Dam Break Generated Flow Behaviour in Box Culverts

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Abstract: Urban areas have extensive networks of storm drains to enable large volumes of rain water to be quickly transported away from areas that may otherwise flood. Storm drains in coastal cities often end at the shore line and rain water is discharged immediately into the sea. Significant amounts sediments enter the storm drains with the rain water. In addition, raw sewage may enter storm drains through illegal discharges, misconnections or surface run off. The storm drain then provides a perfect environment for sulfate reducing bacteria (SRB) to survive. For coastal cities like Hong Kong where the land next to the coast is only a few meters above sea-level, the bottom of storm drains, or box culverts, can be below high tide level. Salt water flowing in and out gradually creates an anaerobic environment in which the SRB generate hydrogen sulfide (H2S) as a metabolism product. The hydrogen sulfide escapes the culvert causing a nuisance smell for the local people, especially during the summer time.

Granular ferric hydroxide particles (GFH) are iron-based particles that are introduced into the box culvert to solve the odor emission problem. By utilizing the oxidability of ferric hydroxide, the odorous H2S can be oxidized to odorless substances. After the particles are exhausted they can be re-oxidized to their original status by reacting with small amount of oxygen from the tidal flow. However, due to the continuous accumulating of sediments in the culvert dissolved oxygen in the seawater has little chance to react with the particles. The current study investigate the feasibility of utilizing the natural energy and turbulence of a dam break generated flow to mix the exhausted particles, sediments and the oxygen to assist in the regeneration process. The dam break generated flow is created by installing a gate-mechanism at the end of the box culvert that is closed during low tide and rapidly opened during high-tide.

A detailed experimental investigation is carried out in the laboratory to investigate the hydrodynamics of the dam-break generated flow in a box culvert and the subsequent sediment transport, mixing of sediments and GFH and the regeneration of GFH. A medium scale model of a box culvert, fronted by a gate that can be lifted rapidly and attached to a relatively large reservoir, is installed in the towing tank. Two high speed cameras are used to obtain measurements of flow depth and wave propagation with and without sediments in the culvert and to record the suspension and transportation of sediments and GFH particles. Preliminary analysis of the results shows that the turbulent flow generated by the dam break is capable of suspending and mixing the sediments and GFH and has the ability to enhance the amount of GFH regenerated for some distance along the box culvert.

Dam break generated flow behavior in box culverts

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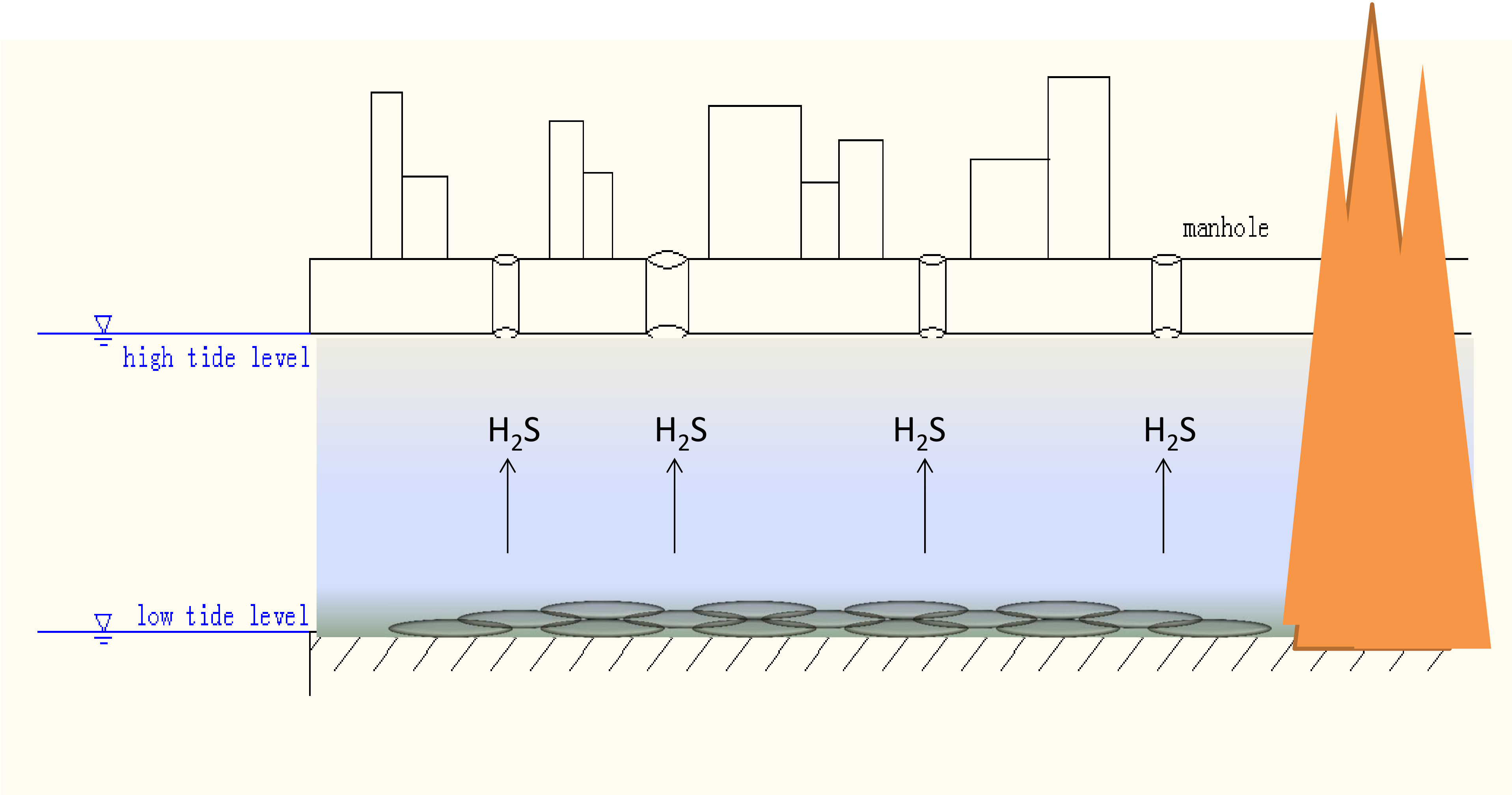
Outline

