

# Comparative Analysis of Defect Leakage Rates at Geomembrane-Lined Cover Systems in the Sydney Coalfield

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Public Services and  
Procurement Canada

*BC MEND MLARD Workshop*

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Western



# Outline

- Background
- Defect Leakage Rates at 'In-Service' WRPs
- Detection of Defects at WRPs

# Background

- **Design Functions of Cover Systems**
  - Waste isolation ('keep clean water clean')
  - Re-establish vegetation and ecosystems
  - Control wind and water erosion of waste material
  - Limit influx of oxygen to reactive waste material
  - Limit net percolation of meteoric water through the waste

# Background

Defects in geomembrane liners

***“All liners leak”***

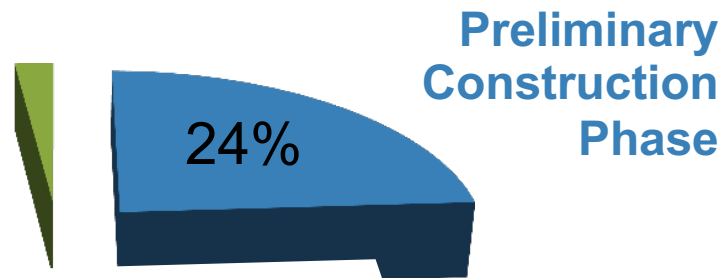
*J.P. Giroud*



# Background

Occurrence of liner defects

**Survey Data - Liner Defect  
Occurrence, Nosko (1996)**



# Background

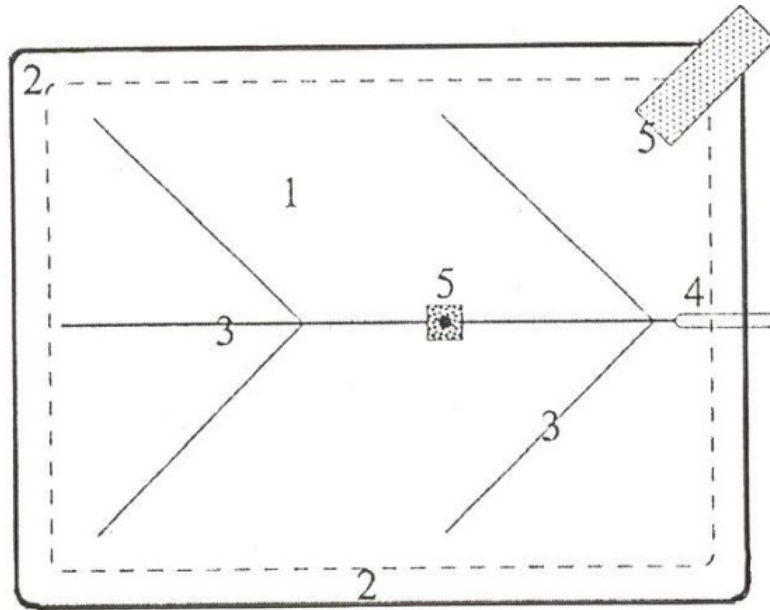
## Occurrence of liner defects

|                       | <i>Exposed HDPe Geomembranes<br/>(Water Puddle)</i>                                             |                           | <i>Covered HDPe Geomembranes<br/>(Dipole)</i>                         |                                                                          |
|-----------------------|-------------------------------------------------------------------------------------------------|---------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|
|                       | Column 1                                                                                        | Column 2                  | Column 3                                                              | Column 4                                                                 |
| Geomembrane Thickness | With CQA                                                                                        | Without CQA               | With CQA and geoelectrical leak survey (water puddle) before covering | Without CQA nor geoelectrical leak survey (water puddle) before covering |
|                       | <b>Number of leaks per hectare (prospected area m<sup>2</sup>) –quantity of site prospected</b> |                           |                                                                       |                                                                          |
| 2.0 mm                | <b>3.2</b> (362 460) – 32                                                                       | No data                   | <b>0.2</b> (170 190) - 16                                             | <b>15.6</b> (50 600) - 3                                                 |
| 1.5 mm                | <b>5.1</b> (66 880) - 4                                                                         | No data                   | No data                                                               | <b>24.7</b> (10 500) - 3                                                 |
| 1.0 mm                | <b>20.5</b> (17 070) - 2                                                                        | <b>31.5</b> (313 770) - 6 | No data                                                               | No data                                                                  |

Forget et al. (2005)

# Background

## Occurrence of liner defects



Notes:

1 = flat floor

2 = corners and edges

3 = under drainage pipes

4 = pipe penetrations

5 = other (access roads, temporary storage, concrete structures)

| No. of Holes | Flat Floor (1) | Corners and Edges (2) | Under Drainage Pipes (3) | Pipe Penetrations (4) | Other (5)   |
|--------------|----------------|-----------------------|--------------------------|-----------------------|-------------|
| 4194<br>100% | 3261<br>77.8%  | 395<br>9.4%           | 165<br>3.9%              | 84<br>2.0%            | 289<br>6.9% |

# Background

## Occurrence of liner defects

| Size of Holes<br>(cm <sup>2</sup> ) | Stones | %    | Heavy Equip. | %    | Welds | %    | Cuts  | %    | Worker Directly | %    | Total |
|-------------------------------------|--------|------|--------------|------|-------|------|-------|------|-----------------|------|-------|
| <0.5                                | 332    | 11.1 | -            | -    | 115   | 43.4 | 5     | 8.5  | 195             | -    | 452   |
| 0.5-2.0                             | 1720   | 57.6 | 41           | 6.3  | 105   | 39.6 | 36    | 61.0 | 105             | 84.4 | 2097  |
| 2.0-10                              | 843    | 28.2 | 117          | 17.9 | 30    | 11.3 | 18    | 30.5 | 36              | 15.6 | 1044  |
| >10                                 | 90     | 3.0  | 496          | 75.8 | 15    | 5.7  | -     | -    | -               | -    | 601   |
| Amount                              | 2985   |      | 654          |      | 265   |      | 59    |      | 231             |      | 4194  |
| Total                               | 71.17% |      | 15.59%       |      | 6.32% |      | 1.41% |      | 5.51%           |      | 100%  |

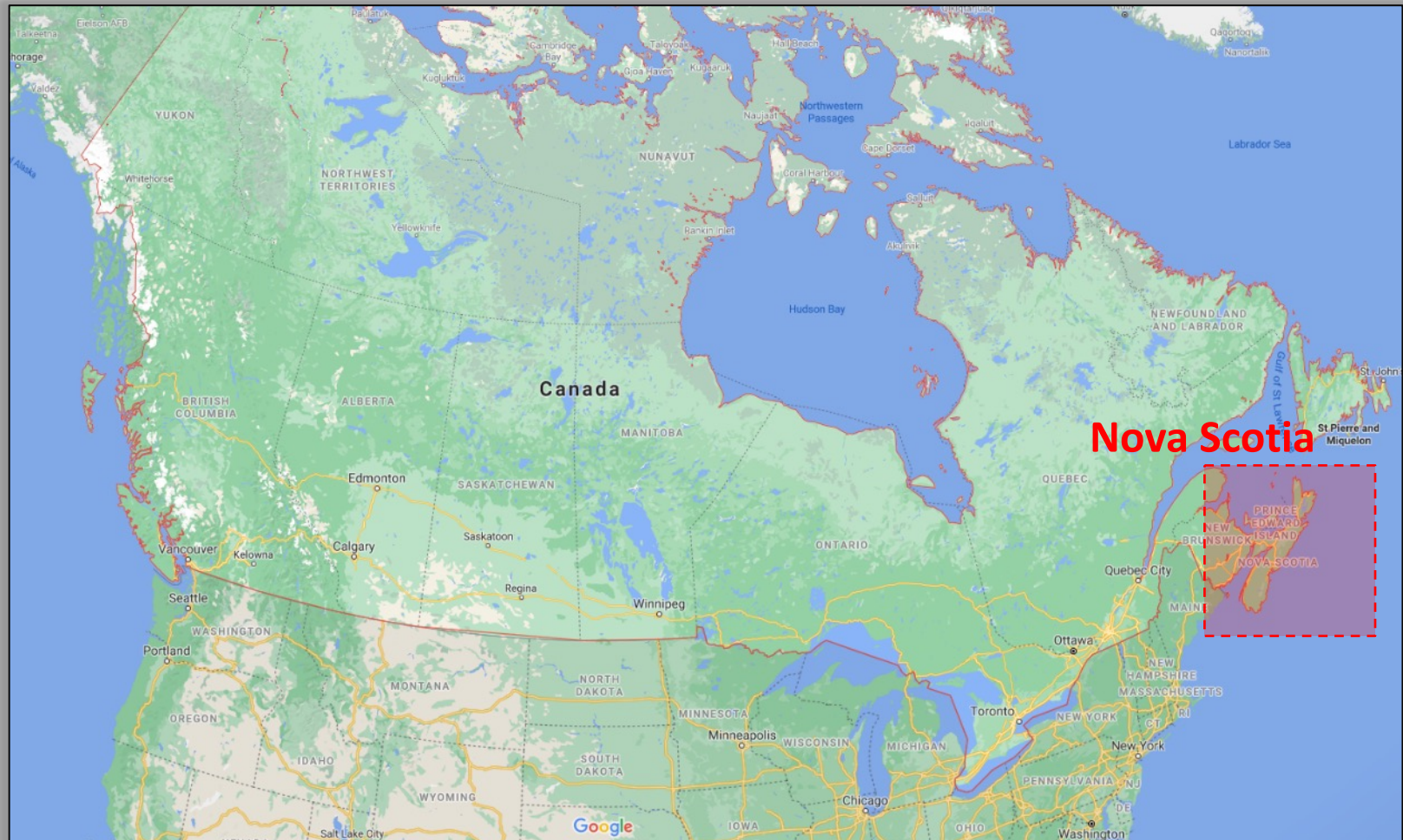
*Noski and Touze-Foltz (2000)*

# Outline

- Background
- Defect Leakage Rates at 'In-Service' WRPs
- Detection of Defects at WRPs

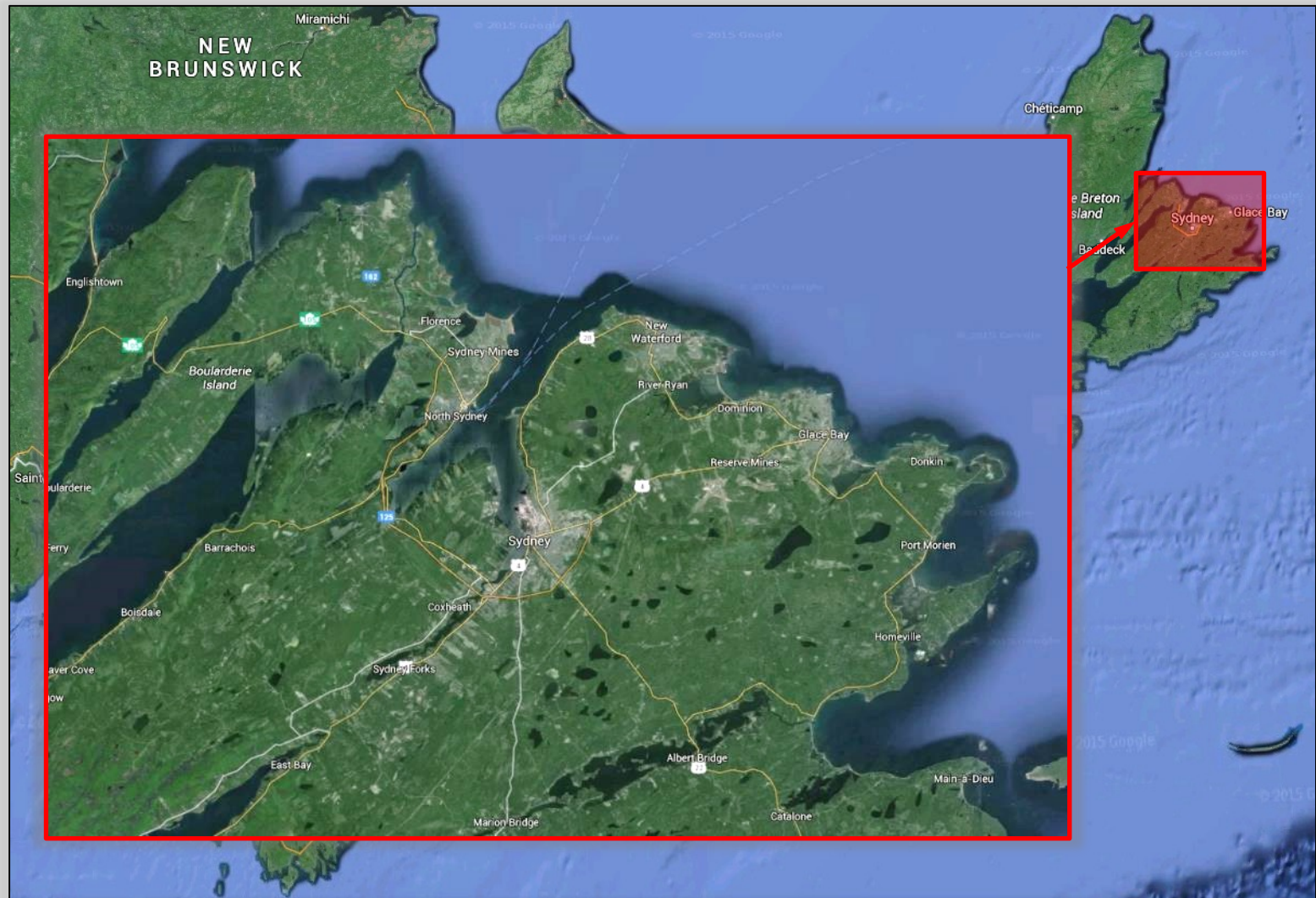
# Defect Leakage Rates

## The Sydney Coalfield, NS, Canada



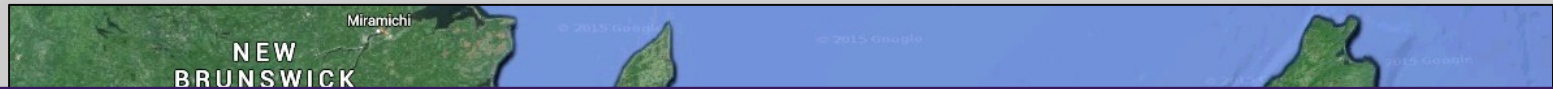
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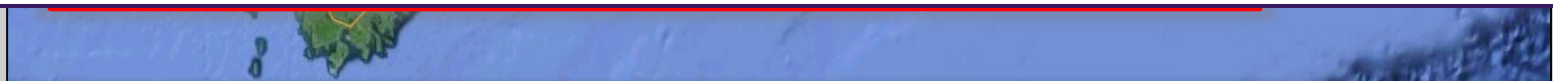
# Defect Leakage Rates

The Sydney Coalfield, NS, Canada



## Mine Site Closure and Reclamation Program

- 2011-2012: mine site closure and reclamation program
- Cost \$200+ million
- 10 legacy mine waste rock piles were overlain with engineered covers, including 7 with geomembrane liners
- Cover system performance monitoring



# Defect Leakage Rates

The Sydney Coalfield, NS, Canada



# Defect Leakage Rates

## Scotchtown Summit

- 2.5 million tonnes of fill/waste rock
- Footprint of 370,000 m<sup>2</sup>
- Thickness range from 1.4 m to 10 m
- Cover installed in 2011

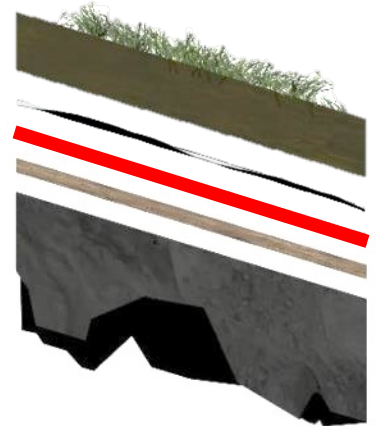
Growth Medium

Geotextile

**HDPE**

Bedding Sand

Waste Rock



# Defect Leakage Rates

The Sydney Coalfield, NS, Canada

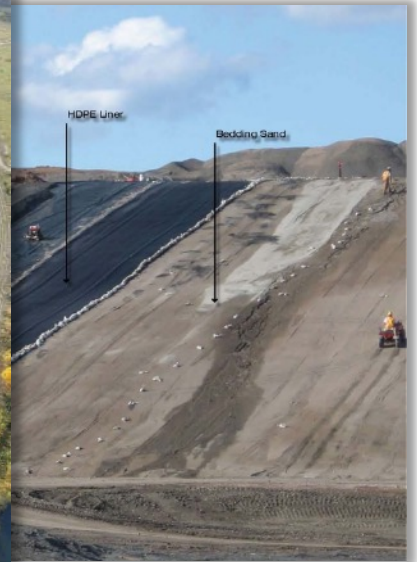
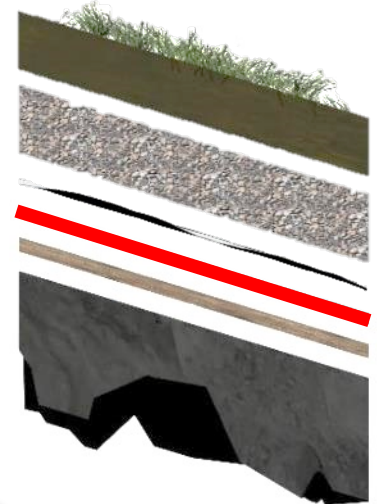


