Comparison of experimental and COMSOL-MP CFD model simulations of erosional growth of a soil pipe

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Justification

- Geomorphic evolution; gully formation

Justification

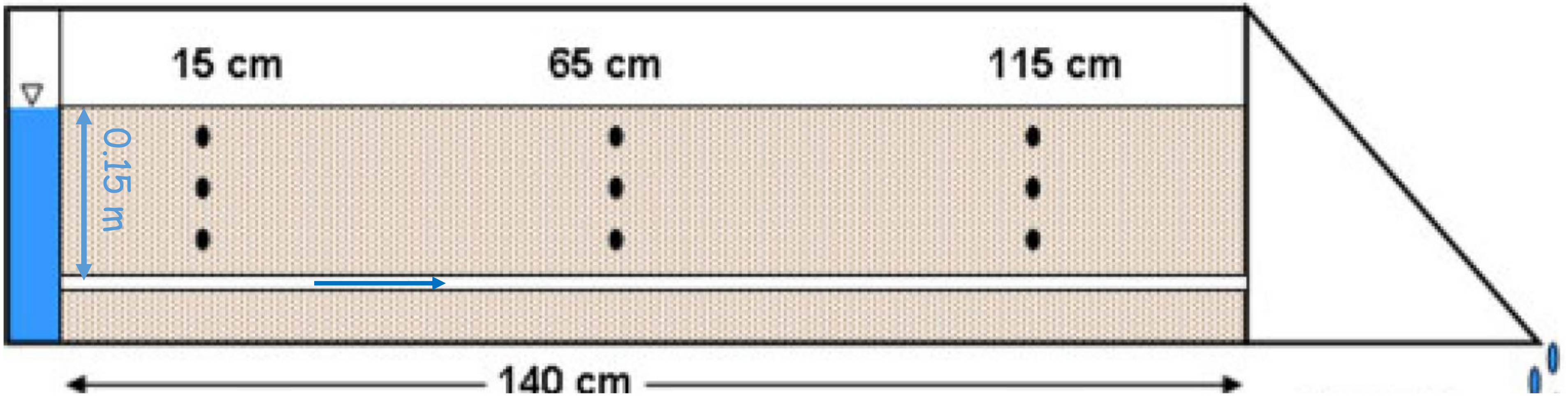
- Undermining infrastructure

Justification

- Failure of earthen embankments

Fontenelle Dam, Green River, Wyoming, 1965
Courtesy, Civil Eng. Dept., UC - Davis

