Solid Transport in near horizontal drainlines

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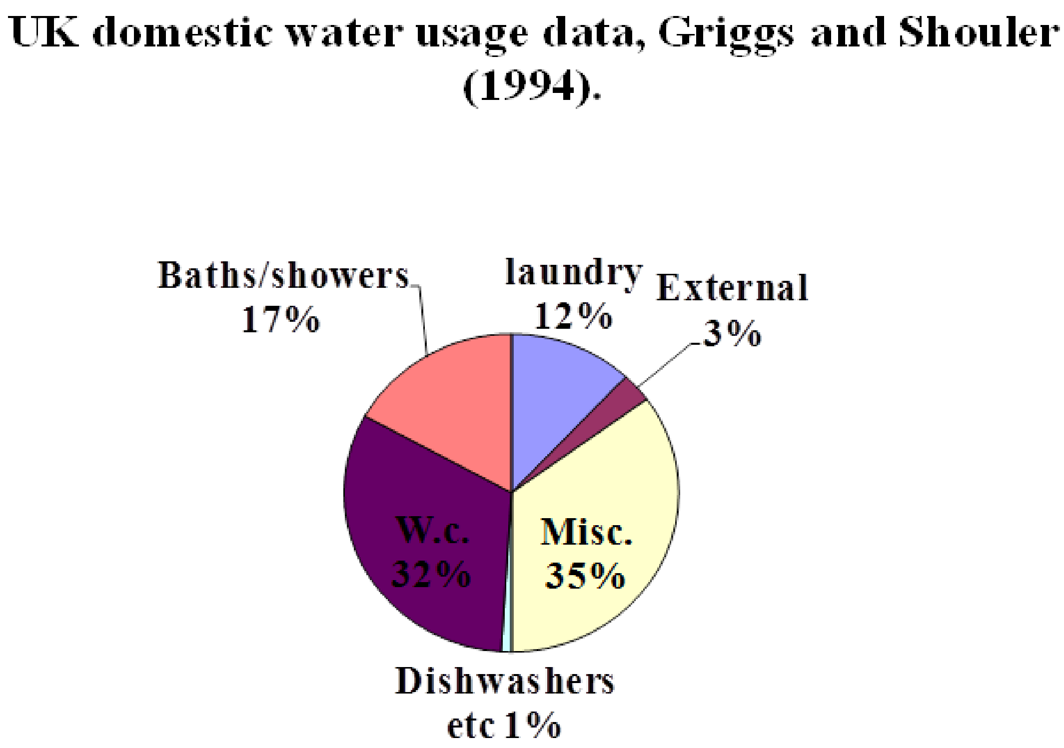
Solid Transport: mechanism and modelling

- Background
- Modelling flows/attenuating waves
- Choice of Solid simulator
- Extra large solids/ partial blockages
- Movement thresholds
- Modelling example
- Conclusions

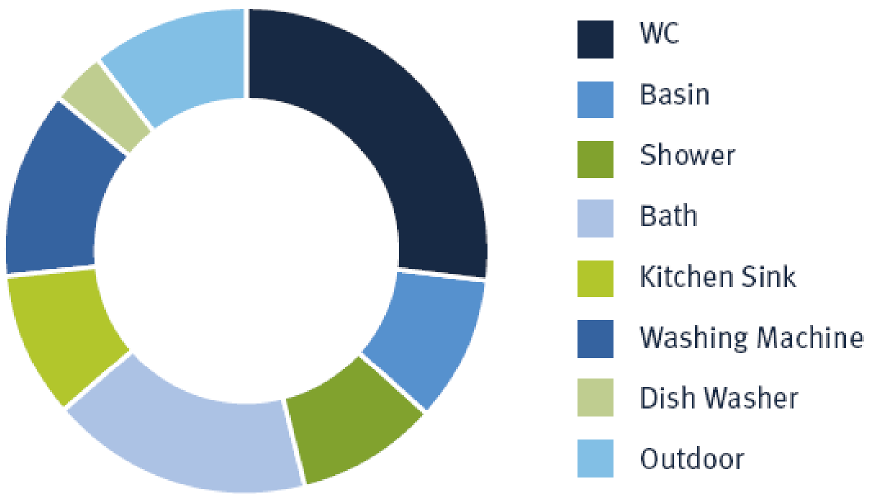
Background

- Engineering modelling of solid transport inside buildings since the 1970s
- Informed Government policy
- Enabled reduction in water volume used by appliances
- And now allows for the continued mornitoring and assessment of these water volume reductions.

Water consuming appliances

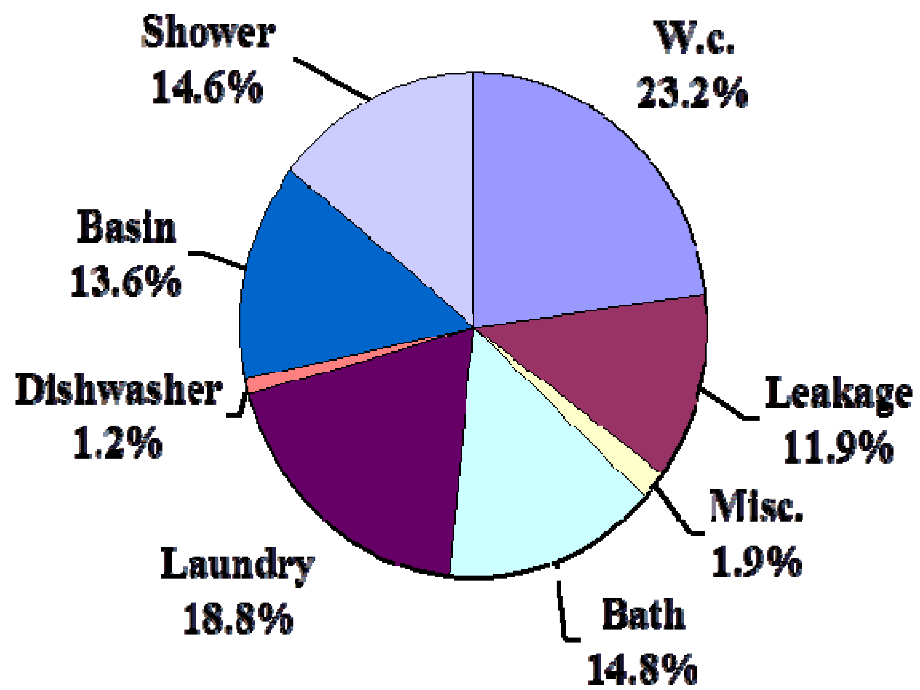


How is water used?

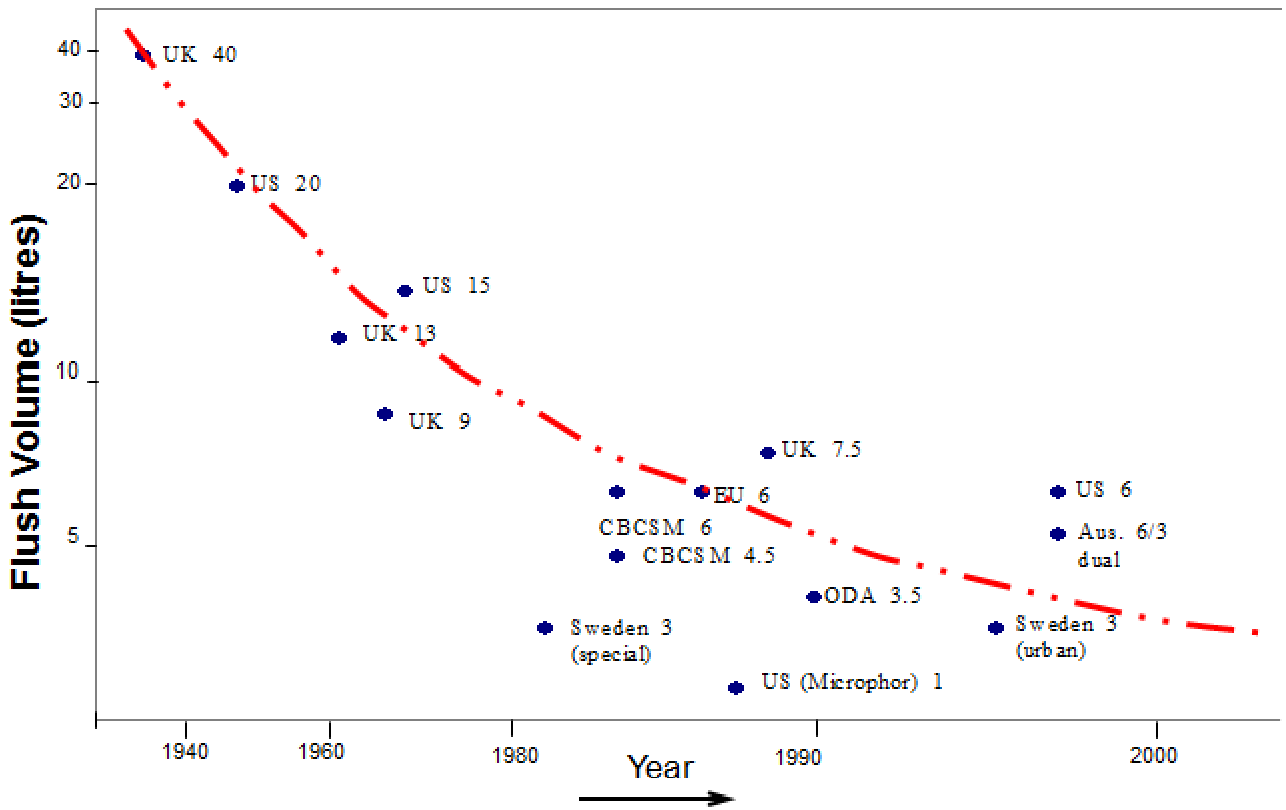


UK – Breakdown of water consuming appliances (2007)

US domestic water use, AWWA Research Foundation (1999).



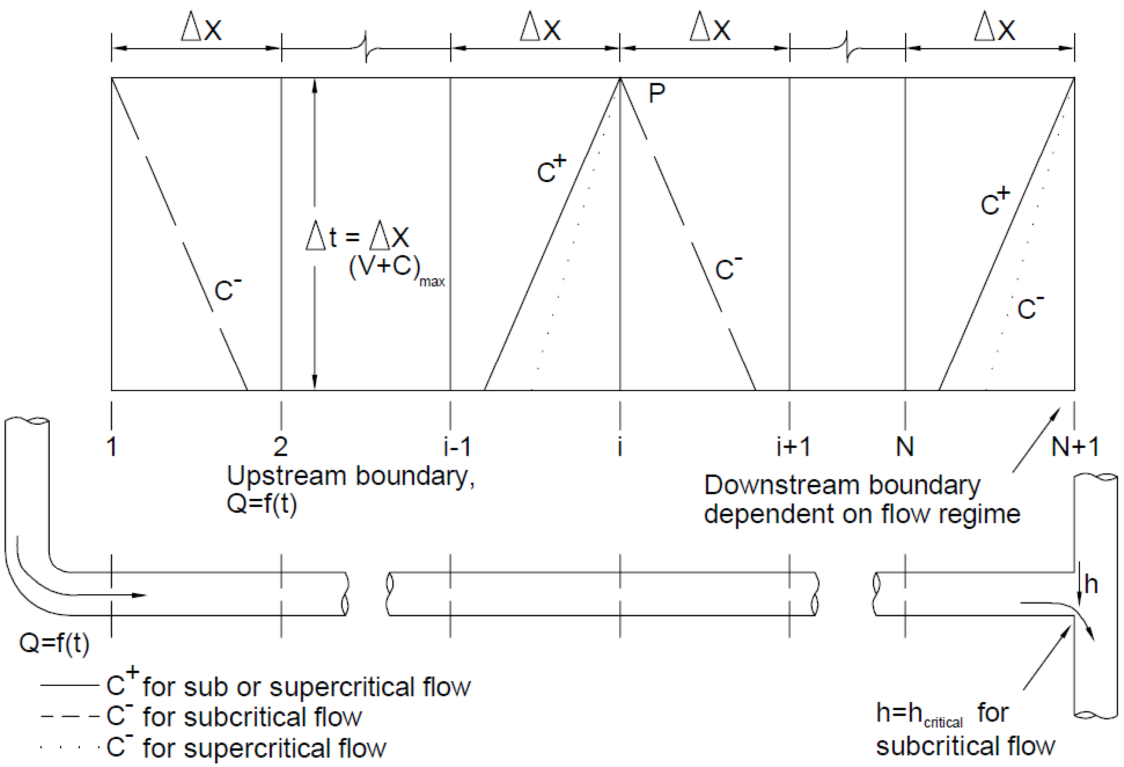
Flush Volume Reduction



Laboratory investigations

- Attenuating flows
- Adjoining flows
- Junction effects
- Hydraulic Jump
- Non-woven products (wipes) transport
- Single solid transport
- Multiple solid transport
- Large solids/ partial blockages

