Activity 4c:

Enhanced ability to predict the likelihood of pipe corrosion and its severity along the pipe

Objective of activity 4c

- **Develop a methodology for predicting soil properties along the pipe length that are relevant to cast iron pipe corrosion**

- **Develop a corrosion model to predict present and future corrosion condition along the pipe**

Activity 4c. Predicting pipe corrosion along the pipe

Activities

1. **Identify soil properties that impact on buried cast iron pipe corrosion**
2. **Development of methods for predicting along the pipe soil properties**
3. **Development of an advanced monitoring tool**

Activity 4c. Predicting pipe corrosion along the pipe

Activities

1. **Identify soil properties that impact on buried cast iron pipe corrosion**

    - **Soil moisture**
    - **Soil nitrates**
    - **Soil chlorides**
    - **Soil texture**
    - **Soil bulk density**
    - **Field capacity**
    - **Wilt point**

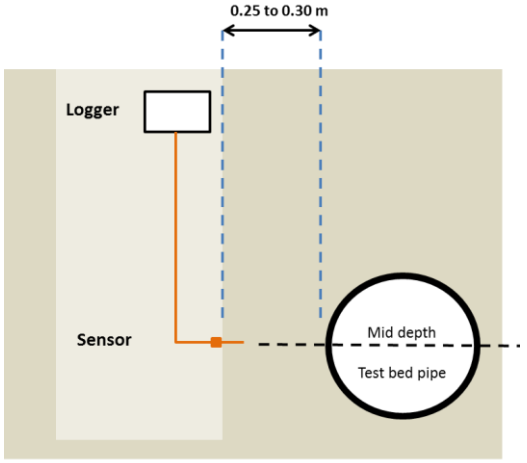
Activity 4c. Predicting pipe corrosion along the pipe

1. **Identify soil properties that impact on buried cast iron pipe corrosion**
    - **Soil moisture – an important variable**
    - **Is SM at pipe depth reasonably constant over time?**
    - **Does SM at pipe depth vary much over distance?**

Activity 4c. Predicting pipe corrosion along the pipe

1. **Identify soil properties that impact on buried cast iron pipe corrosion**

    - **Soil moisture**

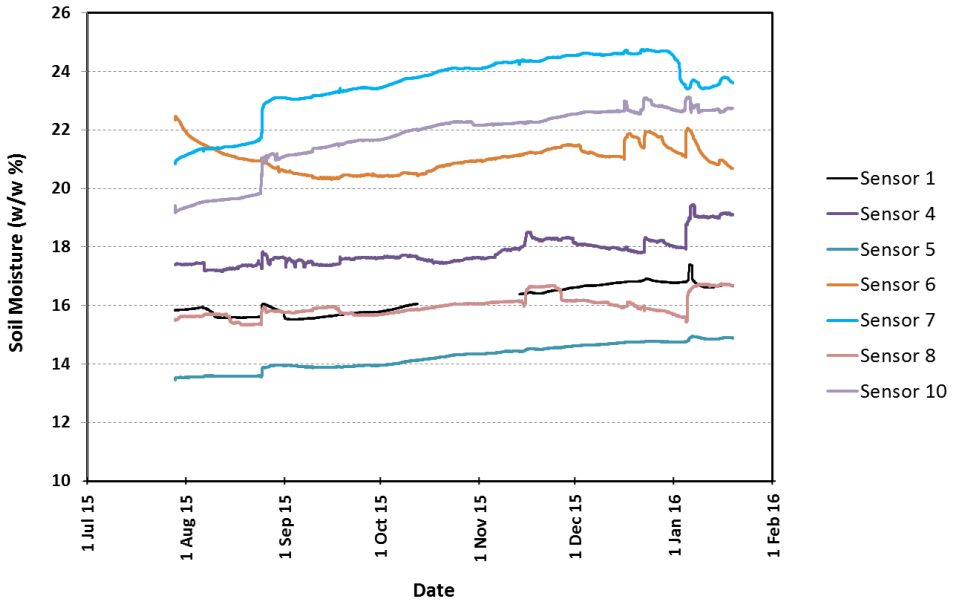


End view of trench

- **Sensors have been in place ~6 months**
- **Data from SM 2,3,9 suggest that water may have infiltrated logging unit**
- **Remaining sensors OK**

Activity 4c. Predicting pipe corrosion along the pipe

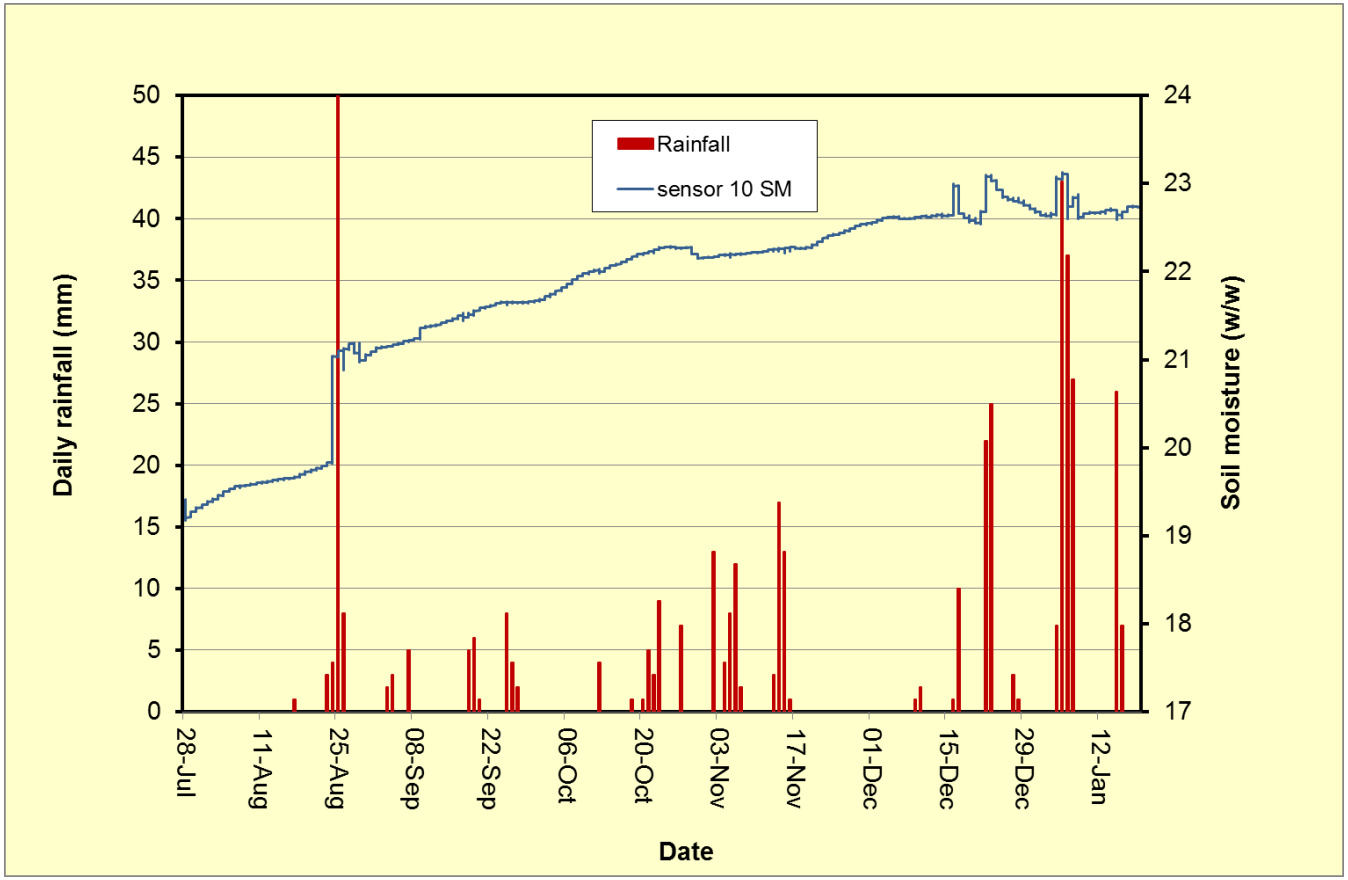
Is SM at pipe depth reasonably constant over time?



