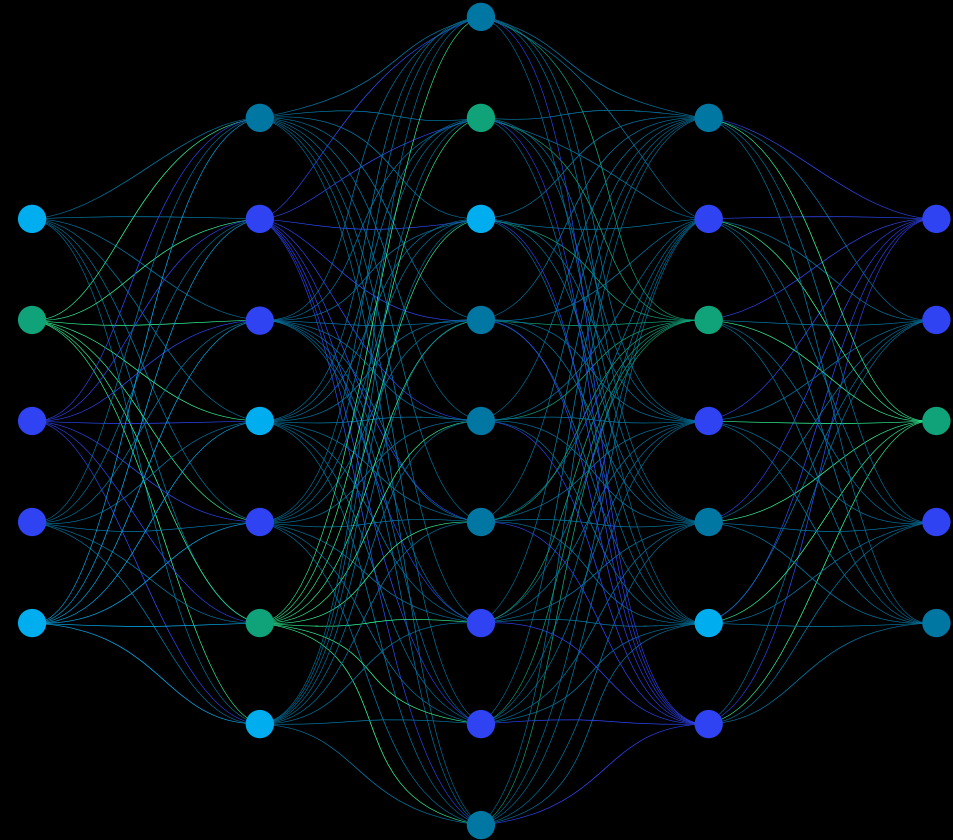
**MATERIAL**

**SOME COMBINATION**

# A new way to prioritize with Machine Learning

**65x**

Improved Accuracy





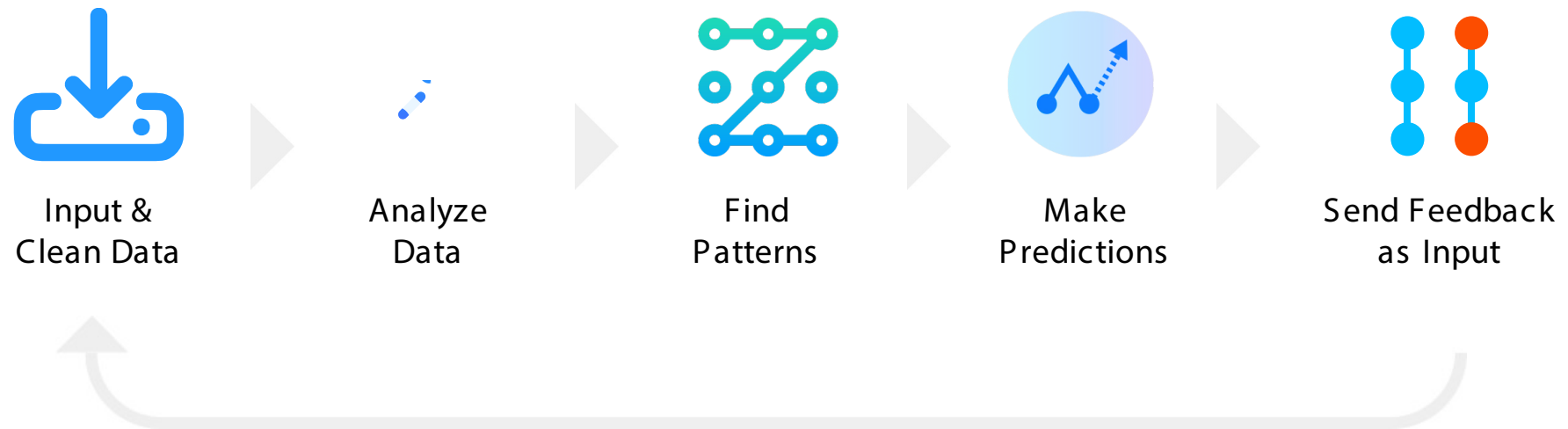
# TARGETED

## CAPITAL AND O&M SPEND

---

- Targeted Leak Detection & Monitoring
- Targeted Valve Maintenance
- Targeted Inventory
- Remaining Useful Life
- Faster Repairs to reduce risk

# How does Machine Learning Work?

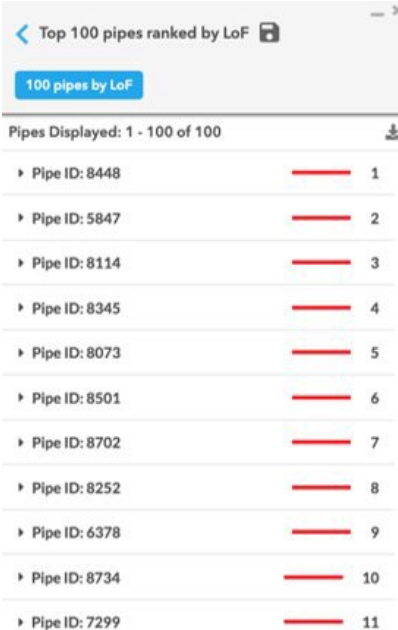


# How Machine Learning “Learns”

Training data\*

$$\begin{matrix} & 1 & 2 & \dots & n \\ \begin{matrix} 1 \\ 2 \\ 3 \\ \vdots \\ m \end{matrix} & \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ a_{31} & a_{32} & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \end{matrix}$$

