WWRP Warning Value Chain Project

Warning Chain Database Questionnaire

I. Purpose

This questionnaire (template) provides for a comprehensive picture of the end-to-end production and flow of information and decision making along the warning chain during a hazardous weather event.

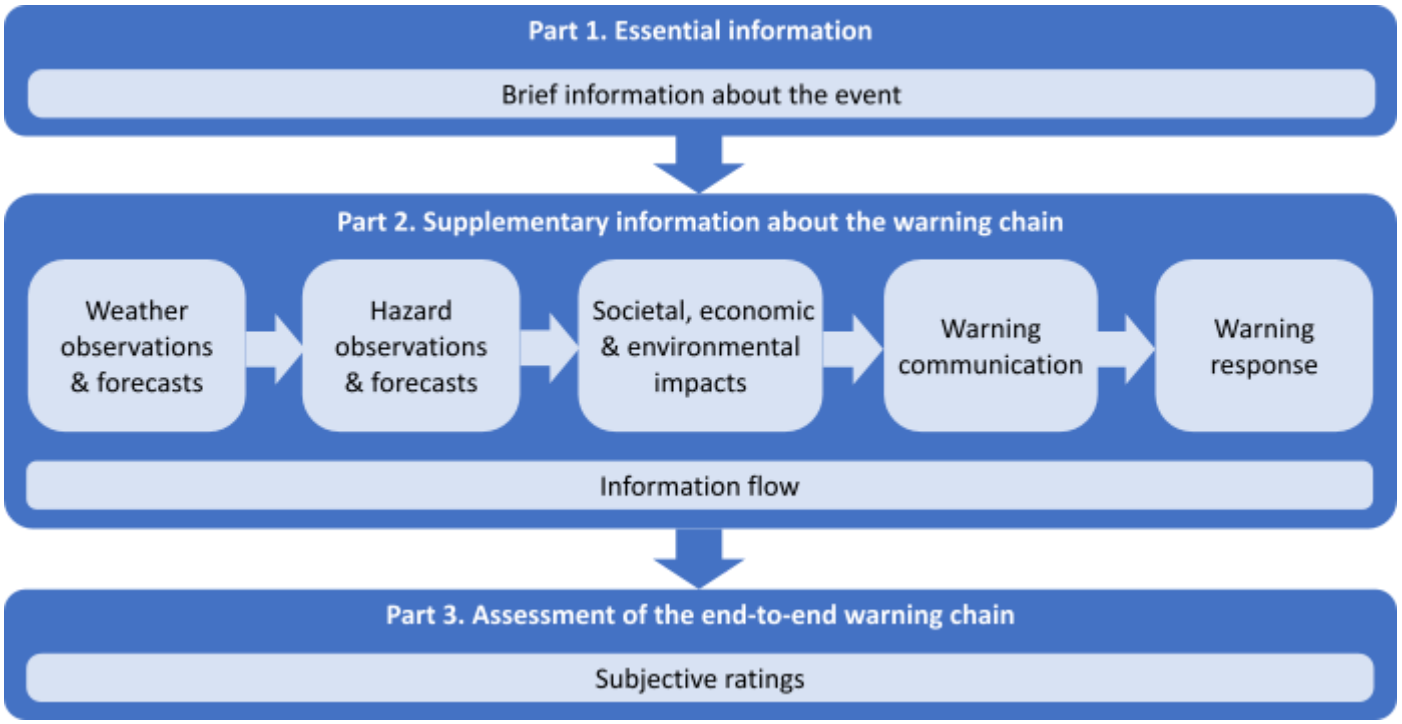
Please use this template to record as much information as possible on the end-to-end warning chain for a particular hazardous weather event. This information will:

- add to a global database of hazardous weather events with rich information covering the many components of the warning value chain,
- enable case studies and cross-cutting analysis of end-to-end warning value chains, from simple to complex, to understand effective practices,
- support the value cycle of review and learning from past events to identify improvements that would enhance future warnings.

More information about the WWRP Warning Value Chain Project can be found at http://hiweather.net/Lists/130.html.

II. Structure and format

The questionnaire consists of three main parts.



Part 1. The **essential information table** requests brief facts about a particular event, such as what happened, when, where, impacts and responses. This information will help users to filter events. Please provide numerical and short text entries. Links to this event in other databases and catalogues (e.g., ECMWF Severe Event Catalogue, EM-DAT, DesInventar, etc.) about this event should be provided if possible.

Part 2. The second part requests **supplementary information** about different stages in the warning value chain. This more detailed information and analysis about the weather, hazards, impacts, warning communication and warning response will help users understand what was unique about the warning chain for this event. The questions in Part 2 probe many aspects of the warning chain but are not exhaustive. Information here might include:

- Graphics (for example, forecast charts, reanalysis maps, warning graphics, photos of impacts, etc.).
- Videos (for example, from social media, weather service outlooks, etc.).
- Free-form text (for example, description of meteorology, selected extracts from reports, data analysis, tables, etc.)
- Links (e.g., to external reports, media, national archives, etc.)

Each section has an "additional analysis" where you can add further information not covered by the items in the questionnaire.

It is not required to complete Part 2, but please provide what information you can. Try to keep your entries brief and include references and links (URLs) to where additional information can be found. Attribute all material that may be subject to copyright (e.g., images and videos).

Many people may contribute information on this event. Where you disagree with another contributor try to provide evidence to support your position. You may wish to acknowledge information providers at the end of the template before Annex 1.

Part 3. The **subjective assessment** asks contributors to rate the effectiveness of the individual elements of the end-to-end warning chain, and its overall effectiveness, on a scale of 1 (poor) to 5 (excellent). This may assist users of the database in choosing cases and performing meta-analysis (recognising the large variability in contributors' judgments).

The accompanying Guide for the Warning Chain Database Questionnaire[1] provides explanation and examples of the type of information that is requested in the questionnaire.

III. How to add resources

Resources for Part 2 (e.g., reports, graphics, data, and other information not easily accessible to the public) should be stored in the event data library of the respective case study. Brief resources such as forecast maps and warning graphics should be inserted directly into the corresponding section of the template. Reports and extensive graphics are not suitable to be embedded in the template but should be referred to. Please store the resources in the event data library first and then insert as a hyperlink to the template. To do so, follow these steps:

1. Go to the event data library on Google Drive (open to anyone).
2. For an existing case study, locate the folder for the event for which you would like to add resources. If the event does not exist yet in the library, refer to the README guide to open a new case study (project members only). If you are a project external contributor, please contact valuechain@bom.gov.au to open a new case study.
3. Place your resource in the folder and give an appropriate name so others know what it is about.
4. Right-click the file you want to embed/refer to and select 'Copy link' to retrieve the hyperlink pointing to the file.
5. In the template, use 'Insert Hyperlink' to paste the hyperlink in the appropriate place.

IV. Tips

- The Value Chain Glossary provides a common terminology.

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1 https://docs.google.com/document/d/1xZENrxLcn3250z-cANHpqRtU9gK7OQxj/edit?usp=sharing&ouid=106255653981108702821&rtpof=true&sd=true

- To assist with searching the database, please use the names of hazard types listed in *Annex 1* of this template.
- A series of prompts (i) in this template provide some quick information to assist with entering the requested data. Simply put your cursor over the information symbol i and text should pop up next to it (ignore the "Ctrl+click to follow link" instruction). *Note, that this feature is only available in the Microsoft Word App, not in the SharePoint or Google Drive browser page.* If this feature does not work for you, please consult the Guide instead.
- A single person may not be able to fill in the entire template. We encourage you to share the template with colleagues who can provide information.
- A worked example of the template is here.
- Questions on the use of this template can be directed to valuechain@bom.gov.au.

V. Completed questionnaire

The completed questionnaire should be stored in the event data library of the respective case study, or sent to valuechain@bom.gov.au.