Method of Characteristics Modelling



$$A\frac{\partial V}{\partial x} + VT\frac{\partial h}{\partial x} + T\frac{\partial h}{\partial t} = 0$$

$$g\frac{\partial h}{\partial x} + g(S - S_o) + V\frac{\partial V}{\partial x} + \frac{\partial V}{\partial t} = 0$$

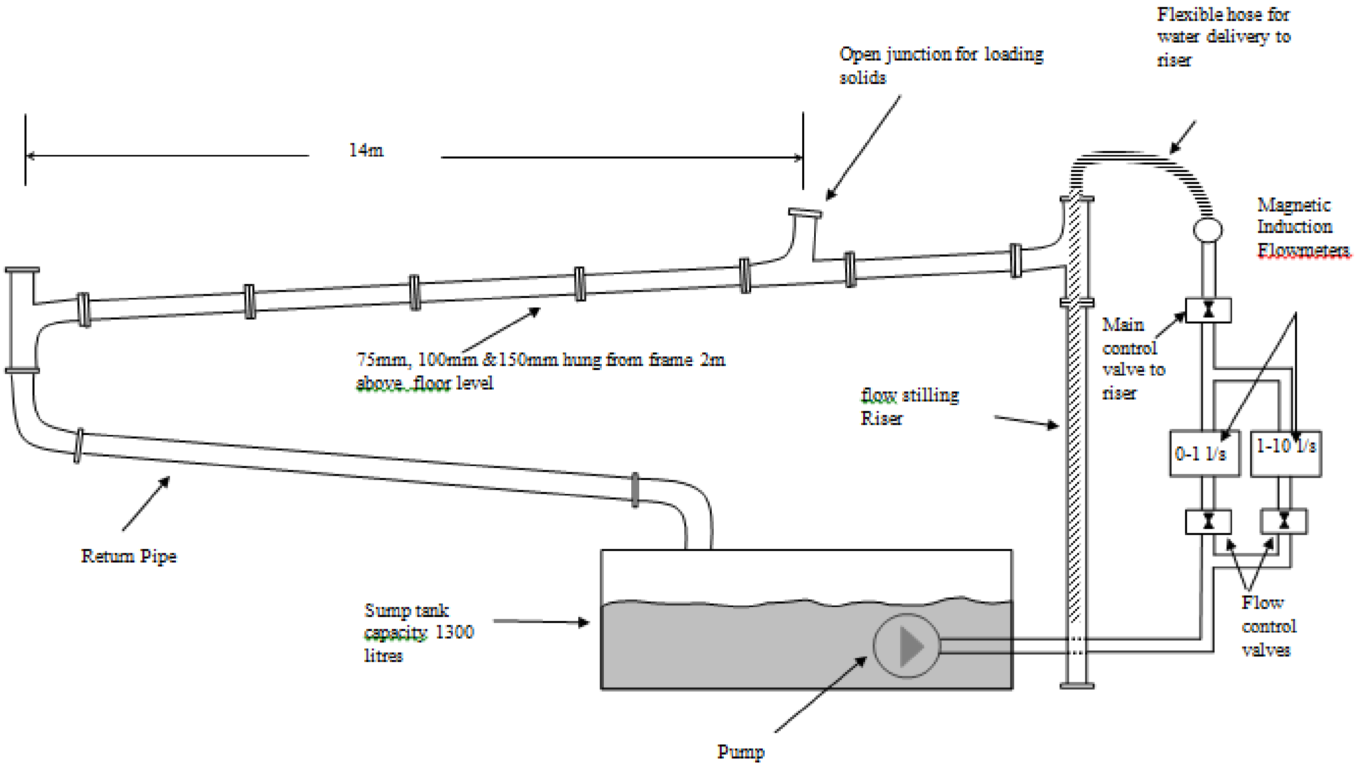
Mathematical basis – Solution of the St. Venant Equations of continuity and momentum

$$\frac{dV}{dt} \pm \frac{g}{c}\frac{dh}{dt} + g(S - S_o) = 0$$

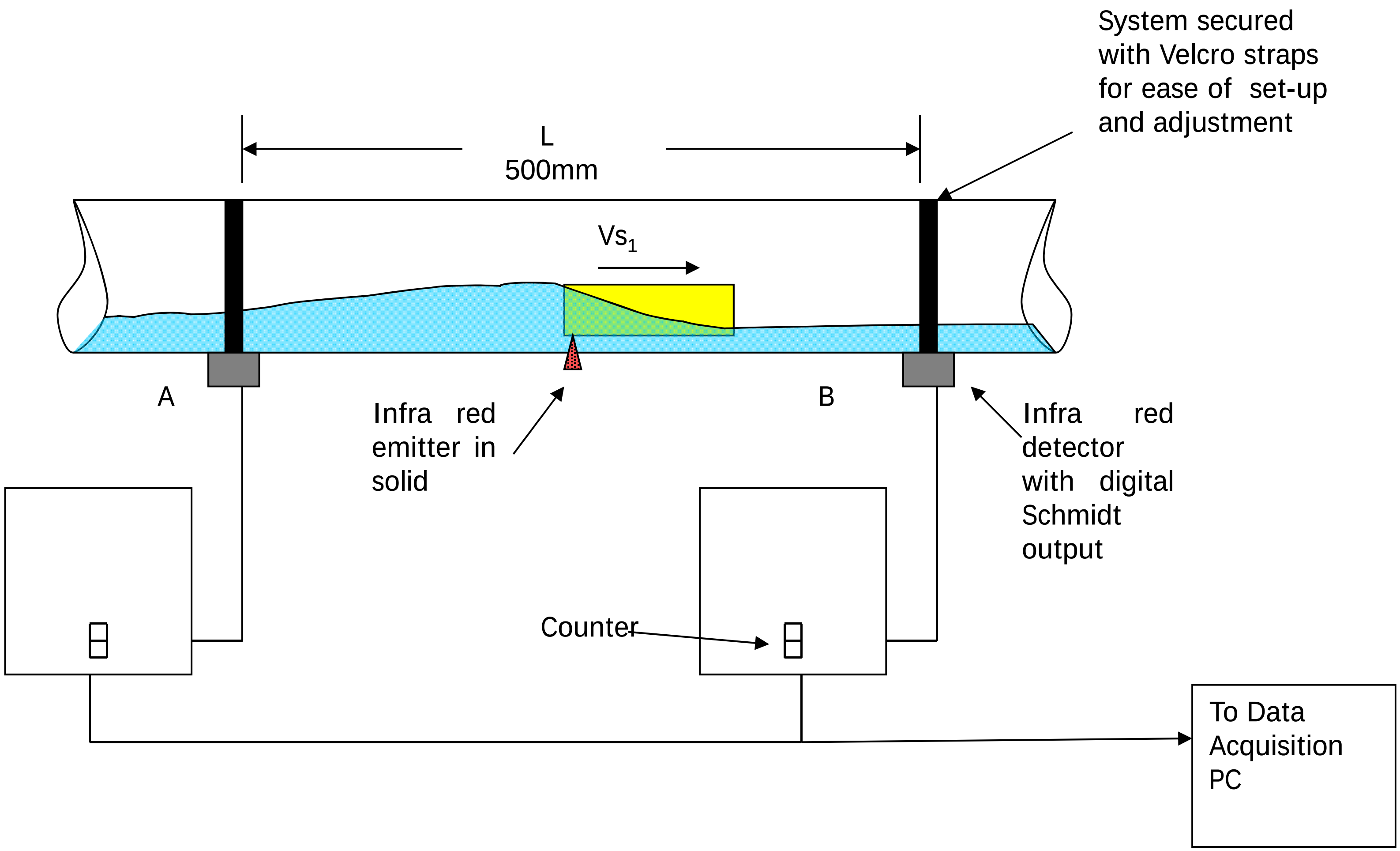
Provided that;

$$\frac{dx}{dt} = V \pm c$$

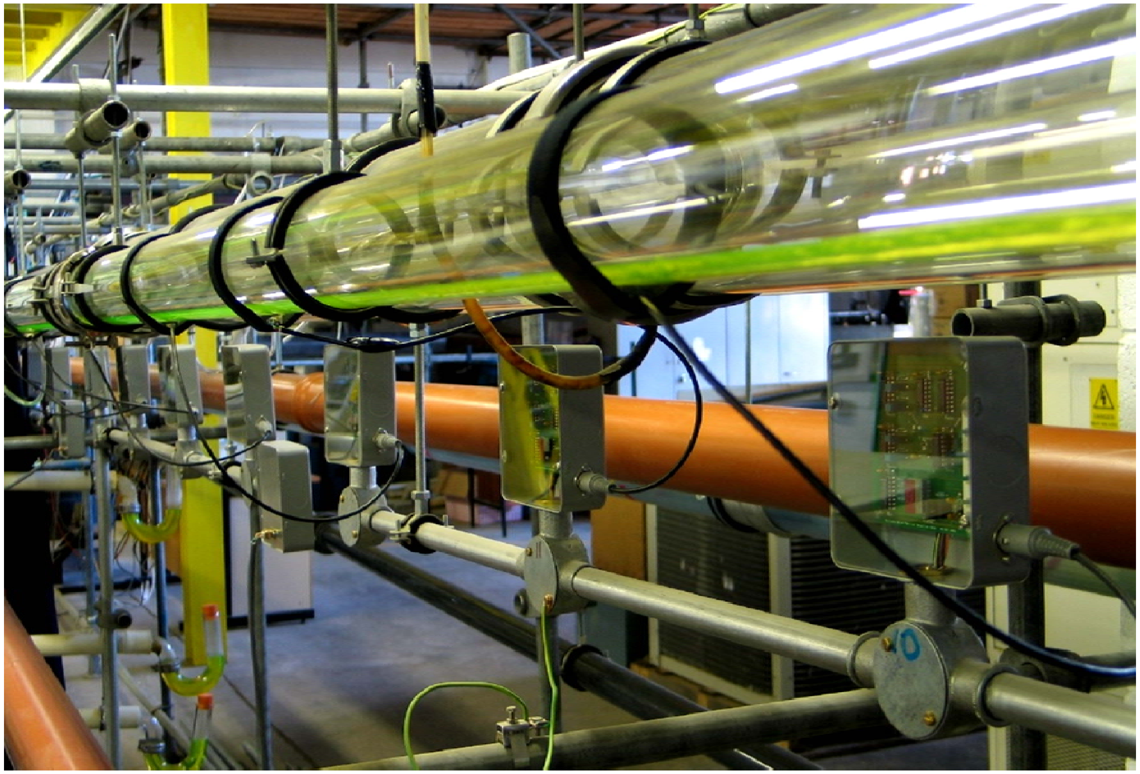
Laboratory test rig



Solid Position Measuring system



Laboratory set-up



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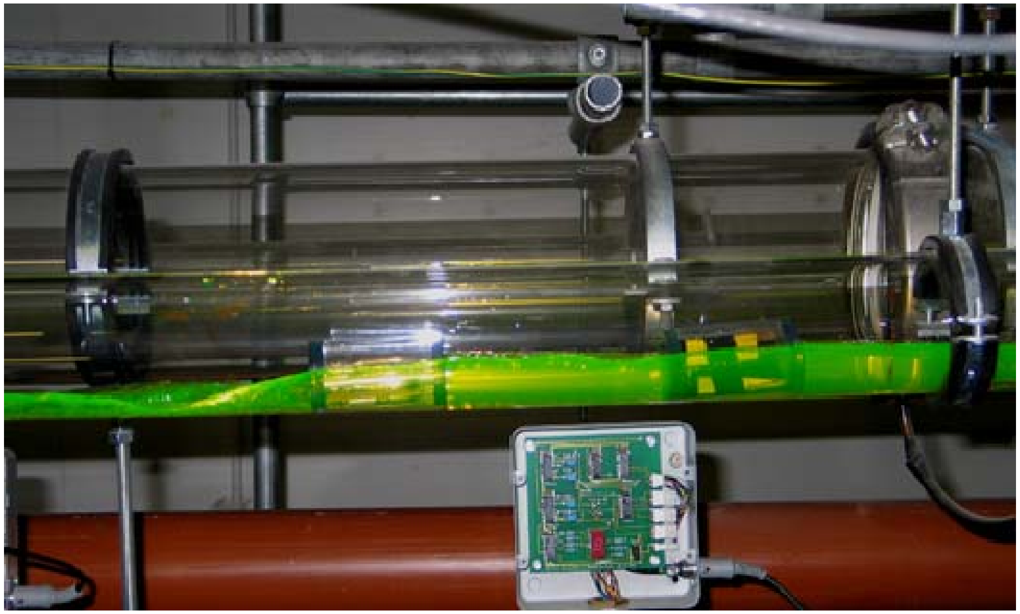
Solids used in laboratory

