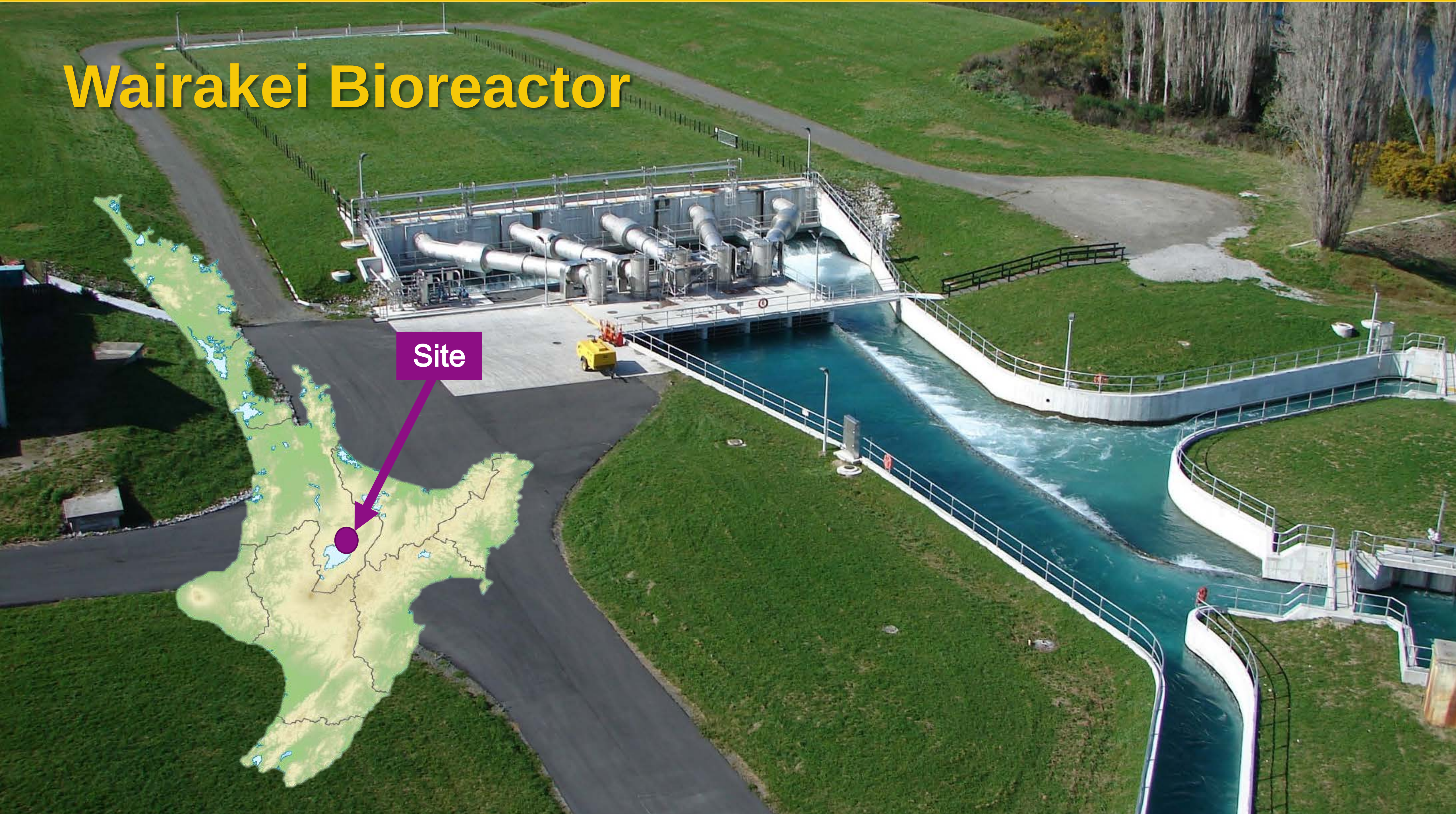
Water NZ Conference 2018

# Extending ASM1 to Model a Tubular Biofilm Reactor

CAROLINE HOPE

# Wairakei Bioreactor



# Hydrogen Sulphide