SULPHIDE MODELLING IN ICM TO IDENTIFY CORROSION POTENTIAL

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Presentation outline

1. The problem
2. The science
3. The tool - ICM
4. Trial results (Hutt Valley)
5. Validation checks
6. Conclusions


VIVO
NO ENTRY


MIND THE GAP
Health Warning
This area has recently been polluted
It is not safe to swim or eat fish or seafood

Figure 4 Cavity as first observed, 6 December 2019

Source: Ian Martin, AECOM (2020) report

Figure 7 Screengrab from Hydrotech camera footage

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

Kiwi Street, 2013

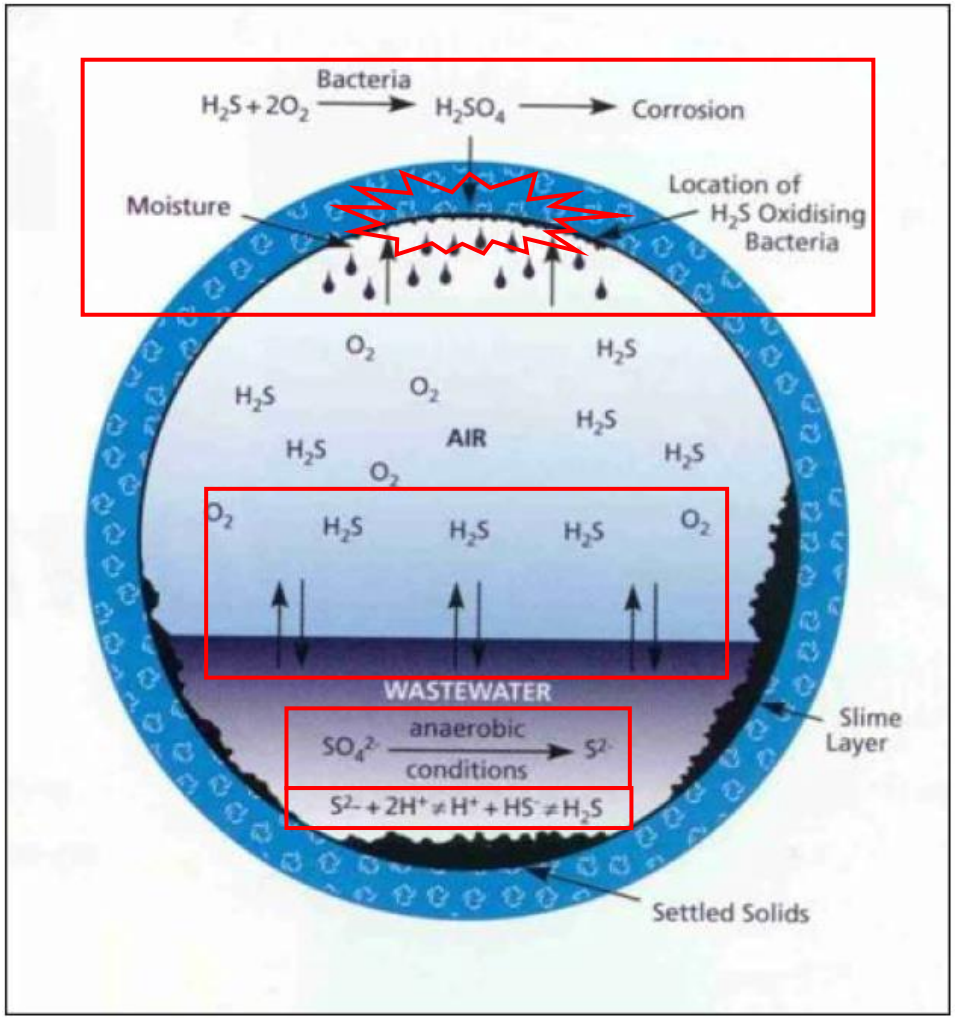
Source: Steve Hutchison, Wellington Water

The problem

1. Sulphide is characterised by “sporadic” or “seemingly random” appearance (until processes are better understood)
2. Corrosion can be gradual and undetected
3. Can seriously impact asset lifespan – to as little as 3 years
4. Historically addressed reactively
5. High cost of emergency maintenance or renewal
6. Odour and toxicity of gaseous sulphide

The science

1. Sulphates to sulphides (septic conditions)
2. Total sulphides to dissolved H_2S
3. Dissolved to gaseous H_2S
4. Oxidised by bacteria to H_2SO_4 in condensation
5. Acid attacks concrete, iron, steel (but not clay or plastic)



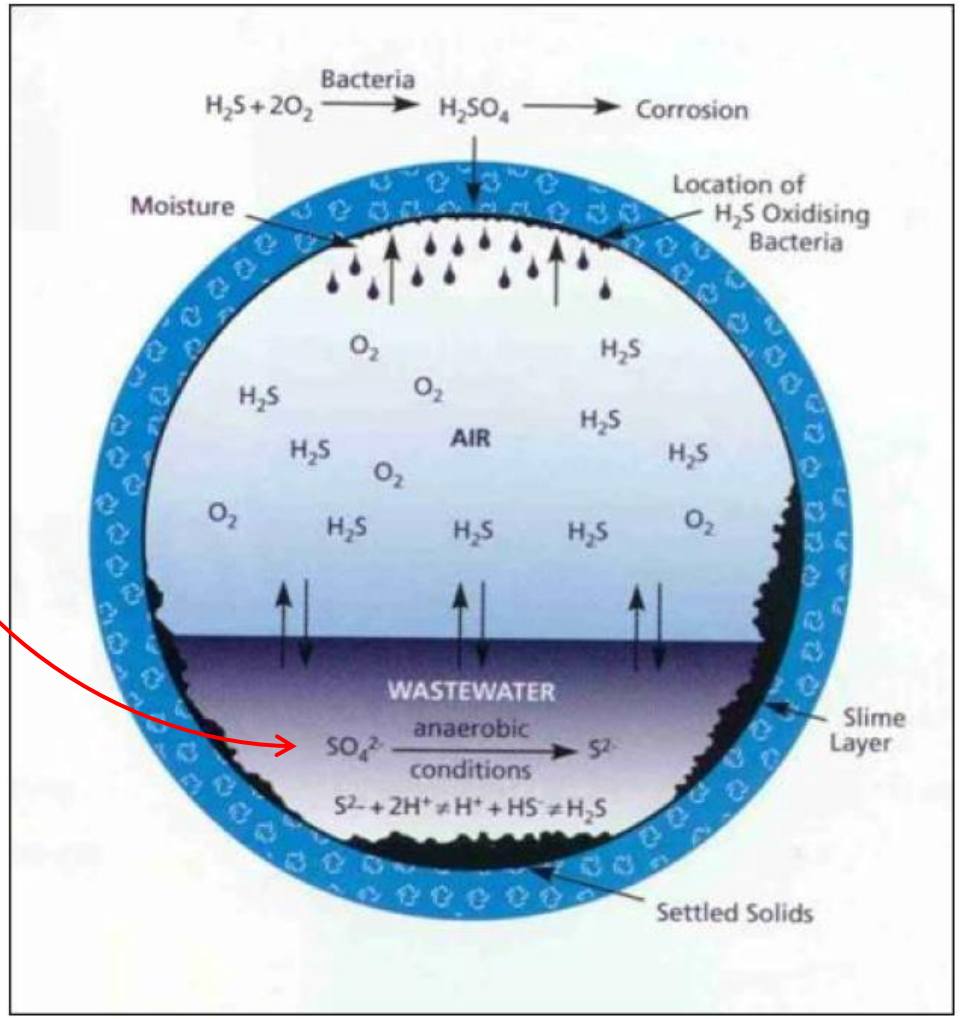
The basic process of sulphide release in a septic environment (Cisca & Crosby, 2015)

The tool

Pomeroy's Equation

$$\frac{d[S]}{dt} = \frac{M'\,EBOD}{R} - \frac{m[S](su)^{\frac{3}{8}}}{d_m}$$

M'	Sulphide flux free coefficient (Default = 0.00032 m/h)
$EBOD$	$BOD \times 1.07^{(T-20)}$
T	Wastewater temperature (°C)
R	Hydraulic Radius (m)
m	Sulphide loss coefficient – empirical coefficient accounts for losses by oxidation and escape to atmosphere (Default = 0.64 (m/h)(m/s)$^{-3/8}$)
$[S]$	Total sulphide concentration (mg/L)
d_m	Mean hydraulic depth (m)
u	Mean sewerage velocity (m/s)
s	Slope of energy grade line (m/m)



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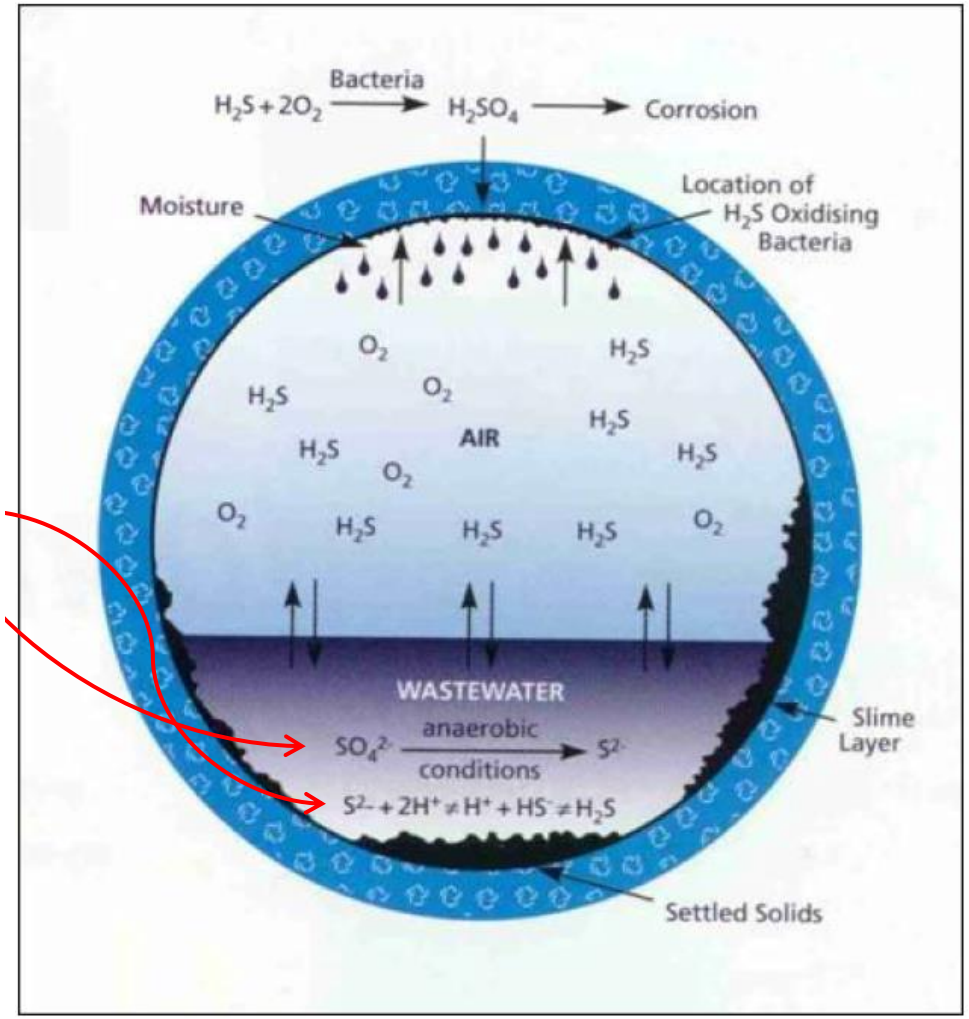
$$\frac{d[S]}{dt} = \frac{M' \, EBOD}{R} - \frac{m[S](su)^{\frac{3}{8}}}{d_m}$$

