Dovenby bund

April 2023

Introduction: Dovenby Beck drains an agricultural catchment area of 2.5 km^2 before flowing through Dovenby Village. Through the village, the stream is constricted between stone walls and passes under several bridges with low capacity. Dovenby is susceptible to flooding due to the flashy response in the catchment and the infrastructure within the village. In total twelve properties and the local pub are at risk of flooding (Dovenby Flood map improvement report, JBA Environment Agency, 2011), with some of these properties at risk in low magnitude events.

This project, funded by the North West Regional Flood and Coastal Committee's Slow the Flow funding, involved the construction of an earth bund across the floodplain to store water during high flow events. The bund was built across an existing 1 m diameter culvert within Dovenby Beck, about 800 m upstream of the village. During heavy rainfall the stream flow exceeds the capacity of the culvert and water spills onto the surrounding field. Before the bund was constructed, this water travelled across the field to re-join the stream further downstream (Figure 1). The bund now holds the water back during the rainfall event and is landscaped so that the water drains away once the peak flow has passed. The bund has a lowered overspill point at its western side to reduce pressure on the structure if it overtops. A pond was excavated to provide material for construction of the bund and create habitat, and retains water semi-permanently (Figure 2).

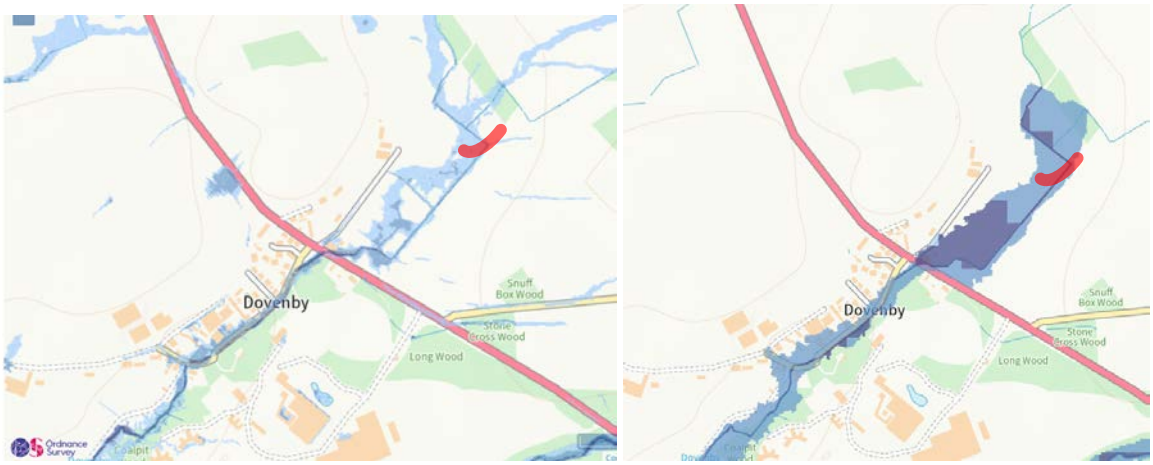

Figure 1 – Environment Agency flood risk maps for Dovenby pre bund construction showing surface water (left) and river flooding (right). The position of the bund is shown in red.

Figure 2 – Dovenby bund, before (left) and after construction (right).

Monitoring methodology:

Data collection: Water level loggers (HOBO U-20L) were installed a few metres upstream of the culvert in September 2021. A further logger was installed to record atmospheric pressure, allowing conversion of the water pressure to a water depth. Reference depths at the loggers were recorded periodically to calibrate the recorded data. A laser level survey of the bund was undertaken after construction to determine the height of the bund crest and overflow above the floodplain and water level logger. This was tied into existing LiDAR data (1m DTM) to give a topography of the whole water storage area.

Analysis: The volume of potential water storage upstream of the bund was calculated from the topographical data at 10 cm depth intervals using the surface volume tool in ARC GIS. These volumes were plotted and a polynomial trend line fitted to the data ($R^2 = 0.999$). The trend line equation was applied to the depth data from the logger, to calculate the volume of water stored every 15 minutes. Each value was subtracted from the previous value to calculate change in storage over time, and averaged to one-second intervals to give volume stored in cubic metres per second.