- **Most sensor show a small ~steady increase over time (~ 3% w/w)**
- **Sensors still settling in ?? or due to fairly wet weather**
- **Can still see (damped) response to rainfall**

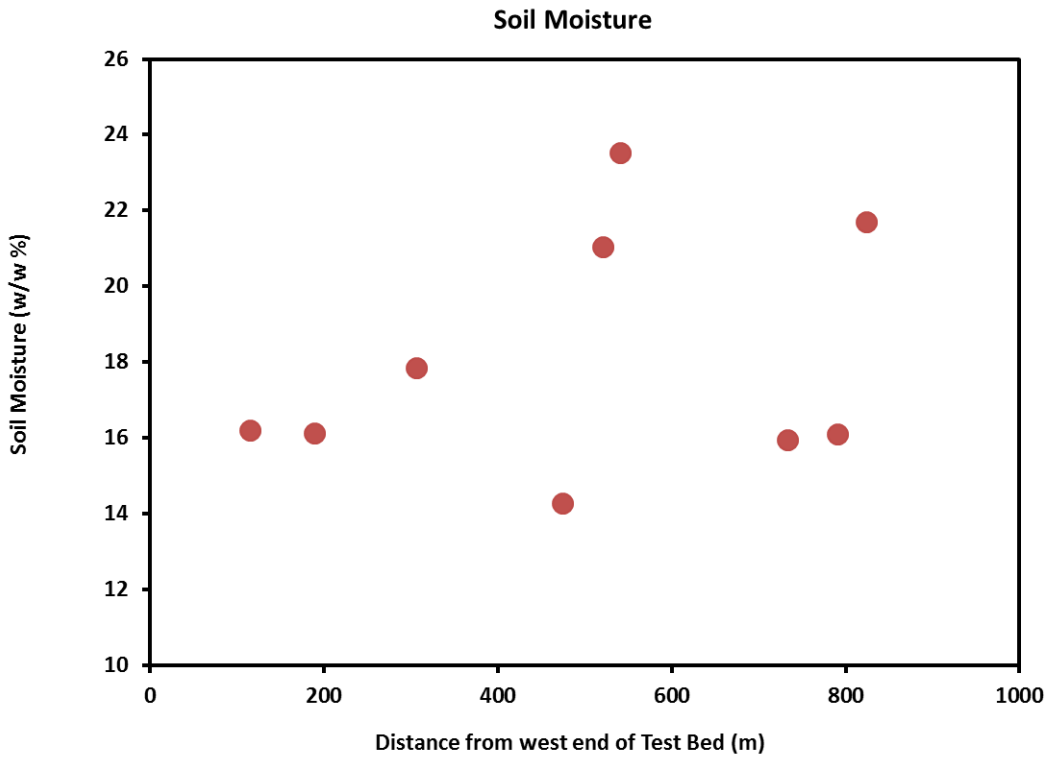
Activity 4c. Predicting pipe corrosion along the pipe

Is SM at pipe depth reasonably constant over time?



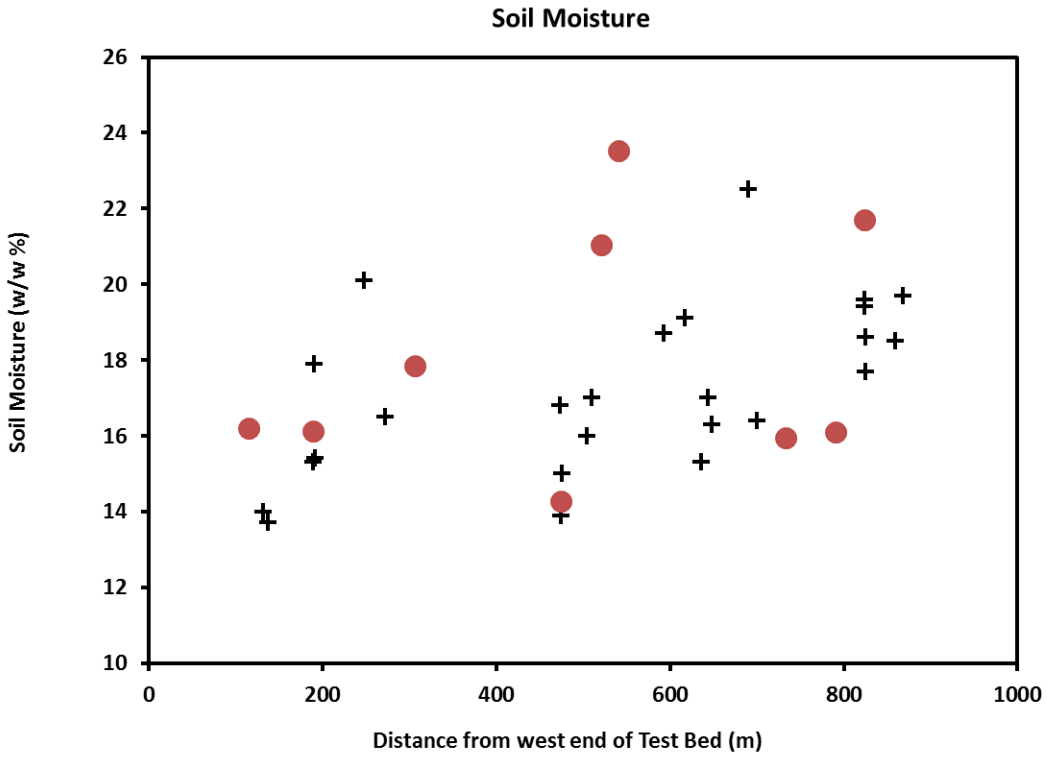
Activity 4c. Predicting pipe corrosion along the pipe

Does SM at pipe depth vary much over distance?



Activity 4c. Predicting pipe corrosion along the pipe

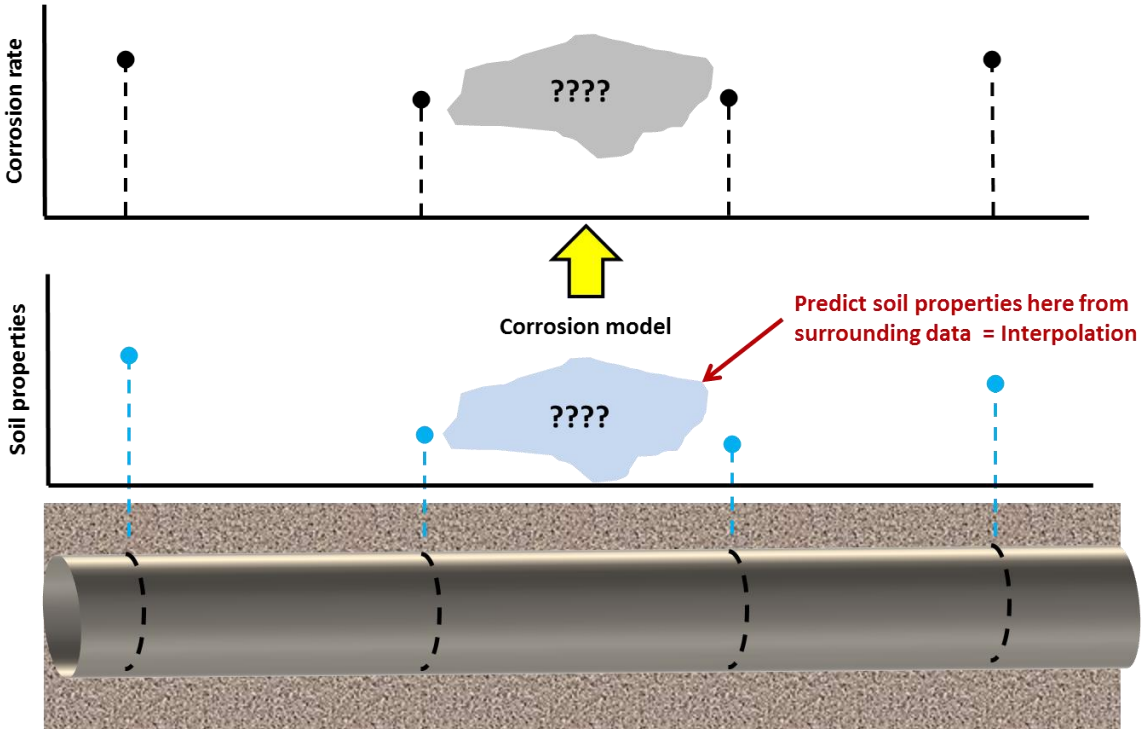
Does SM at pipe depth vary much over distance?