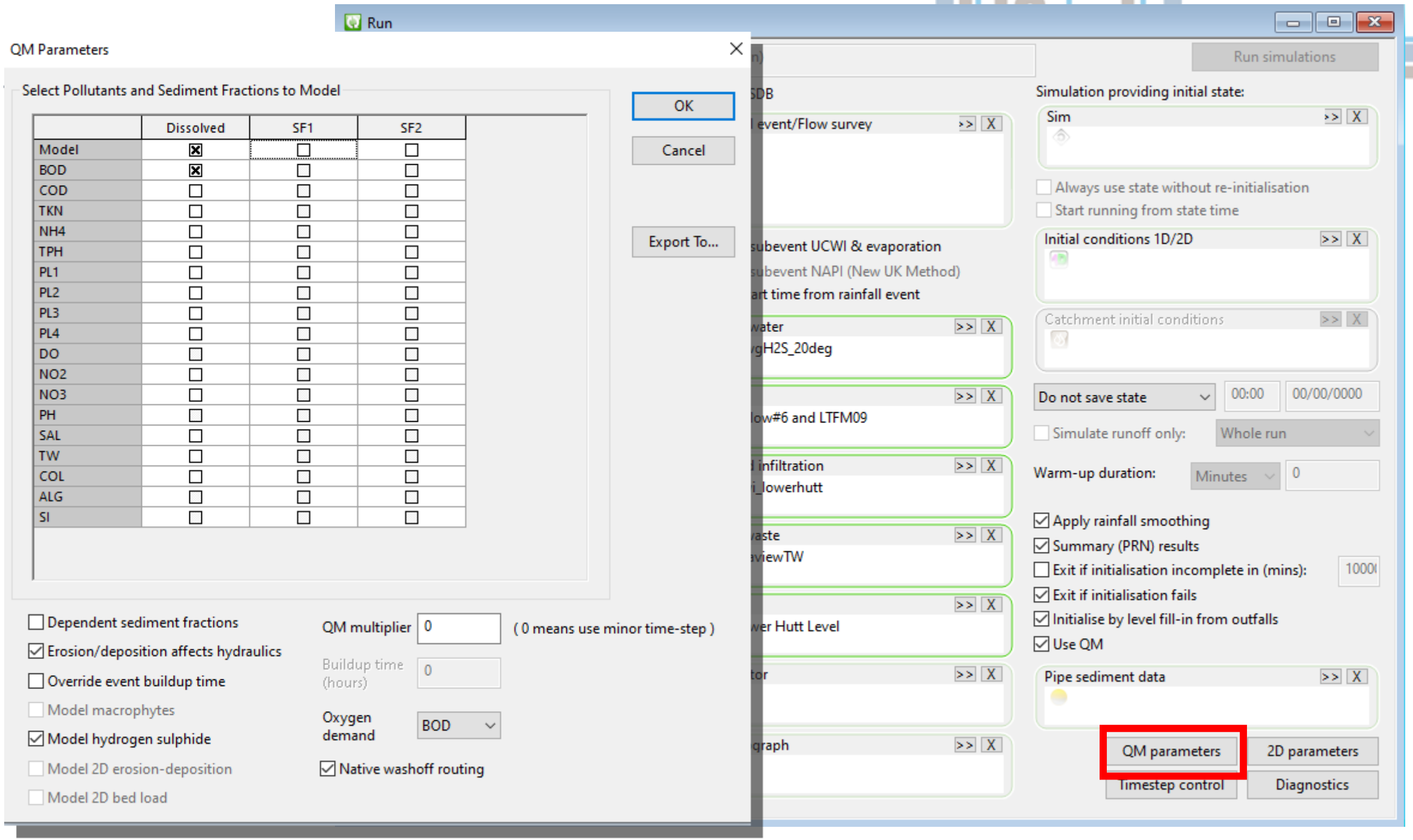
Sulphide solubility

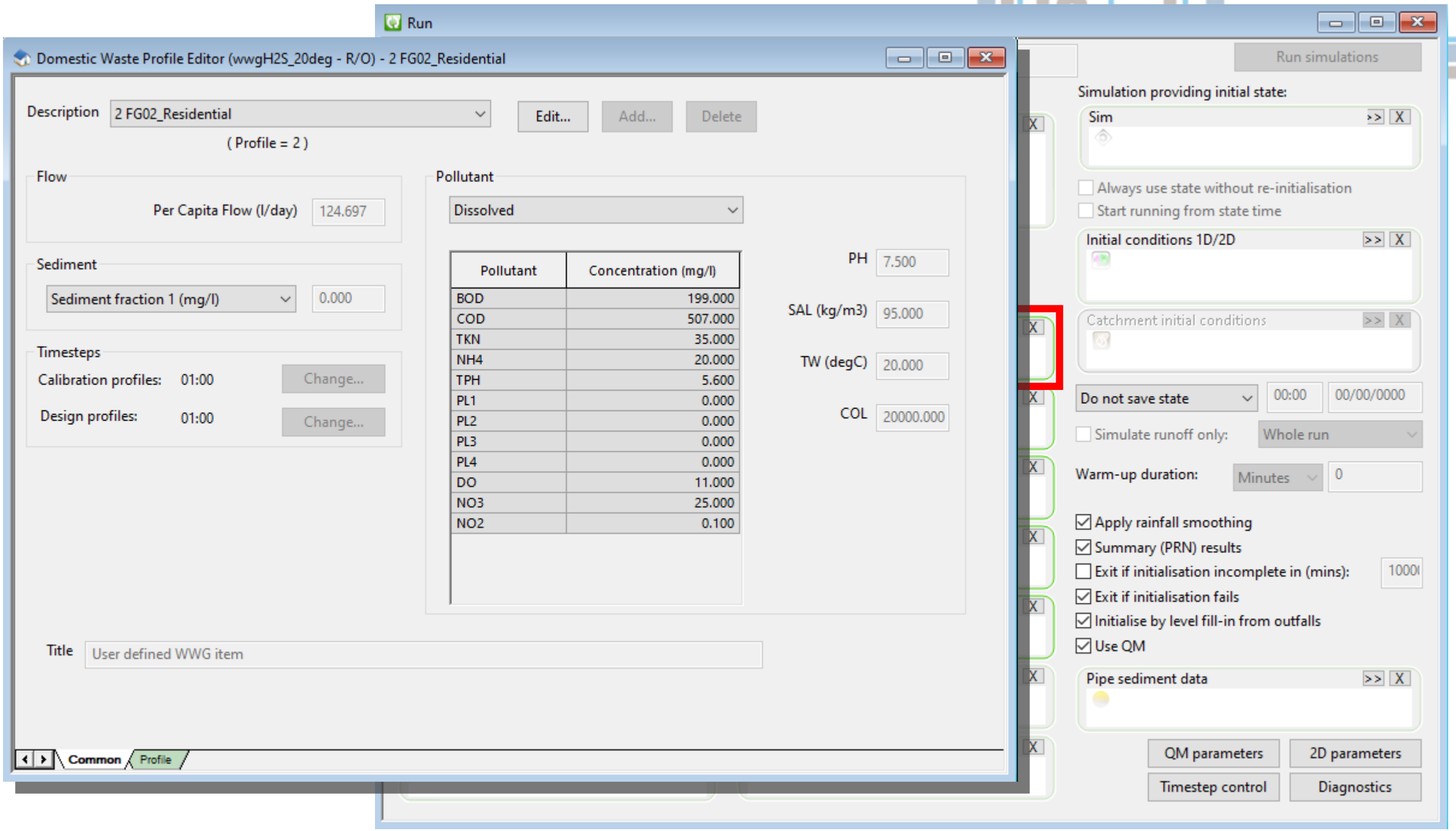
$$H_2S = \frac{\%\ soluble\ sulphide}{100} \times 1.0625 \times \frac{1}{1 + \frac{10^{-pK_1}}{10^{-pH}}} \times Total\ Sulphide$$

pK_1	Ionisation coefficient (default = 7.0)
1.0625	H_2S and S^{2-} molecular weight ratio
% Soluble Sulphide	(Default = 80%)



The basic process of sulphide release in a septic environment (Cisca & Crosby, 2015)


Run
QM Parameters
Select Pollutants and Sediment Fractions to Model
Dissolved
SF1
SF2
Model
BOD
COD
TKN
NH4
TPH
PL1
PL2
PL3
PL4
DO
NO2
NO3
PH
SAL
TW
COL
ALG
SI
OK
Cancel
Export To...
Dependent sediment fractions
Erosion/deposition affects hydraulics
Override event buildup time
Model macrophytes
Model hydrogen sulphide
Model 2D erosion-deposition
Model 2D bed load
QM multiplier
0
(0 means use minor time-step)
Buildup time (hours)
0
Oxygen demand
BOD
Native washoff routing
Run simulations
Simulation providing initial state:
Sim
Always use state without re-initialisation
Start running from state time
Initial conditions 1D/2D
Catchment initial conditions
Do not save state
00:00
00/00/0000
Simulate runoff only:
Whole run
Warm-up duration:
Minutes
0
Apply rainfall smoothing
Summary (PRN) results
Exit if initialisation incomplete in (mins):
Exit if initialisation fails
Initialise by level fill-in from outfalls
Use QM
Pipe sediment data
QM parameters
2D parameters
Timestep control
Diagnostics