The nearest continuous rain gauging station is the Environment Agency's gauge at Sunderland waste water treatment works, which is 8 km inland from Dovenby. This data was used to calculate the return period of high rainfall events using the UK CEH Flood Estimation Handbook, 2022. The exact timing of the rainfall time series used for analysis will therefore have been different to the rainfall in Dovenby. A comparison for the October 2021 event between a rainfall gauge in the village read every 3 hours and the rainfall data from Sunderland showed that the total volume and broad pattern of rainfall was the same in the two locations.

Monitoring results: The bund provides a maximum storage capacity of 1143 m^3 to the bund crest.

The water levels have been above the top of the culvert on 12 occasions between September 2021 and April 2023. Eight of these events were minor (below 1 in 1 year return period) and water levels only rose just above the top of the culvert. During these events, the culvert and bund were acting to slow water within the channel rather than store water. Until the water depth gets above 0.85 cm, i.e. 15 cm above the top of the culvert, the amount of storage is negligible, as the water does not spill over bank.

Since the installation of the bund, there has been four major rainfall events (Table 1). Return period was calculated for both total rainfall volume over the whole event and maximum intensity. The highest of these values is reported in Table 1.

Table 1 – Significant rainfall events in Dovenby between September 2021 and April 2023

Event date	Duration (hours)	Total rainfall (mm)	Max. rainfall mm/hr	Return period (FEH, 2022)	Comment
27th - 28th Oct 2021	36	77.8	6.2	15.5	Event magnitude due to duration rather than intensity, increasing through storm.
31st Dec 2021	5	22	5.4	1.5	Event magnitude due to total rainfall not maximum intensity.
20th Feb 2022	4	21.4	13.4	3.7	Event magnitude due to maximum intensity.
1st January 2023	6	41	19.2	15.6	Magnitude and intensity similar return period.

October 2021 event

During this event, the bund filled gradually between 3 am on 27th October and 2 am on 28th October, reaching 4 cm above the crest of the bund. This provided a maximum storage volume of 1160 m^3. The water storage area then drained back to bankfull level before filling rapidly between 10 am and 1.30 pm on 28th October, reaching the bund crest. The bund then drained back to base level within 5 hours (Figure 3 and 4). A video of the bund filling and draining can be viewed here. The water storage in the bund responded to rainfall intensity, filling most rapidly during the highest intensity rainfall and draining when rainfall eased (Figure 3).

