Modelling Group
WATER NEW ZEALAND

Modelling Symposium

Dynamic Modelling of Hydrogen Sulphide (H2S) in Auckland's Sewer System

Presented by
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DHI Water and Environment

The expert in WATER ENVIRONMENTS

water NEW ZEALAND
The New Zealand Water & Wastes Association Waiora Aotearoa

Dynamic Modelling of Hydrogen Sulphide (H2S) in Auckland's Sewer System

Introduction

Why this project?

How can we tackle this issue?

What is being in place, can we do better?

What are the existing tool to make it better?

Set up a Water quality model

How to build a water quality model using MIKE+?

Discussion

Problems related to generation of H_2S in sewers

- Corrosion of infrastructure
- Odour issues
- Increased maintenance cost
- Unsafe work environment

H_2S gas levels and typical exposure symptoms

LOW	0 - 10 ppm	Irritation of the eyes, nose and throat
MOD	10 - 50 ppm	Headache Dizziness Nausea and vomiting Coughing and breathing difficulty
HIGH	50 - 200 ppm	Severe respratory tract irritation Eye irritation / acute conjunctivitis Shock Convulsions Coma Death in severe cases

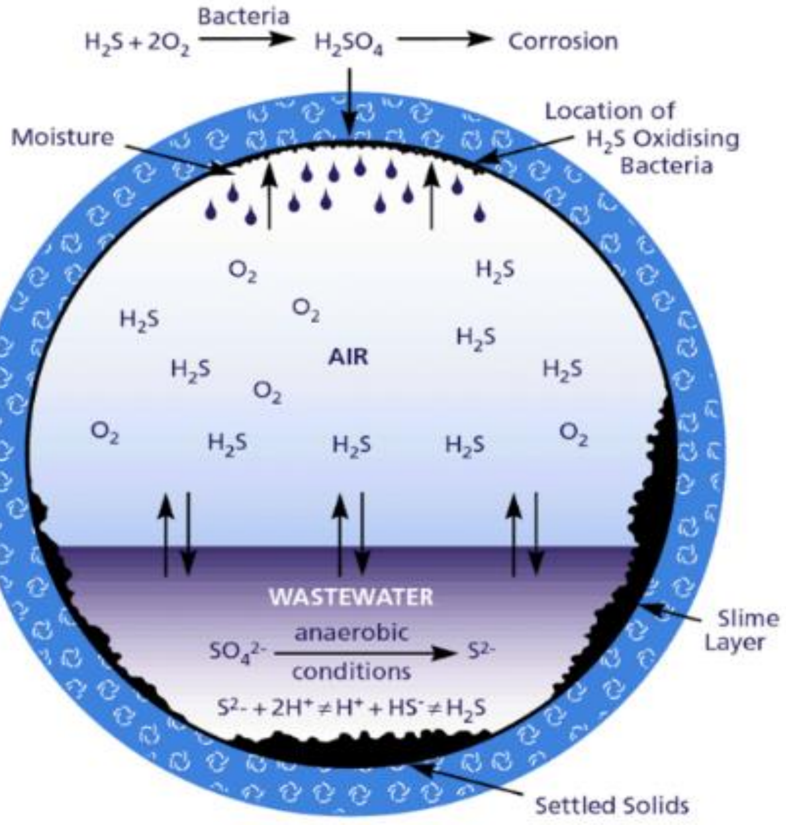
How this H2S being created

organic matter + bacteria + nutrient + others
Wastewater

Anaerobic: Sulphate -> Sulphide

pressure mains and stagnant water

Anaerobic Environment: **Hydrogen Sulphide (H2S)**
Released = odour and corrosion problems



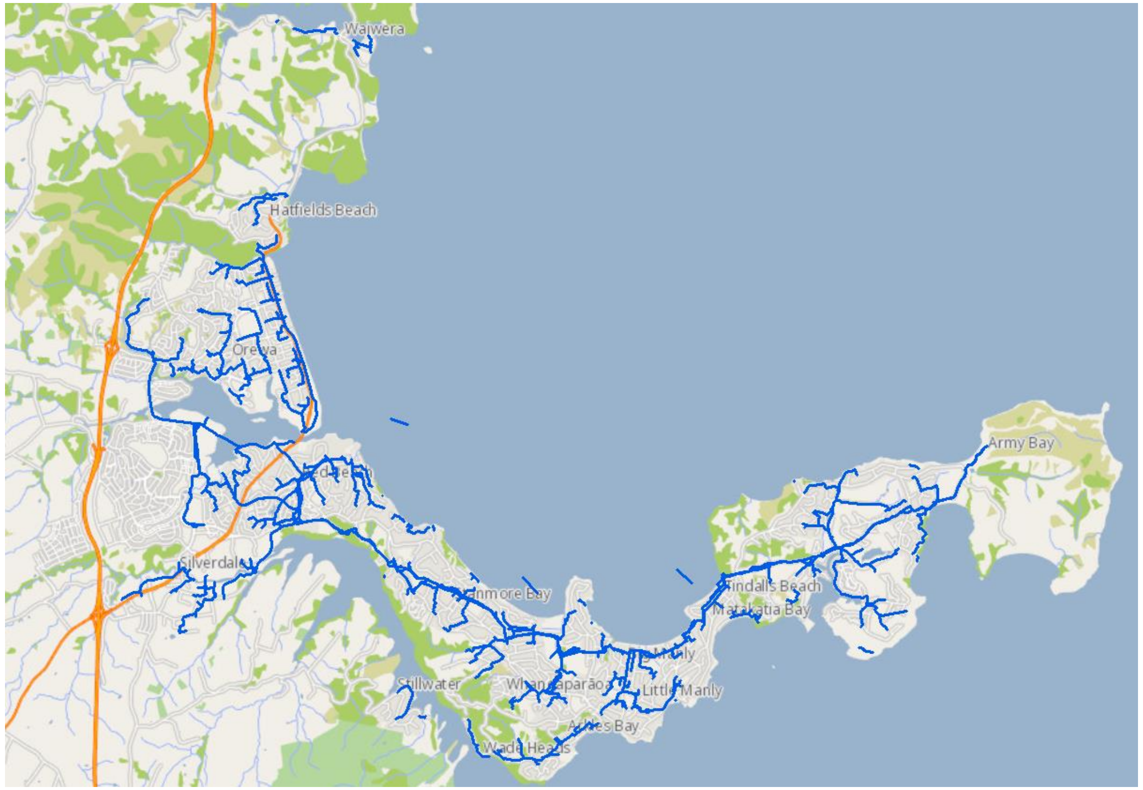
How can we tackle this issue?

- Chemical dosing: Magnesium Hydroxide

Quantify randomly and perform at random locations.

- Hydraulic models

  Can these models be applied to predict H2S in the network? => Water Quality model



To develop a pilot model of H2S based on the Whangaparaoa wastewater network hydraulic model and **demonstrate the ability of network models to estimate H2S at different locations in the wastewater network**.