Run
Domestic Waste Profile Editor (wwgH2S_20deg - R/O) - 2 FG02_Residential
Description
2 FG02_Residential
Edit...
Add...
Delete
(Profile = 2)
Flow
Per Capita Flow (l/day)
124.697
Sediment
Sediment fraction 1 (mg/l)
0.000
Timesteps
Calibration profiles:
01:00
Change...
Design profiles:
01:00
Change...
Pollutant
Dissolved
Pollutant
Concentration (mg/l)
BOD 199.000
COD 507.000
TKN 35.000
NH4 20.000
TPH 5.600
PL1 0.000
PL2 0.000
PL3 0.000
PL4 0.000
DO 11.000
NO3 25.000
NO2 0.100
PH
7.500
SAL (kg/m3)
95.000
TW (degC)
20.000
COL
20000.000
Title
User defined WWG item
Common
Profile
Run simulations
Simulation providing initial state:
Sim
Always use state without re-initialisation
Start running from state time
Initial conditions 1D/2D
Catchment initial conditions
Do not save state
00:00
00/00/0000
Simulate runoff only:
Whole run
Warm-up duration:
Minutes
0
Apply rainfall smoothing
Summary (PRN) results
Exit if initialisation incomplete in (mins):
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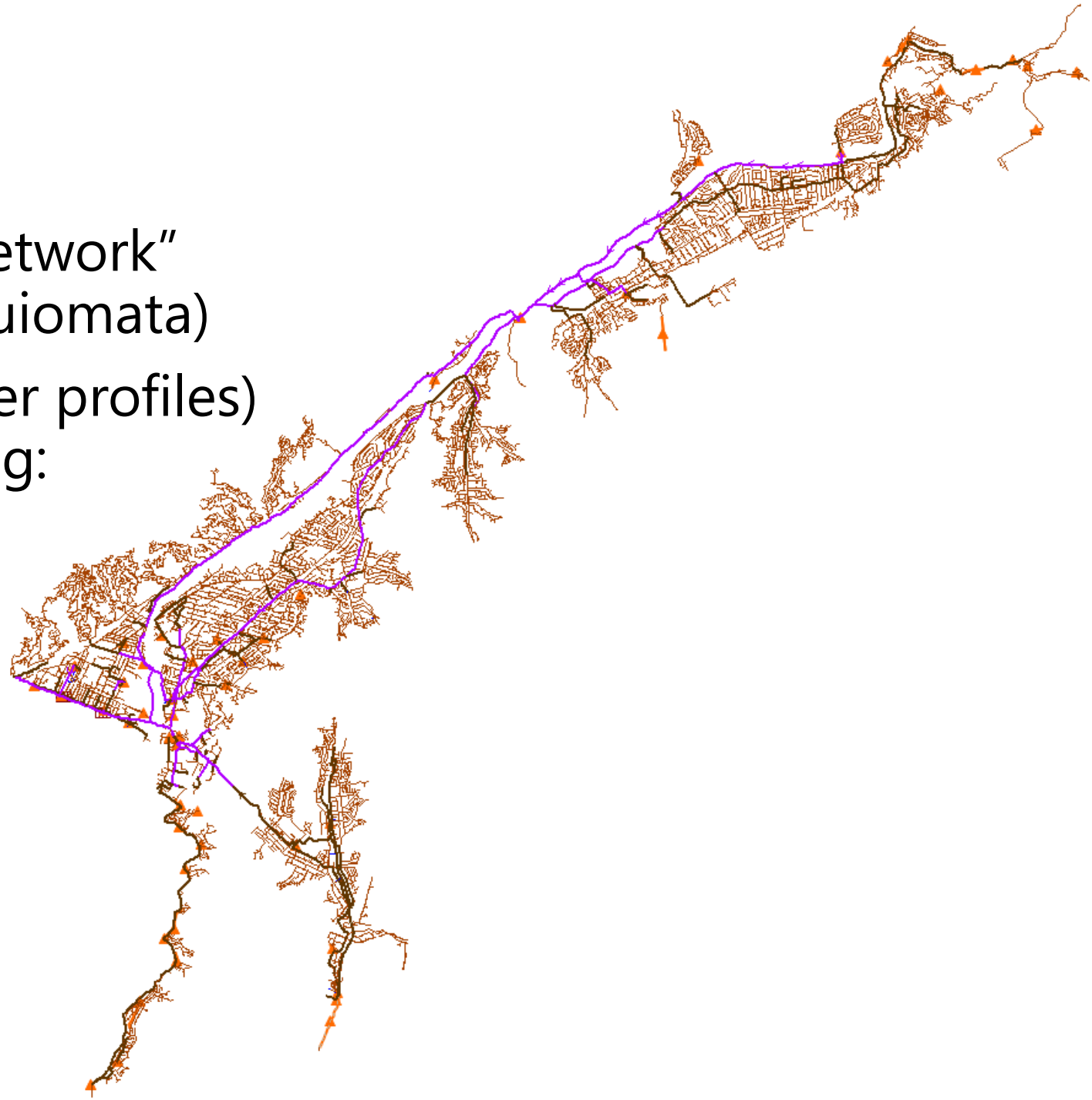
Initialise by level fill-in from outfalls
Use QM
Pipe sediment data
QM parameters
2D parameters
Timestep control
Diagnostics

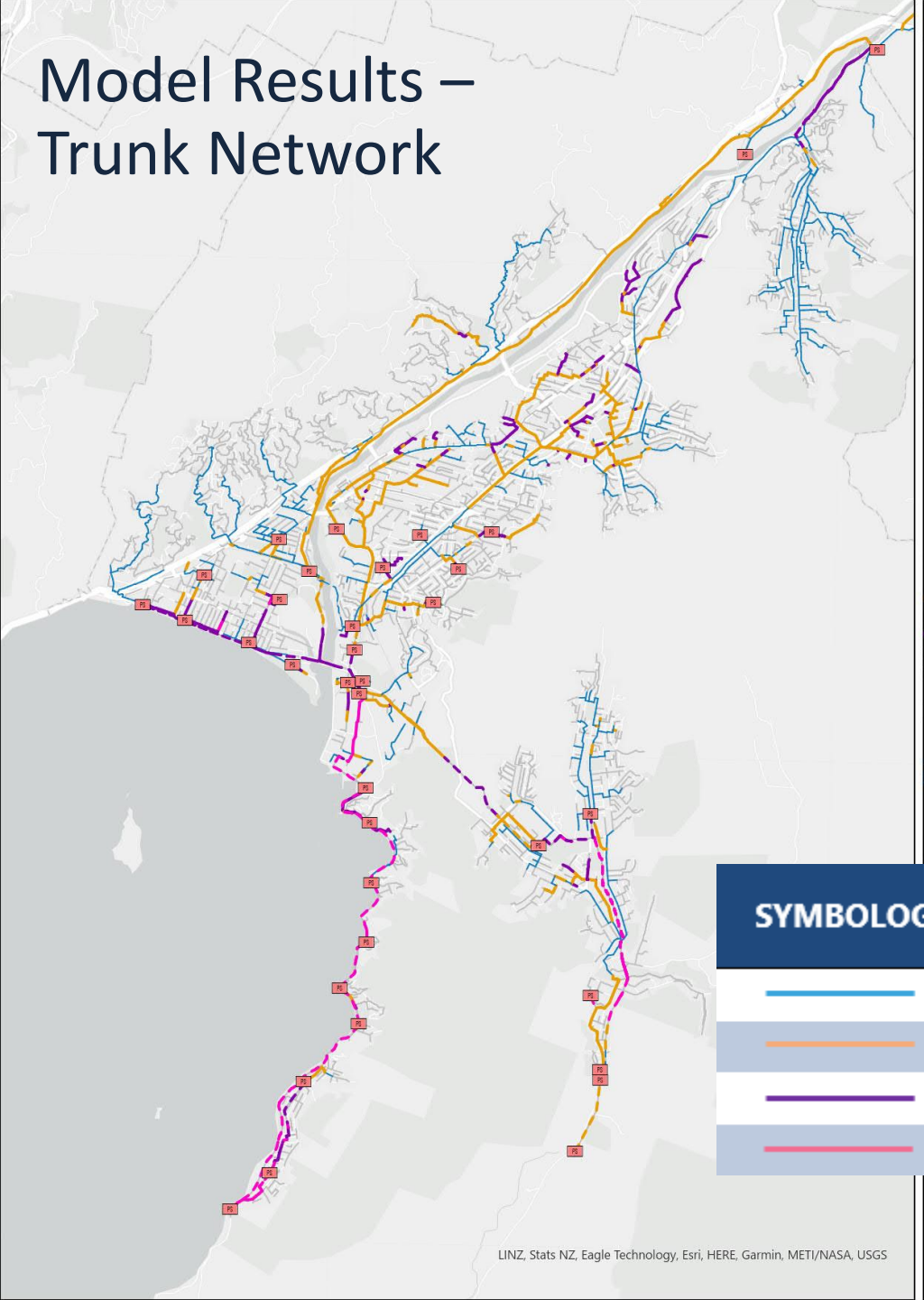
Trial case – Hutt Valley

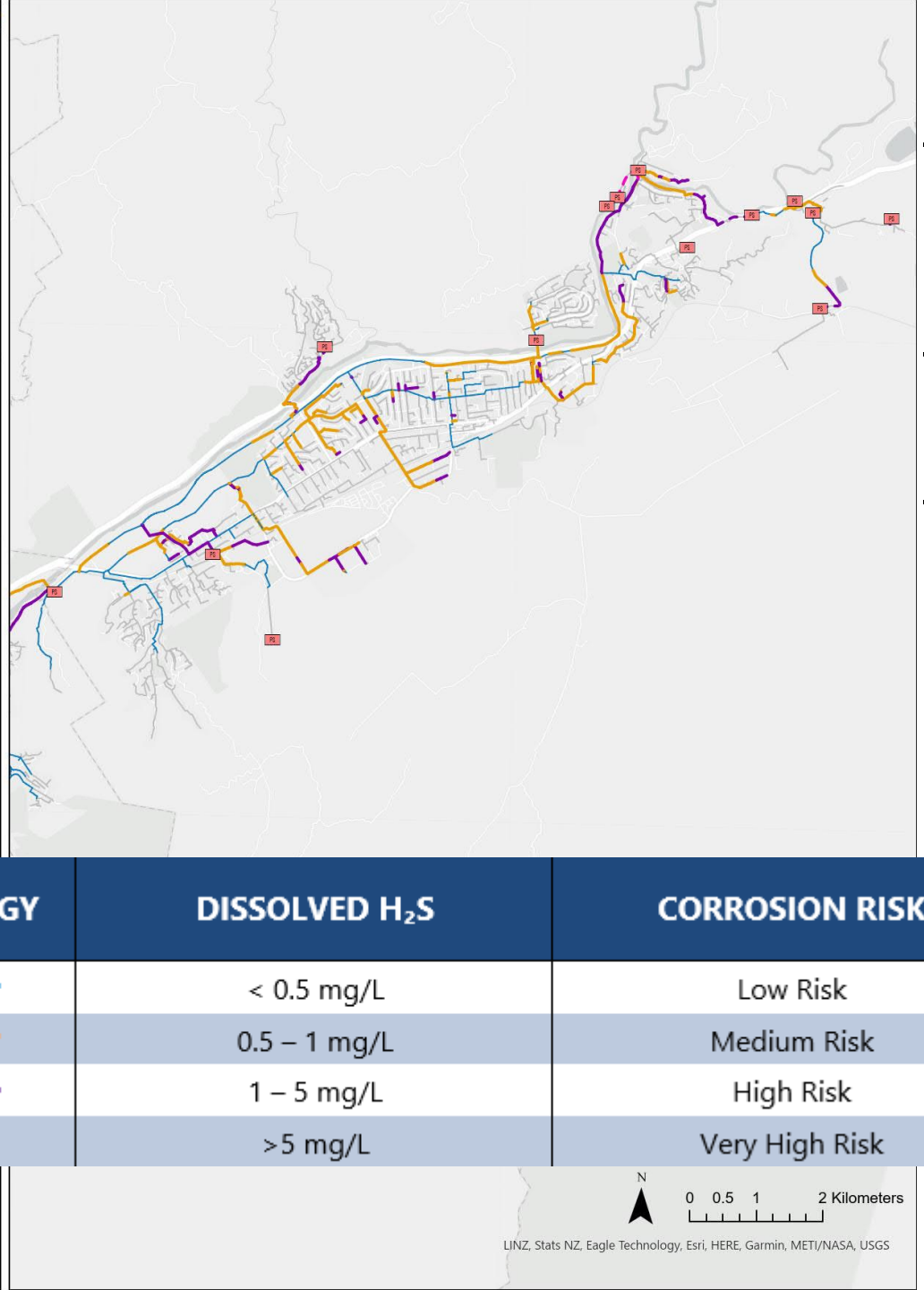
- All-pipes model of “Seaview Network” (Upper Hutt, Lower Hutt, Wainuiomata)
- Pollutant loading (all wastewater profiles) assumed for wastewater loading:

POLLUTANT	VALUE	MODELLED
pH	7.0	☐
SAL (kg/m3)	95	☐
TW (degC)	20	☐
COL	20,000	☐
POLLUTANT	**CONCENTRATION (MG/L)**	**MODELLED**
BOD	199	☒
COD	507	☐
TKN	35	☐
NH4	20	☐
TPH	5.6	☐
DO	11	☐
NO3	25	☐
NO2	0.1	☐