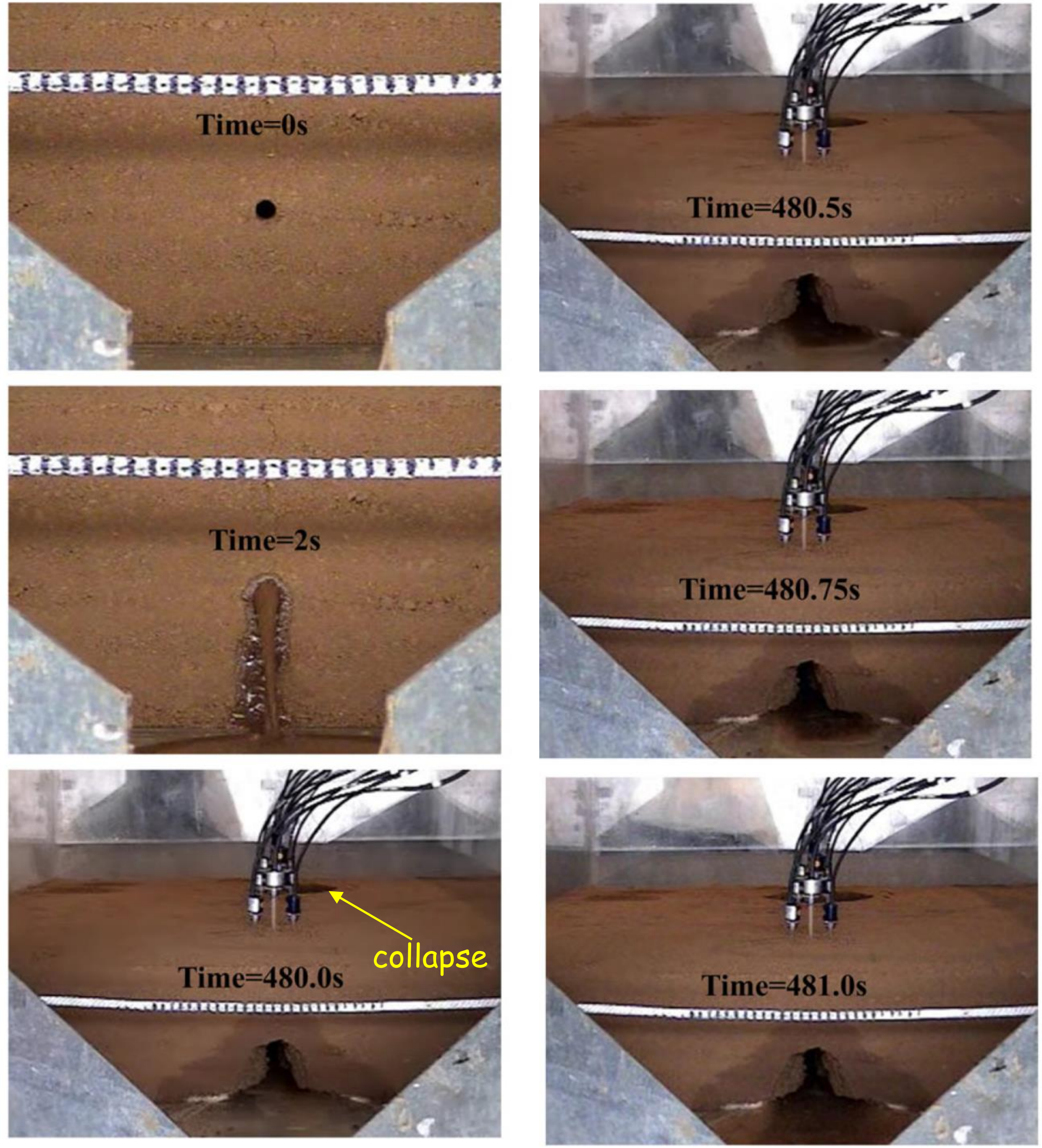
Experimental Work



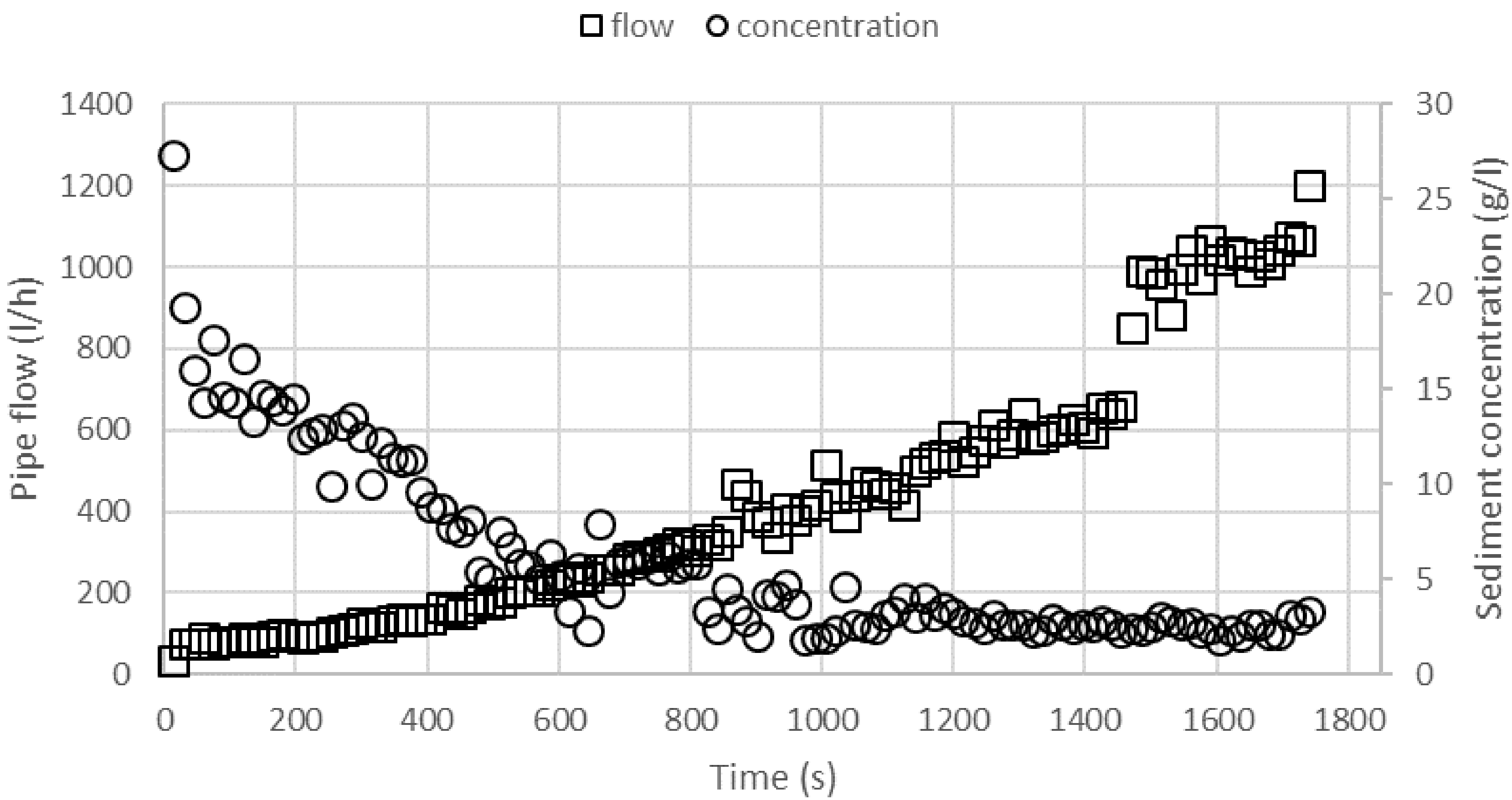
Pipe flow experiment for 10 mm diameter pipe.