Results: patterns & knowledge



Top 100 pipes ranked by LoF

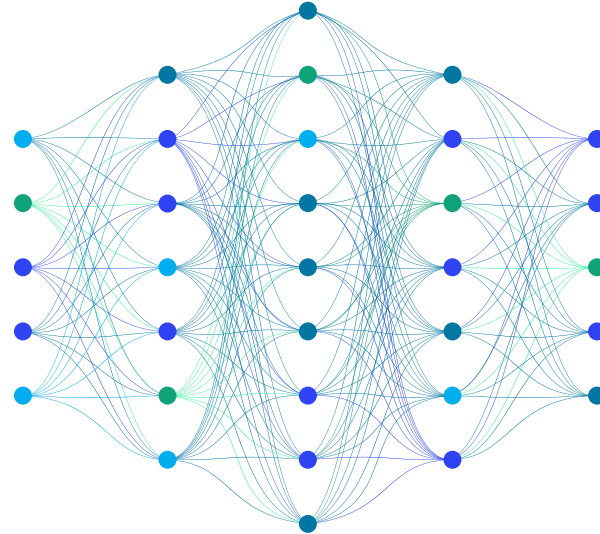
100 pipes by LoF

Pipes Displayed: 1 - 100 of 100

▶ Pipe ID: 8448	1
▶ Pipe ID: 5847	2
▶ Pipe ID: 8114	3
▶ Pipe ID: 8345	4
▶ Pipe ID: 8073	5
▶ Pipe ID: 8501	6
▶ Pipe ID: 8702	7
▶ Pipe ID: 8252	8
▶ Pipe ID: 6378	9
▶ Pipe ID: 8734	10
▶ Pipe ID: 7299	11

Instead of an engineer re-writing code every time there are new data, machine learning changes that algorithm on its own. It's self-learning.

# Process



Top 1% of pipes ranked by BRE	
Pipes Being Displayed: 1 - 99	
> Pipe ID: 6337	1
> Pipe ID: 6118	2
> Pipe ID: 6053	3
> Pipe ID: 5996	4
> Pipe ID: 6398	5
> Pipe ID: 5967	6
> Pipe ID: 5847	7
> Pipe ID: 4999	8
> Pipe ID: 5533	9
> Pipe ID: 5627	10
> Pipe ID: 5677	11
> Pipe ID: 5840	12
> Pipe ID: 5573	13
> Pipe ID: 5737	14

DATA COLLECTION  
AND CLEAN UP

AI RISK ANALYSIS

PIPE RANKING

# Case Studies



## Case Study

# Las Vegas, NV

5,000 miles of water  
mains

250,000 segments



Desktop Modeling  
had been used to  
prioritize decisions

Curiosity about  
machine learning  
led to a pilot with  
VODA.ai

## COMPARING RESULTS: Within the Highest Risk 1%

### Traditional Methods:

Prior Failure — found 11% of Failed Pipes

Pipe Age — found 12%

Desktop Statistical Model — ?

# ML — 50%

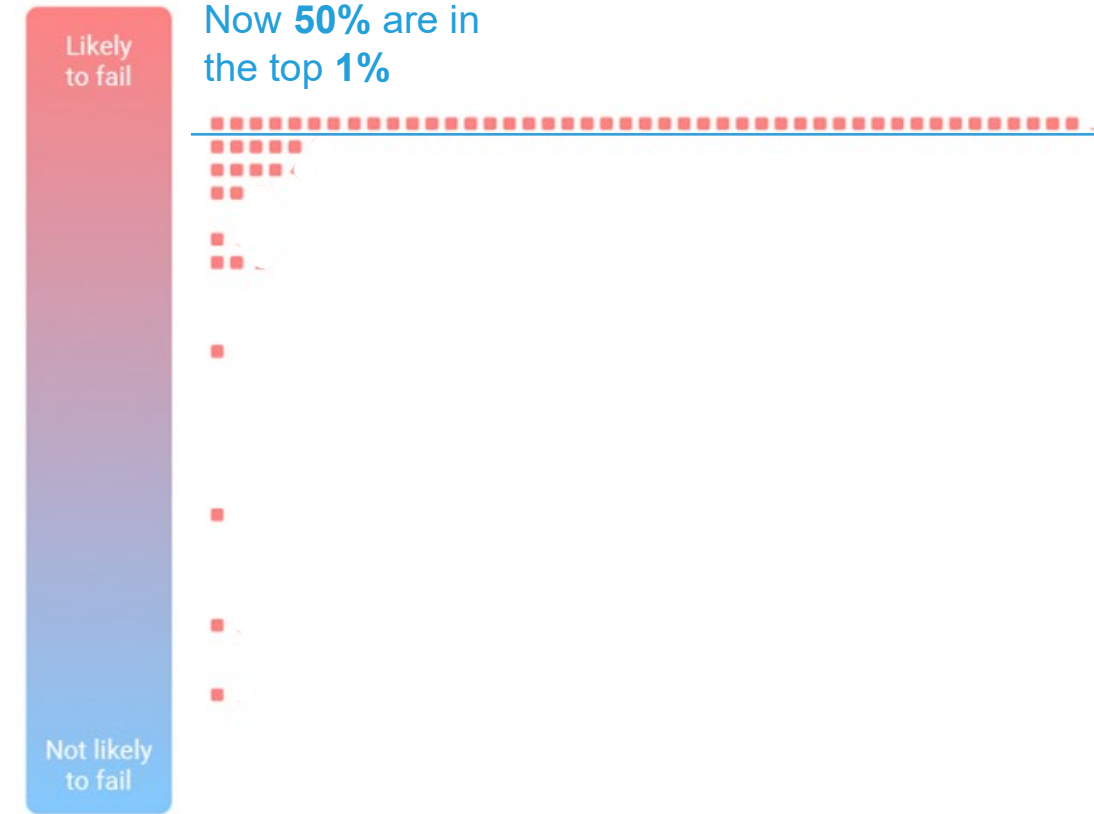
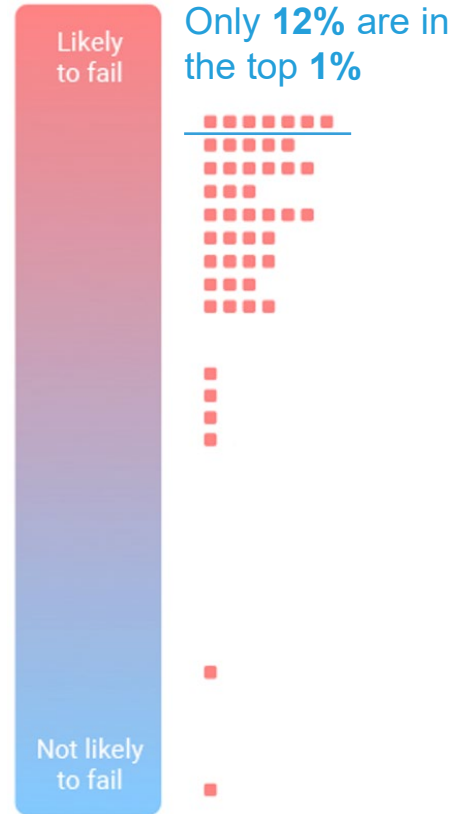
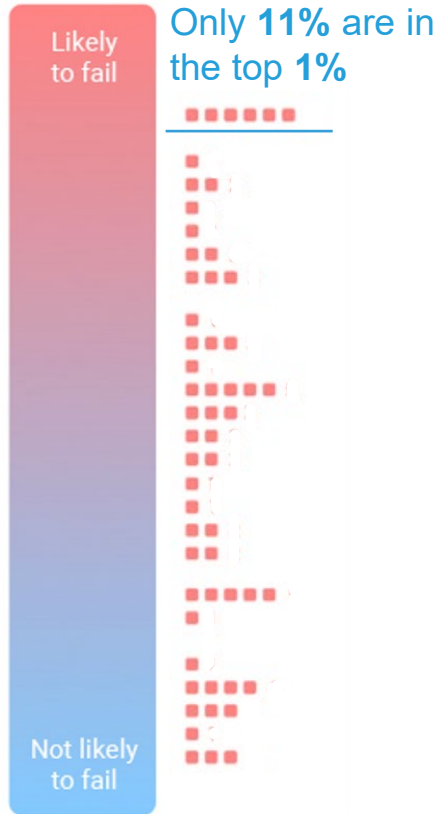
# Comparing Methods