- Background of the project
- Scaled-down physical simulator
- Hydrodynamics experiments of dam-break processes
- Dam-break experiments with sediments sample
- Comparison of the results
- Future work

Background



Background

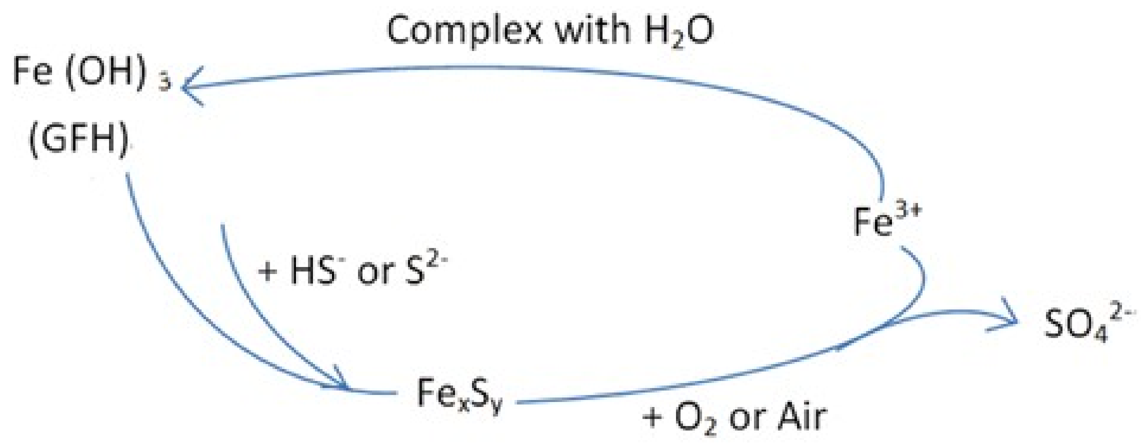


Figure 1. Cycle of ferric hydroxide reacts with sulfide

Scaled-down box-culvert model

Dimension: 660cm(L)*30cm(W)*35cm(cm)
Slope: 1:20

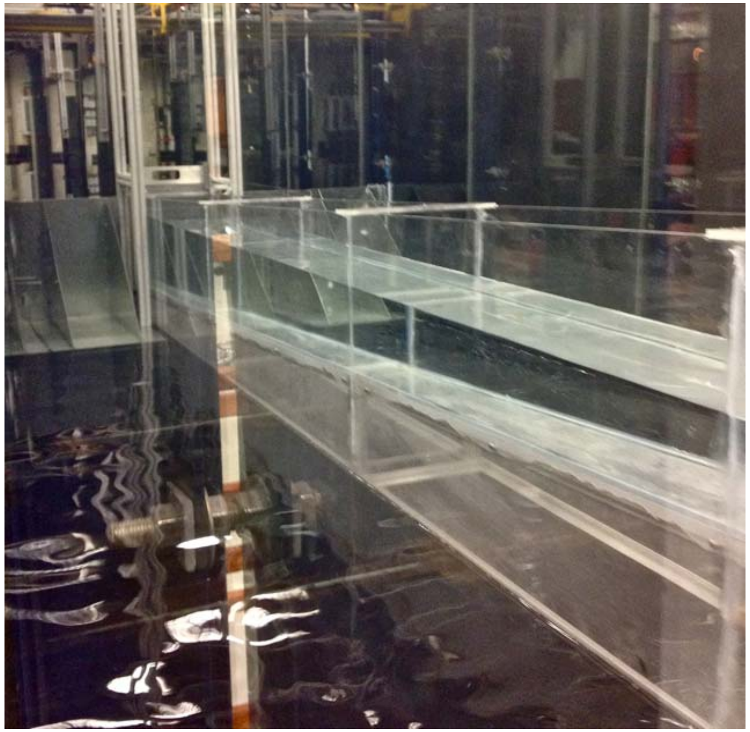


Figure 2. Box culvert--- Side view

Figure 3. Box culvert--- Top view

Parameterization of sediments

Figure 4. Real sediments sample from Tsuen Wan box-culvert near exit

- Typical grain size (d_{50}) is ranging from **0.77mm** to **0.85mm**.

