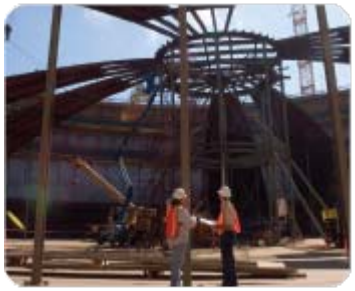
BLACK & VEATCH





PNWS AWWA 2009 Annual Conference

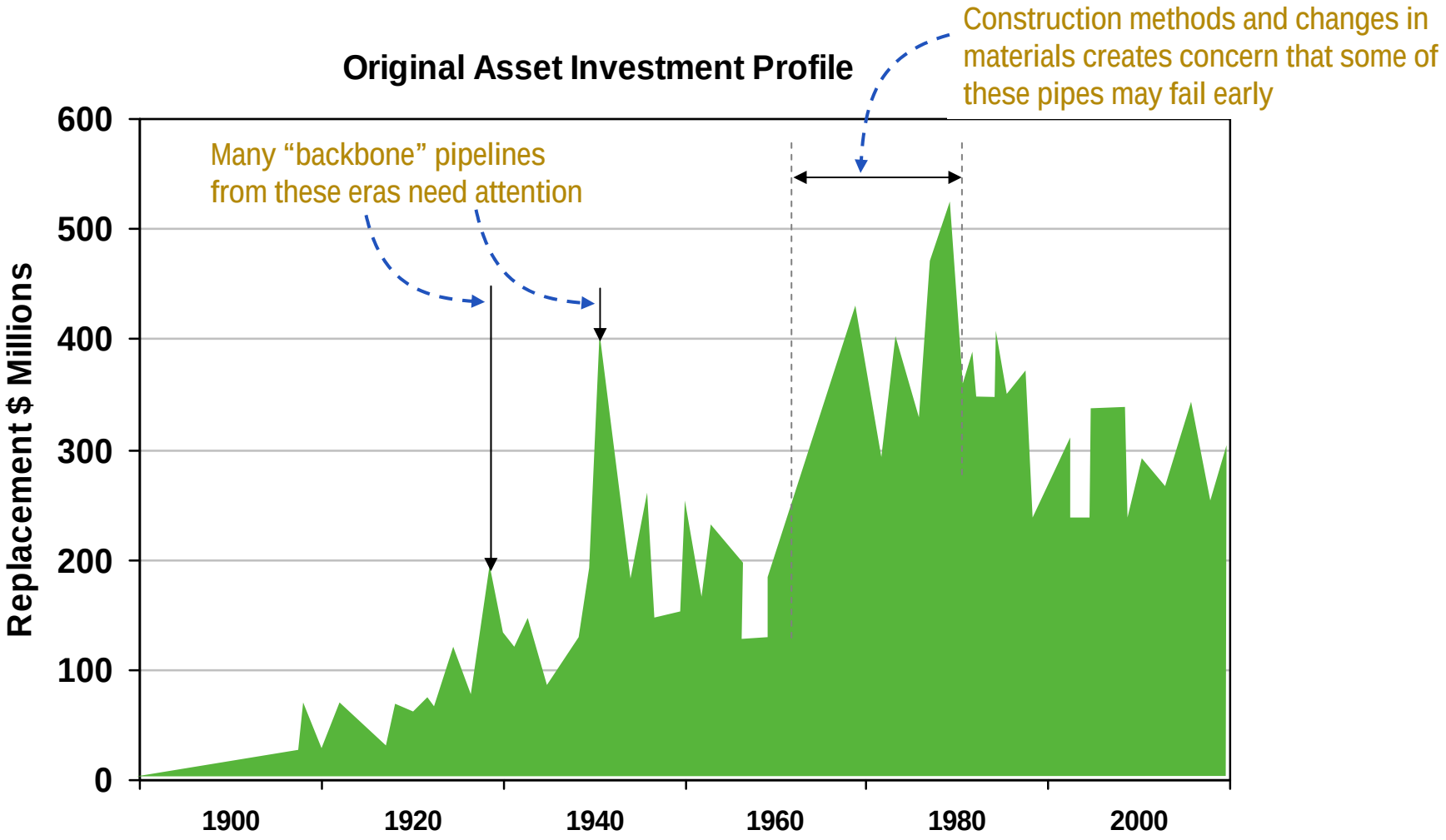
What's its Condition? Inspection of a Large Diameter Transmission Main

Wayne Gresh, P.E.
Project Manager, Black & Veatch
greshhw@bv.com / 503-699-2218

May 6, 2009

Outline

- Background information - why inspect pipes
- Overview of study for Salem, Oregon
- Transmission pipe inspection methods
- Inspection method selected for Salem study

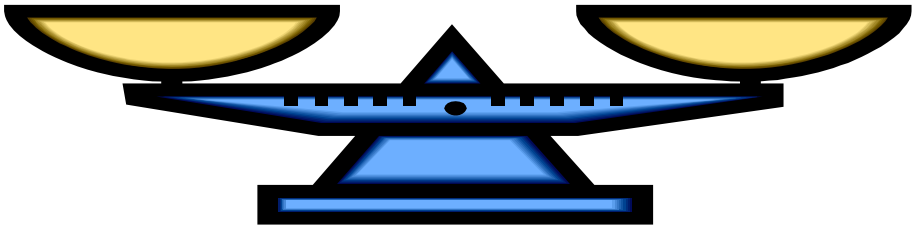

Original Asset Investment Profile
Construction methods and changes in materials creates concern that some of these pipes may fail early
Many "backbone" pipelines from these eras need attention
Replacement $ Millions
600
500
400
300
200
100
0
1900
1920
1940
1960
1980
2000

Assets Have a Life

- Service - PERFORMANCE
- Unknown Condition - RISK
- Rehabilitation and Repair - COST

Affordability
CIP Planning & Mgmt
Inflationary Pressure
Regulatory Issues
Security
Operational Efficiency

Customer
Satisfaction
Aging
Infrastructure
Funding



Balance Performance, Risk and Cost

Management By Crisis - Impacts Performance, Risk and Costs

Gazette.Net

Wednesday, May 23, 2007

Residents still cannot return to homes

WSSC plan calls for multimillion-dollar repairs to pipeline after flood in Chevy Chase

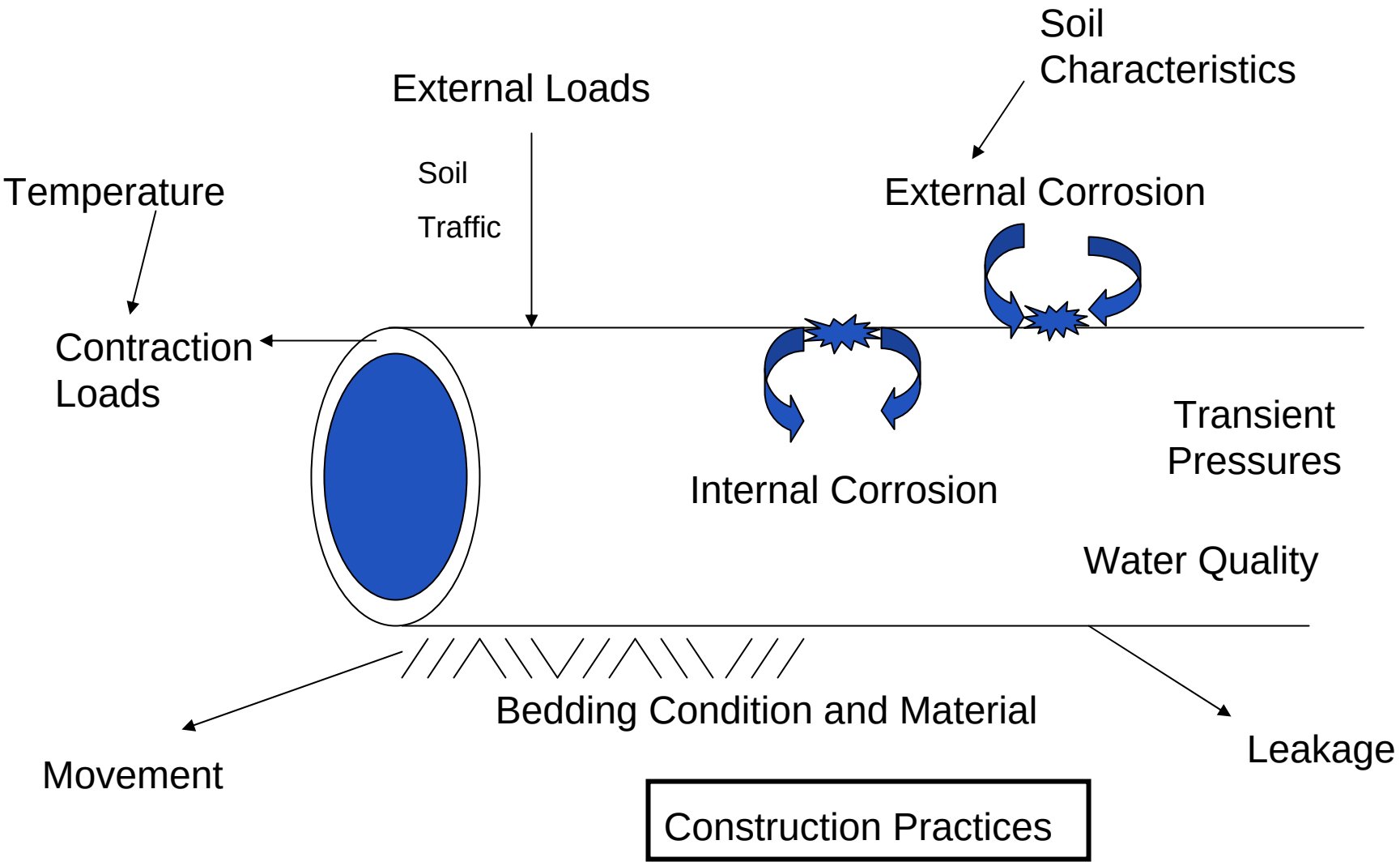
by Audrey Dutton | Staff Writer

Howard County TIMES.com *The voice of your community*

Under Pressure Officials have their fingers crossed that a crucial water main won't explode before they can replace