Part 1. Essential information

Editors (Name & Institute)	*David Hoffmann (BOM)*

HAZARDOUS WEATHER EVENT		
Unique identifier i	*(This will be added by the Project Team at a later date)*	
Name of event	NSW March 2021 heavy rain and flood event	
When did it happen i?	17 to 24 March 2021 (~ 8 days)	
Where did it happen i?	Eastern Australian (inland and coastal NSW)	☐ *rural* ☐ *urban*
Links/UIDs to other databases *(ECMWF catalogue of severe events, WMO CHE, DesInventar, EM-DAT, GLIDE, etc.)*	For BoM people: NSW Sharepoint folder on this event ECMWF Severe Event Catalogue	
WHAT HAPPENED – WEATHER, HAZARDS, IMPACTS, WARNINGS, RESPONSES		
Weather event type/system that caused hazards i *Refer to Annex 1*	Cyclonic storm, rain	
If possible, provide more detail about weather observations & forecasts *(link to page)*		
Were any hazards forecast?	☒ yes ☐ no	
Hazards that caused the main impacts i *Refer to Annex* 1	Flood	
Classify hazard according to the location's climatology i	*1/5 to 1/10 year event*	
If possible, provide more detail about hazard observations & forecasts *(link to page)*		
Were any impacts forecast?	☒ yes ☐ no	
Main direct impacts i	*Inundation and isolation*	
Economic damage in USD i	*> $370 M*	
Fatalities	*3*	
If possible, provide more detail about impact observations & forecasts *(link to page)*		
Were any warnings issued?	☒ yes ☐ no	
Main warnings issued i	Severe weather (heavy rain), flood	
Who issued the warnings? i	*Bureau of Meteorology*	
If possible, provide more detail about the warnings & communication *(link to page)*		
Main responses to warnings i	*Evacuation*	
If possible, provide more detail about responses to warnings *(link to page)*		

Part 2a. Supplementary information about weather i

Wherever possible, please include references to information you provide.

Editors (Name & Institute): David Hoffmann (BOM

Meteorological overview i

Moist easterly flow became established over coastal New South Wales on 17 March, associated with a strong, slow-moving high pressure system in the southern Tasman Sea between Tasmania and New Zealand (Figure 2a.1). This onshore flow persisted for nearly a week. Troughs formed near the coast from time to time, and a small low pressure system (too weak to classify as an ECL) moved slowly south along the New South Wales coast on 19 and 20 March, reinforcing the easterly flow on its southern side. Some of the heaviest rain occurred during these two days.

Meanwhile, a separate area of low pressure formed over central Australia on 22 March, with a trough and associated north-west cloud band extending from the Kimberley in north Western Australia to the far south-west of Queensland. This occurred in spite of a relatively inactive monsoon and the Madden–Julian Oscillation being well outside the Australian region. This consolidated over the following 24 hours into a low pressure system over inland areas of southern Queensland and northern New South Wales, which also reinforced north-easterly flow over south-eastern New South Wales. The low then moved south over inland New South Wales, reaching eastern Bass Strait early on 24 March.

Significant rain began along parts of the New South Wales coast on 17 and 18 March, with heavy falls in the Port Stephens area on 18 March. The heaviest rain began on 19 March, focused on the Mid-North Coast region, with significant falls covering much of the coast from the Illawarra northwards. Heavy falls extended south to the Sydney region on 21 and 22 March, and northwards to south-east Queensland on 22 and 23 March. The South Coast received regular rain during this period but had its heaviest falls on 24 March as a low approached it from inland. By 25 March rain had largely cleared from New South Wales, except for isolated, locally severe thunderstorm activity on parts of the South Coast that afternoon. (*BOM Special Climate Statement 74*)

========== Weather forecast ==========

Special/non-traditional observational data used in the weather forecast or assimilated into NWP i

- Routine lead-up with standard NWP

Comment on the adequacy of the observations available for the weather forecast i

- Observations networks functioned well

Weather models (short- and long-range) i

Name	Horizontal resolution	Ensemble size	Forecast length
ACCESS-G/GE (global det/ens)	10 km/33km	18	10 days
ACCESS-C/CE ("city" det/ens)	1.5km/2.2km	12	1.5 days
ECMWF		51	
ACCESS-S coupled multi-week and seasonal prediction system	60 km	99	3 months

Post-processing/calibration applied to weather model output i

Calibrated multi-model ensemble - OCF Operational Bulletin

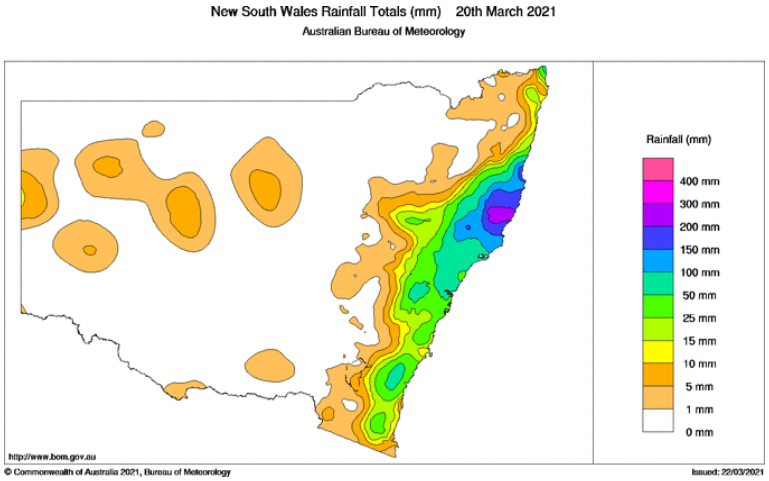
Weather forecast outputs and examples i

From NSW_Floods_2021.pptx (Shaun Cooper)

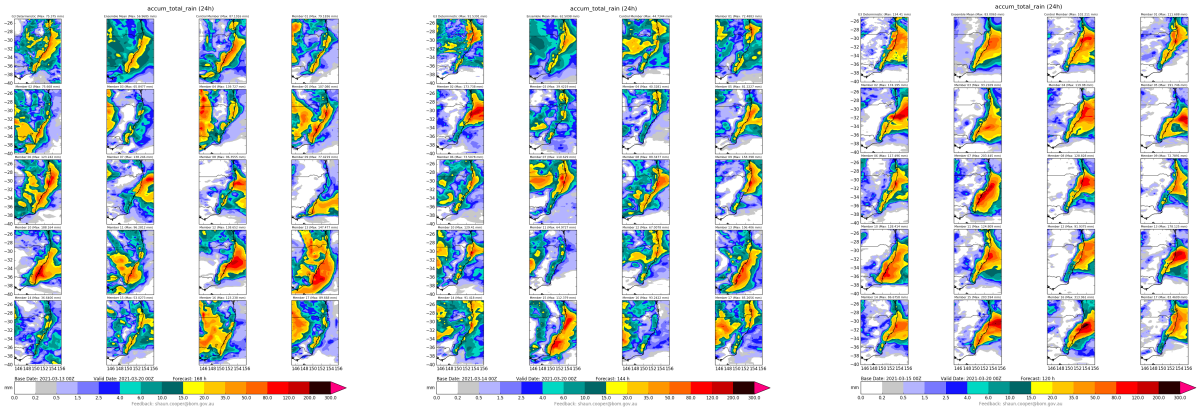
Long-range:

Ensemble forecast valid 20/03/2021:

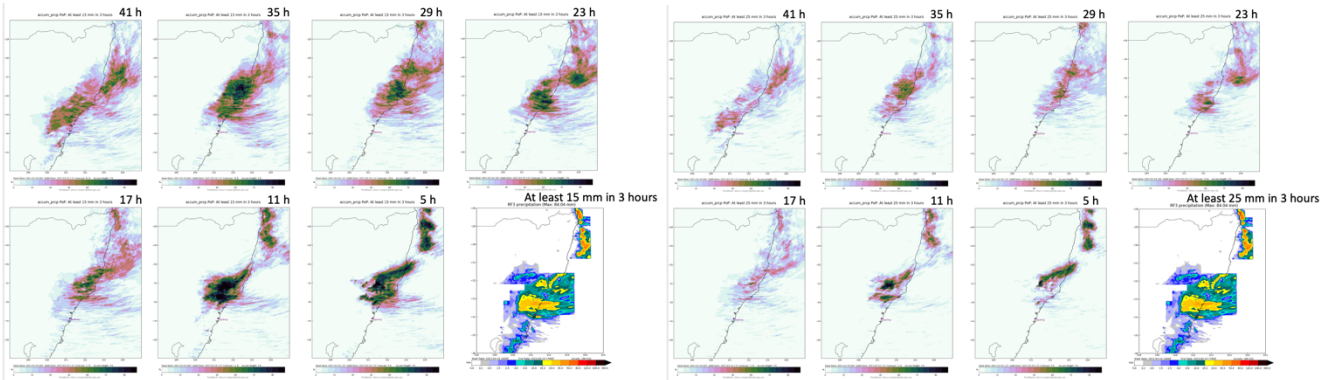
- Daily rainfall analysis 20/03/2021



- Clear signal of an event at 168 hours
  - Ensemble member accumulations > 150mm
  - Location uncertainty generally coastal but too far south for maximum accumulations
- Member 2 at 144 hours surprisingly good forecast for location and large accumulations (173mm)
- G3 forecast intensity jumps at 96 hours
- Ensemble becomes far more confident at 120 hours
  - Spread continues to decrease with reducing lead time
  - Event intensity increases with reducing lead time