Activity 4c. Predicting pipe corrosion along the pipe

Activities

2. **Development of methods for predicting along the pipe soil properties**



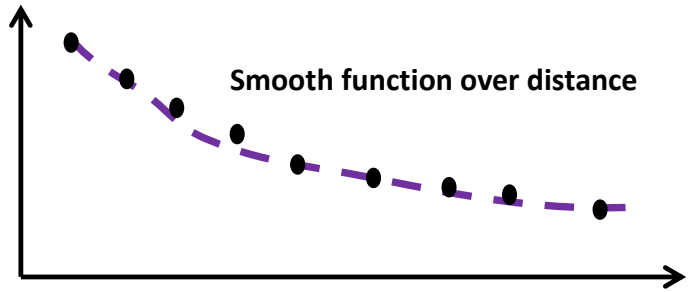
Development of methods for predicting along the pipe soil properties

Issues:

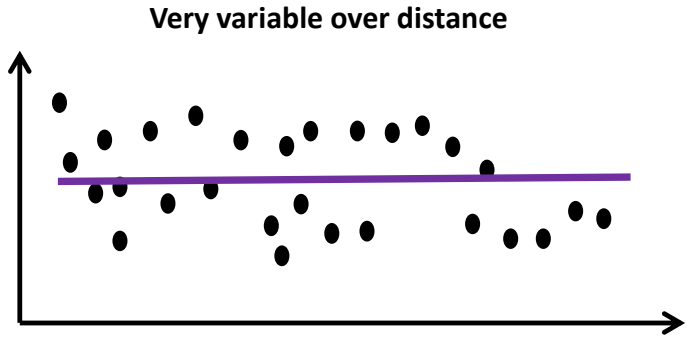
(a) How many samples (resolution)?
(b) Best method of interpolation
- **(simple average, join the dots, polynomial, IDW)**

Depends on:

a) How data varies over distance ('spatial structure')
b) Acceptable uncertainty in corrosion model



Less samples + polynomial fit

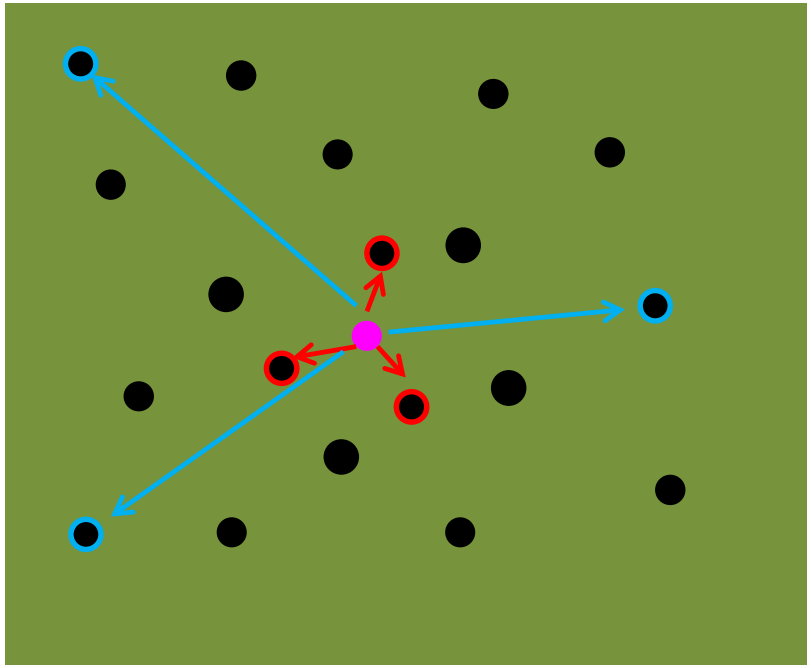


More samples + averaging

Development of methods for predicting along the pipe soil properties

How can we characterise spatial structure?

One method sometimes used in soil science is the variogram



Pts nearby on average:

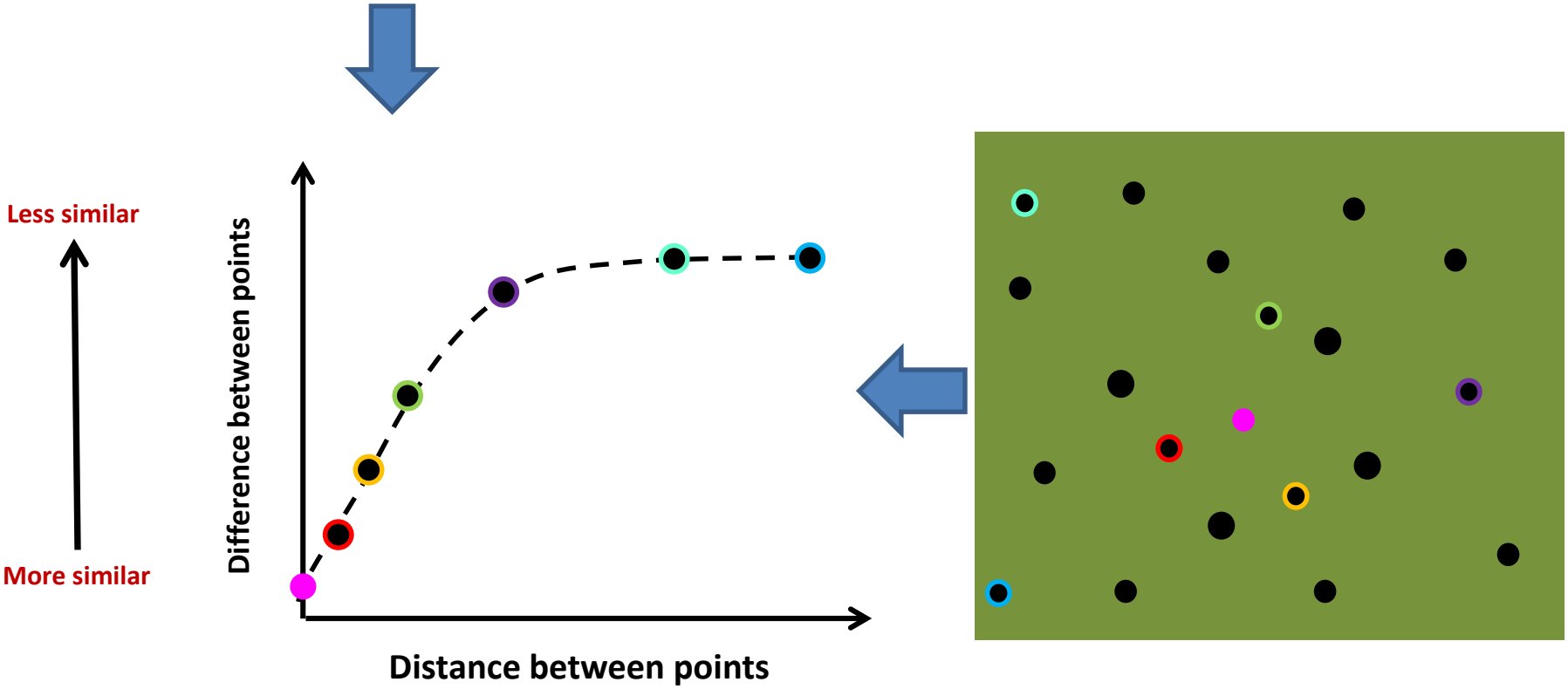
- **tend to have similar values**
- **follow similar trends over time**
- **are said to be better correlated**

Pts far away on average:

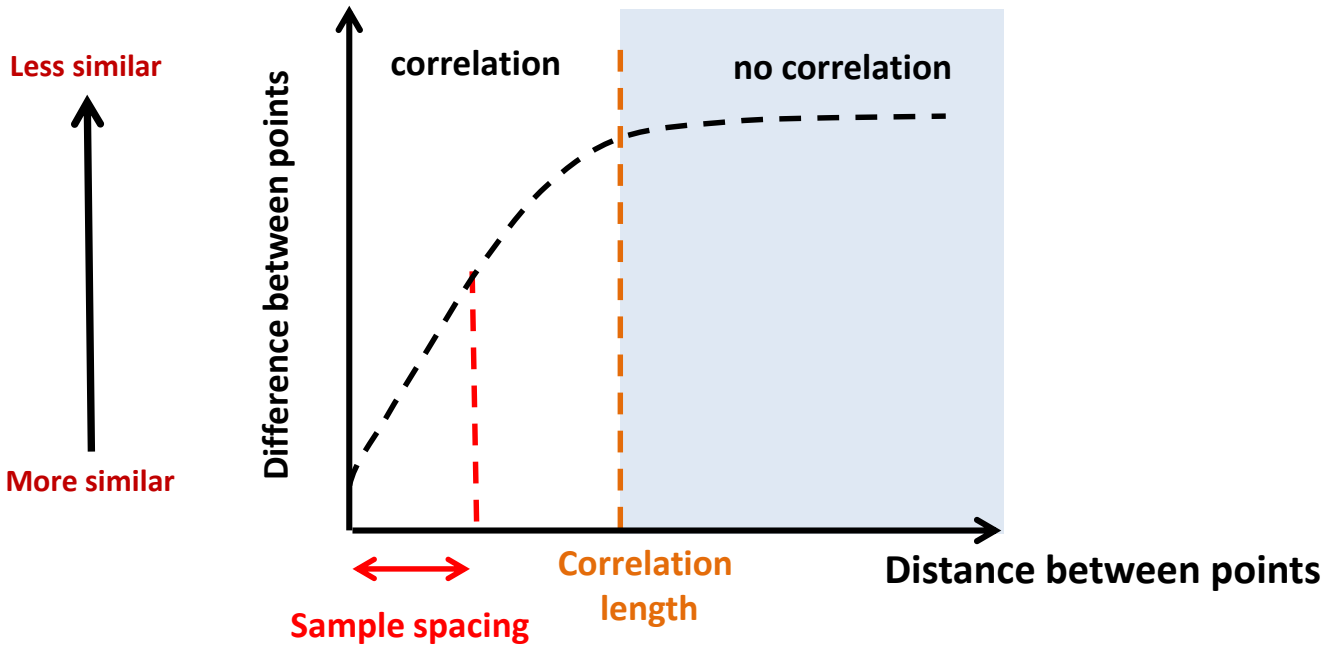
- **tend to have less similar values**
- **less likely to follow similar trends over time**
- **are said to be more poorly correlated**