- d_{50} of GFH particles: **0.62mm**

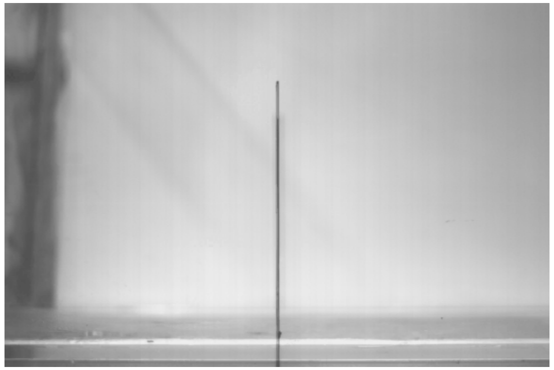
Figure 5. Sediments used in the box-culvert model with d_{50} of **0.75mm**

Hydrodynamics experiments

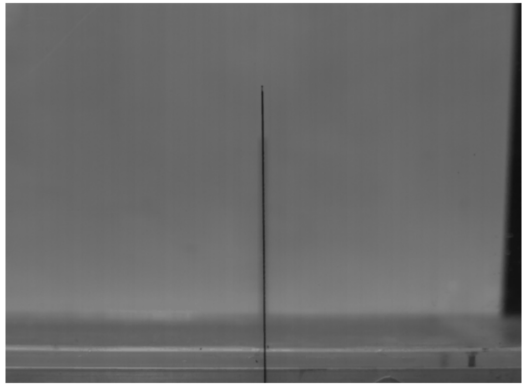
- Unsteady & non-uniform flow

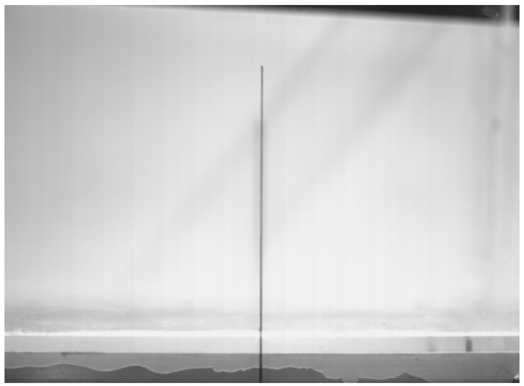
X= 485mm

X= 1335mm

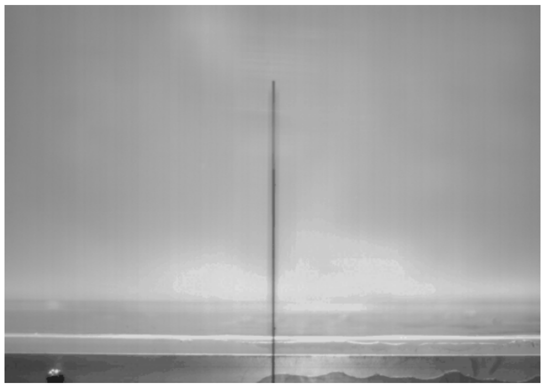


X= 1985mm

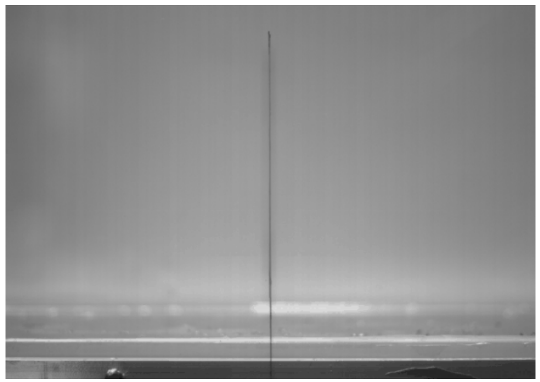




X= 3135mm



X= 5135mm



X= 6185mm

Hydrodynamics experiments

Water level in reservoir 195mm, water level in culvert 35mm (no sediments)

Water level in reservoir 195mm, water level in culvert 35mm (1cm sediment layer)

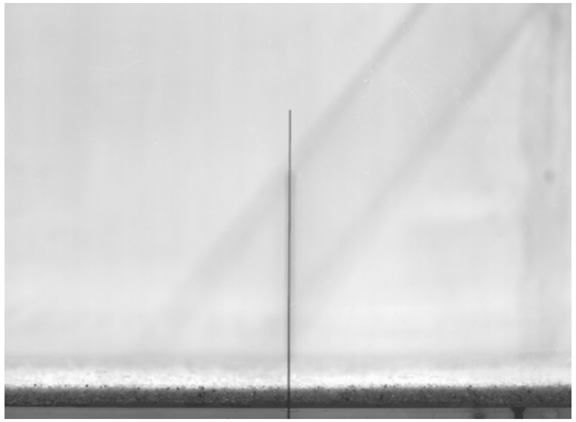
Dam-break experiments with sediments sample

- Sediments with 1cm thickness placing from the gate to the end of the box-culvert
- No water in the box-culvert before dam break (19.5cm water in the reservoir)