Prior Failures

Age

AI/ML

#1



#250K

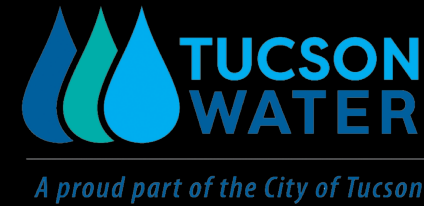
# Tucson, AZ

4,600 miles of water  
mains

230,000 segments



- In 2019, Tucson requested a ML pilot
- We asked for five years of data, but to withhold the most recent year (2018)
- We predicted the 2018 failures; Tucson validated the results
- Half failed for the 1<sup>st</sup> time!



**AI/ML found 200% more failures than using traditional methods**

**50%**

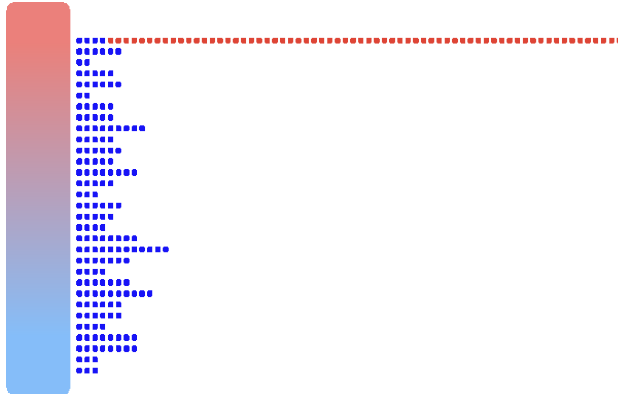
**had no prior failures!**

# Machine Learning Results

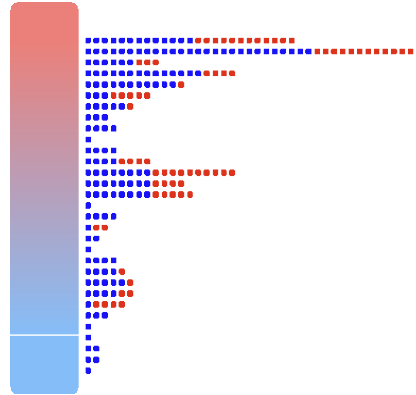
- ML found 55% of the pipe failures in the top 1% of risk rankings
  - 17 of the top 18 segments failed
  - Number 18 failed 2 months later
  - 18 of the ML top 18 failed within 14 months