Left to right: G/GE3 168h, 144h, and 120h forecast valid 20/03/2021 00Z (to enlarge: click on image or right-click on image > “Open Link”)

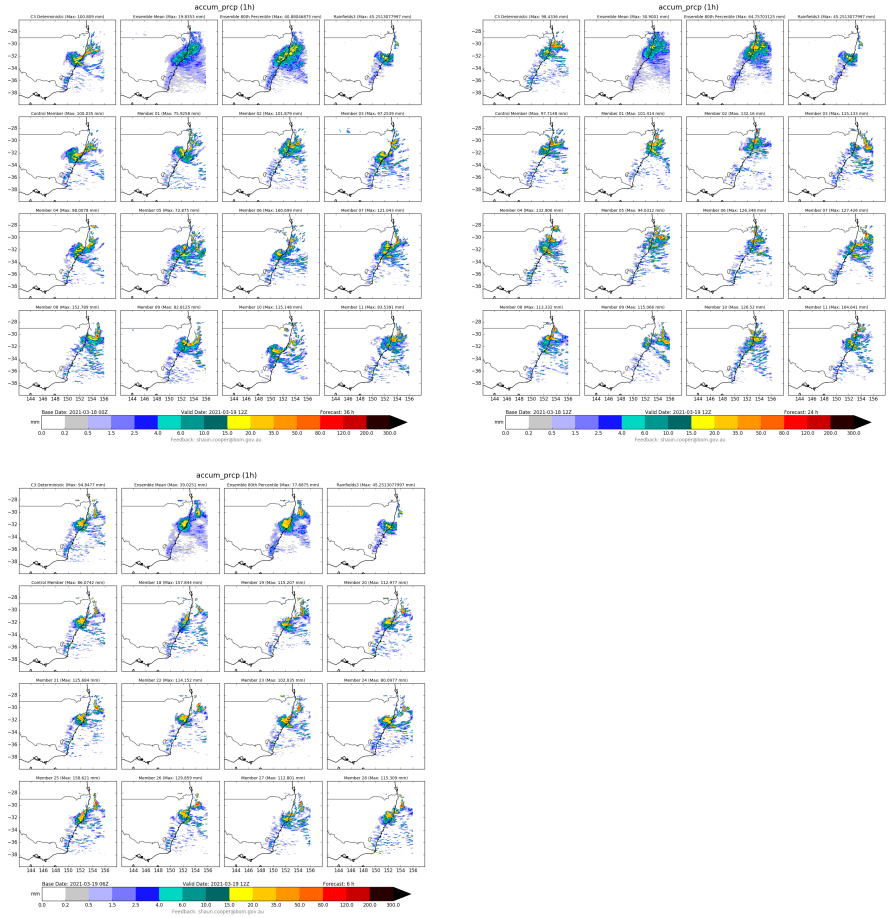


Panels of eight: PoP of at least 15mm (left) and 25mm (right) in 3 hours with Rainfield3 (radar+gauge) observations in the bottom right, valid 19/03/2021 1700Z (to enlarge: click on image or right-click on image > “Open Link”).

Short-range:

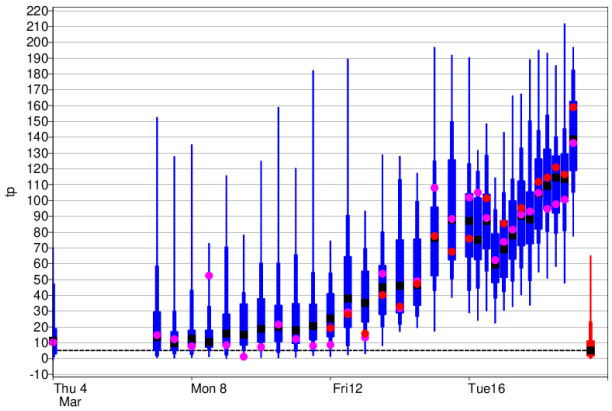
- Heavy hourly rainfall forecast from 36 hours in the deterministic and the ensemble.
  - C3 initial shifted the heavy inland rains north prior to bring them south towards the observed location as lead time decreased.

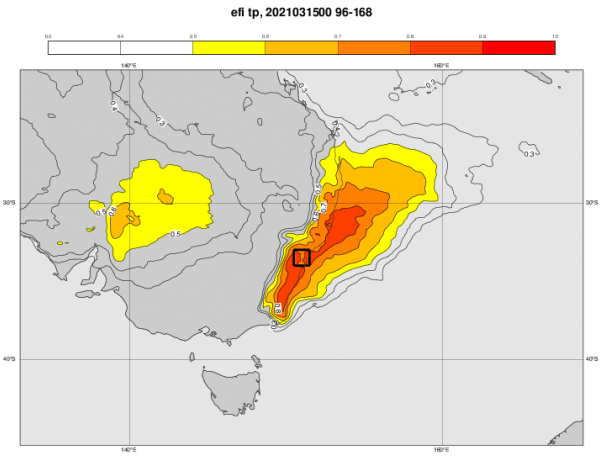
- CE3 ensemble members were also forecasting heavy fall at 36 hours, albeit with a spread in the location.
    - CE3 followed C3 in moving the inland rainfall north before bringing them south towards the observed location.
    - Importantly, throughout the lead times, there was regularly at least one member forecasting heavy rain in the observed location.



Left to right: CE3 1 hour accumulations at 36, 24 and 6 hours, valid 19/03/2021 12Z (to enlarge: click on image or right-click on image > “Open Link”).

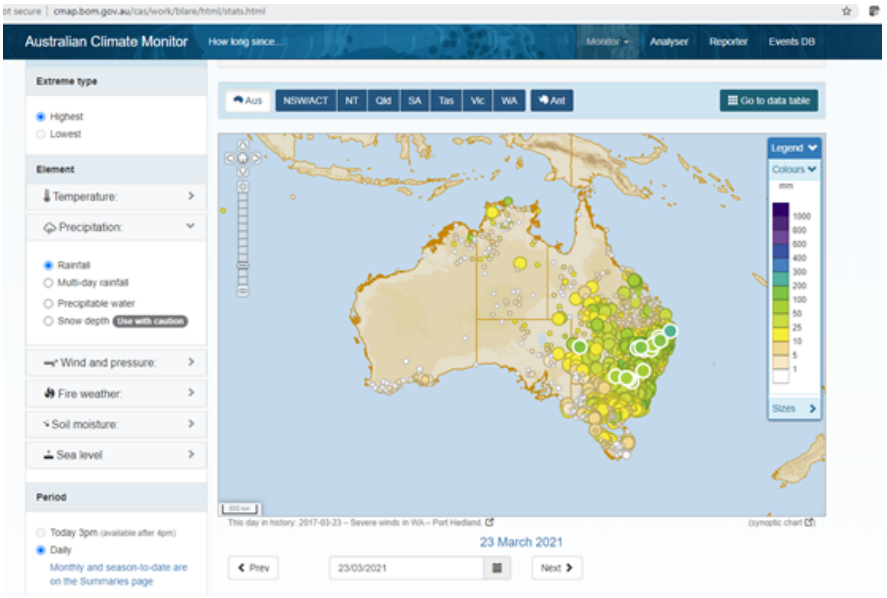
See [ECMWF Severe Event Catalogue] for ECMWF forecasts. Examples of ensemble evolution and Extreme Forecast Index are below





Interpretation/guidance for forecast users i

- Model guidance on its own not sensible to use; it was combination antecedent wet soil + model forecast
    - Guidance was fairly varied due to tropical influence
- La Nina with increased chance of flooding
- Monitoring tool provides information how long it’s been since last time a similar amount of rain has occurred



- Dam operators not interested in single day rainfall but accumulations over a period of time

What was the level of agreement between the different forecasts? i

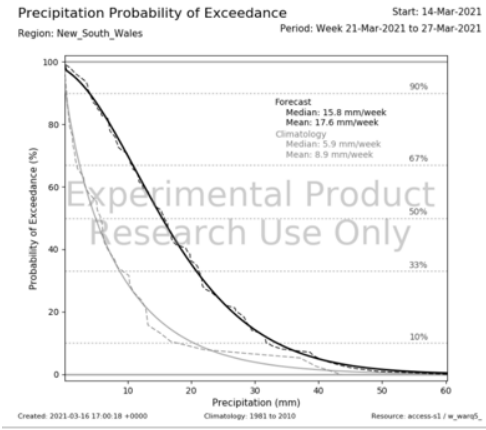
- The ACCESS model didn't converge on the magnitude of the rainfall until close to the event, and even then it was too low.

