**The document KFAG produced on the rain event towards the end of February 2021**

**Rain events from 19th to 24th February 2021**

The rainfall events of 19th to 24th February 2021 are another close call for Keswick, similar to that of Storm Ciara in February 2020. Had rainfall been centred slightly differently, moved in a different direction, or been greater, Keswick could well have flooded.

**What went right:**

- EA contact was early and was very good, phoning a few times during the rain event to advise what the model showed.
- IF we had continued to have heavy rain, as had been forecast, on into Wednesday then it might have been a different story, we were much less at risk because the rain went east, contrary to forecasts over preceding days
- The surface water pump systems put in for Elliott Park and Penrith Road did their job and must have saved quite a few properties.
- We were fortunate that the pond at Springs Road was reported as blocked and CCC got it fixed, too close a near miss but it WAS a miss this time.

Holding pond 22/2/21 before the rain event

**What needs review:**

**The lack of warning for flood risk from river levels in the days leading up to the event.**

- Whilst the risk from surface water was raised to yellow on 22nd February, river level risk remained at green. A flood alert for Rivers Greta, St John's Beck and Bassenthwaite Lake was issued at 17:59 on 23rd, well into the rainfall event and with the Greta Bridge level at 2.87m and rising sharply.

- The event was building up over the previous weekend, did that have an impact as it wasn't during normal working hours?
- The warnings were only for surface water when it was evident that the land was saturated from the preceding storm and Thirlmere reservoir was overspilling, indicating that the rivers would react faster.
- Perhaps naming storms simply on wind makes unnamed ones appear less significant?
- People need time to lift furniture/travel to a property. The warnings need to be accurate AND well in advance.

**Peak Level Prediction on the River level information for River Greta at Greta Bridge - GOV.UK (flood-warning-information.service.gov.uk) website.**

- Normally the peaks AND the timings are forecast fairly accurately by the EA. This time we had no confidence in what we were being told. The forecast graph for the Greta at Greta Bridge is usually more accurate than it was for the event. The table below records forecasts for level at Greta Bridge:

Greta Bridge Peak Forecast levels from 23 Feb 2021:

| Time of Forecast - all Tue 23/2/21 | Forecast Peak level - m | Forecast Peak Time - Tue to Wed | Comments on Actual Levels at the Times of the Forecast |
|---|---|---|---|
| 10:48 | 2.95 | 22:30:00 | |
| 11:15 | 2.8 | 23:00:00 | |
| 13:45 | 2.55 | 06:45:00 | |
| 15:30 | 2.5 | 06:45:00 | |
| 17:00 | 2.8 | 07:30:00 | |
| 18:15 | 2.5 | 06:45:00 | By 18:15 actual was 2.99m |
| 18:45 | 2.92 | 20:15:00 | By 18:45 actual was 3.17m |
| 19:15 | 2.91 | 20:45:00 | By 19:15 actual was 3.35m |

EA said peak 3.3 to 3.4 at 8.15pm to 8.30pm at 7pm call
Actual peak was 3.84 at 00.15am on 24 Feb

- We all must have seen how the peak river height predictions were so consistently wrong. It was miles out. At several times the predicted height for 'now' was significantly lower than the real height. Surely the computer algorithm that calculates the predicted height should have a feedback loop to compare the predicted 'now' with the actual 'now'
- Was it that no modellers were on duty? The system must surely be OK for anyone to use? Was a different model used? Perhaps the new JBA model for Thirlmere?
- How much of an issue is not having Low Briery to pick up all the extra flows? Can it be kept?

**Actions in Keswick**

- KFAG maintains that the park gates should be closed earlier; the community is traumatised after 3 floods and they need the security of knowing actions are being taken. It is a visible sign that the EA are in the area and keeping an eye on us.
- There were questions over the levels for calling out the responders. Does this need review?

**Thirlmere Water Level Management**

- The management of level employed at Thirlmere reservoir needs to be reviewed for flood risk mitigation and a more robust scheme embedded within the Abstraction Licence that will be reissued mid this year.
- Modelling by KFAG indicates that a modified management regime, along the lines of those used in the EA/JBA modelling study from 2020 (draft report January 2021), could have significantly reduced or eliminated overspill from Thirlmere, and therefore peak level at Greta Bridge.

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## Conditions in the Greta Catchment Prior to 23rd February

Early February had been relatively dry, with a period of virtually no rainfall from 6th to 13th. There was then a moderate rainfall from 14th to 18th February (86mm at Dale Head) followed by heavy rain on 19th to 20th (126mm at Dale Head). A significant proportion of the rainfall in the Thirlmere section of the catchment had been held back by the reservoir, which only started to overspill at 08:30 on 20th February. This separated the peak flows from the Glenderamackin and St John's Beck catchments, with Thirlmere catchment actually contributing nothing to the peak level of 3.01m at Greta Bridge at 22:30 on 19thFebruary, after 70mm of rainfall that day.

The catchment was saturated and Thirlmere reservoir overspilling (0.35m above weir) by the end of 20th. Despite a couple of drier days (7.4mm of rain), by the start of the rainfall on 23rd February the catchment was still in that state with Thirlmere still overspilling (0.13m above the weir).

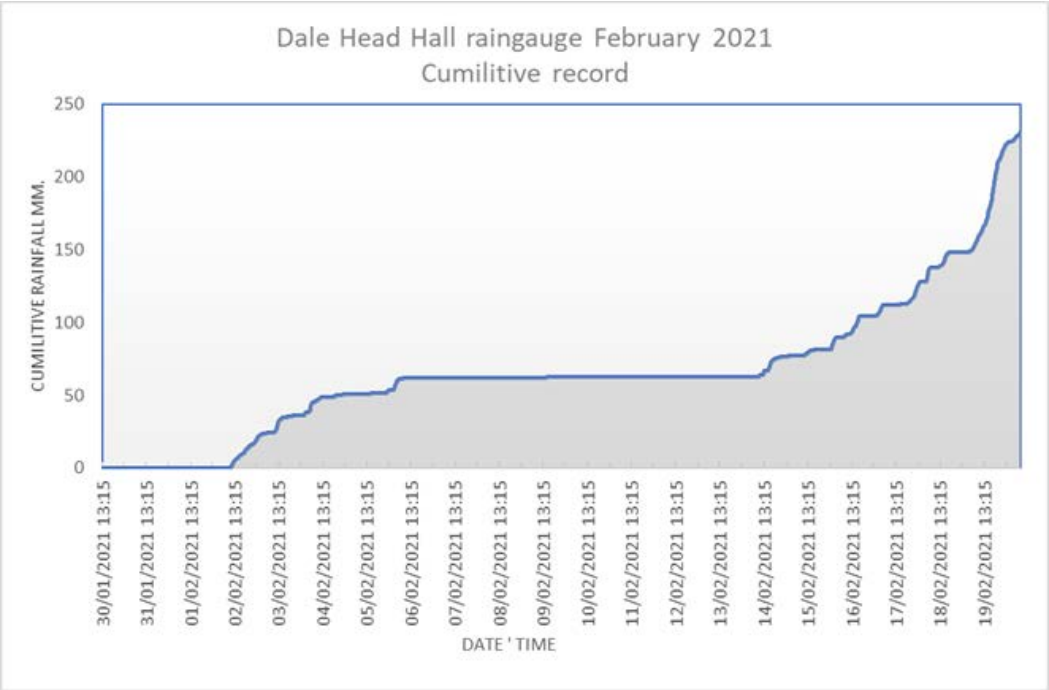
On 21st February rainfall forecasted for Dale Head over 23rd to 24th was a total of 98mm (YR website, Norwegian Meteorological Institute and NRK). Despite this forecast being lower than the actual rainfall experienced on 19th-20th, the lack of any space in Thirlmere, and therefore no decoupling of peak flows, suggested that peak level at Greta Bridge would be a cause for concern for the Keswick community.