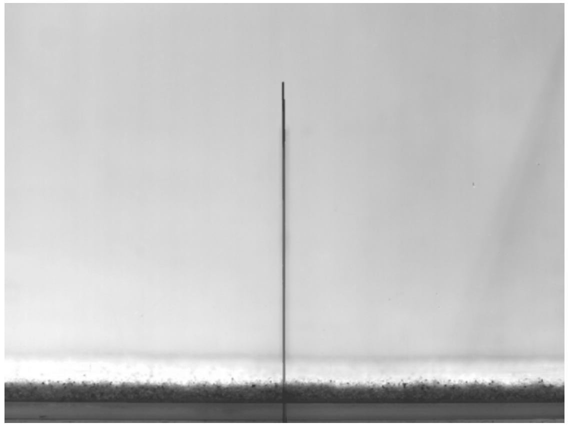
X=485mm

X=1335mm

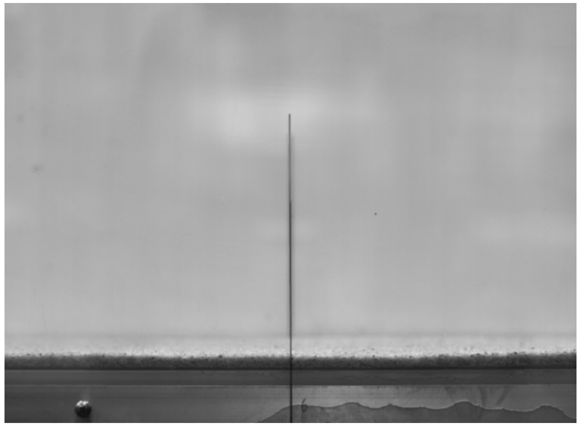
X=1985mm



X=3135mm

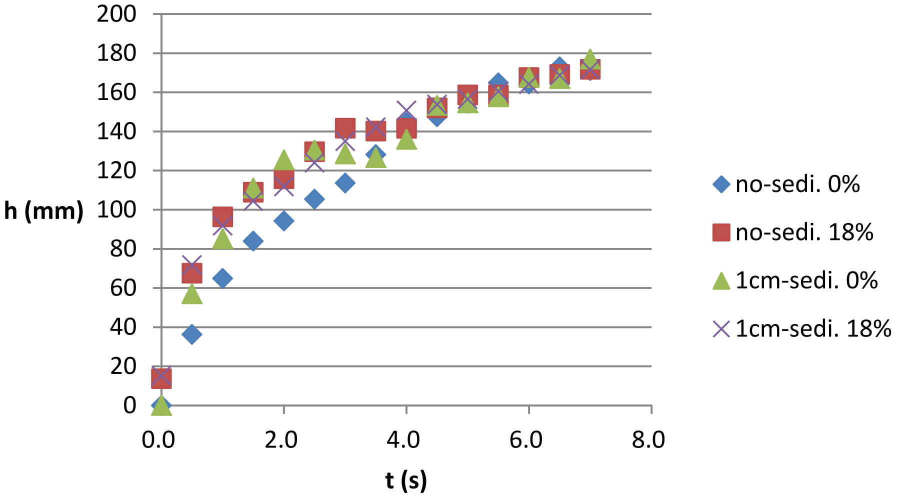


X=5135mm

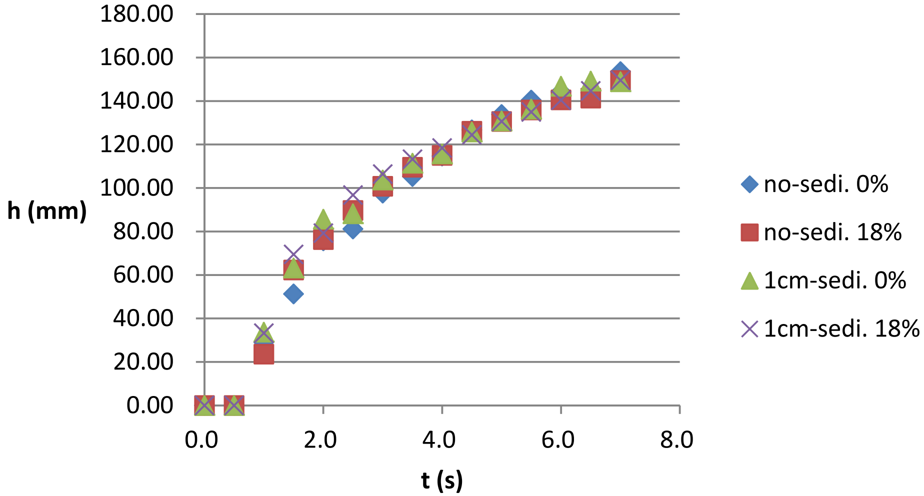


X=6185mm

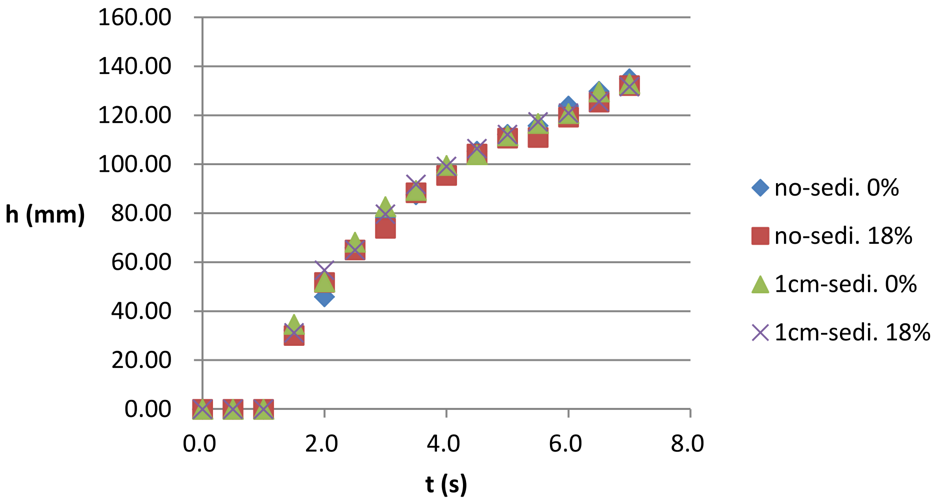