How reliable and accurate were weather forecasts at different lead times? i

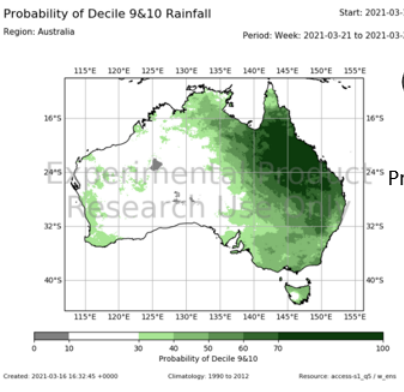
- Good forecast at long lead time, ensemble members first to indicate the possibility of a significant event at 168 hours a lot of GE3 ensemble members locked in the event five days ahead
- C3 and CE3 forecast this event well, with the ensemble providing uncertainty in location and magnitude.
    - The forecast accumulations were generally larger than those observed by RF3 (noting the earlier caveats).
    - Forecasters found City ensembles very useful
- 20% under-forecast bias bias-corrected

When was the potential event first detected in the models? i

- Signal occurred in week 2 coupled model forecast but underestimated the magnitude of the event



"Week 2"
(i.e. 21-27 March)



"Week 2"
(i.e. for 21-27 March)

Probability of being in Decile 9&10

- ACCESS-S drivers: La Nina, SAM close to positive threshold (still an influence being so close to summer) on 7 March
- From about 7th of March, a split flow blocking structure developing in the MSLP and the low level zonal wind

========== Weather observations ==========

Weather observations and analyses i

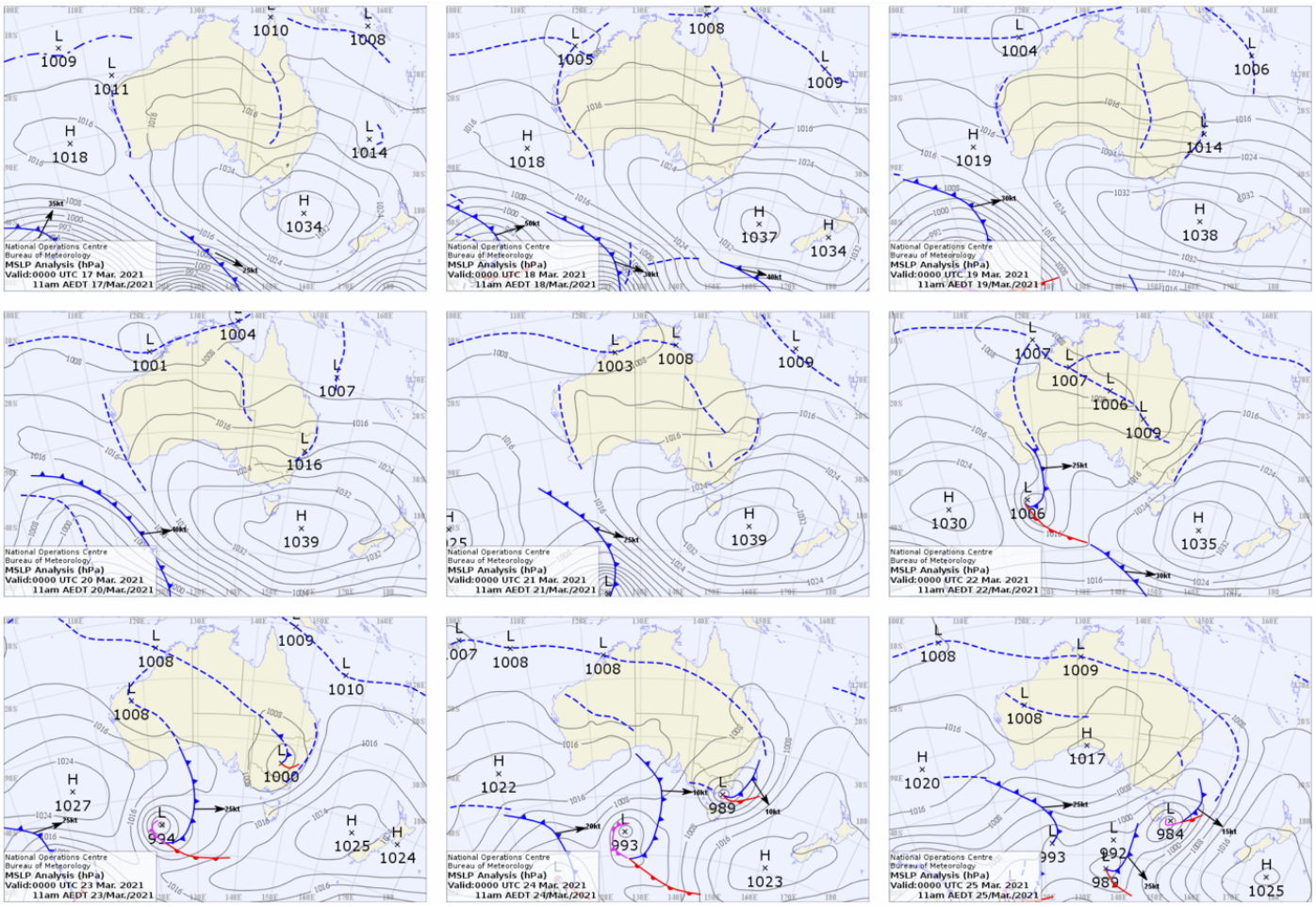


Figure 2a.1: Mean sea level pressure maps at 0000UTC for each day from 17-25 March 2021. *Source: BOM Special Climate Statement 74*

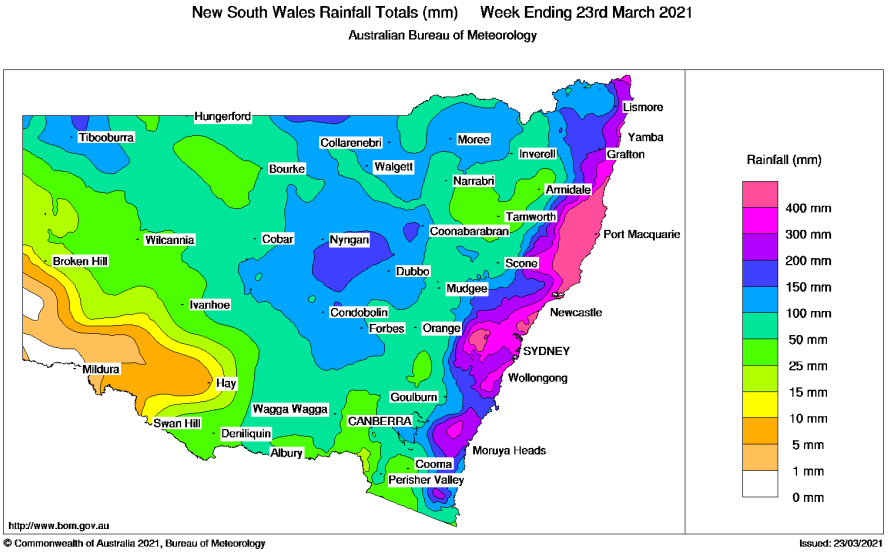


Figure 2a.2: [BOM Weekly Rainfall Update for 7 days to 9 am 23 March 2021]