## Diary of events recorded by Lynne Jones

Fri, 19 /2/21 at 12:44
Subject: Updated Information from The Met Office Advisor - Yellow Warning of Rain for Cumbria On Saturday. Good afternoon all. Just to confirm, as hinted at in my message this morning, a **Yellow Warning of Rain** has now been issued for much of central and western Cumbria (medium likelihood, low impacts) valid from 04:00 to 22:00. I've attached the warning to this email, and you'll also find it in all the usual places. Remember, low impact warnings aren't pushed out via email in the same way medium and high impact ones are.

Sat, 20/2/21at 10:09 RD to LJ Thirlmere is now full and just overtopping. The level has risen by 1.23m since this time on Mon 15th. We can only keep our fingers crossed that there are no major storms in the offing. EA & UU sailing close to the wind (or should that be rain?)

Sat, 20/2/21at 12:38




We will also have had some contributory snow melt
YR rain forecast says 12mm left today and then 60mm ish for Tuesday / Wednesday

Sat, 20/2/21 at 17:19 Reservoir overflowing. Releases ceased.

Sat, 20/2/21 at 17: 34 At least the flow into St John's Beck (from overflows) is now greater than it was prior to the additional releases being stopped. It would be good to have the additional releases back to help lower Thirlmere's level quicker.

Sun, 21/2/21at 11:27 YR prediction for Tuesday/Wednesday has gone up from about 65mm yesterday to 105mm prediction as of today Agree, Thirlmere very unlikely to be below the weir before then.

Sun, 21/2/21 at 11:53 LJ to Met Office We had a shoddy weekend here, I was asked for sandbags early evening on Friday because there was so much water coming down Newlands Valley. We had 1/2meter of storm space in Thirlmere reservoir but that has gone and it is overflowing by about 30cms now and unlikely to recover sufficiently to cope with what looks like an awful 36 hour period starting Tuesday. Looking at the Met Desk rainfall totals for local routes, reading across these show rainfall in the last 24 hours, and forecast for Tuesday and Wednesday

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Bass Lake 20.6 27.6 26.4 A19
Smaithwaite 21.6 32.3 34.8
Grange 20.7 36.1 40.2
Strands B5289 10.2 38.4 44.3
Given it looks like so much more even at lower levels is a yellow warning being issued please for this coming event? Can you give me an idea of rainfall totals expected on the high fells? Everywhere is saturated and this feels the last worrying time of the winter.

Sun, 21/2/121 at 23.42 Met Desk Transportation Portal showing high levels of rainfall on all local roads for Tuesday, 35.7mm to 58.4mm in 24 hours. Forecasts for higher levels likely to be much higher. Wednesday rainfall also forecast high. (see appendix 1)

Mon 22 Feb at 8.47 KW to LJ
From Met Office: As you say, there is a wet spell of weather expected Tuesday/Wednesday. Your local expert, Alan is back from leave today, and he'll be keeping you fully up to date I'm sure.

Mon, 22/2/21 at 11:22 Met Office update A slow-moving Atlantic weather front looks set to bring an extended period of rain across a good part of Cumbria stating tomorrow morning and continuing through into Wednesday morning. The rain will wax and wane in both areal extent and intensity but, as the totals gradually mount up, so some surface water-based impacts look quite possible with accumulations of standing water potentially impacting road and perhaps rail traffic too. One or two localised instances of property flooding also can't be ruled out. As a result a precautionary yellow (low impact) rain warning has been issued this morning for this event, valid from 11:00 tomorrow morning through until 07:00 Wednesday morning. The warning is mirrored in this morning's Flood Guidance Statement which shows Cumbria on low flood risk for tomorrow and Wednesday, the risk derived from surface water with a lower likelihood of any minor river-based impacts.

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Once the rain band finally gets away on Wednesday things are looking to settle down as high pressure starts to build in towards the UK so this will hopefully be the last significant rainfall for a little while. Pending no further changes to the existing warning no further updates to this message are envisaged. However, if there are any changes to report we'll bring them to you tomorrow morning Showed low impact warning for 30 – 60mm locally with 120mm on high ground from 11am on Tuesday to 7am on Wednesday.

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Mon, 22/2/21 at 11:29
The forecast rain on YR has fallen a bit and is now 40mm on Tue and 24m on Wed, so the predicted peak in Thirlmere has also dropped to 16.913m at ~10am on Wed, with a flow of ~1225 Ml/d. So a bit better, but still starting from an overflowing reservoir.

Mon, 22/2/21 at 17:53 LJ email  Those of you not on Facebook I have just pasted a photo of Springs Road storage basin not draining.  Fortunately someone on Springs Road reported it to me earlier today and Doug Coyle (for once in my good books) sent somebody out.  The hydro brake was blocked?!!  Anyway I have asked for a sensor as this was way too random and could have been a disaster if nobody had phoned me - Markus PLEASE KEEP AN EYE OUT.  CCC are getting a water level sensor so long-term this should not be left to chance.

Tue, 23/2/21 at 9:00 Met Desk forecasts for roads in the area still very high, also showing high rain on Wednesday.  (see appendix 2)

Tue, 23/2/21 at 9:05 met Office update Just a brief note to make you aware that overnight the low impact strong wind warning that was in force today across Scotland and N Ireland was extended southwards down the Pennine spine. This reflects the increased likelihood of very gusty conditions particularly affecting the higher level Trans-Pennine routes through until early evening.

A copy of the warning is attached above. Winds apart, the low impact rain warning issued for Cumbria yesterday remains in force with an extended period of rain from this morning running through until later tomorrow. No changes to this warning are envisaged at this point though should any changes come about they will be communicated to you in the normal manner

12.41 on 23/2/21  Basin empty this morning. All ready for storm. I also checked chestnut hill grid and all good their too.

Before dark on Tue 23/2/21 from Low Bridge End

Tue, 23/2/21 at 18:19 from Low Bridge End. Here we go, our beck has gone up steeply and we are well on the way for it to flood, the fields are now going under. Helicopter moved to higher ground. Our increase should show up up on the Thirlmere SJB monitor but I think it tends to spread out there and not show as such a steep rise.

Tue, 23/2/21 at 18:38 EA just phoned but can't give exact info on peak and when. Good to get an update from you Reservoir 16.847 apparently

Tue, 23/2/21 at 18:58 from RDS River is now over the riverbank but has yet to reach the bottom of the steps up to our garden. As far as we are personally concerned no worries.

Tue, 23/2/21 at 20:54 on 23rd Keswick hydrograph already above possible property flooding level.