Development of methods for predicting along the pipe soil properties

- **For any system we would expect the following general trend:**

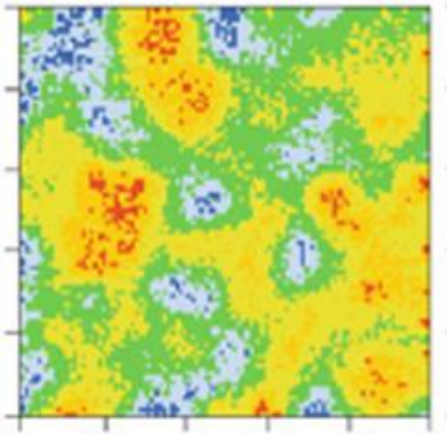


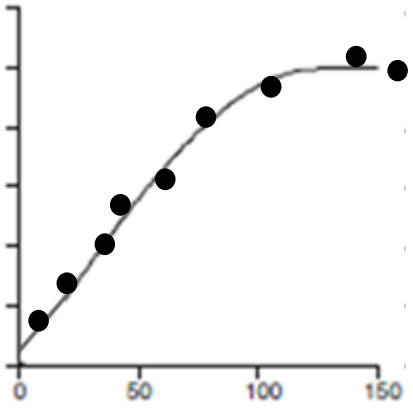
Development of methods for predicting along the pipe soil properties



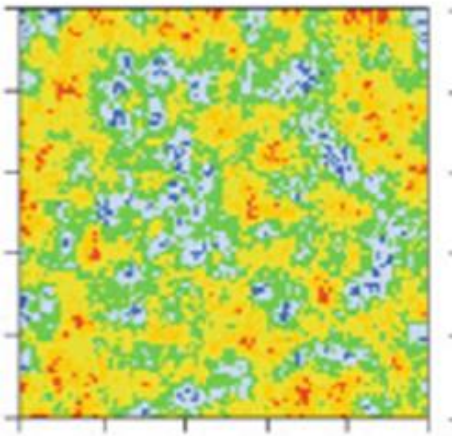
Development of methods for predicting along the pipe soil properties

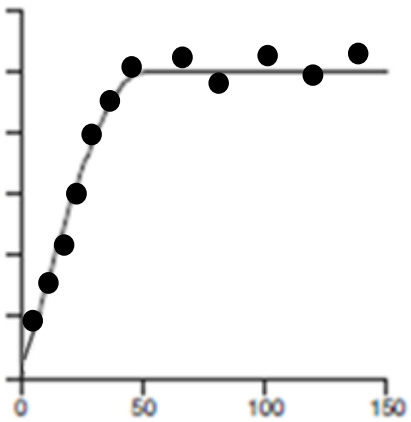
Soil property – same average, same standard deviation