Discharge

**1958** **Power Station Commissioned**

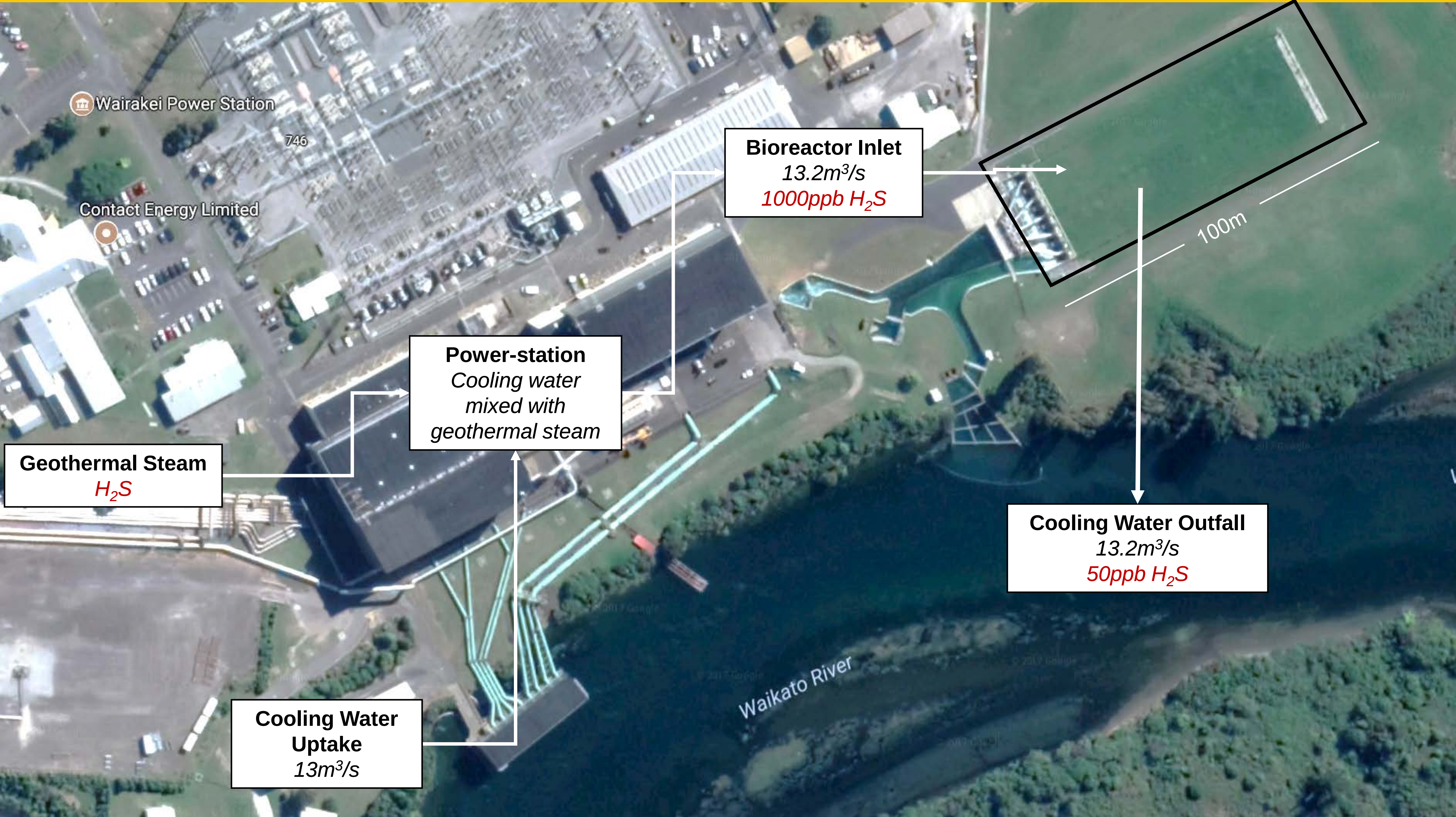
- Direct contact condensers
- Cooling water combined with geothermal steam condensate