Tue, 23/2/21 At 19:00 the EA forecast - Gauges upstream are starting to level off. They think the peak at Greta Bridge will be 3.3m to 3.4m at around 8.15pm to 8.30pm. I can't say as I believe them but I hope they are right. We still have a lot of rain to come....

This was the time when, because the rainfall was so difficult to predict, the EA had looked at the rainfall data, added 50% for safety, and came up with the info below as their best guess/worse case scenario.

Tue, 23/2/21 at 19:44 This was my last email. Level has already gone up to 3.35 so I am even less convinced than I was when I sent this out!

Tue, 23/2/21 at 20: 26 Still very wet in St Johns

Tue, 23/2/21 at 20:45 Workington FAG getting concerned

Tue, 23/2/21 at 21:12 Email and Facebook: You will all have seen that the last EA forecast was way out. The latest is that the Greta will peak at around 3.95 which is the level for the park to flood at around 1.30am tomorrow. The EA have people out in Keswick so the gates to the park will be closed because of that forecast. Obviously there is a lot of uncertainty. I have said I find it hard to believe that it will peak in the early hours as there is a lot of rain to come (really until midnight tomorrow) but the EA say that the intensity will ease which is why they think the river will not go up much more. I also pointed out the Facebook comments of the amount of water in Naddle Beck. In the good old days we had the Low Briery gauge which picked up Naddle as well before the gauge at Greta Bridge. The Low Briery Gauge is decommissioned and being replaced by one at Ridings Wood so that misses the Naddle flows, that can't help. They will phone me at any time of the night for any updates and I'll email and post on Facebook if any of you can't sleep!! Chocolate and wine on standby!!

Tue, 23/2/21 at 21: 27 From Low bridge End : Our fields are well under and the water is getting up to our lonnen gate. It must be getting on for five feet deep (usually under a foot) and very fast. We have just moved the pigs into temporary accommodation another ten feet up. It is raining very hard. I noticed how unreliable the Greta bridge guess/forecast is. Glenridding looks as if it might catch it too. Adding Naddle Beck to SJB plus the Glenderamackin (worryingly near Desmond!) does not look very manageable for Keswick, hope the park alleviation and the gates help. Hopefully we will not have to move the cows, they don't have lights! More worried than I expected to be

Tue, 23/2/21 at 21.30 The level in Thirlmere is 17.03m (0.48m over the spillway). Our pleads to get additional releases made in advance of the latest storm fell on deaf ears. Even releases of up to 200Ml/d would have been appreciated.

Tue, 23/2/21 at 21:37 from RDS Second step up to the garden is now under water. It needs to climb a few more steps before (in the past) there were problems in town. Flood defences raised since then. Jill is concerned but I'm not as yet. River can rise quite a bit more before the river troubles us - unless of course a tree or caravan blocks Calvert bridge.

Tue, 23/2/21 at 21:45 Greta Bridge the level is 3.75m and the EA expects it to peak at 4m.

Tue, 23/2/21 at 21:58 We were told that they were to issue the warning for area B which is Fitz Park and Gretaside and that warning level is 3.95 at Greta Bridge. So the latest model is saying that river will peak at Greta Bridge at 4.10m (Ciara was 4.24 at max so just the park flooded, no overtopping although this is uncomfortably close given the modelling being so "off" today) around 1.30am tomorrow as the rain is supposed to ease and shift to the east for a while. It will wax and wane all tomorrow but they don't think there will be further peaks. I have pointed out that I have just heard from St Johns Vale that the beck is very high and rain still very intense AND the Naddle info but they seem reasonably Ok with the current suggestion so I am taking it with a pinch of salt - and a good deal of hope

Tue, 23/2/21 at 22:00 The water level in St John's Beck was an impressive 1.01m (an increase of 0.54m over the day) and it is still raining hard in that area. With the water level in Thirlmere being 17.03m that means about 1864Ml/d is overtopping into St John's Beck. The water level of the Glenderamackin at Threlkeld was 2.32m at 22.00 a rise of 1.62m over the day. In short I do not envisage any problems from the river in our area – as long as there are no trees or caravans getting stuck under Calvert Bridge!

Tue, 23/2/21 at 22:06 from D Coyle Lynne Both Elliot Park and Penrith Road Pumping stations are working. Pumps are running frequently at both sites

Tue, 23/2/21 at 22:36 The Greta is currently about a yard below the top of Arkanum's riverside wall so well below Lydia's Cottages' floor levels. The EA does not expect it to rise much further.

Tue, 23/2/21 at 23:54 Rain is easing here and there seems quite a break from intense rain until around 10am tomorrow so there is a bit of time for the catchment and levels to recover. The Greta's rise has slowed down and so I think we can all breathe a sigh of relief.

Wed, 24/2/21 at 5:00 Thirlmere peaked at 17.19. Ciara maximum was 17.20 That means that the water level was over the spillway by .64m and the reservoir area is ~3.25sq Km. Yes, Thirlmere is holding it back, all that water will be flowing through Keswick in the coming hours/days

Wed, 24/2/21 at 9:49 Met Desk showed Smaithwaite A591 rainfall 72.5mm. (see appendix 3) The Met Office forecast was for rain to stop 6am and be heavy again 14:00 to 21:00 YrNo & the BBC forecast 1mm of rain 6:00 to 18:00 easing off 19:00 onwards. **Our salvation came because the rain eased and went east at around midnight.**

25/2/21 13.09 Thirlmere is still 0.33m over the spillway.

# Record of River Levels during Events of 19th to 25th February 2021 and Comparison with Storm Ciara 8th to 9th February 2020