Model Results – Trunk Network

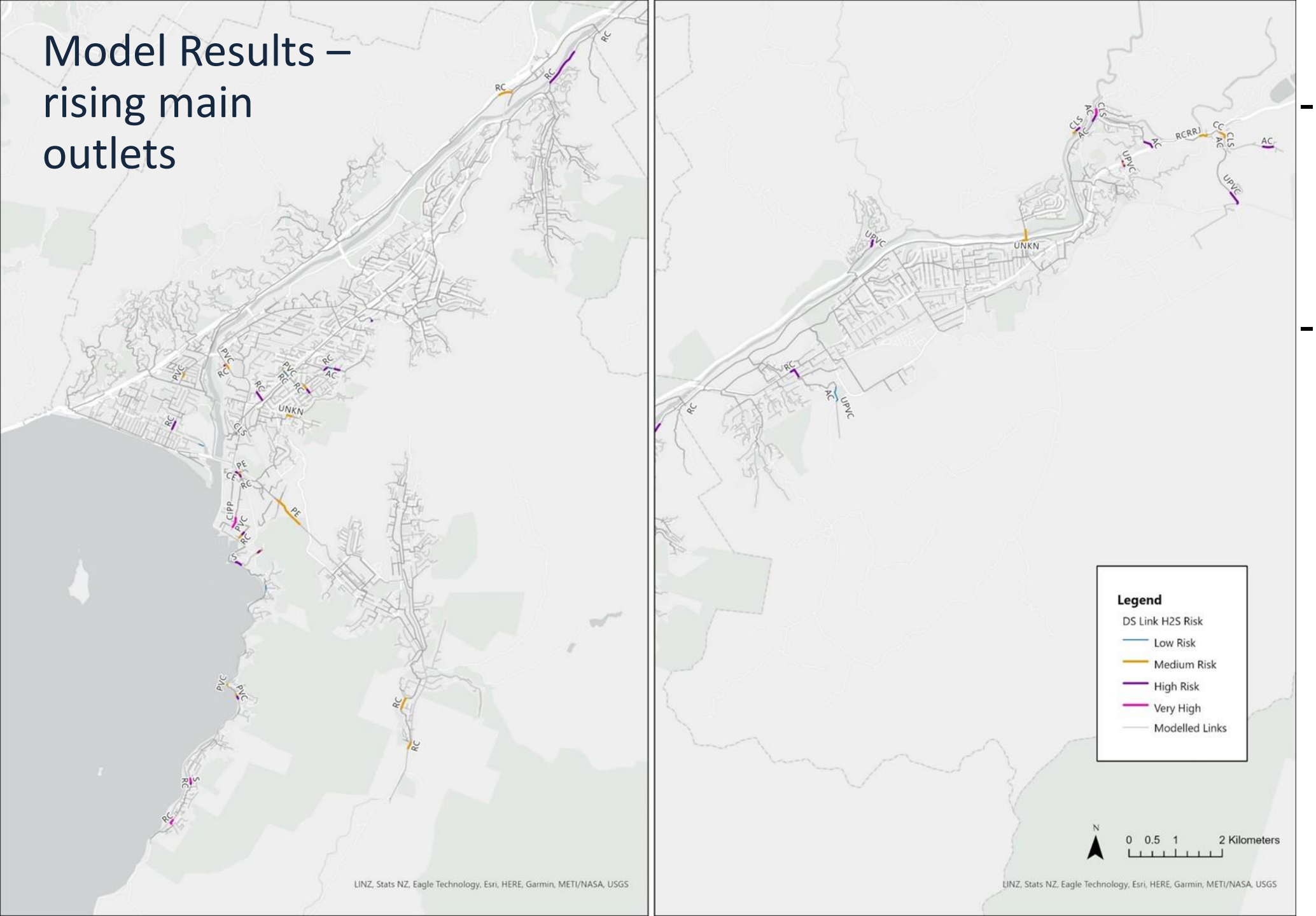




SYMBOLOGY	DISSOLVED H_2S	CORROSION RISK
	< 0.5 mg/L	Low Risk
	0.5 – 1 mg/L	Medium Risk
	1 – 5 mg/L	High Risk
	>5 mg/L	Very High Risk

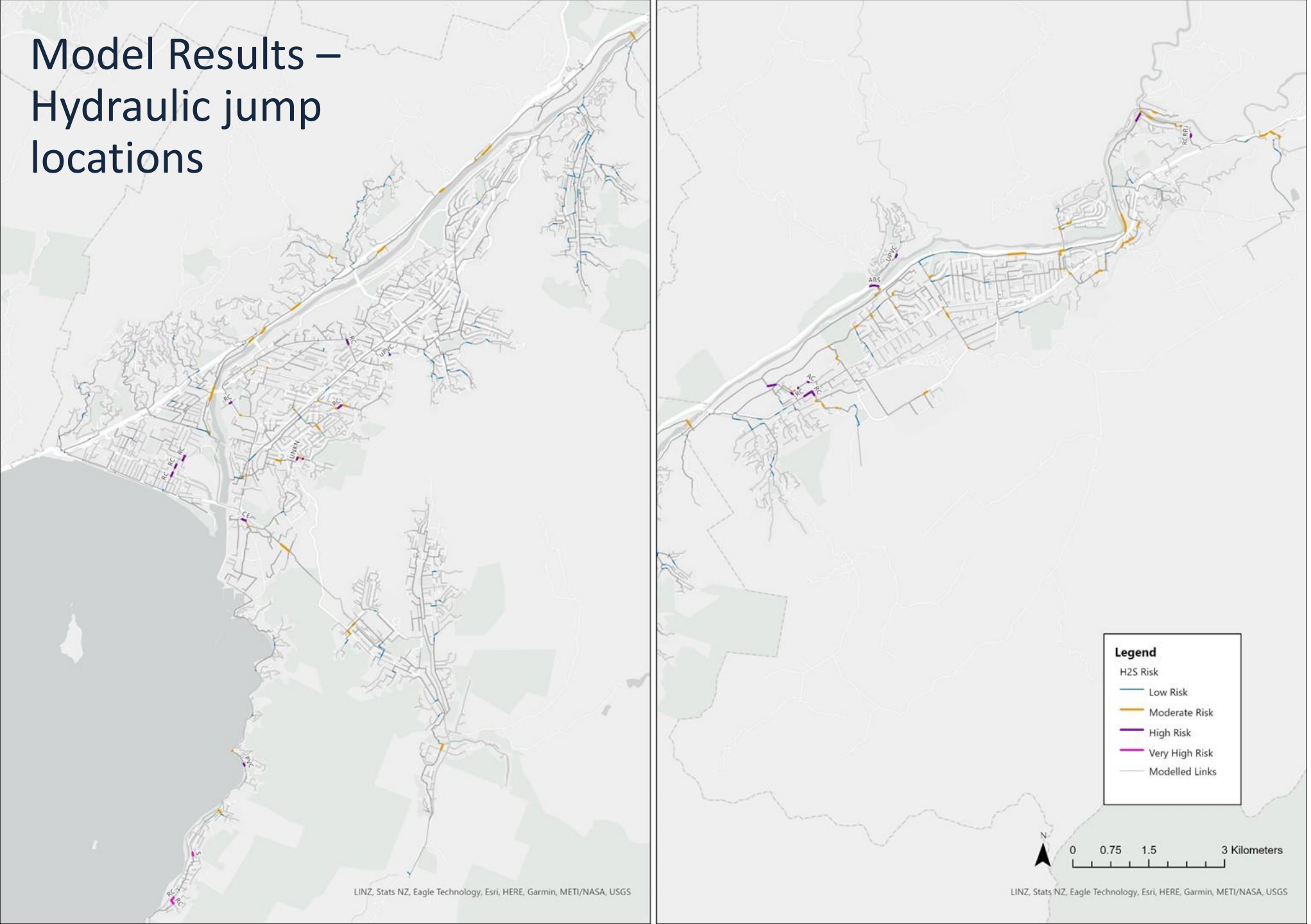
- Highlighting results for trunk network only
- 90th %ile of DWF 24-hr period
- Note Sydney Water targets <0.5 mg/L (blue lines)

Model Results – rising main outlets



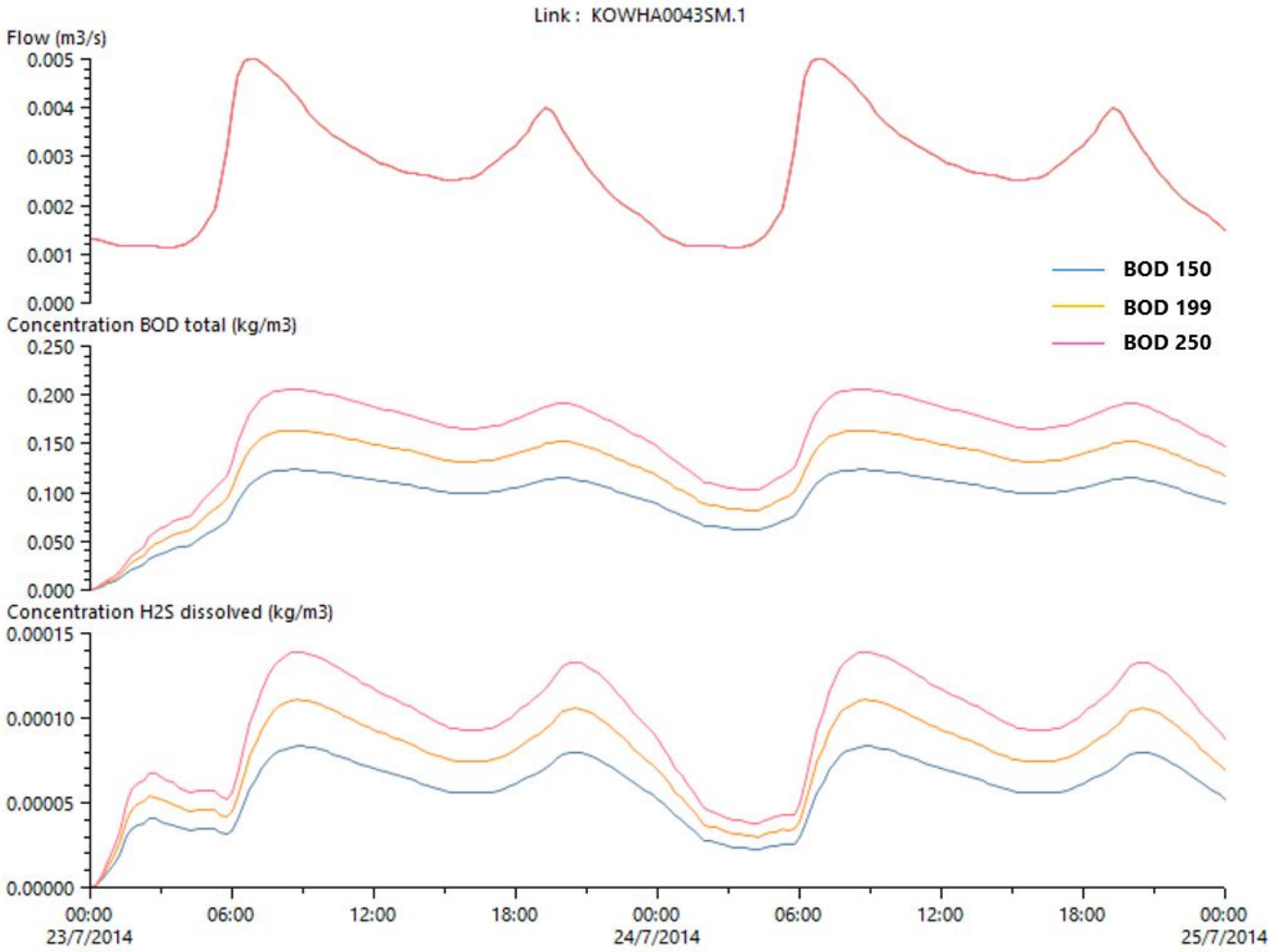
- Gravity mains downstream of a rising main
- 20 locations with >1 mg/L dissolved sulphide

