

Data Storage Report

**Testing a novel explanatory factor for the non-linearity between rainfall event magnitude-frequency and catchment erosion with HYDRALAB+**

CATCHYRAIN

Total Environment Simulator, University of Hull

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**Status form**

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Document objective

This data storage plan describes the experimental program and how tests should be performed. When all data has been obtained, the data storage plan is updated to a data storage report. In the data storage report, the data is described so that others can use them.

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# Objectives

Despite significant research and interventions, soil erosion by water continues to be the dominant soil threat globally. The reduction or prevention of soil erosion is highly complicated, because the relation between rainfall, runoff and erosion is known to be highly non-linear. Both field-based and modelling studies emphasise this non-linearity and self-organising behaviour within a catchment; intense rainfall events do not necessarily produce high net erosion and low rainfall may result in high erosion.

The most pressing issue is the lack of data and the knowledge gap of the effect of varying magnitude-frequency event sequences on erosion and sediment dynamics in catchments. Baartman et al. (2013) explored the temporal effect using a modelling approach and 50 different sequences of rainfall events, all having equal total rainfall, but with varying temporal occurrence of higher and lower magnitude events. Interestingly, the erosion response did not seem to follow a particular trend, with some simulations showing hardly any variation over time and others showing a sudden increase in net erosion. A possible explanation for the observed behaviour is a change in connectivity within the catchment, resulting in a sudden pulse of sediment in the landscape. This research project will test this hypothesis; the objectives are:

* To test and quantify the (non-linear) effect of varying temporal sequences of rainfall event frequency-magnitudes on erosion and sediment dynamics;
* To quantify the connectivity after each event as a novel explanatory factor for this non-linearity.

# Experimental setup

## General description

The experiments were conducted in the Total Environment Simulator (TES) at the University of Hull. The TES has an approximate working area of 6m wide by 11m long in total, and for these experiments was subdivided into two separate idealised catchments, each measuring 4m wide by 4m long, tapering at an angle to 1.5m wide across the final 1m of the catchment.

The shapes of the two catchments were identical to each other, and carefully rebuilt after each experimental run using a sliding template that could pass over a frame. This system was used to ensure repeatability in the experiments. Each catchment consisted of a valley shape with sloping sides of gradient 1 in 25, with an overall downward gradient of 1 in 10 towards the bottom of the catchment. This set-up can be seen in Figure 1.

The catchments themselves were constructed using two different varieties of sand. Plot 1 consisted of a fine sand with an average grain size of 215 microns and plot 2 consisted of a coarser sand with an average grain size of 458 microns.

Across the outfall of each catchment, a large box was placed on a set of scales. This allowed water to flow into it, and deposit sediment that had been mobilised. At the opposite side of each box, was a high level water outflow. This allowed water to flow out into separate larger containers, each also placed on a set of scales. The water level within the sediment box was kept to just below the outfall, so as soon as water flowed in off the catchment, it could then flow out into the larger containers. Within these larger containers, pumps were placed that could empty the water as they became full. This system allowed us to measure the sediment and water coming off of each plot whilst the experiments were running.

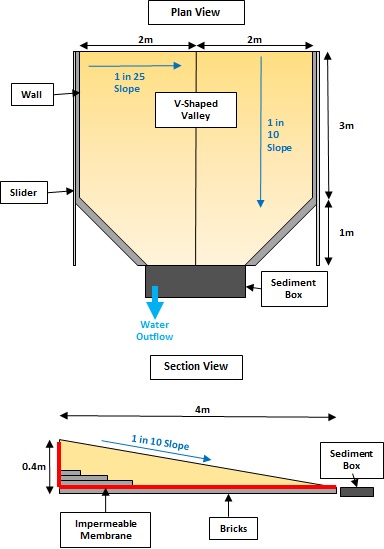


Figure . Experimental Set-up

The TES is equipped with a rainfall generator system, comprising a total of 50 nozzles, each capable of producing an even water distribution over a square area. The nozzles are spaced to ensure water will fall on all areas of the catchment. For this work, it was decided to remove 10 nozzles which were not directly over the catchments.