| | | River levels in m.cm | | | River levels February 2021 doc in KFAG 2021 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Thirlmere | St John's Beck | Glendermackin | Greta Bridge | Portinscale | Lodore | Castle Howe | Ouse Bridge |
| 19-02-21 | 22.30 | 16.29 | 0.51 | 1.91 | 3.01 | 1.91 | 1.97 | 1.75 | 1.51 |
| | 22.45 | 16.31 | 0.51 | 1.88 | 2.94 | 1.93 | 1.99 | 1.77 | 1.52 |
| | 23.15 | 16.34 | 0.51 | 1.82 | 2.98 | 1.95 | 2.04 | 1.83 | 1.55 |
| | | | | | | | | | |
| 20-02-21 | 4.30am | 16.49 | 0.49 | 1.36 | 2.27 | | 2.29 | 2.12 | 1.90 |
| | 11.00 | 16.60 | ..41 | 1.09 | 1.83 | 1.77 | 2.33 | 2.35 | 2.06 |
| | 16.45 | 16.84 | 0.71 | 1.66 | 2.50 | 2.05 | 2.38 | 2.48 | 2.18 |
| | 23.00 | 16.87 | 0.81 | 1.55 | 2.57 | 2.09 | 2.44 | 2.61 | 2.28 |
| | | | | | | | | | |
| 21-02-21 | dry day | | | | | | | | |
| | | | | | | | | | |
| 22-02-21 | 9am | 16.75 | 0.57 | 0.85 | 1.57 | 1.44 | 2.07 | 2.55 | 2.22 |
| | | | | | | | | | |
| | | | | | | | | | |
| 23-02-21 | 9.00 | 16.70 | 0.49 | 0.70 | | | | | |
| | 9.45 | | | | 1.40 | 1.16 | 1.77 | 2.30 | 2.04 |
| | | | | | | | | | |
| | 15.00 | 16.68 | 0.48 | 0.94 | | 1.20 | 1.74 | 2.22 | 1.93 |
| | 17.00 | | 0.58 | 1.71 | 2.28 | 1.54 | 1.77 | 2.22 | 1.93 |
| | 18:15 | 16.84 | 0.70 | 2.06 | 2.99 | 1.82 | 1.84 | 2.23 | 1.96 |
| | 18:30 | 16.85 | 0.73 | 2.10 | 3.11 | 1.87 | 1.86 | 2.28 | 1.96 |
| | 19:00 | 16.88 | 0.79 | 2.16 | 3.28 | 1.96 | 1.90 | 2.25 | 1.98 |
| | 19.15 | 16.93 | 0.81 | 2.18 | 3.35 | 2.00 | 1.92 | 2.28 | 1.97 |
| | 19.30 | 16.94 | 0.84 | 2.19 | 3.40 | 2.03 | 1.95 | 2.25 | 1.99 |
| | 19.45 | 16.91 | 0.86 | 2.21 | 3.44 | 2.06 | 1.97 | | |
| | 20.00 | 16.97 | 0.88 | 2.22 | 3.47 | | | | |
| | 20.30 | | | | | | | | |
| | 20.45 | 16.98 | 0.94 | 2.26 | 3.66 | 2.17 | 2.06 | 2.29 | 2.02 |
| Ciara Max | | 17.20 | 1.32 | 2.44 | 4.24 | | 2.94 | | 2.64 |
| | | | | | | | | | |
| Date | Time | Thirlmere | St John's Beck | Glendermackin | Greta Bridge | Portinscale | Lodore | Castle Howe | Ouse Bridge |
| Date | Time | Thirlmere | St John's Beck | Glendermackin | Greta Bridge | Portinscale | Lodore | Castle Howe | Ouse Bridge |
| 23-02-21 | 21.00 | 16.99 | 0.96 | 2.27 | 3.72 | 2.19 | | | |
| | 22.00 | 17.04 | 1.01 | 2.32 | 3.77 | 2.23 | 2.18 | 2.34 | 2.05 |
| | 22.30 | 17.07 | 1.04 | 2.32 | 3.79 | 2.25 | 2.22 | 2.37 | 2.07 |
| | 23.00 | 17.09 | 1.07 | 2.32 | 3.81 | 2.26 | 2.27 | 2.38 | 2.08 |
| | 23.30 | 17.11 | 1.10 | 2.31 | 3.82 | 2.28 | 2.32 | 2.41 | 2.10 |
| 24-02-21 | 00.15 | 17.12 | 1.13 | 2.27 | 3.84 | 2.30 | 2.39 | 2.44 | 2.13 |
| | 04.30 | 17.17 | 1.23 | 1.85 | 3.50 | 2.36 | 2.72 | 2.62 | 2.28 |
| | 4.45 | 17.18 | 1.25 | 1.83 | 3.50 | 2.36 | 2.75 | 2.62 | 2.29 |
| | 5.00 | 17.19 | 1.25 | 1.81 | 3.48 | 2.36 | 2.75 | 2.63 | 2.30 |
| | 5.15 | 17.18 | 1.24 | 1.79 | 3.47 | 2.37 | 2.76 | 2.64 | 2.31 |
| | 9.45 | 17.15 | 1.19 | 1.38 | 3.09 | 2.39 | 2.89 | 2.81 | 2.45 |
| | | | | | | | | | |
| | | | | | | | | | |
| | 18.30 | | | | | | 2.96 | | |
| | | | | | | | | | |
| 25-02-21 | 5.15 | | | | | | | | 2.61 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Ciara Max | | 17.20 | 1.32 | 2.44 | 4.24 | | 2.94 | | 2.64 |
| Date | Time | Thirlmere | St John's Beck | Glendermackin | Greta Bridge | Portinscale | Lodore | Castle Howe | Ouse Bridge |

# Forecast Rainfall from Met Office on 21st to 24th February 2021

23.42 on 21/2/21

| Search | Radar (mm) | | | | | | | | | Forecast (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Last 24h | 20-21 | 21-22 | 22-23 | 23-00 | 00-01 | 01-02 | 03-15 | 15-03 | Mon | Tue | Wed | Thu | Fri |
| 01 - A29 Northside (A597) | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.4 | 0.7 | 0.0 | 1.5 | 35.7 | 28.1 | 0.9 | 0.0 |
| 02 - A3 Derwent (Gote) (A5086) | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.7 | 0.7 | 1.0 | 0.0 | 1.9 | 41.7 | 31.2 | 1.2 | 0.0 |
| 03 - A50 Ouse (B5291) | 0.2 | 0.0 | 0.0 | 0.2 | 0.7 | 0.7 | 0.5 | 1.2 | 0.0 | 2.1 | 42.3 | 29.0 | 1.1 | 0.0 |
| 04 - A49 Dubwath (B5291) | 0.2 | 0.0 | 0.0 | 0.1 | 0.6 | 0.6 | 0.5 | 1.2 | 0.0 | 2.2 | 43.3 | 29.6 | 1.2 | 0.0 |
| 05 - A15 North Row (A591) | 0.8 | 0.0 | 0.0 | 0.7 | 0.8 | 0.8 | 0.5 | 1.3 | 0.0 | 2.2 | 42.8 | 28.5 | 1.1 | 0.0 |
| 06 - A9 Chapel (Bassenthwaite) (A591) | 0.7 | 0.0 | 0.0 | 0.7 | 0.9 | 0.9 | 0.5 | 1.3 | 0.0 | 2.3 | 43.2 | 28.6 | 1.1 | 0.0 |
| 07 - A13 Lair Beck (A591) | 0.3 | 0.0 | 0.0 | 0.3 | 0.8 | 0.9 | 0.6 | 1.5 | 0.0 | 2.8 | 49.6 | 31.9 | 1.5 | 0.0 |
| 08 - A34 Derwent (Keswick) (B5289) | 0.2 | 0.0 | 0.0 | 0.2 | 0.7 | 0.9 | 0.6 | 1.5 | 0.0 | 2.8 | 50.8 | 32.7 | 1.6 | 0.0 |
| 09 - A165 Pow (C2057) | 0.2 | 0.0 | 0.0 | 0.1 | 0.7 | 0.8 | 0.6 | 1.5 | 0.0 | 2.7 | 51.3 | 33.1 | 1.6 | 0.0 |
| 10 - A6 Greta (A5271) | 0.3 | 0.0 | 0.0 | 0.3 | 0.9 | 0.9 | 0.6 | 1.5 | 0.0 | 2.8 | 50.4 | 32.5 | 1.5 | 0.0 |
| 11 - A90 Townfield (B5322) | 1.2 | 0.0 | 0.2 | 0.9 | 0.8 | 0.9 | 0.6 | 1.6 | 0.0 | 3.1 | 45.9 | 29.7 | 1.0 | 0.0 |
| 12 - A19 Smaithwaite (A591) | 2.5 | 0.0 | 1.0 | 1.0 | 1.2 | 0.9 | 0.6 | 1.7 | 0.0 | 3.4 | 49.8 | 34.6 | 1.3 | 0.0 |
| 13 - A163 Grange (C2057) | 2.8 | 0.0 | 0.8 | 1.5 | 1.4 | 0.8 | 0.6 | 1.6 | 0.0 | 3.1 | 55.5 | 38.2 | 1.9 | 0.0 |
| 14 - A45 Strands (B5289) | 1.5 | 0.0 | 0.3 | 1.0 | 1.6 | 0.7 | 0.6 | 1.7 | 0.0 | 3.3 | 58.4 | 41.5 | 2.1 | 0.0 |