Solid in a steady flow

Multiple Solids in a steady flow

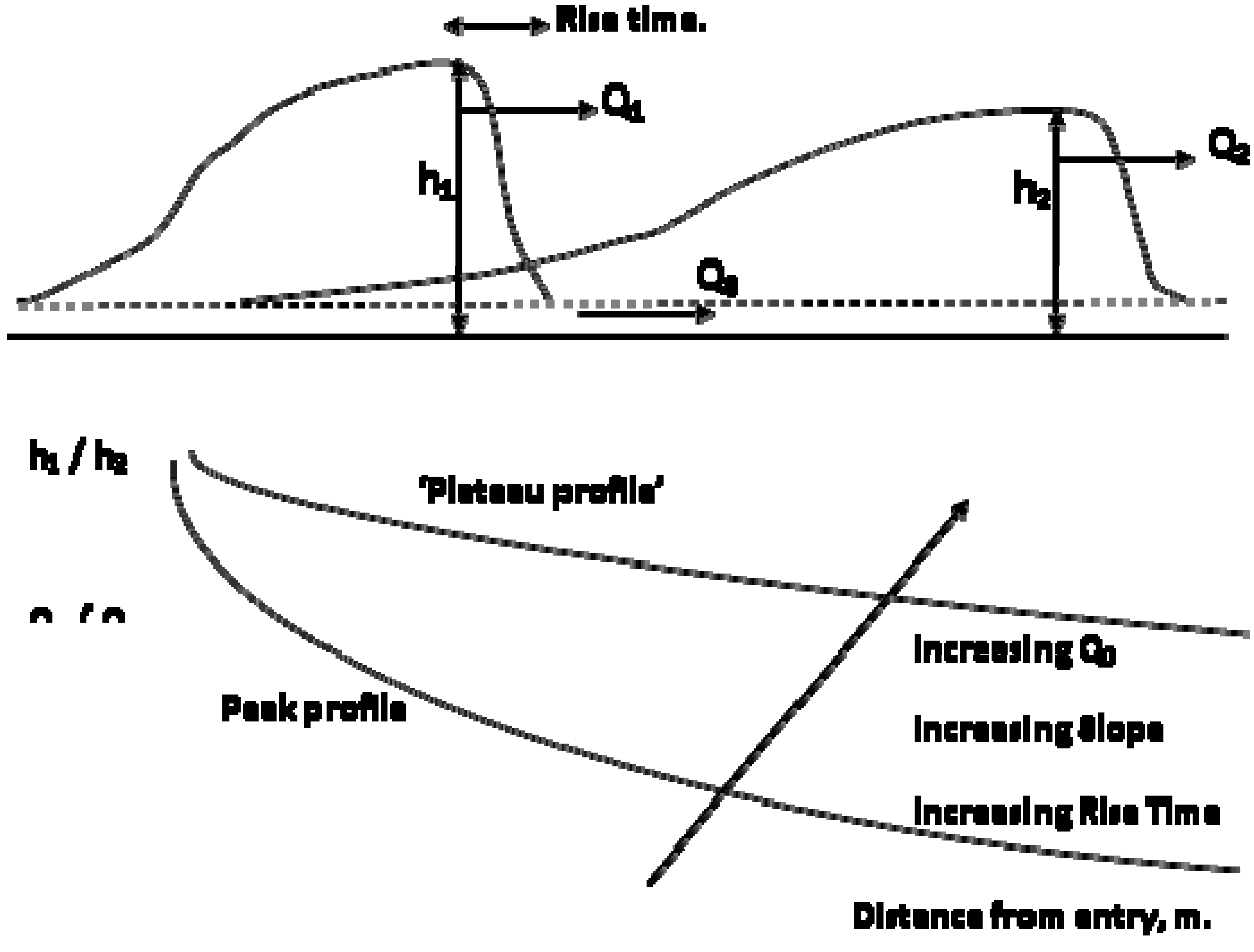


Solids used for modelling large accumulations or partial blockages

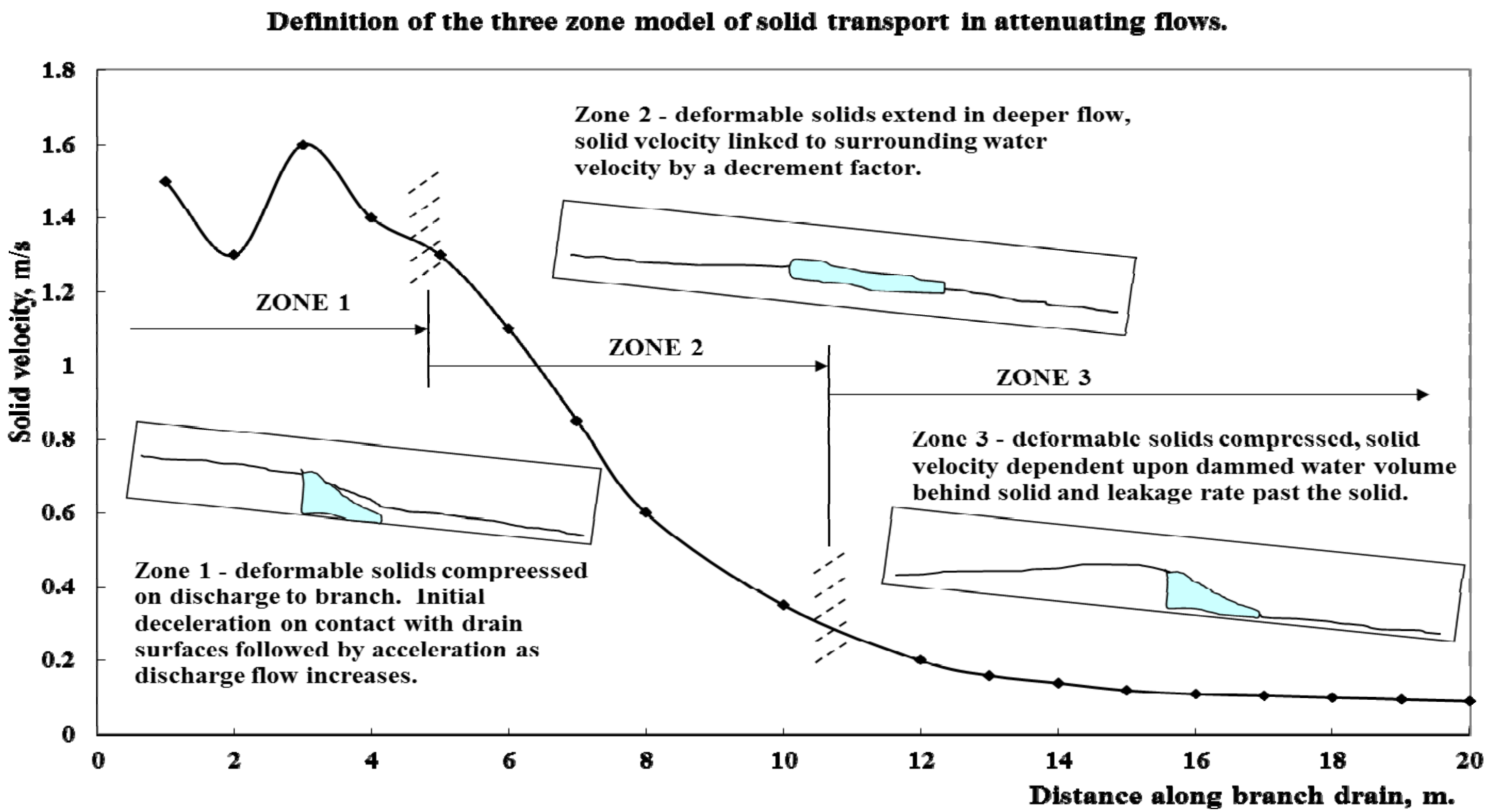
Large Accumulated Solids

Partial blockage : leak past

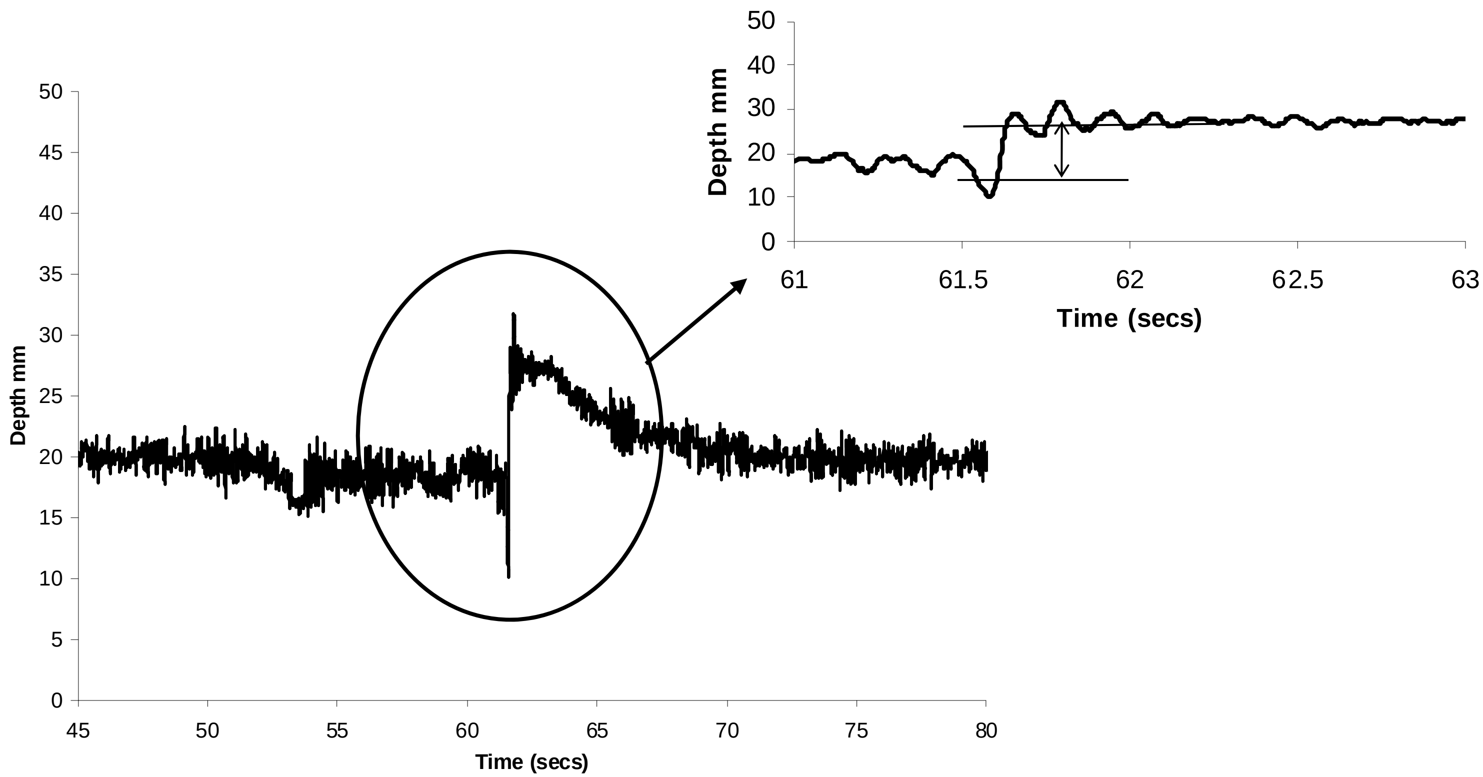
Mathematical modelling : Attenuation dependencies