**2012** **Wairākei Bioreactor Successfully Commissioned**

- 95% reduction in $H_2S$

~ 1000ppb

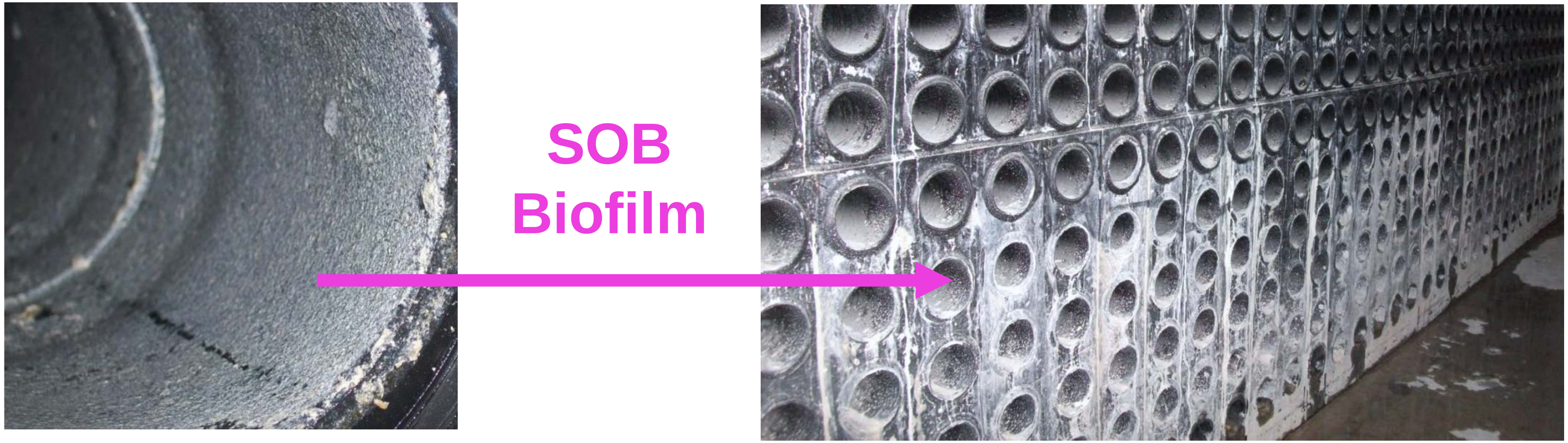
~ 50ppb


Wairakei Power Station
746
Contact Energy Limited
Bioreactor Inlet
13.2m³/s
1000ppb $H_2S$
100m
Power-station
Cooling water
mixed with
geothermal steam
Geothermal Steam
$H_2S$
Cooling Water Outfall
13.2m³/s
50ppb $H_2S$
Waikato River
Cooling Water
Uptake
13m³/s

# Process

1. Bio-mechanistic Model
2. Biofilm Model
3. Calibration
4. Test Disturbance Variables

# Sulphur Oxidising Bacteria



# Sulphur Reactions

| | | | |
|---|---|---|---|
| *Equation 1* | $H_2S + 0.5O_2$ | $\xrightarrow{SOB}$ | $S° + H_2O$ |
| *Equation 2* | $S° + 1.5O_2 + H_2O$ | $\xrightarrow{SOB}$ | $SO_4^{2-} + 2H^+$ |
| *Equation 3* | $H_2S + 2O_2$ | $\xrightarrow{SOB}$ | $SO_4^{2-} + 2H^+$ |

# Hydrogen Sulphide Removal

Hydrogen Sulphide Removal Rate

Particulate Sulphur Oxidising Bacteria Conc.

Soluble Hydrogen Sulphide

Dissolved Oxygen

$$\frac{dS_{H2S}}{dt} = -\mu_{max} * X_{SOB} * \left(\frac{S_{H2S}}{K_{H2SSOB}+S_{H2S}}\right) * \left(\frac{S_O}{K_{OSOB}+S_O}\right)$$

Maximum Specific Growth Rate

Half Saturation Constant for SOB growth on H2S

Half Saturation Constant for SOB growth on oxygen

# Additional ASM 1 Processes

| | Process | Rate Equation |
|---|---|---|
| 1 | Aerobic growth of $X_{SOB}$ on $S_{H2S}$ | $\mu_{SOB} \times \left(\frac{S_{H2S}}{K_{H2SSOB} + S_{H2S}}\right) \times \left(\frac{S_O}{K_{OSOB} + S_O}\right) \times X_{SOB}$ |
| 2 | Aerobic growth of $X_{SOB}$ on $S_S{}^o$ | $\mu_{SOB} \times \left(\frac{X_{S^o}}{K_{S^oSOB} + X_{S^o}}\right) \times \left(\frac{S_O}{K_{OSOB} + S_O}\right) \times X_{SOB}$ |
| 3 | Lysis of $X_{SOB}$ | $b_{SOB} \times X_{SOB}$ |