9AM on 23/2/21

| Search | Radar (mm) | | | | | | | | | Forecast (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Last 24h | 06-07 | 07-08 | 08-09 | 09-10 | 10-11 | 11-12 | 12-00 | 00-12 | Wed | Thu | Fri | Sat | Sun |
| 01 - A29 Northside (A597) | 2.3 | 0.0 | 0.1 | 0.8 | 0.2 | 0.0 | 0.0 | 26.2 | 8.0 | 19.4 | 1.9 | 0.0 | 0.0 | 0.0 |
| 02 - A3 Derwent (Gote) (A5086) | 1.8 | 0.1 | 0.1 | 0.7 | 0.4 | 0.1 | 0.0 | 32.0 | 9.9 | 21.9 | 2.7 | 0.0 | 0.0 | 0.0 |
| 03 - A50 Ouse (B5291) | 3.0 | 0.0 | 0.8 | 1.4 | 0.9 | 0.2 | 0.0 | 31.8 | 10.7 | 22.6 | 2.5 | 0.0 | 0.0 | 0.2 |
| 04 - A49 Dubwath (B5291) | 3.2 | 0.0 | 0.9 | 1.5 | 0.8 | 0.2 | 0.0 | 32.6 | 10.8 | 22.8 | 2.6 | 0.0 | 0.0 | 0.2 |
| 05 - A15 North Row (A591) | 3.0 | 0.0 | 0.8 | 1.5 | 1.1 | 0.2 | 0.0 | 32.0 | 10.9 | 22.9 | 2.5 | 0.0 | 0.0 | 0.2 |
| 06 - A9 Chapel (Bassenthwaite) (A591) | 3.0 | 0.0 | 0.8 | 1.4 | 1.2 | 0.2 | 0.0 | 32.3 | 11.0 | 23.0 | 2.5 | 0.0 | 0.0 | 0.2 |
| 07 - A13 Lair Beck (A591) | 2.7 | 0.0 | 0.5 | 0.6 | 0.4 | 0.0 | 0.0 | 37.8 | 12.1 | 24.9 | 2.9 | 0.0 | 0.0 | 0.2 |
| 08 - A34 Derwent (Keswick) (B5289) | 2.2 | 0.0 | 0.2 | 0.4 | 0.4 | 0.1 | 0.0 | 38.7 | 12.2 | 25.1 | 3.1 | 0.0 | 0.0 | 0.2 |
| 09 - A165 Pow (C2057) | 2.2 | 0.0 | 0.2 | 0.4 | 0.4 | 0.1 | 0.0 | 39.1 | 12.3 | 25.2 | 3.1 | 0.0 | 0.0 | 0.2 |
| 10 - A6 Greta (A5271) | 2.7 | 0.0 | 0.5 | 0.6 | 0.4 | 0.0 | 0.0 | 38.6 | 12.2 | 25.1 | 3.0 | 0.0 | 0.0 | 0.2 |
| 11 - A90 Townfield (B5322) | 3.0 | 0.0 | 0.9 | 0.8 | 0.8 | 0.0 | 0.0 | 35.4 | 11.7 | 24.4 | 2.6 | 0.0 | 0.0 | 0.2 |
| 12 - A19 Smaithwaite (A591) | 5.0 | 0.2 | 1.6 | 1.4 | 0.4 | 0.0 | 0.0 | 39.9 | 12.6 | 26.5 | 2.8 | 0.0 | 0.0 | 0.2 |
| 13 - A163 Grange (C2057) | 7.3 | 0.1 | 2.1 | 2.3 | 0.2 | 0.0 | 0.0 | 44.4 | 13.3 | 27.7 | 3.3 | 0.0 | 0.0 | 0.1 |
| 14 - A45 Strands (B5289) | 5.8 | 0.2 | 1.0 | 0.9 | 0.1 | 0.0 | 0.0 | 47.8 | 14.0 | 29.2 | 3.5 | 0.0 | 0.0 | 0.1 |

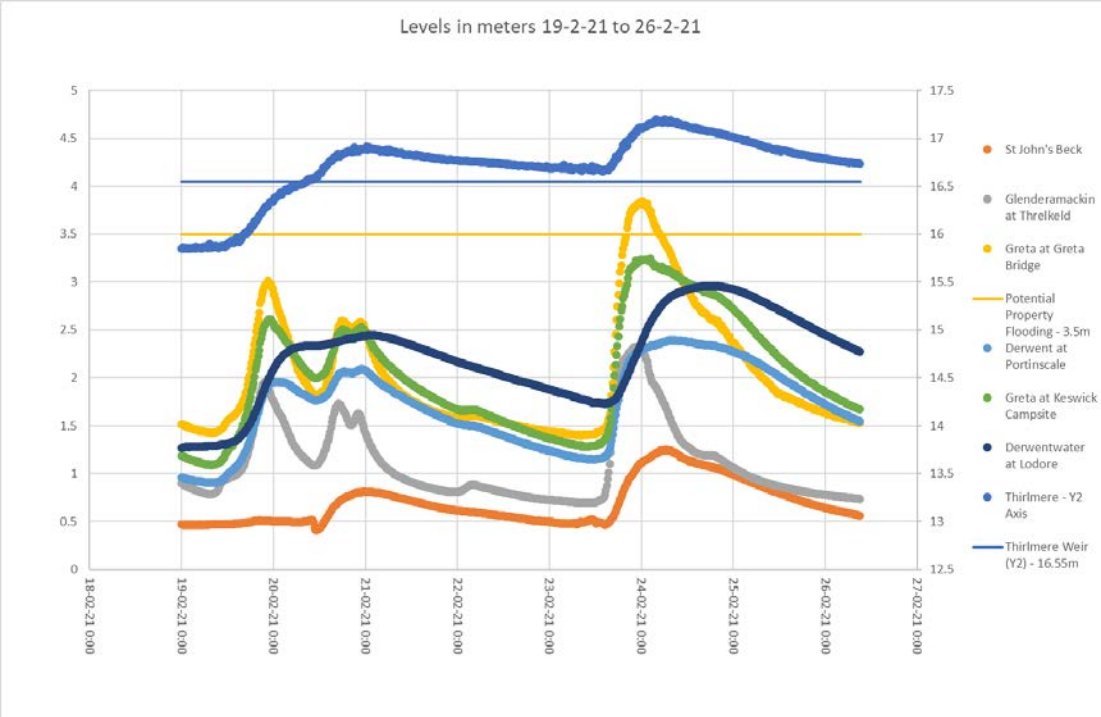
9.49 on 24/2/21.