05/24/07 *By Nate Sandstrom*

Factors Impacting Pipe Life



Avoid Catastrophic Events

Salem, Oregon

Chicago, Illinois

Denver, Colorado

Avoid Catastrophic Events

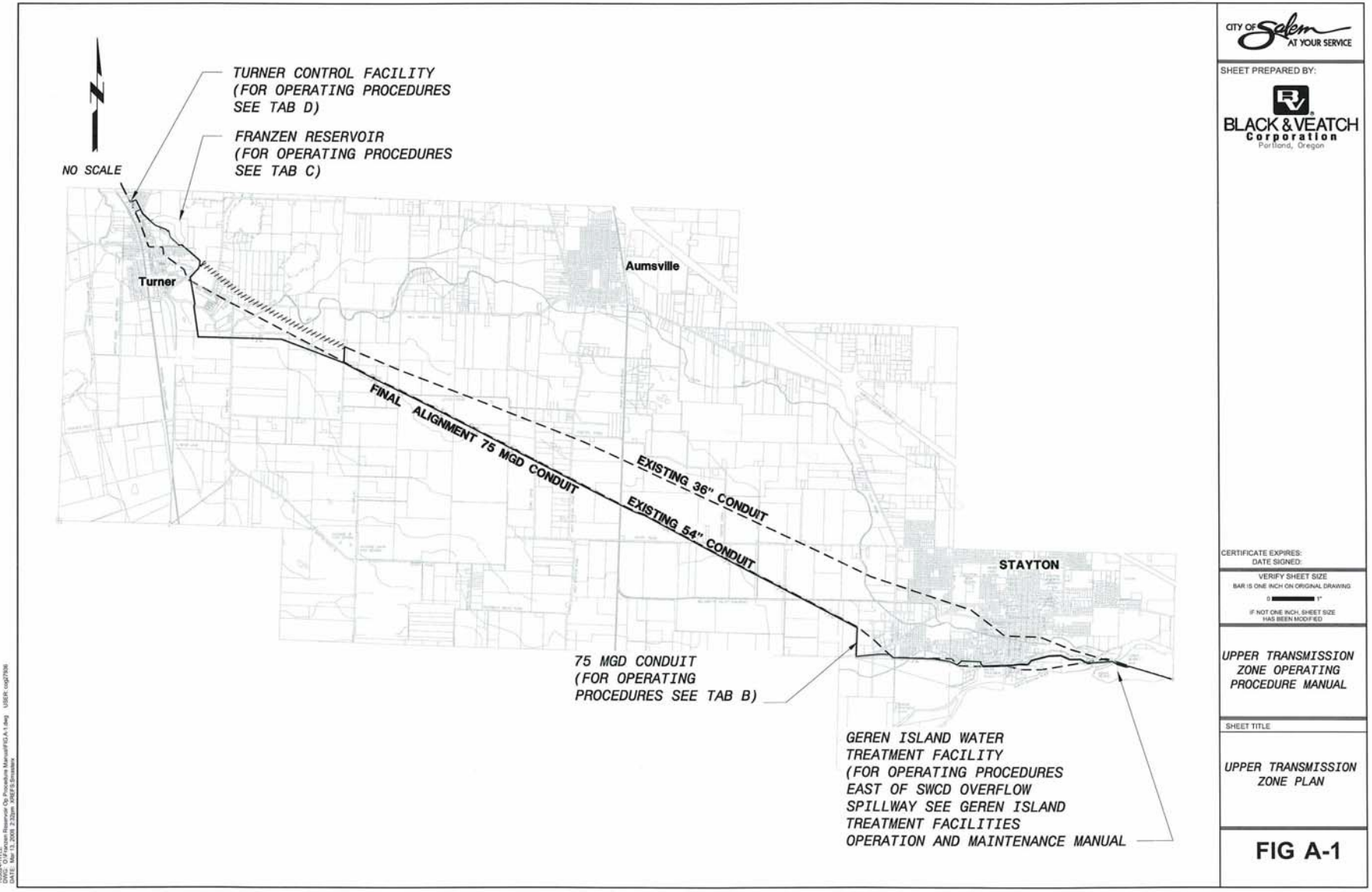
Avoid Catastrophic Events

Failure of Critical Pipelines Can Have Substantial Consequences…

- Impacts service to a large number of customers
- Often laid under major roads - substantial traffic problems
- Potential damage to environment
- Repair can be very costly
- A large volume of water is lost
- **Public perception of utility!!**

Salem 54” Transmission Main Inspection

- Two cross-country transmission mains
- 36” concrete pipe constructed in 1937
  - Being replaced with 75 MGD conduit
- 54” PCCP constructed in 1957
  - Ruptured April 9, 2007 for the second time
  - Surge was within opinion of design pressure limit
  - Corrosion was suspected as cause of failure


TURNER CONTROL FACILITY
(FOR OPERATING PROCEDURES
SEE TAB D)
FRANZEN RESERVOIR
(FOR OPERATING PROCEDURES
SEE TAB C)
NO SCALE
Turner
Aumsville
FINAL ALIGNMENT 75 MGD CONDUIT
EXISTING 36" CONDUIT
EXISTING 54" CONDUIT
STAYTON
75 MGD CONDUIT
(FOR OPERATING
PROCEDURES SEE TAB B)
GEREN ISLAND WATER
TREATMENT FACILITY
(FOR OPERATING PROCEDURES
EAST OF SWCD OVERFLOW
SPILLWAY SEE GEREN ISLAND
TREATMENT FACILITIES
OPERATION AND MAINTENANCE MANUAL
CITY OF Salem AT YOUR SERVICE
SHEET PREPARED BY:
BLACK & VEATCH Corporation
Portland, Oregon
CERTIFICATE EXPIRES:
DATE SIGNED:
VERIFY SHEET SIZE
BAR IS ONE INCH ON ORIGINAL DRAWING
IF NOT ONE INCH, SHEET SIZE
HAS BEEN MODIFIED
UPPER TRANSMISSION
ZONE OPERATING
PROCEDURE MANUAL
SHEET TITLE
UPPER TRANSMISSION
ZONE PLAN
FIG A-1

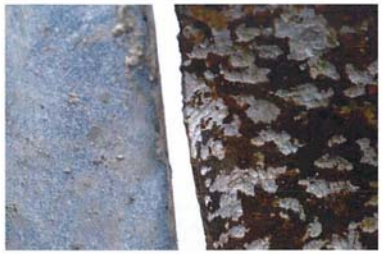
54” Transmission Line 2 Failure
April 9, 2007

Steel Plate from Upper Transmission Line 2 Failure

Corrosion of Steel Cylinder from Upper Transmission Line 2 Failure

Steel Cylinder from Upper Transmission Line 2 Failure. There are 3 holes shown in this picture, each with a fuchsia colored circle drawn around it. There were smaller pin holes on the plate which were too difficult to photograph.

Section of Steel Cylinder from the Upper Transmission Line 2 at 70th (on left side in each photograph) and a Section From the Recent Failure (on right side in each photograph)



Notice the thinning of the steel wall of the piece removed from the recent break compared to that removed from Upper Transmission Line 2 at 70th.

Pipe Condition Assessment Technologies:

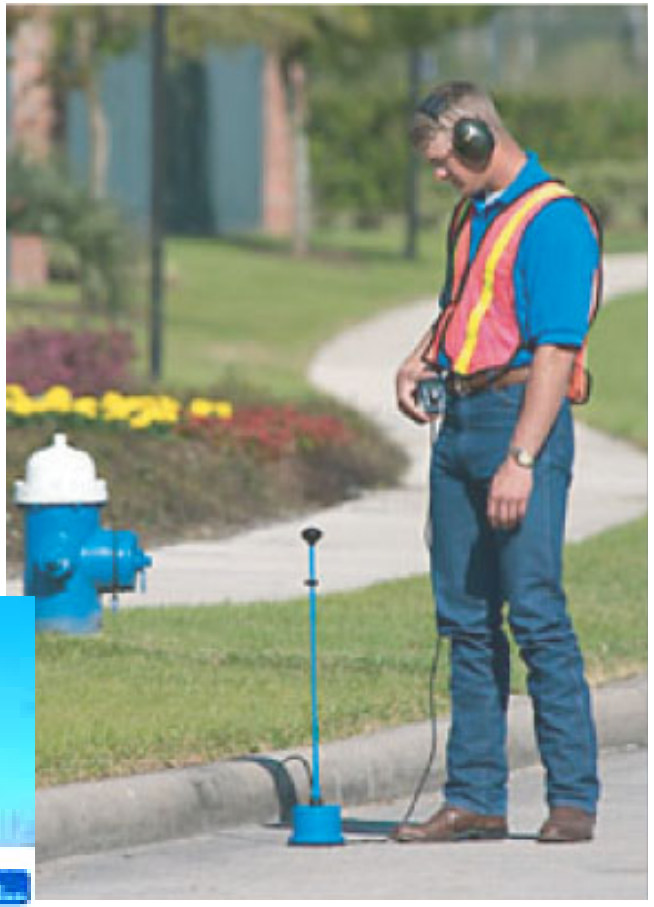
- Visual Inspection
- Leak Detection
- Closed Circuit TV (CCTV, Laser, Sonar)
- Remote Field Eddy Current/Transformer Coupling
- Acoustic Emission Technology
- Cathodic Survey
- Electromagnetic (Broad Band and Remote Field)
- Ultrasonic (G-Wave, Impact Echo)
- Magnetic Flux Leakage

Visual Inspection

- Physical entry into pipe:
  - Dive team – limited to large diameter pipes
  - Entry into drained pipeline
- Limited information to visual observation
  - Can locate areas for further exploration
- Entry likely will be confined space
- When confined space entry costs are included cost is about equal to CCTV using ROV