# Looking for the Bull's Eye

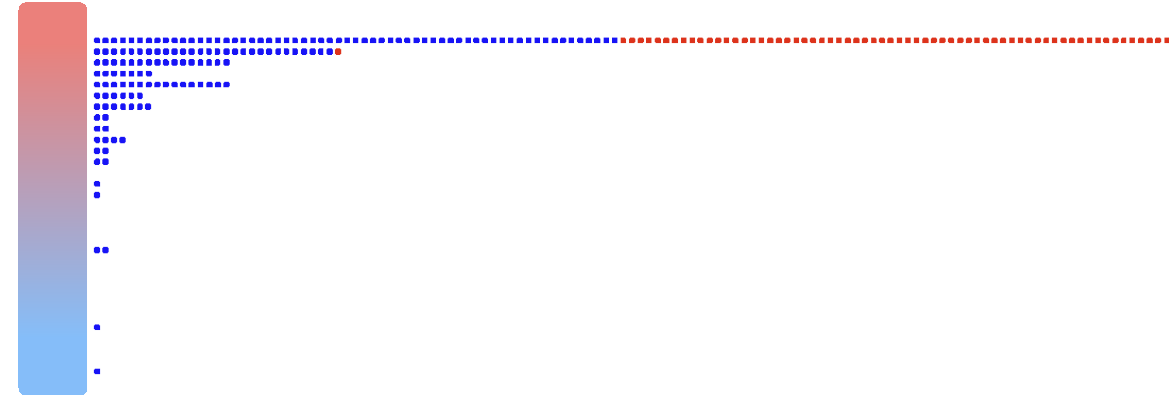
Prior Failures



Pipe Age



AI/ML

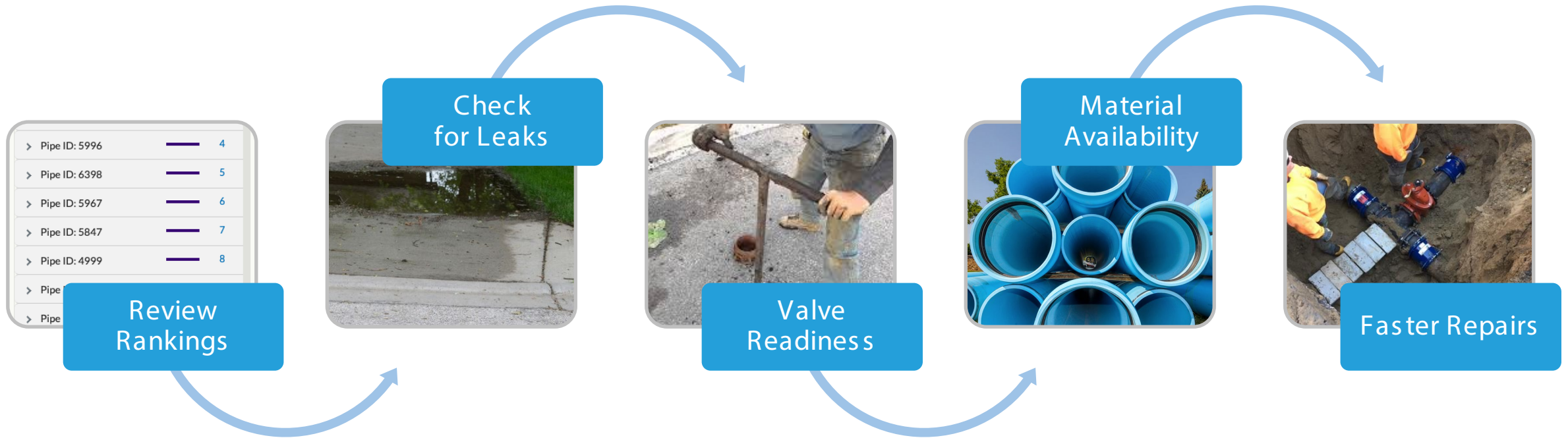


■ = Failed Pipes with No Break History

■ = Failed Pipes with Prior Breaks

AI/ML caught twice as many failures as the prior break model and **50% had never failed before**