- Rainfall totals in excess of 400 mm were reported along the coastal areas and Central Tablelands in New South Wales, and a number of locations in Queensland's central and south-east coast districts.
- Locations in the Hunter and Mid North Coast districts in New South Wales received over 600 mm of rainfall, including the highest weekly total of 991 mm at Bellwood in the Mid North Coast, which has exceeded the long-term autumn rainfall average less than one month into the season (Figure 2a.2).
- 1600 sites provided by councils, state water agencies, contractors and BoM

How did the observed weather relate to climatology and/or previous extreme events? i

- Similar event (amount of rain in locations) about one year prior (March 2020, left in Figure 2a.3) that broke the drought

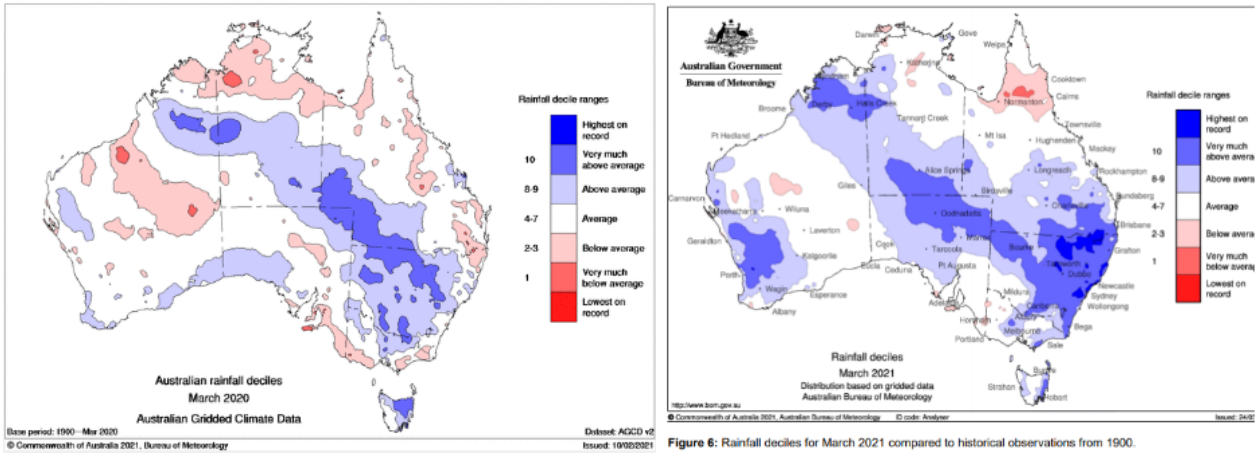


Figure 6: Rainfall deciles for March 2021 compared to historical observations from 1900.

Figure 2a.3: Rainfall deciles for March 2020 (left) and March 2021 (right). Source: BOM

- 1 in 5/10 year event? (more unusual in inland area west of the divide)
- Record multi-day totals over a widespread area
  - Coastal New South Wales, including Sydney, experienced multiple days of heavy rainfall, and the week ending 24 March 2021 was the wettest week for the region since national daily records began in 1900.
  - New South Wales had its second-wettest day, third-wettest week, and second-wettest March on record since 1900 (more extreme in the inland parts of northern NSW)

Additional analysis i

Successes/issues/challenges experienced i

- Producing a real-time briefing document updating several times a day (that was a new service – a challenge); needed to make sure that no erroneous numbers were published
- No operational issues such as delayed data
- Success: Climatologists for the first time producing a briefing document in real time that was available on SharePoint for all staff and updated several times a day with major statistics and everything to give climatological context and situational awareness.
- Success: Increasing collaboration between Research, Water, Climate – has increased markedly over the past 2 years; we are not functioning in silos anymore; that has been the reason for our success; Climatologists supporting forecasters
- Challenge: Complexity of event (initial coastal trough and inland features) made it not as straightforward as other heavy rain events caused by East Coast Lows
- Issue: no QPF training for operational forecasters
- Observations:
  - Issue 1: FTP feed from external agency delayed due to excessive hits on their website (12 AM – 6 AM – not discovered until then)
  - Issue2: Battery voltages low overnight (no solar)
  - Issue 3: Mobile network outages
  - Need more layers of redundancy (minimum of 2 weeks of battery life during no-sun periods)

Part 2b. Supplementary information about hazards

Wherever possible, please include references to information you provide.

Editors (Name & Institute): David Hoffmann (BOM

Brief overview of the hazard event(s)

The rain resulted in widespread riverine flooding over numerous coastal and inland rivers, especially along the Mid North Coast of NSW, as well as parts of Sydney and southeastern Queensland.

The spatial extent, severity and longevity of the riverine flooding across much of northern and eastern NSW was exceptional. In Queensland, the flooding was less significant, with the severity of flooding notably less than recent flood events including the 2011 and 2017 floods. The geographic scale and magnitude of the flooding made this the most significant flooding event in decades in NSW. Impacts from the flooding stretched from southern Queensland southward along almost the entire coast of NSW. The flooding was particularly severe on the NSW coast but also affected many inland catchments, including the Barwon–Darling, where the riverine flooding lasted for about two months.

Many communities along most of the NSW coast experienced heavy rainfall from 17 to 24 March 2021 resulting in widespread and prolonged minor, moderate and major flooding across coastal and inland NSW (Figure 2b.1). Minor to major flooding occurred across 34 river systems in NSW (22 coastal and 12 inland) and 15 river systems in Queensland (3 coastal and 12 inland). Of these, major flooding occurred across 11 river systems at 31 forecast locations in NSW and 6 river systems at 10 locations in Queensland (Table 1 in report), with record flooding observed across several locations along the NSW Mid North Coast (Table 2 in report).

(Source: BOM report "March-April 2021 flooding in QLD and NSW")

Inland flood lasted a long time (weeks to month)

========== Hazard forecast ==========

Observational data used in the hazard forecast or assimilated into the hazard model

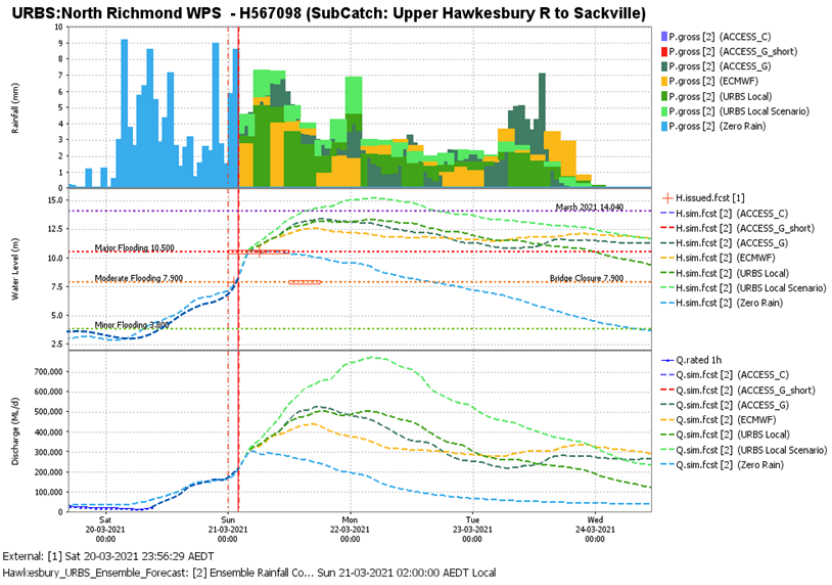
Rain gauges, poor man's ensemble of deterministic quantitative precipitation forecasts from direct NWP model output and post-processed NWP (OCF)

Comment on the adequacy of observations available for the hazard forecast

Hazard prediction models/tools

Name	Resolution	Ensemble size	Forecast length
URBS			

Hazard forecast outputs and examples



How reliable and accurate were the hazard forecasts? i

- Good performance of flood forecasts
    - 64% of forecast locations were within 0.3m of flood level
    - 51% on lead time, e.g., 6 hours

What process or trigger(s) identified the event as hazardous and started the warning process? i