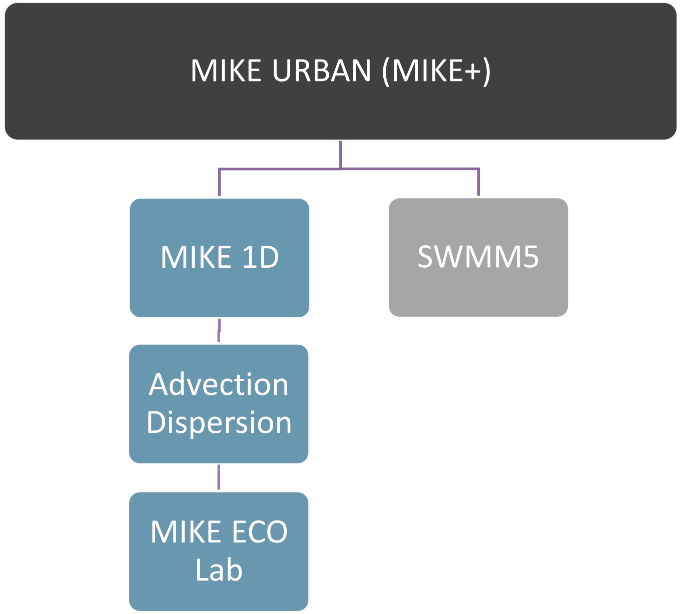
How to build a water quality model

MIKE 1D - hydraulic calculations

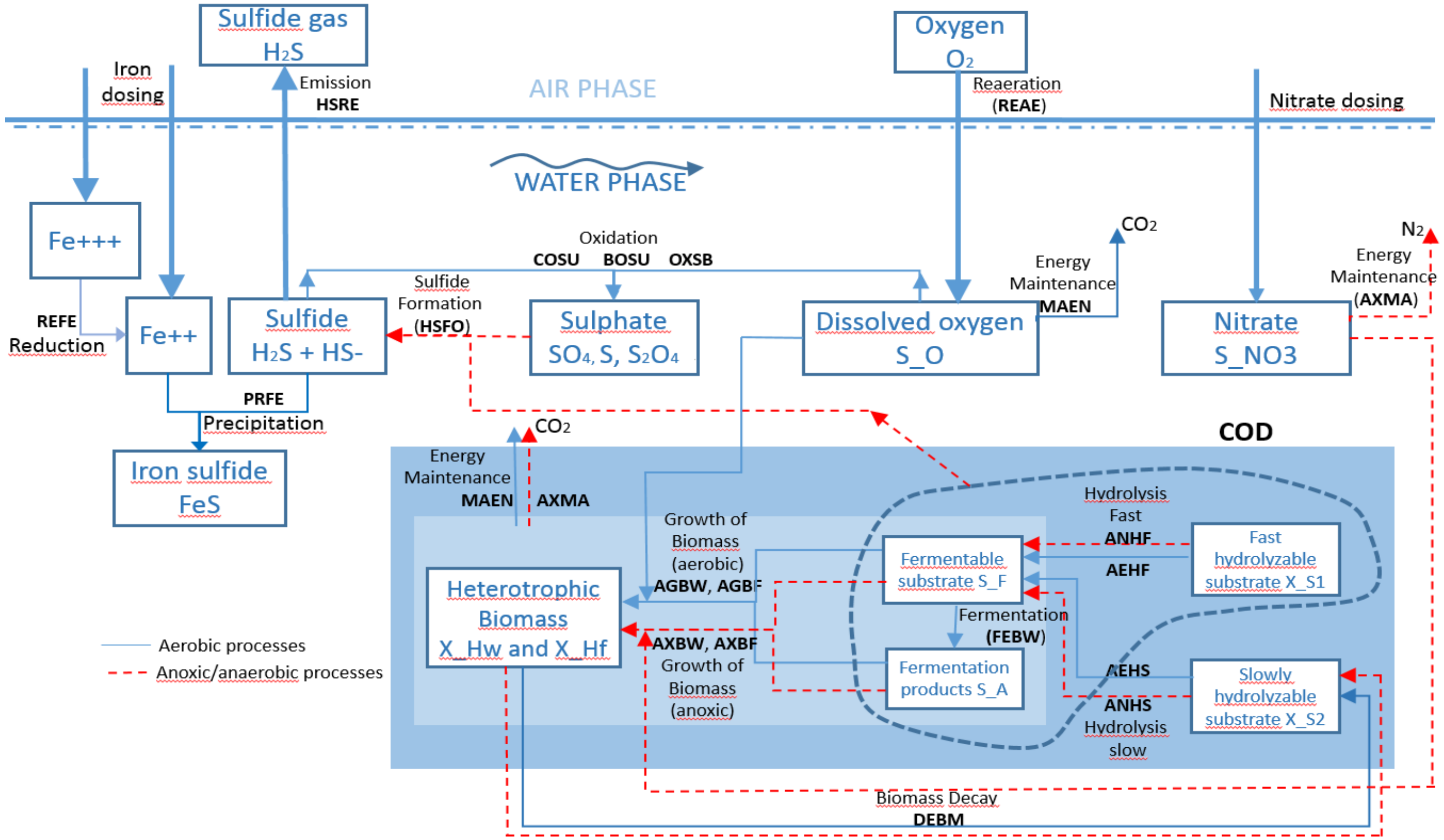
Transport of pollutants in water phase by Advection-Dispersion

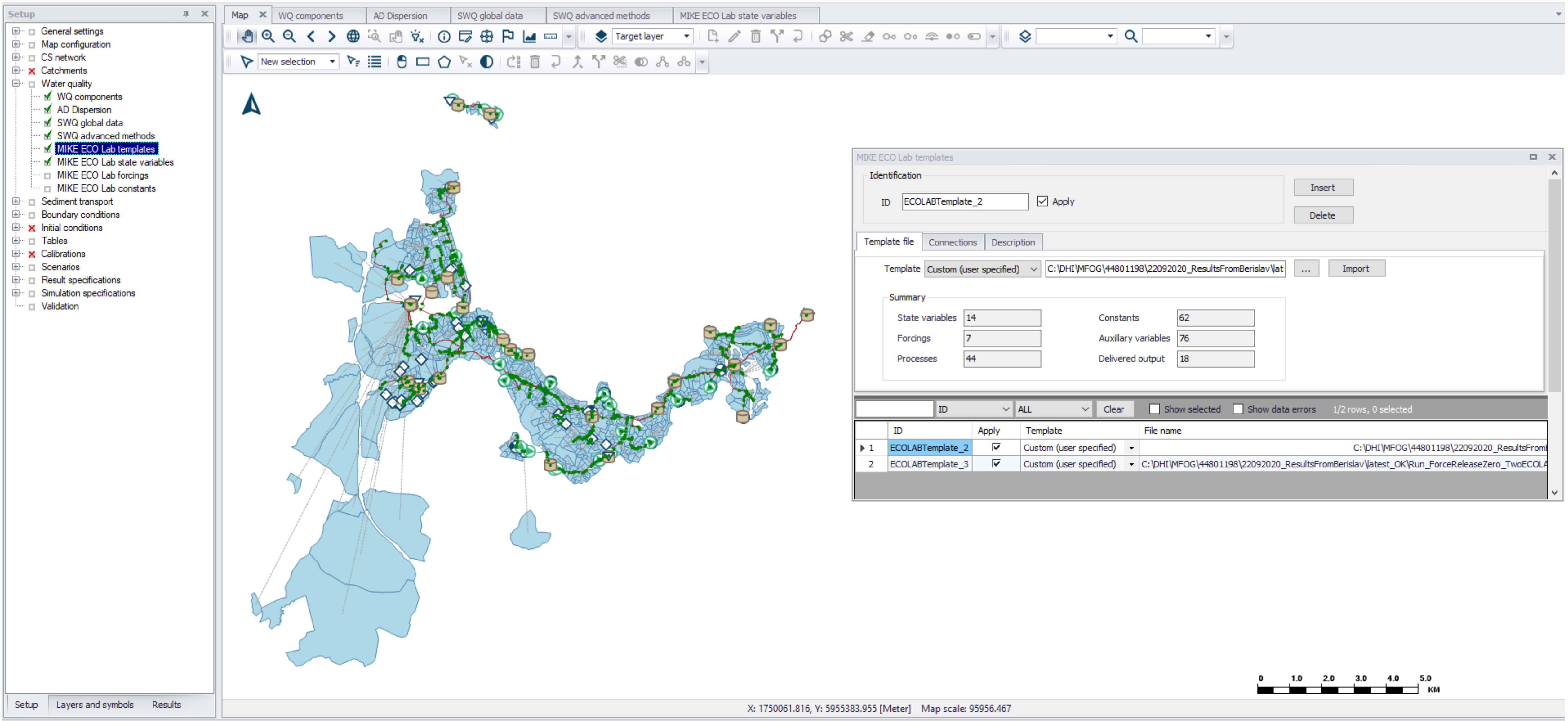
MIKE ECO Lab WATS template coupling to MIKE 1D for Water Quality modelling

WATS – Wasterwater Aerobic/Anaerobic Transformation in Sewers



MIKE ECO Lab WATS

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Auxillary variables
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Map scale: 95956.467

MIKE Zero - [H2S_module_WATS2013_latest.ecolab]