# ML Assists Operations





# Planning

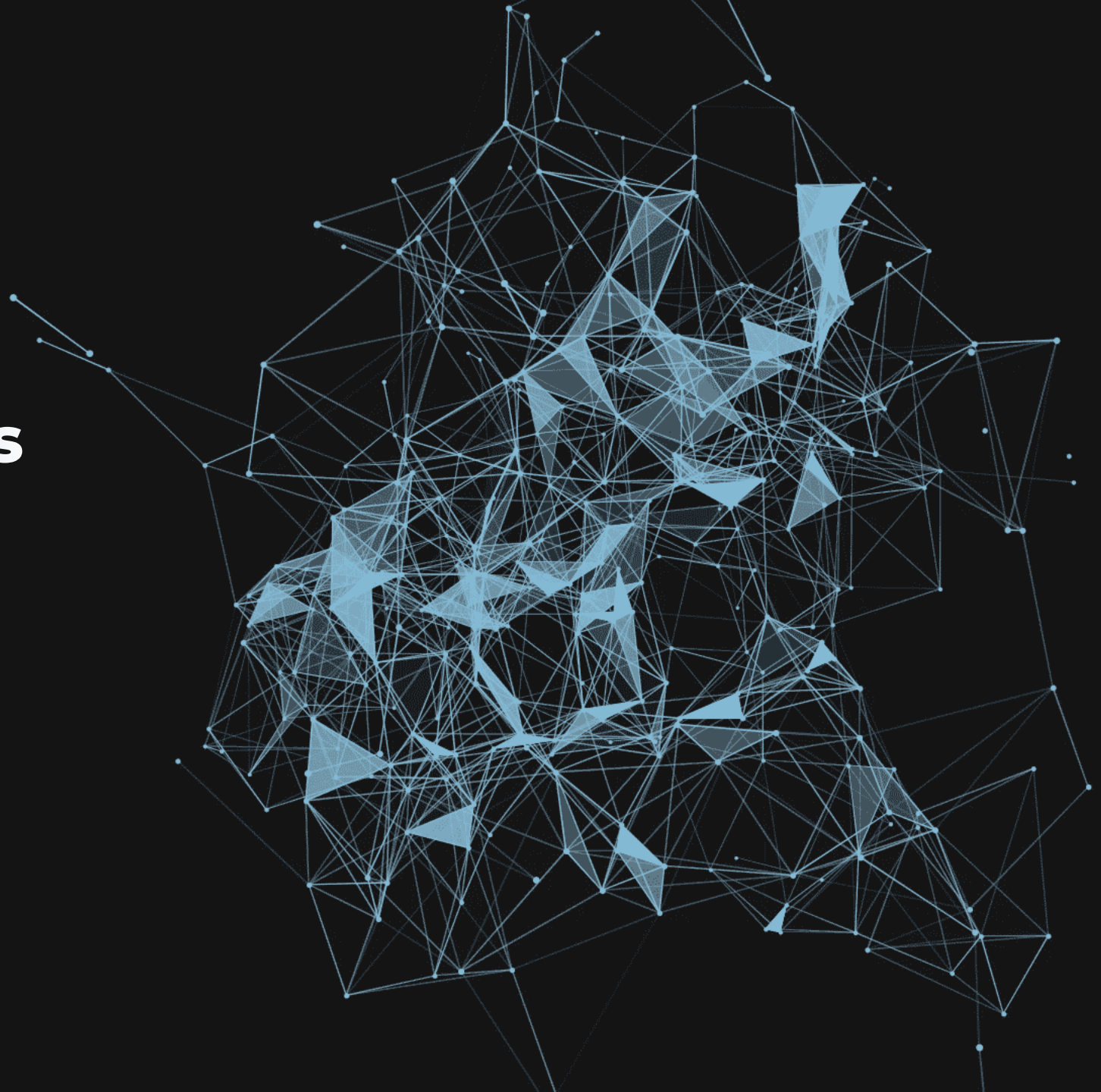
Replace more of these

And less of these



# **Machine Learning Finds Lead**

**A powerful engine  
created for utilities**



# Challenges

Missing service line data

Unknown pipes are a problem

Visiting every location is costly

LCRR deadlines



# Appleton, Wisconsin

29,000

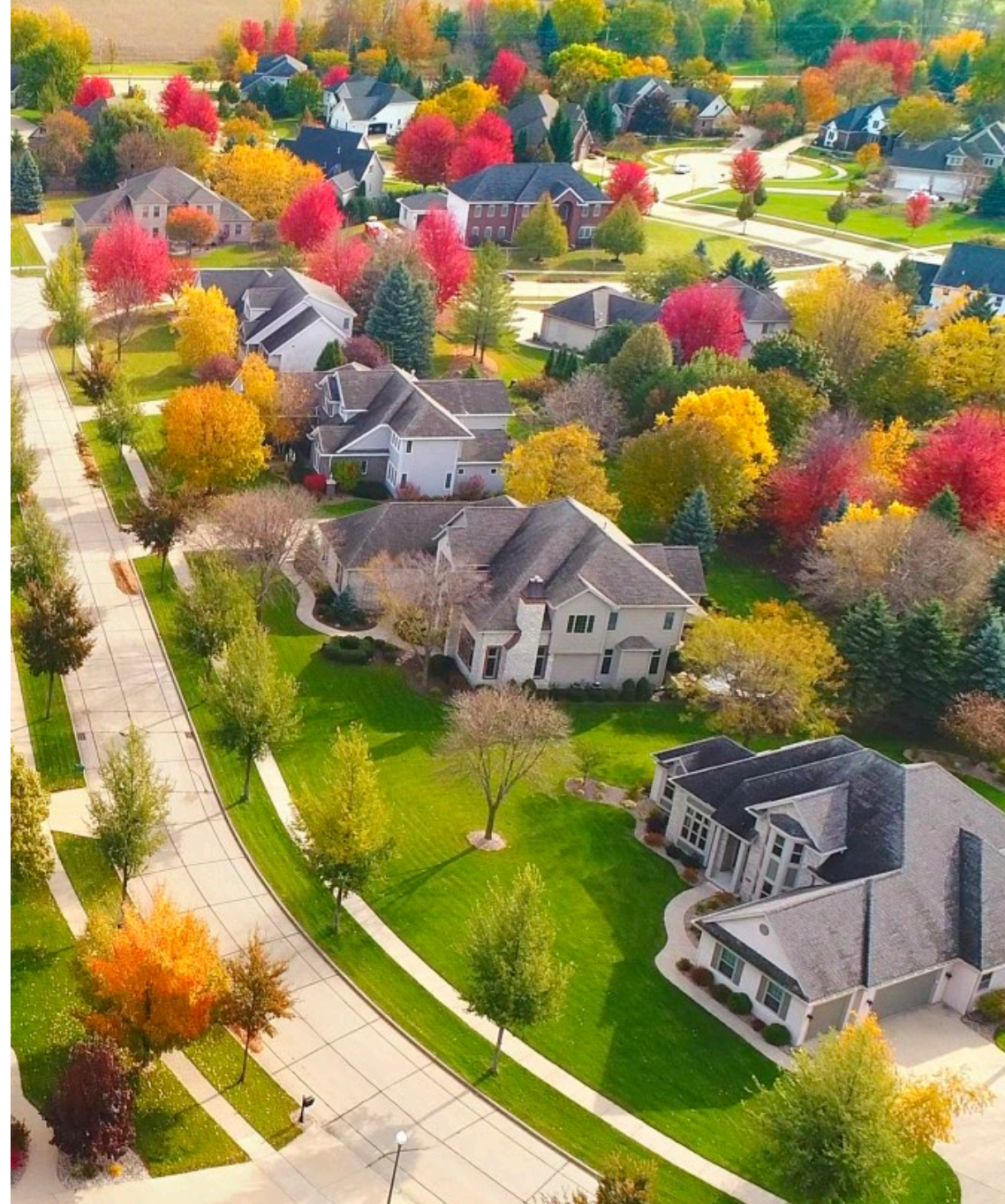
73

15,000