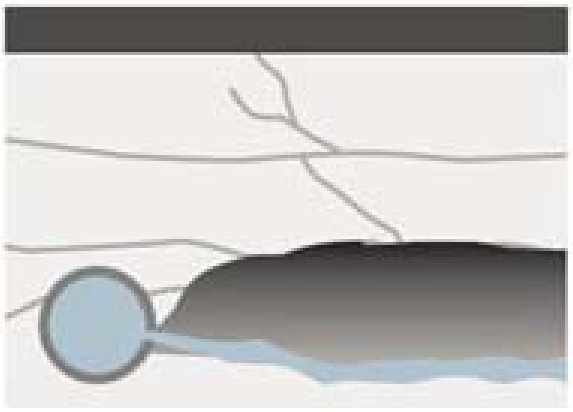
Leak Detection Systems

- Acoustic Leak Detection
- Metering
- Noise Correlation



How a Sinkhole is Formed

1. A small leak develops in the pipe.

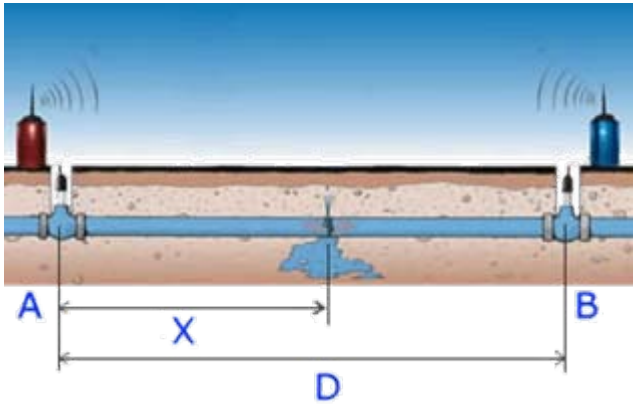


2. The water pressure from the leak washes away the soil around the pipe. The water moves through existing cracks in the ground.

3. The erosion of the soil through the cracks form a cavity. In time, the size of the cavity increases until the weight of the soil and road way cause a collapse.

Correlators

- Array of sensors attached to water main
  - Determines location by recorded transit time of acoustic pressure wave between sensors



- Smallest leaks detected 125 gal/hr
  - 3000 gal/day --- 1.1 million gal/year
- Perform better in smaller diameters (≤12”)
  - Signal attenuates & weakens in large diameter pipe
- Location usually within 10-ft of leak
- Multiple leaks tend to distort signal

Sahara® Leak Detection Technology

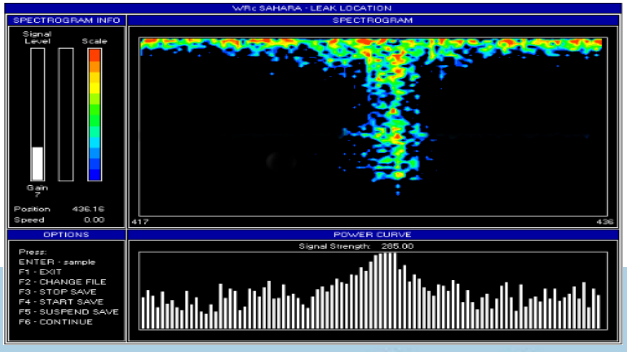
- Compliments Other Technologies
- Detects Small Leaks, 0.5 gal/hr at 85 psi
- Locates Leak within inches
- Technology can be used on any pipe of any material.
- Data Results Identified in Real Time
- Limited to 5,000 Feet and 12” and Larger Pipe