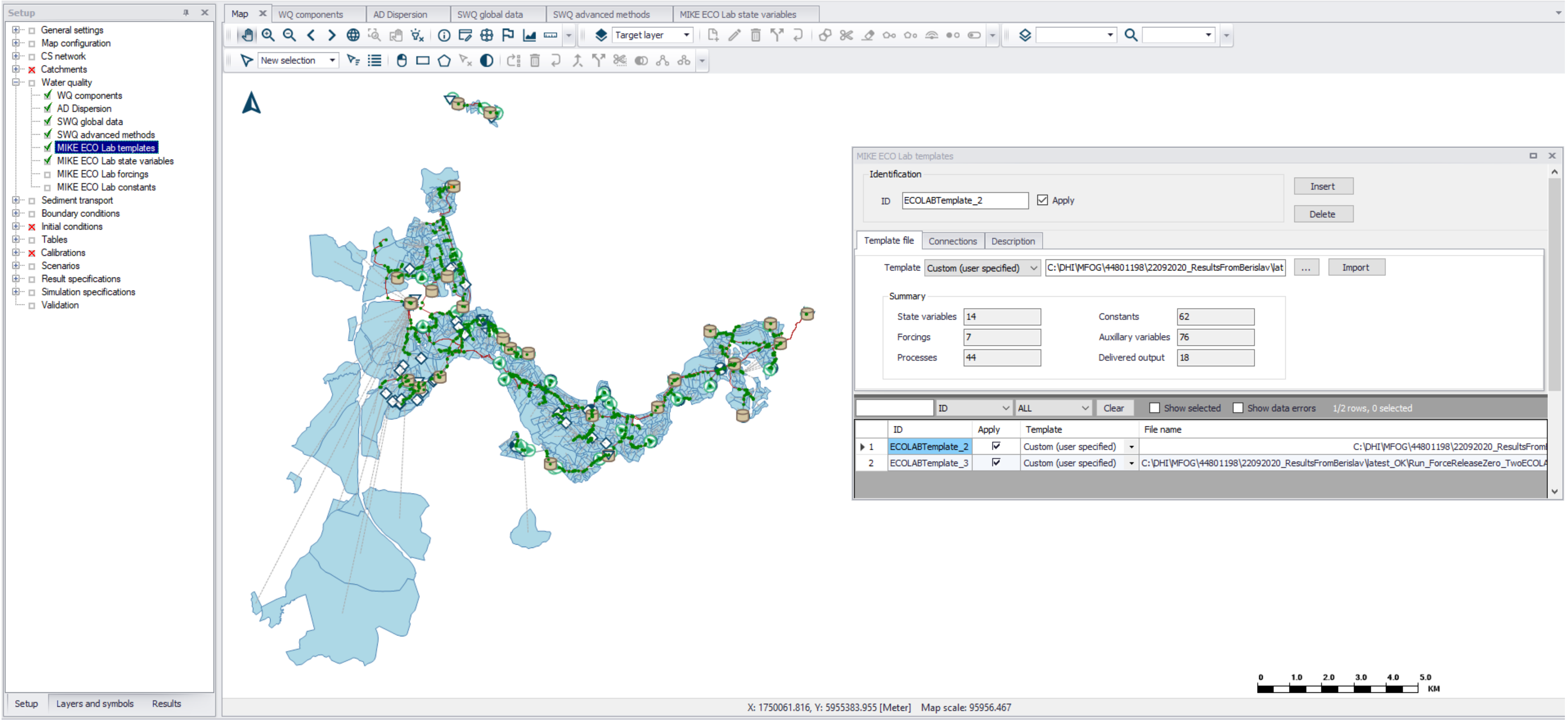
File View Window Help

Processes

- S_A
- X_Hw
- X_S1
- X_S2
- S_O
- S_II
- S_NO3N
- S_SO4S
- pH
- Temperature
- X_Fe2
- X_Fe3
- X_FeS
- Constants
- Forcing
- Auxiliaries
- Processes
  - AGBW1
  - AGBW2
  - AGBW3
  - AGBF1
  - AGBF2
  - AGBF3
  - MAEN
  - MAEN_S
  - MAEN_X
  - AEHF
  - AEHS
  - ANHF
  - ANHS
  - FEBW
  - COSU
  - HSRE
  - REAE
  - AXBW
  - AXBF
  - AXMA
  - AXMA_S
  - AXMA_X
  - DEBM
  - BOSU
  - OXSB
  - HSFO
  - REFE
  - S_O_balance