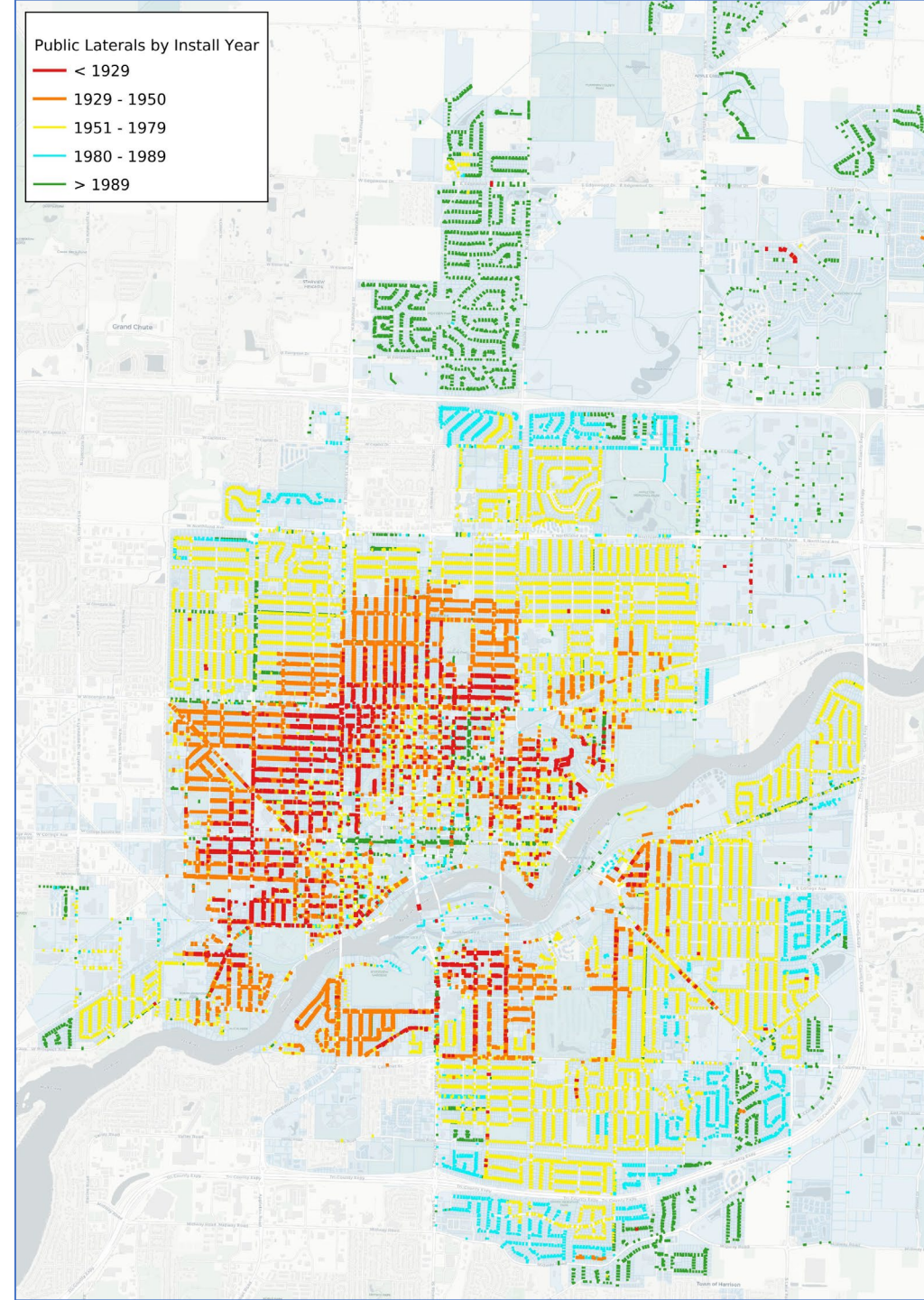
Service  
Lines

Confirmed  
Lead

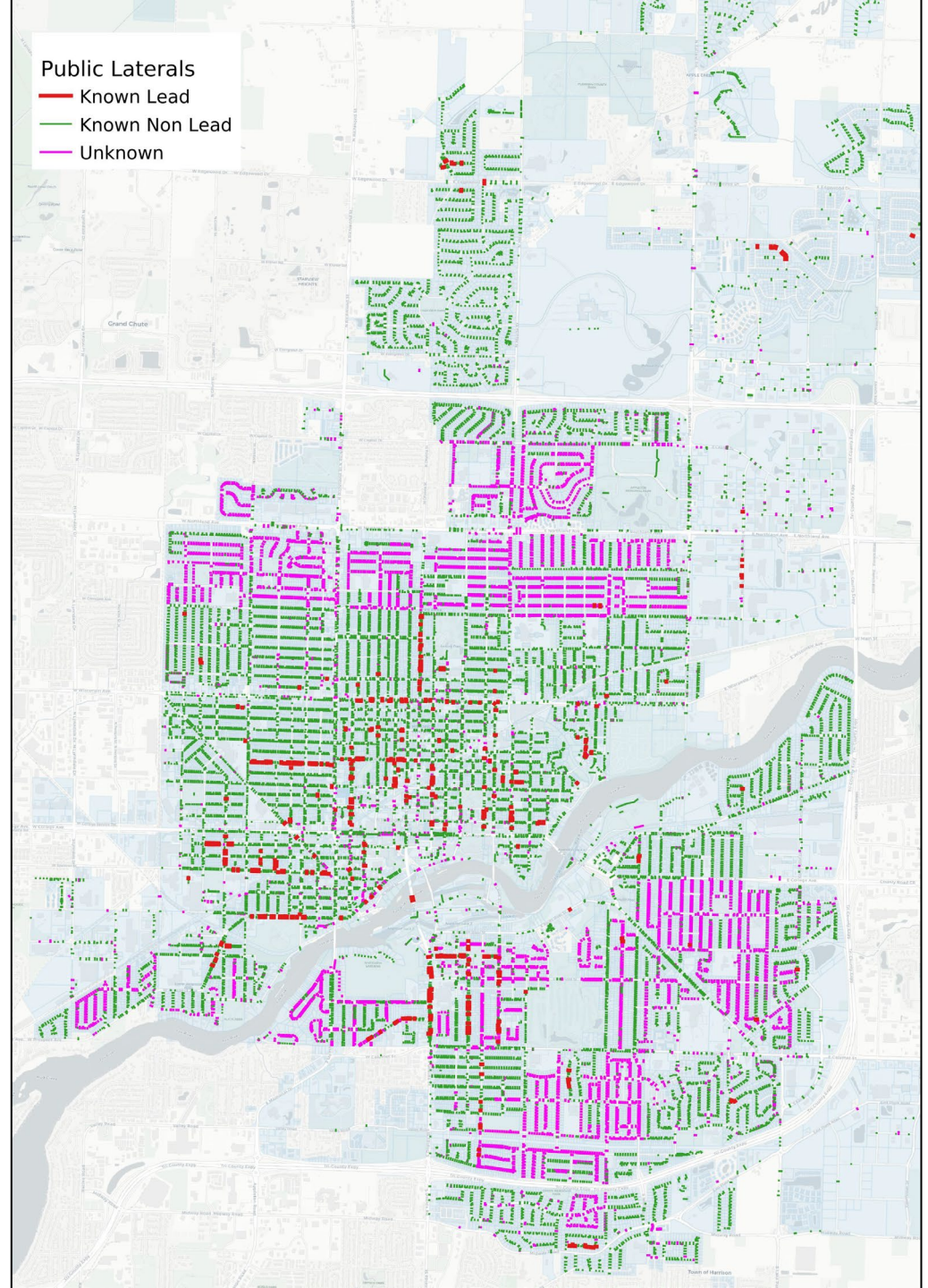
Unknown  
Material



Public service lines –  
likely lead pipes using  
installation year



Public service lines – likely lead pipes using known & unknown material



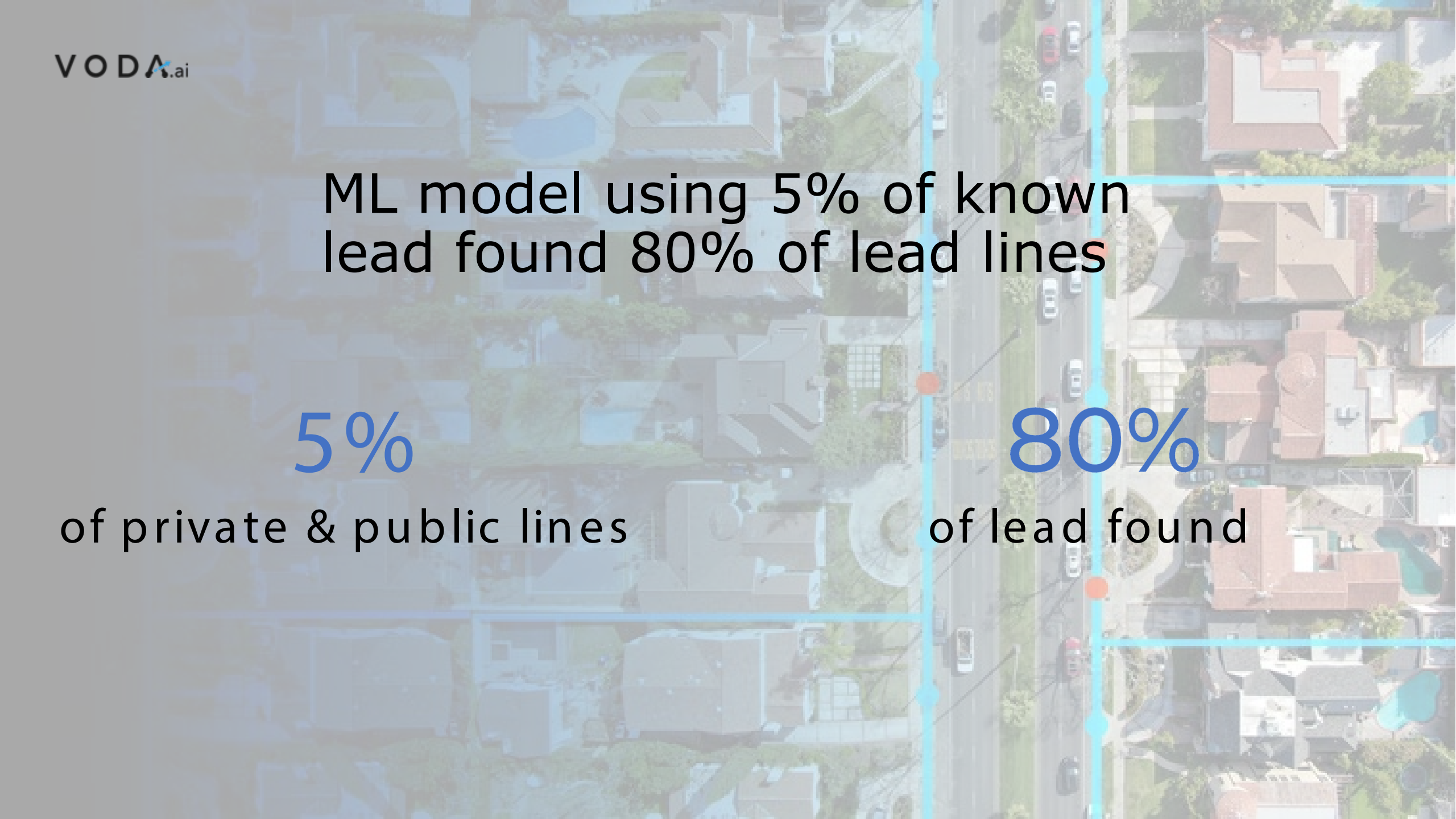
ML model using 5% of known  
lead found 80% of lead lines

5%

of private & public lines

80%