========== Hazard Observations ==========

Hazard observations and analyses i

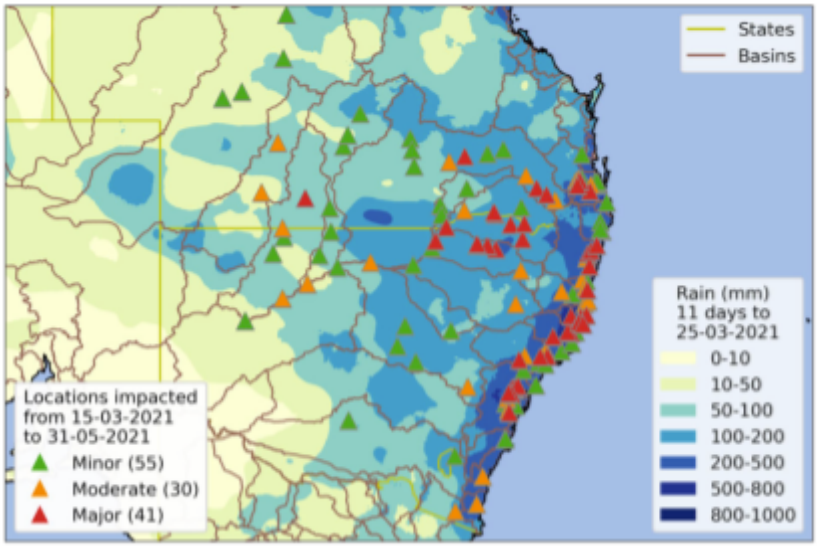
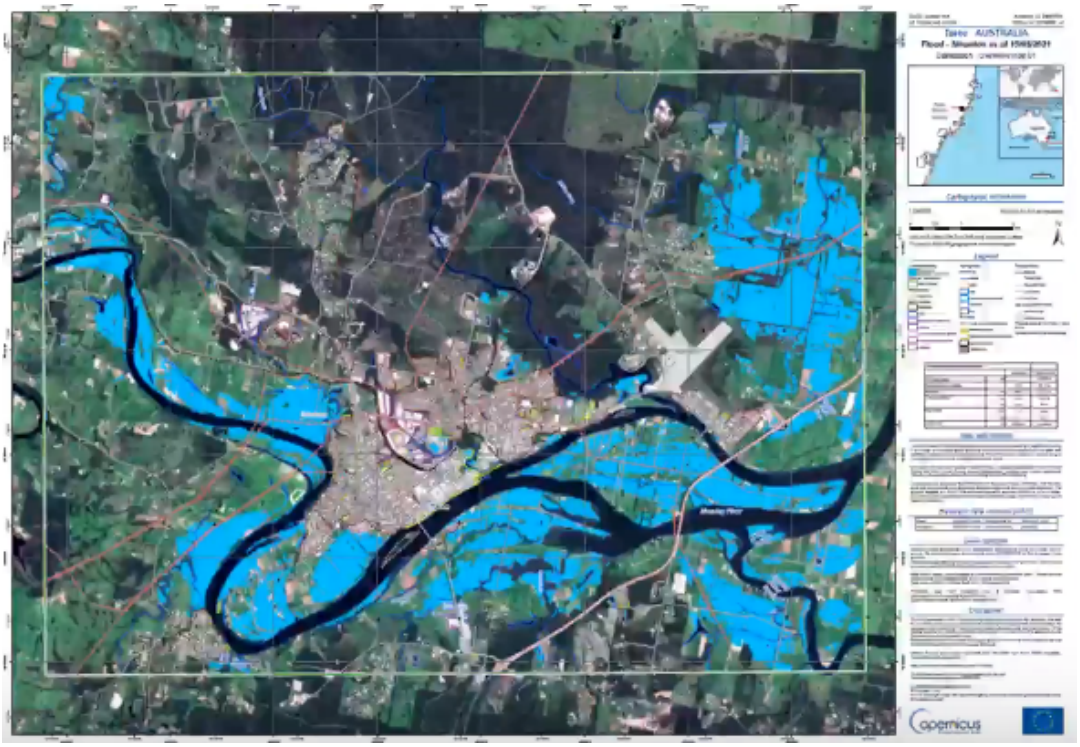


Figure 2b.1: *Classification of observed flood peaks at forecast locations for the March 2021 event and event rainfall*

Source: BOM report "March-April 2021 flooding in QLD and NSW")

High resolution Sentinel satellite imagery from Copernicus provided emergency managers with spatial detail in many locations (https://sentinel.esa.int/web/success-stories/-/copernicus-sentinel-1-facilitates-australia-s-flood-extent-delineation)



How did the hazard(s) relate to climatology? i

- Two broadly comparable events that resulted in notable flooding, primarily along the east coast of NSW, occurred in June 2016 and February 2020 (*BOM report "March-April 2021 flooding in QLD and NSW")*.
    - All those rainfall events, including March 2021, were similar in size, however, the scale, severity and magnitude of the flooding along the east coast was more significant in March 2021.
    - Riverine flooding in March 2021 occurred along a larger number of river systems, and with more extensive major flooding than in the 2016 and 2020 events (except Georges River).

Event	*Major Flood Peaks*	*Moderate Flood Peaks*	*Minor Flood Peaks*	*Total Flood Peaks*
June 2016	*2*	*11*	*25*	*38*
Feb 2020	*3*	*6*	*18*	*27*
March 2021	*39*	*32*	*54*	*125*

Table 2b.1: *Number of peaks for June 2016, February 2020 and March 2021 floods. Peak count for March 2021 is for the special extent in Figure 2b.1.*
Source: BOM report "March-April 2021 flooding in QLD and NSW"

- Some locations with extreme flooding not seen for a long time (Sydney area, Hawksbury-Nepean valley)
- Flooding reached record heights on the Hastings and Manning Rivers and the Hawkesbury–Nepean catchment in Sydney experienced its most significant flooding for more than 30 years.
- Northern Murray–Darling Basin catchments had two of their three largest one-day increases in water storage levels since 1993.

How was the hazard(s) made worse by pre-existing conditions? i

- Above average rainfall in the summer months leading up to the March 2021 flooding event, especially along the Mid-North Coast (Figure 2b.2)

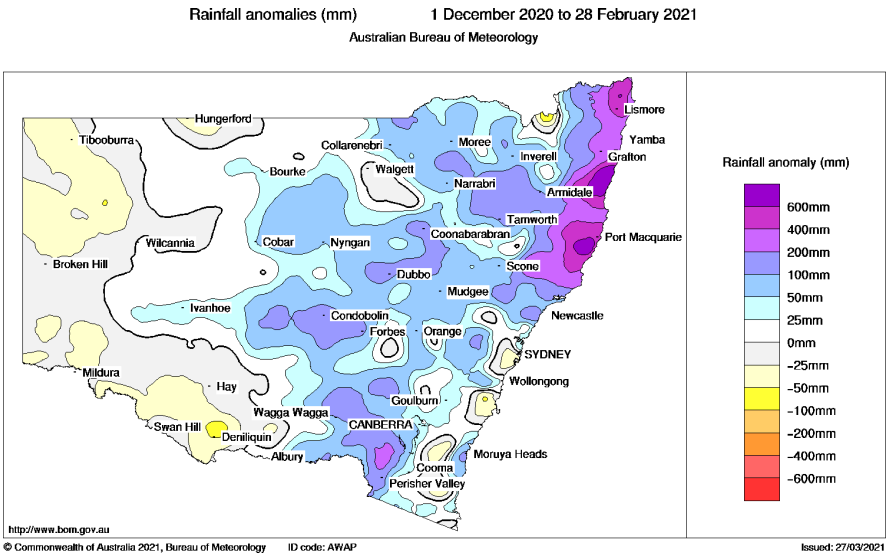


Figure 2b.2: *NSW rainfall anomalies over the preceding summer (Dec-Feb).* ***Source: BOM.***

- This led to wet/saturated catchments/soils, particularly in the northeast of NSW