Visibility group: any   Level: all   expand

No.	Symbol	Expression	Description
4	AGBF1	Y_Hf/(1-Y_Hf) * S_S/(K_Sf+S_S) * k_half * POW(MAX(0, S_O),0.5) * A_wp/V * ftemp_alphaf	Aerobic growth in biofilm
5	AGBF2	-AGBF1/Y_Hf	Aerobic growth in biofilm for S_F and S_A calculation
6	AGBF3	((1-Y_Hf)/Y_Hf)*AGBF1	Aerobic growth in biofilm for S_O calculation
7	MAEN	q_m * fsat1_SO * X_Hw * ftemp_alphaW	Maintenance energy requirement (aerobic)
8	MAEN_S	IF ((S_S > 0.5), MAEN, 0)	Maintenance energy requirement (aerobic) for readily biodegradable substrate
9	MAEN_X	IF ((S_S > 0.5), 0, MAEN)	Maintenance energy requirement (aerobic) for heterothophic biomass
10	AEHF	k_h1 *f_S1 * fsat1_SO * f_BW_E_a * ftemp_alphaW	Aerobic hydrolysis for fast hydrolyzable substrate (X_S1)
11	AEHS	k_h2 * f_S2 * fsat1_SO * f_BW_E_a * ftemp_alphaW	Aerobic hydrolysis for slow hydrolyzable substrate (X_S2)
12	ANHF	n_fe * k_h1 * f_S1 * fsat2_SO *Anox_sat2* f_BW_E_an * ftemp_alphaW	Anaerobic hydrolysis for fast hydrolyzable substrate (X_S1)
13	ANHS	n_fe * k_h2 * f_S2 * fsat2_SO *Anox_sat2* f_BW_E_an * ftemp_alphaW	Anaerobic hydrolysis for slow hydrolyzable substrate (X_S2)
14	FEBW	q_fe * S_F/(K_fe+S_F) * fsat2_SO *Anox_sat2* f_BW_E_an * ftemp_alphaW	Fermentation in bulk water and biofilm
15	COSU	24 *kSIIc*(POW(MAX(0,SulfideDis),n1))*POW(MAX(0,S_O),n2)*ftemp_alphaW	Chemical oxidation of sulfide
16	HSRE	24 * 0.69 * (1+0.17*POW(Fr,2)) * POW(ABS(Slope*u),(3/8)) * j * SulfideDis / d_m * ftemp_alphaT	Sulfide release to gaseous phase
17	REAE	IF (Rel_Depth >=1.0) THEN 0 ELSE alpha_reae*K_La * (beta_reae*S_Os - S_O)*ftemp_alphaT	Reaeration
18	AXBW	if K_Sw+S_S <= 0 then 0 else (my_h_NO3*(S_S/(K_Sw+S_S))*Anox_sat1*fsat2_SO*X_Hw*ftemp_alphaW)	Anoxic bio mass growth in bulk water
19	AXBF	k_half_NO3*POW(MAX(0, S_NO3N),0.5)*2.86*Y_Hf_NO3/(1-Y_Hf_NO3)*S_S/(K_Sf+S_S)*fsat2_SO*A_wp/V*ftemp_alphaf	Anoxic bio mass growth in biofilm
20	AXMA	q_m_NO3*Anox_sat1*fsat2_SO*X_Hw*ftemp_alphaW	Maintenance energy requirement (anoxic)
21	AXMA_S	IF ((S_S > 0.5), AXMA, 0)	Maintenance energy requirement (anoxic) for readily biodegradable substrate
22	AXMA_X	IF ((S_S > 0.5), 0, AXMA)	Maintenance energy requirement (anoxic) for heterothophic biomass
23	DEBM	d_H_ana*fsat2_SO*Anox_sat2*X_Hw*ftemp_alphaW	Decay of biomass
24	BOSU	24 *kSIIb*(POW(MAX(0,SulfideDis),n1))*POW(MAX(0,(S_O)),n2)*ftemp_alphaW	Biological oxidation of sulfide
25	OXSB	24*kSIIoxf*POW(MAX(0,SulfideDis),0.5)*POW(MAX(0,S_O),0.5)* A_wp/V*ftemp_alphaf*fSIIb_pH	Oxidation of sulfide in biofilm
26	HSFO	24 * a*POW(MAX(0,(S_F+S_A+X_S1)), 0.5) *fsat2_SO*Anox_sat2*Anox_sat3* A_wp/V * ftemp_alphaSf	H2S formation
27	REFE	K_Fe3 * X_Fe3	Iron+++ reduction to iron++
28	S_O_balance	MAX(-S_O * 86400/dt,(-AGBW3-AGBF3-MAEN-1/Rcwc*COSU-1/Rcwb*BOSU-1/Rcwb*OXSB+REAE))	Dissolved oxygen balance
29	S_F_balance	MAX(-S_F * 86400/dt,(AGBW2+AGBF2-1/Y_Hw*AXBW-1/Y_Hw*AXBF-MAEN_S-AXMA_S+AEHF+AEHS+ANHF+ANHS-FEBW-2*HSFO))	Fermentable and readily biodegradable products balance
30	S_A_balance	MAX(-S_A * 86400/dt,(AGBW2+AGBF2-1/Y_Hw*AXBW-1/Y_Hw*AXBF-MAEN_S-AXMA_S+AEHF+AEHS+FEBW-2*HSFO))	Fermentation products balance
31	X_Hw_balance	MAX(-X_Hw * 86400/dt,(AGBW1+AGBF1+AXBW+AXBF-MAEN_X-AXMA_X-DEBM))	Heterotrophic active biomass in water phase balance
32	X_S1_balance	MAX(-X_S1 * 86400/dt, -AEHF-ANHF-2*HSFO)	Fast hydrolyzable substrate balance
33	X_S2_balance	MAX(-X_S2 * 86400/dt,(-AEHS-ANHS+DEBM))	Slowly hydrolyzable products balance
34	PRFE	if((K_FeST_calc < K_FeST), Prec_rate , 0)	Iron precipitation
35	S_II_balance	MAX(-S_II* 86400/dt, (-PRFE + HSFO-COSU-BOSU-OXSB-HSRE))	Total Sulfide (H2S+HS-) balance
36	S_NO3N_balance	MAX(-S_NO3N * 86400/dt,(-1*(1-Y_Hw_NO3)/(2.86*Y_Hw_NO3)*AXBW-1*(1-Y_Hf_NO3)/(2.86*Y_Hf_NO3)*AXBF-1/2.86*AXMA))	Nitrate balance
37	S_SO4S_balance	MAX(-S_SO4S * 86400/dt,(-HSFO+COSU+BOSU+OXSB))	Sulfate balance
38	H2SR	HSRE*V/dx	H2S release per meter
39	H2SR_Abs	HSRE*V	H2S release per volume
40	Fe2_balance	MAX(-X_Fe2 * 86400/dt, if(pH < 8, REFE - (-2.2823 * pH + 20)* PRFE, REFE - Fe_mw/S_mw * PRFE))	2-valent iron balance
41	Fe3_balance	MAX(-X_Fe3 * 86400/dt, -REFE)	3-valent iron balance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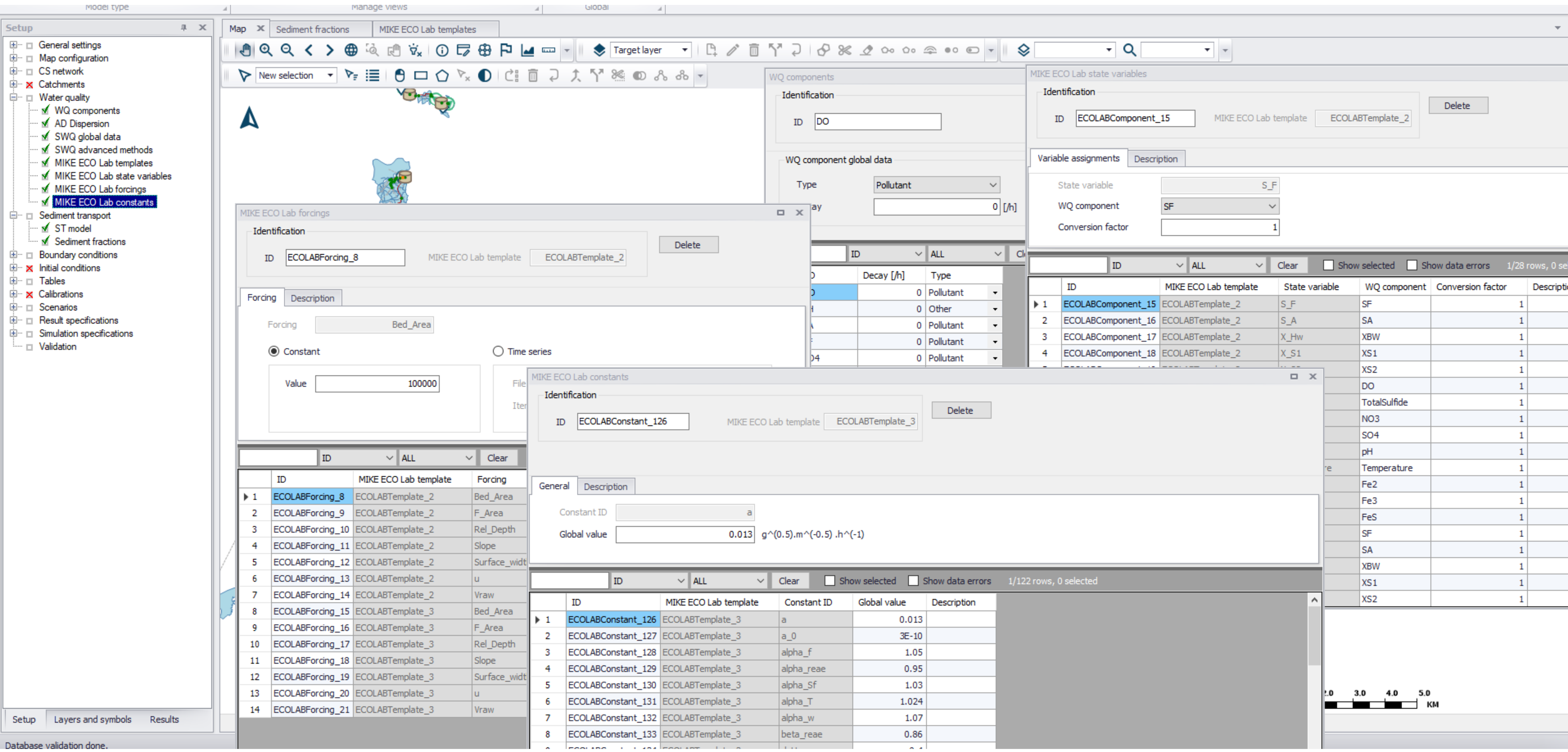
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FeS
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Initial Conditions of the H_2S Model

Boundary type	WQ Components									
	DO	Temperature (in waste water)	SO4	pH	SA Fermentation products	SF Fermentable and readily biodegradable products	XBW active biomass in water phase	XS1 Fast hydrolyzable substrate	XS2 Slowly hydrolyzable products	Total COD
	1	2	3	4	5	6	7	8	9	5+6+7+8+9
	mg/l	Deg C	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Storm runoff	10	15	0	7	0	0	0	0	0	0
Catchment discharge *PE-based; diurnal; wastewater*	8	25	150	7	25	50	67	202	477	821
Catchment discharge *area-based; constant; baseflow*	8	15	0	7	0	0	0	0	0	0
Network load *Trade waste; geocoded; loadpoints*	8	25	150	7	25	50	67	202	477	821
Network load *Millwater; single inflow*	8	25	150	7	25	50	67	202	477	821