Search

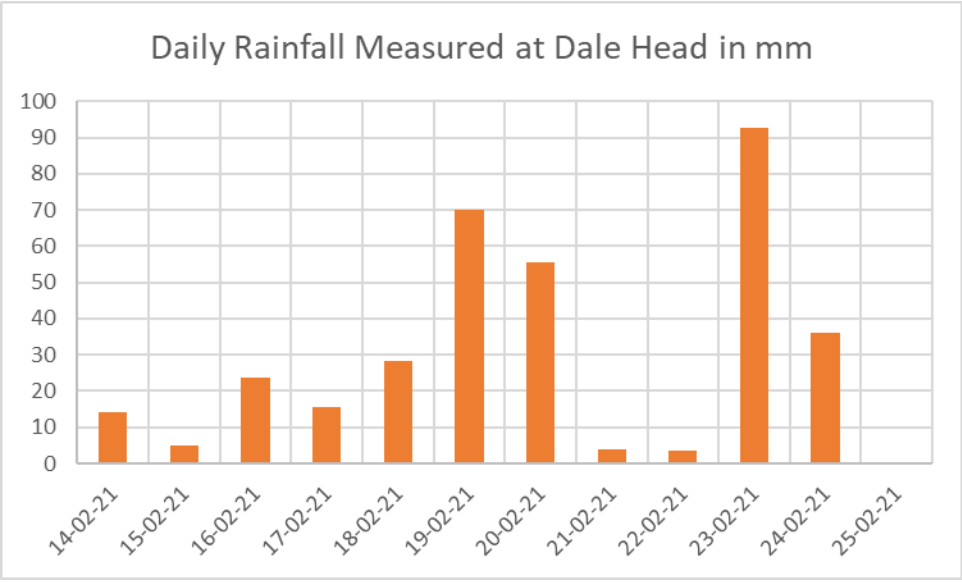
| | Radar (mm) | | | | | | | | | Forecast (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Last 24h | 06-07 | 07-08 | 08-09 | 09-10 | 10-11 | 11-12 | 12-00 | 00-12 | Thu | Fri | Sat | Sun | Mon |
| 01 - A29 Northside (A597) | 16.0 | 0.6 | 0.8 | 0.2 | 0.2 | 0.0 | 0.0 | 7.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 02 - A3 Derwent (Gote) (A5086) | 17.7 | 0.9 | 0.5 | 0.1 | 0.2 | 0.1 | 0.0 | 9.4 | 0.4 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| 03 - A50 Ouse (B5291) | 39.3 | 1.4 | 0.3 | 0.2 | 0.5 | 0.2 | 0.0 | 10.1 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 04 - A49 Dubwath (B5291) | 38.0 | 1.1 | 0.2 | 0.2 | 0.5 | 0.2 | 0.0 | 10.2 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 05 - A15 North Row (A591) | 54.6 | 1.6 | 0.2 | 0.1 | 0.6 | 0.2 | 0.0 | 10.4 | 0.7 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 06 - A9 Chapel (Bassenthwaite) (A591) | 56.7 | 1.5 | 0.2 | 0.1 | 0.6 | 0.3 | 0.0 | 10.4 | 0.7 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 07 - A13 Lair Beck (A591) | 31.5 | 0.7 | 0.2 | 0.2 | 1.0 | 0.4 | 0.1 | 11.0 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 08 - A34 Derwent (Keswick) (B5289) | 24.0 | 0.5 | 0.1 | 0.2 | 1.0 | 0.3 | 0.1 | 11.1 | 0.7 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 09 - A165 Pow (C2057) | 23.0 | 0.5 | 0.2 | 0.2 | 0.9 | 0.3 | 0.1 | 11.1 | 0.7 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 - A6 Greta (A5271) | 28.5 | 0.6 | 0.2 | 0.2 | 1.0 | 0.3 | 0.1 | 11.1 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 - A90 Townfield (B5322) | 57.0 | 1.3 | 0.8 | 1.0 | 1.5 | 0.4 | 0.2 | 10.7 | 0.3 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 - A19 Smaithwaite (A591) | 72.5 | 0.6 | 0.3 | 0.9 | 1.1 | 0.3 | 0.1 | 11.1 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 - A163 Grange (C2057) | 59.7 | 1.3 | 0.6 | 0.5 | 1.2 | 0.3 | 0.1 | 11.5 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 - A45 Strands (B5289) | 37.2 | 0.7 | 0.7 | 0.9 | 1.0 | 0.2 | 0.0 | 11.7 | 0.6 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |

## River and Lake Levels and Rainfall graphs

River and Lake levels from 19th to 26th February 2021. Thirlmere level is on the Y2 axis.




Actual Rainfall Recoded at Dale Head



## Met office feedback

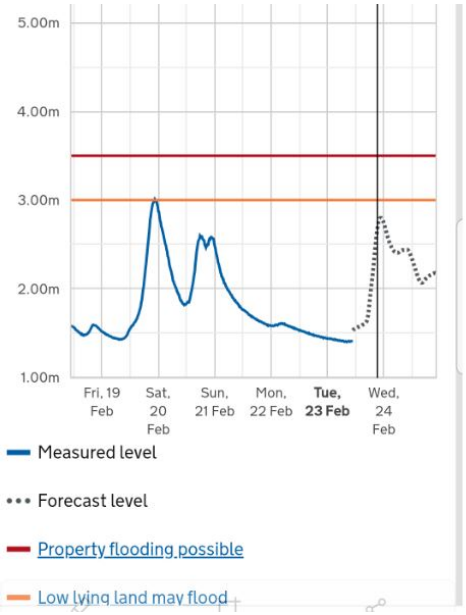
1. Draft Flood Guidance Statement (FGS) for Monday 22nd morning covering Mon to Fri was low likelihood of low impacts (green) for Cumbria for rivers and surface water on the Tuesday and Wednesday.
2. I checked the forecast rainfall totals for Cumbria and, noting the duration of the event also, feel we need some sort of warning out for Cumbria, especially coming relatively soon after the Thu/Fri rain. On the 09:45 FGS teleconference hosted by the Flood Forecasting Centre (FFC) I argue to go yellow for at least surface water and say I have already heard concerns from local flood response groups (KFAG) about the risk posed from the forthcoming event. EA on the conference are happy to stay green for rivers. (Understand that I can't argue for elevated river-based flood risk on the basis of a personal hunch.) The decision for the finalised FGS will await discussions between myself and the Chief Meteorologist at the Met Office.
3. After consultation with the Met Office Chief Meteorologist he's in accord with my concerns and happy to issue the yellow warning for Cumbria but, in tandem with the FFC verdict, will major on surface water impacts.
4. Warning is issued and the FGS issued the following day (Tuesday) stays the same (green for rivers, yellow for surface water).
5. Greta flood warnings are subsequently issued later Tuesday (17:59) as rainfall totals mount up.

That covers the main points. The MO warning was good, the EA river assessment (low likelihood of low impacts) was not strictly calamitous (in terms of what actually happened) but they underestimated the response of the Greta.

Hope that covers things. Happy to speak direct with the EA if required, we need to be working together on these matters.