During the initial set-up, work to calibrate the rainfall was carried out. This was completed by using rain gauges distributed across each catchment, to measure the rainfall over a set time period. Different intensities were achieved by either altering the flow through the water pump, or by shutting off certain nozzles, resulting in three different rain intensities, representative of low (35mm/h), medium (92mm/h) and high (125mm/h) for these experiments.

Each time, after the catchment was rebuilt, a spin up event was run. This was the same for each experimental sequence and was designed to ensure that the initial conditions of the catchment remained constant throughout the experiments. Then five different individual rain events as shown in Table 1, were used for the main experiments. The order of these events was altered for each experimental run resulting in a total of 9 different sequences.

*Table 1 . Individual Rainfall Events*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Rain Intensity** | Spin Up (Low) | Low | Low | Medium | Medium | High |
| **Event Length** | 60 mins | 30 mins | 60 mins | 15 mins | 30 mins | 15 mins |

After each rainfall event, the nozzles had a tendency to drip. During this initial period, covers were deployed to protect the evolved landscape from these. Once the dripping had ceased, a terrestrial laser scanner was used to scan the surfaces of the catchment. These could be used to produce a digital elevation model of both catchments, allowing comparisons with the previous event, so the evolution of the catchment during each rain event could be observed. Also, during this period, the sediment collected in the boxes was manually removed and weighed, before the next rain event began.

# Instrumentation and data acquisition

## Instruments

A number of different measurement techniques were deployed during these experiments, the positions of each type of measurement device is shown in Figure 2. A total of 30 soil moisture sensors were distributed across the two plots, generally buried approximately 10cm below the catchment surface, although at the rear of the plots, additional sensors were buried around 20cm below the surface.

A terrestrial laser scanner was used to create digital elevation models of the catchment surface after each rain event. This was positioned four separate times, twice on the ceiling for a full 360 degree scan, and once on the ground at either end of the flume for a 180 degree scan. These four separate scans could then be merged into a single model to ensure all parts of the catchment were captured.

There were 4 sets of scales used in these experiments. One at the bottom of each catchment located under the box. These measured the water and sediment coming off of each catchment in real time. Water was directed out of these boxes into separate boxes also placed on scales, so the water run-off could be recorded separately in real time.

Rain gauges were located within the footprint of the rain system, although outside of the catchments themselves. These gave a simple volumetric total of rain that fell into the gauges.

Go Pros cameras were located around the catchments, obtaining a time lapse throughout each rain event. These do not provide any quantitative results, but do show the evolution of the catchment during each event.

Finally, high quality digital photographs were taken of each of the catchments, between rain events. The locations of these varied each time.

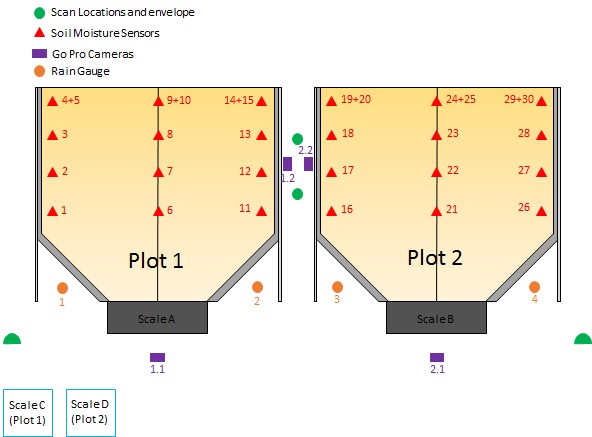


Figure . Location of Measurement Instruments

## Definition of time origin and instrument synchronization

Information about the timing and frequency of weight measurements are detailed on the individual files. Generally, the sampling frequency was 1Hz.

## Measured parameters

The main parameter measured is weight of sediment and water running off. These are measured in kg.

# Experimental procedure and test programme

The purpose of these experiments was to explore the influence of the sequencing of rain events on sediment mobility. To test this, different sequences were run, these are detailed in Table 4.1.