Technical model set up - Simplification

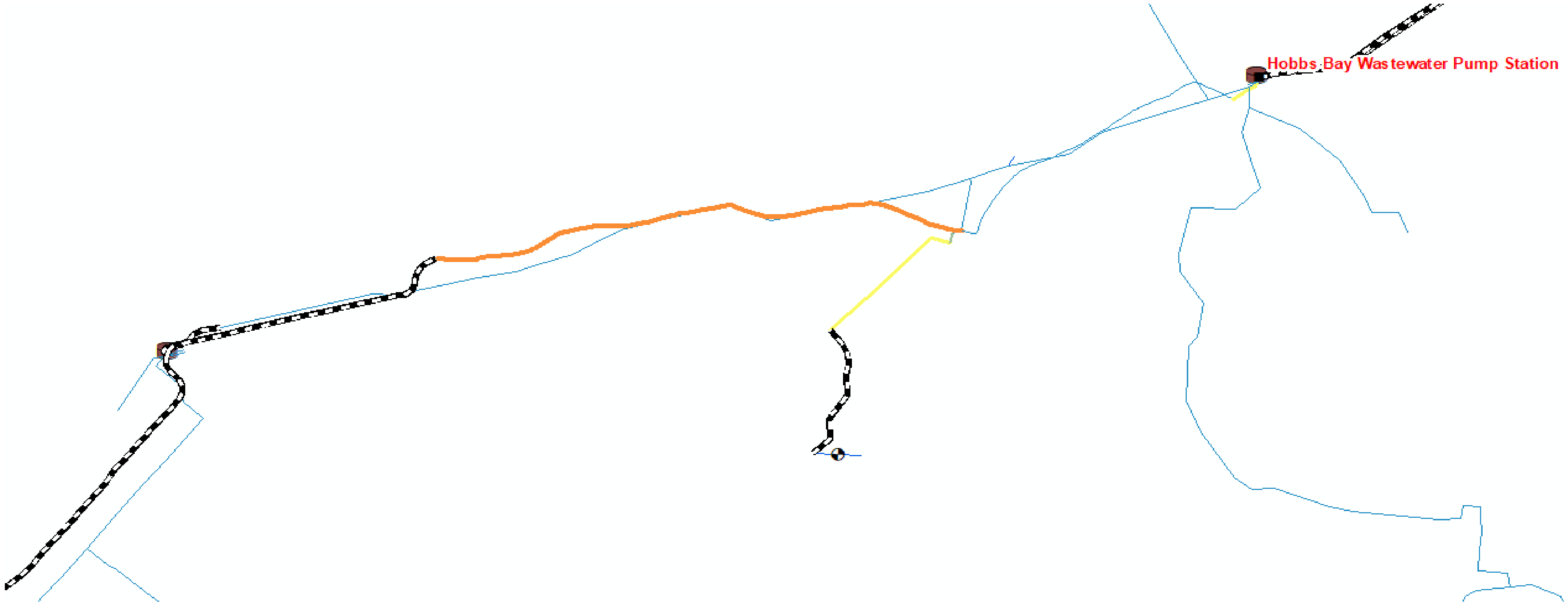
- Rising mains needed to be modelled
- Model simplification to improve stability and decrease the computation time
    - Water Quality calculation are time and space consuming due to the advection-dispersion equation