Model Results – Hydraulic jump locations

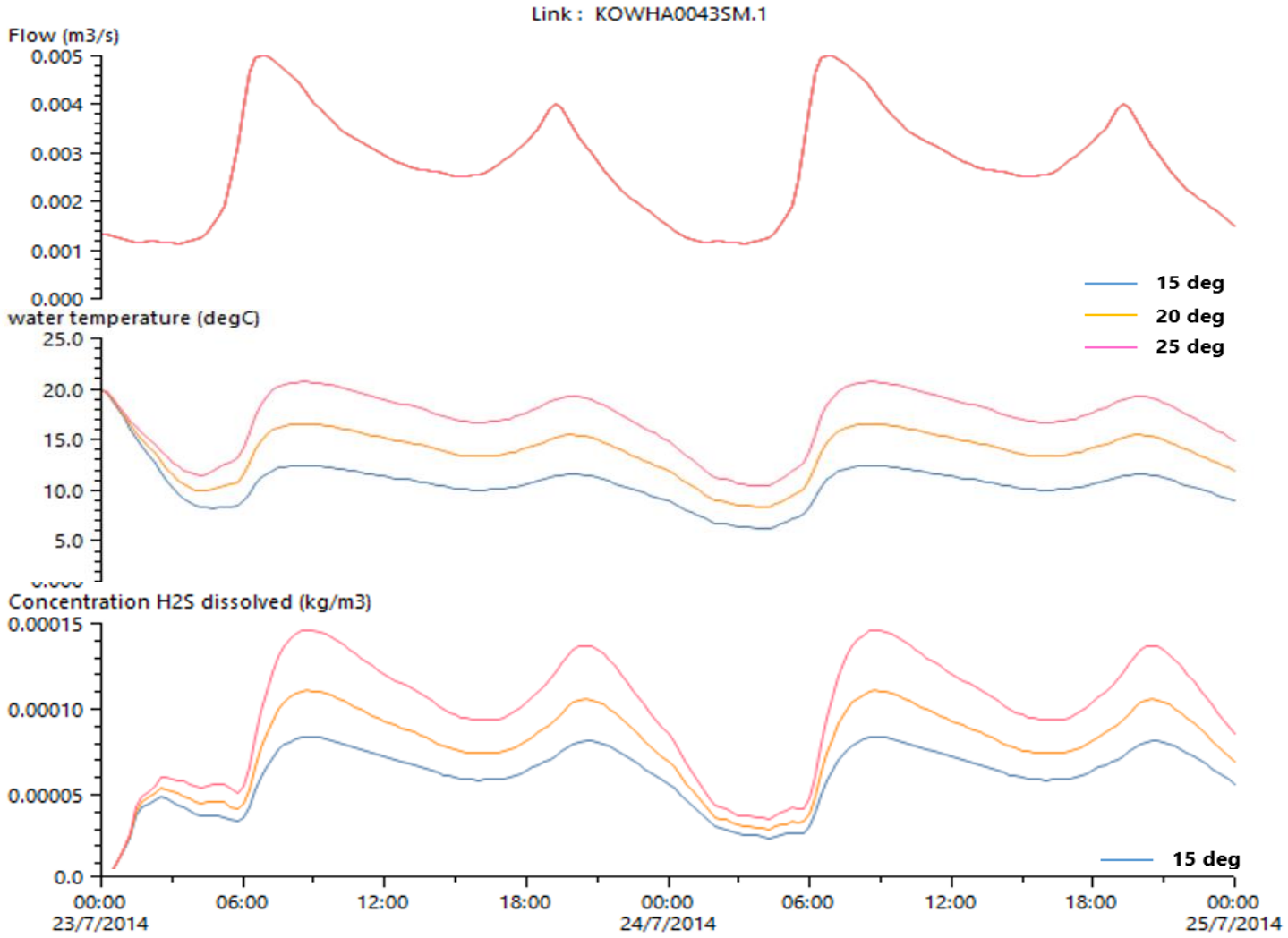


- Gravity pipes where max modelled Froude No. transitions from >1 to <1
- 25 locations with >1 mg/L dissolved sulphide