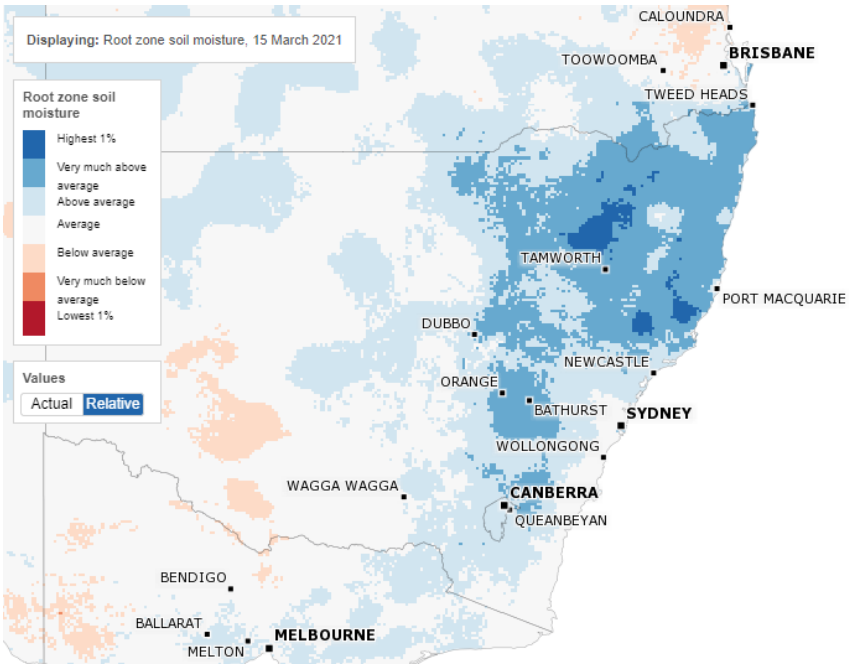


Figure 2b.3: *AWRA-L root zone soil moisture anomalies for 15 March 2021.* ***Source: BOM.***

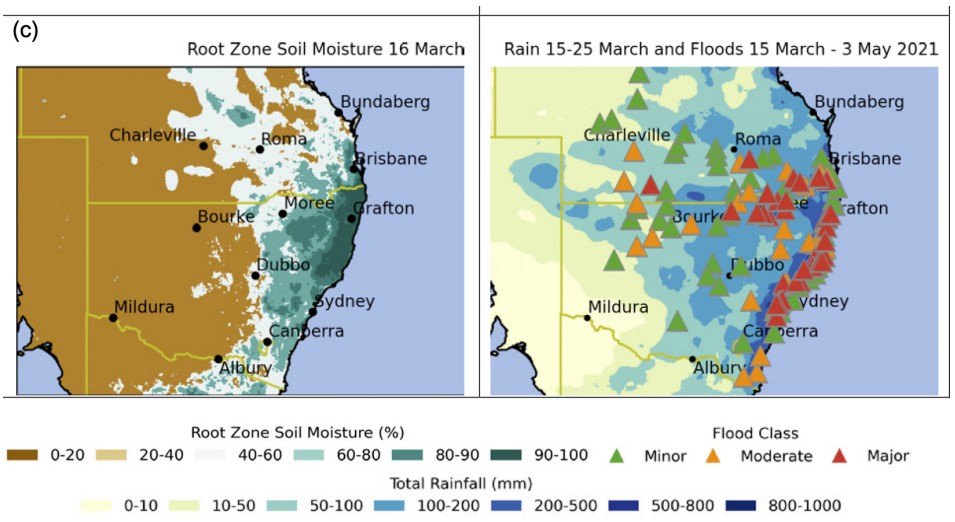


Figure 2b.4: *Relative root zone soil moisture conditions (left) for 16 March 2021 and total rainfall accumulation for 15-25 March overlayed with flood peak classification (right).* ***Source: BOM report "March-April 2021 flooding in QLD and NSW".***

- Warragamba dam was at 90% dam capacity in March 2021 prior to the event (Figure 2b.5) and dam managers are under a lot of pressure to keep those dam levels high because we might swing back into dry conditions (second time in a decade that this has happened – 2011 and 2021)

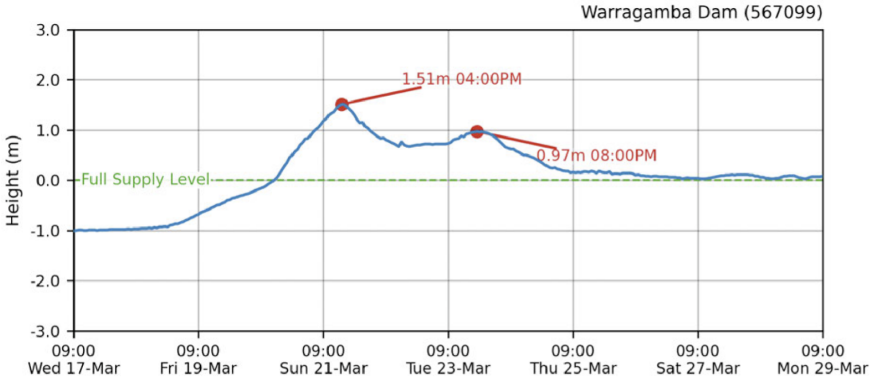


Figure 2b.5: *Warragamba Dam water level from 17 to 29 March 2021.* ***Source: BOM report "March-April 2021 flooding in QLD and NSW".***

Additional analysis i

Successes/issues/challenges experienced i

- Stressful, understaffed (not available?), not enough emotional support when handling life-threatening hazard conditions human error/behaviour in stressful situations as part of verification
- Problems communicating 'super major' flooding, unprecedented

Part 2c. Supplementary information about impacts i

Wherever possible, please include references to information you provide.

Editors (Name & Institute): David Hoffmann (BOM)

Brief overview of the impact(s) i

After the event the NSW SES provided the Bureau with details of the key impacts on the local NSW communities. Approximately 81 000 people were impacted by flooding due to inundation or isolation. Around 1 500 residential properties were destroyed or severely damaged by floodwater. Disruptions to road and traffic networks, utility services, damage to agriculture and business and the closure of schools also occurred. Livestock losses and substantial impacts on crops, pastures, infrastructure, oyster production were also recorded. The damage bill for agriculture alone is estimated to have run into the hundreds of millions of dollars.

Emergency services partners response operations included 24 evacuation orders impacting over 25 000 residents (15 000 on the Mid North Coast alone), 15 evacuation centres were established, and NSW SES received over 26 900 calls, responded to more than 14 500 requests for assistance and carried out more than 1 000 flood rescues. Tragically two lives were lost in NSW.

Information regarding flood impacts in southern Queensland catchments was sourced from QFES. The floods caused widespread disruption to roads and rail services, isolation of communities and damage to crops. Multiple schools and educational facilities in southeastern Queensland were closed. The SES received approximately 1400 requests for assistance across southeastern Queensland over the 72- hour period ending 9:30 am on Wednesday 24 March, mostly related to storm and flood damage. Several swift water rescues were undertaken. Sadly, at least one life was lost. Residents in Beaudesert on the Logan River were advised via an emergency alert to evacuate and move to higher ground due to major flooding. Impacts to crops and agricultural land were particularly significant in parts of the Macintyre River and Dumaresq River catchments close to the Queensland–NSW border.
(Source: BOM report "March-April 2021 flooding in QLD and NSW")

========== Impact forecast ==========

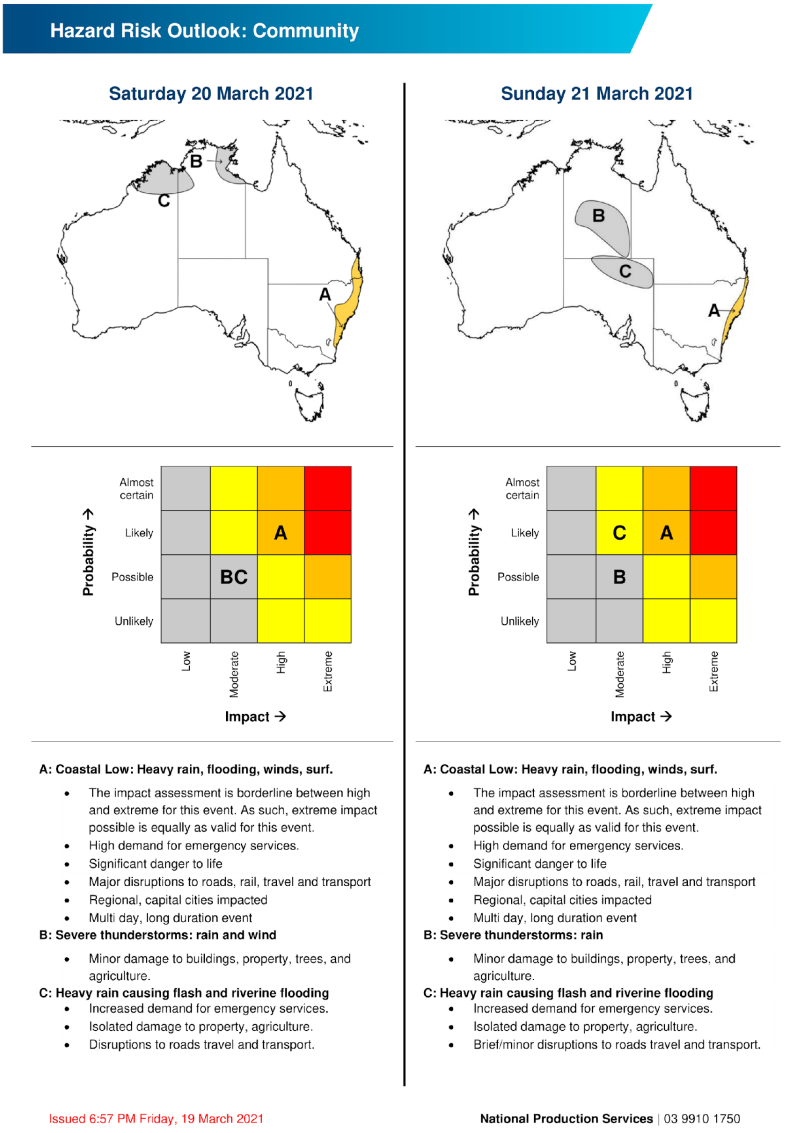
Data used in the impact forecast or model i