## Forecast and Actual Greta Bridge Levels Prior to and During the Rainfall Event of 23-24 February 2021

On 23/2/21 at approximately 10am the River level information for River Greta at Greta Bridge - GOV.UK (flood-warning-information.service.gov.uk) website showed the River Greta level to be ~1.45m, with a predicted peak on 24/2/21 of ~2.8m, below the level of any likely flooding (see right).

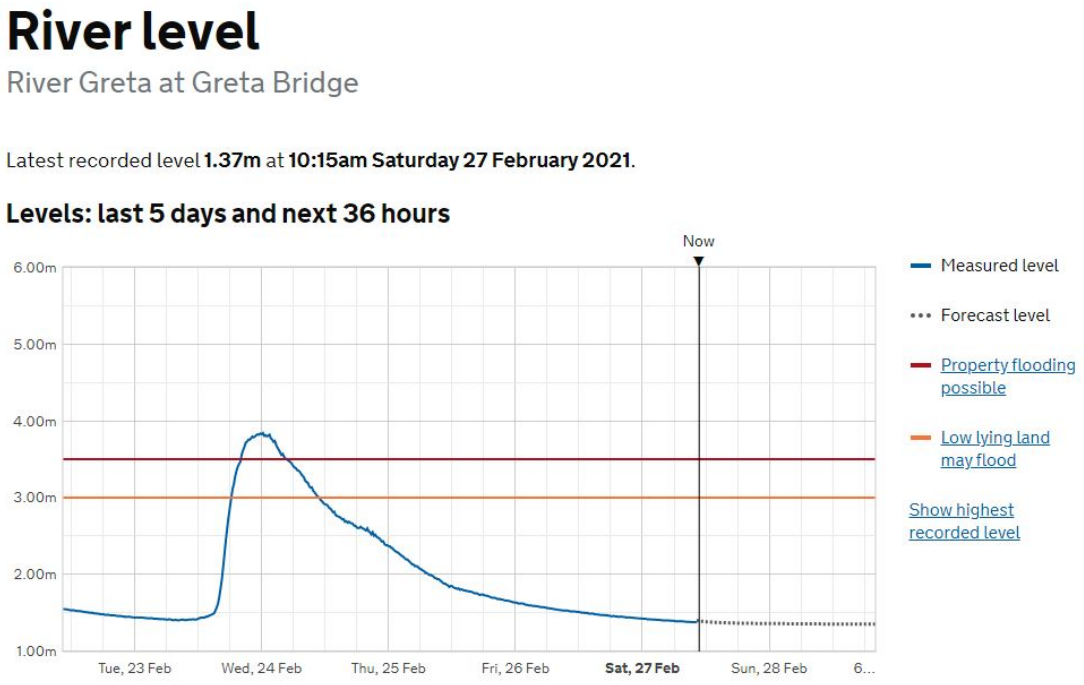



A previous rain event on 19/2/21 had given a peak of 3m (also in graph to right).

On 21/2/21 the forecast rainfall (YR website, Norwegian Meteorological Institute and NRK) at Dale Head for 23 and 24 February was 98mm (54mm and 44mm respectively). Therefore, the predicted level would be expected to be higher than the 3m reached on 19/2/21, but was actually shown on the graph above to be lower, at around 2.8m.

This prediction does not fit with the forecast, and in showing a level below that of any likelihood of flooding, was very misleading.

During the rainfall of 23-24/2/21, the actual level at Greta Bridge reached 3.84m, way above that predicted, and above both the lines indicating probability of flooding, confirming how poor the prediction just a couple of hours before the event was (see graph below).



**Prediction of Greta Bridge Level by Simple Ratios**

Below I have tried to predict the level at Greta Bridge from simple ratios of rainfall (actual and forecast) across the catchment and size of catchment involved, all of which was available as of 21/2/21, well before the actual event.

Thirlmere was not overspilling on 19/2/21, therefore its part of the catchment did not contribute to the Greta Bridge peak on that day. It was overspilling throughout 23-24/2/21, and therefore did contribute.

Assuming direct proportionality of rainfall to level gives a predicted level of 4.4m, higher than the 3.84m actually recorded.

As the volume of rivers is generally not linear with level, (eg banks are not vertical, and any flooding greatly increase the spread of a given volume without a level rise), a square root relationship was also calculated, giving a predicted peak level of 3.94m, which is much closer to the 3.84m recorded.

Therefore simple rainfall ratios using forecasts, in this particular circumstance, seem to provide a much better prediction of level at Greta Bridge than whatever calculation was used by the government website.

| | |
|---|---|
| Rainfall on 19/2/21 - mm | 70 |
| Rainfall Predicted for 23-24/2/21 - mm | 98 |
| Rise in level at Greta Bridge on 19/2/21 - m | 1.5 |
| Therefore for the same catchment area (104.3 km2) rise expected from rainfall on 23-24/2/21 - m | 2.1 |
| Increased catchment area due to Thirlmere overspilling on 23-24/2/21 - km2 | 42 |
| Therefore increase in Greta Bridge level including Thirlmere catchment - m | 2.95 |
| **Therefore predicted level for 23-24/2/21 accounting for rainfall forecast and Thirlmere overspill - m** | **4.40** |
| Or using square root relationship ie level is proportional to the root of rainfall: | |
| | |
| Therefore for the same catchment area (104.3 km2) rise expected from rainfall on 23-24/2/21 - m | 1.77 |
| Increased catchment area due to Thirlmere overspilling on 23-24/2/21 - km2 | 42 |
| Therefore increase in Greta Bridge level including Thirlmere catchment - m | 2.49 |
| **Therefore predicted level for 23-24/2/21 accounting for rainfall forecast and Thirlmere overspill - m** | **3.94** |

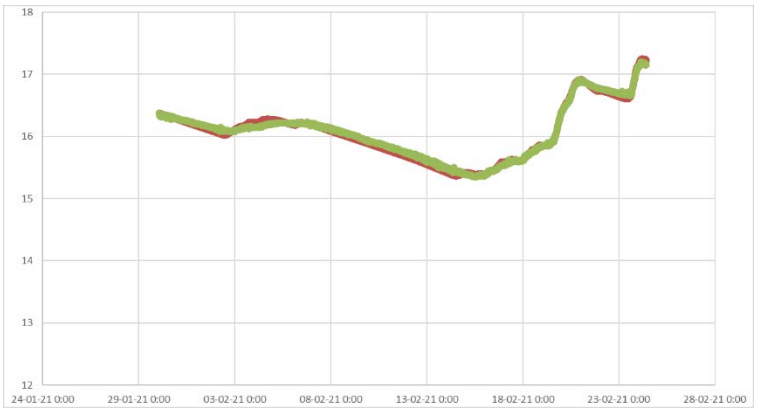
## Use of the Thirlmere Water Balance Model to Demonstrate the effect of Actual and Potential Level Management Scenarios

The Thirlmere reservoir water balance model, developed by Alistair Cook and Ed Henderson in 2018, has been used firstly to obtain a fit with the actual Thirlmere level data between 1st and 25th February 2021, and then to model the effects of various trigger levels and release flows on the level and resultant overspill from the reservoir into St John's Beck. The conclusions are:

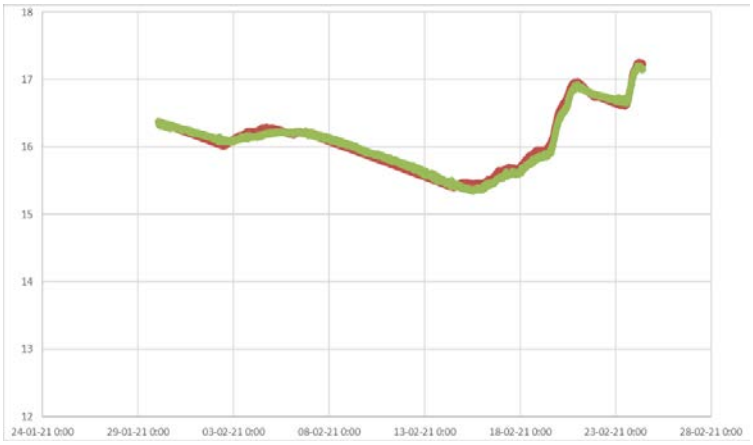
- The increased trigger flow of 200 ML/d from 12/2/21 made no significant difference to the maximum overspill of 3250 ML/d on 24/2/21, therefore had no benefit over the normal 140 ML/d.
- If 400 ML/d trigger release had been used over then entire period modelled (30/1/21 to 24/2/21) the maximum overspill would have reduced slightly to 3100 ML/d. 700 ML/d would have reduced it much more significantly to 1400 ML/d.
- Therefore for the rainfall scenario that occurred, with 2 significant events just 2 days apart, a 700 ML/d trigger release could have significantly reduced overspill flow by ~57%, and flow at Greta bridge by ~17%.
- If a trigger level of 2m rather than the current 1m for Jan and Feb were used, the maximum overspills on 24/2/21 for actual, 400 and 700 ML/d releases would have been 3250 ML/d, 190 ML/d and zero (ie no overspill). This last scenario (2m trigger and 700 ML/d) is what is called for in the KFAG Memorandum.

Graphs of the fit to actual data and the 6 scenarios are presented below.

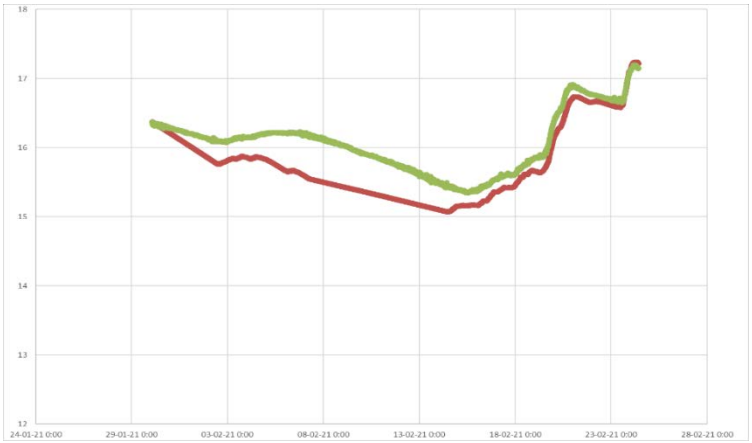
Base case fitting showing agreement between actual Thirlmere level (green) and modelled level (red). This incorporates the increased release rate of 200 ML/d from 12/2/21, with the normal February trigger level of 1m below the weir, ie 15.55m. Maximum overspill rate on 24/2/21 of 3250 ML/d. Maximum level reached at Greta Bridge was 3.84m



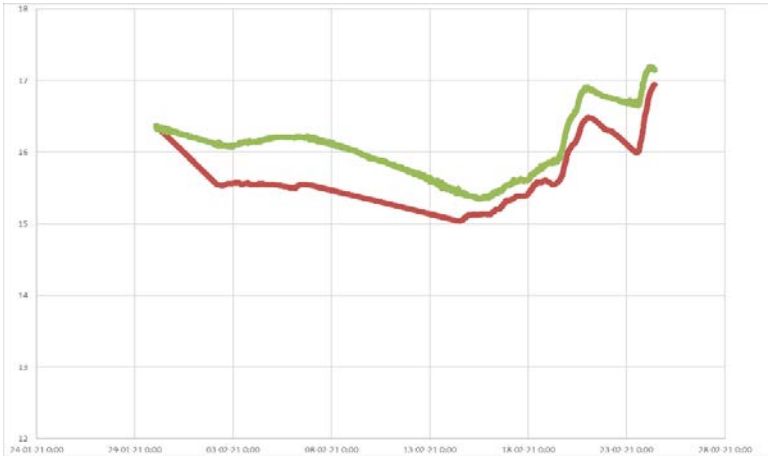
Effect of retaining the normal 140 ML/d trigger release throughout (ie 140 ML/d rather than 200 ML/d from 12/2/21). Maximum overspill rate 3260 ML/d on 24/2/21, ie no effective difference and therefore no benefit in the event from the increase trigger release.




Effect of a 400 ML/d trigger release throughout the period. Maximum overspill on 24/2/21 slightly reduced to 3100 ML/d due to decrease reservoir level prior to major rainfall from 19/2/21.

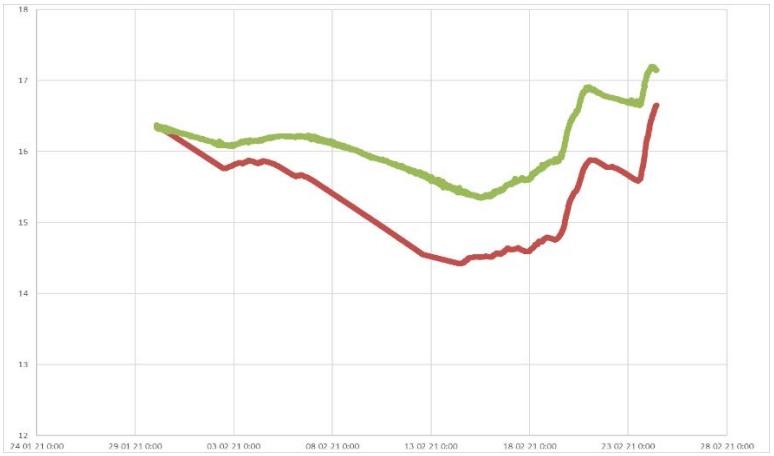



Effect of 700ML/d trigger release throughout the period. Overspill on 19/2/21 is prevented, allowing the trigger release to operate in period between rainfalls (20-22/2/21). Maximum overspill on 24/2/21 reduced significantly to 1400 ML/d. This would have reduced peak flow at Greta Bridge by ~17%.



Effect of 2m trigger level (rather than actual 1m) but all else as base case. There is no difference as the level does not fall below a 1m trigger level for any significant time to allow the 2m trigger to have an effect.


Effect of 2m trigger level and 400 ML/d throughout. Maximum overspill greatly reduced to ~190 ML/d on 24/2/21. This effectively removes the Thirlmere catchment (42km$^2$) from the Greta catchment, reducing it by 29% and would give a similar reduction in peak flow at Greta Bridge.



Effect of 2m trigger level and 700 ML/d. No overspill as weir not reached. This eliminated the Thirlmere catchment entirely from the Greta. In this scenario the peak level at Greta Bridge would be similar to that on 19/2/21 (3.01m).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