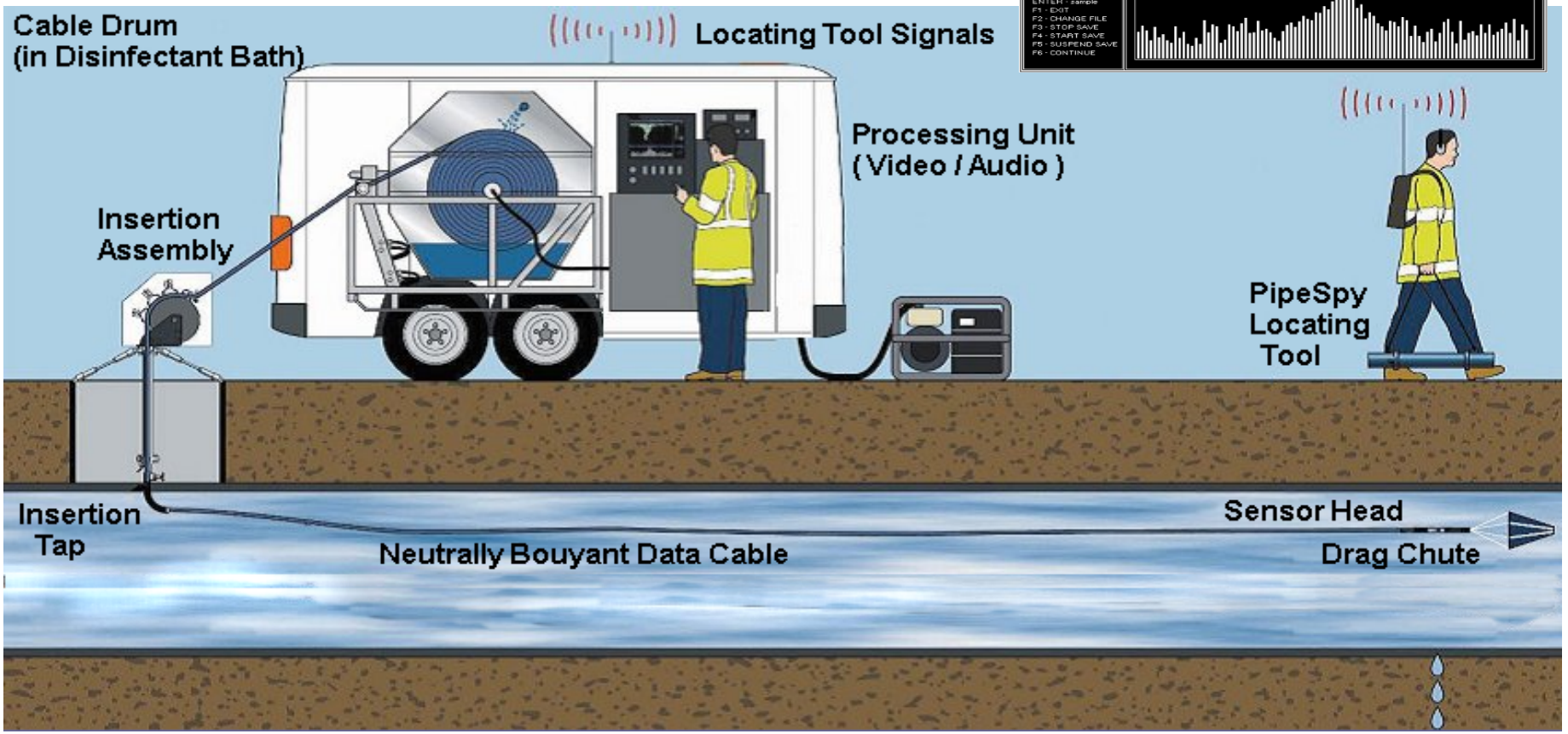
Sahara - Methods

Flow

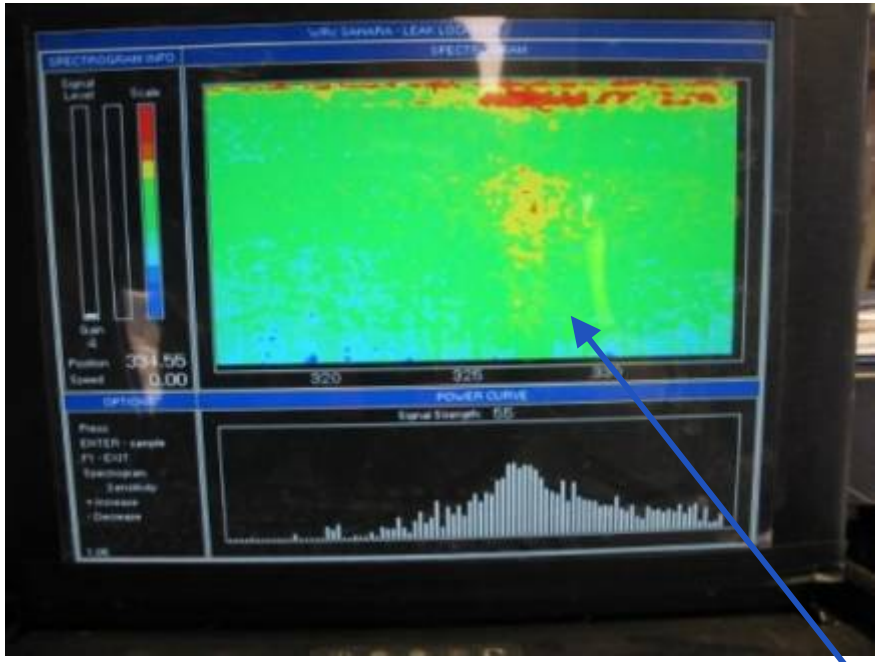
MuleTape

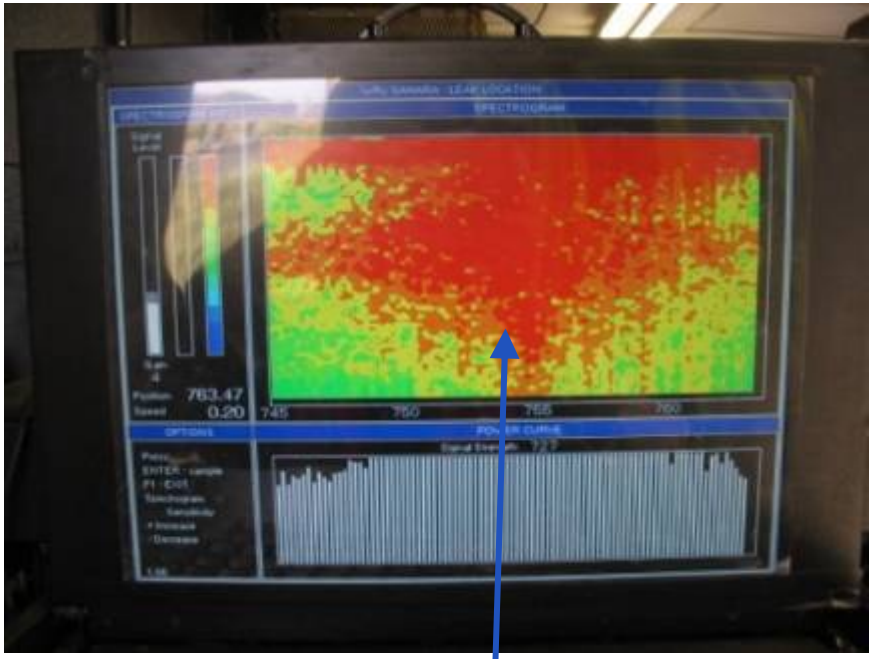
Sahara® Leak Detection System





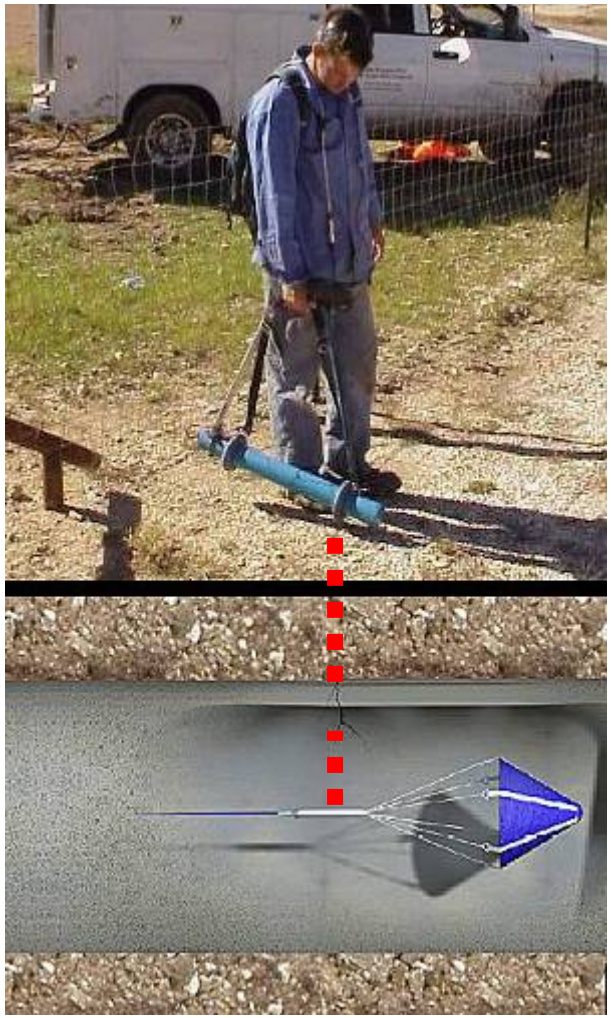
Leak Size Quantified During the Inspection





Sahara screen displaying a small leak and a large leak

PipeSpy Locates an Underground Leak and the Corresponding Location on the Surface



- PipeSpy transmits signal to Sensor Head
- Detectable through ALL pipe materials
- Depths to 35 foot range
- Locates within 18” of linear alignment of pipeline
- Stakeout, mark out, and/or GPS coordinate exact leak location

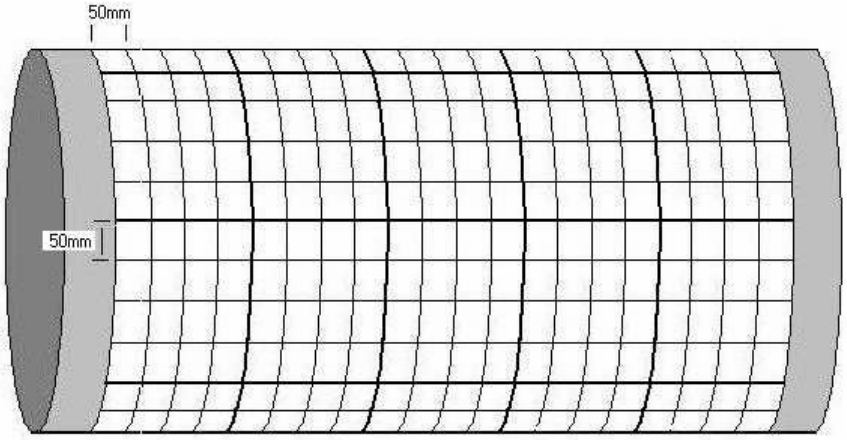
Sahara Flow Method - Parameters

Pipeline Materials	**All Types**
Pipeline Diameter	**12” and above**
Pipeline Pressure	**10 psi to 200 psi (MuleTape up to 250 psi)**
Flow Velocity	**1 ft/sec and above (Min is pipeline /section specific)**
Insertion Point Bore	**Any tap point 1-7/8” or greater on the 12:00 position on the pipe**
Survey Ditance	**Up to 6,000 ft**
Survey Distance / Day	**Typically 1 mile / day**
Directional Change Accomodation	**Max 270 degrees of bends, except in PCCP* - interior sharp edges may damage cable**
Sensitivity	**Detects leaks as small as 0.25 US gallons / hr at 87 psi (.08 gal/min @ 20 psi)**
Vault Configuration	**Must accommodate insertion tubes (72” or 168”) (dependent on riser length)**

Broadband (BEM) Electromagnetic Technology

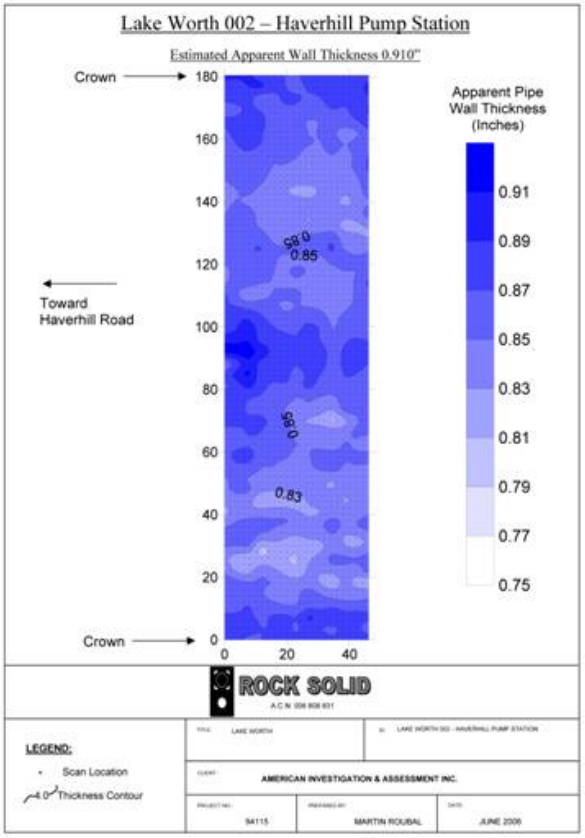
- For metallic pipe
- Measures wall thickness & pits
- Near-field electromagnetics
- Internal survey by droid
- External scan by “blanket”; 50mm grid system
- Pipe must be exposed and out-of-service
- Pipe must be very close to round
- Survey must be performed in straight line
- Gives average thickness based on spot measurements at nodes
- Ultrasonic inspection used to confirm findings

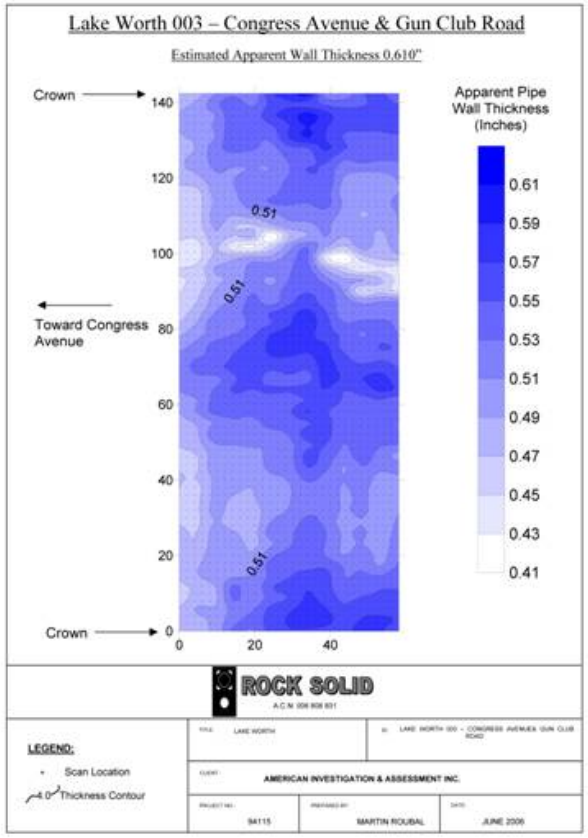
Broadband (BEM) Electromagnetic Technoloy