# Defect Leakage Rates

## Victoria Junction

- 10 million tonnes of fill/waste rock
- Footprint of 260,000 m<sup>2</sup>
- Waste rock height = 40 m
- Cover installed in 2007

Growth Medium  
Drainage Layer  
Geotextile  
**HDPE**  
Bedding Sand  
Waste Rock



# Defect Leakage Rates

The Sydney Coalfield, NS, Canada

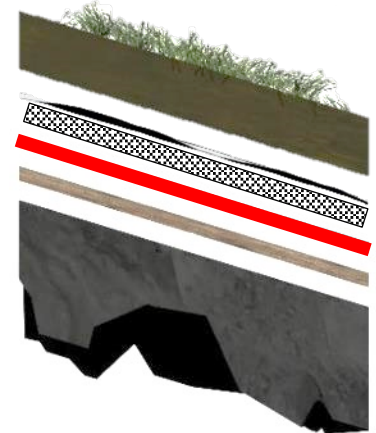


# Defect Leakage Rates

## Franklin

- 319,005 tonnes of fill/waste rock
- Footprint of 31,000 m<sup>2</sup>
- Thickness at center = 11 m
- Cover installed in 2010

Growth Medium  
Drainage Layer  
Geotextile  
**HDPE**  
Bedding Sand  
Waste Rock

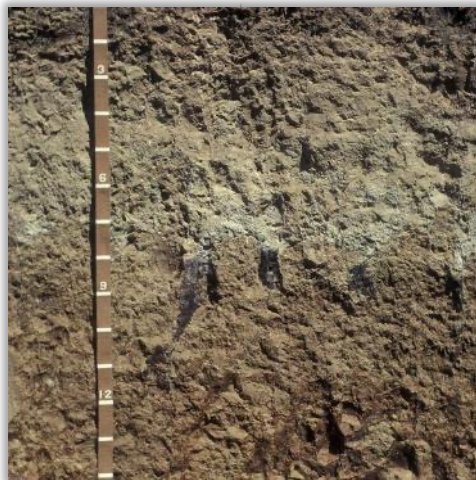


# Defect Leakage Rates

## Comparison of Cover Systems

- Different drainage options to influence head of water above the geomembrane liner

**NO DRAINAGE**



**Scotchtown Summit**

**NATURAL GRAVEL**



**Franklin**

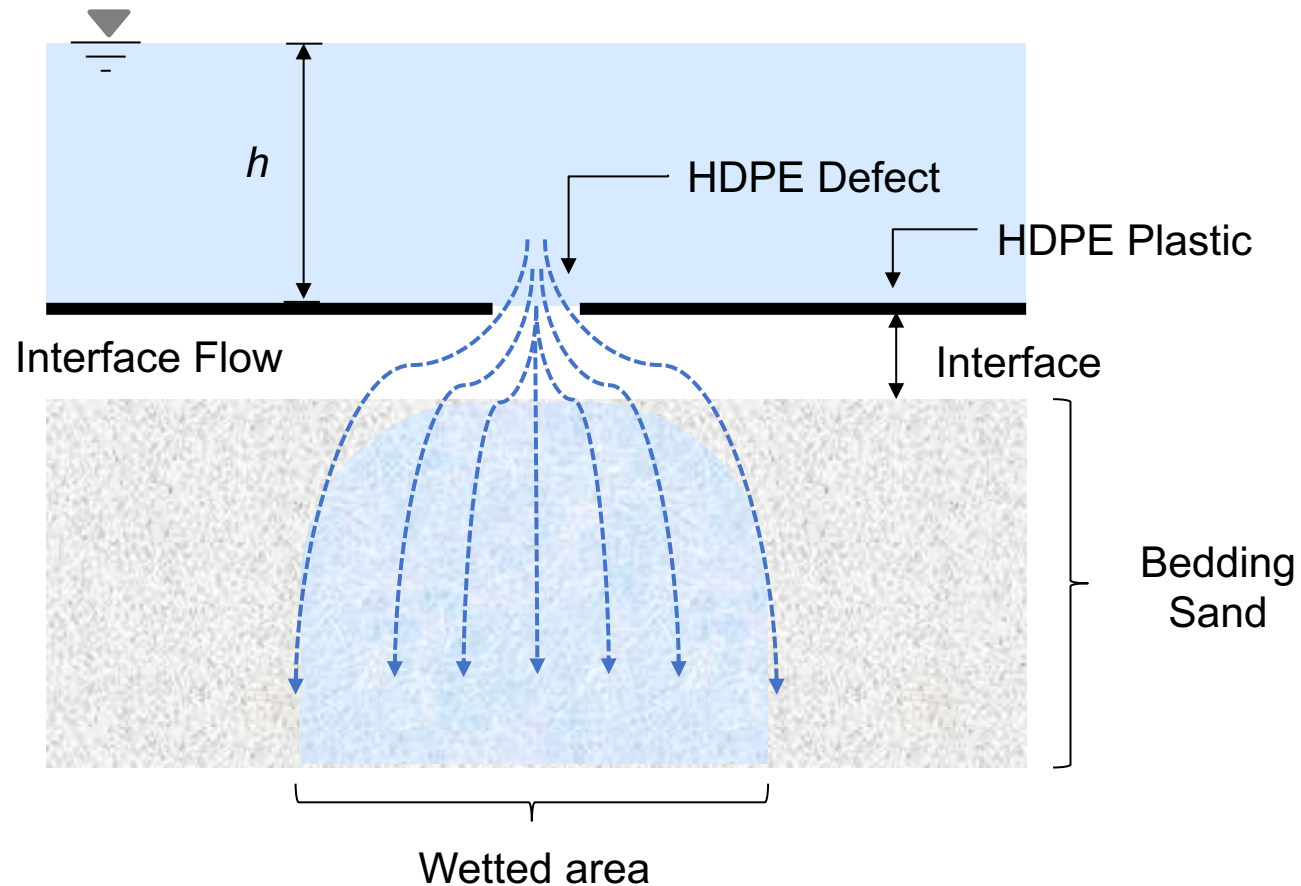
**GEOCOMPOSITE**



**Victoria Junction**

# Defect Leakage Rates

Estimates of defect leakage rates



*Modified from Touze-Foltz & Giroud, 2003*

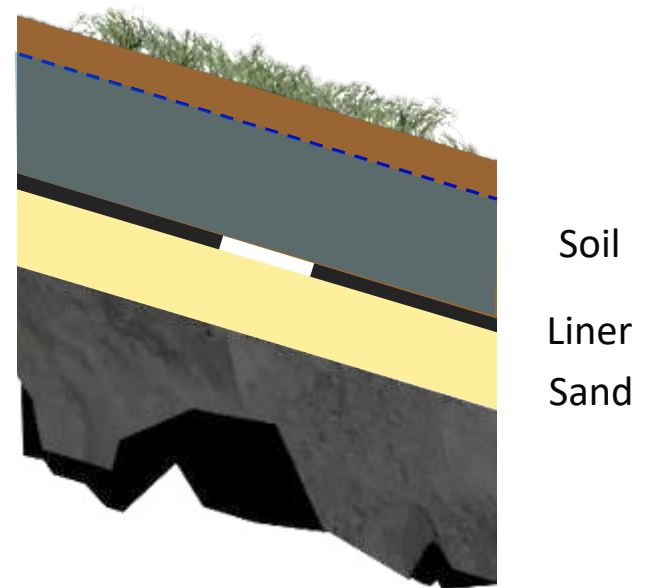
# Defect Leakage Rates

Estimates of defect leakage rates

## Leakage through Liner

$$Q = C_{qo} \cdot A^{0.1} \cdot h^{0.9} \cdot K_{sat}^{0.74}$$

*Giroud et al. (1992)*



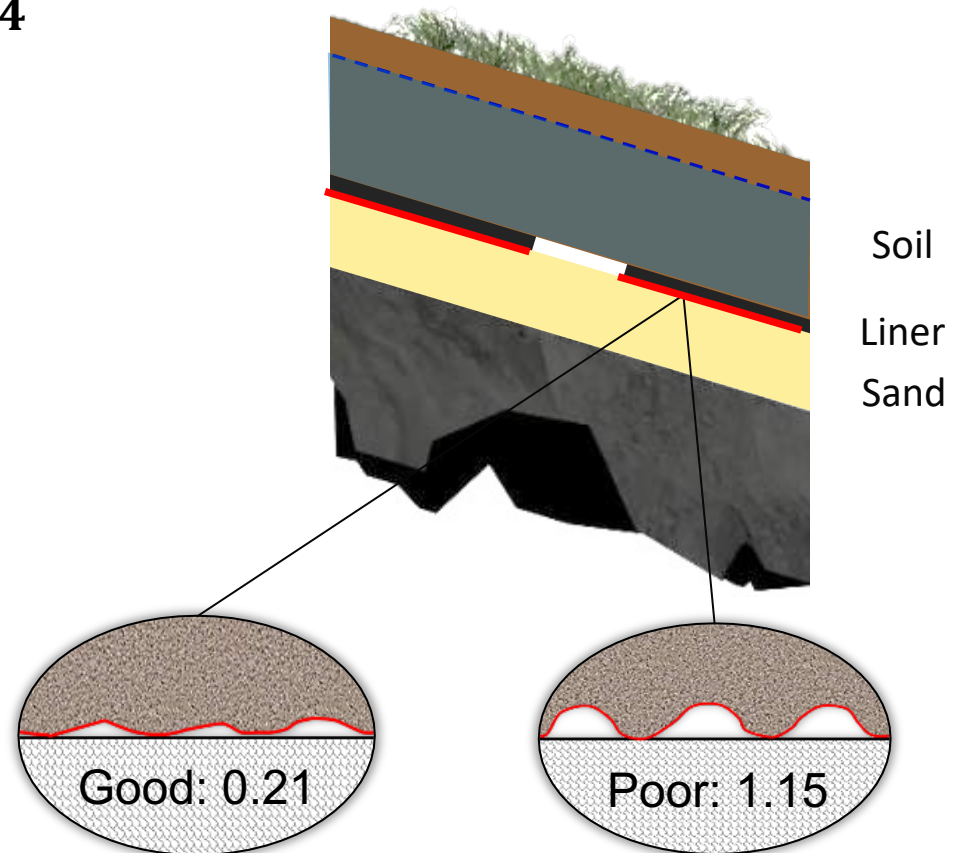
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$C_{qo}$  contact quality factor (-)  
[0.27 to 1.21]



# Defect Leakage Rates

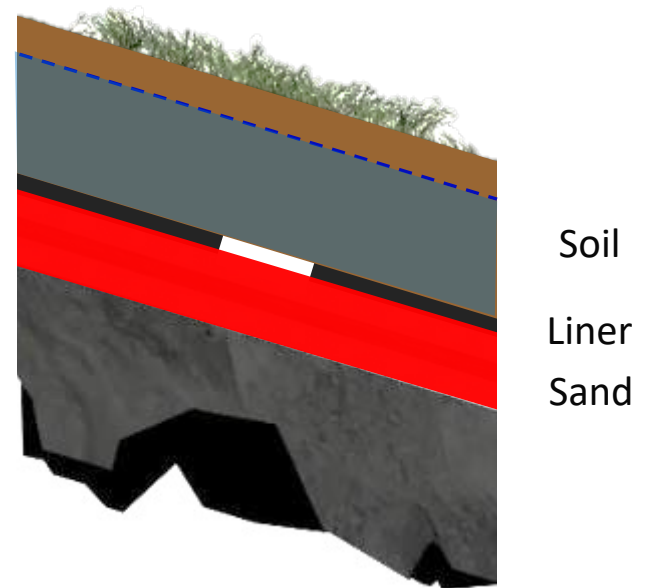
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[0.27 to 1.21]

$K_{sat}$  saturated K of sand (m/s)  
[measured]



# Defect Leakage Rates

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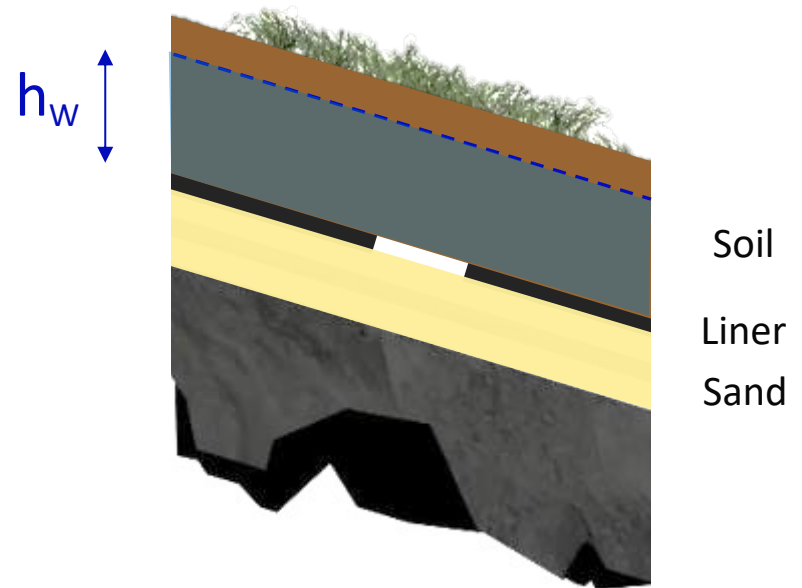
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$h_w$  water pressure head (m)  
[HOBO water logger]



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Estimates of defect leakage rates

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$C_{qo}$  contact quality factor (-)  
[0.27 to 1.21]

$K_{sat}$  saturated K of sand (m/s)  
[measured]

$h_w$  water pressure head (m)  
[HOBO water logger]

$A$  area of the defect (m<sup>2</sup>)  
[assumed]



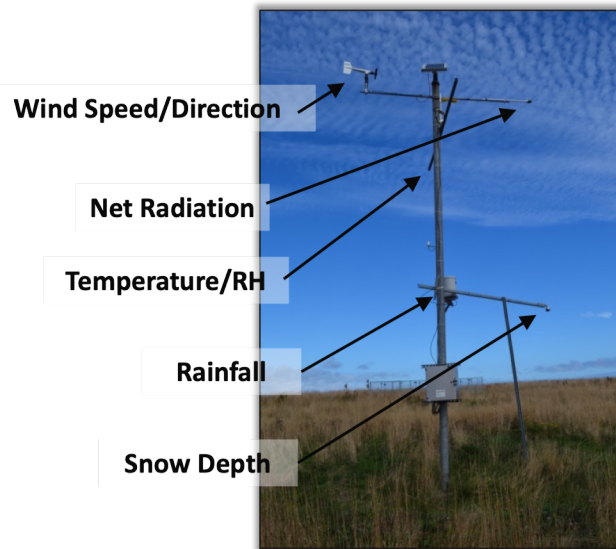
### Industry Assumption

*Defect size = 1 cm<sup>2</sup> circle  
15 – 20 defects per hectare*

# Defect Leakage Rates

Key monitoring parameters:

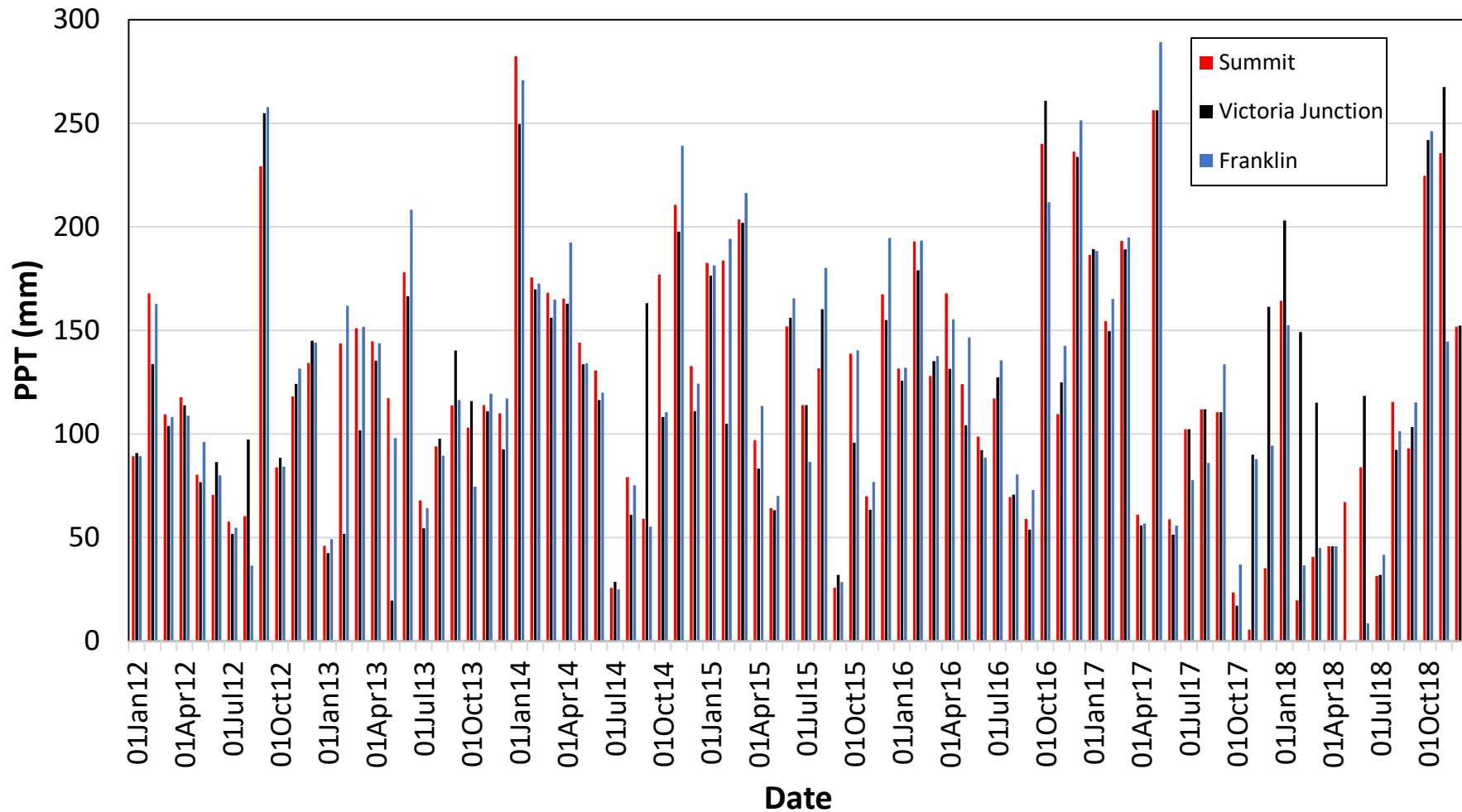
## Weather Station



**Precipitation (PPT)**

# Defect Leakage Rates

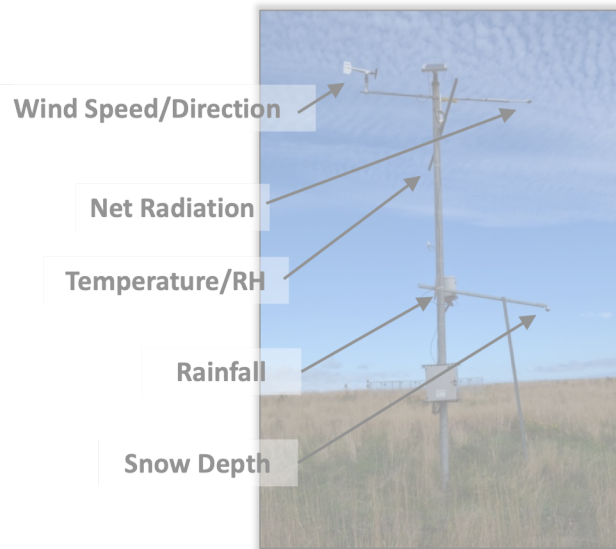
Key monitoring parameters:



# Defect Leakage Rates

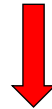
Key monitoring parameters:

## Weather Station



**Precipitation (PPT)**

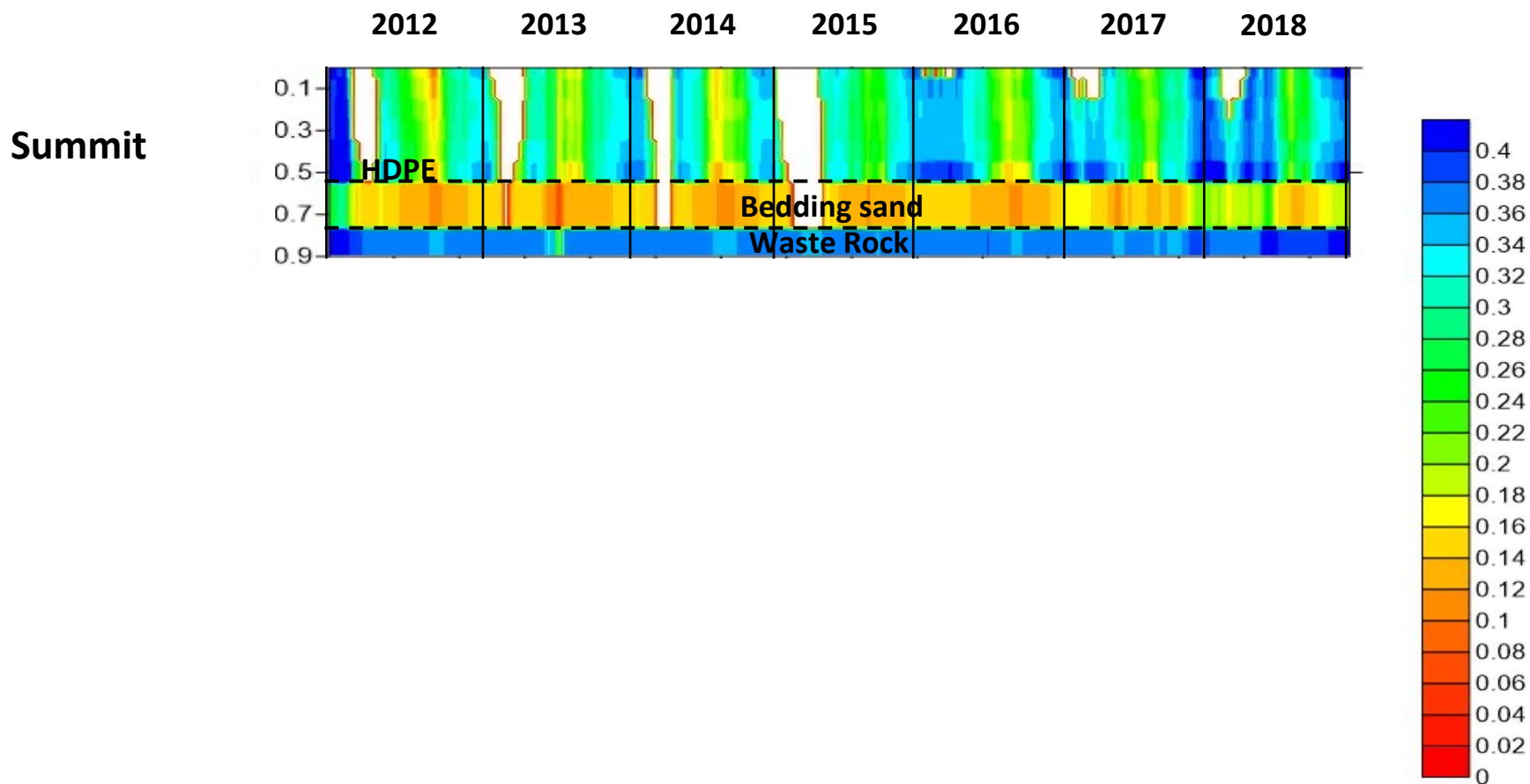
## Moisture Sensors



**Moisture Content**

# Defect Leakage Rates

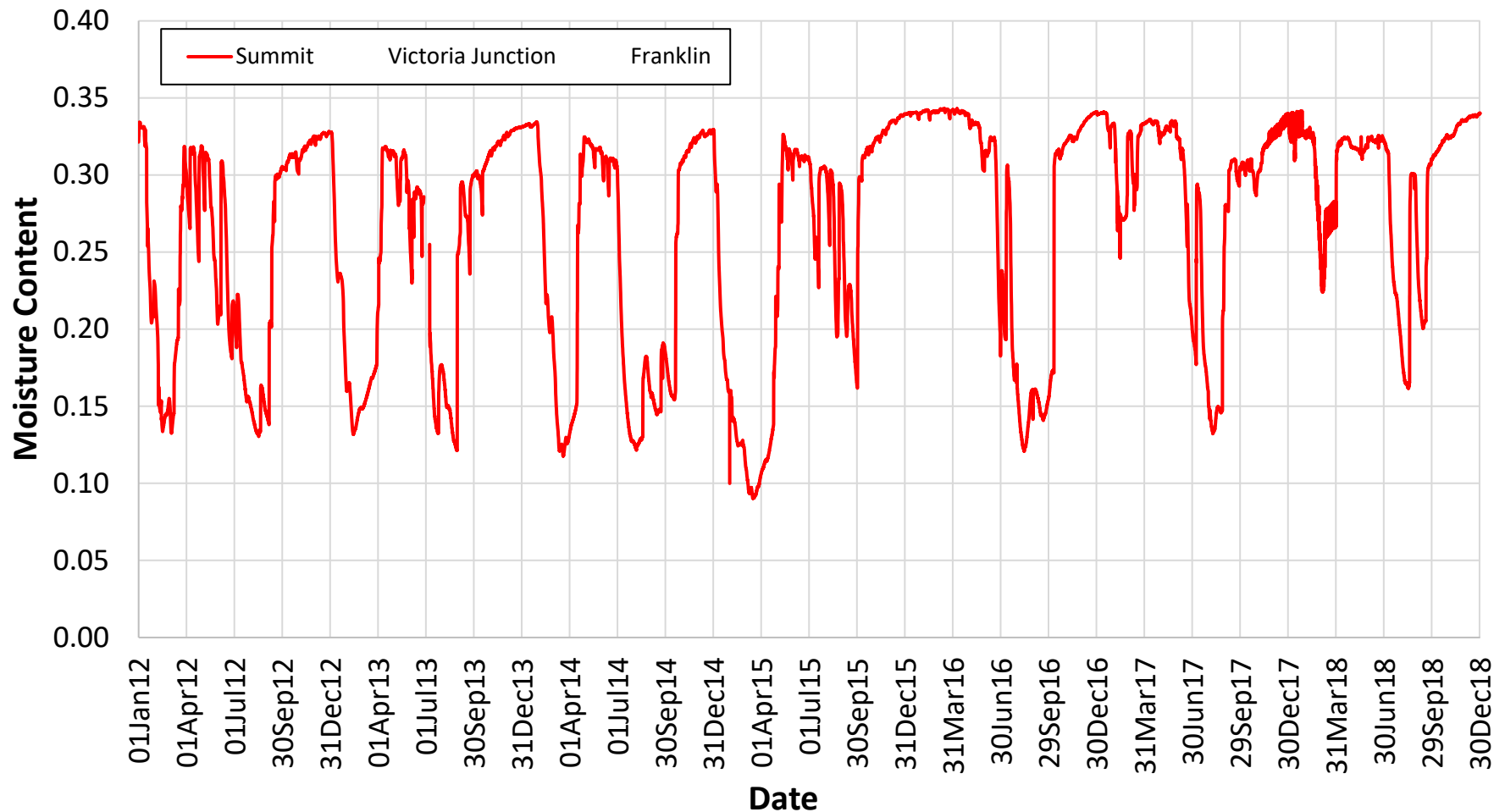
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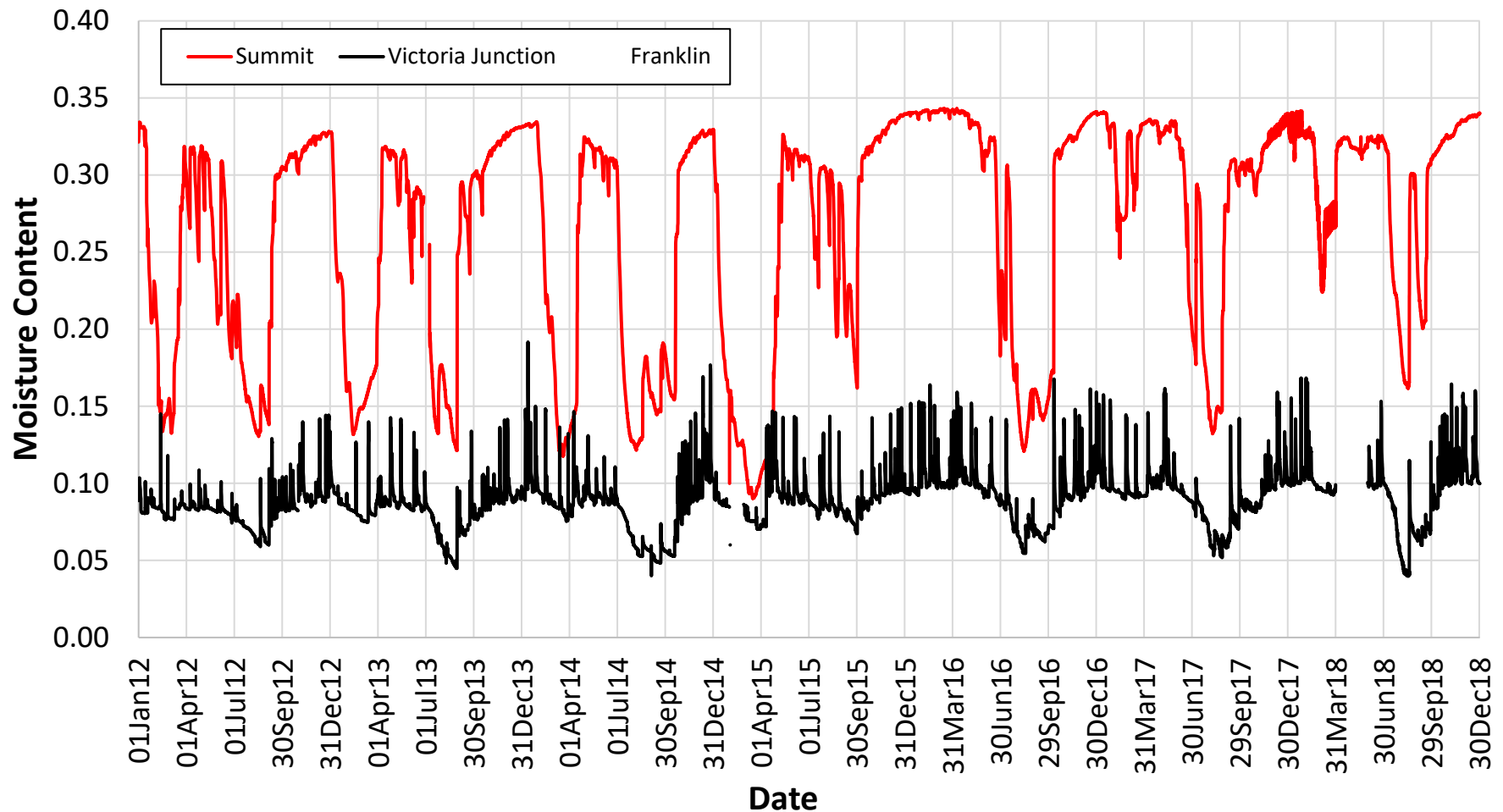
## Moisture Content Above Liner



# Defect Leakage Rates

Key monitoring parameters:

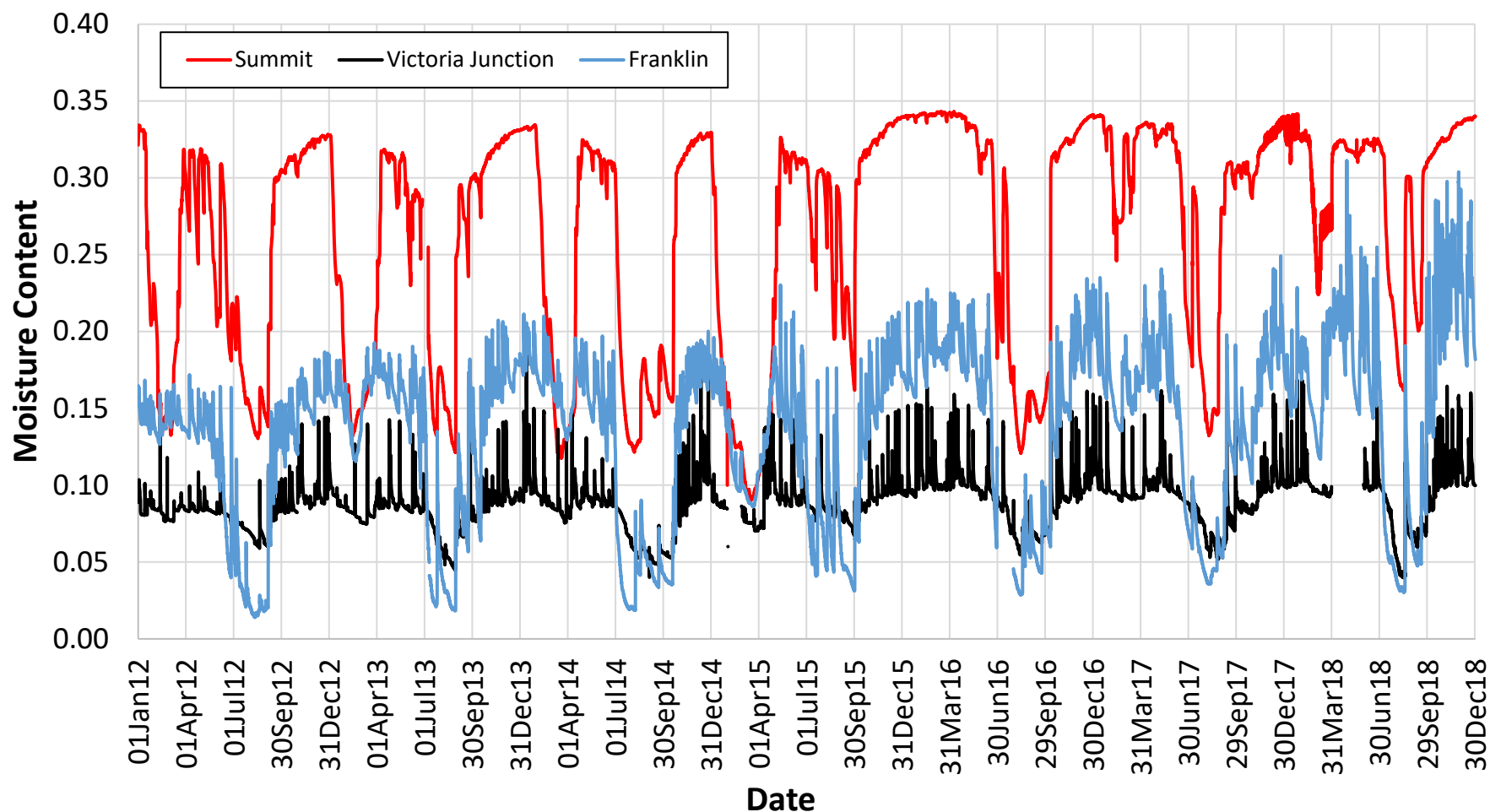
**Moisture Content Above Liner**



# Defect Leakage Rates

Key monitoring parameters:

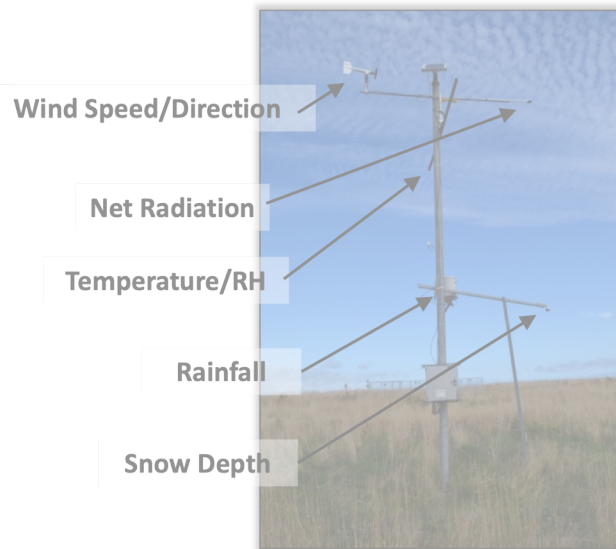
**Moisture Content Above Liner**



# Defect Leakage Rates

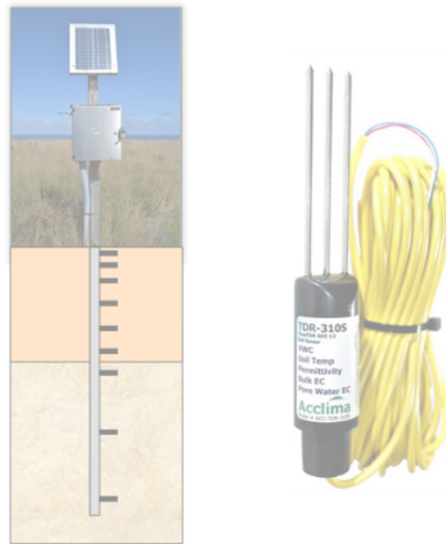
Key monitoring parameters:

## Weather Station



Precipitation (PPT)