1. The photo at 2 sec shows the pipeflow contains a high concentration of sediment.

2. At 470 sec the soil over the pipe collapsed, stopping the flow until about 480 sec.



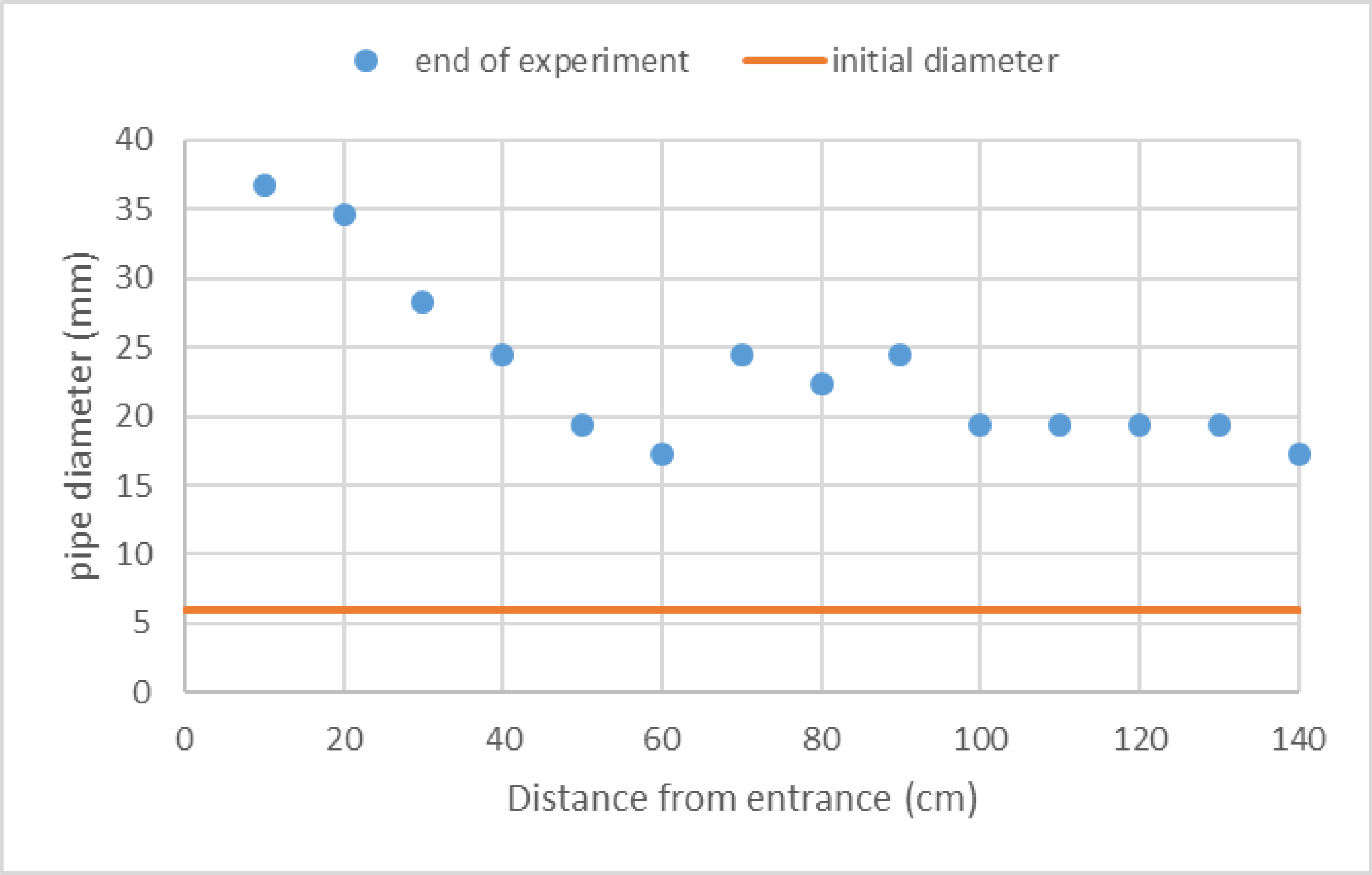
Case of the 6 mm soil pipe (from Wilson, 2011)



- Flow rate increases with time as pipe diameter increases

- Erosion rate increases with time but flow rate increases faster still, leading to a diluting effect on concentration

Measured pipe diameter



Observed diameter is measured at the end of the experiment (1800 s)

Piping erosion model

- Conservation of mass and conservation of linear momentum equations (time-averaged turbulent Navier-Stokes equations)

- $k - \omega$ turbulence model
  - Turbulent energy and specific dissipation
  - Low Re wall treatment

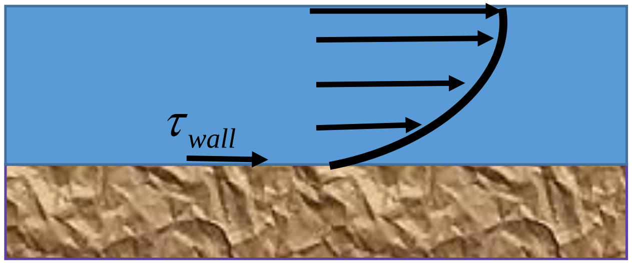
- Transport of suspended sediment – advection-dispersion equation