BEM Results

Lighter colors show pipe wall thinning pattern

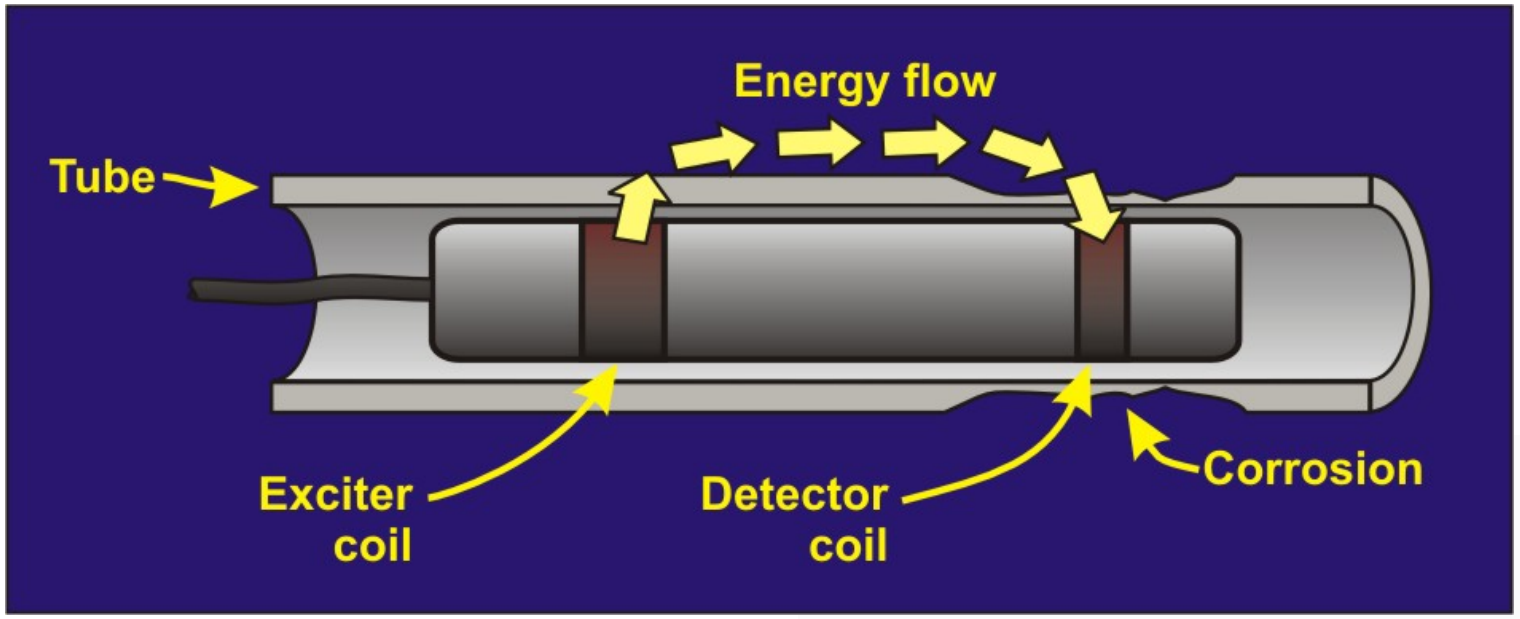




RFEC - Remote Field Eddy Current

- Internal inspection
- For metallic pipe assessment only
  - Ductile iron
  - Cast iron
  - Steel
- Detects internal & external defects equally well
  - Pits (20mm) with metal loss or cracks
- Limited by pipe lining materials
- Ultrasonic inspection used to confirm findings
- Technology developed for oil & gas pipelines

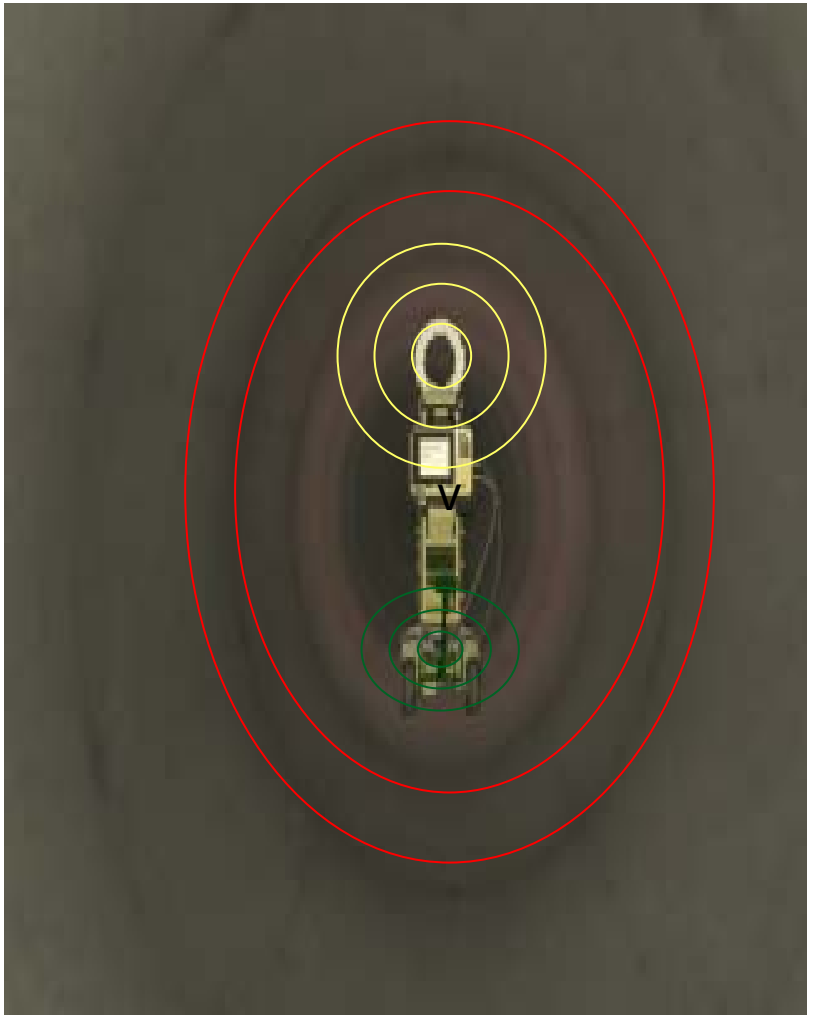
Remote Field Technology Equipment



Russell NDE Systems Inc.,

Remote Field Eddy Current Transformer Coupling (RFEC/TC) Technology

- A Technology That Utilizes Electromagnetic Waves to Evaluate Current Condition of Prestressing Wires
- Applicable for C-301 and 303 pipe (Prestressed Concrete Pipe)
- Technology Patented in 1977
- Normally Used Prior to Acoustic Monitoring to Establish Baseline.



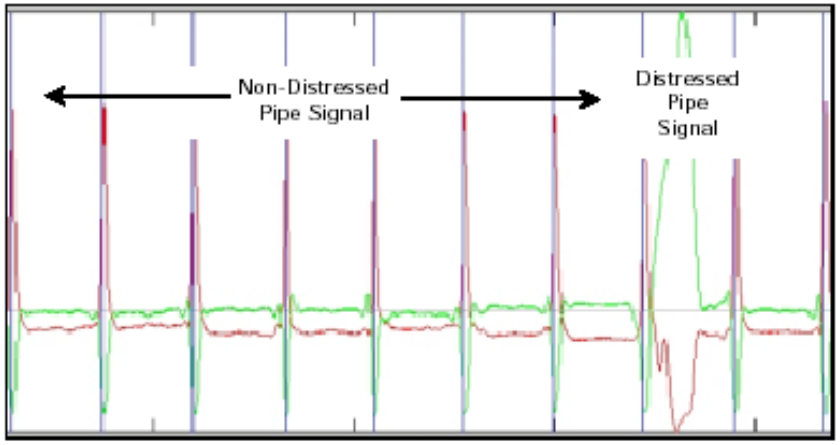
RFEC/TC Inspection Tools

20” to 60” **C301 LCP/ECP**	36” to 48” C301 LCP	48” to 60” C301 ECP	60” and up C301 ECP
Filled	Dewatered	Dewatered	Dewatered
24” manhole	20” manhole	20” manhole	24” manhole
Remote PipeCrawler	Manned PipeRider	Manned PipeWalker	Manned PipeWalker

Homestake Colorado Project

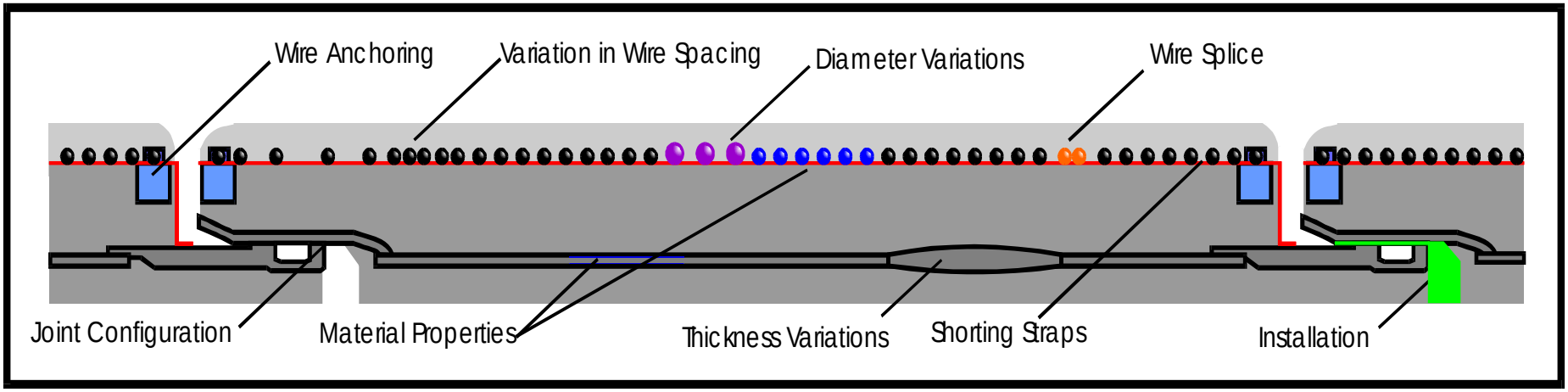
Validated Location of Distress Identified by RFEC/TC in Pipe by X-Ray