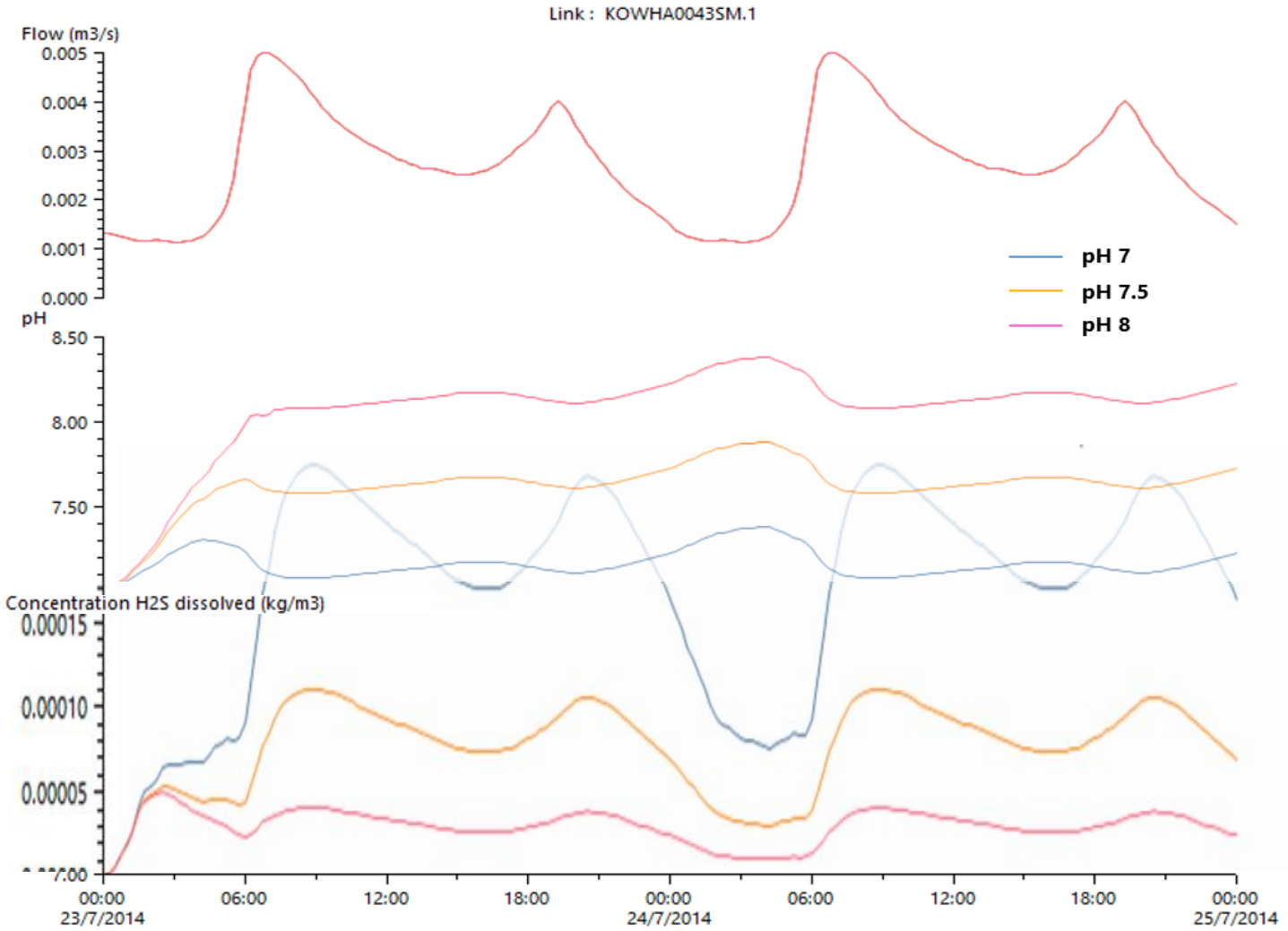
Results Sensitivity - BOD



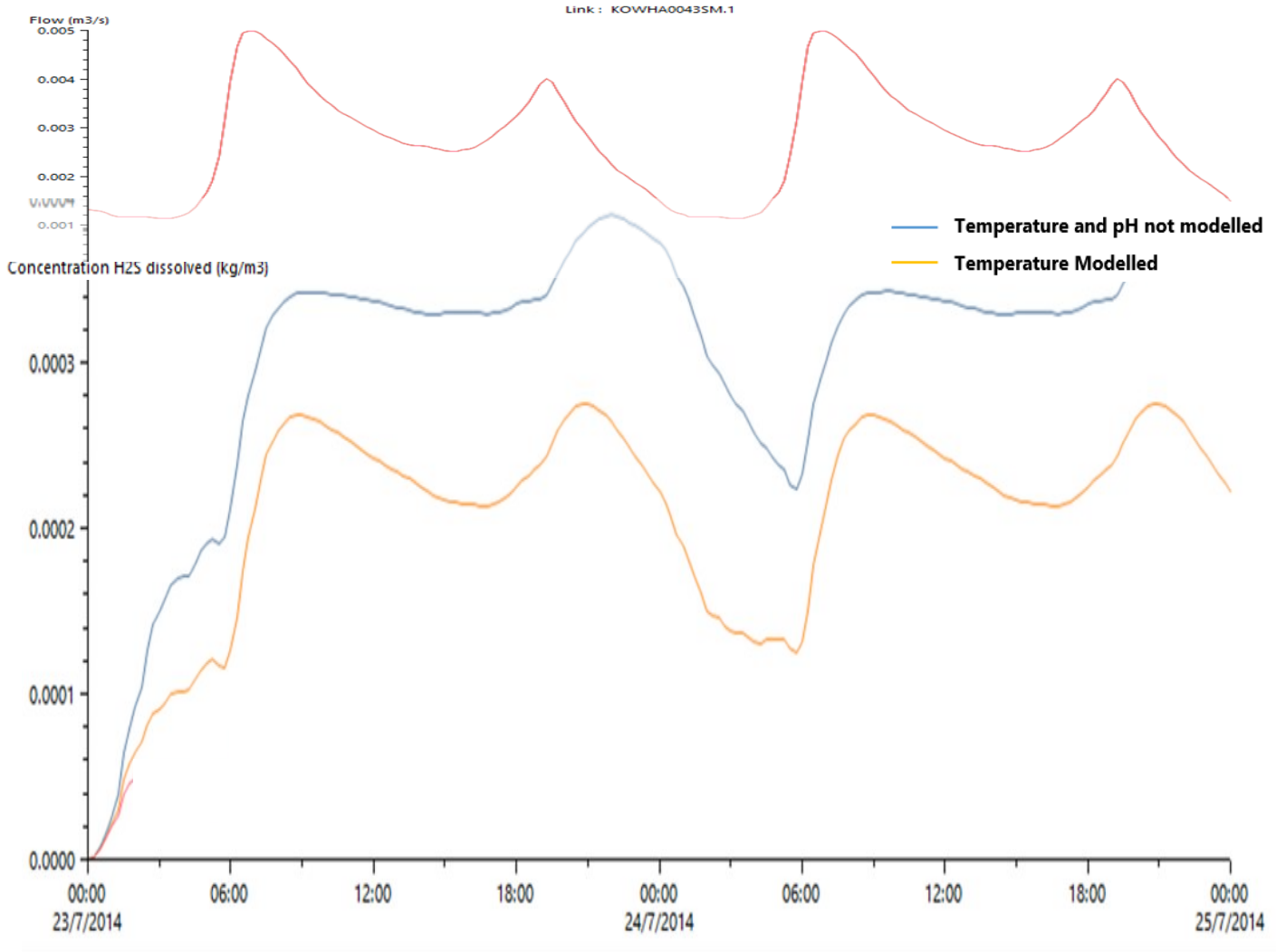
Results Sensitivity - Temperature



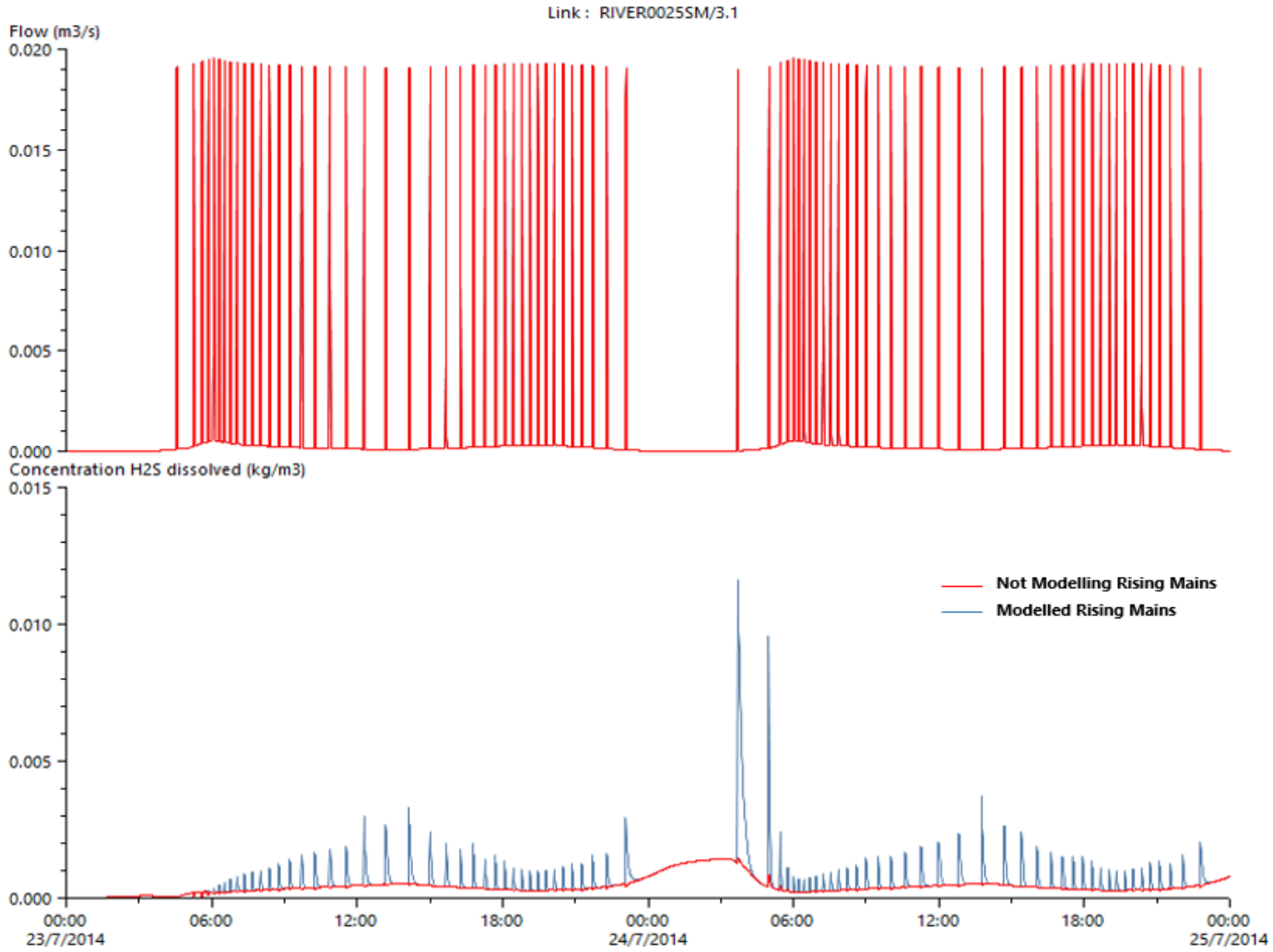
Results Sensitivity - pH



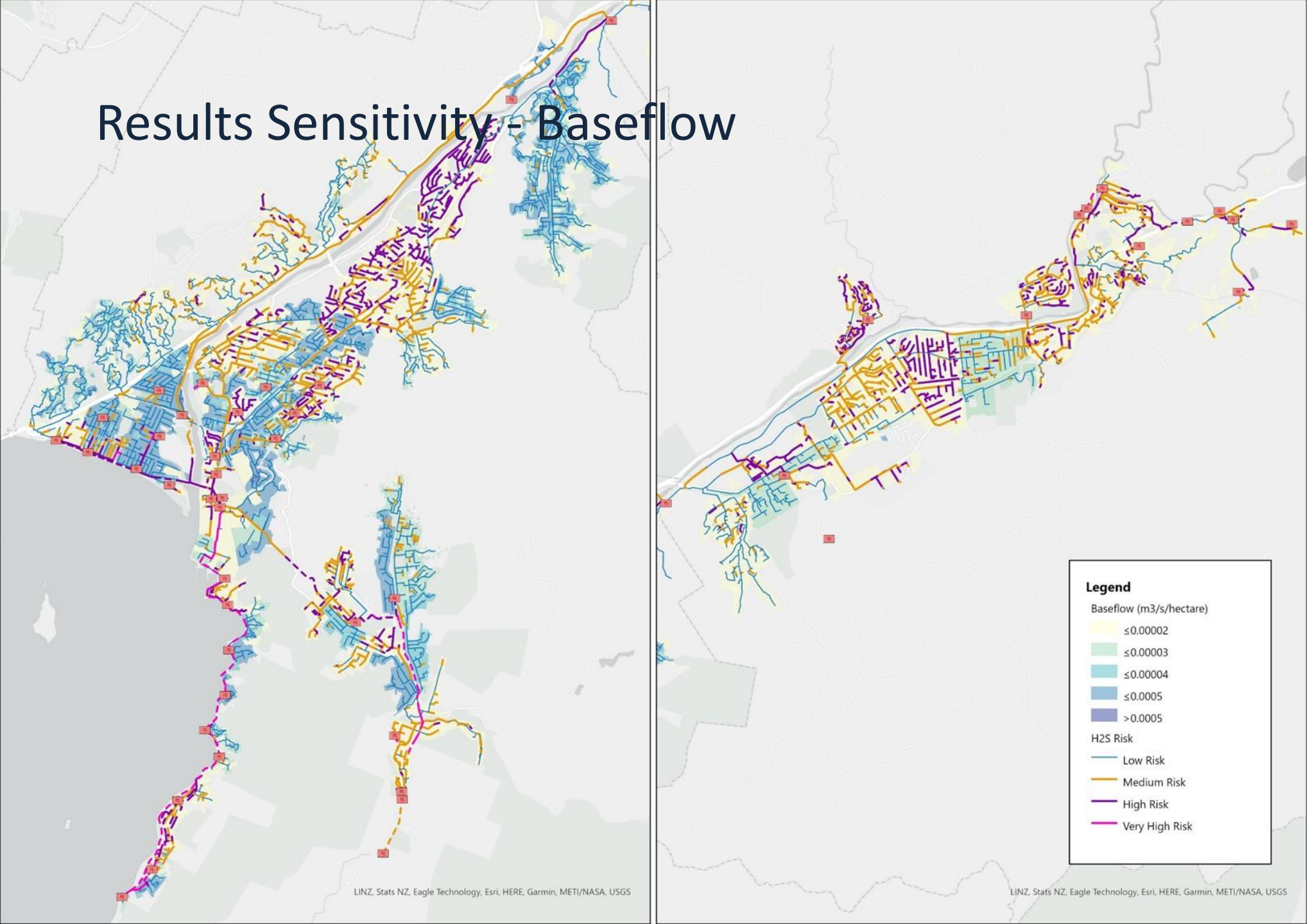
Results Sensitivity – WQ setup



Results Sensitivity - BOD



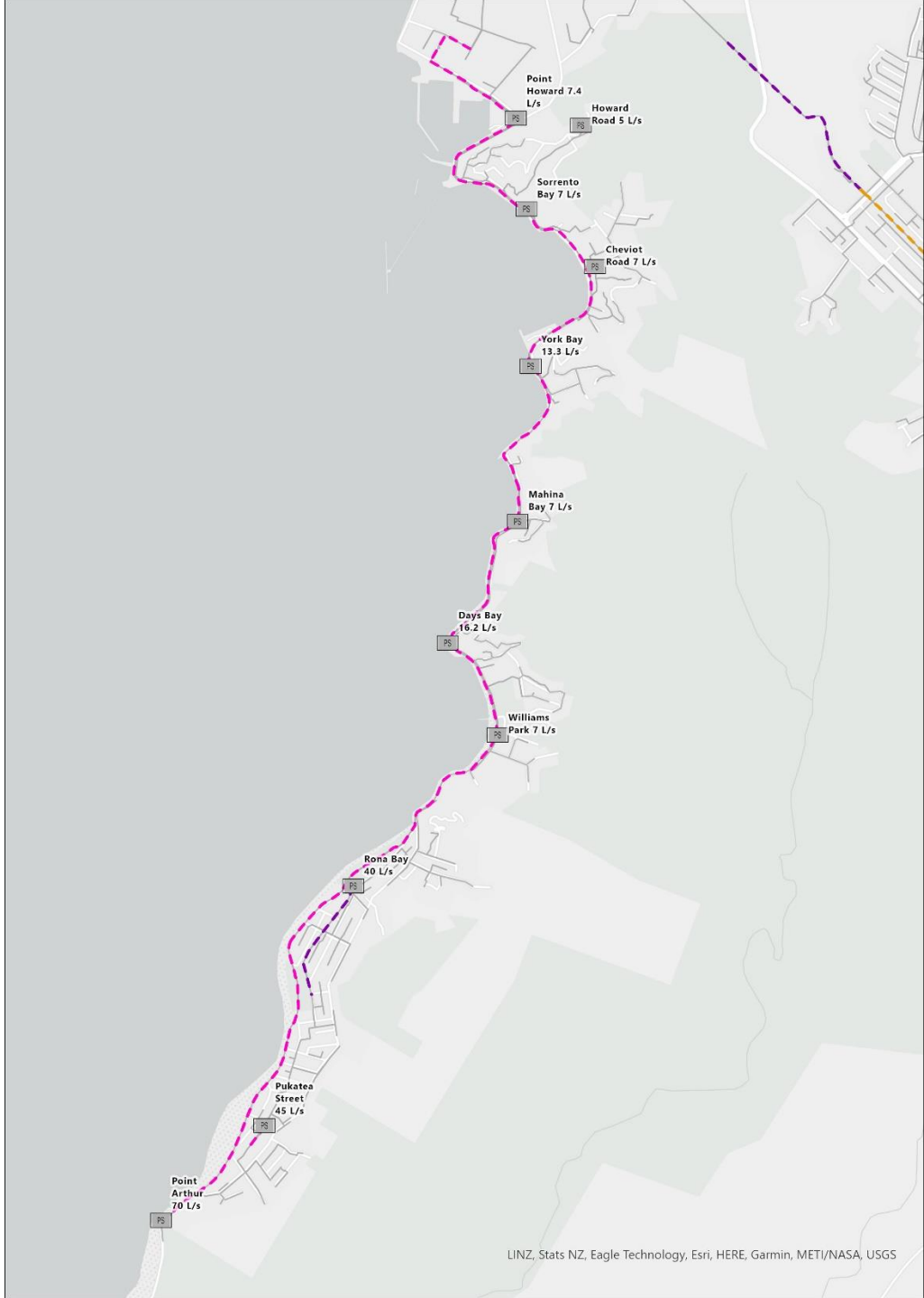
Results Sensitivity - Baseflow



- Baseflow reduces dissolved sulphide

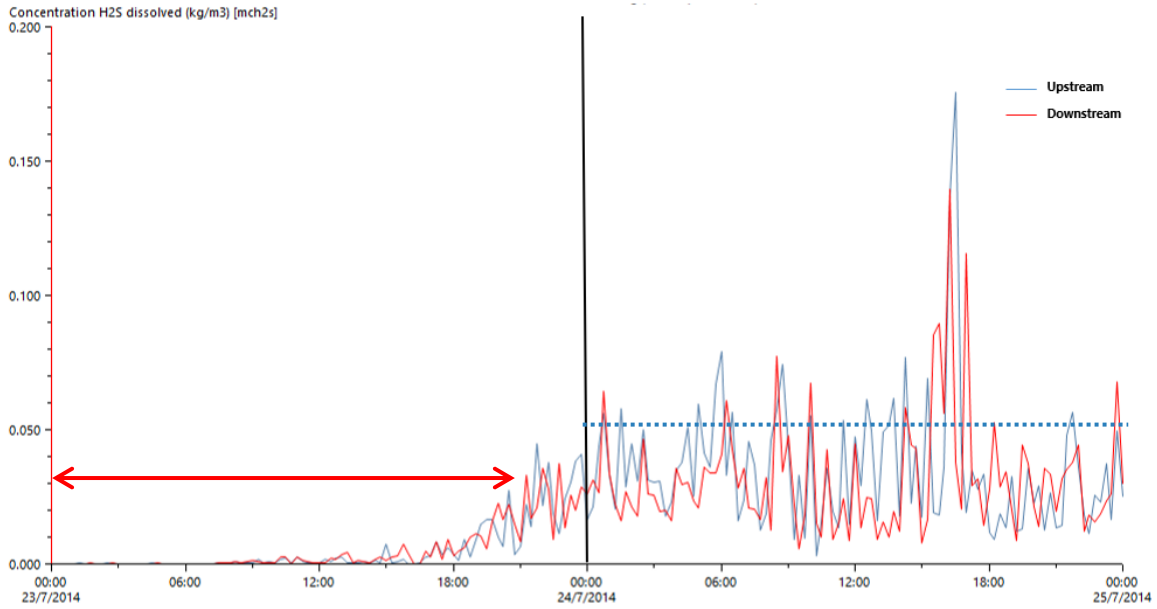