- Sediment production on pipe wall – excess shear equation

- Deformed geometry component

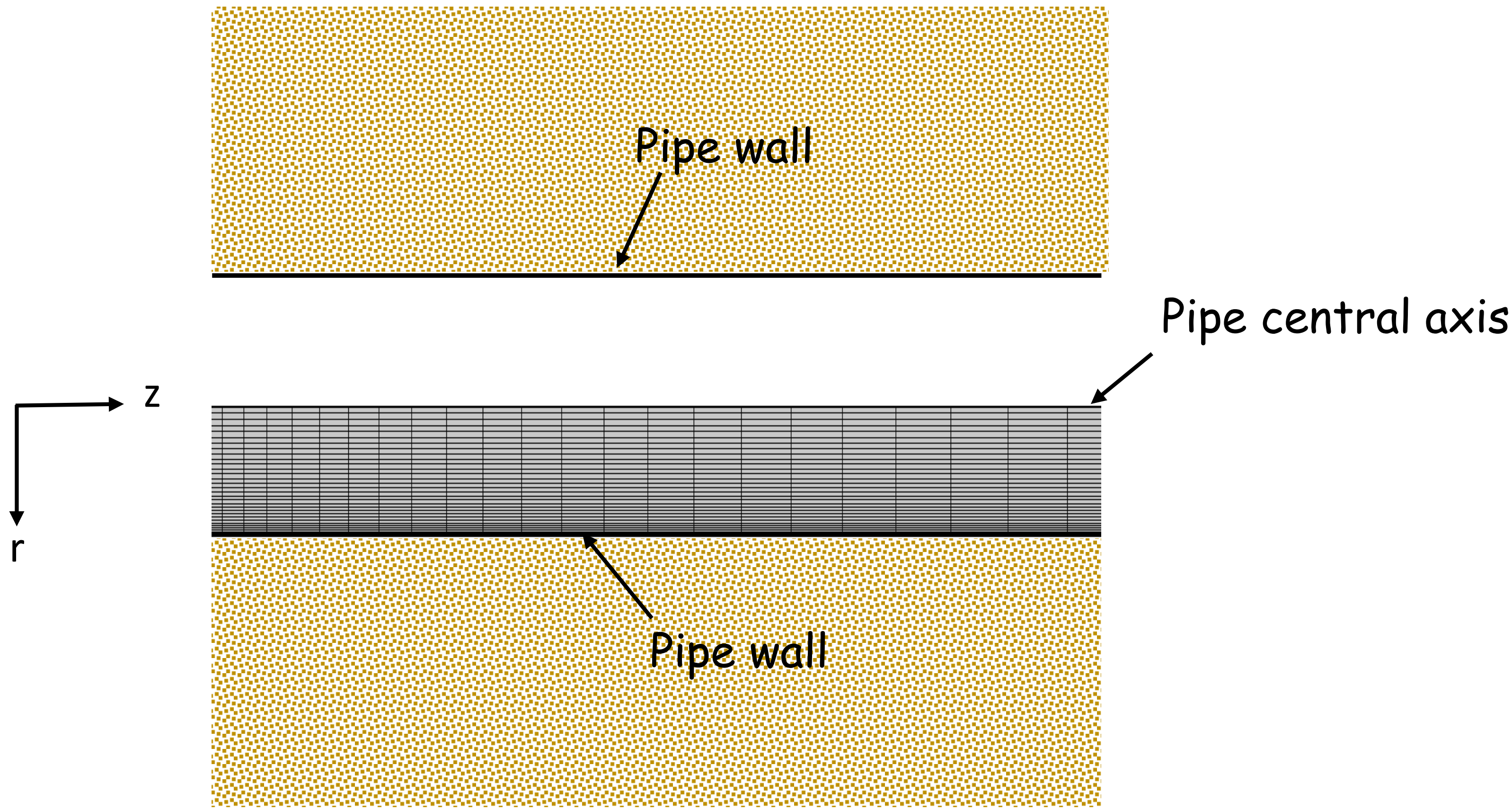
Excess shear equation; empirical

$$q_s = k_{eros}\left(\underbrace{\mu \frac{\partial u}{\partial r}_{wall}}_{\tau_{wall}} - \tau_{crit}\right)$$