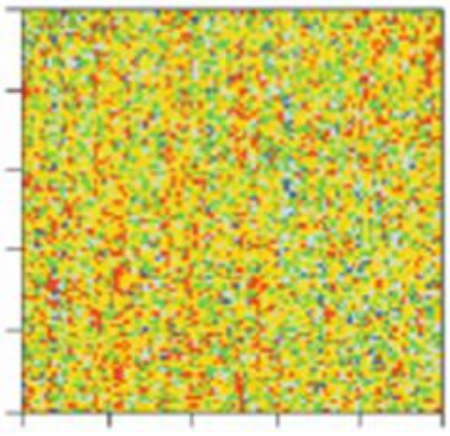


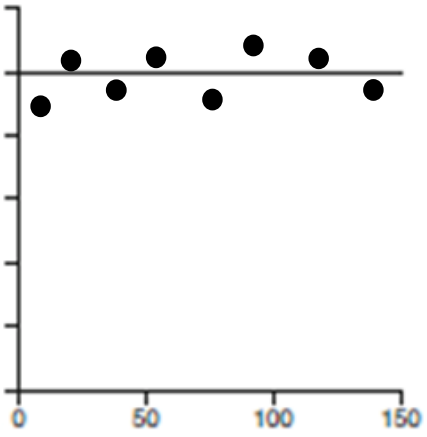
Interpolation OK
less samples





Interpolation OK
but more samples

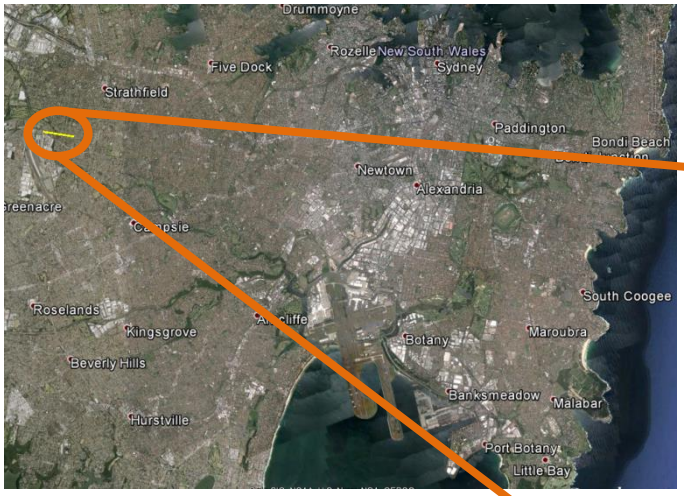




Random – need to average

Development of methods for predicting along the pipe soil properties

Soil sampling sites



(1) Sydney – Verona St test bed

Primarily clay soils

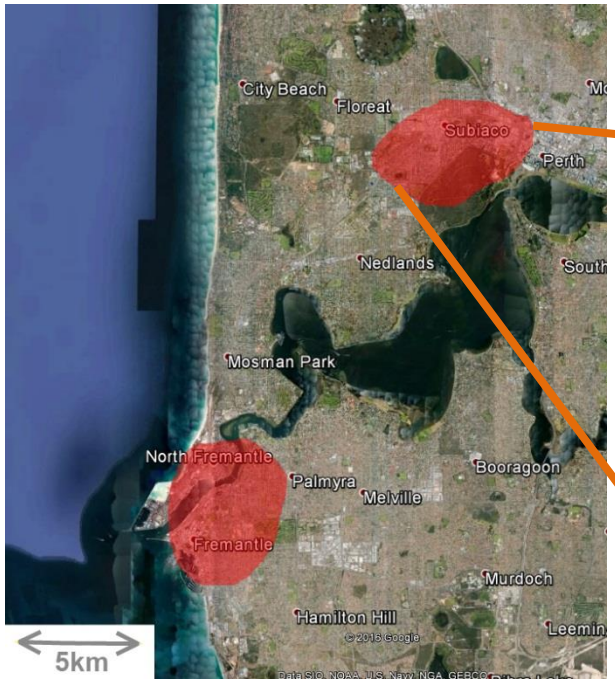
Samples taken at pipe depth

Essentially a transect

Samples 0.5 to 800m apart

Development of methods for predicting along the pipe soil properties

Soil sampling sites



(2) Perth – Subiaco

Primarily sandy soils

Samples taken at pipe depth

2D grid

Samples 2m to 3km apart

Development of methods for predicting along the pipe soil properties

Soil sampling sites

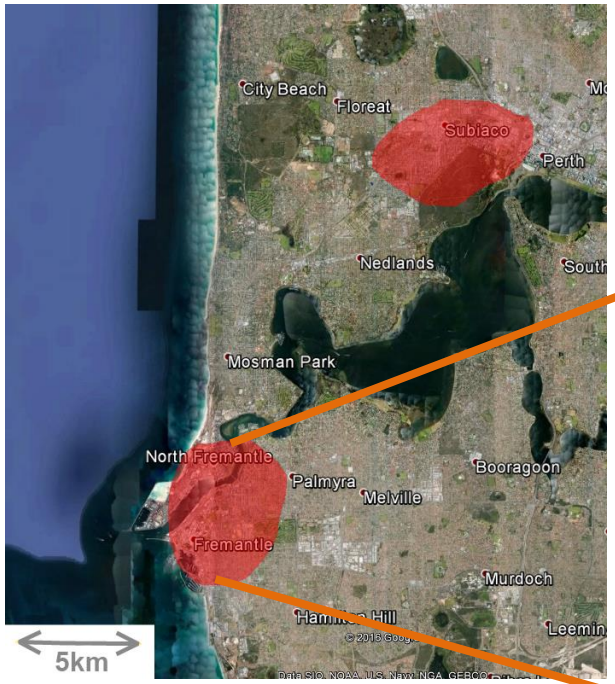
(3) Fremantle

Primarily sandy soils

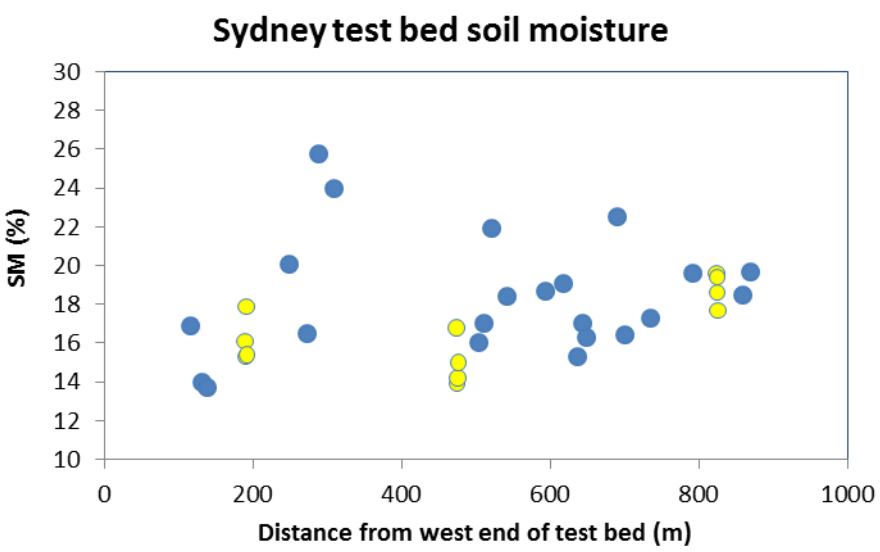
Samples taken at pipe depth

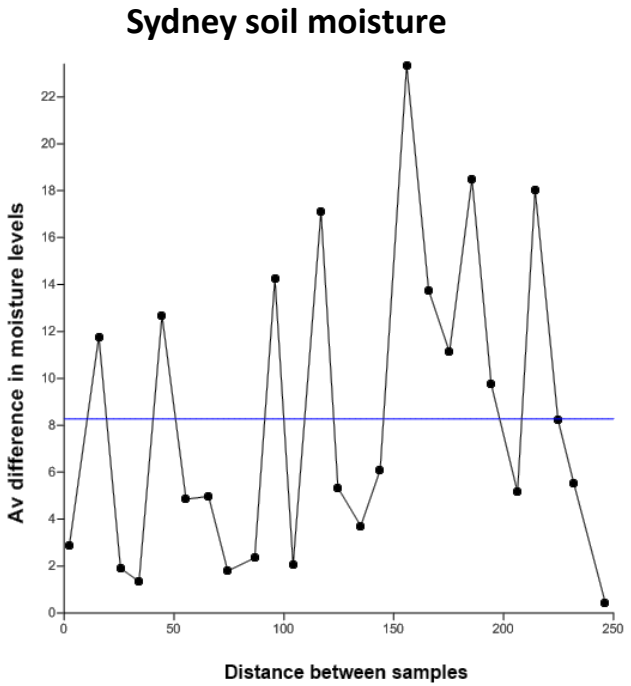
2D grid

Samples 30m to 3km apart



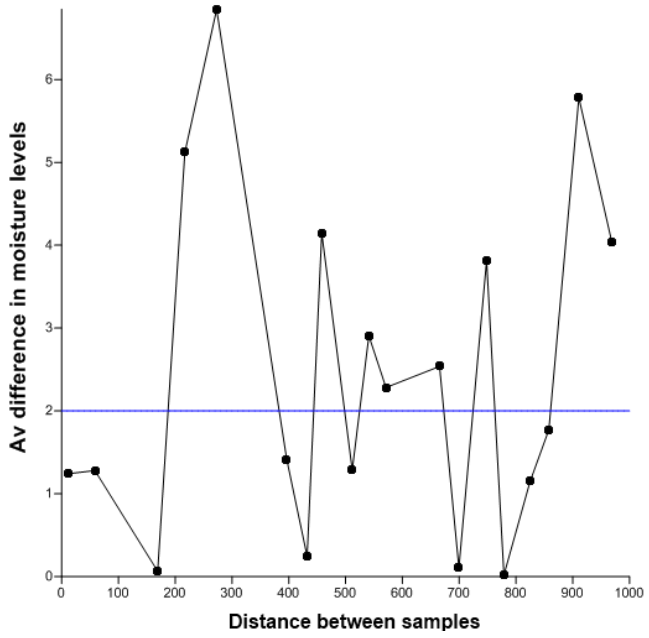
Development of methods for predicting along the pipe soil properties