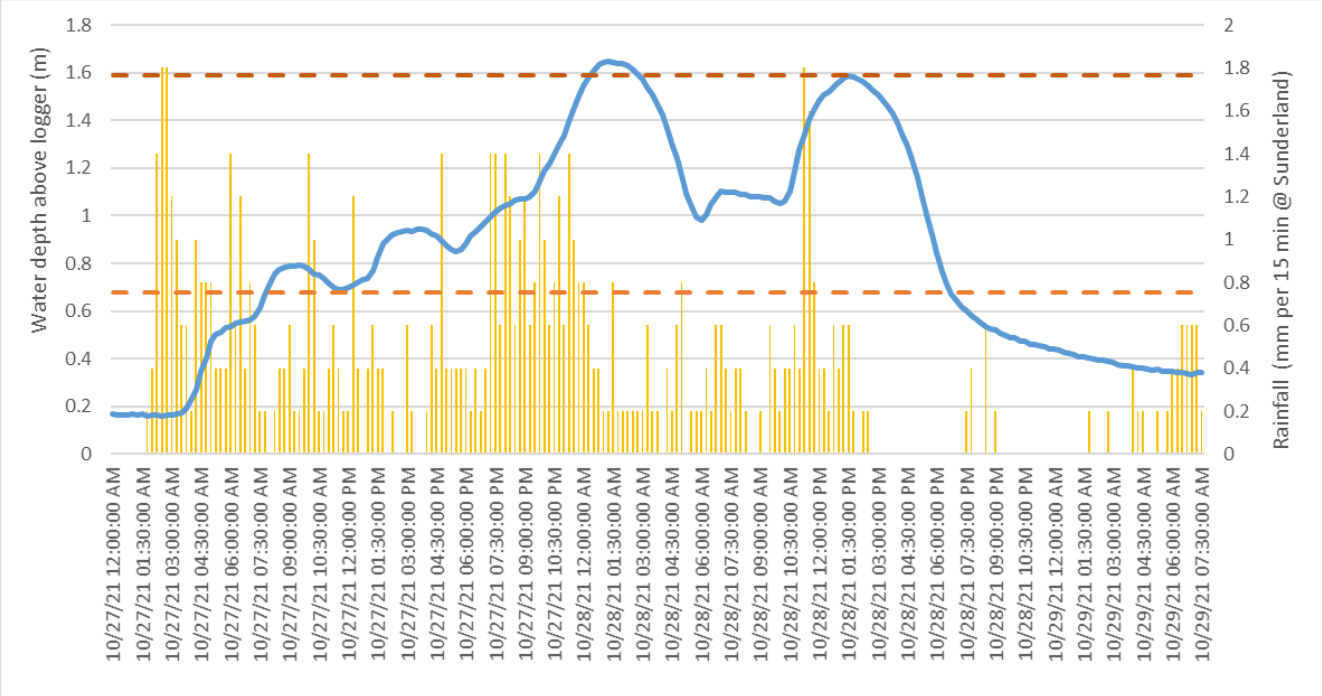

Figure 3 – Water levels within the Dovenby bund during the event on 27th/28th October. The dashed orange line shows the height of the top of the culvert and the red line shows the lowest point on the crest of the bund. Yellow bars show rainfall at Sunderland Environment Agency rain gauge.

Figure 4 – Bund filling on 28th October 2021

During this event, the water storage area filled at a maximum rate of 144 m^3 in 15 minutes. This equates to 0.16 m^3/sec. The rate of fill did not change when the overspill level was reached.

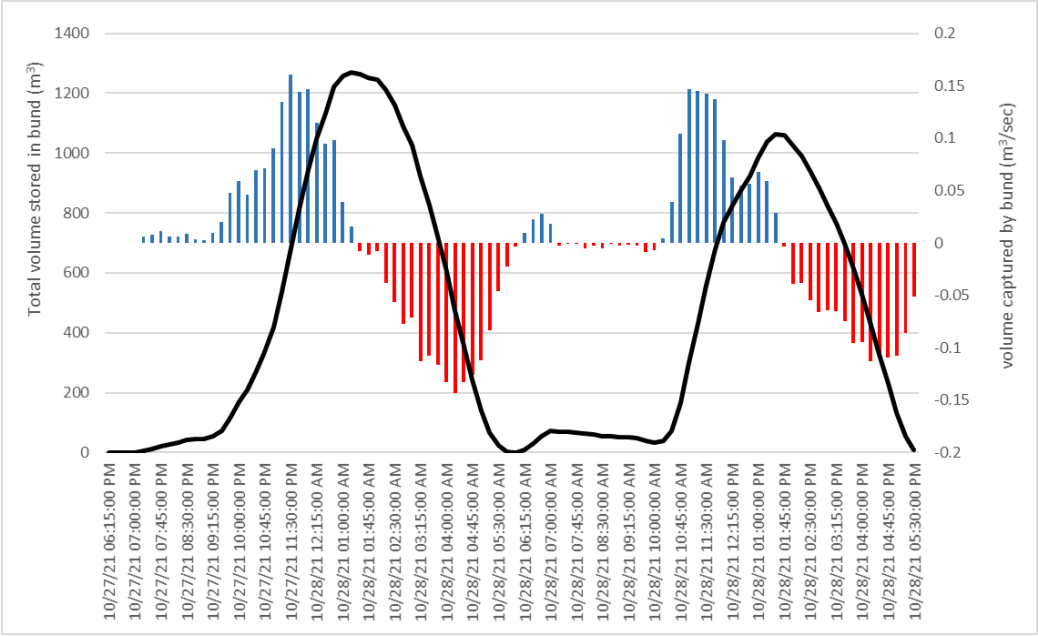

Figure 5 - Volume of water within the Dovenby bund during the high flow event on 27th-28th October 2021 (black line) and change in volume stored over time in cubic meters per second. Positive values (blue) show the feature filling and negative values (red) show the feature draining.