Time-series of flow depth



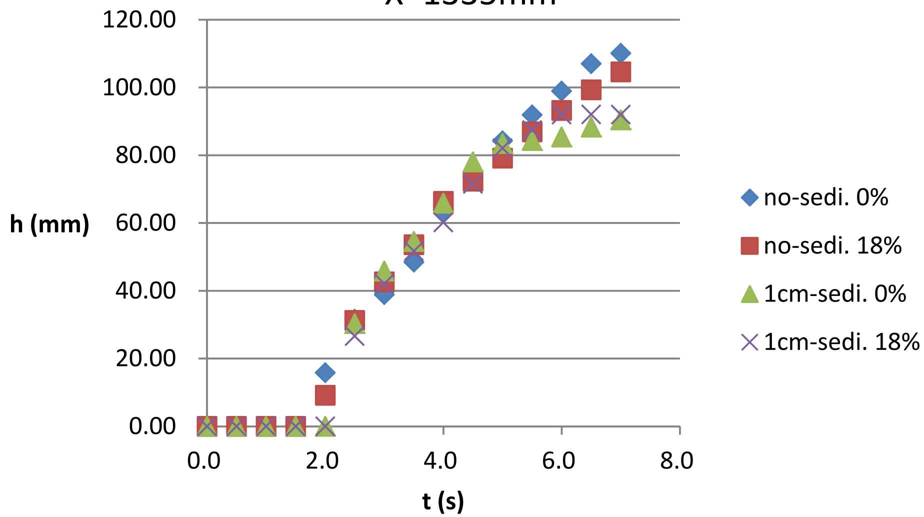
X=485mm



X=1335mm

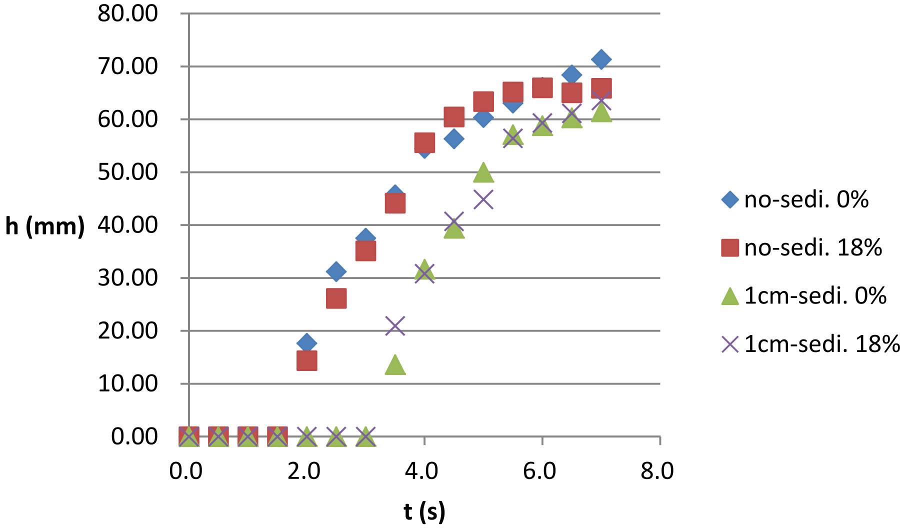


X=1985mm

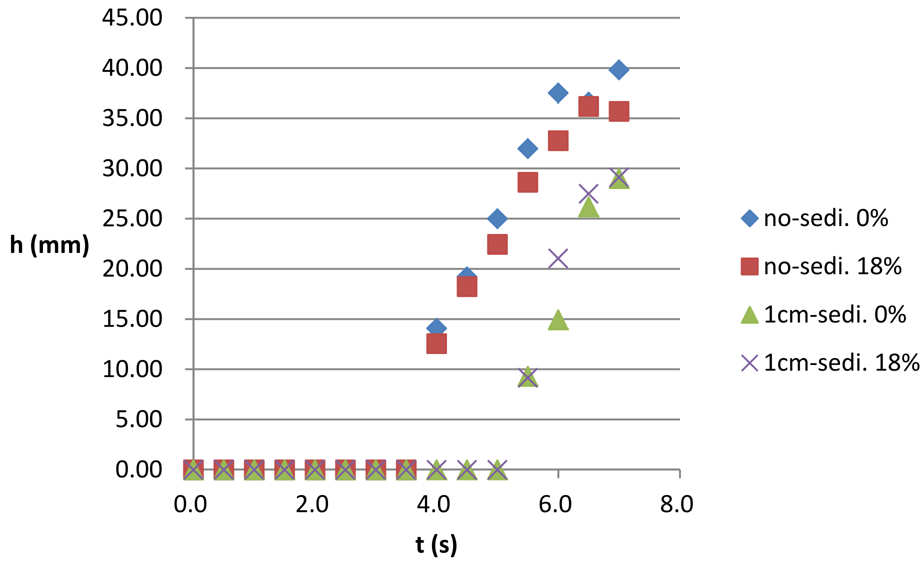


X=3135mm

Time-series of flow depth

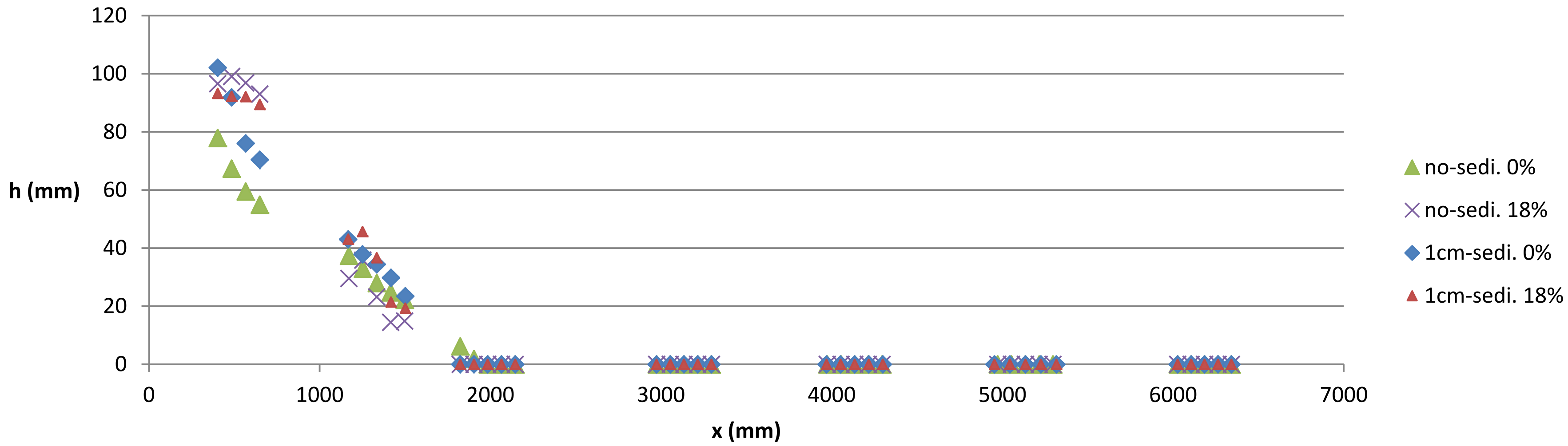