Additional Components

# Additional ASM 1 Processes

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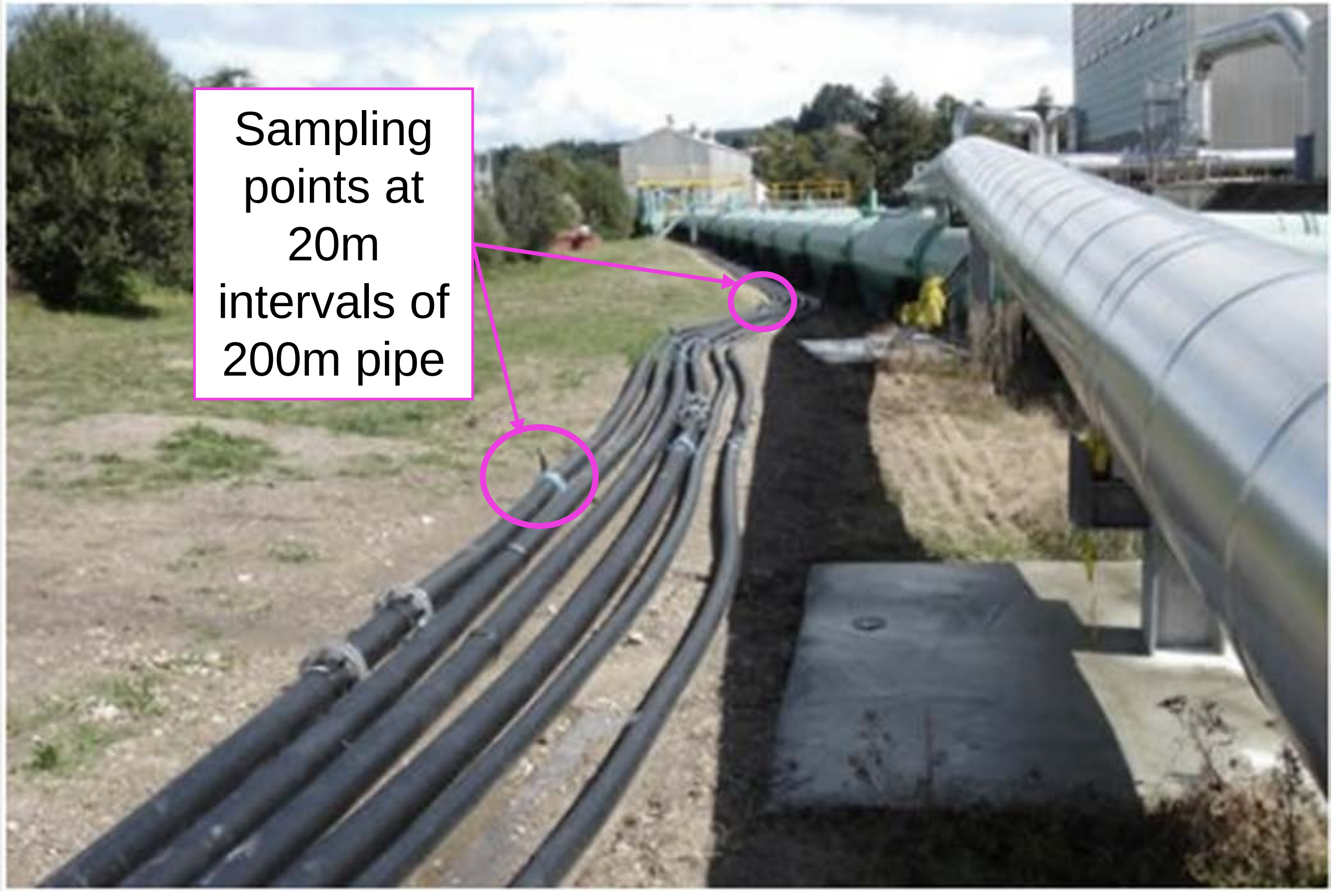
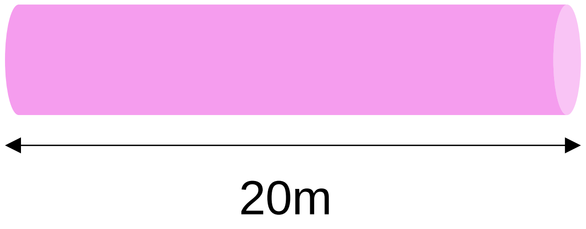
| 3 | Lysis of $X_{SOB}$ | $b_{SOB} \times X_{SOB}$ |