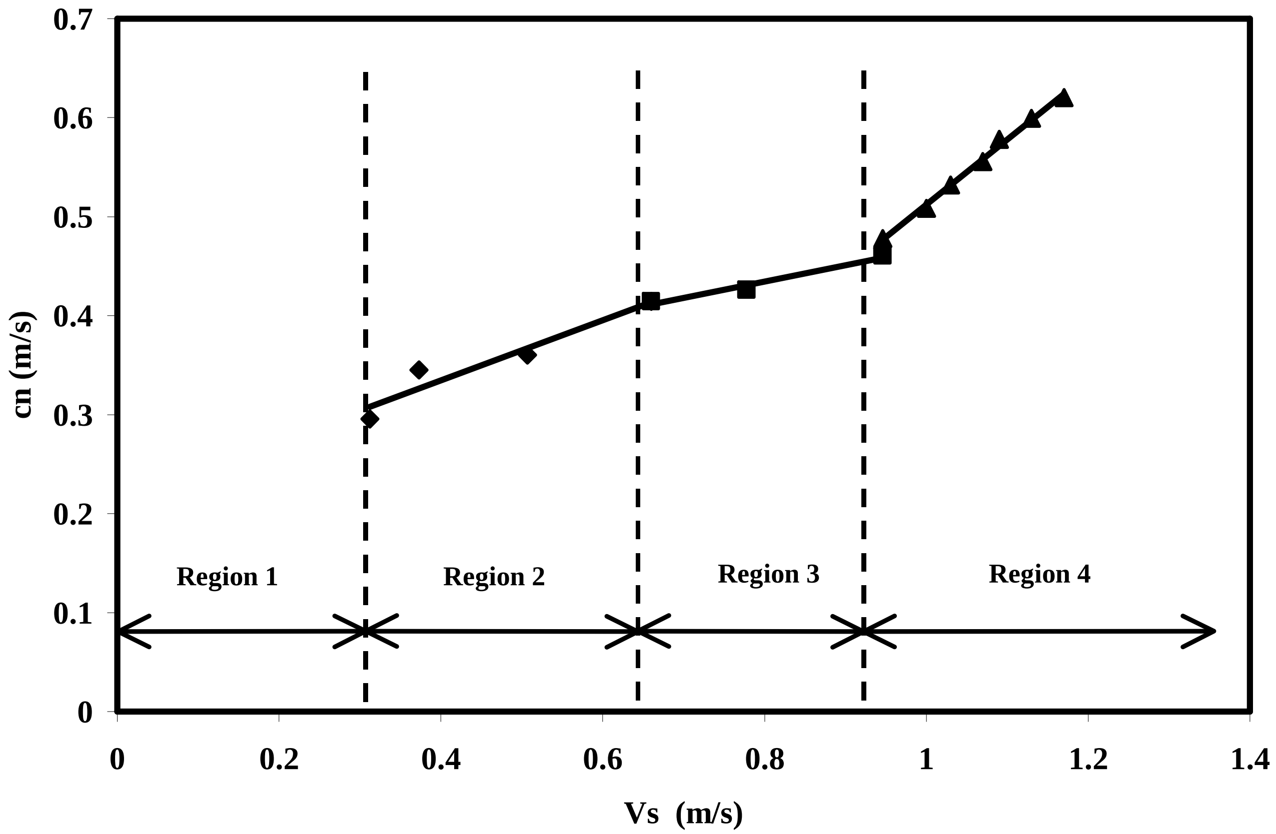
Mathematical modelling: Velocity decrement Zones