Table .: Test programme

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sequence** | ***Event No.*** | ***0.0 (Spin Up)*** | ***1.0*** | ***2.0*** | ***3.0*** | ***4.0*** | ***5.0*** |
| **1** | **Increase** | Low 60 | Low 30 | Low 60 | Med 15 | Med 30 | High 15 |
| **2** | **Decrease** | Low 60 | High 15 | Med 30 | Med 15 | Low 60 | Low 30 |
| **3** | **Hill** | Low 60 | Low 30 | Med 30 | High 15 | Med 15 | Low 60 |
| **4** | **Valley** | Low 60 | Med 30 | Low 60 | Low 30 | Med 15 | High 15 |
| **5** | **Stabilise** | Low 60 | High 15 | Low 30 | Med 30 | Low 60 | Med 15 |
| **6** | **Destabilise** | Low 60 | Med 15 | Low 60 | Med 30 | Low 30 | High 15 |
| **7** | **Base** | Low 60 | Med 19 | Med 19 | Med 19 | Med 19 | Med 19 |
| **8** | **Random 1** | Low 60 | Low 30 | Med 30 | Med 15 | High 15 | Low 60 |
| **9** | **Random 2** | Low 60 | Med 15 | Low 30 | Low 60 | High 15 | Med 30 |
| **10** | **Random 3** | Low 60 | Low 60 | Low 30 | High 15 | Med 15 | Med 30 |

The overall experimental procedure involved building the catchment, followed by an initial spin up event (Low intensity, 60 minutes), on one day. A soaker hose was then used overnight to keep the catchment saturated. The sequence would then be run on the following day. At the start of each event, the scales would start data acquisition. After each rain event, covers would be deployed over the catchment for approximately 15 minutes, to avoid dripping on the evolved catchment. The covers would then be removed, and scans of the catchments completed. In addition, the sediment in the boxes would be manually removed and weighed, before the next event began.

# Data post-processing

## TLS Scans

All scans were processed using the Faro Scene software (v6.2.4.30) the process (in general terms) was:

1. The scans were processed, the default settings for the processing were:
   1. Colourise scans, create scan point cloud, dark scan point filter applied, distance filter (10m) applied, automatically find targets (‘Planes’ and ‘Spheres’).
2. After processing the scans each individual epoch is then registered (spatially located). This is an iterative process: the initial ‘gross’ target-based registration is undertaken, the default settings for registration were:
   1. Use inclinometer, find correspondence for scan positions, calculate scan point based statistics, target distribution threshold: 0.001.
3. The resulting registration was then examined and any reference spheres or planes which exceeded a 10mm threshold were deleted, the target registration process was repeated until all targets were below 10mm tolerances.
4. The final stage of the registration process was a cloud-to-cloud registration, this customarily resulted in a 2-3mm mean point error. The default settings for cloud-to-cloud registration were:
   1. Use inclinometer, subsampling: 0.010m, calculate target & scan based statistics, maximum number of iterations: 30, maximum search distance: 10m.
5. The point cloud data was then exported via Scene. Each individual scan was exported in the E57 format (http://www.libe57.org/), this is a vendor-neutral format for storing point clouds.
6. Cloud Compare software (http://www.danielgm.net/cc/) can then be used to load and analyse the point clouds. Please note: whilst this software is provided ‘free’ you should acknowledge its use in any report or published works.

# Organisation of data files

All data files are saved on Box. They can be found here:

<https://universityofhull.app.box.com/folder/32431103984>

## Organisation of Data Folders

### Individual\_Event\_Time\_Lapses

These can be used to observe the evolution of the two catchments from two different angles throughout each rain event, and consist of photos taken at 10 second intervals.

Folder Location: Individual Event Time Lapses > Sequence\_x (Date) > Camera\_No (Location) > Event\_No (Event Type)

Where sequence\_x (date) is the sequence number based on the test programme in table 4.1, and the date on which the experiments were run. The camera\_no is based on number system shown in figure 2, the location identifies the plot number and camera location. The event\_no is based on the test programme in table 4.1, with event type identifying the rain intensity and length of event.