of lead found



# 100%

more accurate than  
installation year alone



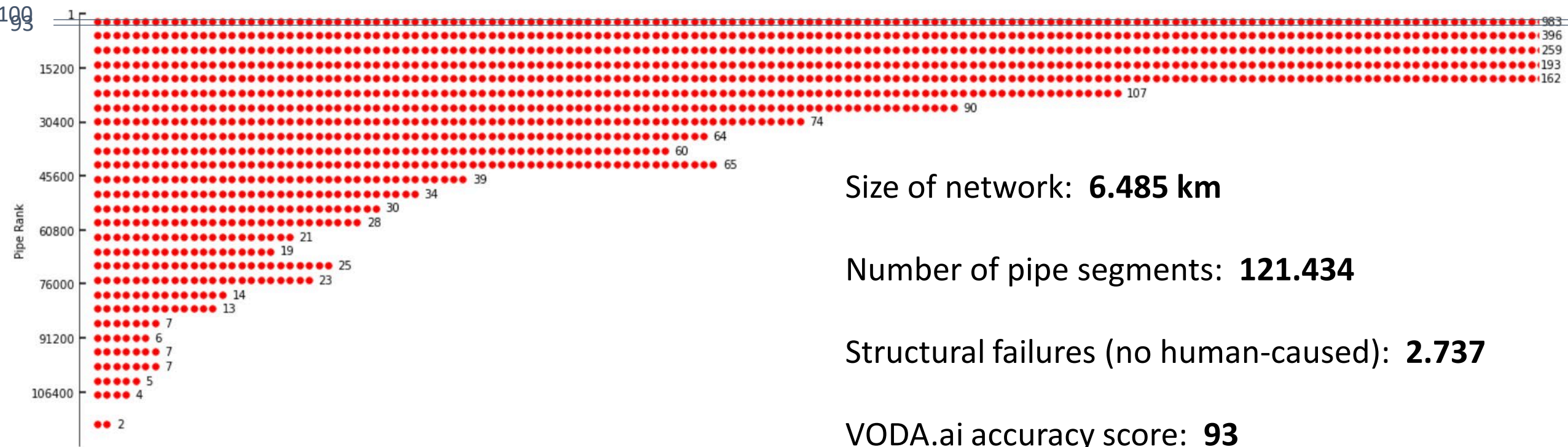


A wide-angle photograph of the Santiago skyline at dusk. The sky is a mix of deep blue and purple, with some light clouds. The city's buildings are silhouetted against the sky, with some windows glowing. In the foreground, a large body of water reflects the city and the sky. The text is overlaid on the image.