31st December 2021

In December 2021, the antecedent conditions were wet. During this event, there was 22 mm rainfall in the 5 hours between 9:45 am and 2:30 am, with a maximum intensity of 5.4 mm/hour and 1.8 mm in 15 min. The stream went over-bank at midnight and water level peaked at 3 am. It took 2 hrs 15 minutes to drain back below bank height after the rainfall had ceased.

The water level within the bund rose to 1.55 m, just below the height of the bund crest (1.59 m). This is a volume of 954 m^3. The water storage area filled at a maximum rate of 0.039 m^3/sec (Figure 7). Again, the rate of fill did not change when the overspill level was reached.

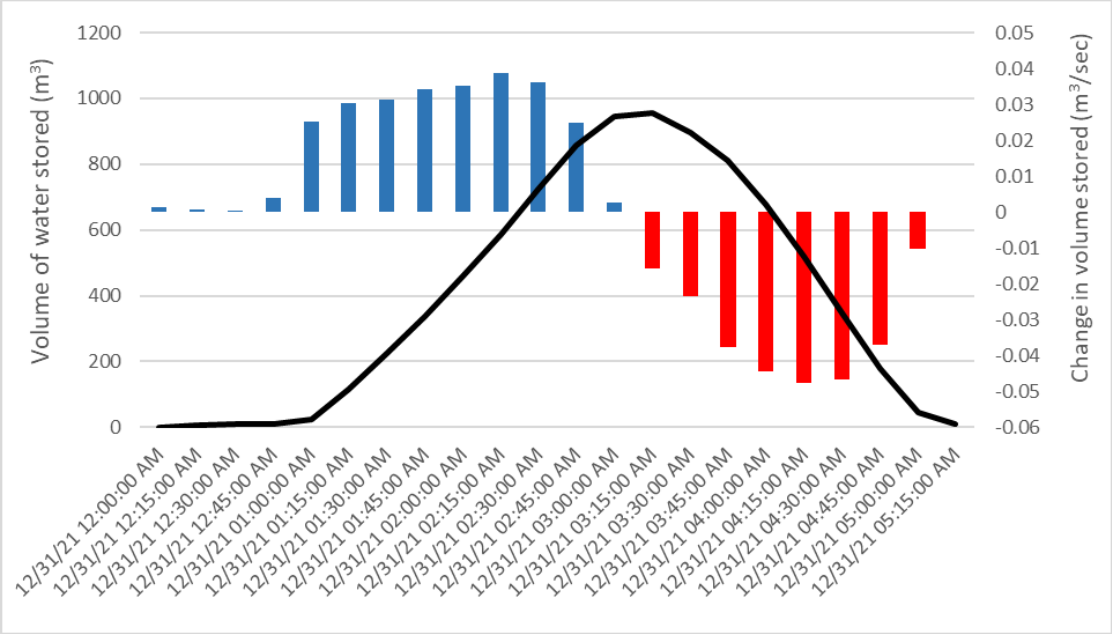

Figure 7 - Volume of water within the Dovenby bund during the high flow event on 31st December 2021 (black line) and change in volume stored over time in cubic meters per second. Positive values (blue) show the feature filling and negative values (red) show the feature draining.

20th February 2022

As for December, the antecedent conditions were wet meaning overland runoff was generated quickly after the onset of rainfall. The rainfall event started at 10:30 am on 20th February and lasted until 2:30 pm. Over the course of these four hours, there was 21.4 mm rain, with a maximum intensity at 11 am of 7.4 mm in 15 min and 13.4 mm in an hour. The water level rose to 1.45 m, a volume of 665 m^3. The water storage area filled at a maximum rate of 0.054 m^3/sec. After the rainfall had eased, the water level had drained back below bankfull within 1 hour.