### DSLR\_SFM\_Photos.

These are high quality photos taken of the plots after each rain event, that can be used for Structure For Motion (SFM).

Folder Location: DLSR\_Photos > Sequence\_x (date) > Plot\_No > Event\_No (Event Type)

Where sequence\_x (date) is the sequence number based on the test programme in table 4.1, and the date on which the experiments were run. The plot\_No refers to plot 1 or 2 as shown in figure 2. The event\_no is based on the test programme in table 4.1, with event type identifying the rain intensity and length of event.

### General\_Setup\_Photos

These are a selection of photos taken throughout the experimental period, showing the overall setup and equipment used.

### Surface Elevation Point Clouds.

After each rain event, a total of four scans were taken, to ensure coverage of the entire experiment. Each individual scan has been exported as a point cloud.

Folder Location: Surface Elevation Point Clouds > Sequence\_x (date) > Event\_No (Event Type)

Where sequence\_x (date) is the sequence number based on the test programme in table 4.1, and the date on which the experiments were run. The event\_no is based on the test programme in table 4.1, with event type identifying the rain intensity and length of event.

### Soil Moisture.

Folder Location: Soil Moisture

The soil moisture sensors recorded permanently. Within the files the timestamp of readings can be found. This can be matched with the dates of each experimental run found in the manual weighing data files.

### Experimental Logs Manual Measurements.

Folder Location: Experimental Logs Manual Measurements > Sequence\_X (date).xls

Where sequence\_x (date) is the sequence number based on the test programme in table 4.1, and the date on which the experiments were run.

### Sediment Water Mass Balance.

Folder Location: OneDrive > Sequence\_X (date)> Rain X\_Event.txt

Where sequence\_x (date) is the sequence number based on the test programme in table 4.1, and the date on which the experiments were run. Rain X identifies the event number in that particular sequence with event identifying the rain intensity and length of event.

## Format of Data Files

### Individual\_Event\_Time\_Lapses

File Format: JPEG

### DSLR\_SFM\_Photos.

File Format: JPEG

### General\_Setup\_Photos

File Format: JPEG

### Surface Elevation Point Clouds.

File Format: FLS

### Soil Moisture.

File Format: XLS

|  |  |
| --- | --- |
| TIMESTAMP | VWC(1-30) |

Time Stamp = Time of reading

VWC(1-30) = Reading from probe numbered

### Manual Weighing Data.

File Format: XLS

Front Sheet:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Event No. | Intensity | Duration (min) | Pump Set (Bar) | Nozzles | Time | Total Runoff (kg) | Rain gauges (mm) |

Event No = Location of event in overall sequence

Intensity = Low, Medium or High

Duration = Length of event

Pump Set = Value the pump was set to, to achieve required intensity

Nozzles = Open / Close Nozzle Locations

Time = Start Time and End Time of Event

Total Runoff = Manual weight of sediment collected

Rain gauges = Depth of rain collected in rain gauges

Individual Event Sheets:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t | Tank plot 1 level | volume m^3 | Tank plot 2 level | volume m^3 | p1 Time (s) not measured | p2 Time (s) not measured |

T= Time at which water box was emptied

Tank plot levels = Level in box before and after emptying is carried out.

Volume m^3 = Equivalent volume of water removed calculated from levels

Time not measured = the period of time that emptying took.

### Automated Weighing Data.

File Format: TXT

Labview PC timestamp: 01/08/2017 13:18:26.453

Scale A: 20.60kg

Scale B: 14.50kg

Scale C:NET: 11.5 kg

Scale D:NET: 14.0 kg

Scale A = Sediment, Plot 1

Scale B = Sediment, Plot 2

Scale C = Water, Plot 1

Scale D = Water, Plot 2

# Remarks

Throughout the experiments, there were various issues encountered. A table is given in the Appendix showing the quality of the data has been produced, ranging from green (good) to red (poor or non-existent).

## Data Quality Table Plot 1



## Data Quality Table Plot 2