Risk Mapping - Max Total H_2S Release

Risk Mapping - Max Total H_2S Formation

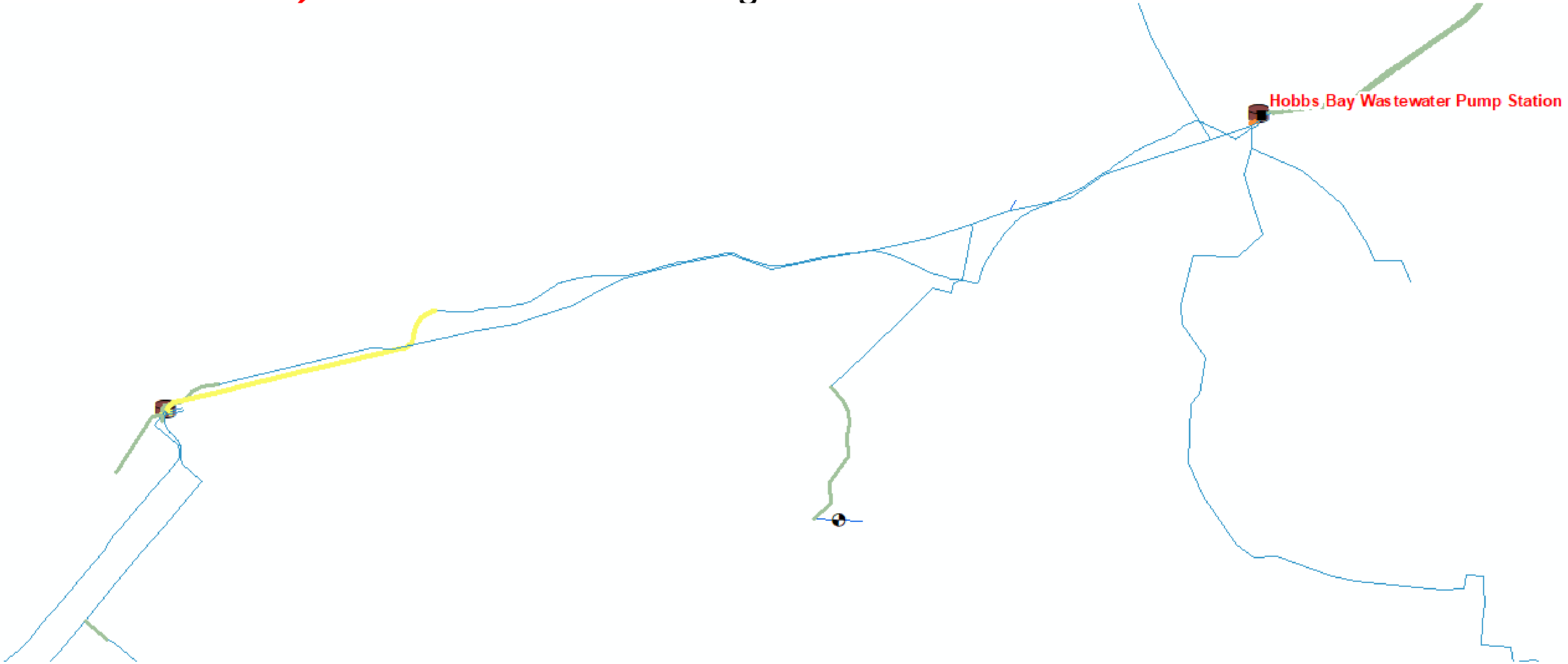
H_2S Model Results

H_2S release per meter of pipe in the rising main downstream of Stanmore PS



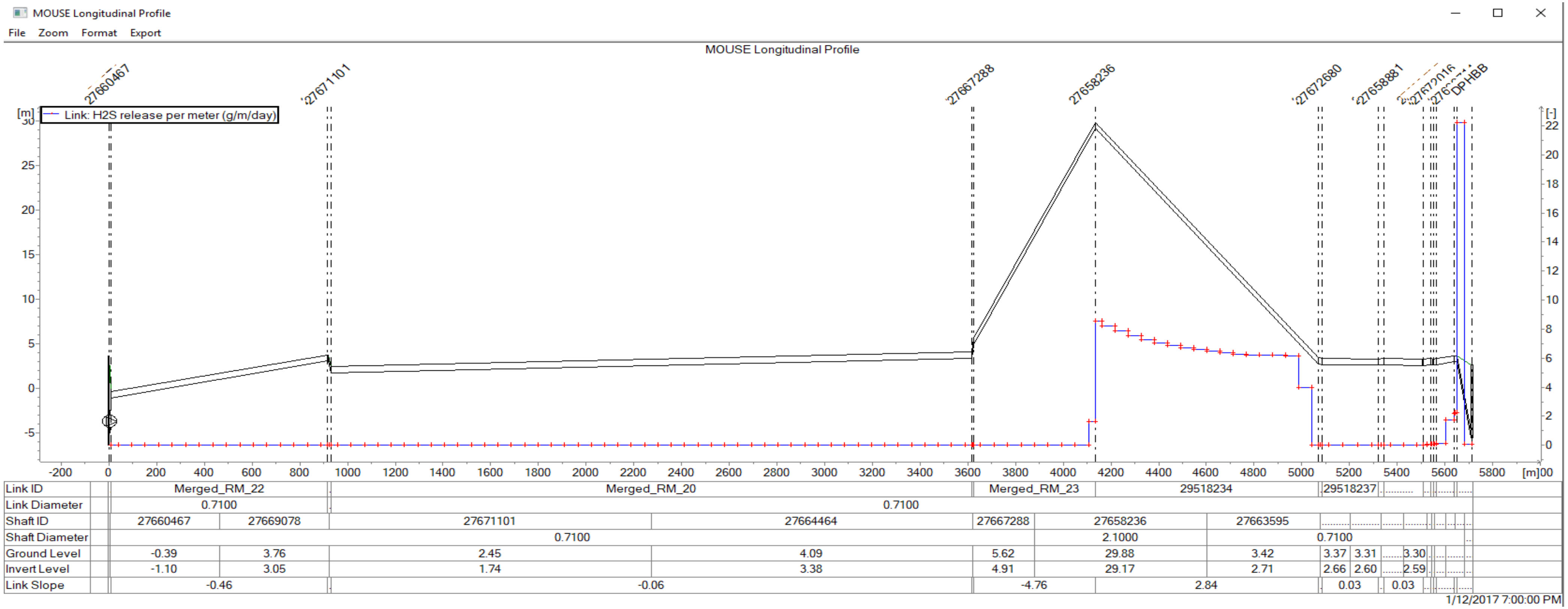
H_2S Model Results

H_2S formation in the rising main downstream of Stanmore PS



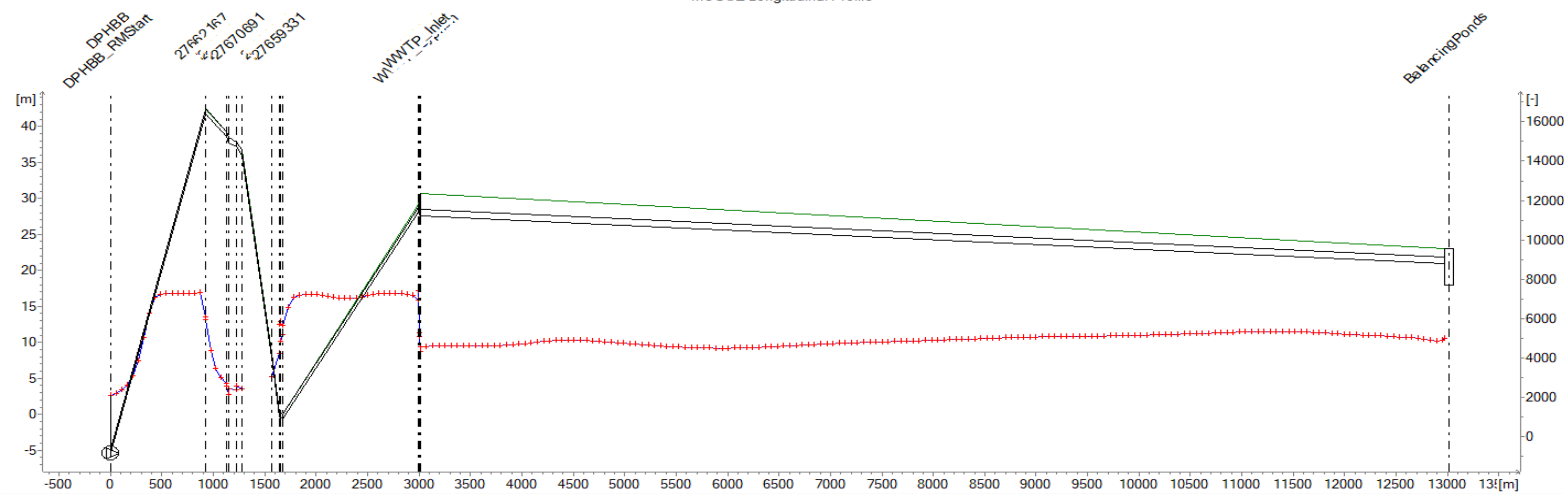
H_2S Model Results

Longitudinal profile from Stanmore to Hobbs PS – Rising main until node 27658236.
H_2S **release** per meter (g/m) at 7 pm.



H_2S Model Results

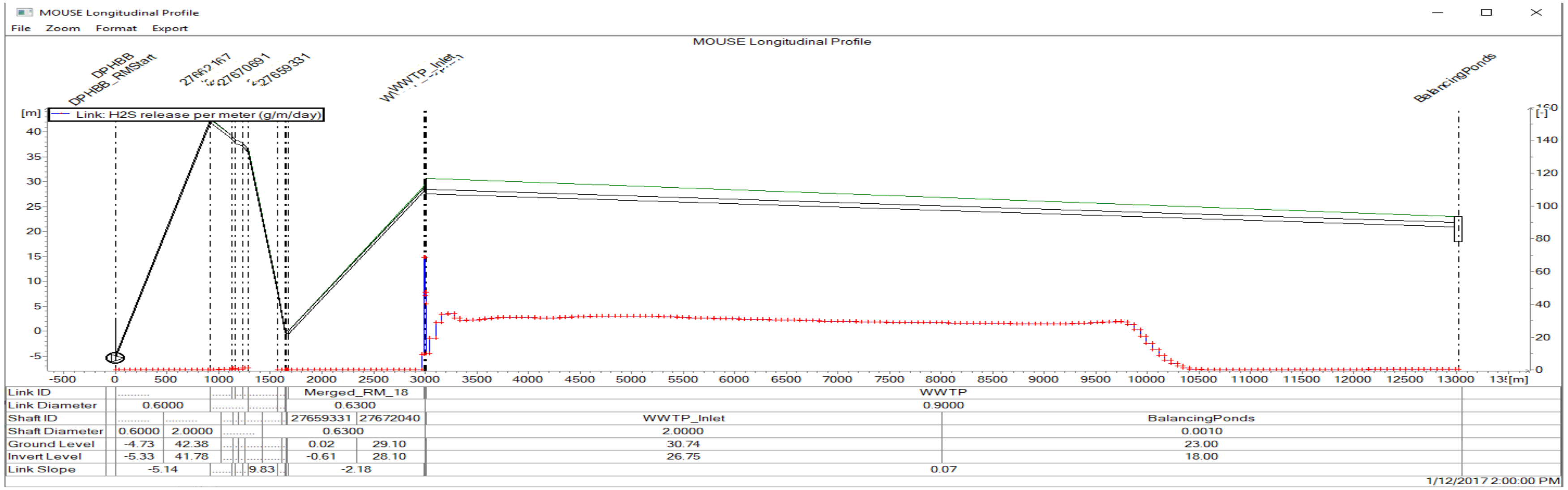
Longitudinal profile from Hobbs PS to WWTP – Rising main until node 27672040.
H_2S **formation** per meter (g/m) at 9 am.



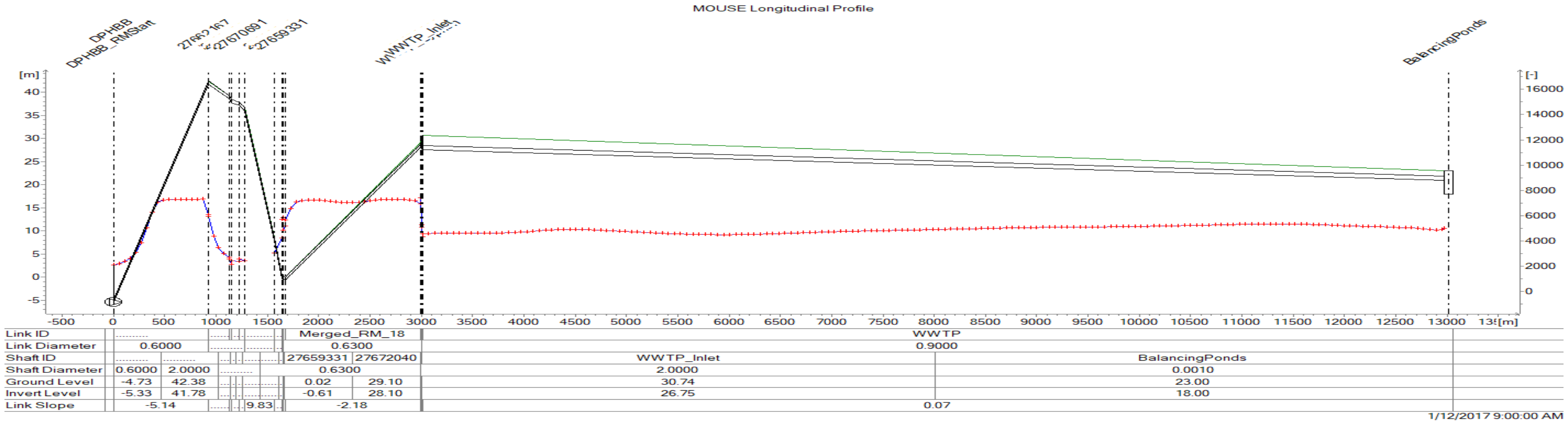
Link ID	....	Merged_RM_18	WWTP		
Link Diameter	0.6000	0.6300	0.9000		
Shaft ID	....	....	27659331	27672040	WWTP_Inlet	BalancingPonds
Shaft Diameter	0.6000	2.0000	....	0.6300	2.0000	0.0010
Ground Level	-4.73	42.38	0.02	29.10	30.74	23.00
Invert Level	-5.33	41.78	-0.61	28.10	26.75	18.00
Link Slope	-5.14	9.83	-2.18	0.07		