Mathematical modelling: Solid characteristics in a flow

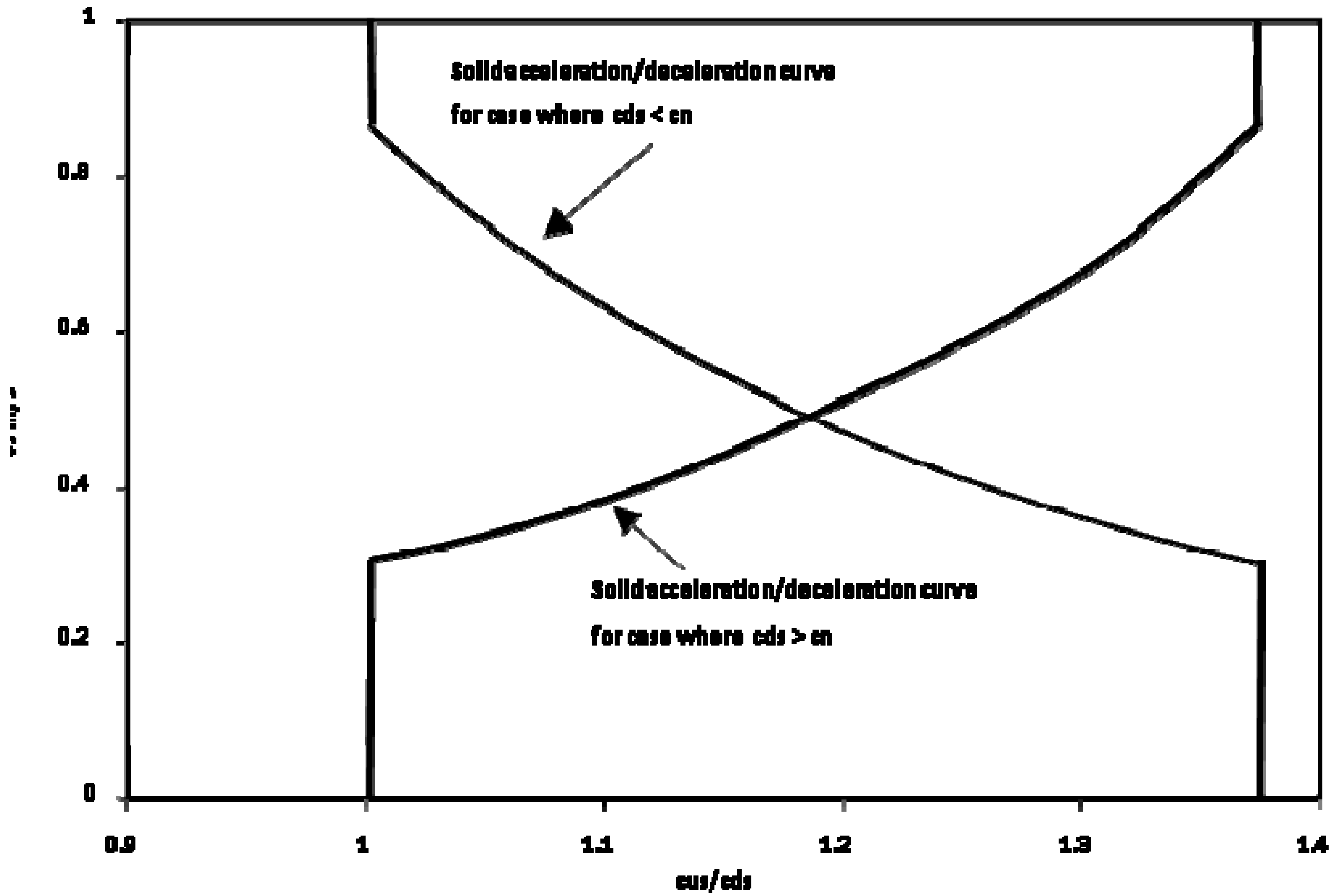


Mathematical modelling: Mach model

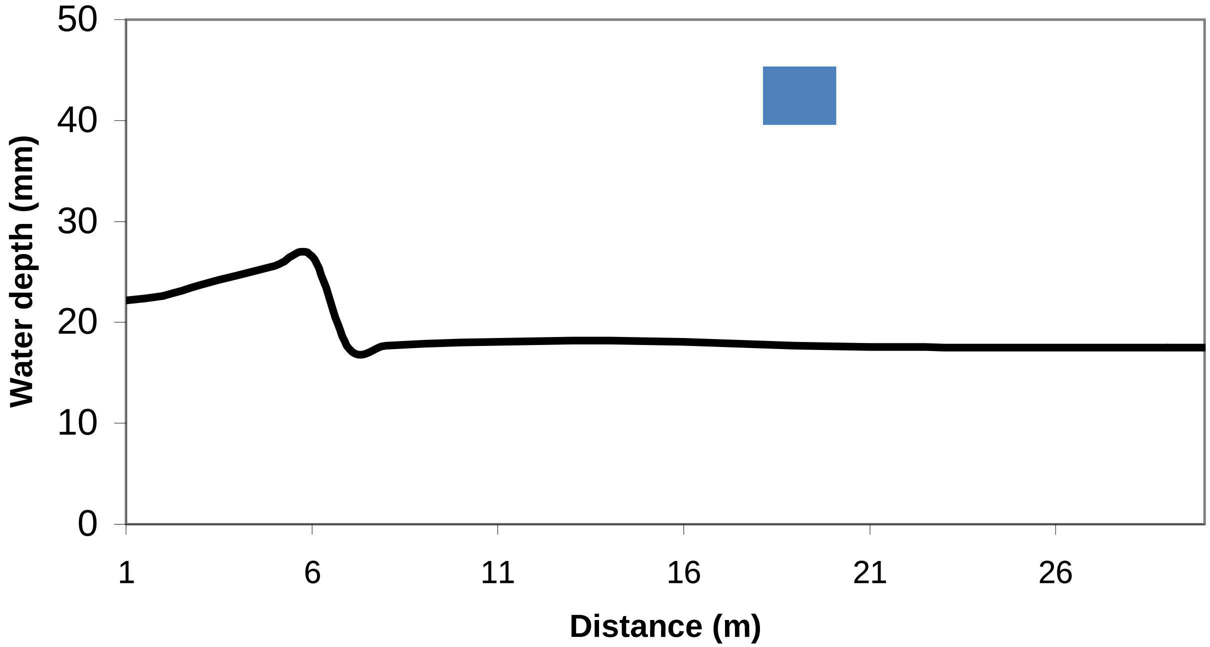


Solid Velocity against normal depth wavespeed

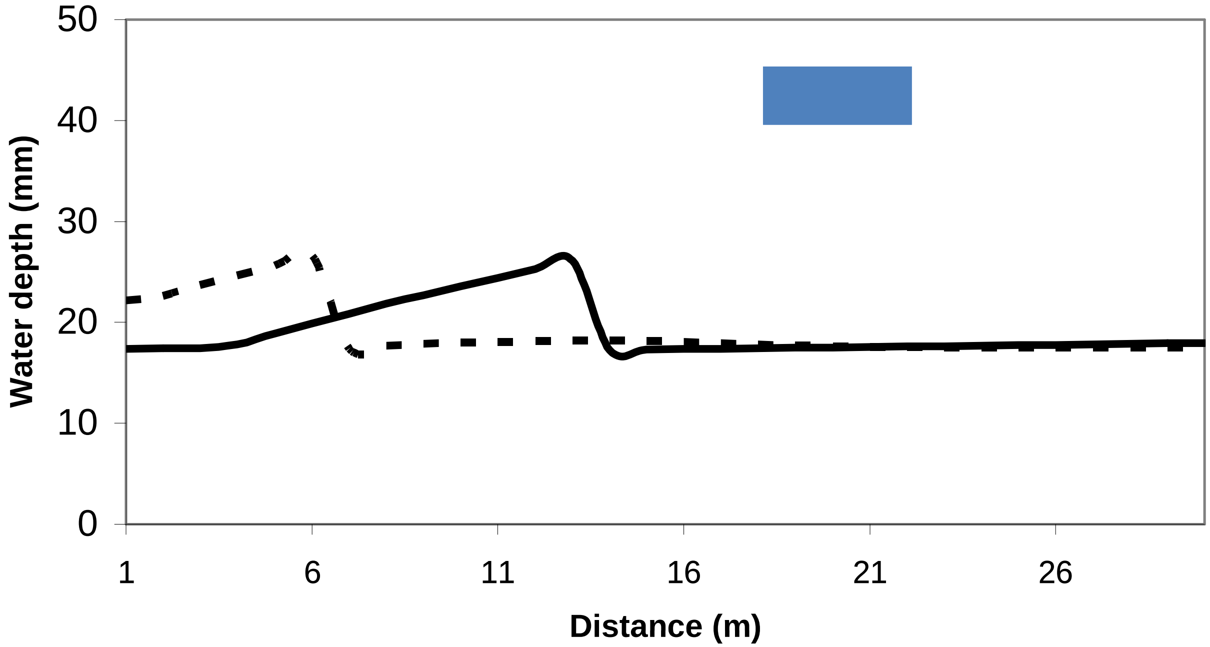
Mach model for interacting solids



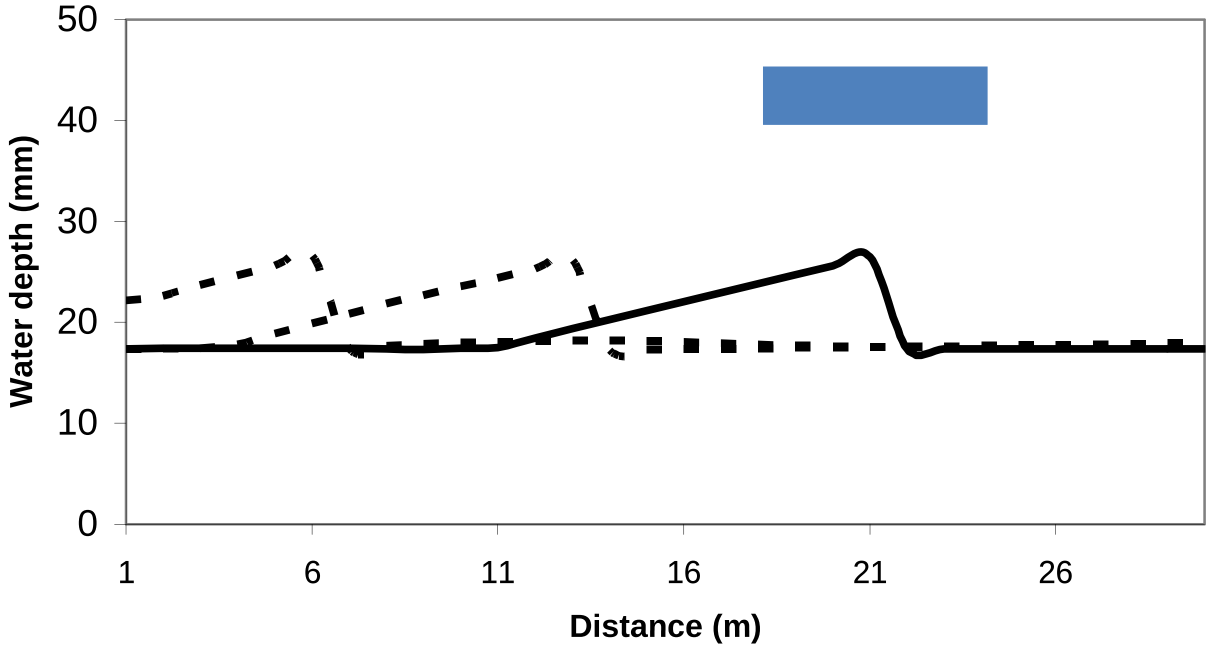
Model outputs: Depth profile due to presence of solid



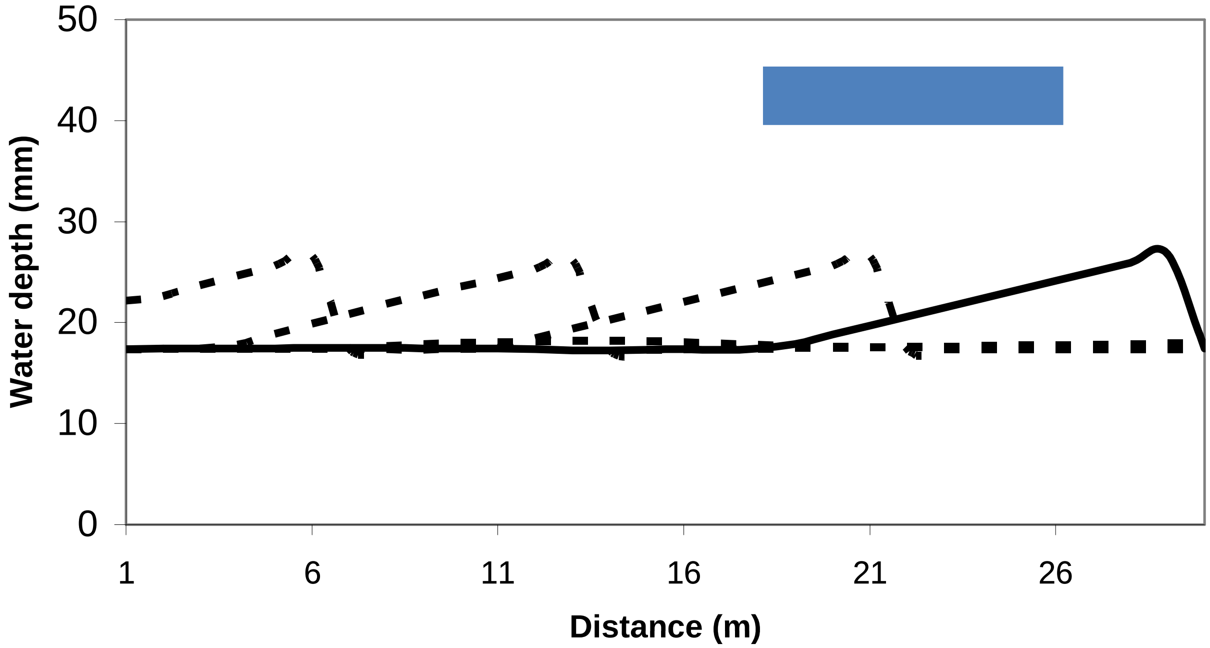
Model outputs: Depth profile due to presence of solid



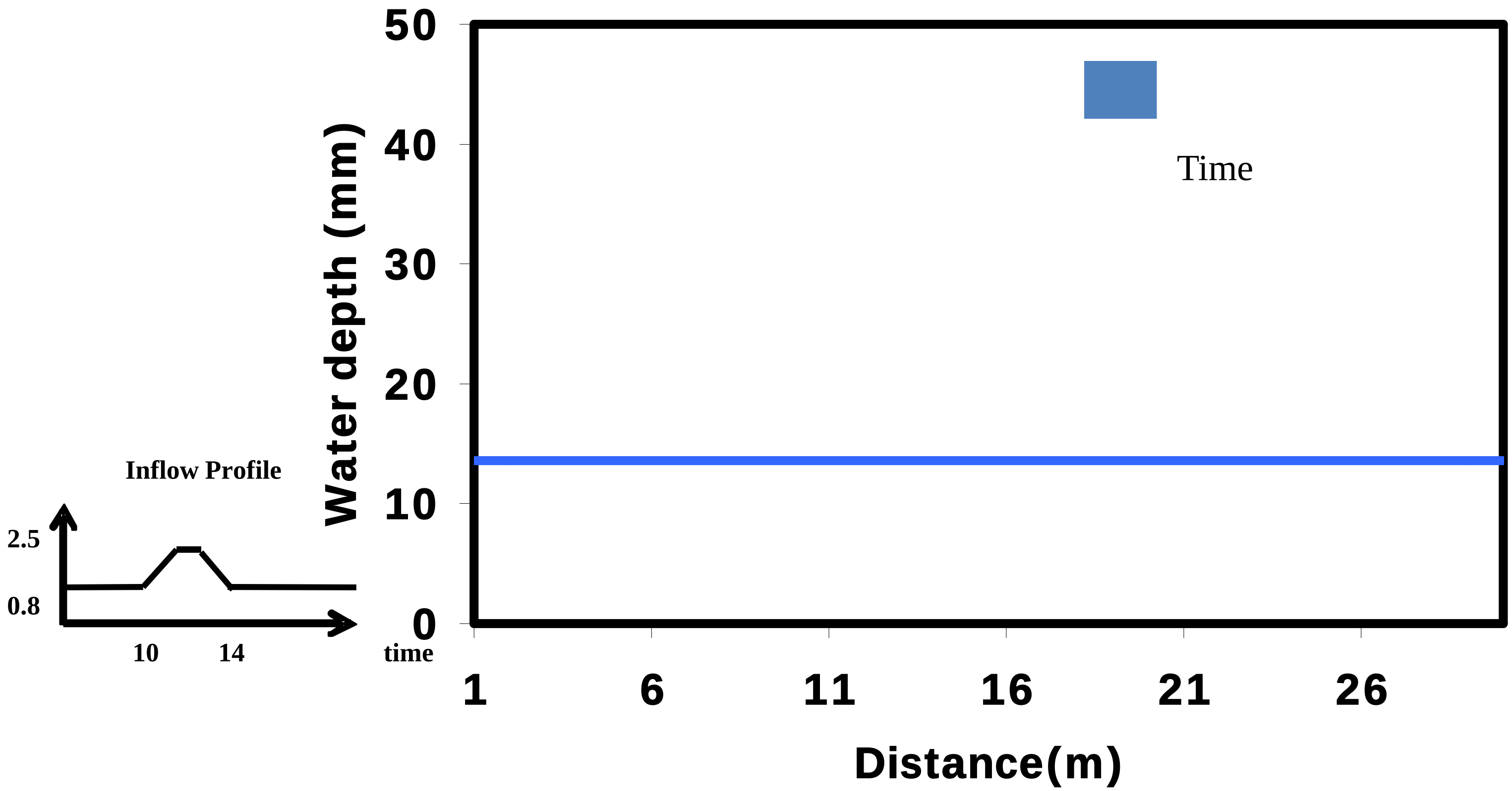
Model outputs: Depth profile due to presence of solid