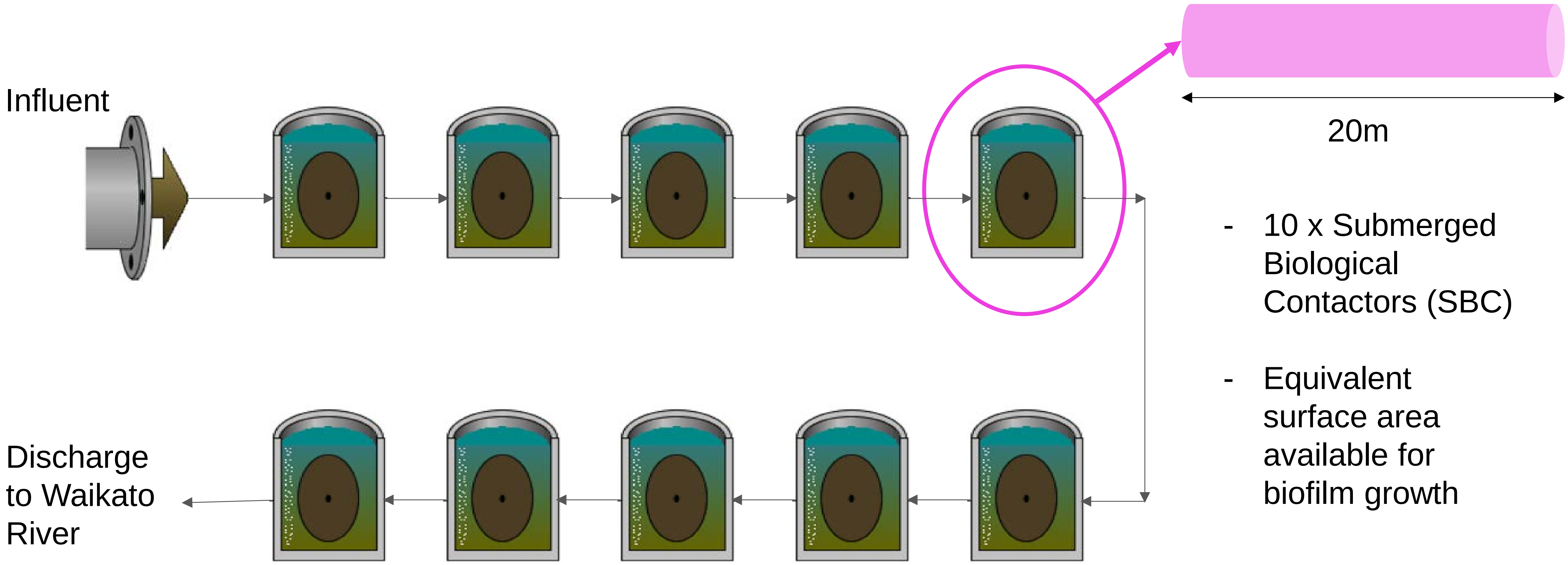
Additional Kinetic Parameters

# Bioreactor Trial Pipes



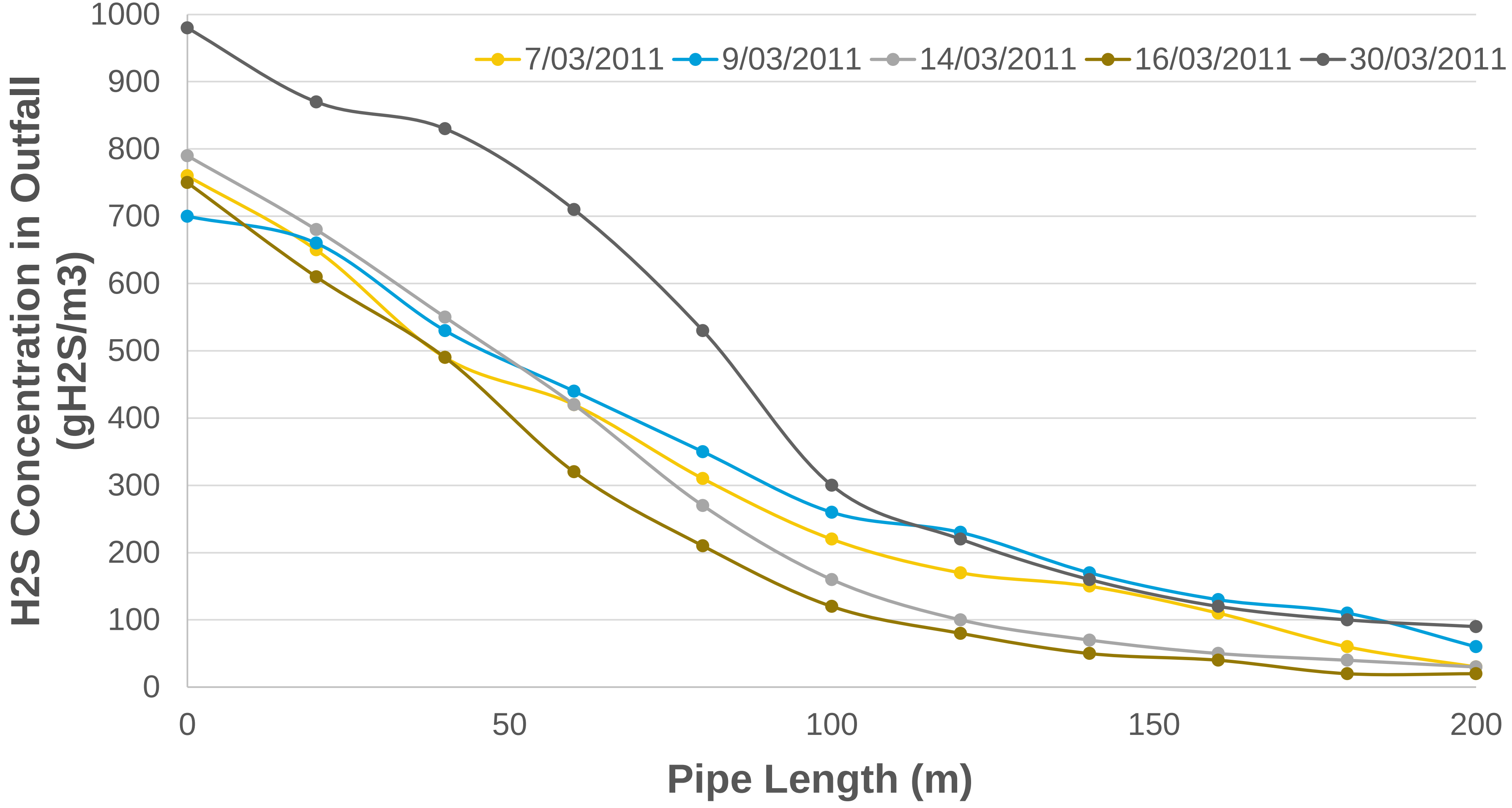



# GPS-X Pipe Simulation



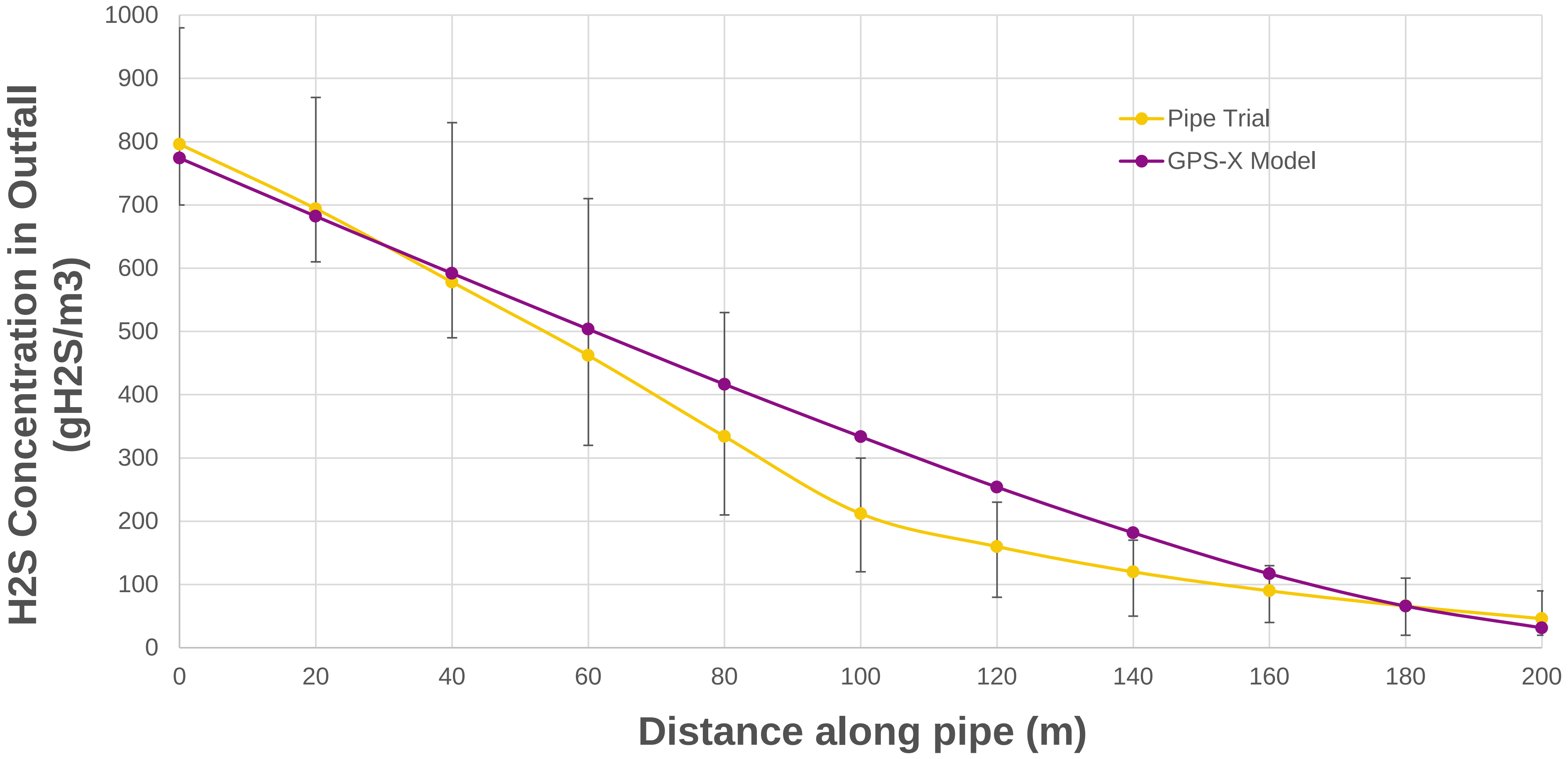

- 10 x Submerged Biological Contactors (SBC)
- Equivalent surface area available for biofilm growth

# Pipe Trial Data




Stable Velocity of 0.8m/s

# Calibration



# Model Kinetic Parameters

| Symbol | Parameter | Model | Literature | Units |
|---|---|---|---|---|
| $\mu_{SOB}$ | SOB specific growth rate | 5.28 | 5.28 | 1/d |
| $b_{SOB}$ | Rate constant for lysis | 0.15 | 0.15 | 1/d |
| $K_{OSOB}$ | SOB saturation for $O_2$ | 0.1 | 0.2 | $gO_2 /m^3$ |
| $K_{H2SSOB}$ | SOB saturation coefficient for $H_2S$ | 0.06 | 0.24 | $gS /m^3$ |
| $K_{S°SOB}$ | SOB saturation coefficient for S° | 0.09 | 3.2 | $gS /m^3$ |