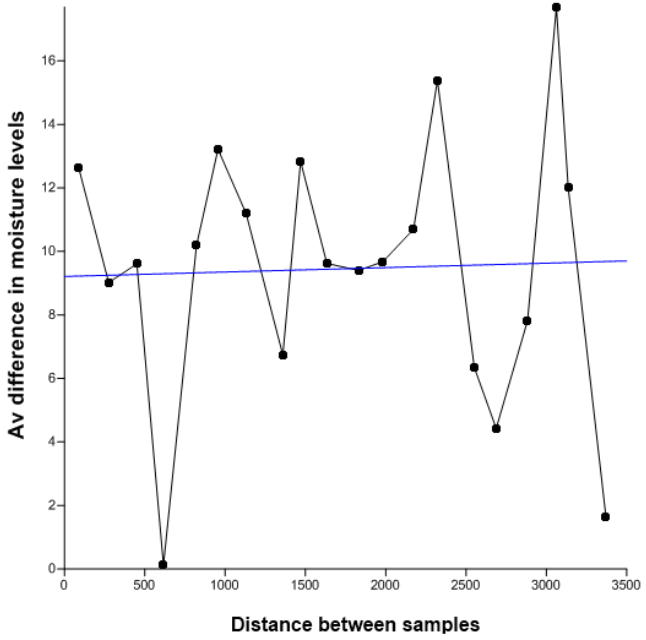


Development of methods for predicting along the pipe soil properties

Subiaco soil moisture

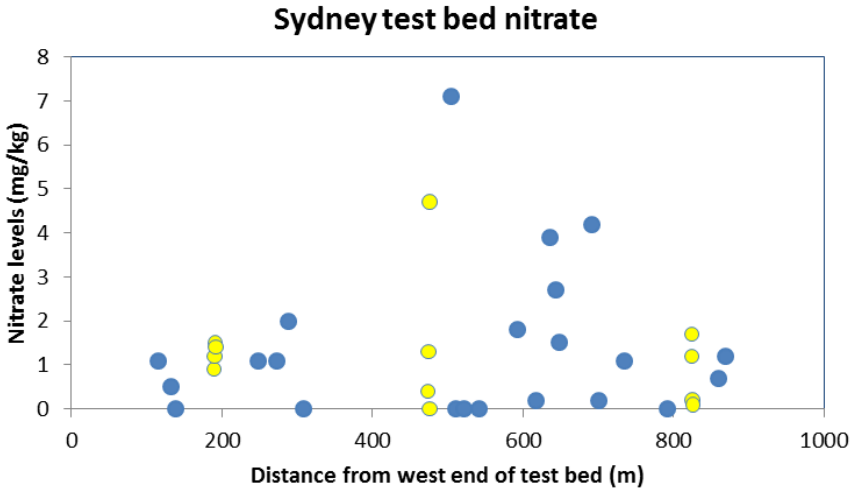


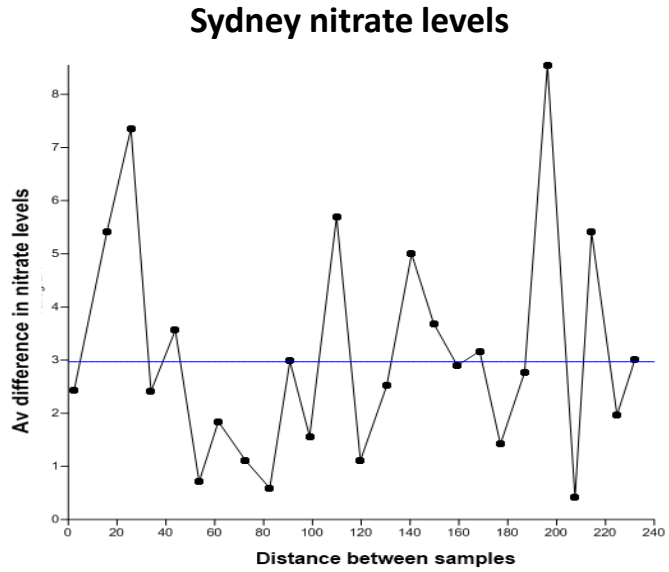
Fremantle soil moisture



No adequate sampling resolution

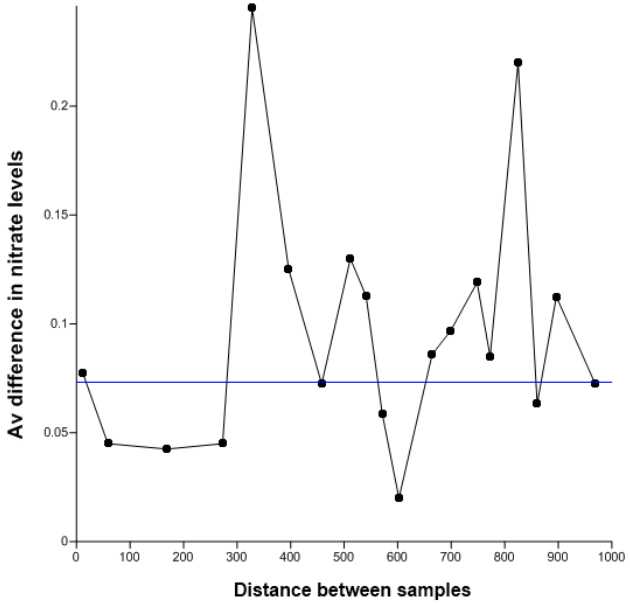
Development of methods for predicting along the pipe soil properties



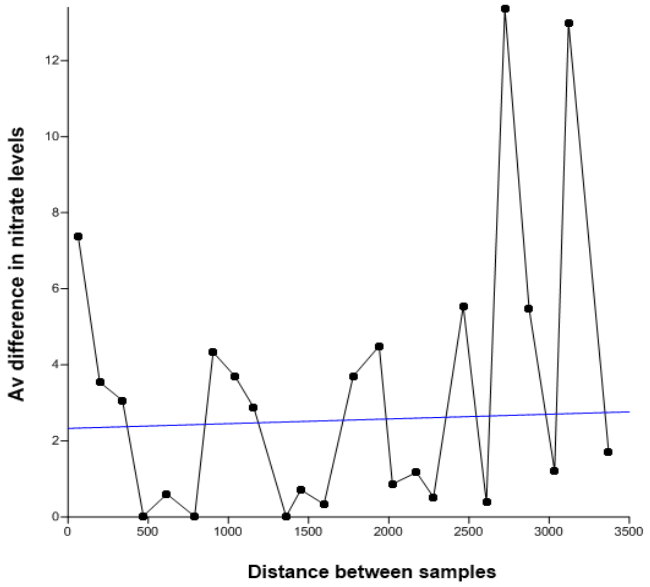


Development of methods for predicting along the pipe soil properties

Subiaco nitrate levels

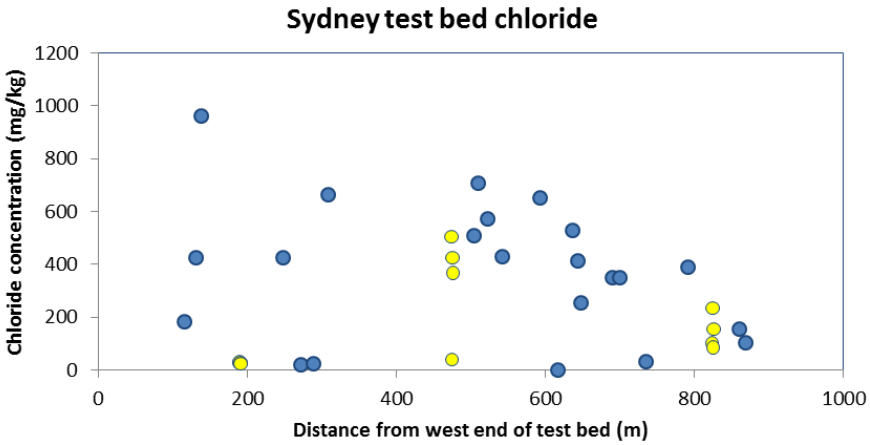


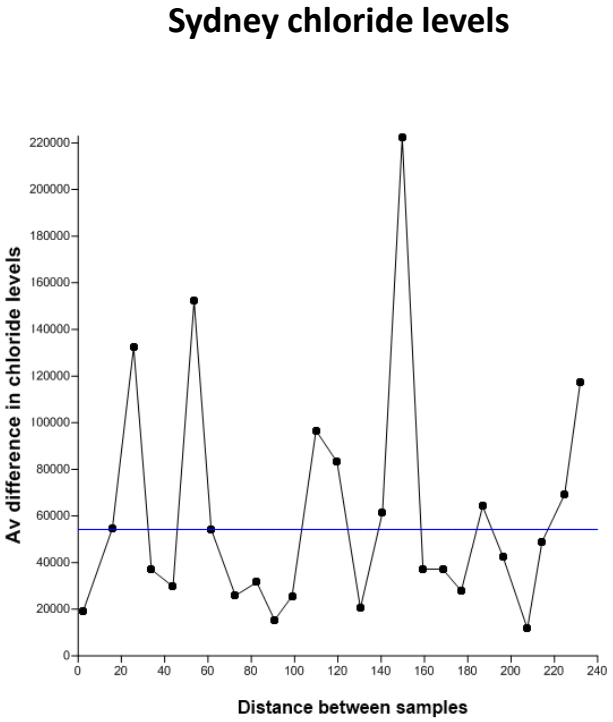
Fremantle nitrate levels



No adequate sampling resolution

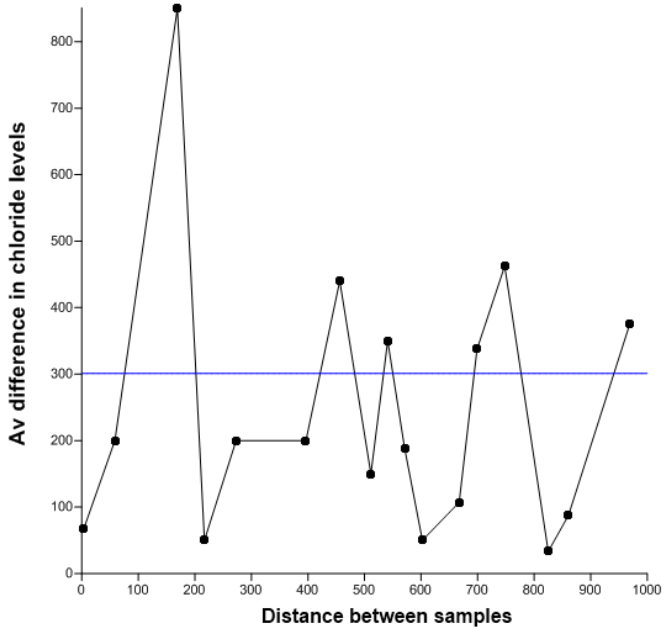
Development of methods for predicting along the pipe soil properties