## Moisture Sensors



Moisture Content

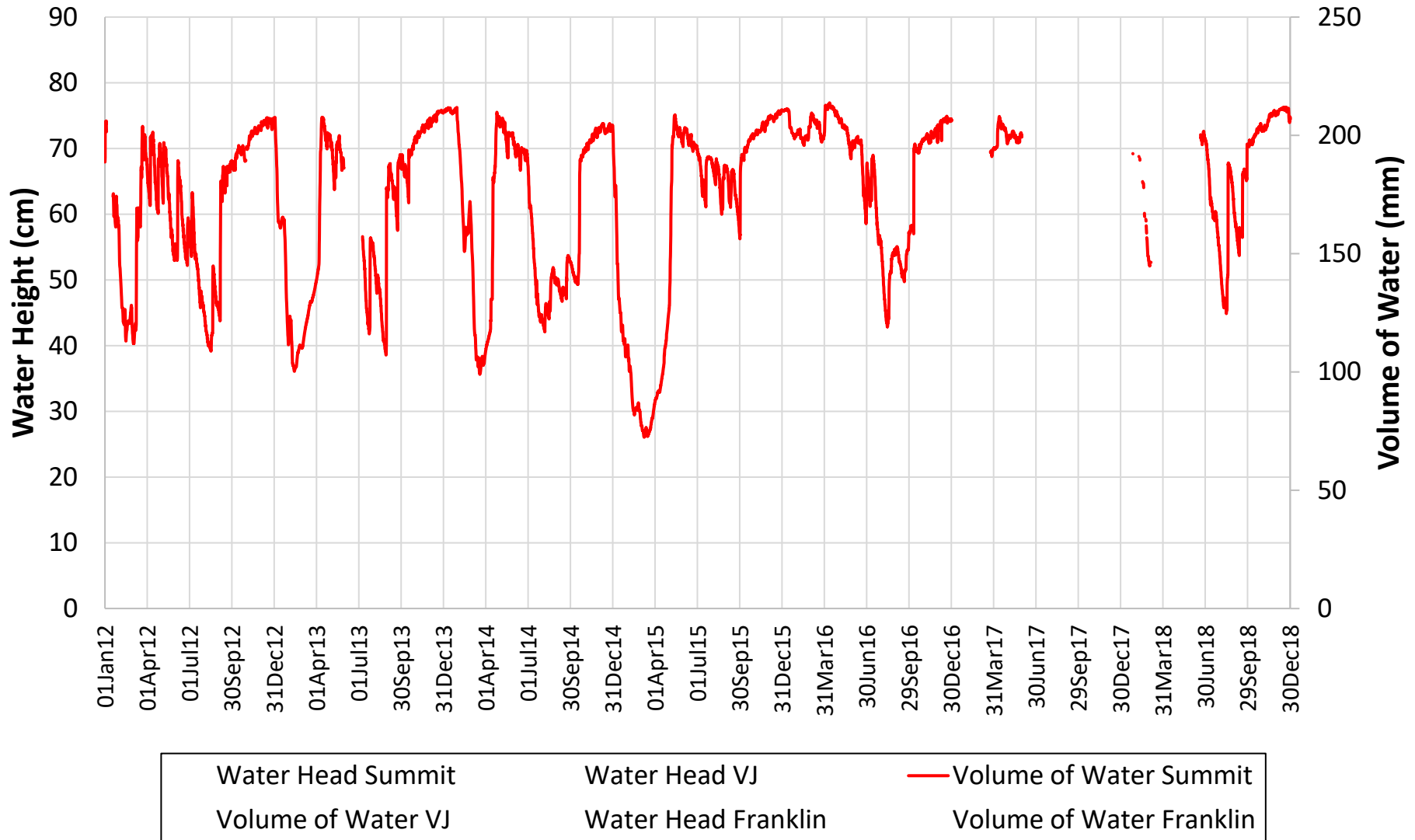
## Water Level Loggers



Head of water above liner

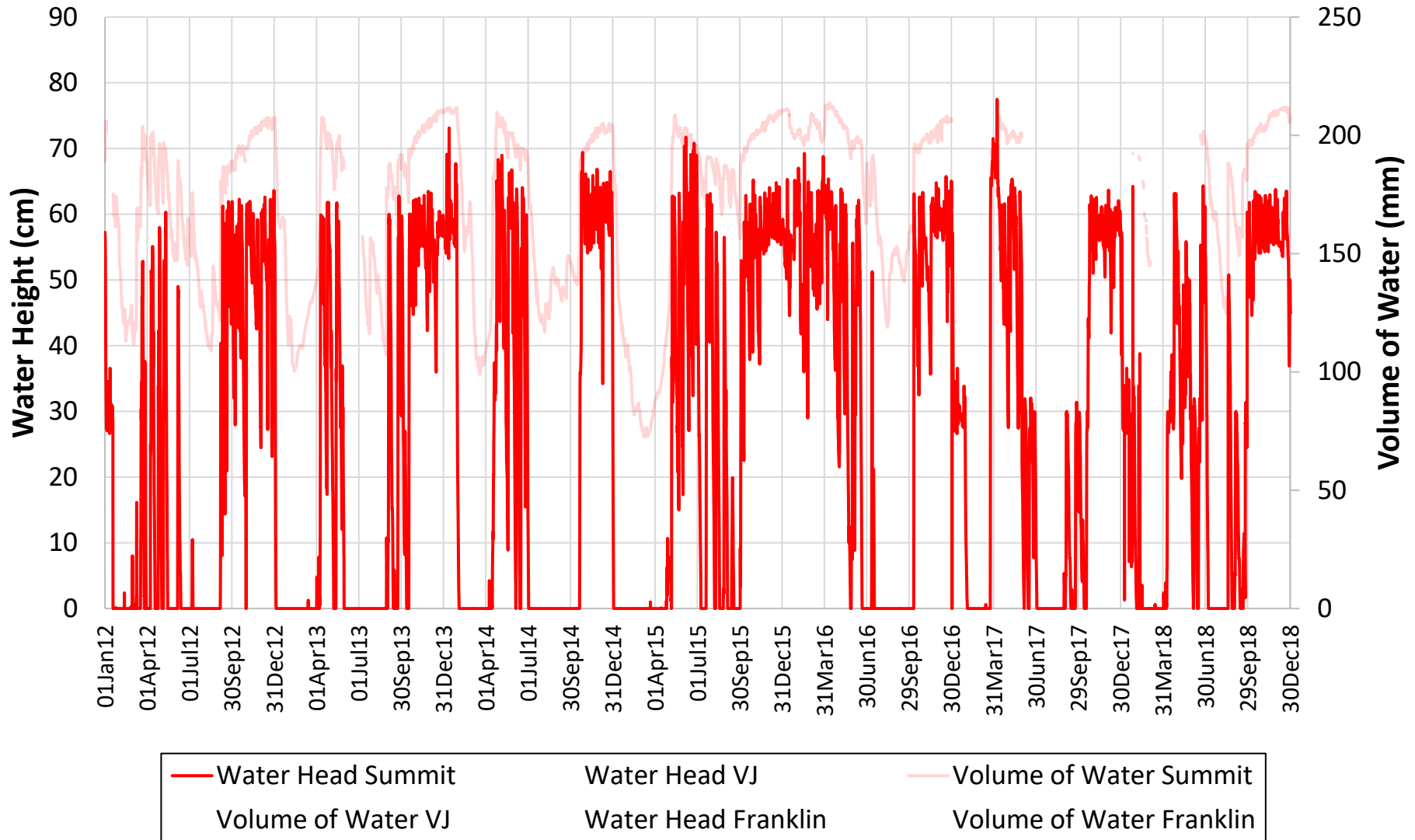
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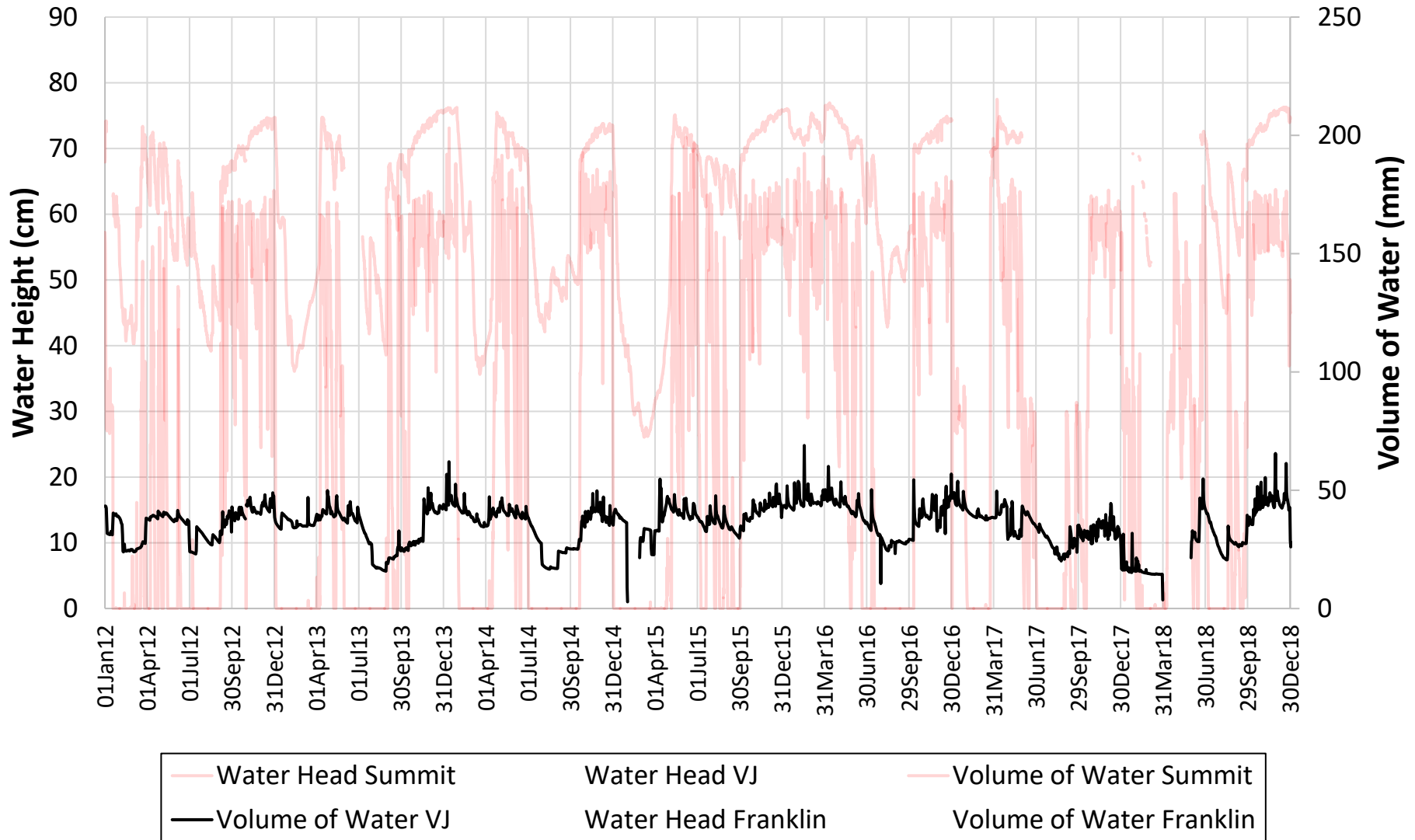
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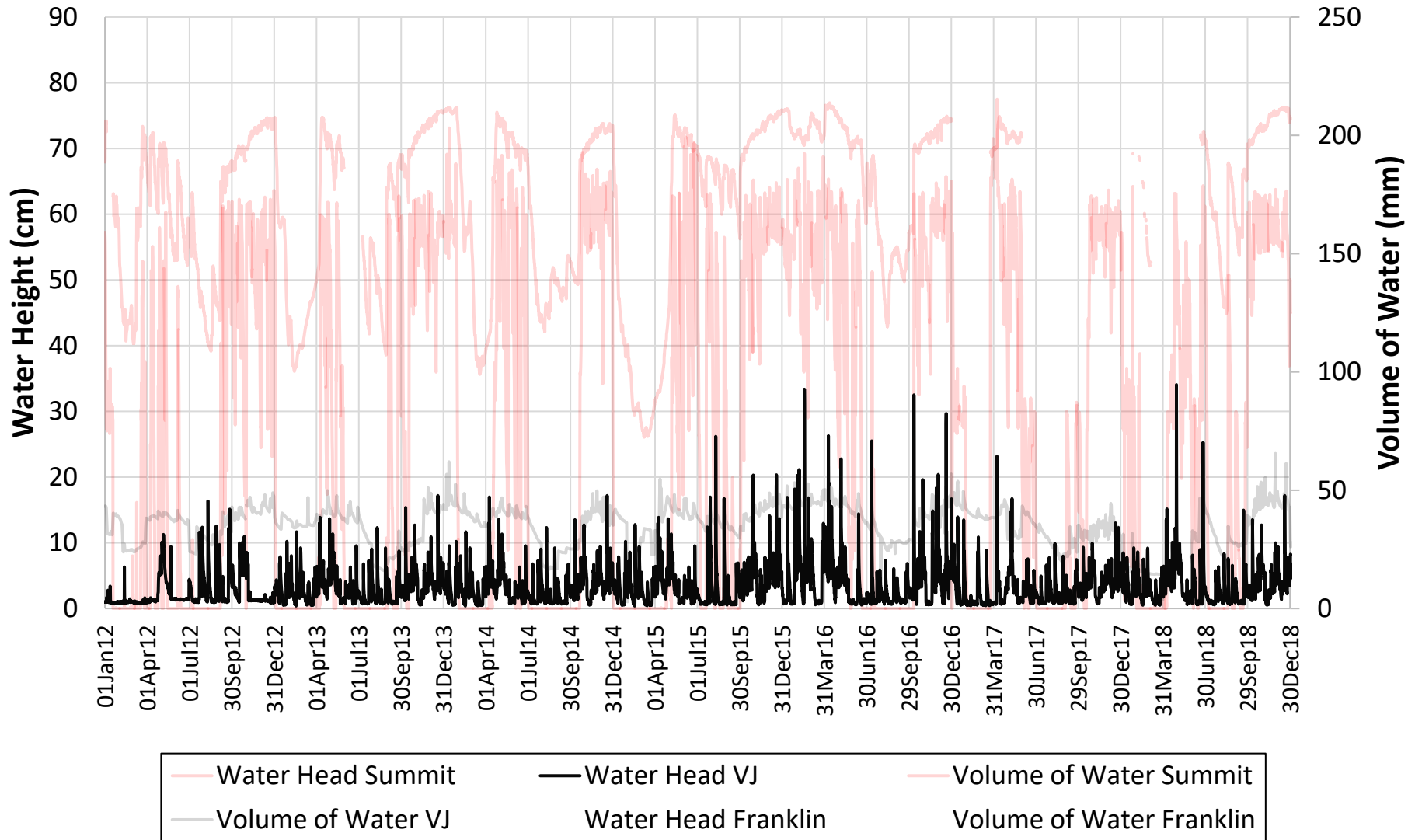
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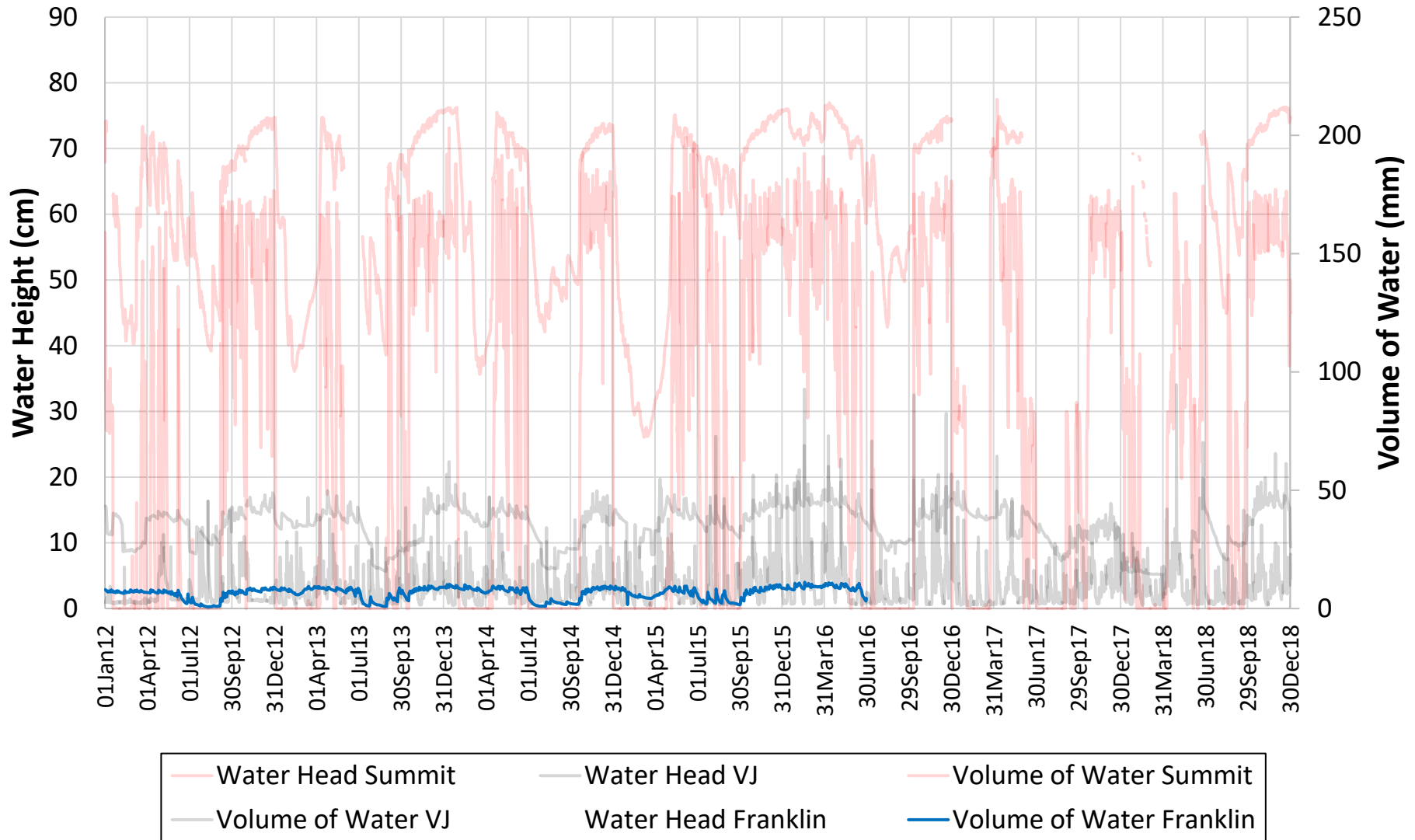
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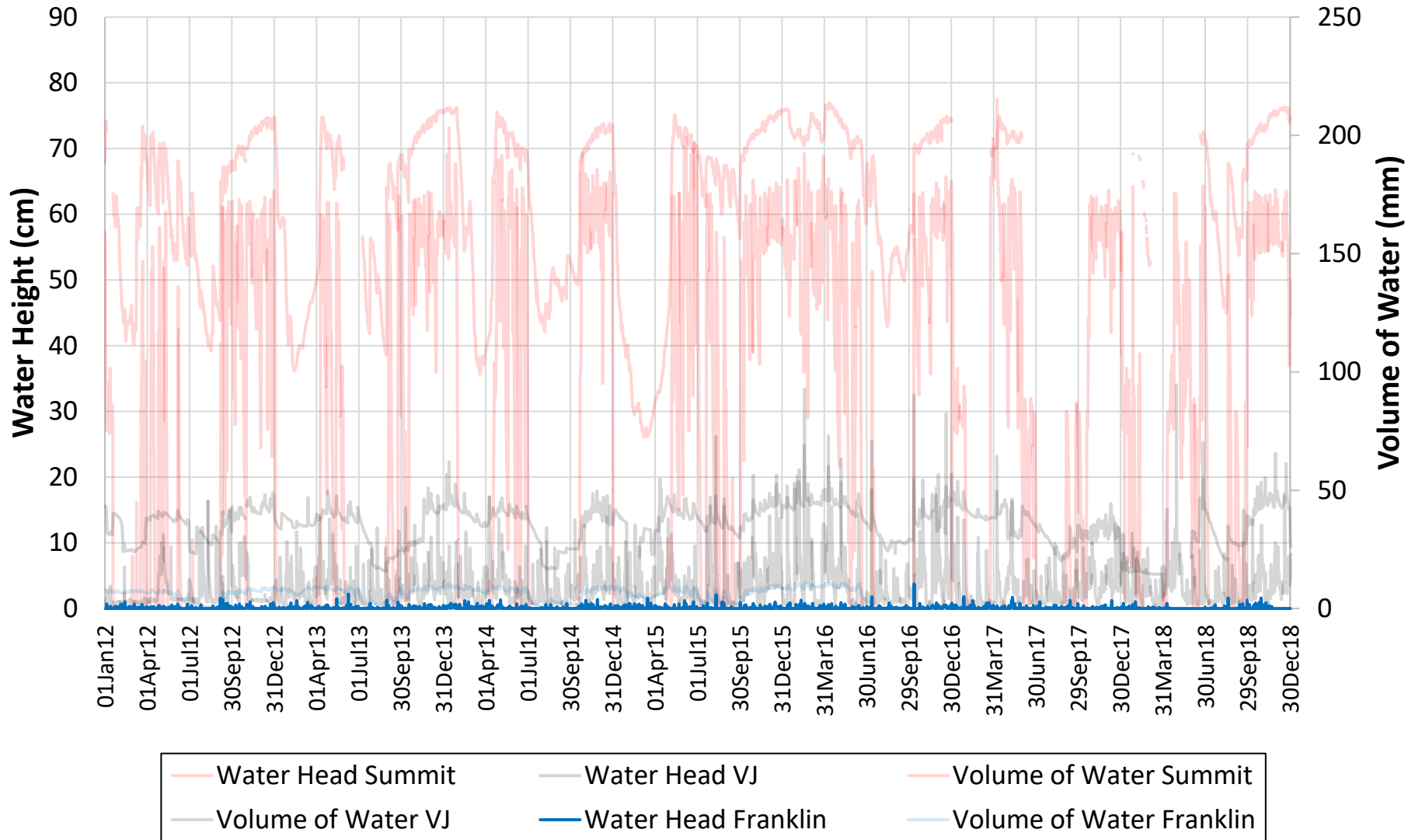
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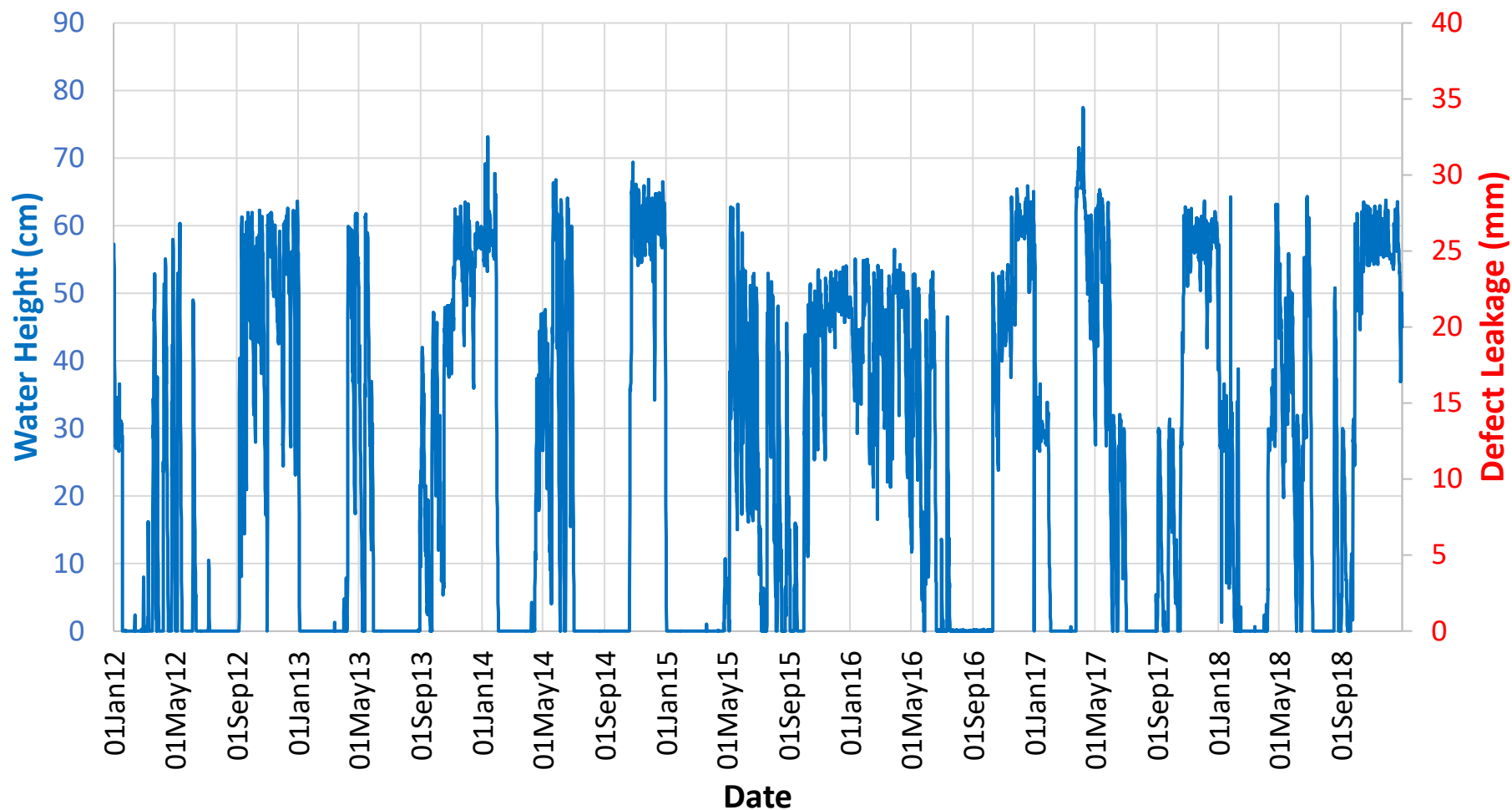
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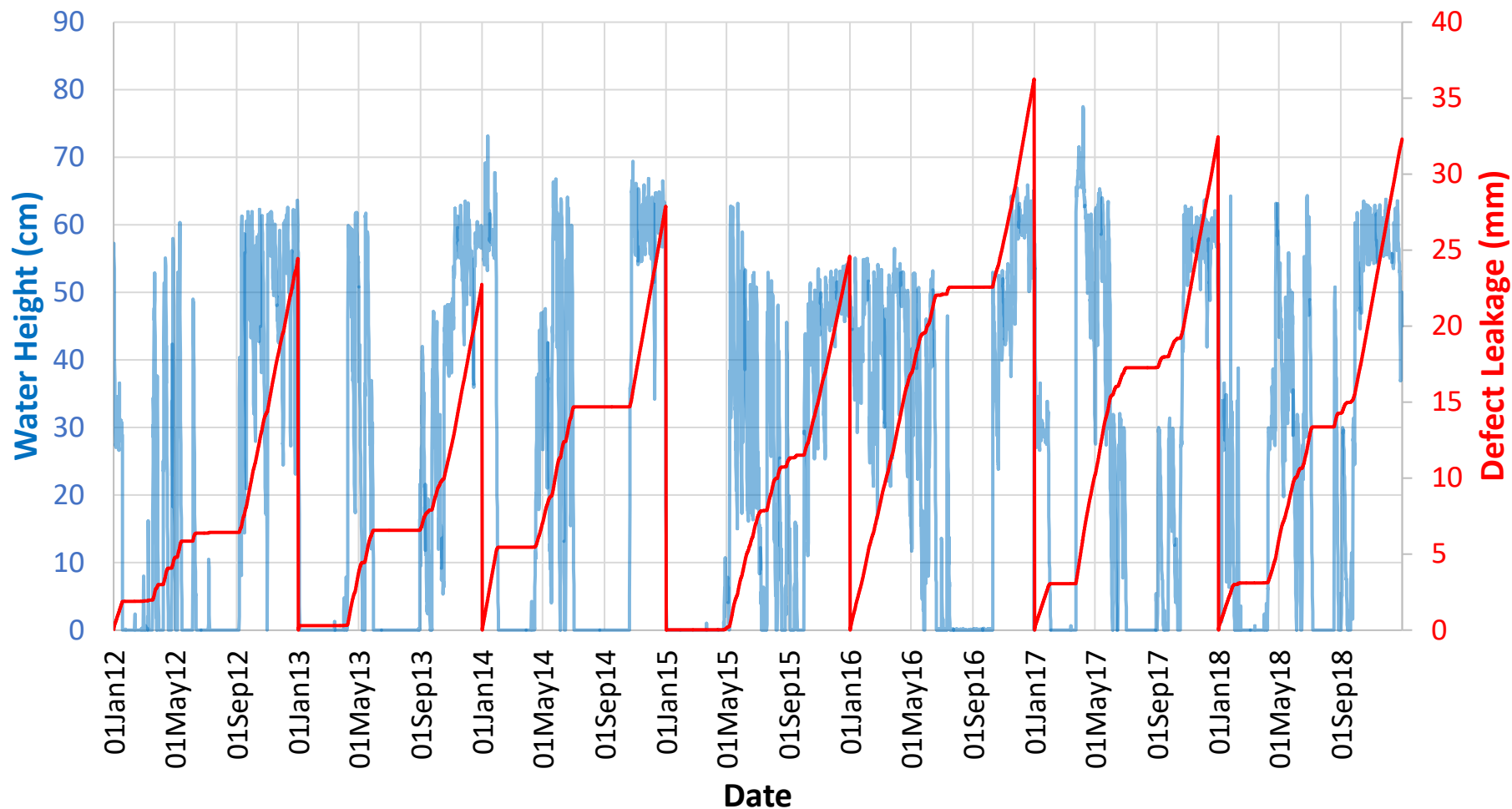
# Defect Leakage Rates