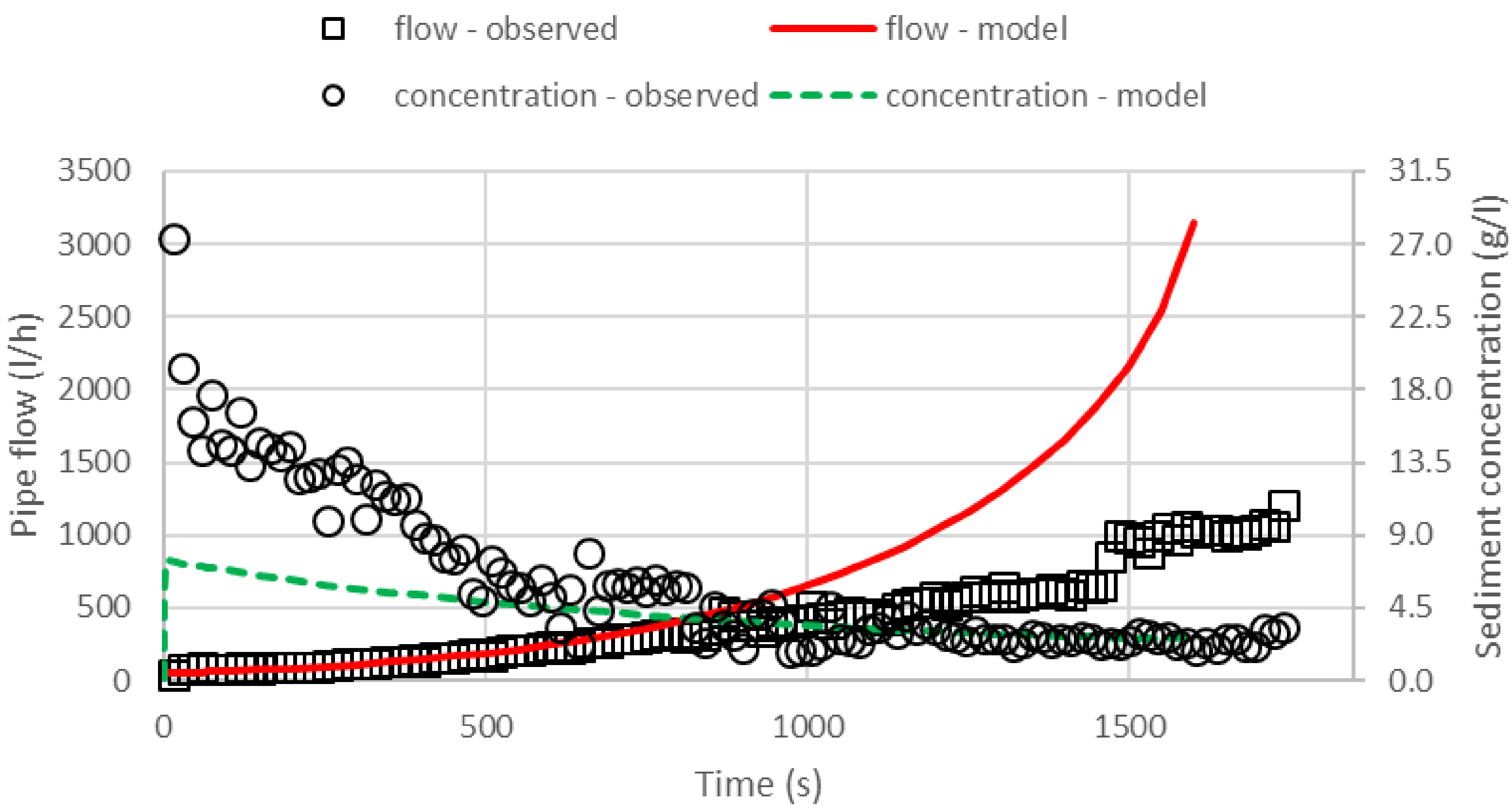


Numerical implementation COMSOL MP

Pipe modeled as an axisymmetric domain

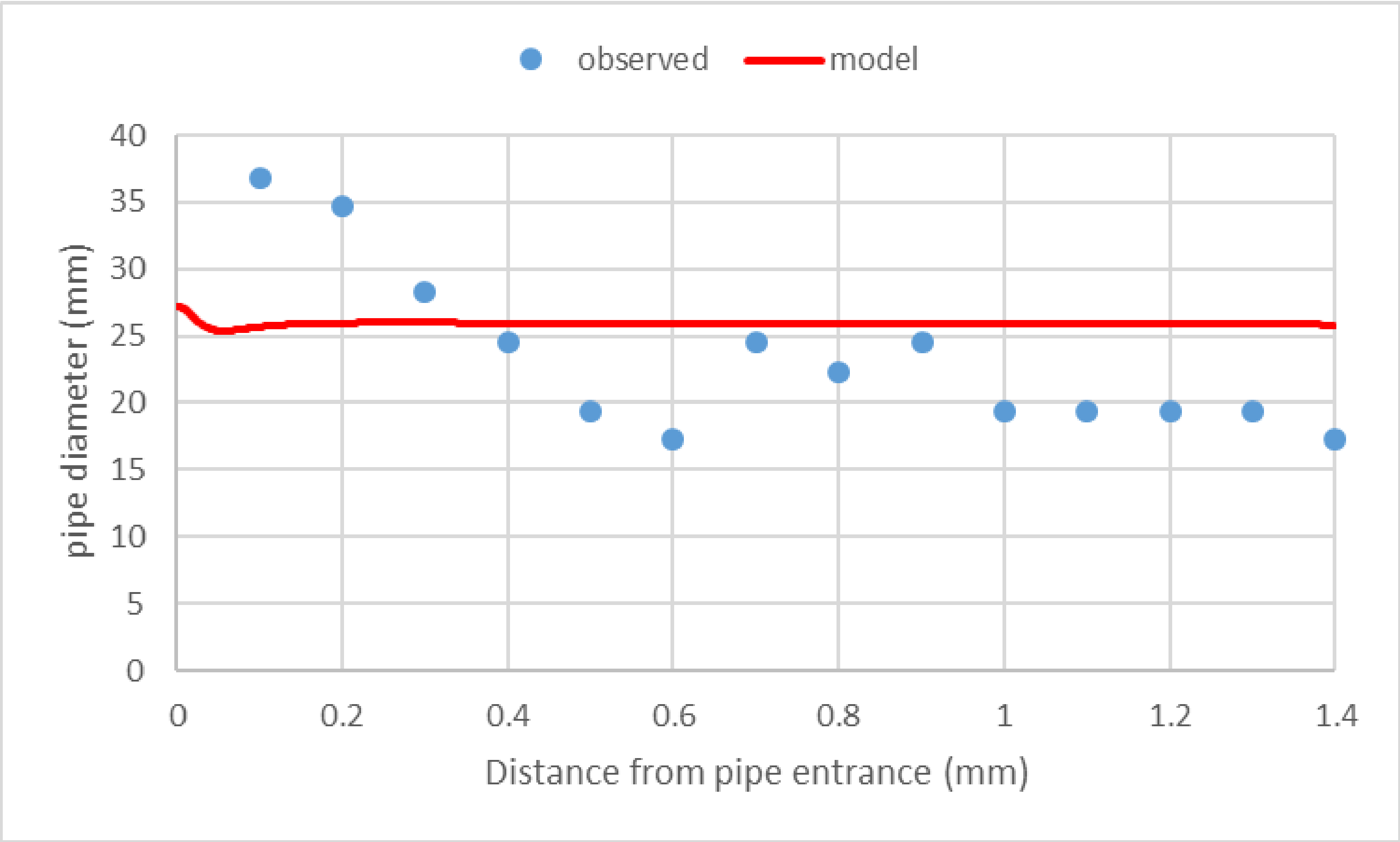


Constant k_{ero}: 0.0025 s/m



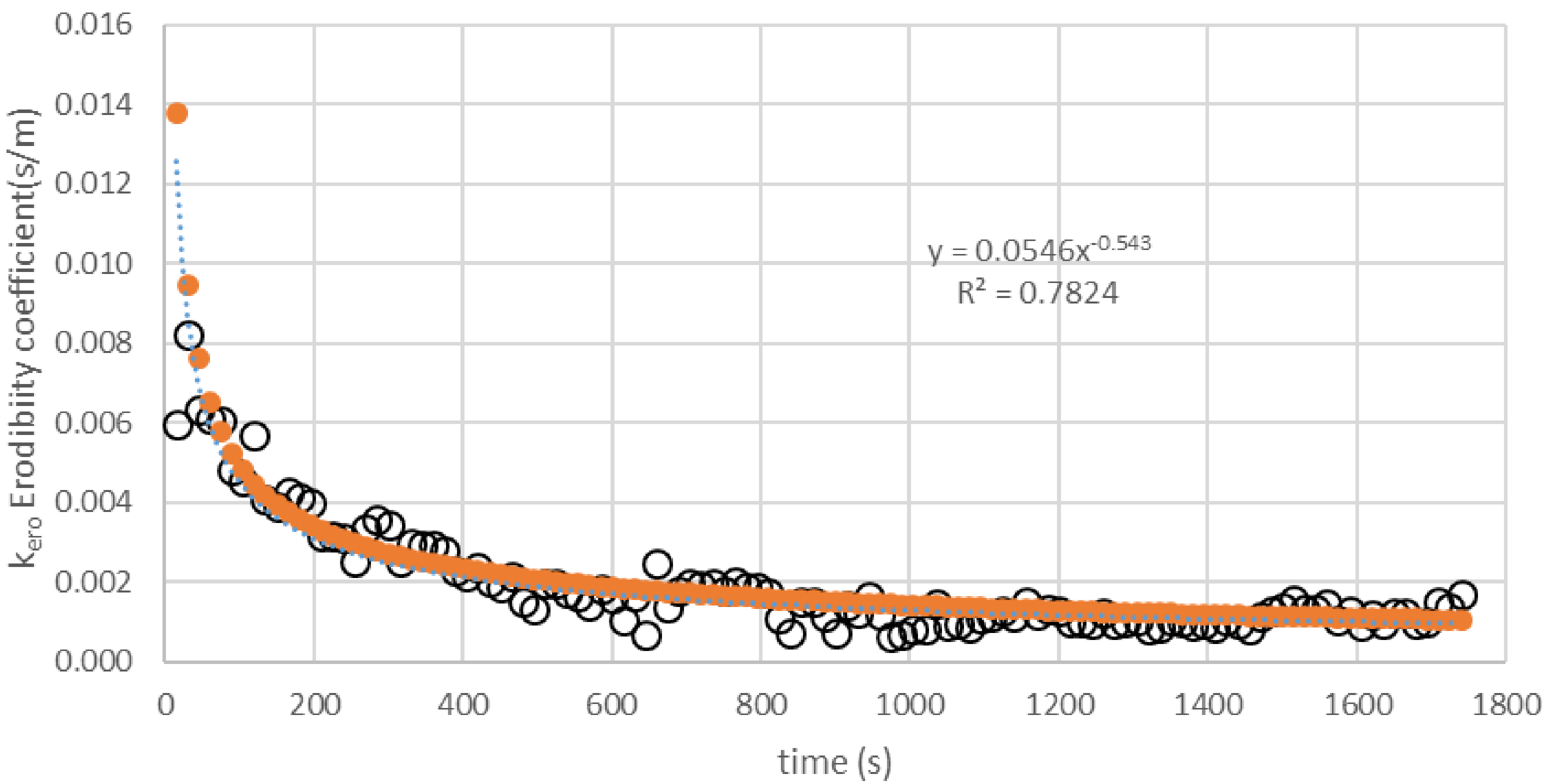
Constant k_{ero}

Pipe diameter