Figure 3.5 Distressed Pipe Example



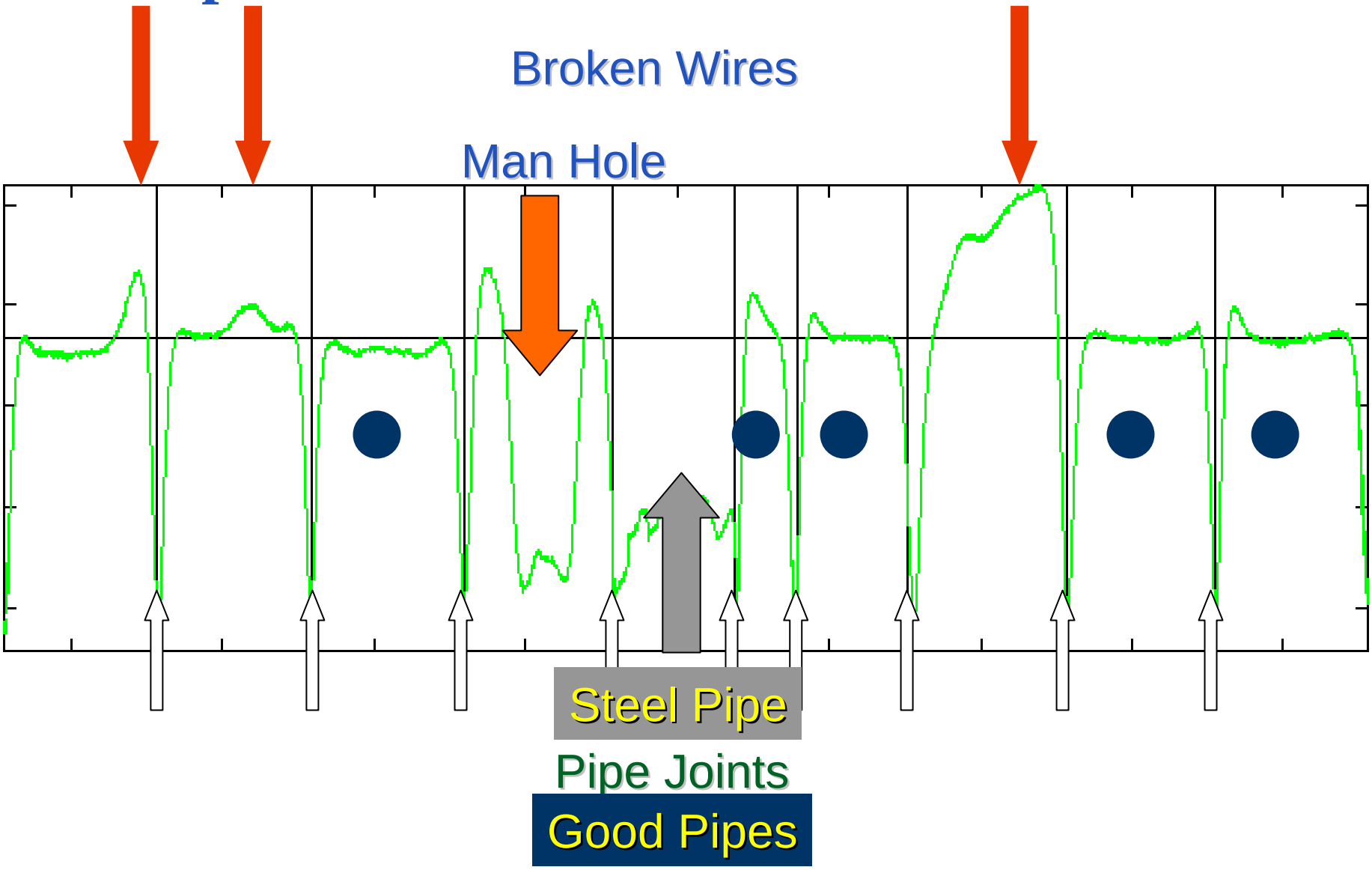
The distressed pipe in this example was referred to as Pipe #43 during the verification process, and as Pipe #165 in Table 3.4.

Factors affecting the signal



- Evaluation of Signal is Critical to Interpretation of Data and is Based on Experience
- Calibration of Equipment Provides Improved Results

Example of data

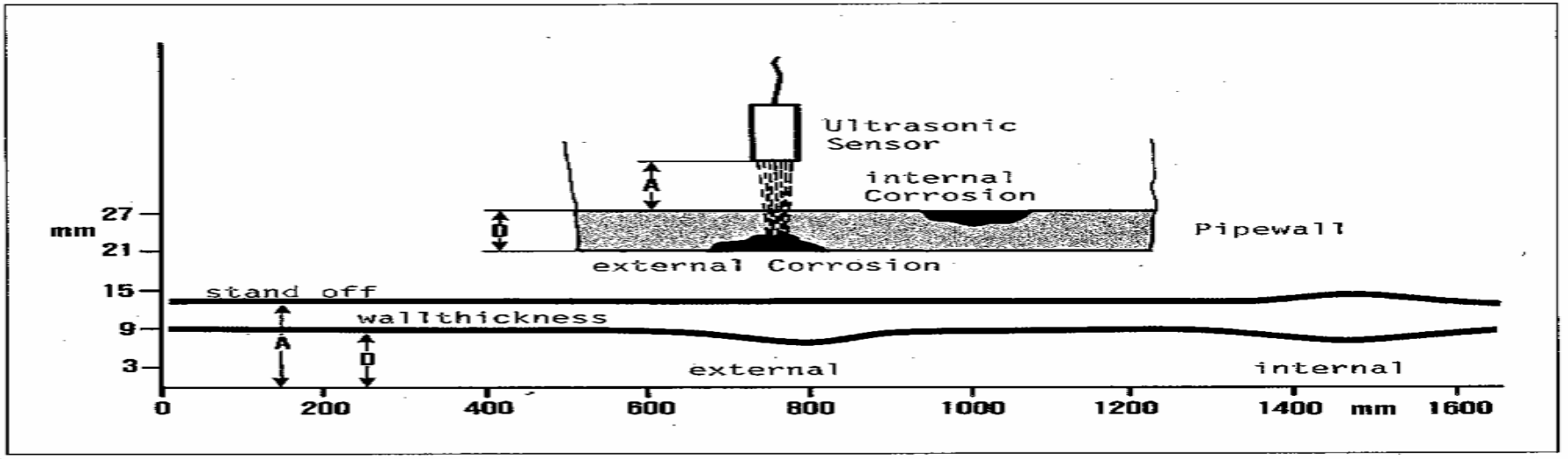



NORTHWEST PIPE

Ultrasonic Inspection Technology

- For metallic pipes
- External inspection
- Determines wall thickness
- Measures transit time of sound waves through pipe wall
- Spot measurements only
  - Must properly determine areas of likely wall loss / pitting
- Pipe wall must be very clean
  - Good contact between sensor and pipe wall required
  - Couplant normally used to improve contact
- Handheld instrument

Ultrasonic Thickness Technology



Ultrasonic Techniques

G-Scan

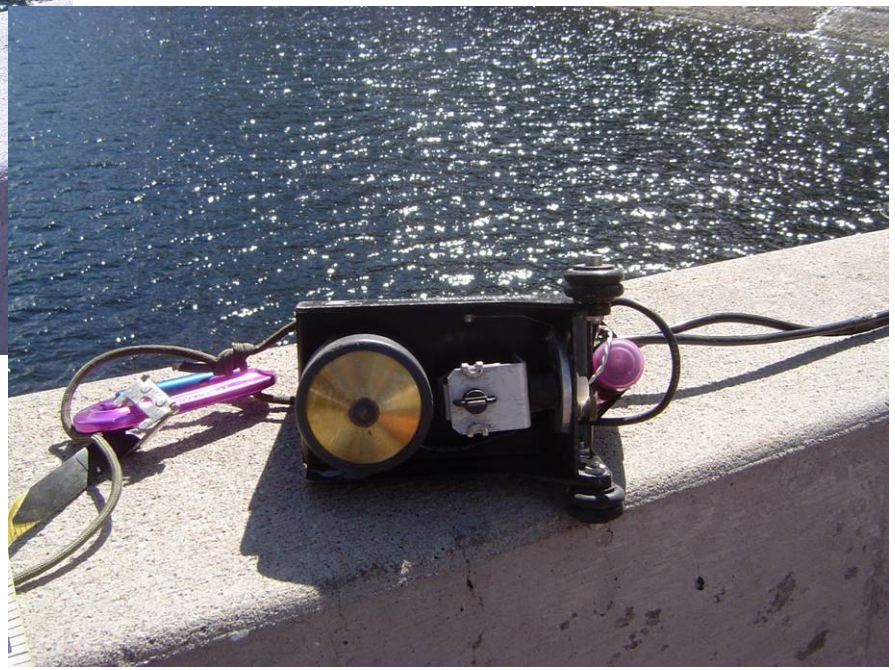
Inspect up to
260 feet

B-Scan

Fast & Portable

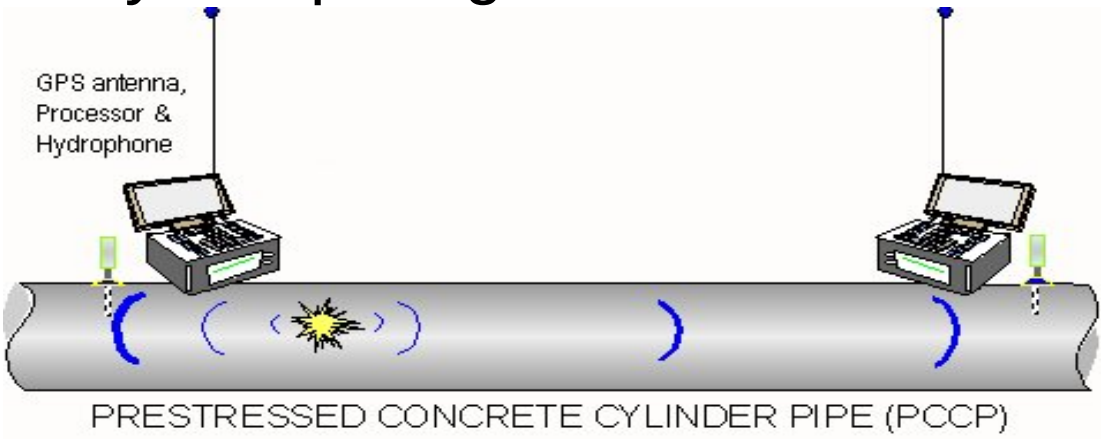
Structural Integrity Associates, Inc.