Leakage Rates: Scotchtown Summit



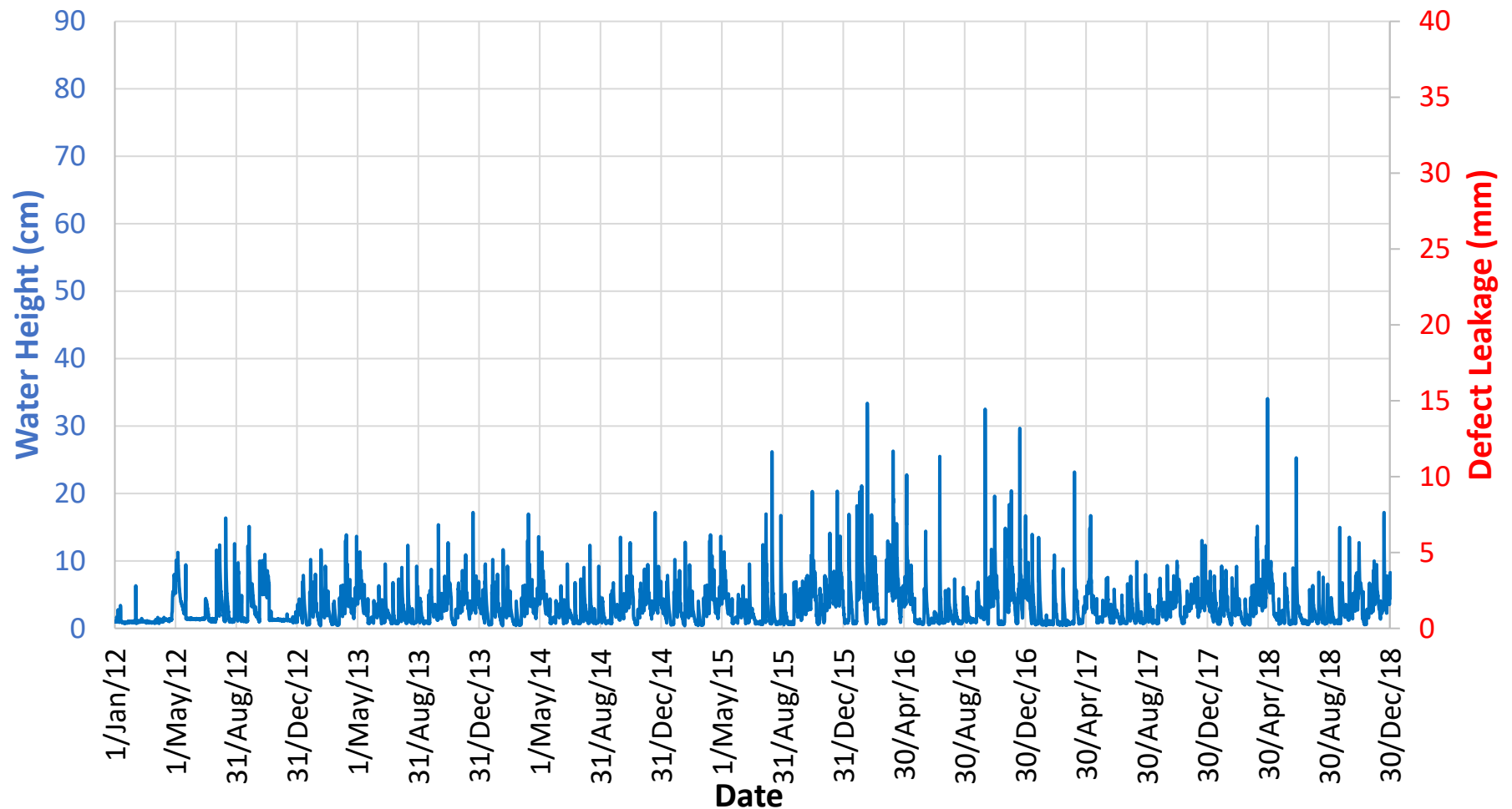
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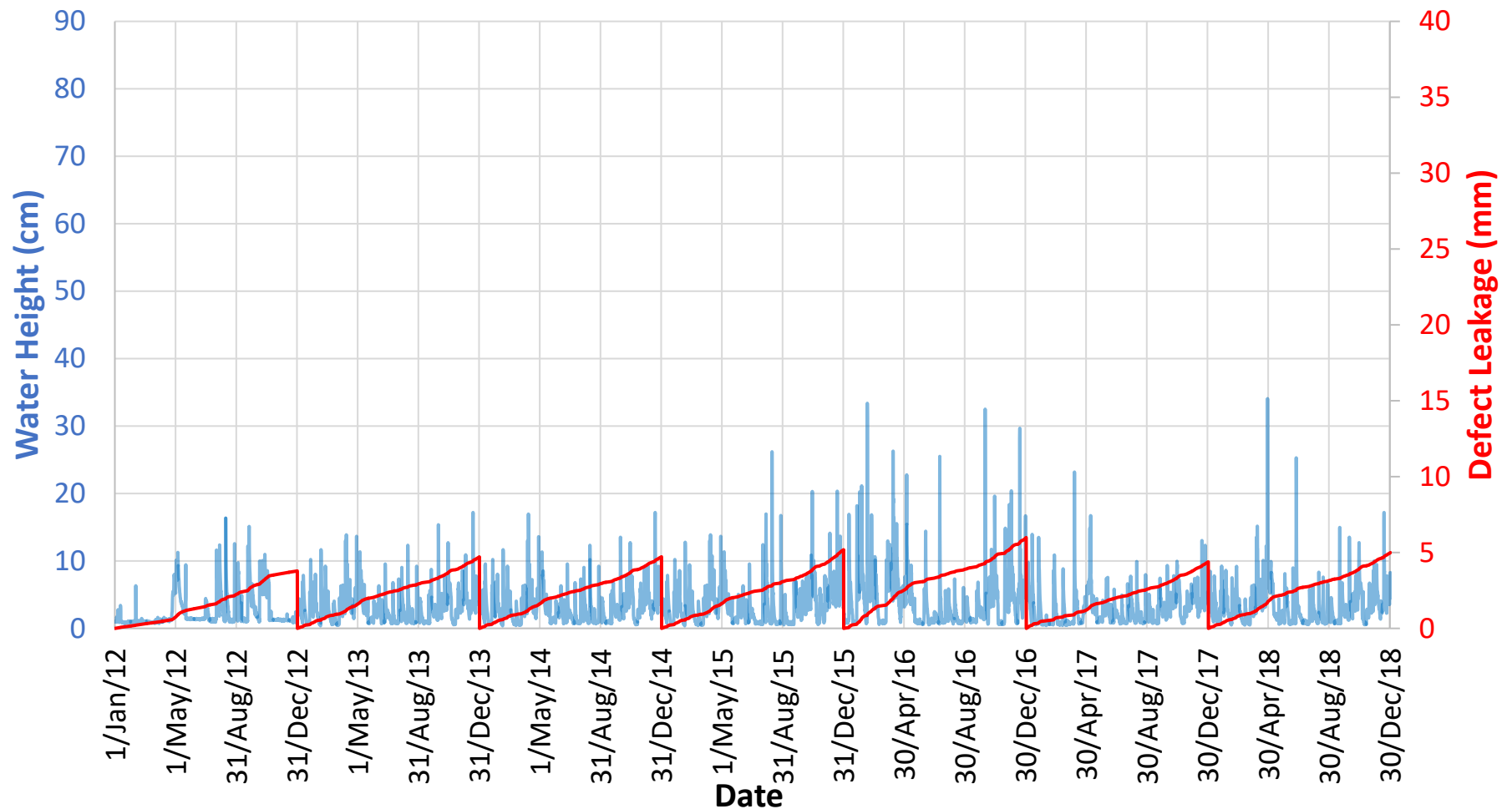
# Defect Leakage Rates

## Leakage Rates: Victoria Junction



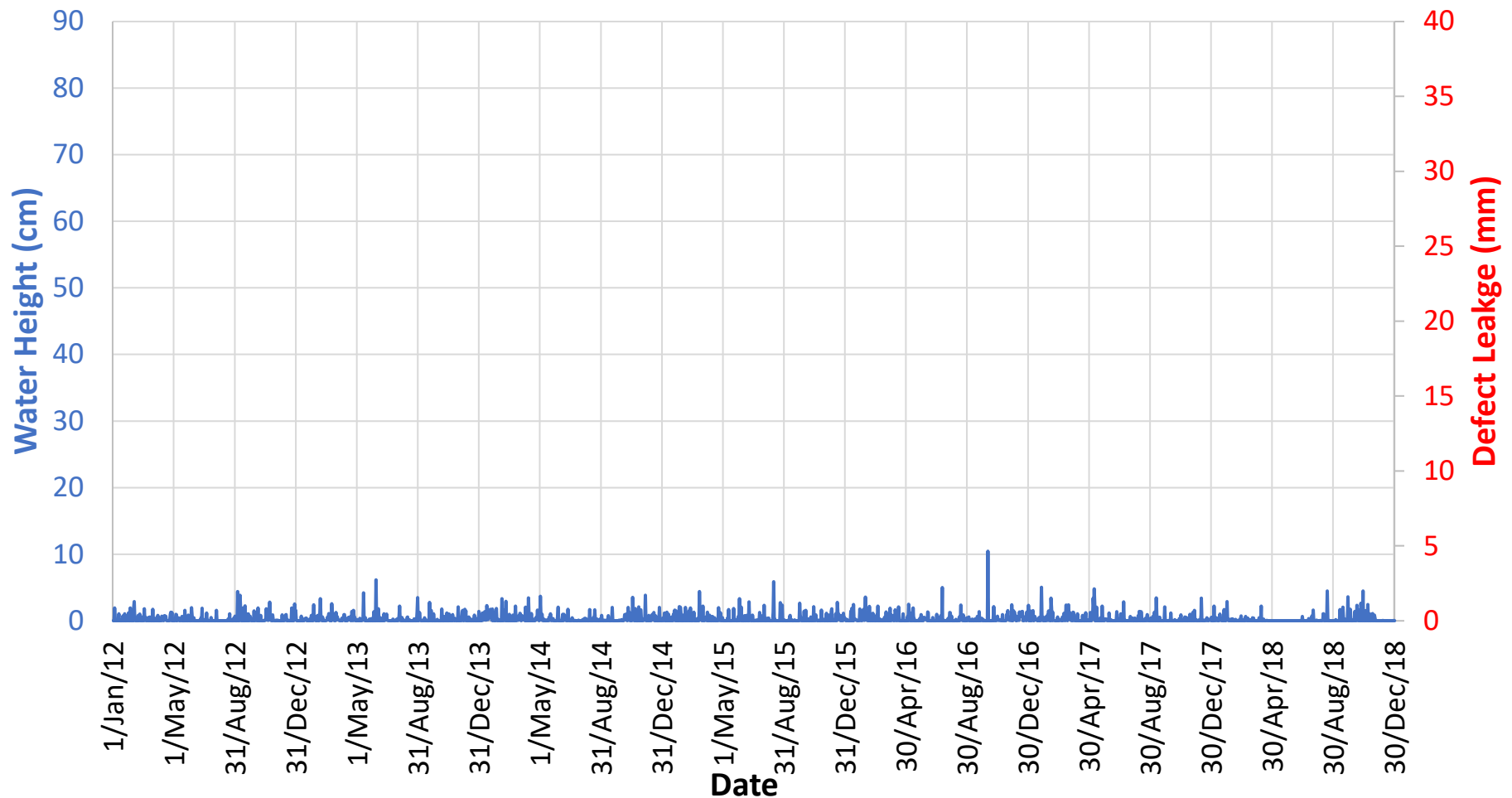
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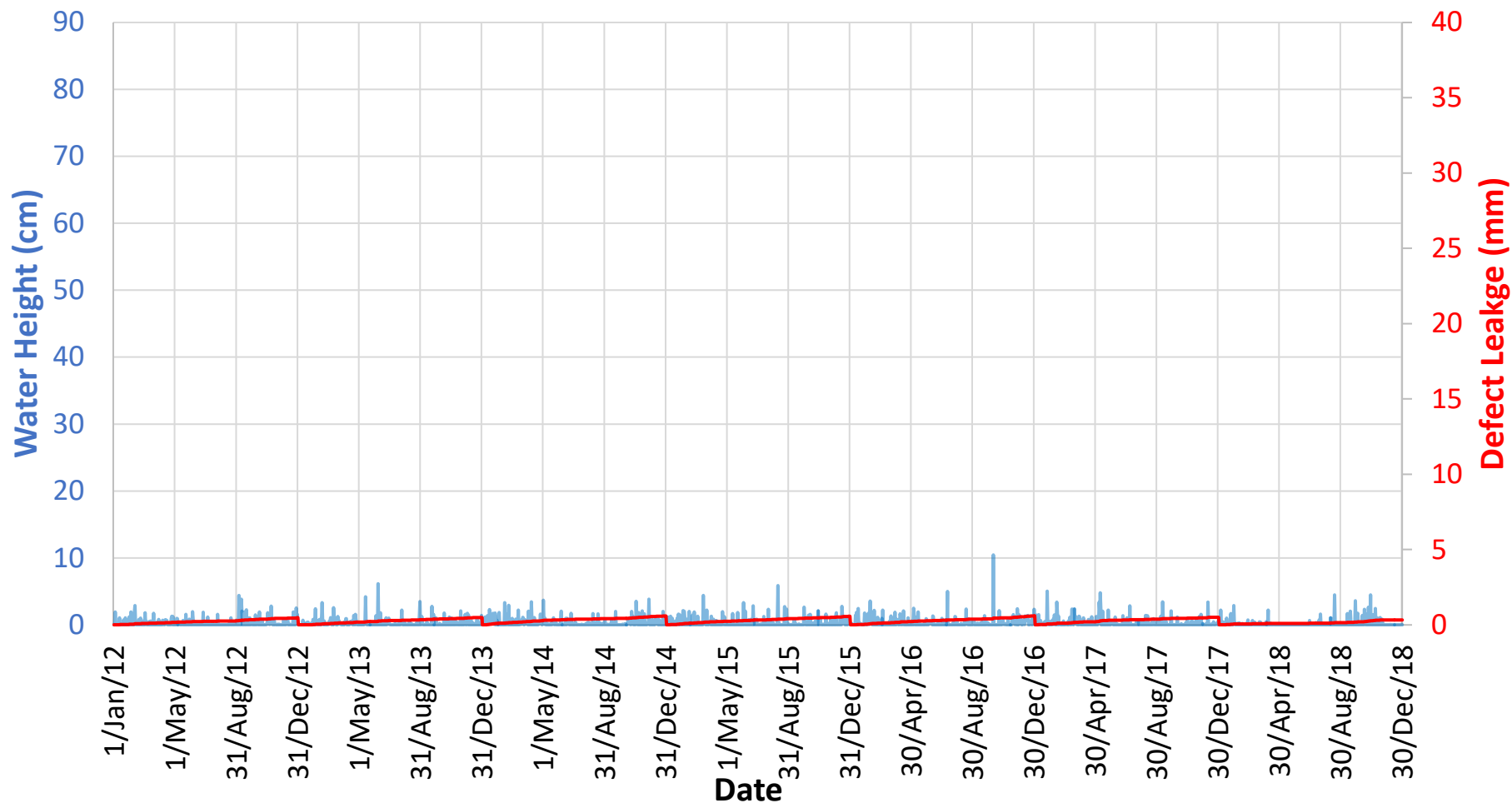
# Defect Leakage Rates

Leakage Rates: Franklin



# Defect Leakage Rates

Leakage Rates: Franklin



# Defect Leakage Rates

## Leakage Rates: Summary

| Year | Leakage Rate (mm) |      |          | Leakage Rate (%PPT) |      |          |
|------|-------------------|------|----------|---------------------|------|----------|
|      | Summit            | VJ   | Franklin | Summit              | VJ   | Franklin |
| 2012 | 24.45             | 3.78 | 0.48     | 1.85                | 0.28 | 0.035    |
| 2013 | 22.79             | 4.71 | 0.49     | 1.65                | 0.42 | 0.035    |
| 2014 | 27.93             | 4.72 | 0.59     | 1.60                | 0.28 | 0.035    |
| 2015 | 24.61             | 5.18 | 0.57     | 1.61                | 0.40 | 0.034    |
| 2016 | 36.30             | 5.99 | 0.61     | 2.17                | 0.37 | 0.034    |
| 2017 | 32.50             | 4.39 | 0.51     | 2.55                | 0.38 | 0.035    |
| 2018 | 32.36             | 5.00 | 0.33     | 2.68                | 0.33 | 0.024    |

# Defect Leakage Rates

## Conclusions

- Defects in HDPE-lined cover systems highly influences water flux
- Drainage layers improve the performance of HDPE cover systems
- Contact quality and size/number of defects -> hard to control
- Water head and hydraulic conductivity of underlying medium -> easier to control

# Outline

- Defects in Geomembrane Liners
- Defect Leakage Rates at 'In-Service' WRPs
- Detection of Defects at WRPs