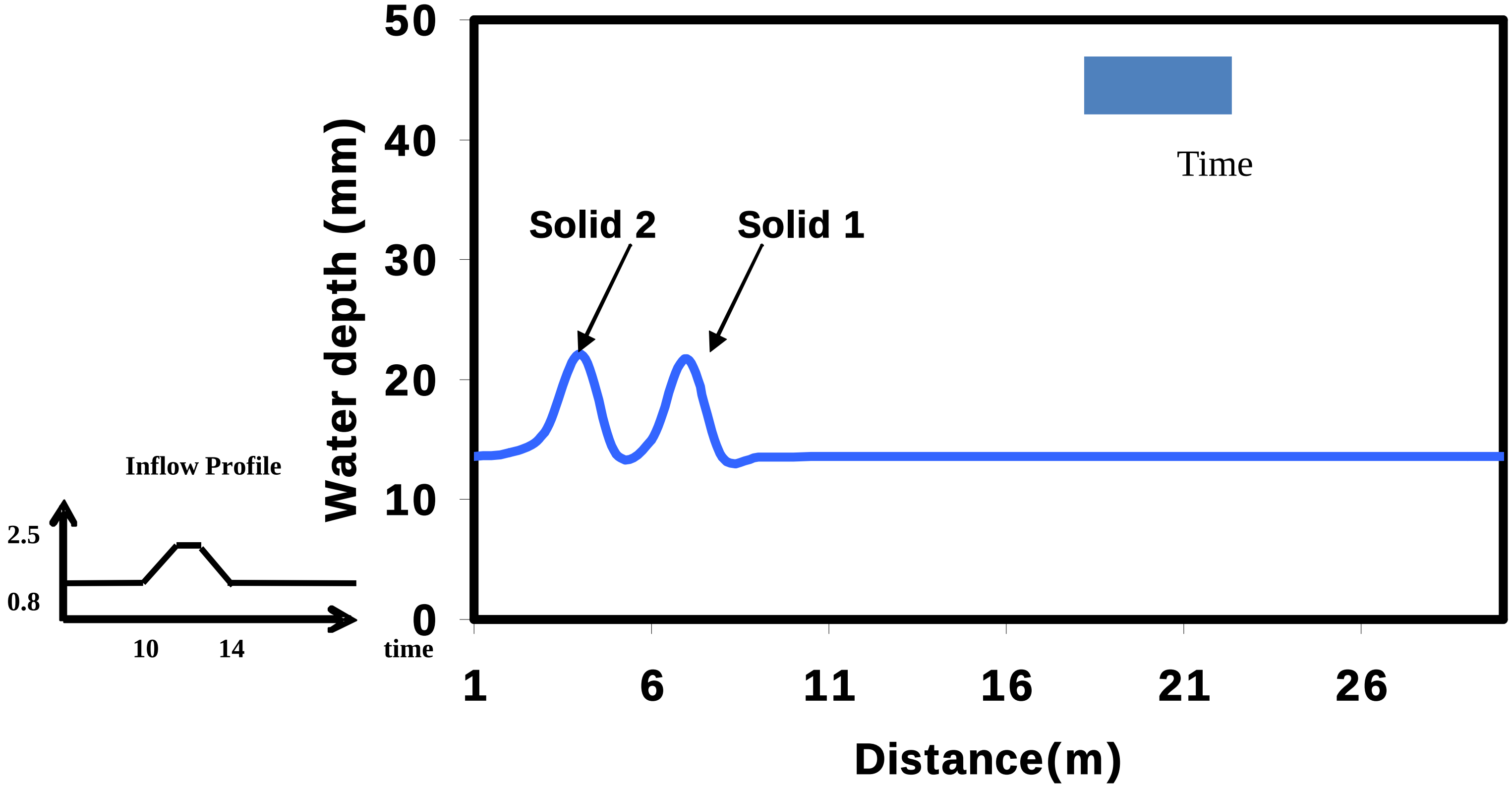
Model outputs: Depth profile due to presence of solid



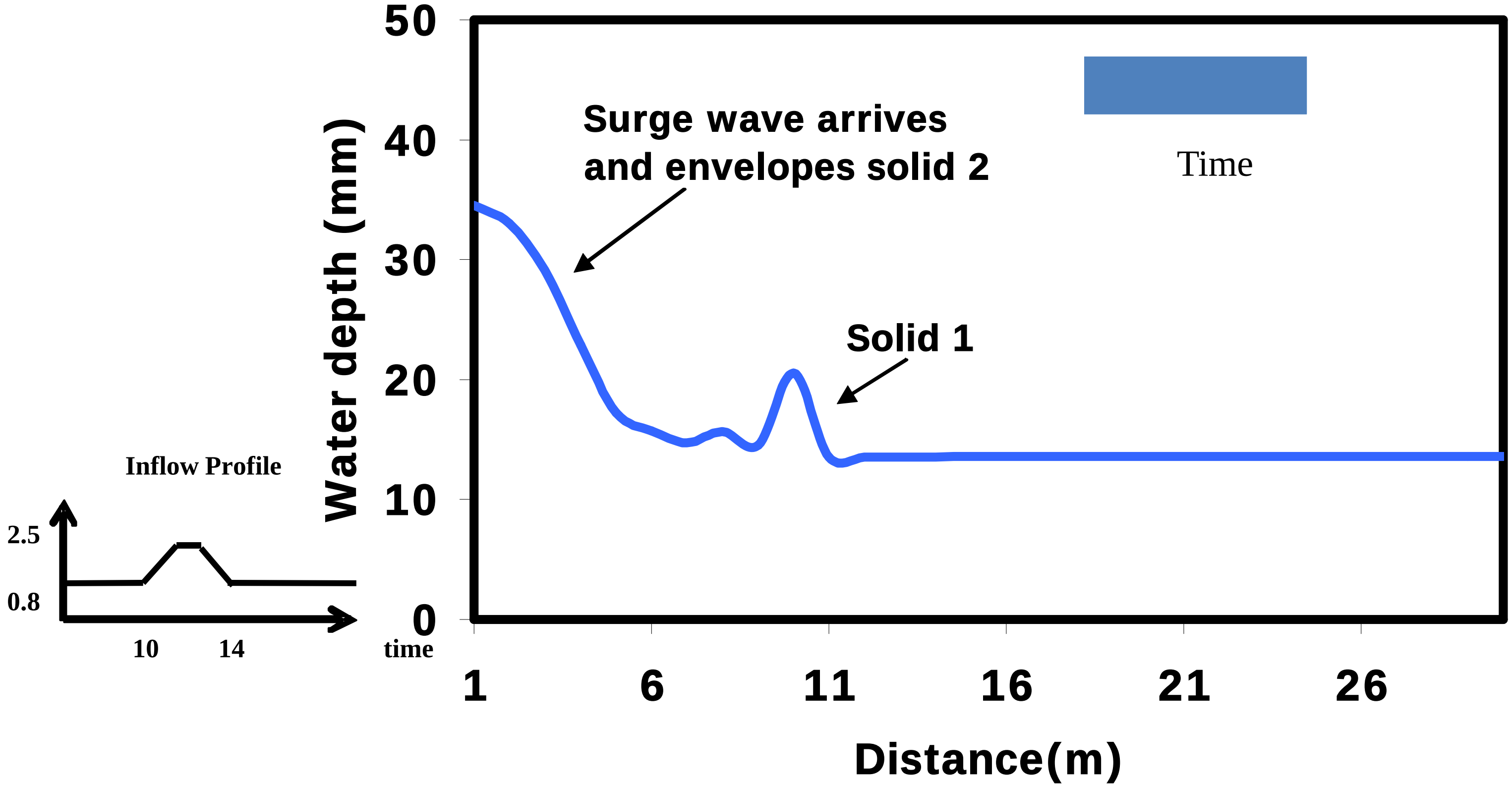
Model Outputs: Depth profile for interacting solids



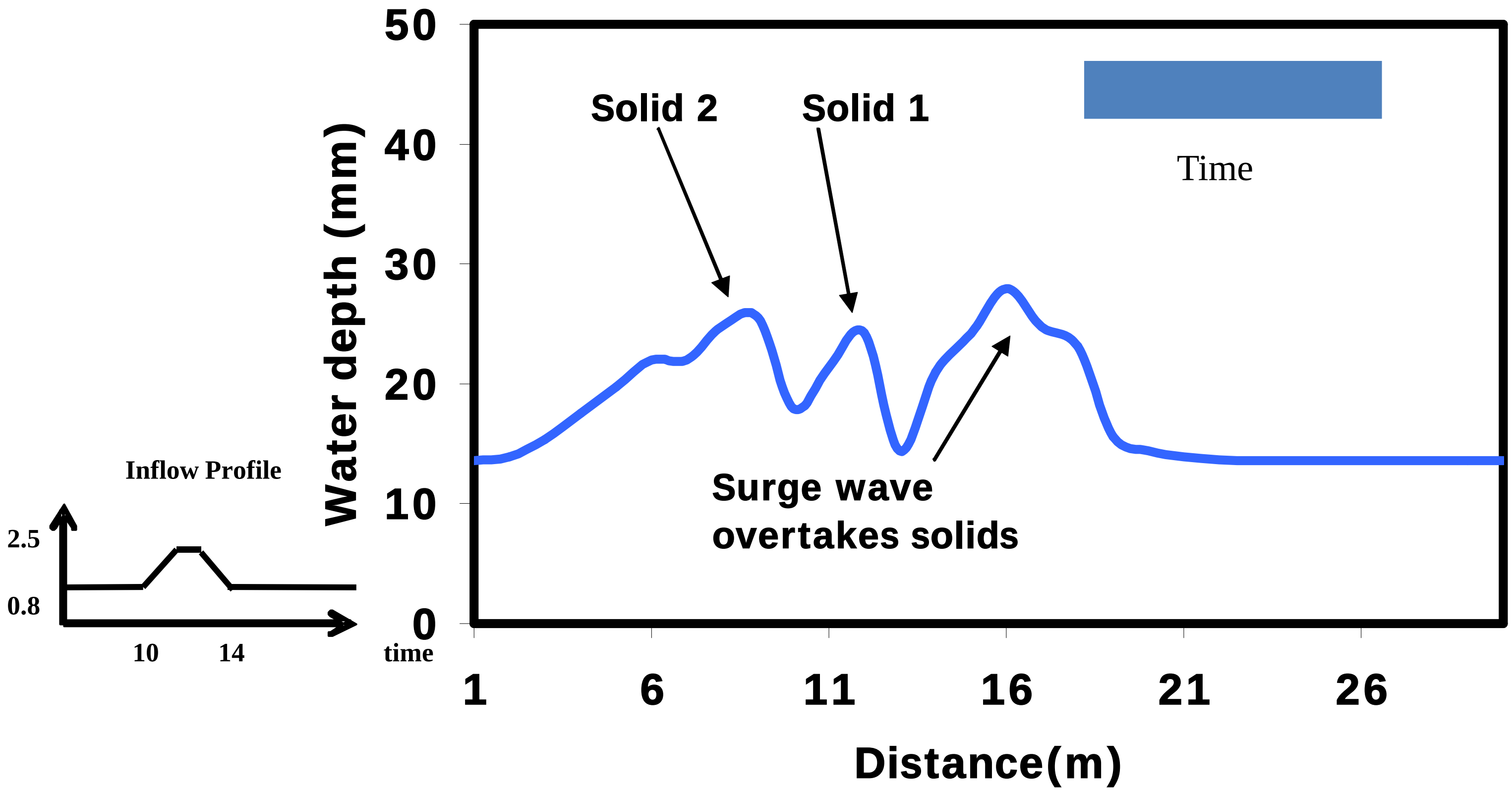
Model Outputs: Depth profile for interacting solids



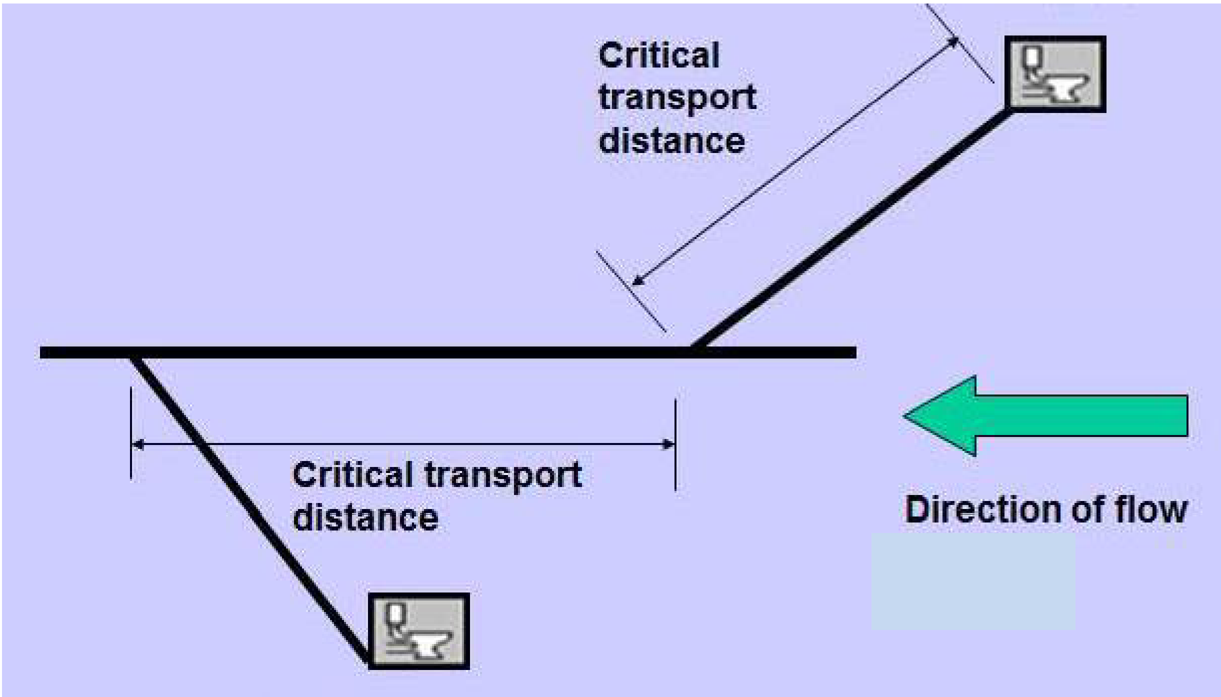
Model Outputs: Depth profile for interacting solids