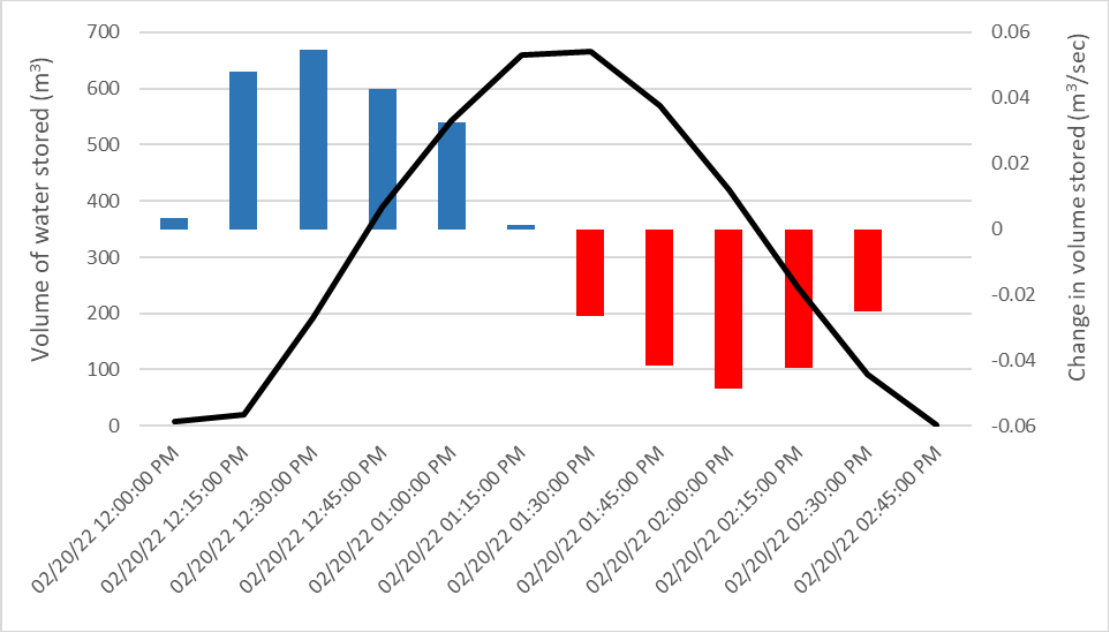

Figure 8 - Volume of water within the Dovenby bund during the high flow event on 20th February 2022 (black line) and change in volume stored over time in cubic meters per second. Positive values (blue) show the feature filling and negative values (red) show the feature draining.

1st January 2023

On 1st January 2023, there was a short but very intense rainfall event, with 41 mm of rainfall falling in six hours and a maximum intensity of 19.2 mm within an hour. During this event, the bund filled to 1.5 m. This is above the overspill height (1.32m) but below the crest of the bund (1.59m) (Figure 9).