Model validation – Pt Arthur

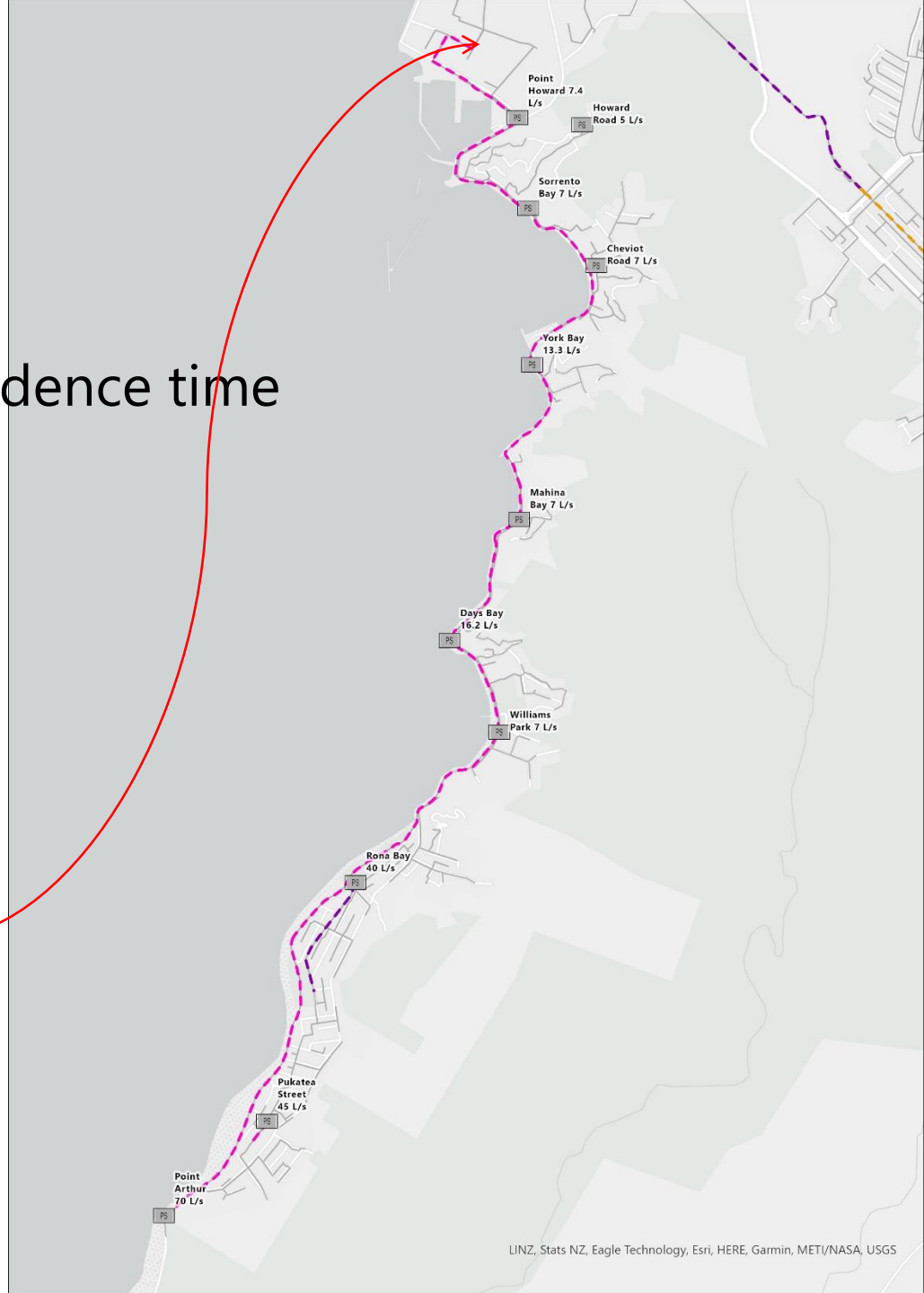
- 300 mm diameter rising main, 9.3 km,
- Pt Arthur catchment:
  - Population ~3,000
  - ADWF ~9 L/s
- Manual calculation:
  - Estimated residence time = 20.6 hrs
  - Dissolved sulphide at RM outlet = 26 mg/L



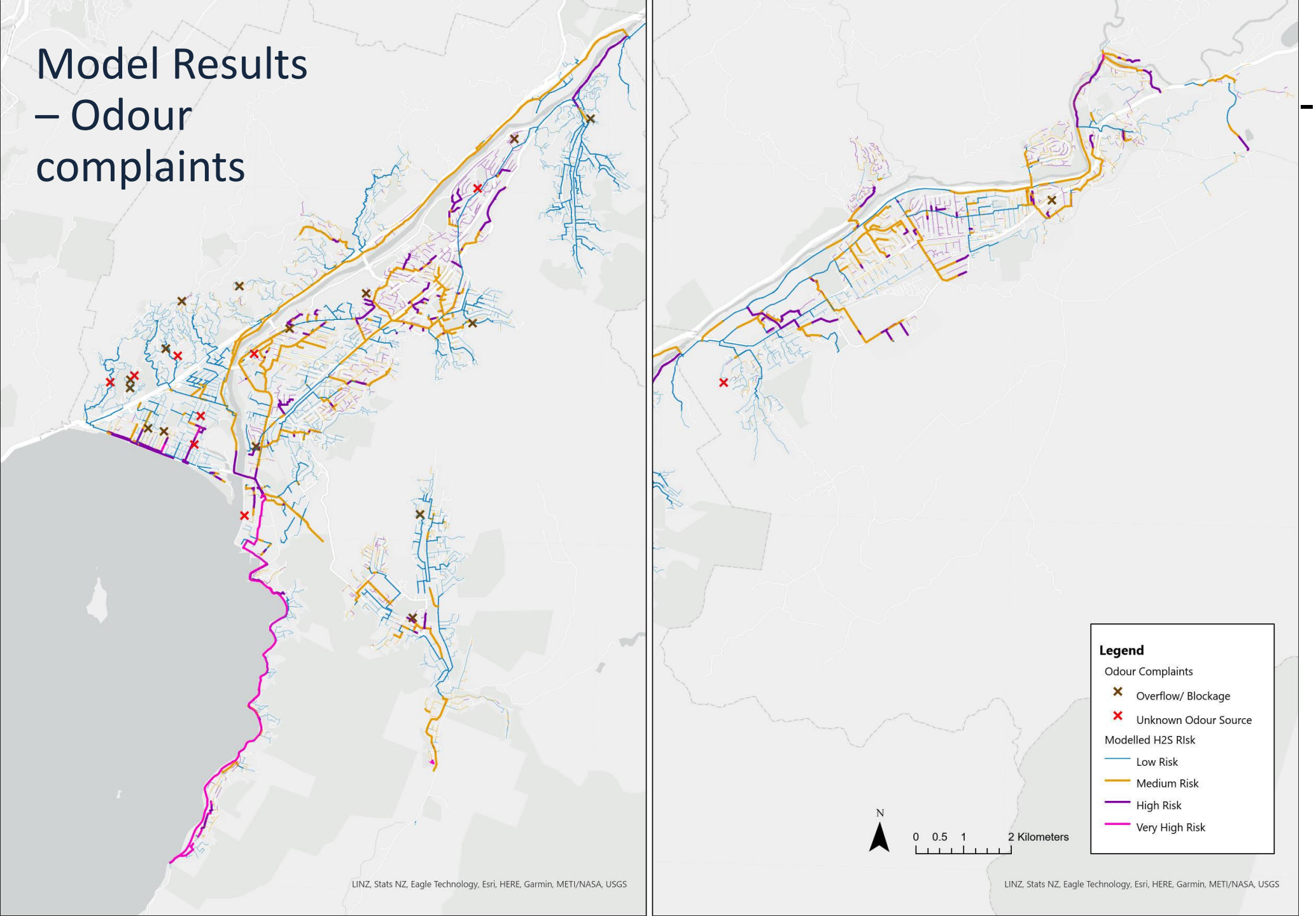
Model validation – Pt Arthur

- Modelled result:
  - Build-up time corresponds to estimated residence time
  - Average dissolved sulphide = 51 mg/L