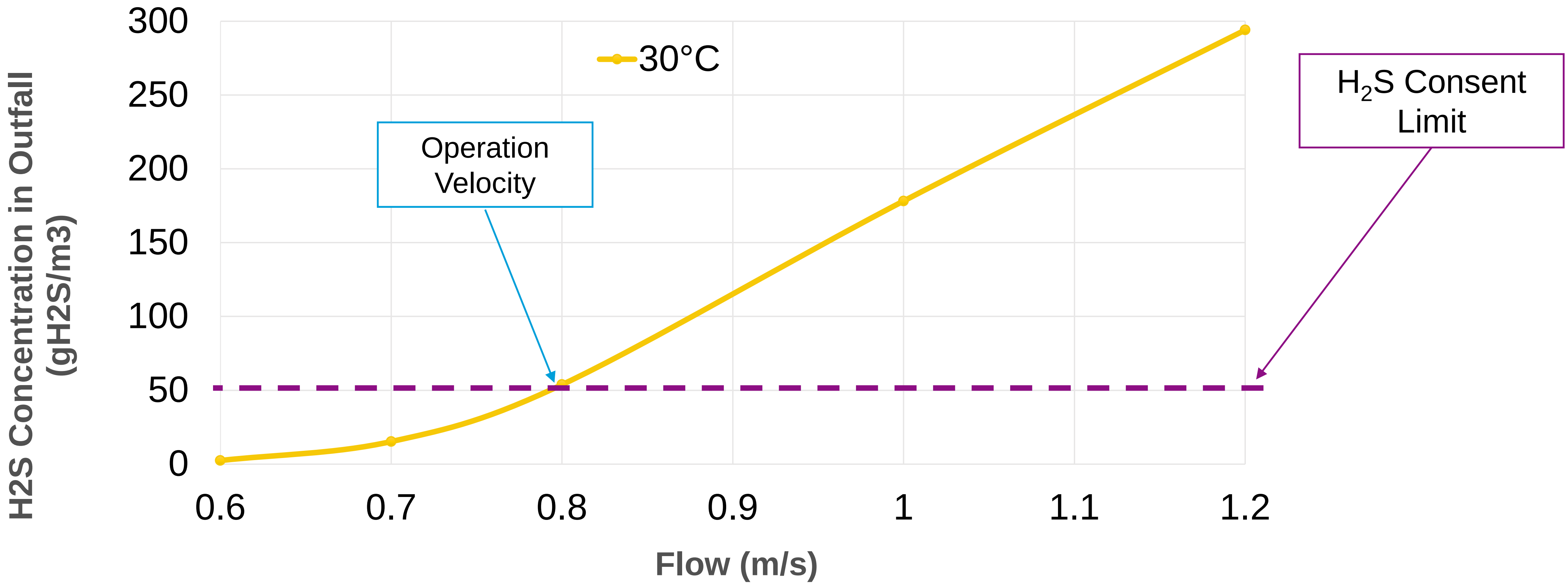
# Model Tests

A. Flowrate on $H_2S$ Removal

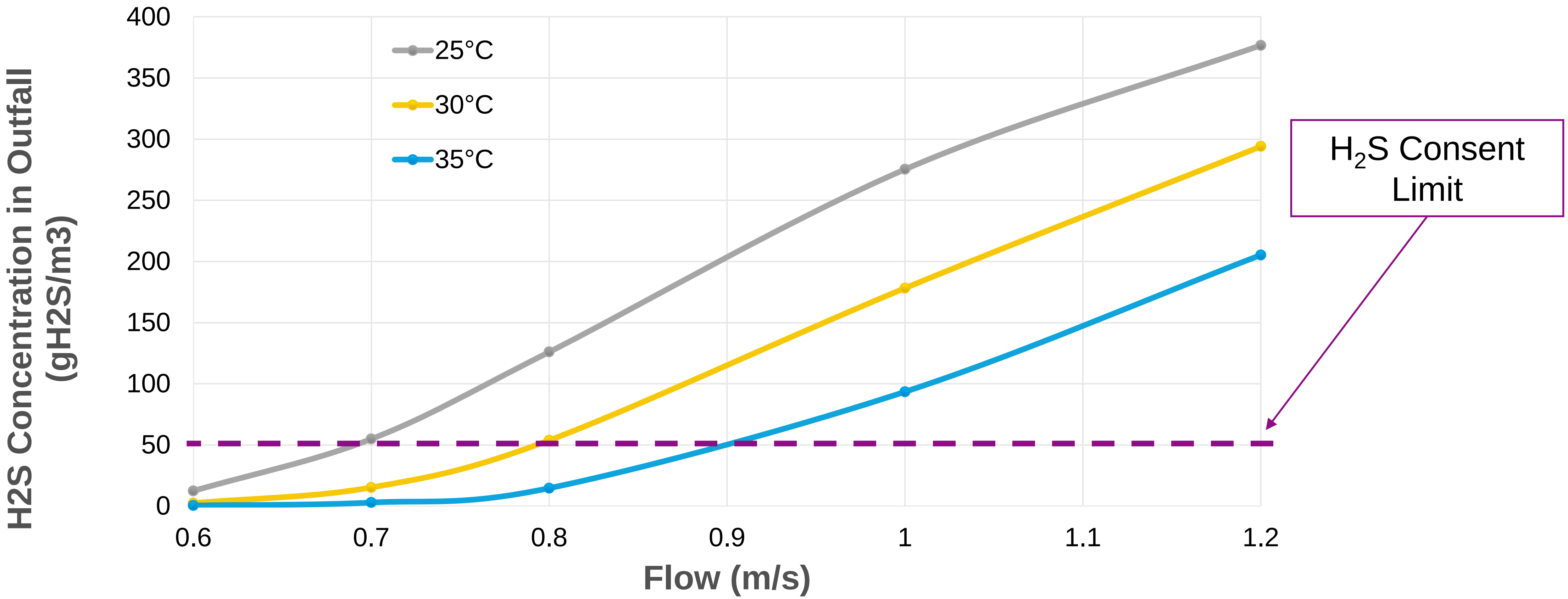
B. Temperature and Flowrate on $H_2S$ Removal

C. Dissolved Oxygen Conditions on Reaction Products

# A. Flowrate on $H_2S$ Removal

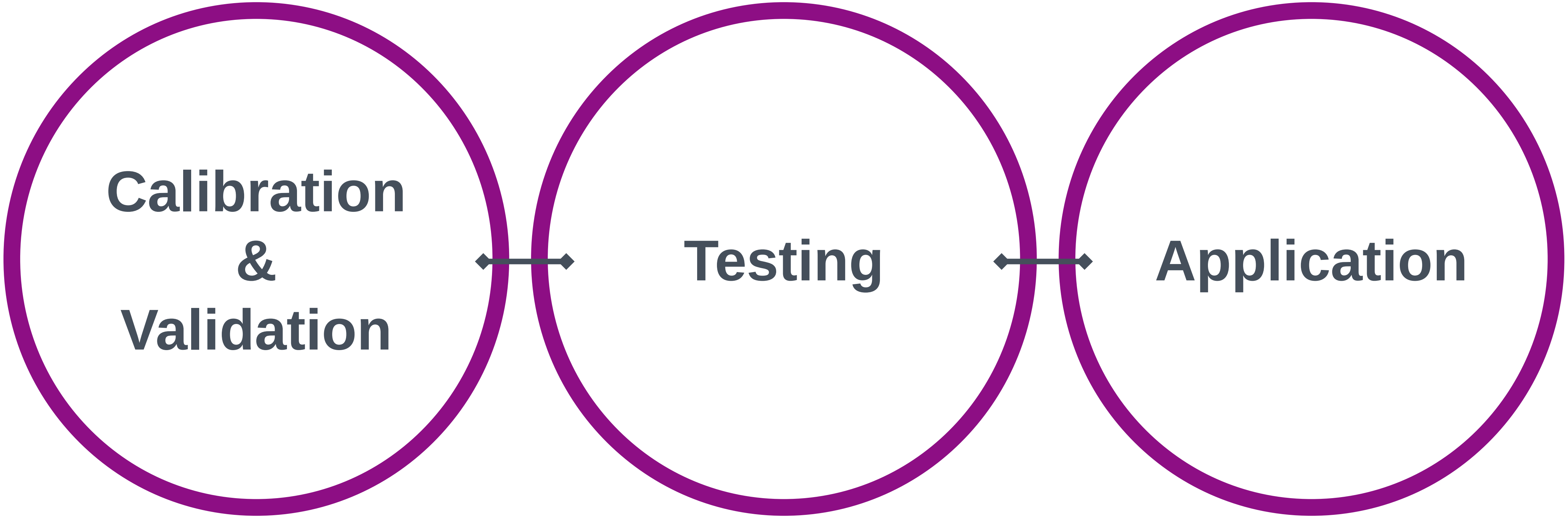


# B. Temperature and Flowrate on $H_2S$ Removal



# C. Dissolved Oxygen Conditions

| Ratio ($H_2S/O_2$) | Favoured Reaction |
|---|---|
| < 0.5 | $H_2S + 0.5O_2 \rightarrow S^{\circ} + H_2O$ |
| > 2 | $H_2S + 2O_2 \rightarrow SO_4^{2-} + 2H^+$ |




# Further Research

#wemakethingshappen