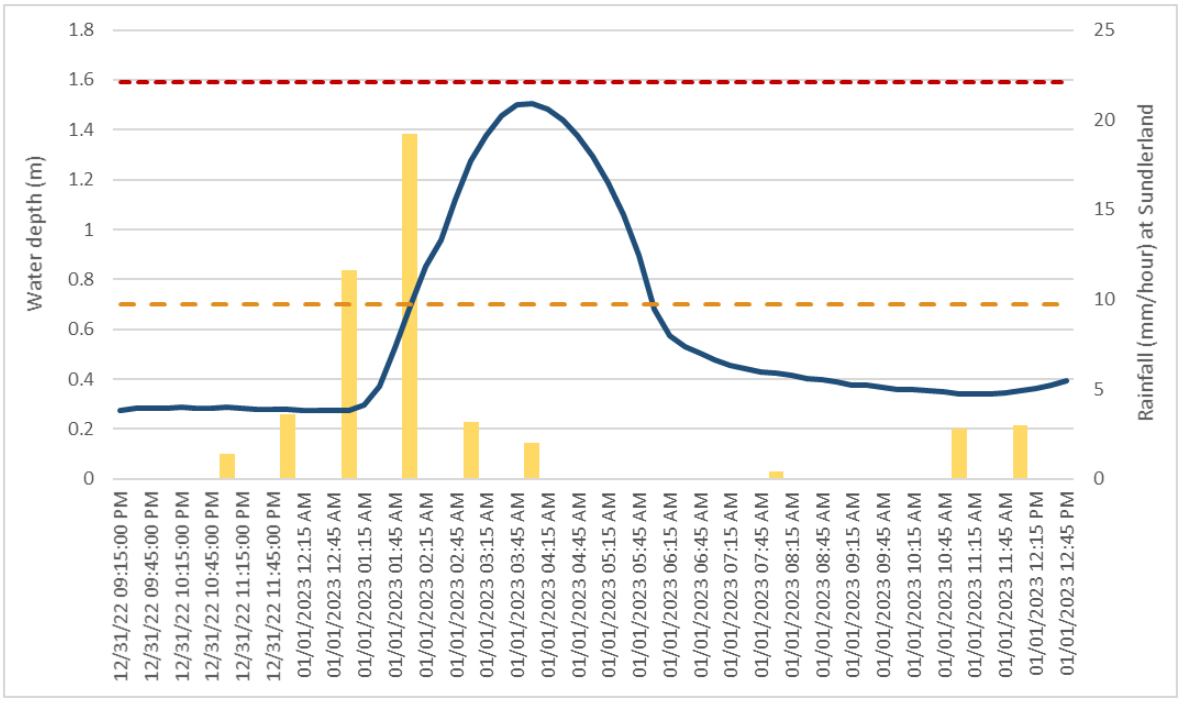

Figure 9 – Water depth in the Dovenby bund and rainfall on 31st December 2022 to 1st January 2023. The dashed orange line shows the height of the top of the culvert and the red line shows the lowest point on the crest of the bund. Yellow bars show rainfall at Sunderland Environment Agency rain gauge.

The bund began filling at 1 am, as rainfall intensity increased to 10 mm/hr, and peaked at 4 am. The maximum volume stored during this event was 816 m^3. The fill rate was a maximum of 0.23 m^3/sec, reflecting the high intensity of rainfall. The bund drained within 2 hours (Figure 10).