1/12/2017 9:00:00 AM

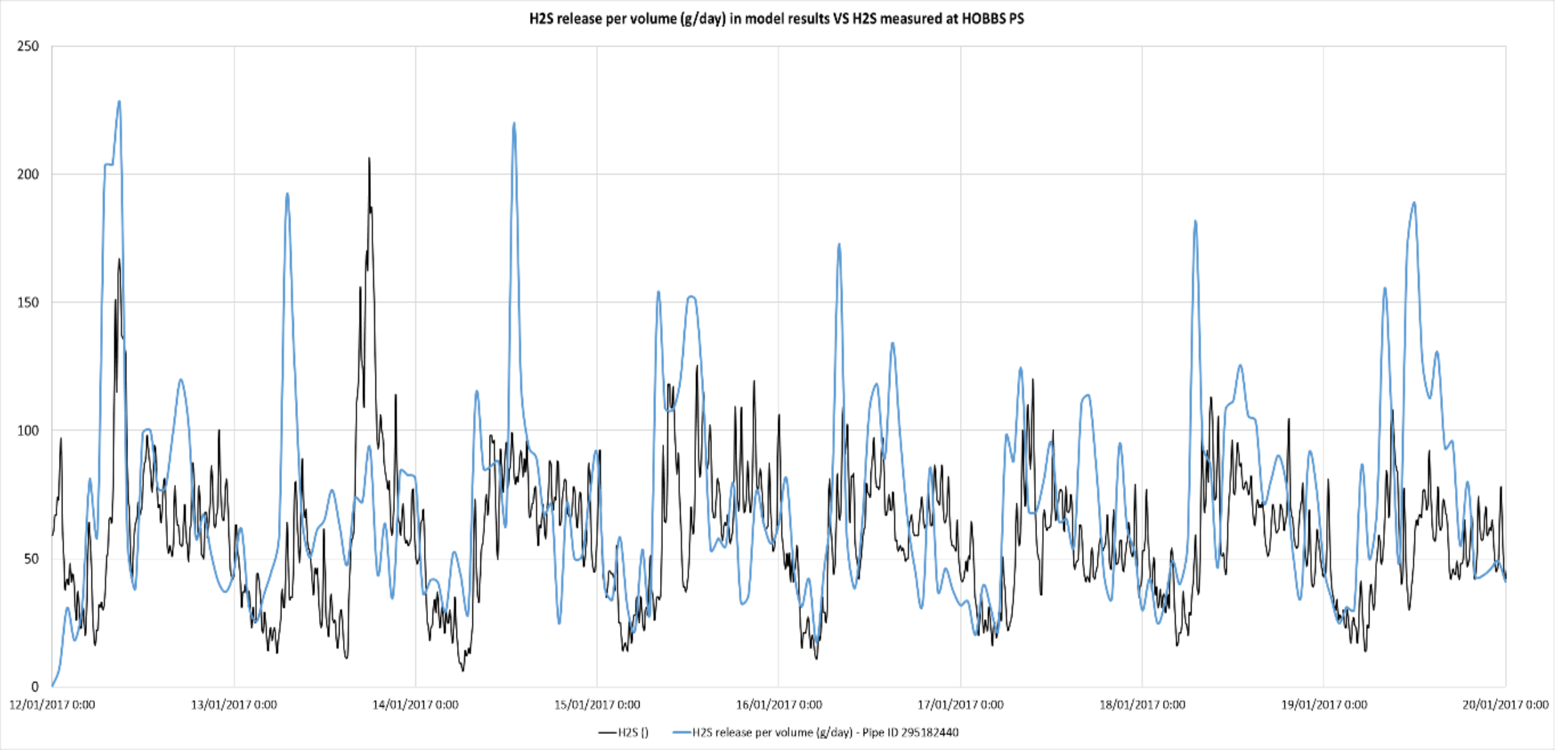
H_2S **release** per meter (g/m) at 2 pm. Longitudinal profile from Hobbs PS to WWTP – Rising main until node 27672040.



H_2S **formation** per meter (g/m) at 9 am. Longitudinal profile from Hobbs PS to WWTP – Rising main until node 27672040.

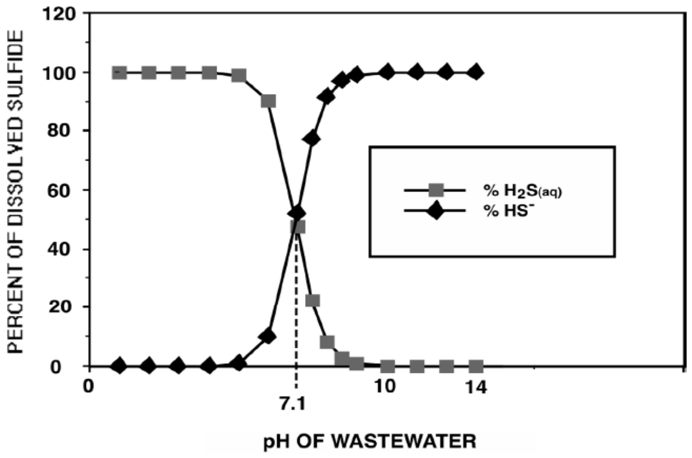


Qualitative comparison between H_2S measured (ppm) and H_2S release per volume in gravity pipe upstream of Hobbs PS.



Dosing Scenario

Result of Magnesium Hydroxide [$Mg(OH)_2$] Dosing – **Increase in pH**



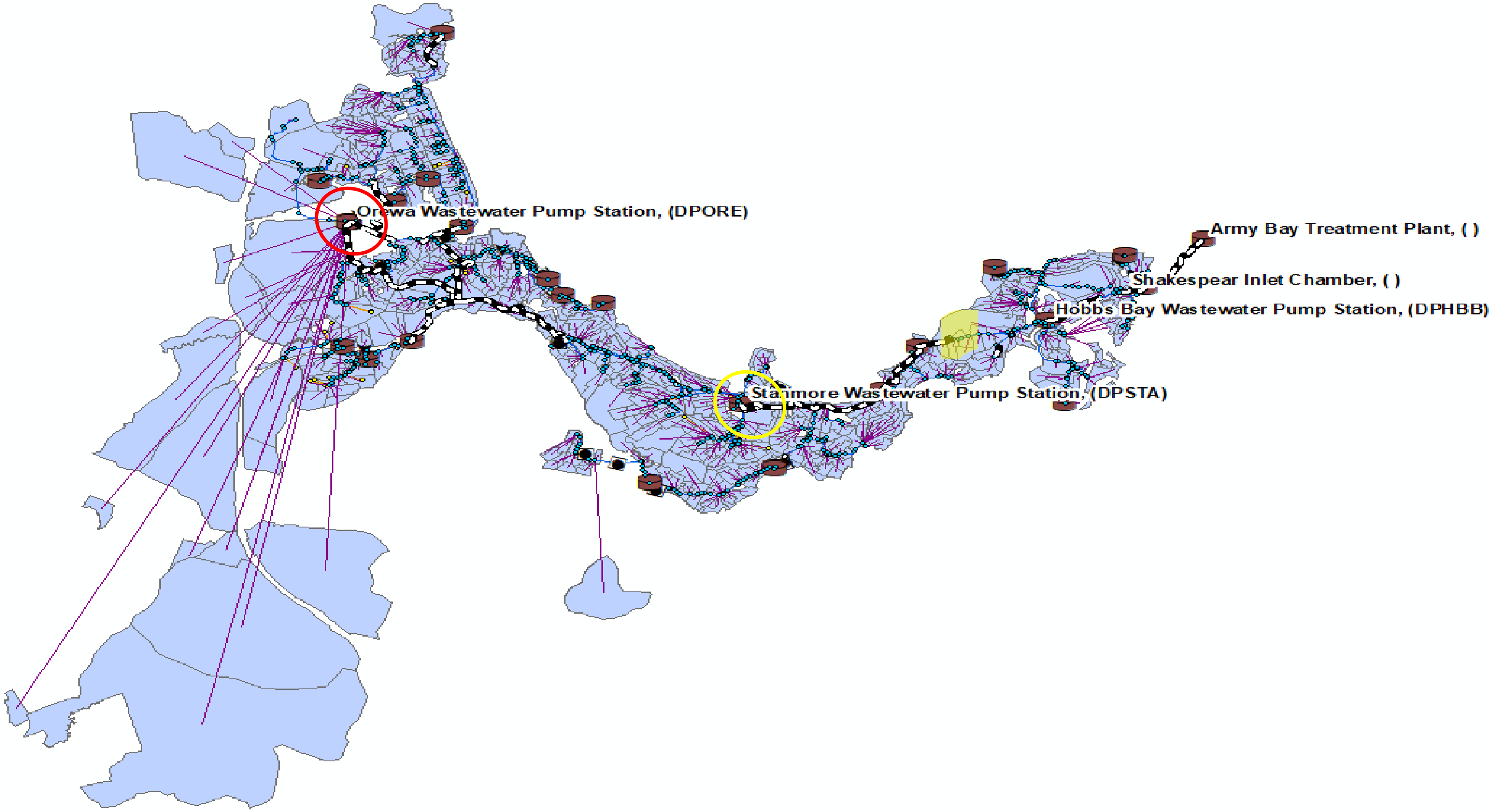
Distribution of Sulfide Species at Selected pH Values at 20°C