# Detection of Defects

Let's look at Victoria Junction



## Industry Assumption

Defect size: 1 cm<sup>2</sup>

20 defects \* 28 hectares

**560 cm<sup>2</sup>**

# Detection of Defects

## ASTM's for Electrical Leak Location

- ASTM D6747 – Selection/Method
- ASTM D7002 – Water Puddle Method
- ASTM D7703 – Water Lance Method
- ASTM D7953 – Arc Testing Method
- ASTM D7240 – Spark Testing Method

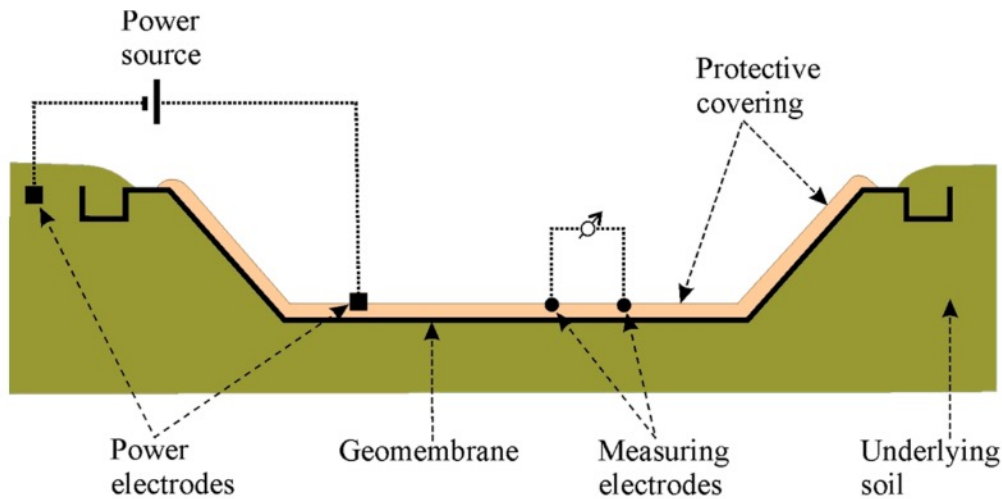
**Exposed**

- ASTM D7007 – Dipole Method (Water & Soil)

**Covered**

# Detection of Defects

## Current 'Covered' Method: ASTM D7007 – Dipole Method



## Overview

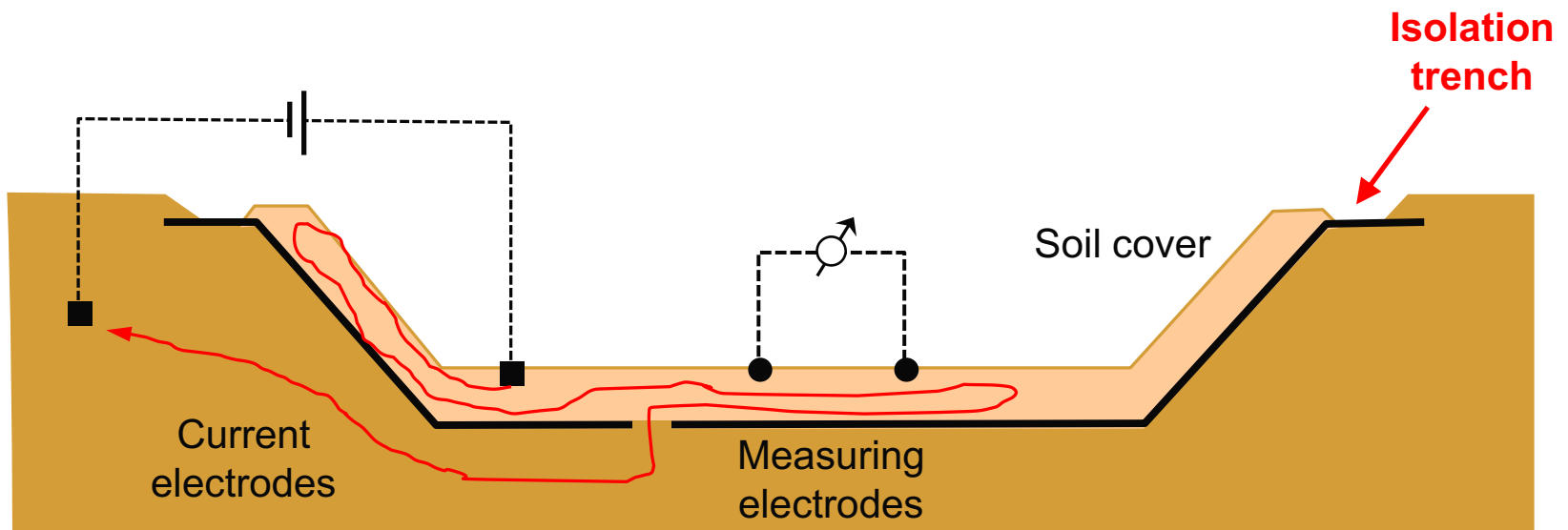
- The dipole method is well-established and widely used
- Method of choice for leak location companies
- Very effective once boundary conditions are ensured

# Detection of Defects

Current 'Covered' Method: ASTM D7007 – Dipole Method

## Conditions required

- 1 Isolation Trench around Entire Perimeter



# Detection of Defects

Current 'Covered' Method: ASTM D7007 – Dipole Method

## Conditions required

### ① Isolation Trench around Entire Perimeter



# Detection of Defects

Current 'Covered' Method: ASTM D7007 – Dipole Method

## Conditions required

### ② Isolation Flaps on Access Roads



# Detection of Defects

Current 'Covered' Method: ASTM D7007 – Dipole Method

## Conditions required

- ③ All Penetrations Need to be Booted/Isolated

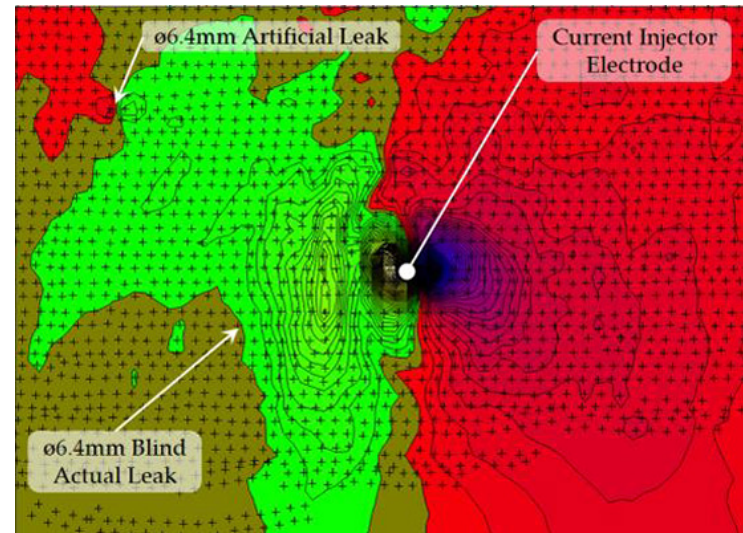
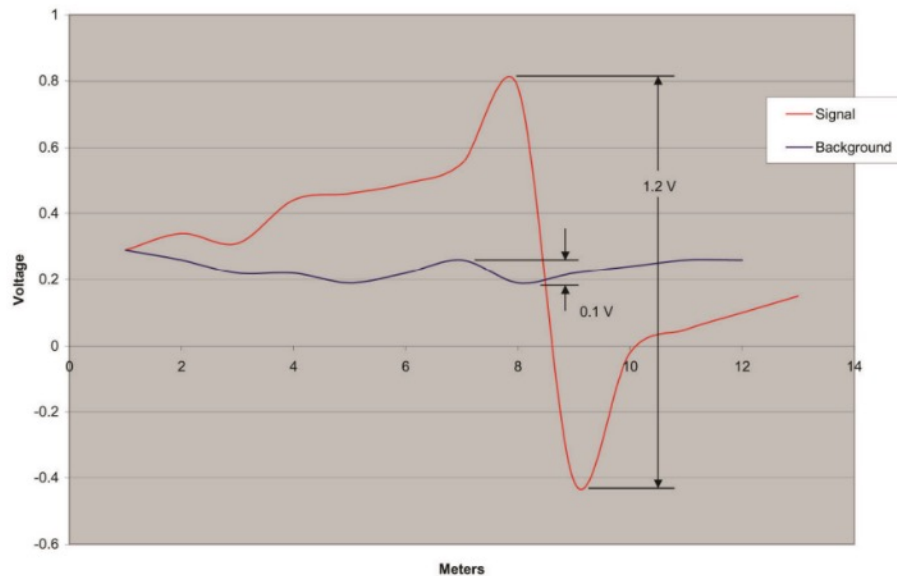


# Detection of Defects

## Current 'Covered' Method: ASTM D7007 – Dipole Method

### Conditions required

#### ④ Requires Large 'R' Values

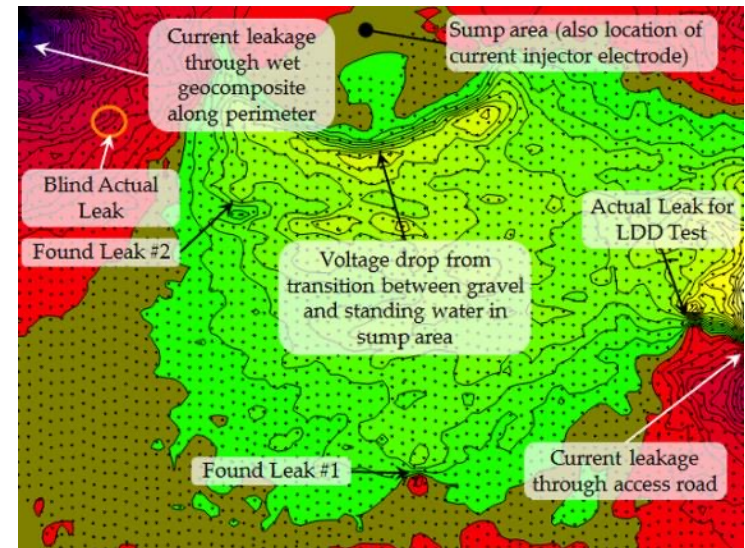
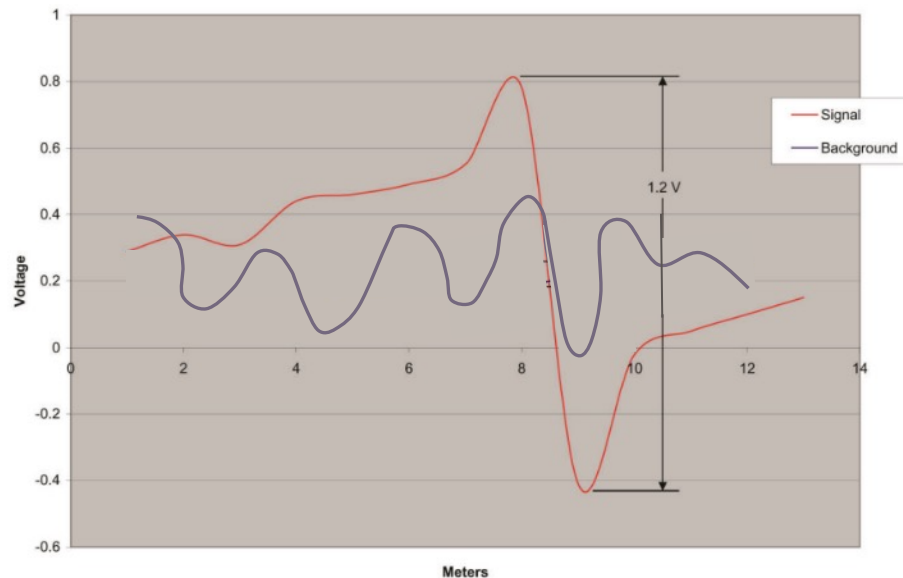


# Detection of Defects

## Current 'Covered' Method: ASTM D7007 – Dipole Method

### Conditions required

#### ④ Requires Large 'R' Values



# Detection of Defects

## Victoria Junction: Cover Performance

*I wa*

*tS...*



*Tota*

# Detection of Defects

## Victoria Junction: Cover Performance

*I wanted to map the cover*

*HOW*

- No electrical isolation existed
- No isolation flap on access



*Total leakage area: 560 cm<sup>2</sup>*

# Detection of Defects

## Victoria Junction: Cover Performance

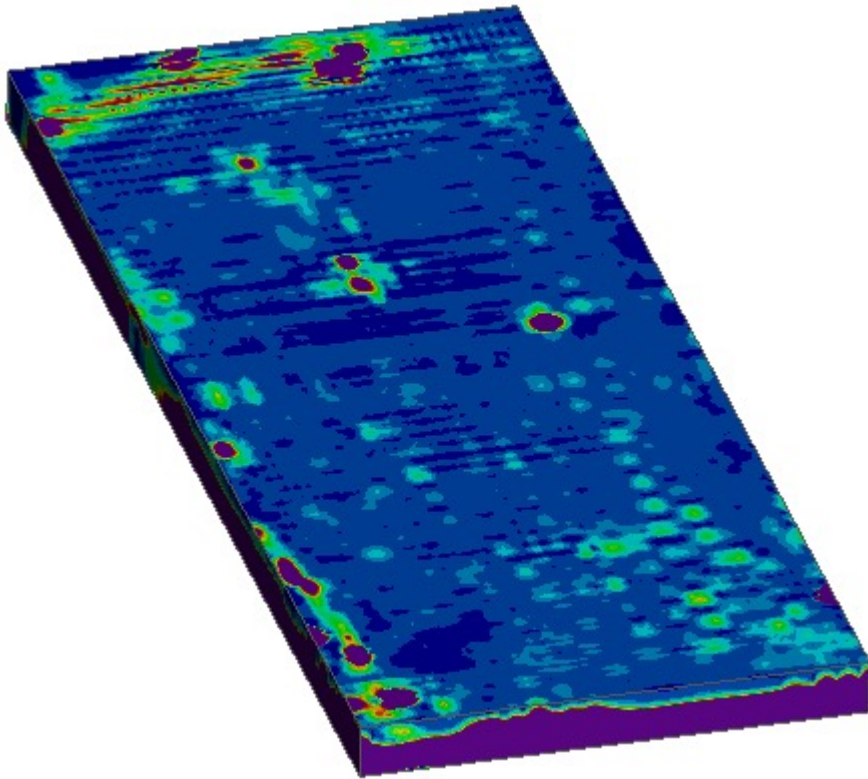
*I wanted to map the*



(clar support posts)

# Detection of Defects

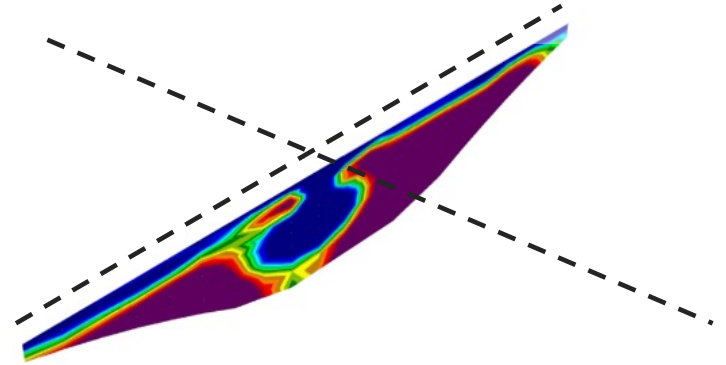
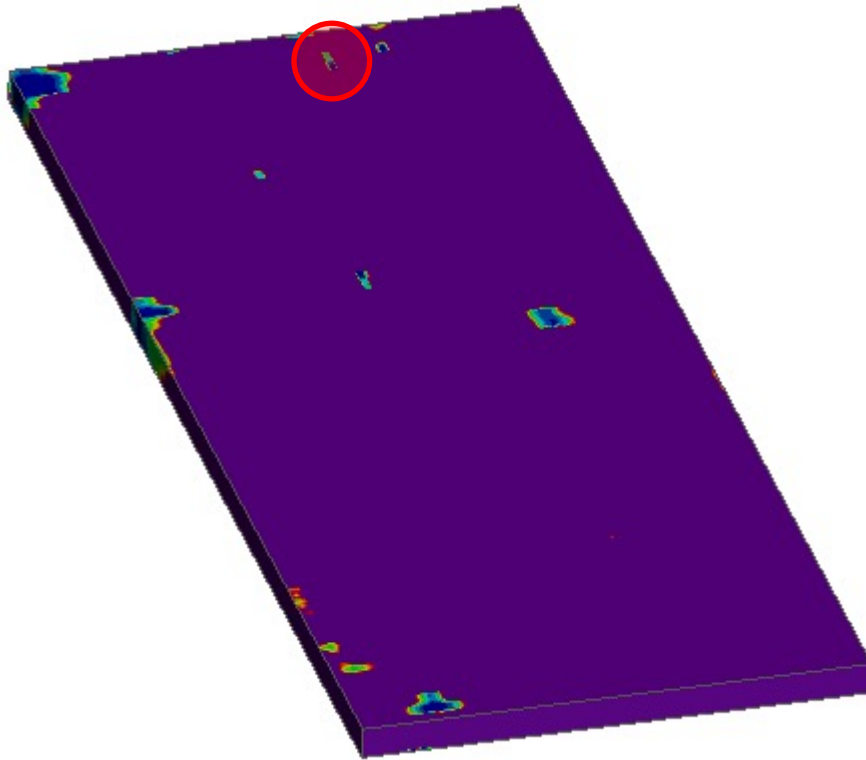
Victoria Junction