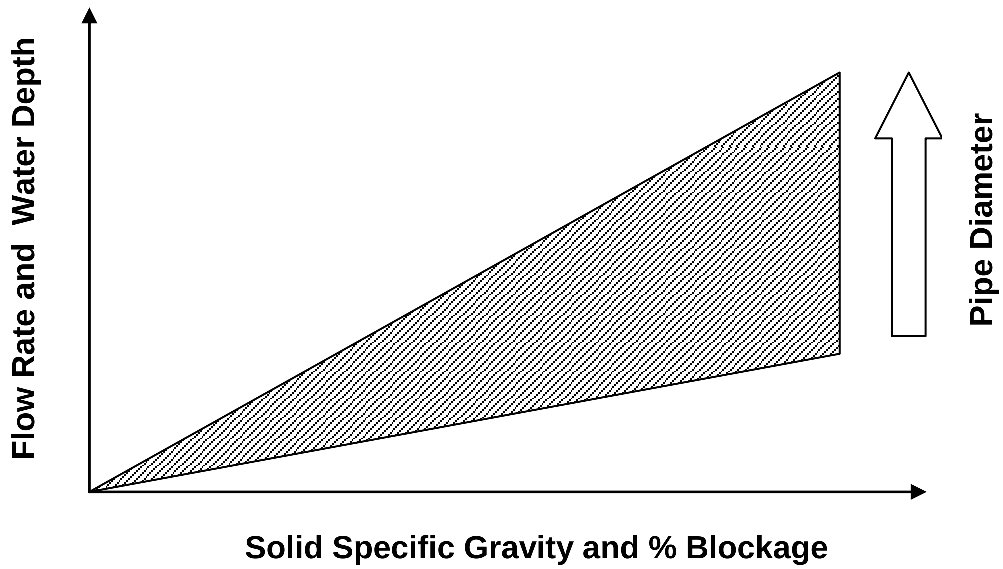
Model Outputs: Depth profile for interacting solids



Critical Distances



Conceptual model for large accumulated solids in long pipe runs (no adjoining flows)

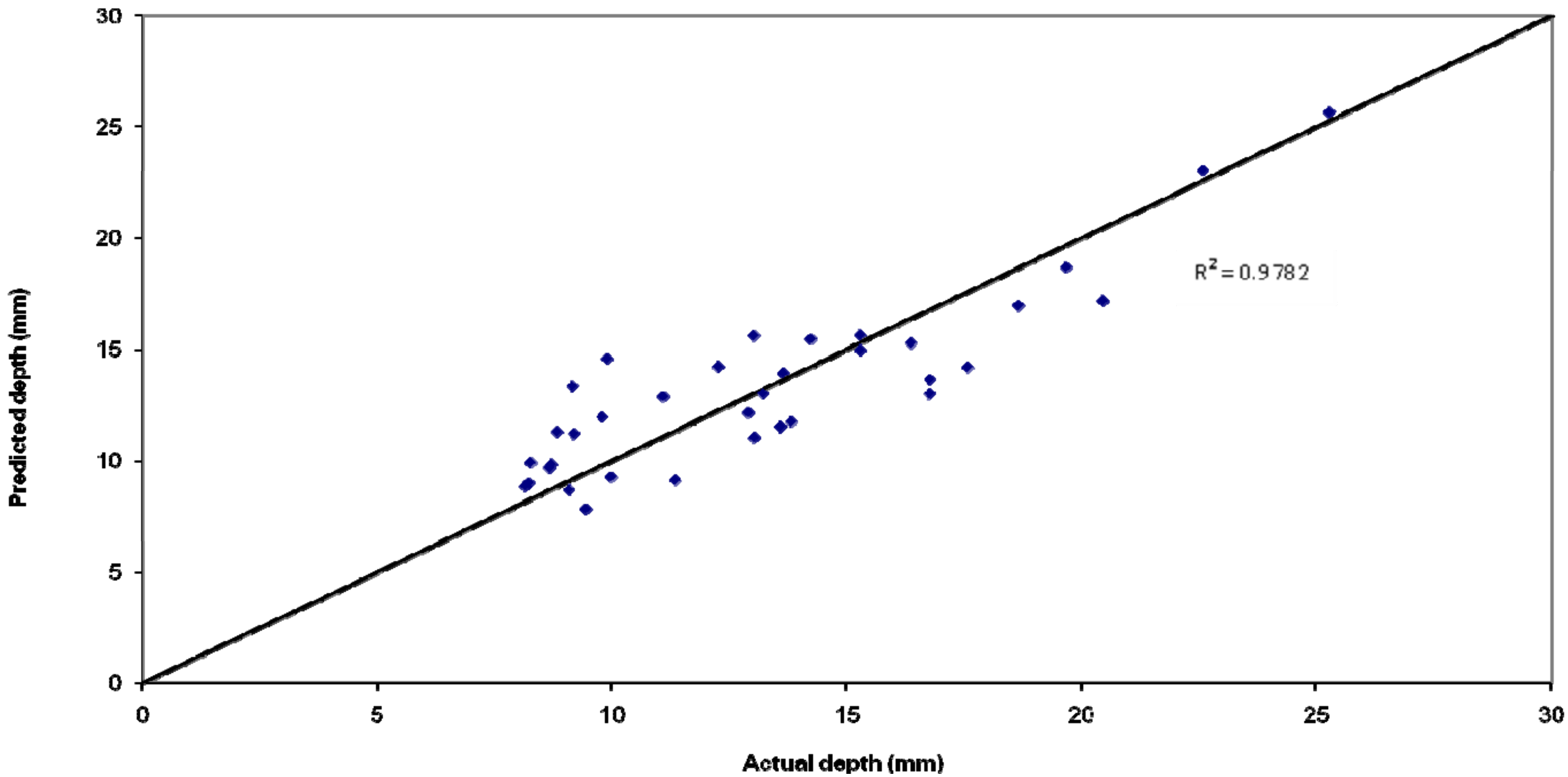


Solid movement threshold

$$H_n = \left(\left(2.643\,x\,10^{-7} * B^{0.78} - 9.064x10^{-8}\right) * D^{3.784} + 8.384\right) * S + 4.72$$

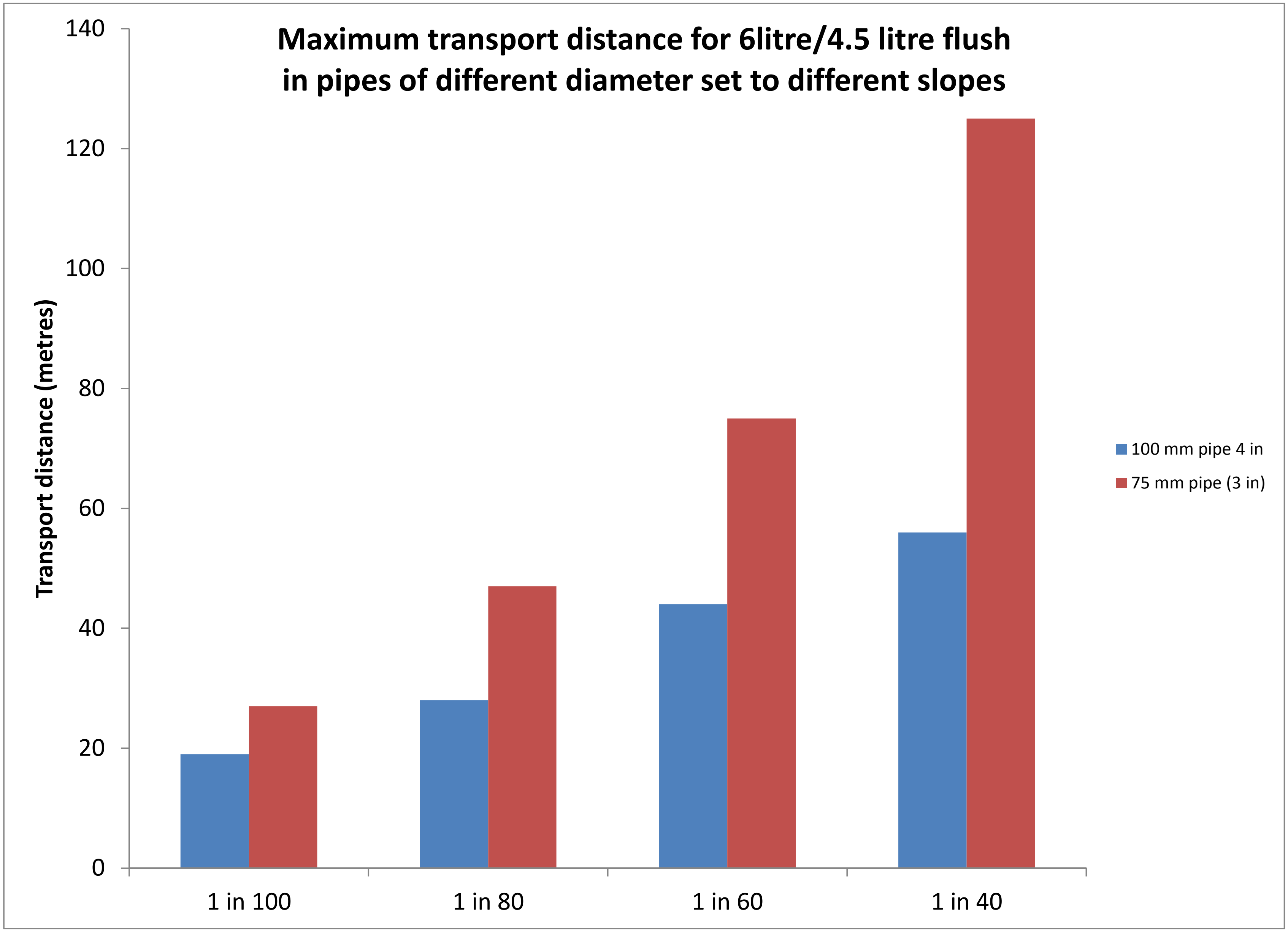
Where
Hn = normal water depth
B = % blockage
D = Pipe Diameter
S = Specific gravity