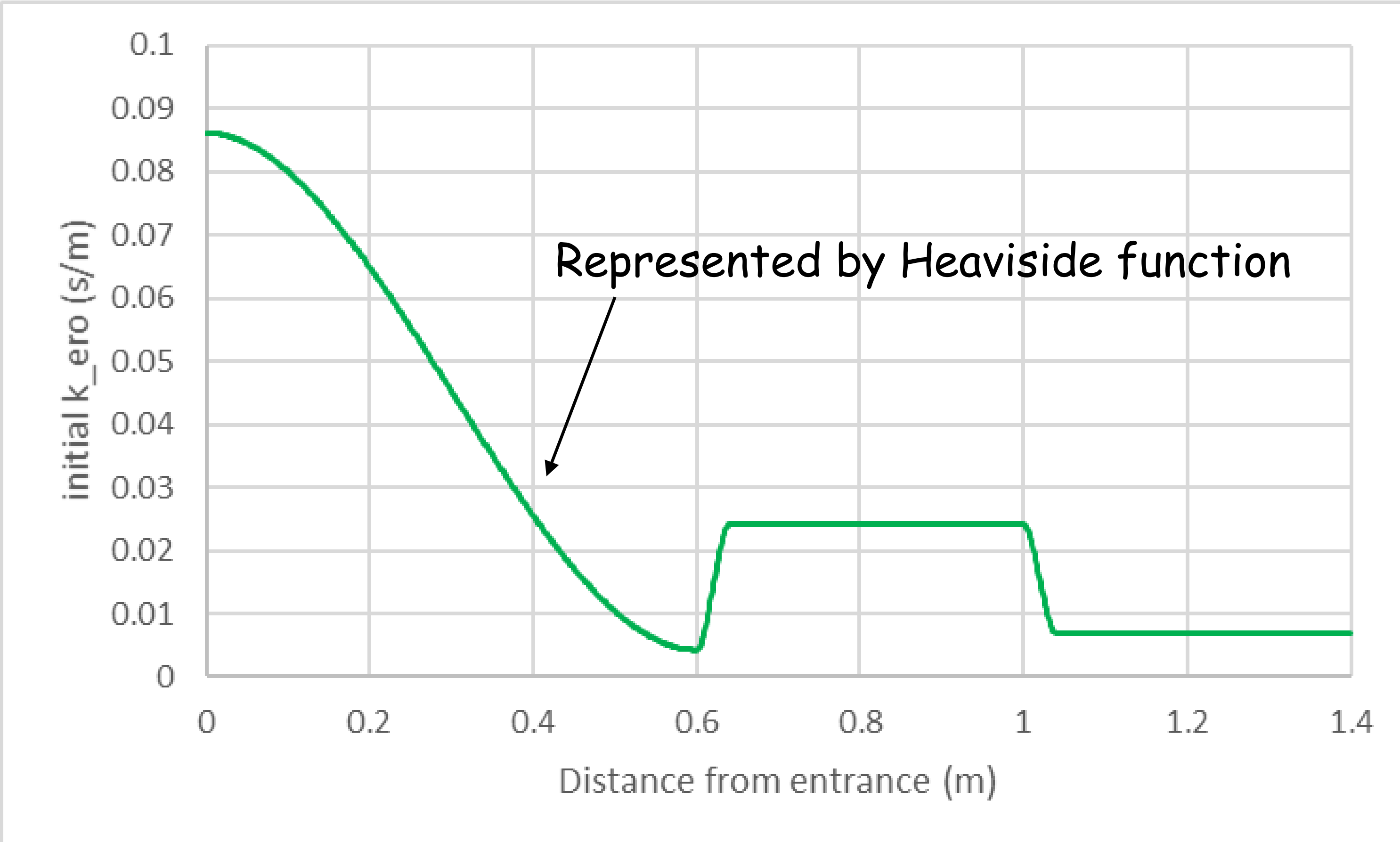
Observed diameter is measured at the end of the experiment (1800 s)

Variable k_{ero}



Time-dependent variation in k_{ero} is derived using experimental data and assuming the growing soil pipe is uniform in diameter for the duration of the experiment