Impact Echo Testing – Concrete Lining or Pipe

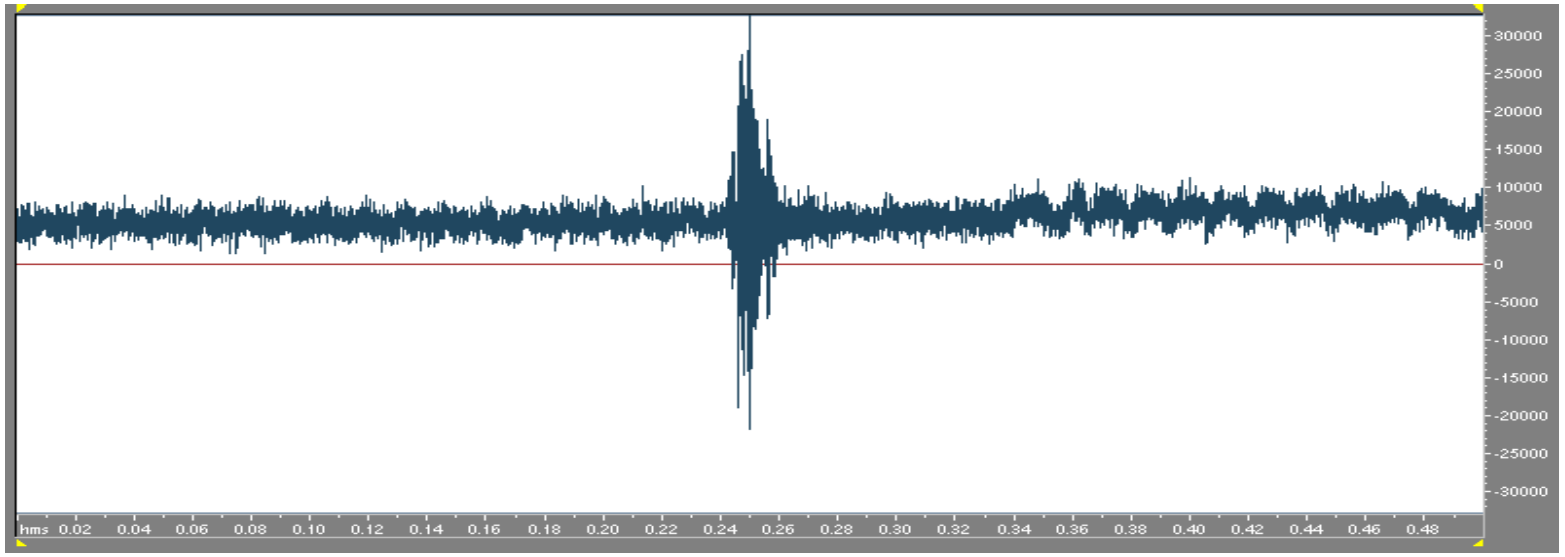


Acoustic Emission Technology - AET

- Prestressing wire breaks or releases tension (slips) generating acoustic energy
- Energy propagates into water in pipeline
- Wire-related transient has unique acoustic signature that is detected as it passes the temporarily installed hydrophone
- Origin is determined by comparing arrival times at each site

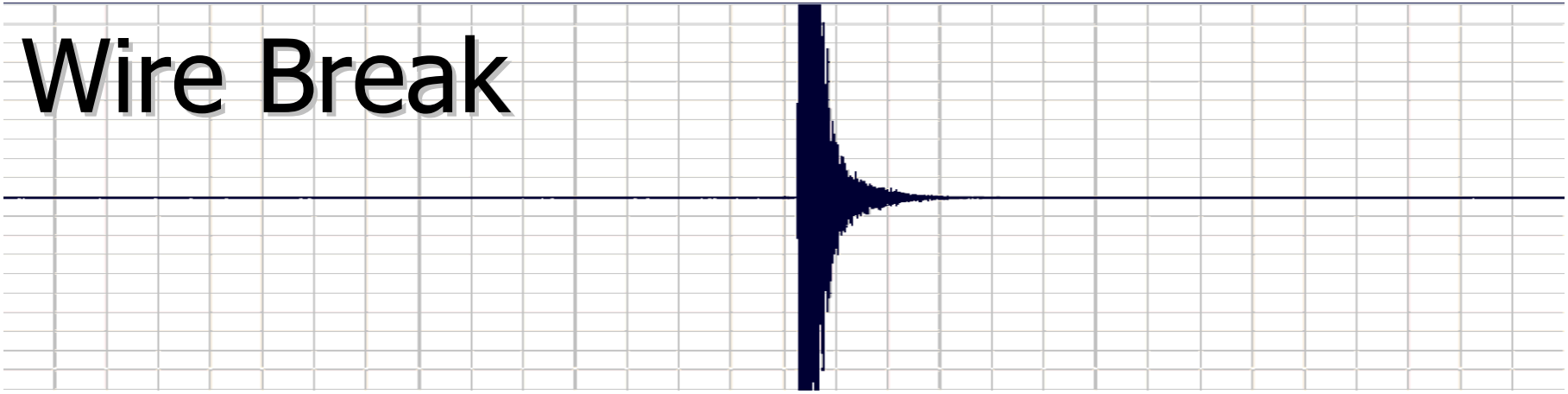


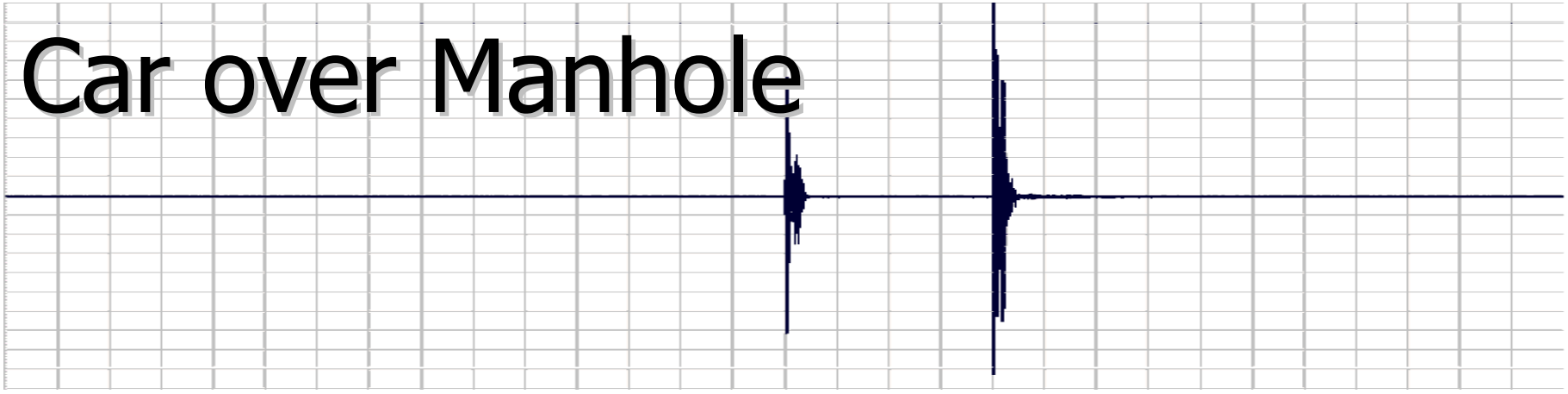
Acoustic Emission Technology - AET



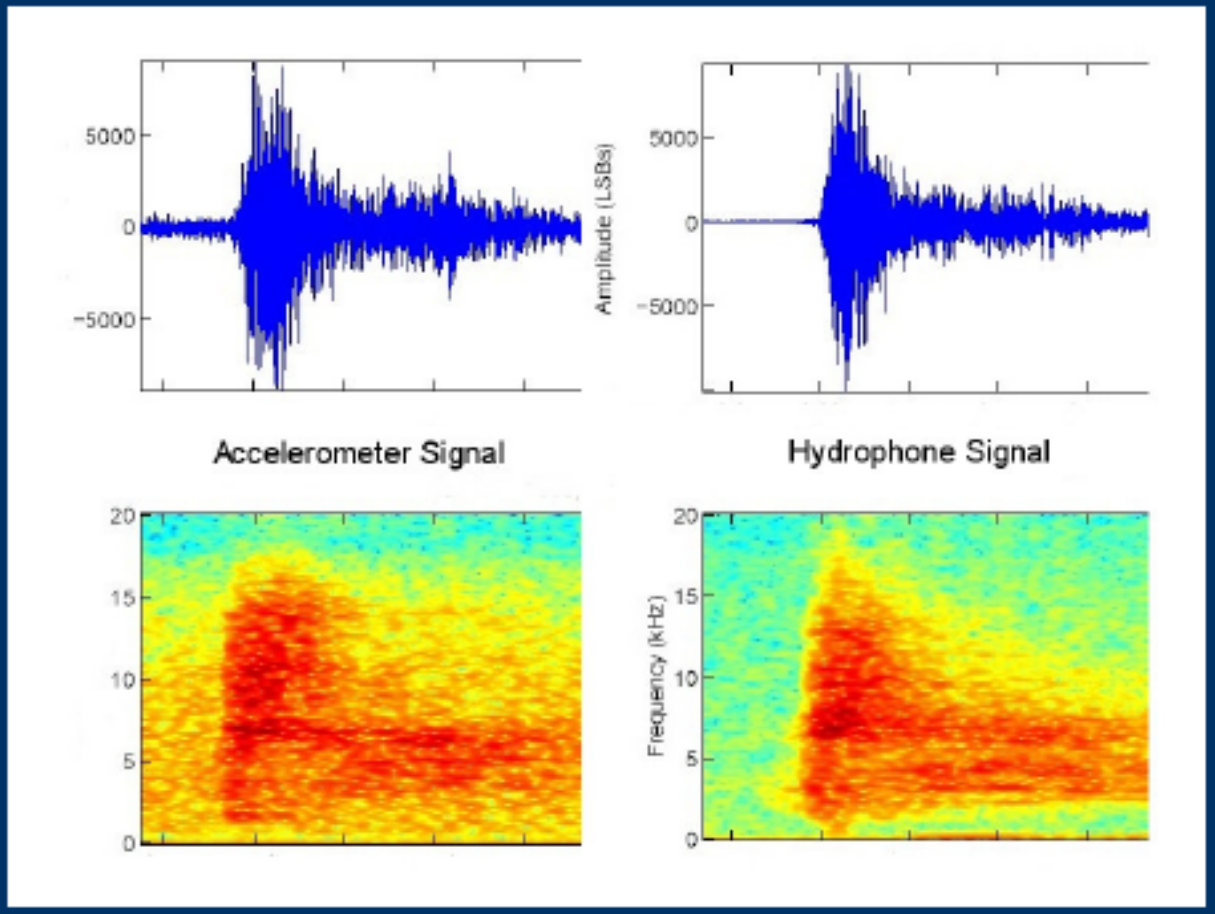
AET detects areas of active deterioration by measuring the frequency and number of distress-related acoustic events that occur along the monitored PCCP pipe section over a defined period of time.