pH	7.0	7.5	8.0	8.5	9.0
H_2S (%)	51	25	9	3	1
HS^- (%)	49	75	91	97	99

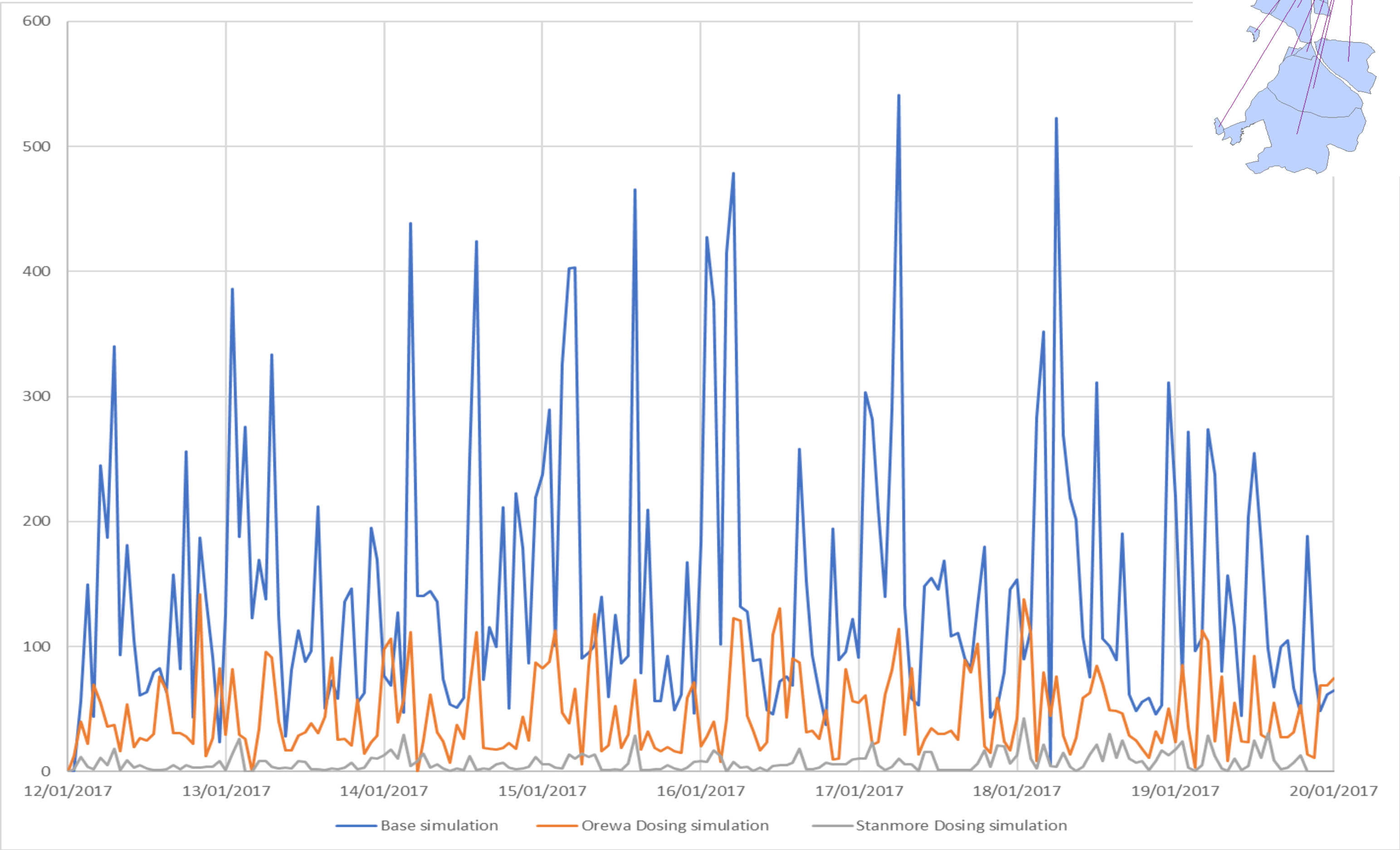
Chemical dosing was simulated by increasing pH from 7 to 9

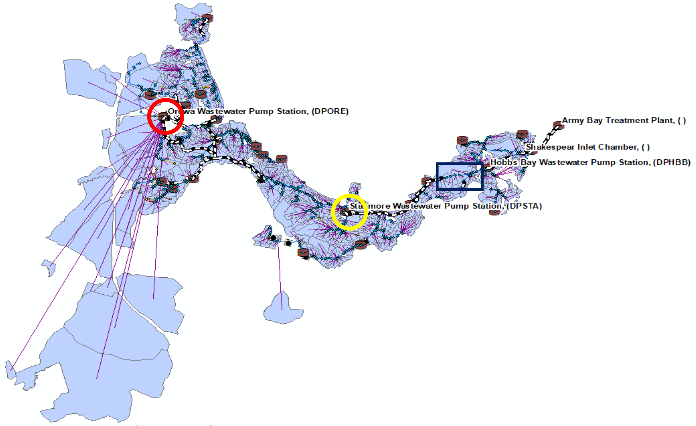
In MIKE ECO Lab, chemical dosing is possible with Nitrate and Iron

Sites for Chemical Dosing – Orewa PS and Stanmore PS



H_2S Model Results





Discussion – Model outputs

H_2S model results provided insight into the following:

- **Where is sulphide being formed in the network?** – Water, nutrient - Anaerobic , - Water age
- **Where will the release happen - identify critical location in the network?** – potential air availability, velocity of the flow/steepness of slope
- **Where it is possible to decrease the release of the H_2S?**
- **How much does the dosing impact the release of H_2S?**

Summary of Results – Model efficiency

- H_2S model at network scale is possible.
- H_2S in gas phase results can be visualized spatially across the network.
- Chemical Dosing (Magnesium Hydroxide) can be modelled and assess it’s efficiency
- Limitation: input data

Recommended Monitoring Campaign

Constituents to be monitored	Period	Sampling interval	Comment
Flow	2-7 days	15 min	Flow at same sampling interval as the WQ parameters listed below
Total COD	2-7 days	60 min	
Filterable COD	2-7 days	60 min	
Dissolved Oxygen	2-7 days	15 min	
pH	2-7 days	15 min	
Temperature	2-7 days	15 min	
Total dissolved sulfide	2-7 days	15 min	
H_2S in liquid	2-7 days	15 min	
SO_4			
Free Iron	2-7 days	15 min	Required only if dosing. However, it is preferred that any dosing is turned off during measuring campaign
NO_3	2-7 days	15 min	Required only if dosing. However, it is preferred that any dosing is turned off during measuring campaign

Recommendations

- Monitoring campaign
- Ventilations
- Pumping Regime Optimization
- Dosing

Conclusion

Model able to predict formation and release of H_2S => H_2S risk maps

No need to export to another model

Result viewing made in MIKE platform MIKE+

The model supports the assessment of mitigation options

Modelling Group
WATER NEW ZEALAND

Modelling Symposium

The expert in WATER ENVIRONMENTS

Thank you!
Questions? Patai?

water
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