X=4135mm

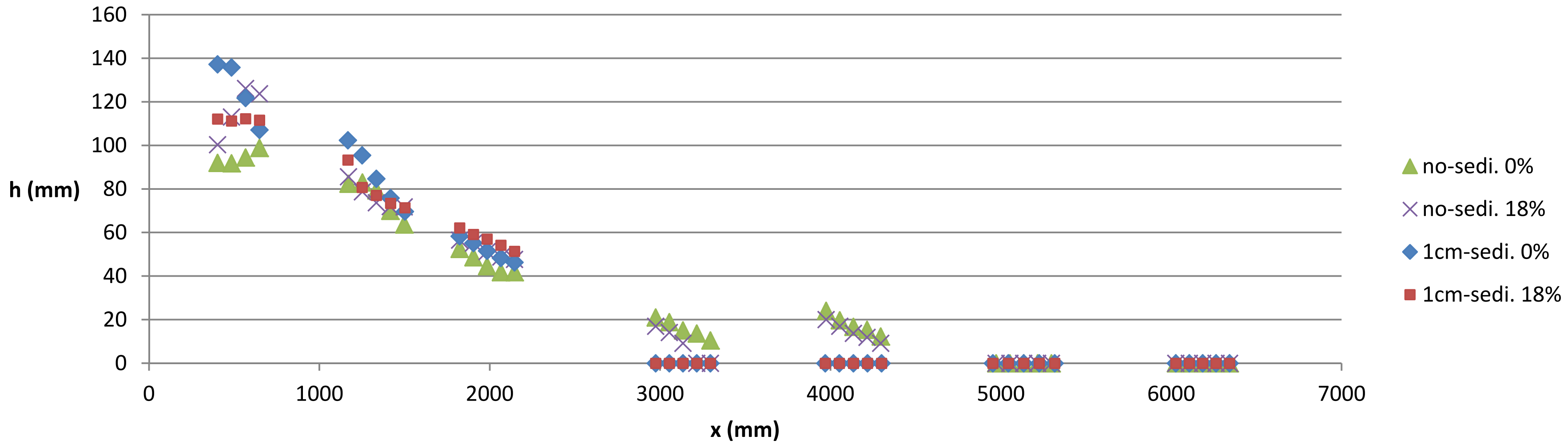


X=5135mm

Flow path for different times

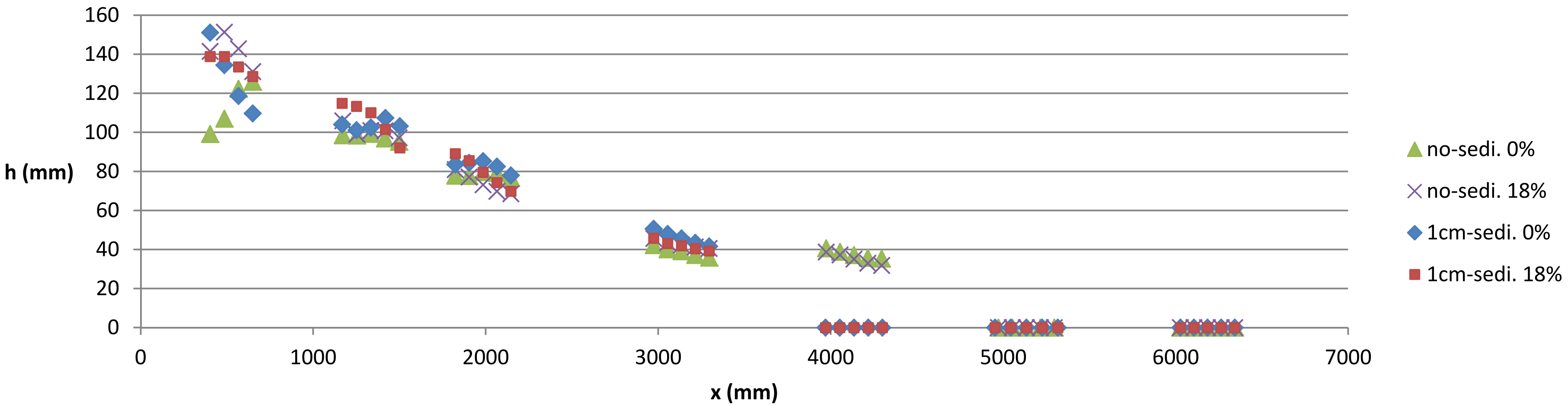


t=1s

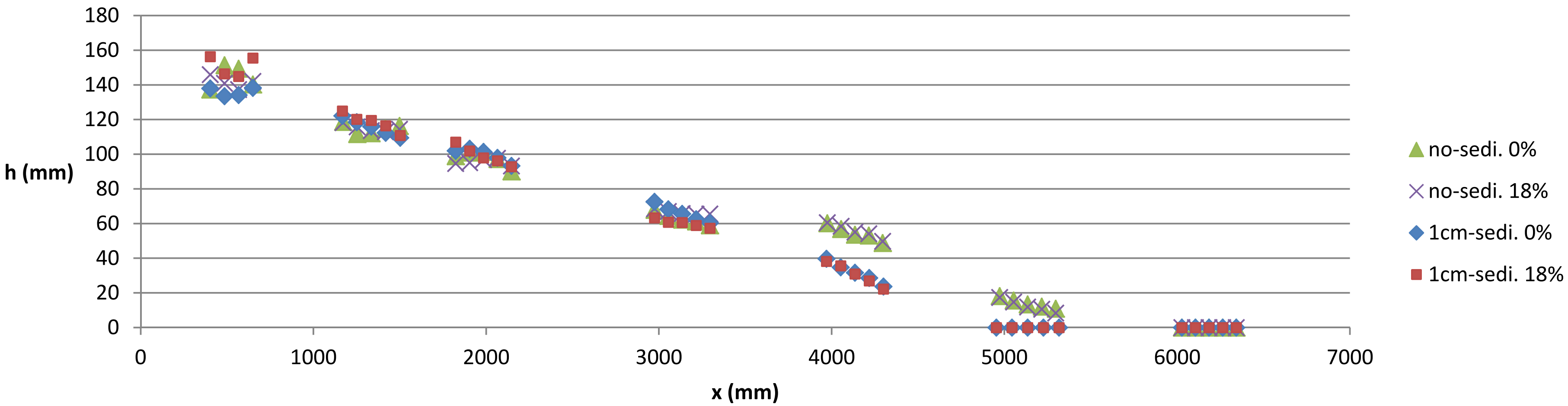


t=2s

Flow path for different times

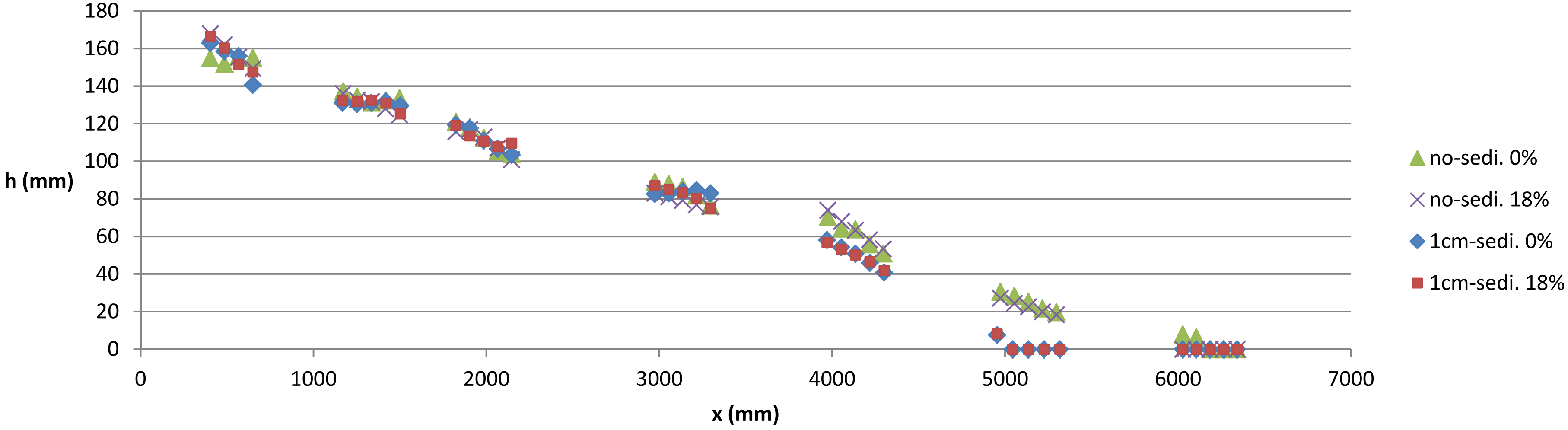


t=3s