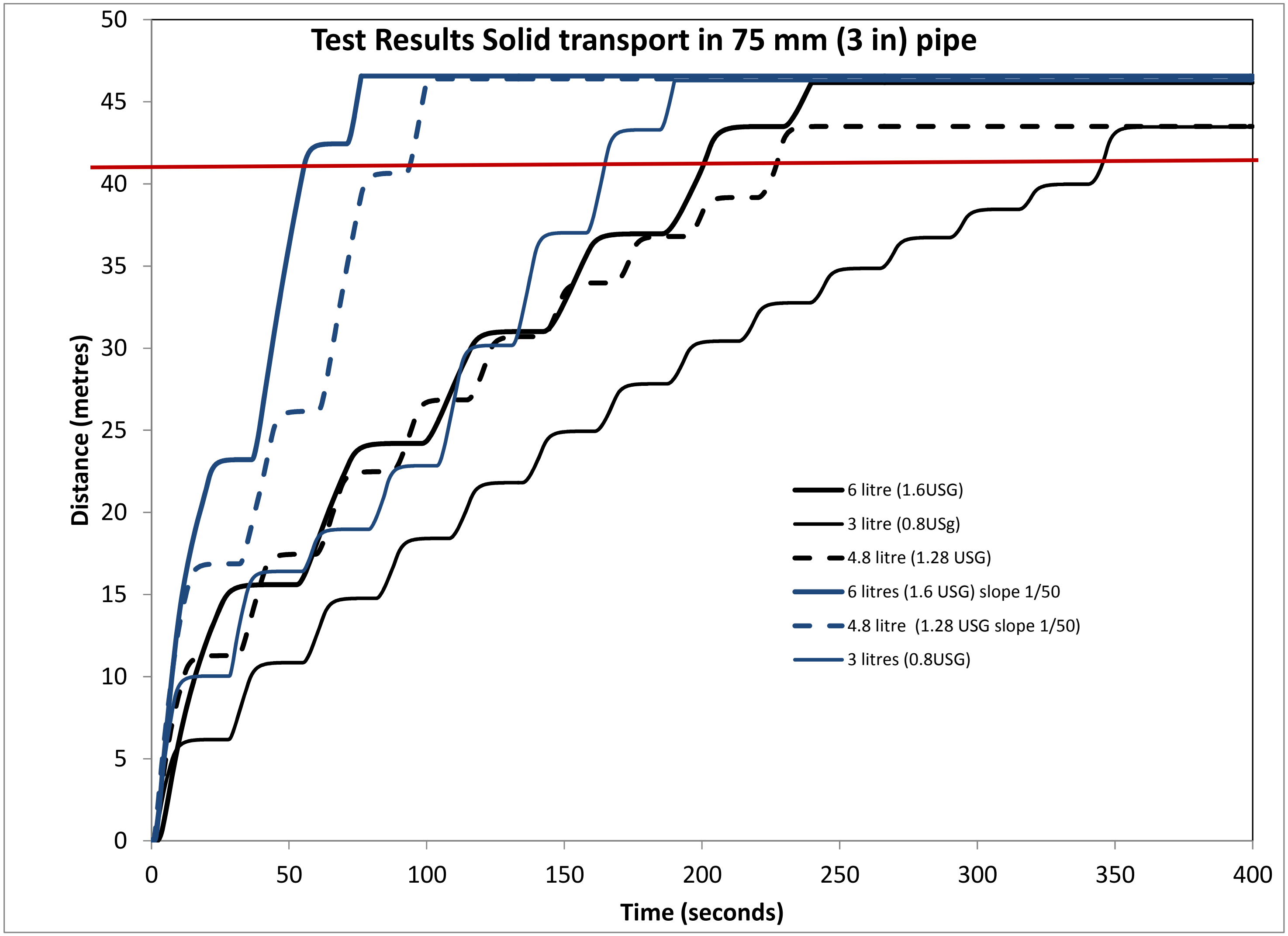
Validation of model for large accumulated solids

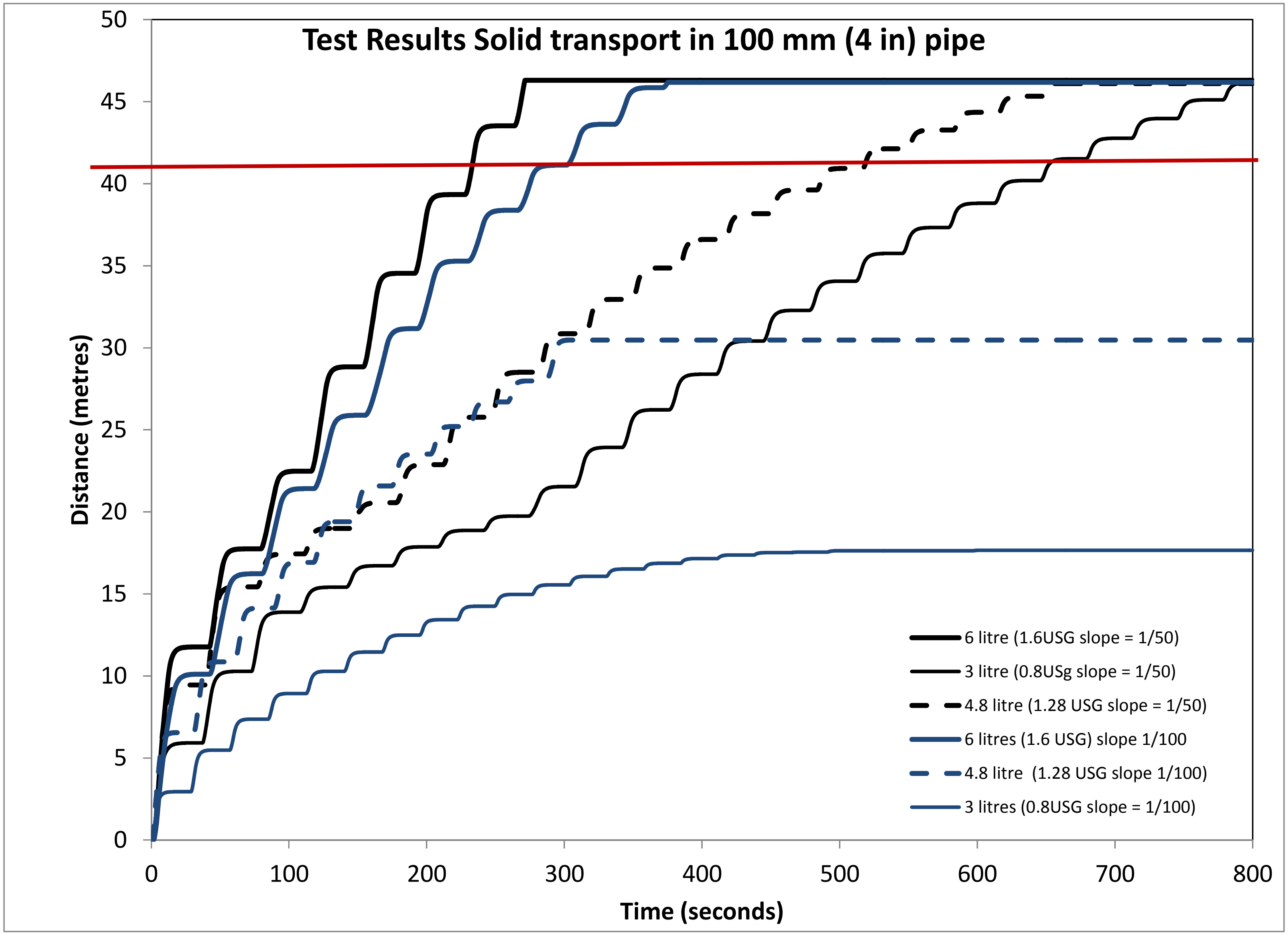


Example: 41 m test rig

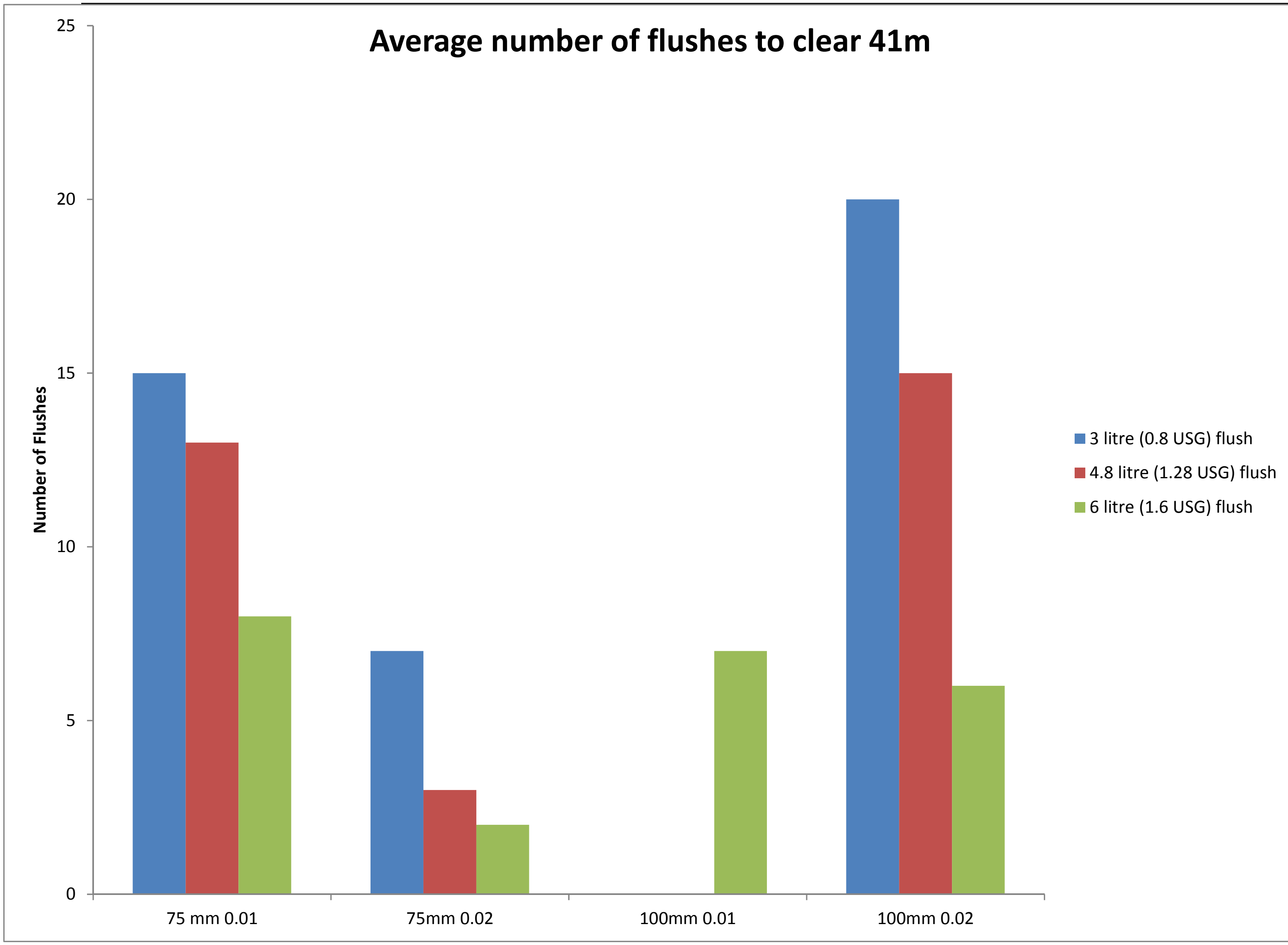
41 m (135 ft) test rig in 3 m (10ft) lengths with swept bends


Maximum transport distance for 6litre/4.5 litre flush
in pipes of different diameter set to different slopes
Transport distance (metres)
0
20
40
60
80
100
120
140
1 in 100
1 in 80
1 in 60
1 in 40
100 mm pipe 4 in
75 mm pipe (3 in)


Test Results Solid transport in 75 mm (3 in) pipe
Distance (metres)
Time (seconds)
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300
350
400
6 litre (1.6USG)
3 litre (0.8USg)
4.8 litre (1.28 USG)
6 litres (1.6 USG) slope 1/50
4.8 litre (1.28 USG slope 1/50)
3 litres (0.8USG)



Test Results Solid transport in 100 mm (4 in) pipe
Distance (metres)
Time (seconds)
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
700
800
6 litre (1.6USG slope = 1/50)
3 litre (0.8USg slope = 1/50)
4.8 litre (1.28 USG slope = 1/50)
6 litres (1.6 USG) slope 1/100
4.8 litre (1.28 USG slope 1/100)
3 litres (0.8USG slope = 1/100)


Average number of flushes to clear 41m
Number of Flushes
25
20
15
10
5
0
75 mm 0.01
75mm 0.02
100mm 0.01
100mm 0.02
3 litre (0.8 USG) flush
4.8 litre (1.28 USG) flush
6 litre (1.6 USG) flush

Conclusions

- Modelling solid transport is as important now as it's ever been
- Water conserving strategies must take solid transport into account, however a pragmatic approach is required.
- WC characteristics are important close to the point of discharge – less so, further down stream.

Conclusions continued

- Critical transport distances (distance to adjoining flows) are very important and cannot be ignored.
- There is a maximum distance solids can travel given a fixed set of system parameters – design codes should recognise this.
- Innovative methods are required to ensure systems are kept clear in a system without adjoining flows.

Thank you for listening