# Wastewater Santiago, Chile

Prioritizing Infrastructure

# Wastewater Results – Chile, South America



Size of network: **6.485 km**

Number of pipe segments: **121.434**

Structural failures (no human-caused): **2.737**

VODA.ai accuracy score: **93**

In first 500 pipes...

**484 Failures!**

In last 5000 pipes...

**0 Failures!**

# Wastewater Results - Chile

Events caught at top 1% of ranked segments

## Comparison

	Age method	Prior breaks method	VODA.ai method
Full area (all regions)	12	245	787

# 3X

## Improvement

## Water Failure Predictions



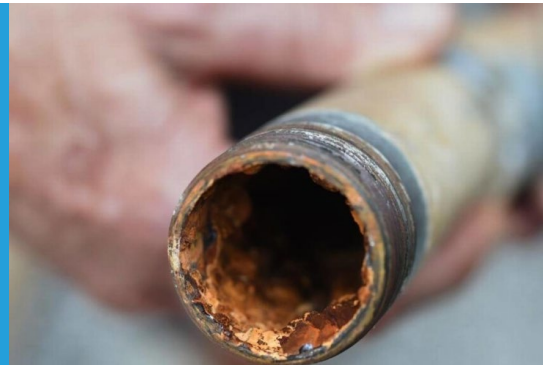
## Wastewater Condition Assessment



## Wastewater Incident Predictions



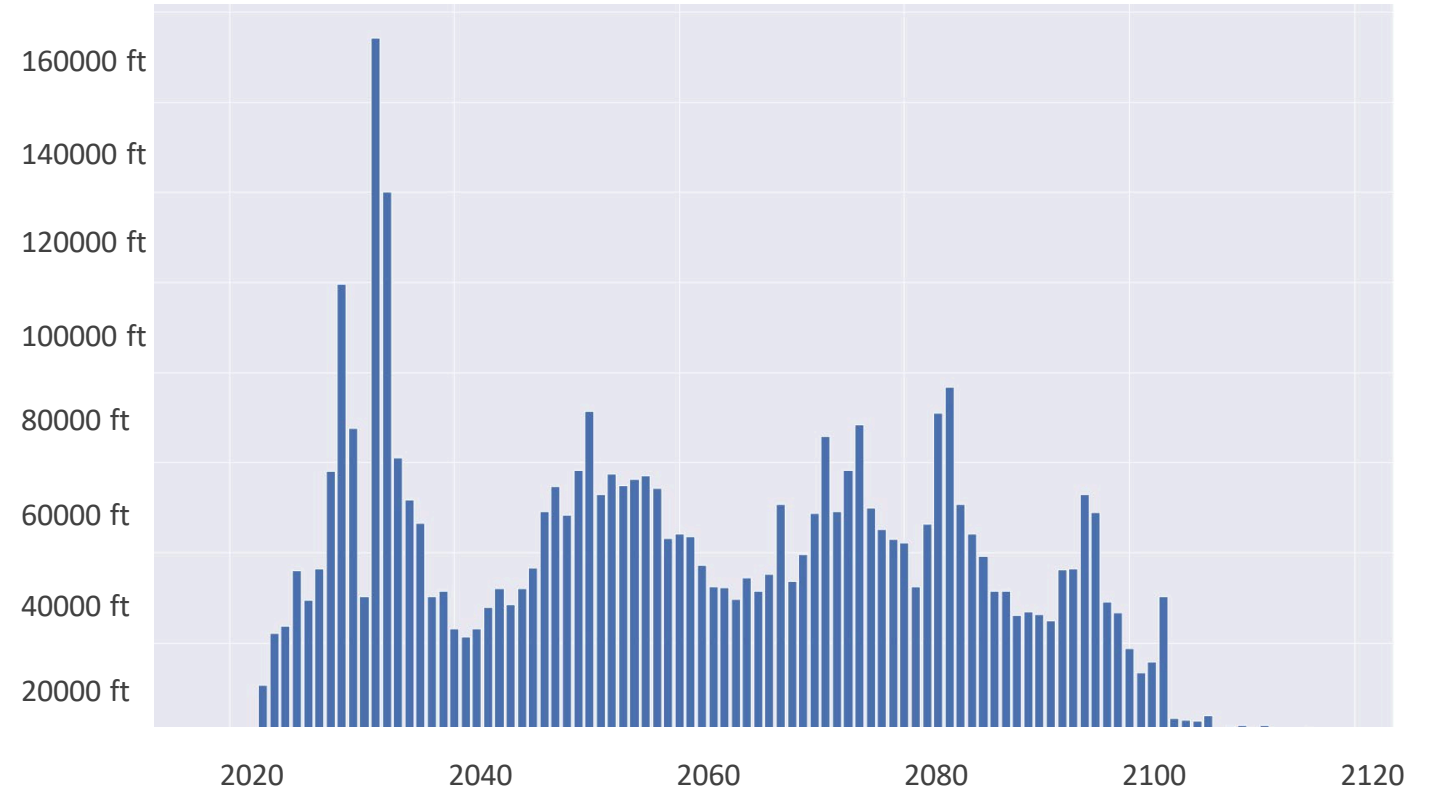
## Lead Pipe Finder



# AI/ML Based Remaining Useful Life

# RUL

- AI-RUL is calculated using AI/ML
- Understand investment needed to avoided large increases in future failures



The logo for VODA.ai, featuring the word "VODA" in a bold, white, sans-serif font, followed by ".ai" in a smaller font. A small registered trademark symbol (®) is positioned to the upper right of the ".ai". A stylized green and blue graphic element is integrated into the letter "A".

VODA.ai®

Prioritizing Infrastructure™

A photograph of a modern building facade with a grid of windows. Large, light-colored letters spell out "50 Milk Street" above the entrance. The "0" in "50" has a blue and white striped pattern.

50 Milk Street

Contact: Jim  
[Jim@voda.ai](mailto:Jim@voda.ai)



Are you ready for  
the next step in  
your digital  
transformation?

50 Milk Street | Floor 15 | Boston, MA 02109