Model Results – Odour complaints

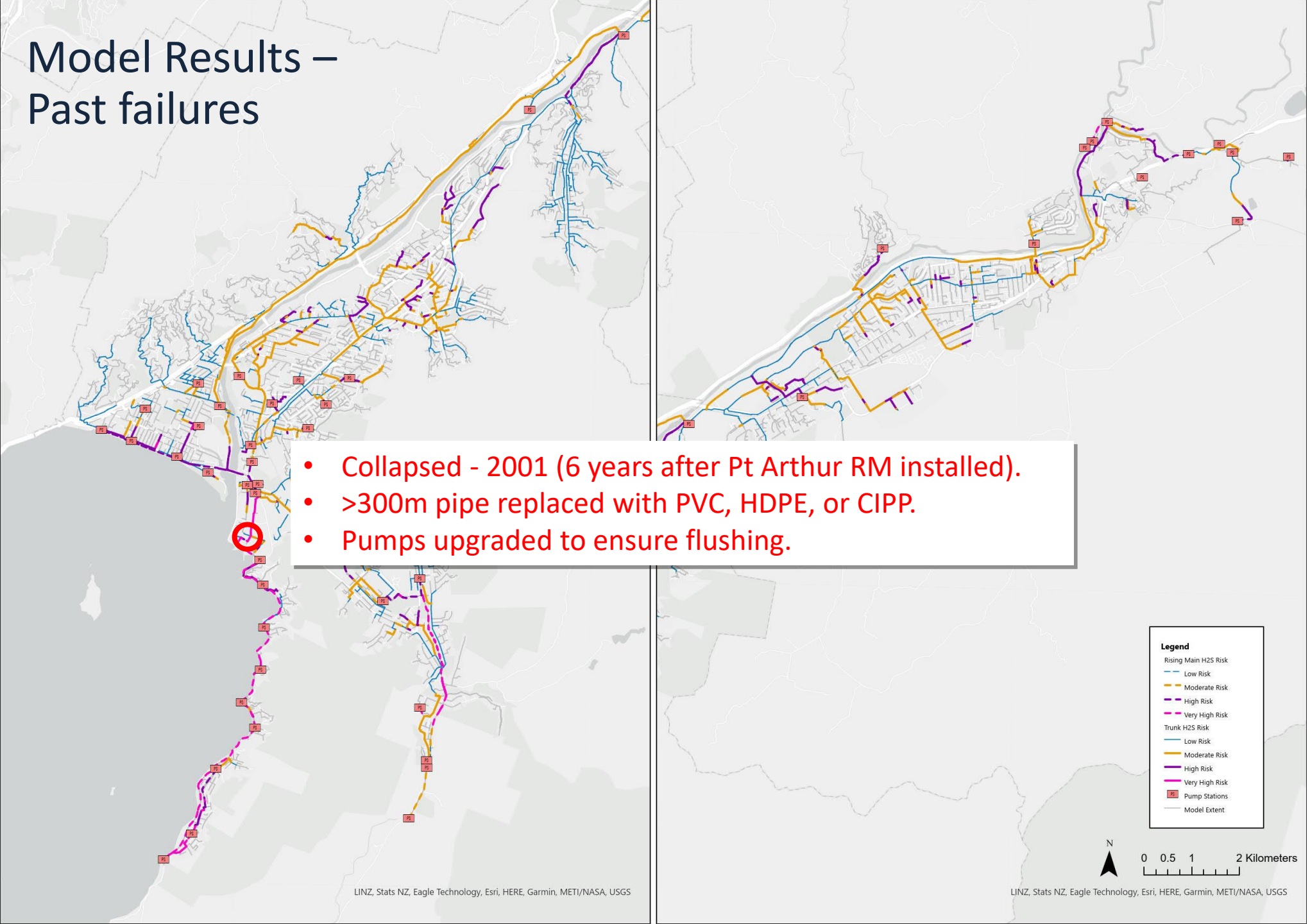


- Filtered customer complaints

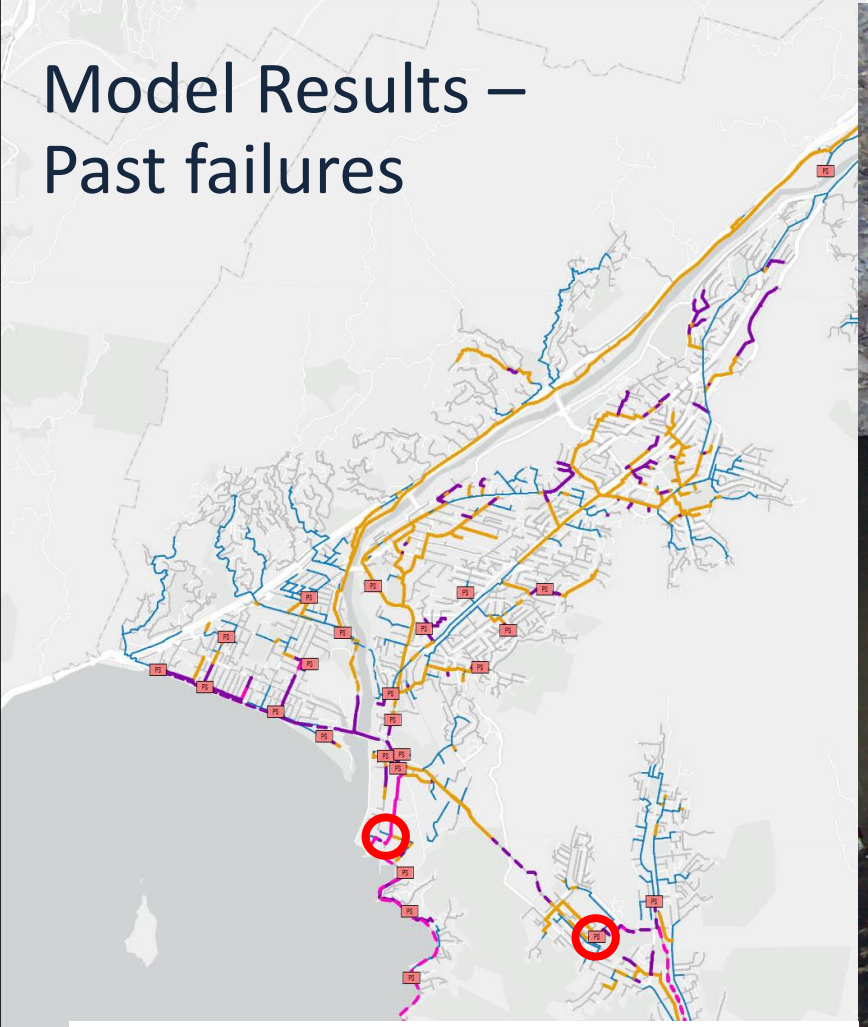
Model Results – Past failures

- Operational knowledge

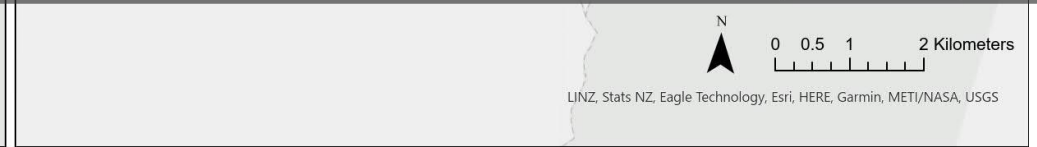
- Collapsed - 2001 (6 years after Pt Arthur RM installed).
- >300m pipe replaced with PVC, HDPE, or CIPP.
- Pumps upgraded to ensure flushing.



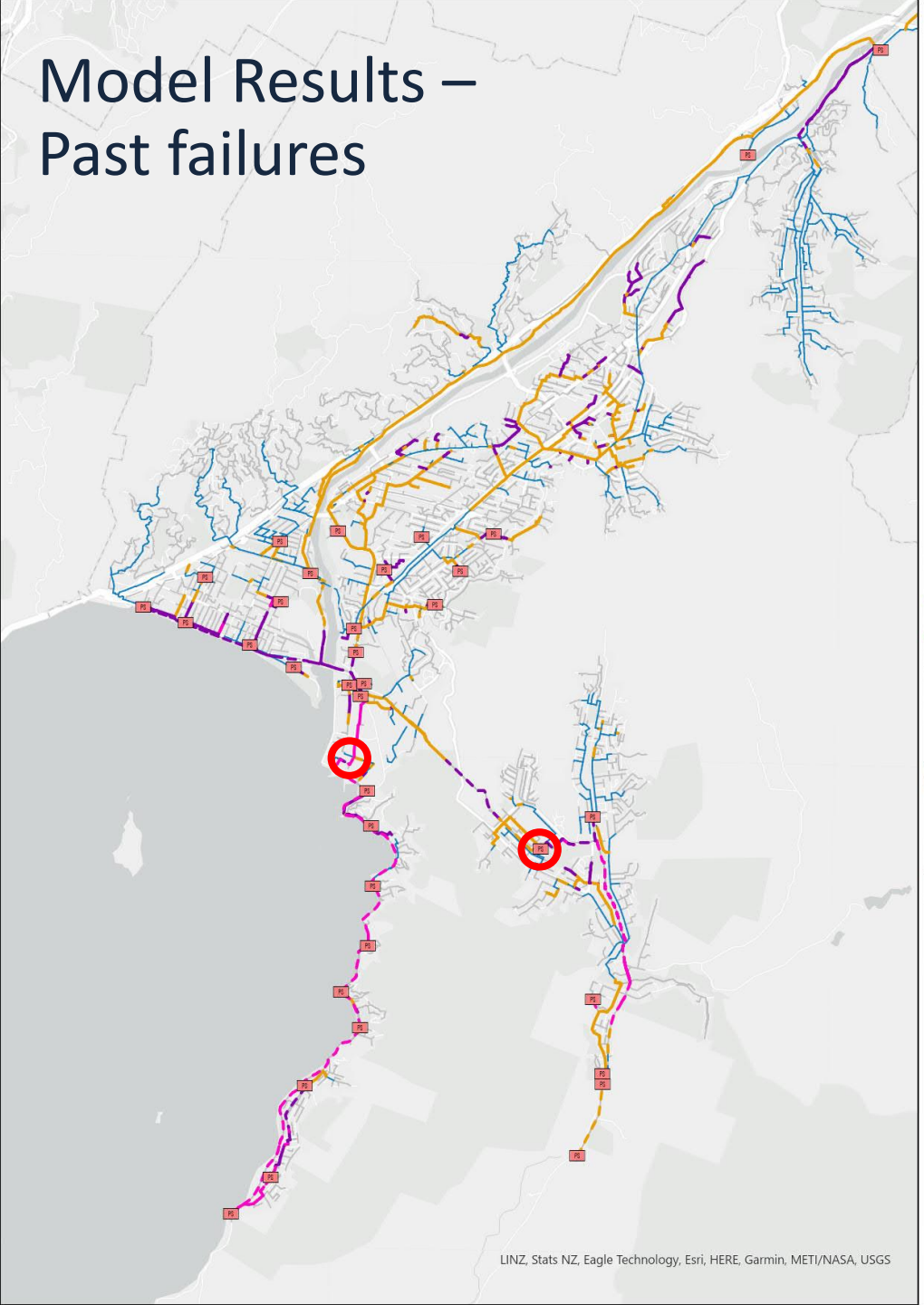
Model Results – Past failures



- Wise Park Wetwell after 10 years of receiving new RM
- Remedial epoxy coating and new drop structure with ventilation



Model Results – Past failures



- Collapsed – 2013, downstream of turbulent drop.
- 50m pipe replaced with HDPE.
- Ventilation pipe installed.

Future work

1. Other data collection to verify locations of concern
2. Inspection and monitoring programme
3. Modelling trial assessments in other networks (eg Moa Point)

Conclusions

1. ICM can estimate *dissolved H_2S* - an indicator of potential corrosion.
2. Dissolved H_2S is estimated using Pomeroy's Equation, which is inherently conservative.
3. For simplicity and stability, our trial case assumed constant temperature and pH – more conservative results.
4. Results can be filtered to prioritise RM discharge points and hydraulic jumps locations (~45 locations in Hutt Valley)
5. Due to the complexity and uncertainty involved, maps are presented as 'heat-maps' as a starting point for prioritising inspection locations.

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