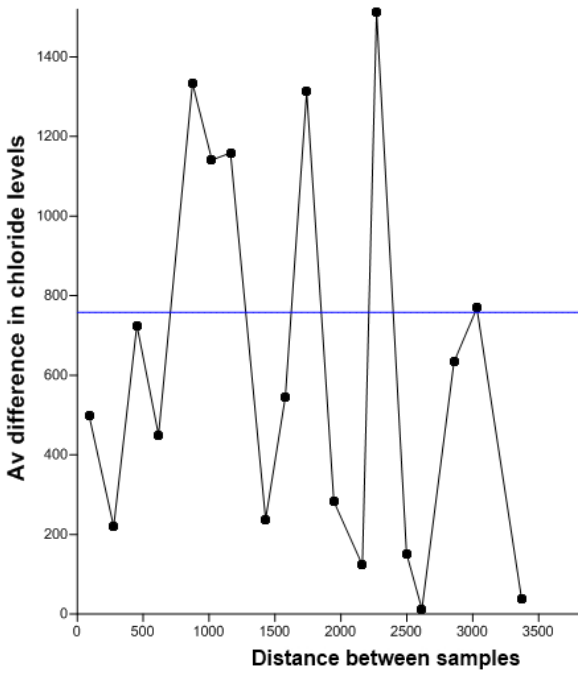


Development of methods for predicting along the pipe soil properties

Subiaco chloride levels



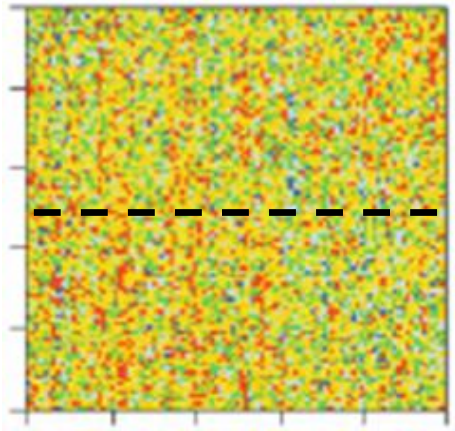
Fremantle chloride levels

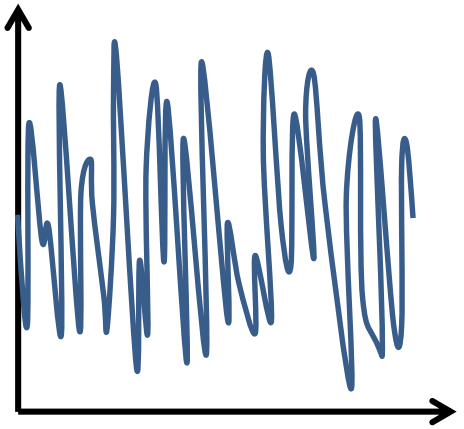


No adequate sampling resolution

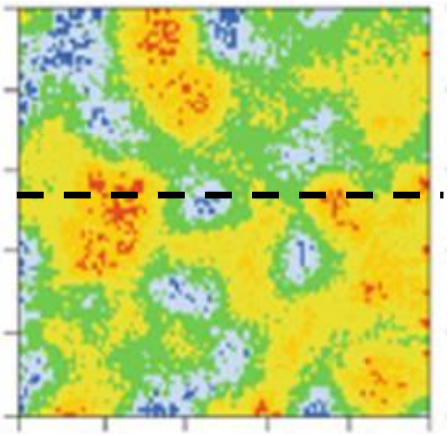
Development of methods for predicting along the pipe soil properties

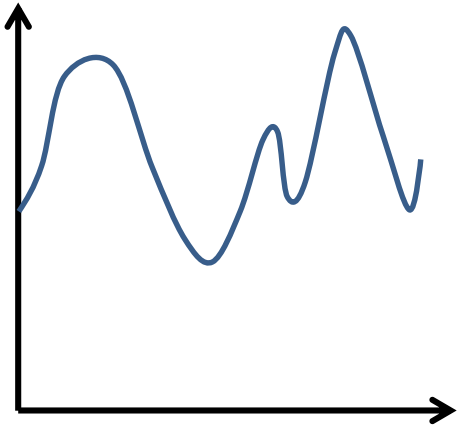
What we have is more like this….





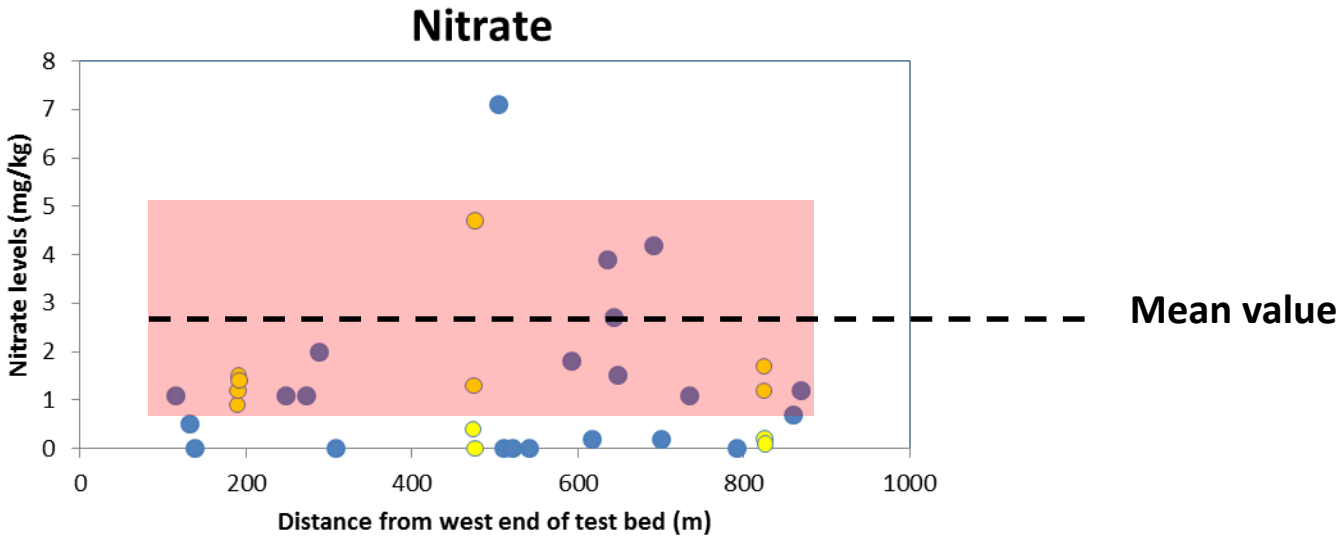
Rather than this …





Development of methods for predicting along the pipe soil properties

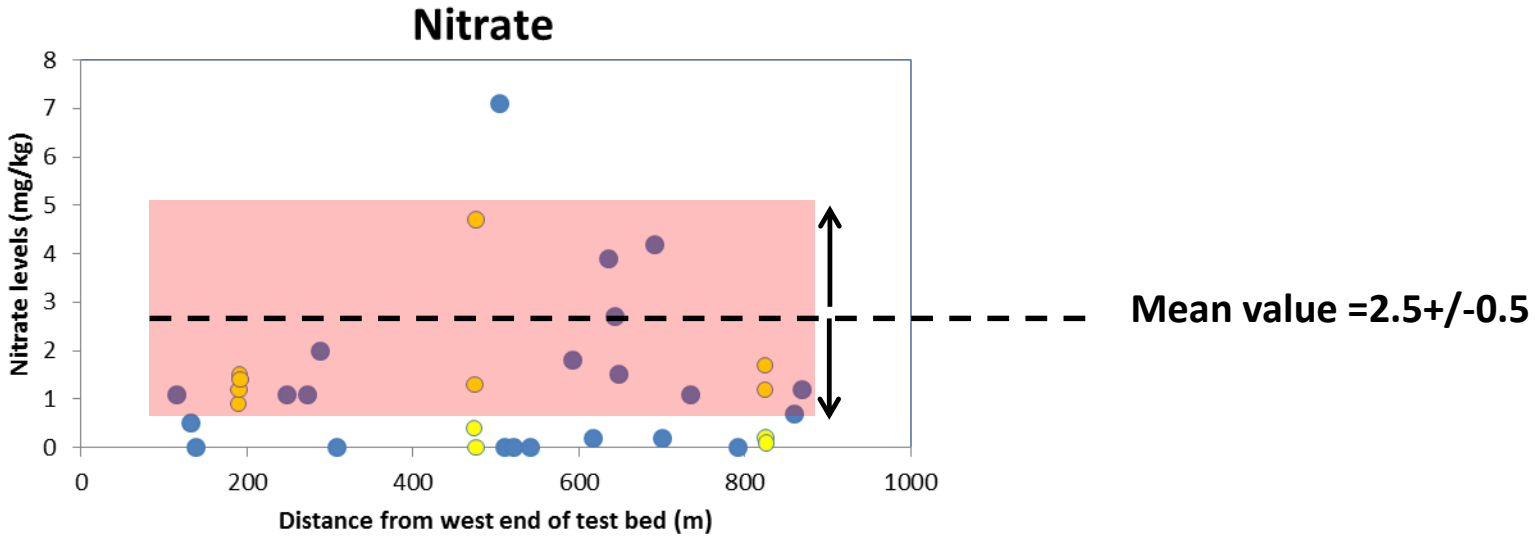
- If soil property has no structure we can't interpolate
- Best we can do is take a whole bunch of samples and from them estimate the average value along the pipe for that variable (e.g soil nitrate)