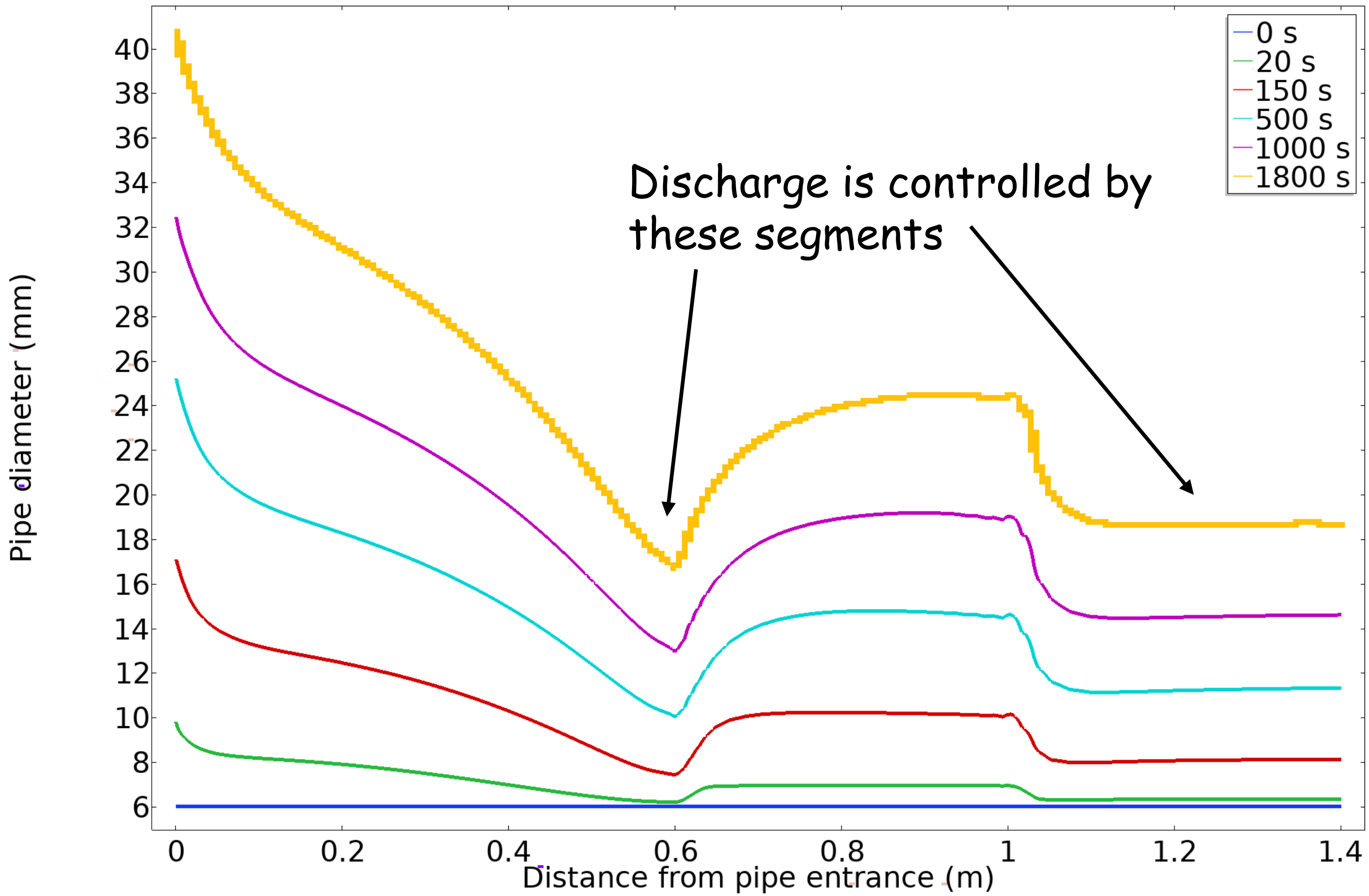
$k_{ero}(z,t=0)$



$$k_{eros}\left(z,t\right)=k_{eros}\left(z,0\right)\left(0.0546z^{-0.543}\right)$$