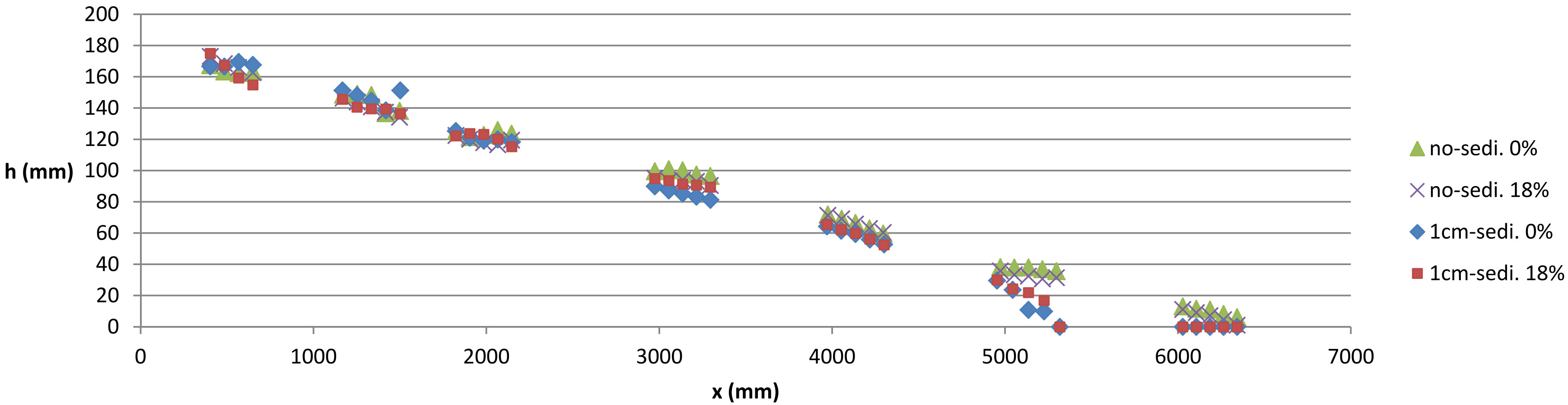


t=4s

Flow path for different times



t=5s



t=6s

- Shorelines (no water in box culvert before dam break)

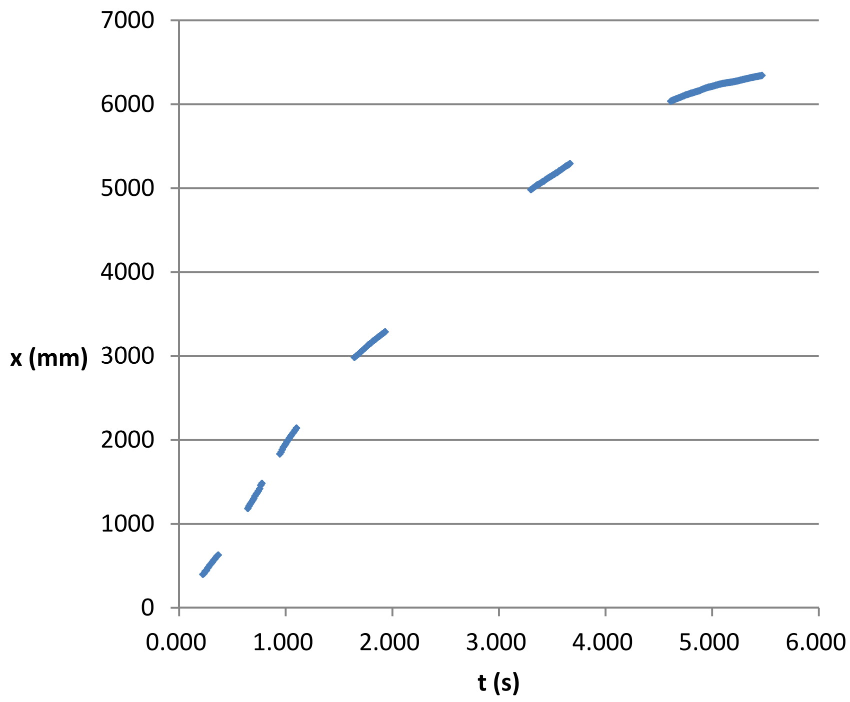


Figure 1. No sediments sample

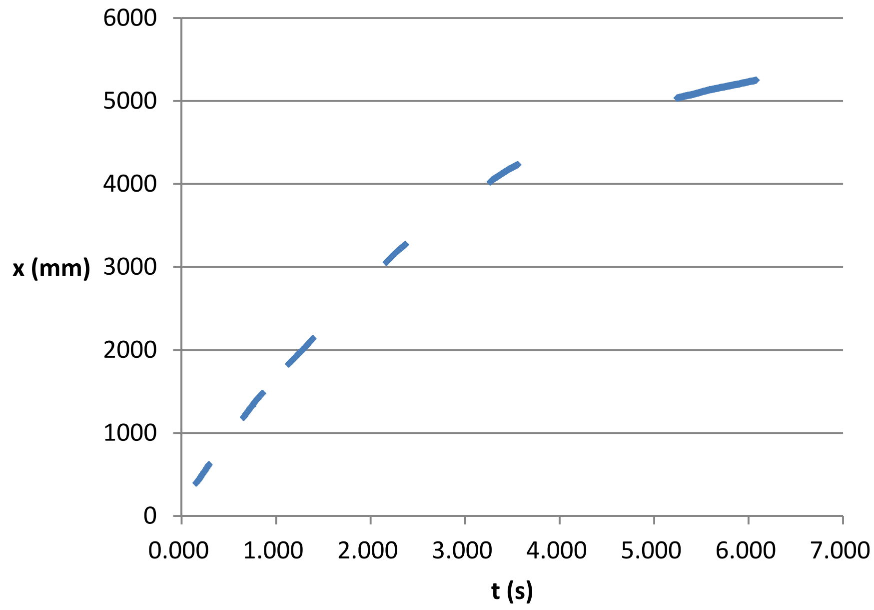


Figure 1. Sediments sample with 1 cm thickness

Future work

- Investigating the effect of regeneration of GFH by dam break processes
- PIV system would be introduced to this project for getting more details about the flow behaviors generated by dam break.

Thank you!

Q & A