AET - Comparison of Acoustic Events





Characteristics of Broken Wire Signal



- Sharp transient
- Broad band
- Frequency up to 40 kHz and above
- Signal length 15 to 75 milliseconds
- Can be detected up to 2500’

the Pressure Pipe Inspection Company Ltd.

AET Installations (Hydrophone sensors)

AET Installations (Accelerometers)

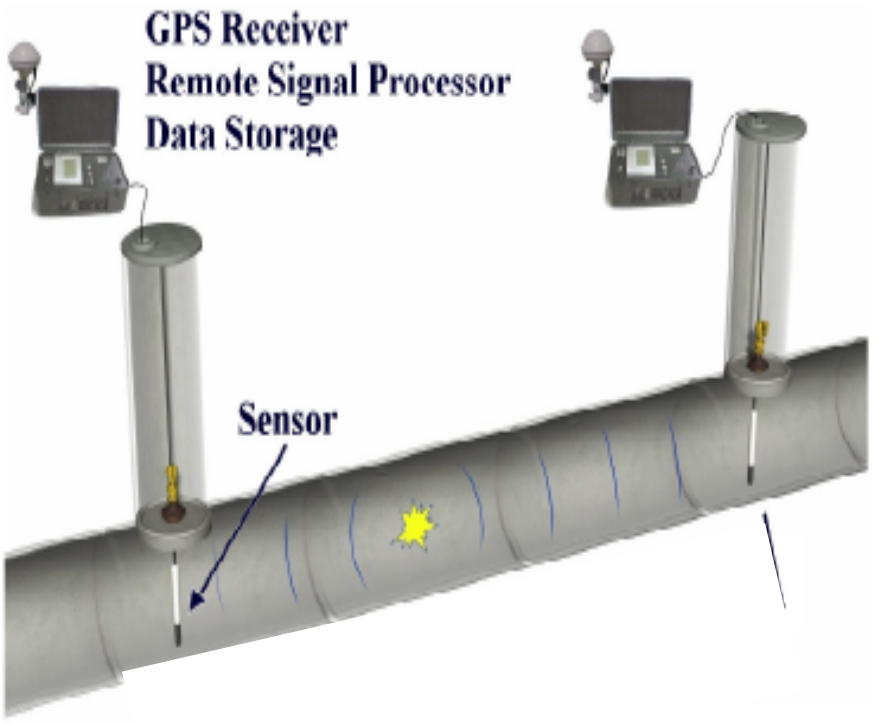
the Pressure Pipe Inspection Company Ltd.

AET - Accelerometers vs Hydrophones

- Hydrophone advantages:
  - Higher frequency response
  - Lower noise level
  - Built in pre-amp
- Accelerometer advantages:
  - Easy and inexpensive to install
  - Few restrictions on sensor location
  - Not subject to nuisance mechanical noises

AET Acoustic Emission Testing System

- Pipeline remains operational during installation and monitoring
- PPIC's AH System can monitor anywhere from ¼ mile to 10+ miles at anytime, installed between 500' and 2000' apart.
- The AET System operates regardless of internal obstacles (butterfly valves, etc)



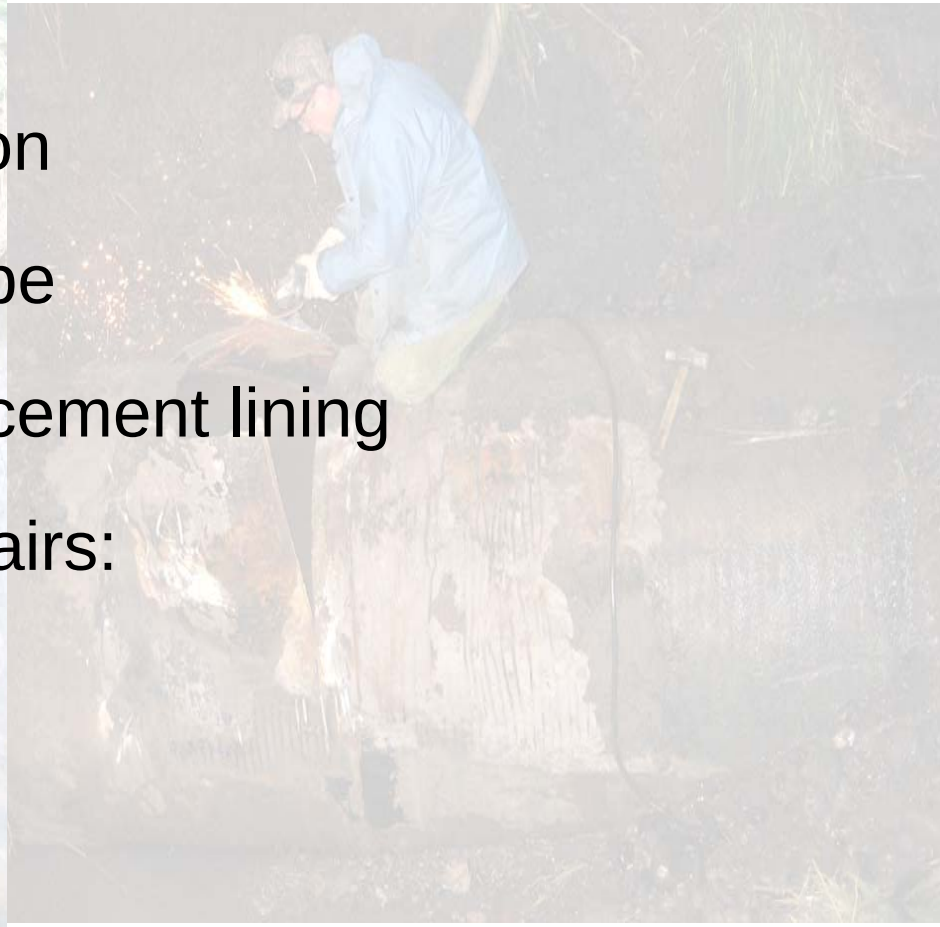
AET - An indication of condition

- What happens before or after the listening period?
- A ‘snapshot’ in time only
- No noise does not mean no distress
- Noise is an indicator of wire breaks or movement of wire
- Remember:
  - **96% of pipe has no distress**
  - **We are trying to identify the other 4%**
- Specific location for short period
  - acoustic activity warrants further investigation
- Cover an entire pipeline in rolling segments
- Construction damage monitoring
- Useful tool when used in conjunction with RFEC/TC baseline

Cathodic Investigation

- Soil corrosivity tests
- Over-the-line corrosion survey
  - Induced current
  - Pipe to soil measurements taken along pipe
  - Field conditions recorded
  - Data analyzed
- Used to locate pipe reaches for further investigation

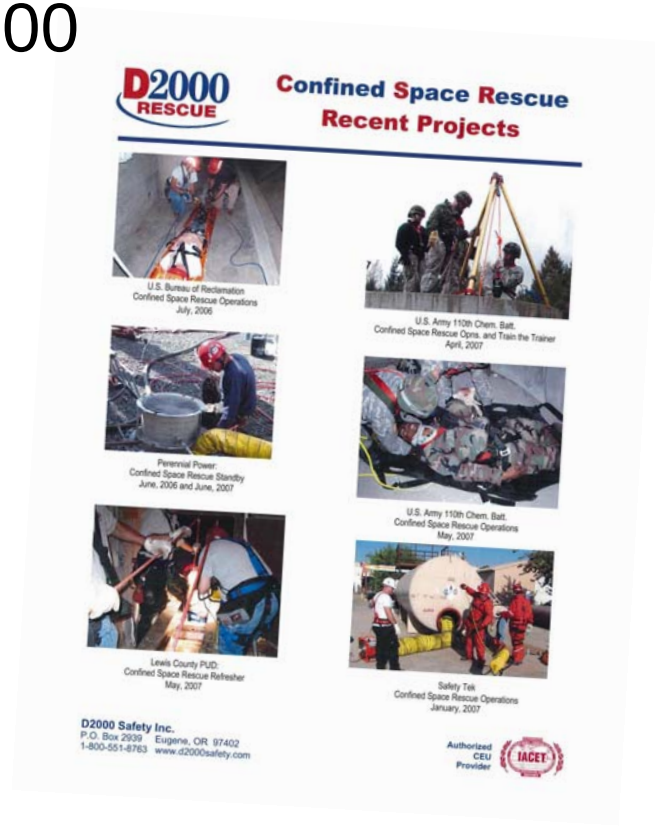
Transmission Line 2 Condition Assessment



- Confirm opinion for corrosion
- Inspect interior of PCCP pipe
  - Observe areas of failed cement lining
- Determine CIP plan for repairs:
  - Cost
  - Schedule

Assessment Alternatives – Pipe Entry

- Entry into pipe:
  - Confined space entry – $75,000 to $100,000
  - Dive team - $130,000 to $150,000
- Not selected:
  - Safety risk
  - Required most access points
  - Operational contraints



Assessment Alternatives – RFEC/TC

- Entry using remote operated vehicle
- Provides data on pipe condition including wires
- Limited to about 2,500 to 3,000 feet between entry points
- Cost $290,000 or higher
- Not selected - cost / benefit – too much information

Assessment Alternatives – CCTV

- High quality picture
  - Add GPR to provide pipe cylinder information
- ROV limited to 2,500 to 3,000 feet between entry points
- ROV limited by slope and traction
- Pipe will be drained – with water standing in low points
- Cost - $125,000 to $175,000
- Selected for cost / benefit

Comments & Questions

Salem, Oregon

Chicago, Illinois

Denver, Colorado