# Detection of Defects

Victoria Junction

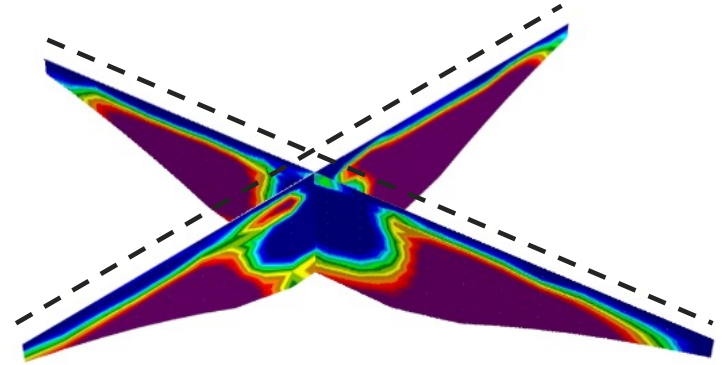
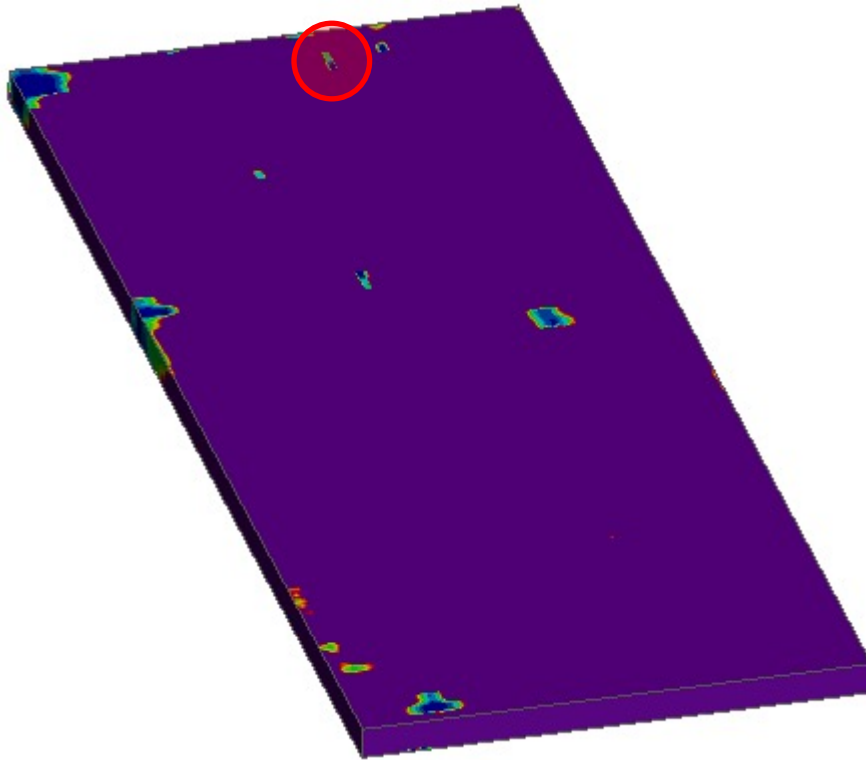
Defect 1



# Detection of Defects

Victoria Junction

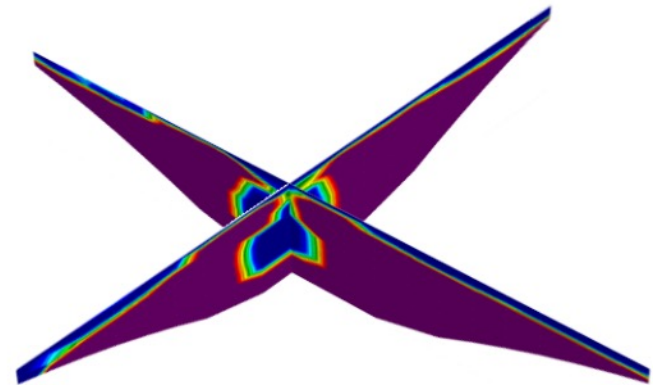
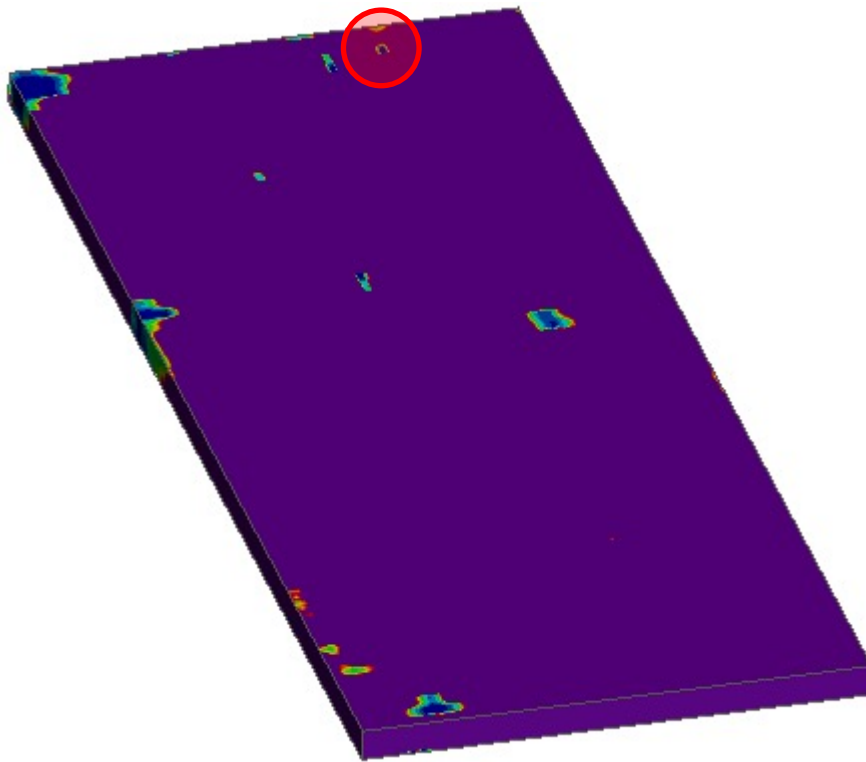
Defect 1



# Detection of Defects

Victoria Junction

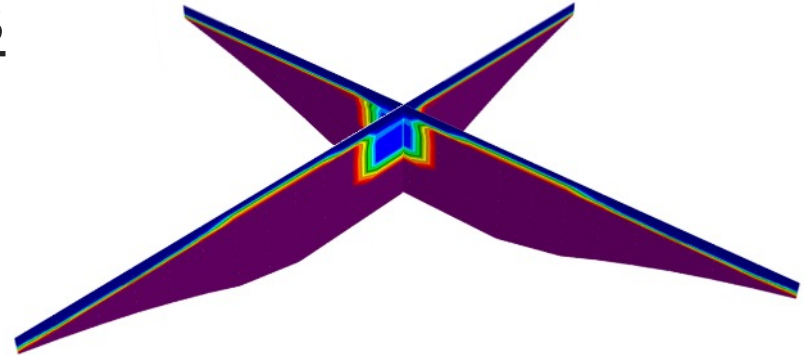
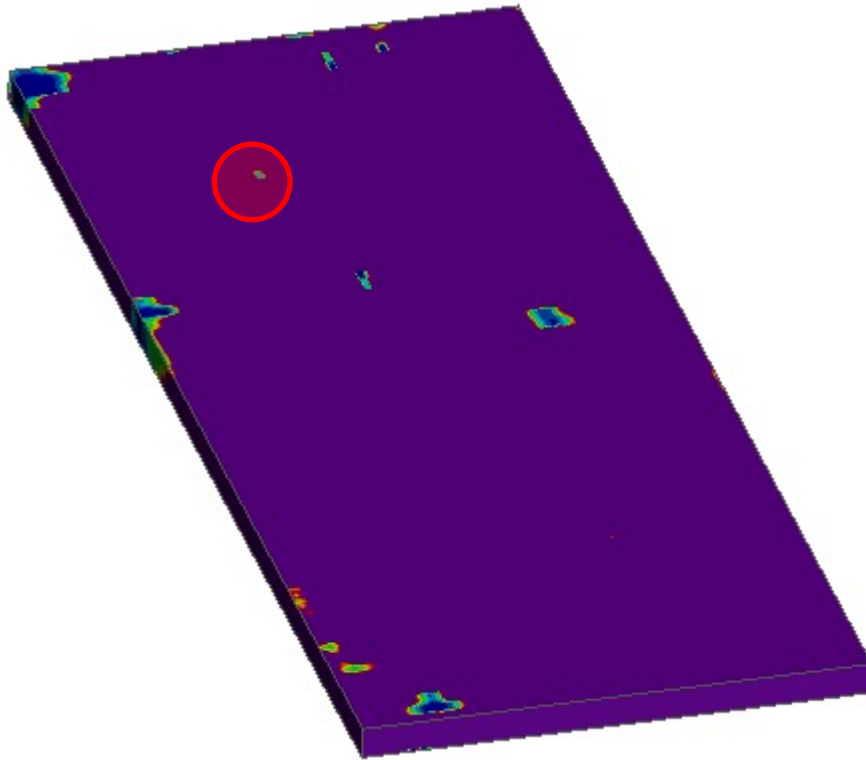
Defect 2



# Detection of Defects

Victoria Junction

Defect 3



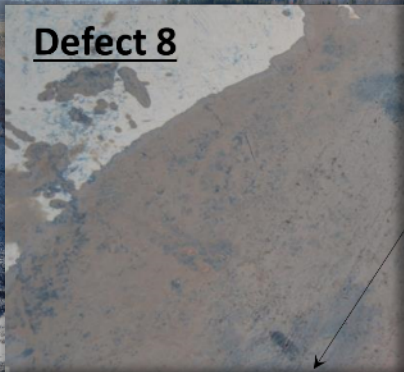
# Detection of Defects

## Victoria Junction

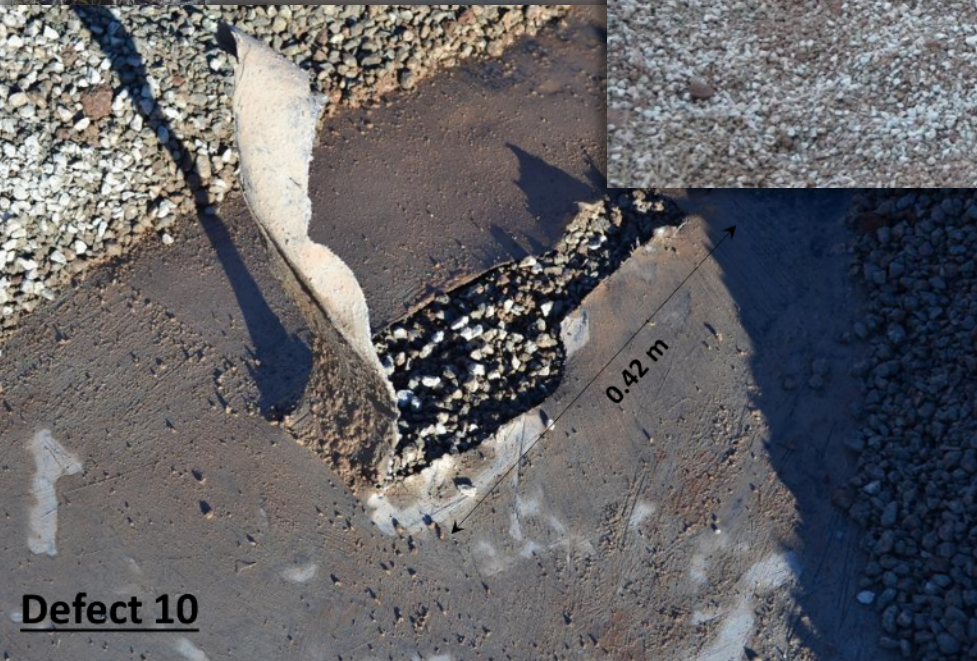
Defect 4



Defect 8



Defect 11



Defect 10



Defect 7

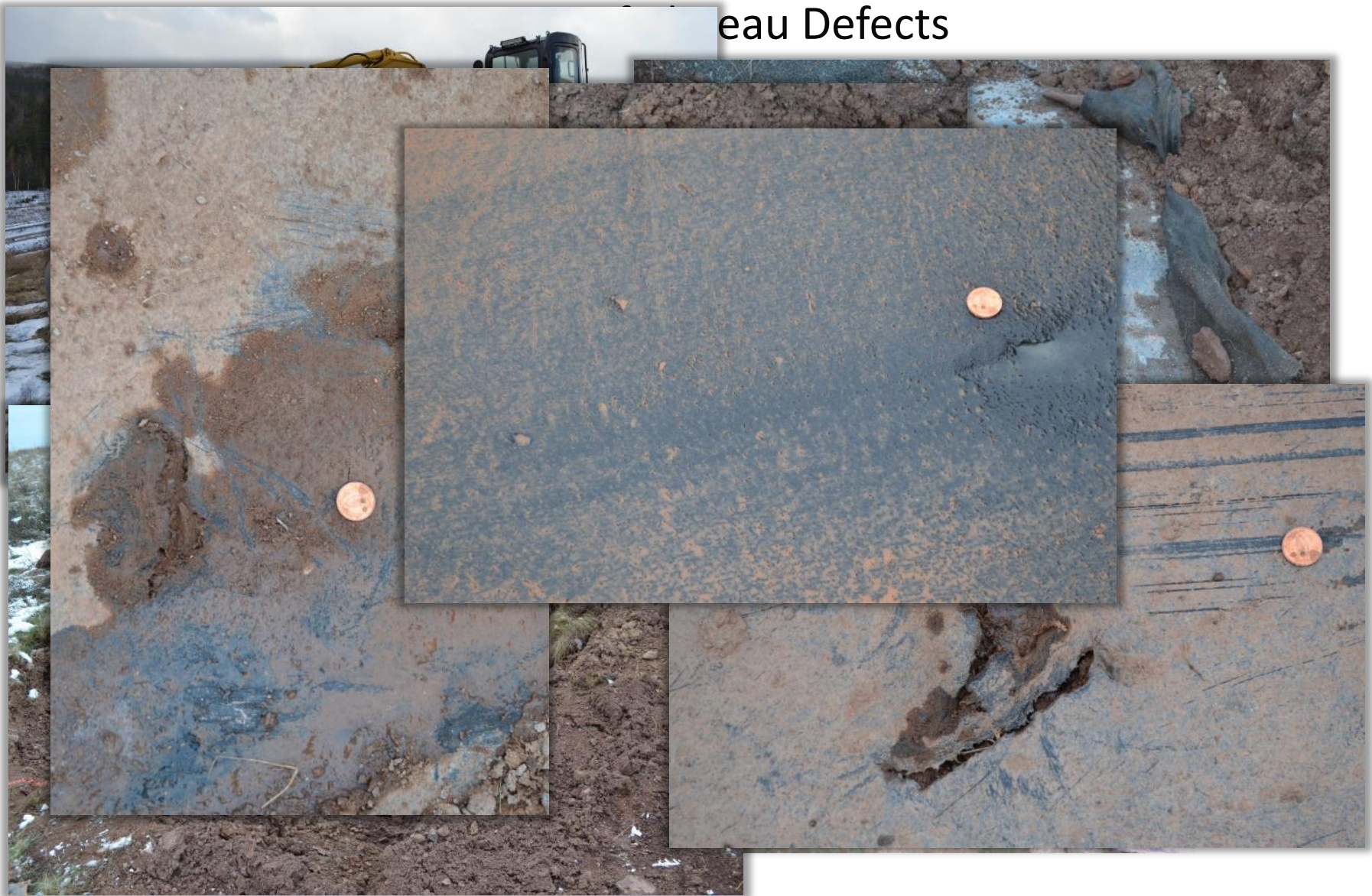
# Detection of Defects

## Victoria Junction – Summary of Plateau Defects



# Detection of Defects

Water Defects



# Detection of Defects

Victoria Junction

*Total Defects = 26*



## Industry Assumption

Defect size:  $1 \text{ cm}^2$

20 defects \* 28 hectares

**$560 \text{ cm}^2$**

## Actual

26 defects discovered

Defect 1 was  $5 \text{ m} * 0.5 \text{ m}$

**$25,000 \text{ cm}^2$**

# Detection of Defects

## Conclusions

### Overlying gravel drainage layer

High lateral drainage

Lower head of water

High cost



Good engineering



Generates higher  
number of defects

- Electrical method more versatile than the Dipole Method
  - Does not require electrical isolation trenches or access road flaps
  - Works alongside non-booted conductive penetrations
  - Less sensitive to cover soil heterogeneity and background noise
  - Can be extended to other geomembrane applications and other cover systems such as GCLs and bituminous liners
- Lots of research ideas -> seeking industry collaboration

# Thank you for listening!

## Any questions?

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Western