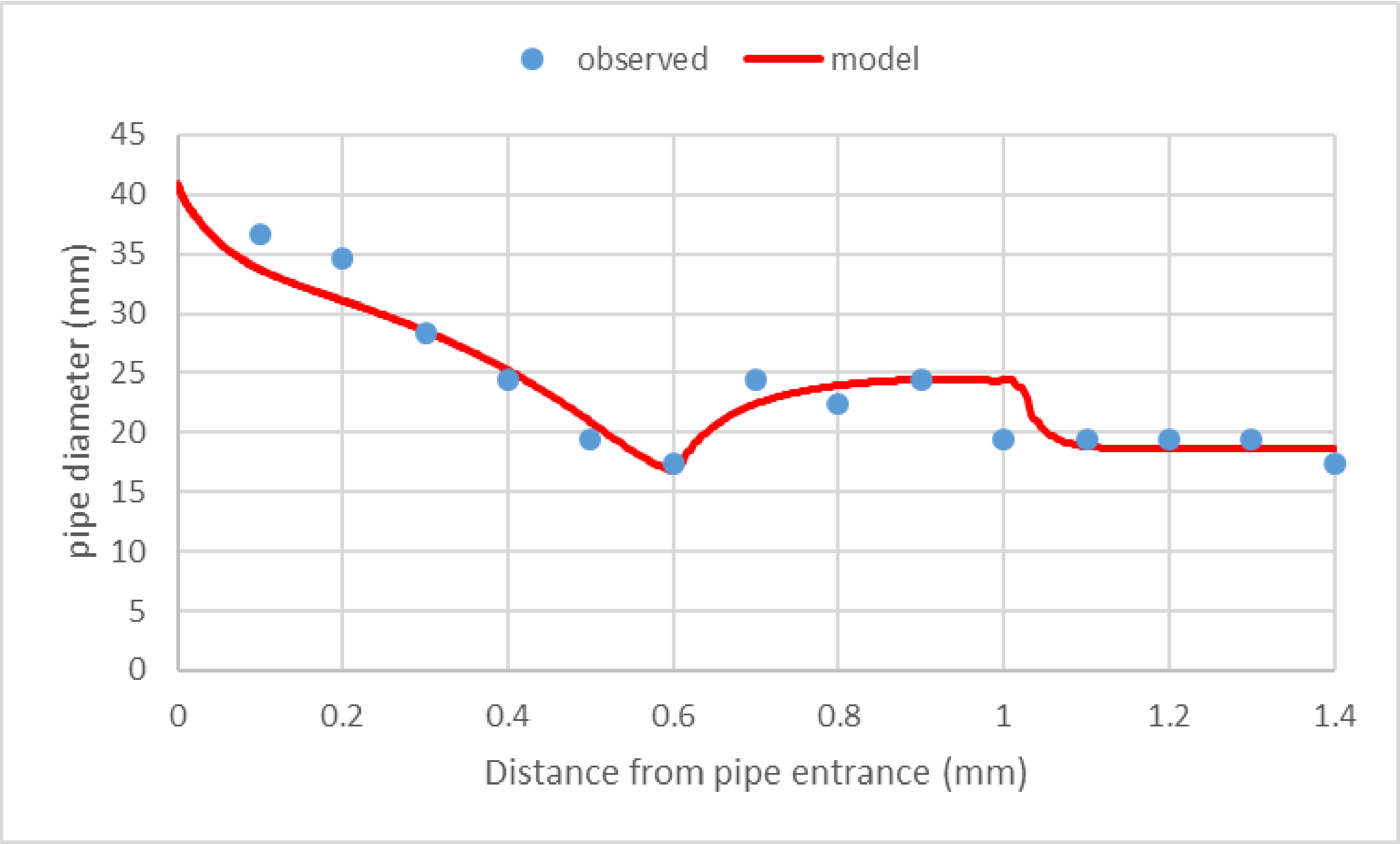
Variable k_{ero}

Pipe diameter evolution



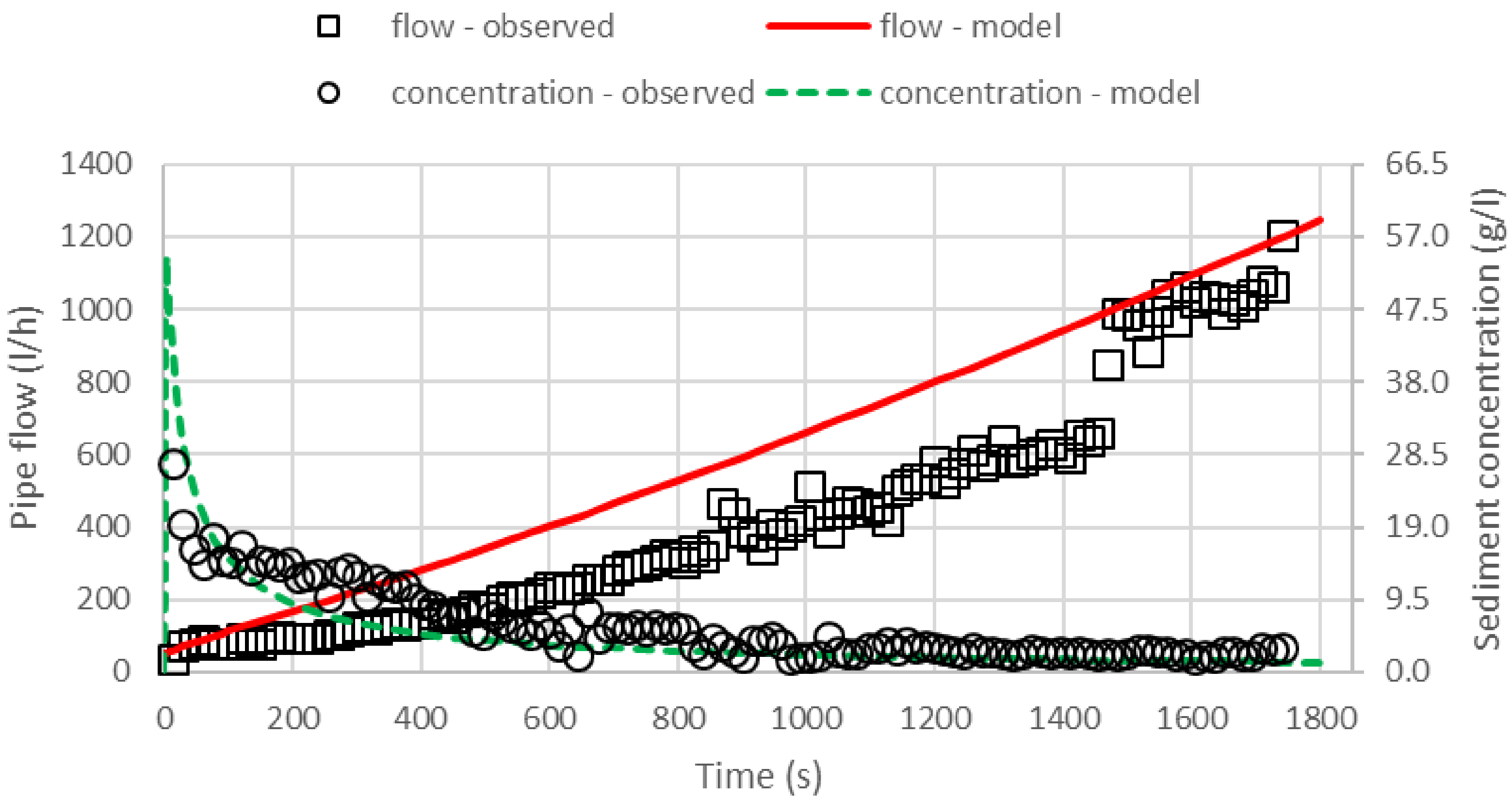
Variable k_{ero}

Pipe diameter



Observed diameter is measured at the end of the experiment (1800 s)

Variable k_{ero}



Acknowledgment:

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