- Unless we take an infinite number of samples however we can't determine the "true" (population) mean

Development of methods for predicting along the pipe soil properties

- **Best we can do is take a practical number of samples and from them make an estimation of the average value +/- error to a certain level of confidence**
- **For example we might determine that:**
- **"we are 90% confident the average nitrate level along this section of pipe falls between 2 and 3 mg/kg (i.e. 2.5+/- 0.5 mg/kg)"**

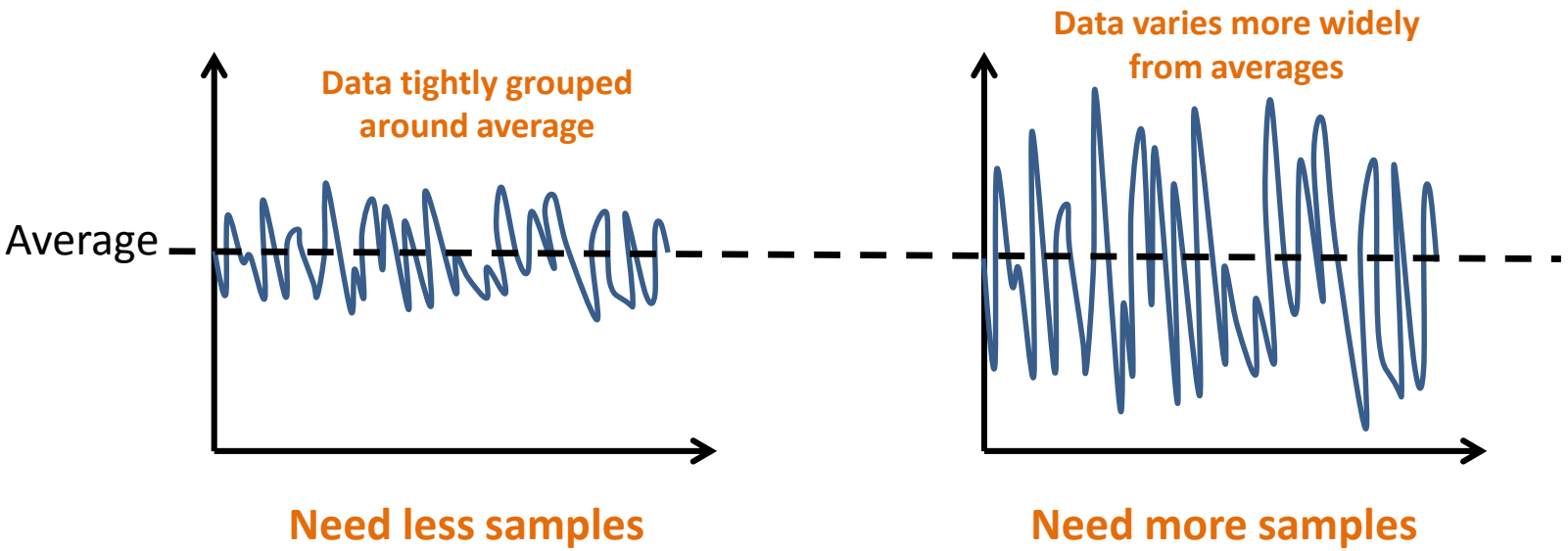


Development of methods for predicting along the pipe soil properties

But how many samples do we need to take to estimate the average?

Depends on:

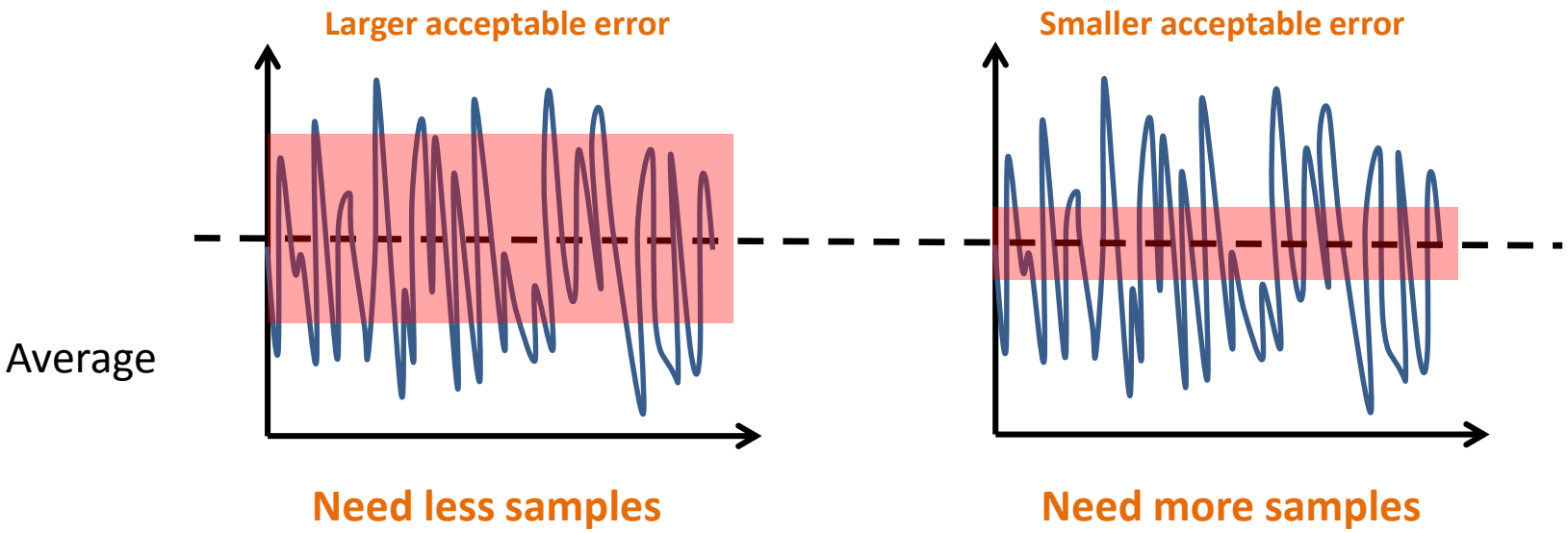
(1) The spread of the data from the average (the standard deviation = s)



- **either guess from previous experience or idea of processes taking place**
- **or do a small pilot survey**

Development of methods for predicting along the pipe soil properties

(2) The acceptable level of error (i.e. average +/- E)?



- **Acceptable level of error will be determined from the sensitivity of the corrosion model to that parameter**
- **For e.g. if the model is less sensitive to that parameter we can relax (expand) the acceptable level of error**

Development of methods for predicting along the pipe soil properties

(3) Level of confidence that you have determined the average +/- error

I am 99% confident the average falls in the range 2.5+/-0.5.	I am 90% confident the average falls in the range 2.5+/-0.5.
Need more samples	Need less samples

- **The level of confidence we desire in our estimate will depend on a trade off between the acceptable level of confidence we want in the final corrosion estimates and the cost of sampling**

Development of methods for predicting along the pipe soil properties

How many samples to take to estimate average?

Once we know these factors we use some maths (used by pollsters)…

$$no\ of\ samples = \left(t_{df,\alpha/2} \frac{s}{E} \right)^2$$

For example

How many soil samples do we need to take to estimate the average soil moisture to within +/- 3% w/w along a length of pipe to with a 95% confidence?

Estimated from previous sampling (e.g. test bed) = s = 2.8%
Acceptable level of error = E =1%
Confidence we want = CI = 90% (alpha=0.05)

Number of samples required =24

3. Development of an advanced monitoring tool

Advanced sensors.

Soil moisture.

- **Many portable probes around**
- **Commercially available**
- **Some units with built in GPS some with ability to measure EC at same time (an advantage)**
- **Will borrow and test over next few months**

Soil chemistry (nitrates,chlorides)

- **More problematic**
- **Most promising based on ion selective membranes**
- **Small handheld units for nitrates and "salt" (=chlorides or sodium??)**
- **May need to modify procedures to be more useful for field work**

Activity 4c. Predicting pipe corrosion along the pipe

Pending work

- **Continue deep SM monitoring at Sydney test bed (who to collect data?)**
- **Long term SM trends – how variable? – complete analysis of field data (incl. SASMAS and Oznet)**
- **Determine laboratory reproducibility for SM, soil chemistry**
- **Investigate sampling protocols for non-normally distributed data**
- **Investigate sampling protocols for soil properties such as wilt point, sand/silt/clay**
- **Continued investigation of smart sensors**
- **Integration of activity 4c findings with activity 3 corrosion model**

Activity 4c. Predicting pipe corrosion along the pipe

The end

Activity 4c. Predicting pipe corrosion along the pipe

Development of methods for predicting along the pipe soil properties

Normally distributed data