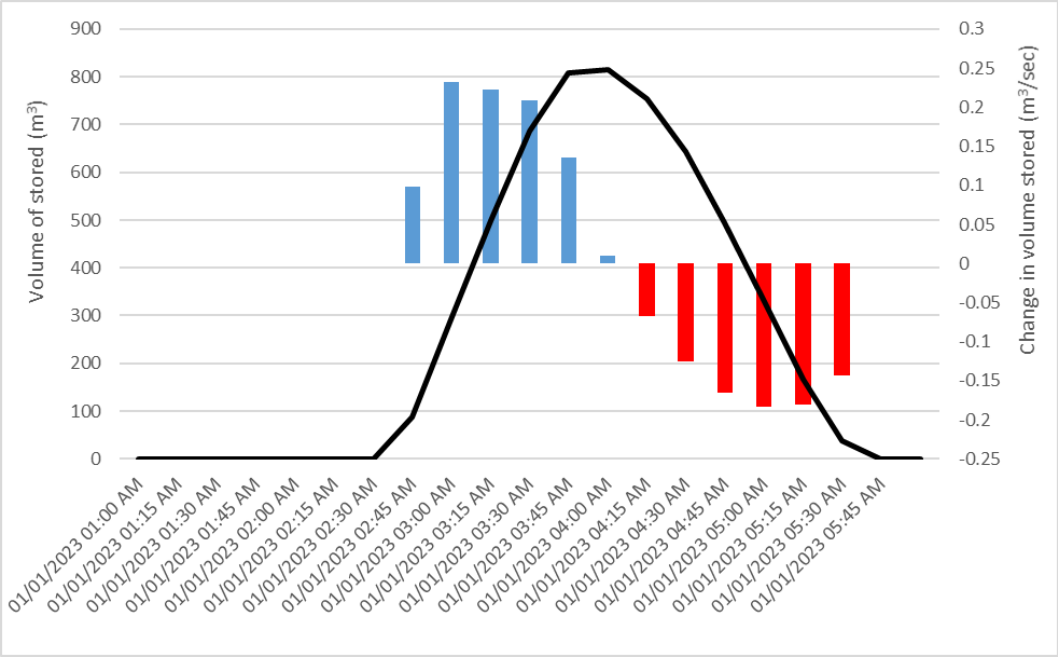

Figure 10 - Volume of water within the Dovenby bund during the high flow event on 1st January 2023 (black line) and change in volume stored over time in cubic meters per second. Positive values (blue) show the feature filling and negative values (red) show the feature draining.

Downstream impact

As there are no gauging stations in the catchment, the impact of the bund storage on downstream flows cannot be accurately determined. By considering the bund storage against estimated flows and runoff, an indication of the efficacy of the bund have been made. These are intended to be indicative, rather than accurate measurements.

The area draining into the bund is 1.96 km^2. By multiplying the total rainfall for each of the events by this catchment area, the theoretical maximum runoff into the bund was calculated. For the October 2021 event, during the period of intense rainfall between 7pm on 27th October and 1:15 am on 28th October, 22.8 mm rainfall fell on the catchment. Therefore, the theoretical maximum runoff into the bund was 44,688 m^3. During this time, the bund captured 1,270 m^3, equivalent to 2.8 % of maximum runoff. During the second period of intense rainfall between 10:15 am and 1:45 pm on 28th October, there was 9.2 mm rainfall over the catchment giving a maximum runoff of 18,032 m^3. The bund captured 1,030 m^3, equivalent to 5.7 % of maximum runoff. In January 2021, 41 mm fell on the catchment, giving a theoretical maximum runoff of 80,360 m^3. The bund stored 816m^3, equivalent to 1%.

Another way to view this is to look only at the rate of fill of the bund during the highest intensity rainfall. In October 2021, the maximum intensity of rainfall was 6.2mm per hour. This equates to a maximum potential

runoff of 3.38m^3/second from the whole catchment area. The maximum fill rate of the bund was 0.16m^3/sec or 4.7% of this runoff. In January 2023, the maximum intensity of rainfall was 19.2mm per hour. This equates to a maximum potential runoff of 10.45m^3/second. The maximum fill rate of the bund was 0.2m^3/sec or 1.9%. These two methods give broadly comparable results about the percentage reduction in flow from the bund. In reality, not all of the rain falling on the catchment would have been converted to streamflow so these figures are likely to underrepresent the performance of the bund on reducing downstream discharge.

Conclusions: The water storage area filled and drained in high magnitude events (above 1 in 1 year) as designed, and likely reduces flood risk in Dovenby Village by taking a significant volume of water off the peak discharge. The impact of the water storage on downstream discharge could not be accurately quantified but simple analyses estimate it to be between 2 and 6 % in events up to 1 in 15 year return periods.

The volume of water stored and the rate of fill of the bund was dependent on both the intensity and total volume of rainfall and was variable between the four storms analysed. The fastest fill rate was 0.23m^3/sec during a period of very intense rainfall in January 2023, whereas the maximum storage observed was 1280m^3 during the longer and higher volume event in October 2021.

The bund drains rapidly after intense rainfall, ensuring storage was available for successive periods of high intensity rainfall. The bund appeared to have limited additional capacity to store water in events of larger magnitude than those observed in the period of monitoring. Continued monitoring over a number of years is required to determine the response of the feature to higher magnitude events or those with different patterns and intensities of rainfall.

The North-West Regional Flood and Coastal Committee's 'Slow the Flow' funding, administered by the Environment Agency, funded this project. Further funding for monitoring equipment and activity was funded directly by the Environment Agency.

Special thanks to the landowners for agreeing to host and maintain this feature on their land for the benefit of the downstream households and businesses.