Impact prediction models/tools (if used) i

Name	Method
BoM National Hazard Outlook	National 4-day outlook for events that will impact the community and/or BoM operations, completed manually by the meteorologist using Hazard Impact Rubrics Tables.
NSW State Emergency Service Flood Intelligence System	NSW SES utilises gauge information to prepare flood intelligence, issue warning products and to respond to flooding. Strategic Flood Database is for government use only. Provision and Requirements for Flood Warning in New South Wales More about geospatial data in NSW SES: https://www.youtube.com/watch?v=REyw7gR3qPw

Informal rules/tools used to identify impacts i

Impact forecast outputs and examples i
BoM National Hazard Risk Outlook: Community



Comparison of predicted/expected and actual impacts i

========== Impact Observations ==========

Observed impacts:

Health and social impacts i:

- mental health; relationship breakdown; alcohol/drug misuse
- 3 lives lost (2 in NSW, 1 in QLD)

Property and business impacts i:

- $517m+ from insurance claims (34,000 claims)
- $74m primary producer grants
- $23m small business grants

Agriculture (NSW):

- 1042 drowned stock -> $1.8m loss
- $3.8m pasture losses
- $14.5m horticulture losses
- $15.6m forestry losses
- $3.4m cropping losses
- $17.1m aquaculture
- Ongoing impacts, e.g., flystrike, parasites, etc.

Critical infrastructure damage and service disruption i:

- Disruptions to road and traffic networks, utility services
- Defence and aviation impacts small
- $500M road and rail damages

Environmental damage i:

- 16k tonnes of waste from food; asbestos contamination and other hazardous items (chemicals; solar panels)
- Wildlife:
    - Flooded burrows and drowned animals, e.g., echidnas and wombats
    - Kangaroos stuck in drains
    - Animals hit by cars when fleeing to higher grounds
    - Turtles and seabirds swept away from their natural habitat

Who and what were exposed to the hazards, when, for how long? i

Of those exposed, who and what were vulnerable to the hazards and why? i

Additional analysis i

- Positive long term impacts as rain inland eased drought conditions. General population benefited more from easing of drought than it suffered from short term flood impacts.

Successes/issues/challenges experienced i

Part 2d. Supplementary information about warning communication

Wherever possible, please include references to information you provide.

Editors (Name & Institute): David Hoffmann (BOM

Brief overview of the communication "story" i

Throughout the course of the event, the Bureau escalated and enhanced its messaging across numerous media channels to ensure communities at risk were provided with consistent and up-to-date information. Daily media conferences commenced in the early stages of the event from Thursday 18 March until Friday 26 March 2021 to enhance timely messaging and prompt action within communities. The first media conference was held 24 hours ahead of the commencement of flooding in the NSW Mid North Coast and 48 hours ahead of it starting in the Hawkesbury– Nepean Valley. The conferences continued throughout the event until the risk of further impact had abated.

A total of 11 media conferences were held, many of these jointly with emergency services and the Premier of NSW. The national public television network, SBS, translated the content into numerous languages based on the need to reach a high number of non-English speaking and Indigenous communities in the area. More than 150 media enquiries were dealt with by the Sydney office. Nine separate video news release updates were sent to media outlets during critical phases of the event and used by a wide variety of local, state and national media outlets.

Regular media conferences were undertaken in Queensland from Thursday 18 March 2021 until Friday 26 March 2021. A total of five media briefings were held in Queensland over this period, one of these jointly with the Queensland Premier and included some Ministers and QPS and QFES Commissioners. More than 180 media calls related to flooding and the severe weather were handled in the Bureau's operational centre in Brisbane. Seven TV interviews and eight audio news releases were sent to media outlets during critical phases of the event and used by a wide variety of local, state, and national media outlets.

The delivery of Bureau's safety, warning, forecast and observation messages were further amplified into the community through the continuous and targeted use of social media channels (including Twitter, Facebook and YouTube) together with the Bureau's weather app. A total of 475 posts were made across the national, NSW and Queensland Twitter and Facebook accounts, the majority (relating to NSW) were issued during the event.

The Bureau also provided 24-hour support that enabled rolling ABC emergency broadcasting operations over multiple days. This helped NSW residents understand what was happening and what to expect next. The continual communication allowed the community to prepare and act as the emergency unfolded.
(*Source: BOM report "March-April 2021 flooding in QLD and NSW")*

- Early messaging about persistent wet conditions for the coming week coming through on Monday (15 March)
- Since then, weather/hazard/impact forecast escalated every day
- NSW: From Thursday (18 March) call to distribute messaging via video news releases, tweeting, and media conferences every day (18-26 March, 11 in total following particular strategy), 24 hours/day ad-hoc interviews and scheduled radio crosses; daily video release to all media
- Daily 1pm media conference broadcasted online and to TV and radio
- Emergency broadcast on Friday about life-threatening rainfall;
- ABC emergency broadcasting, additional support to SBS to reach high population of ESL residents in high-risk areas, translated the content into numerous languages based on the need to reach a high number of non-English speaking and Indigenous communities in the area
- Starting out with broad messages and tailoring over time to impacts and users
    - One day ahead messages addressed main threats of the next day
- BOM issues warning SES puts out bulletin

What information was provided to emergency responders, government and other stakeholders about the hazard and its possible impact(s), and by whom? i

- Weekly hazard briefing to emergency service agencies
- Embedded meteorologist at State Emergency Services (SES) – a regular staff placement
- Dedicated team of experienced hydrologists to provide forecasts and warnings alongside frequent briefings to the NSW SES and WaterNSW in the Hawkesbury– Nepean Valley (expected highest flood level in 30 years)

- Extra resourcing to enable experienced flood hydrologists to focus on issuing forecasts for high profile inland catchments such as the Upper Macintyre, Gwydir and Barwon-Darling (expected highest flood level in 10 years)
- Permanently outposted Bureau meteorologist at the Kedron headquarters in Queensland was in regular contact with Bureau hydrologists to ensure information on the flooding situation (including forecasts and warnings) was available to staff within QFES in a timely manner. Additional (non-routine) briefings were undertaken by the outposted meteorologist for the state government, QFES emergency management staff and local disaster management groups (LDMGs)

Public warnings i

Warning name	Warning lead time	Issued by i	Warning area i	Type of warning i	Did it include safety advice?	Scaled i	Channels i	Warning frequency

How was warning information communicated by other organizations? i

Warning outputs and examples i

- >900 flood warnings issued

Bureau Flood Product	Queensland	NSW
Flood Watch^	*8*	14
Flood Warning*	*223*	736
Major Flood Warnings*	*51*	210

^Flood Watches issued between 9 March – 24 March 2021.
**Flood Warnings issued between 9 March – 23April 2021. For the Barwon Darling, warnings continued until 24 May 2021.*

Table 2d.1: *Flood watch and warnings issues for the March-April 2021 event.*
Source: BOM report "March-April 2021 flooding in QLD and NSW"

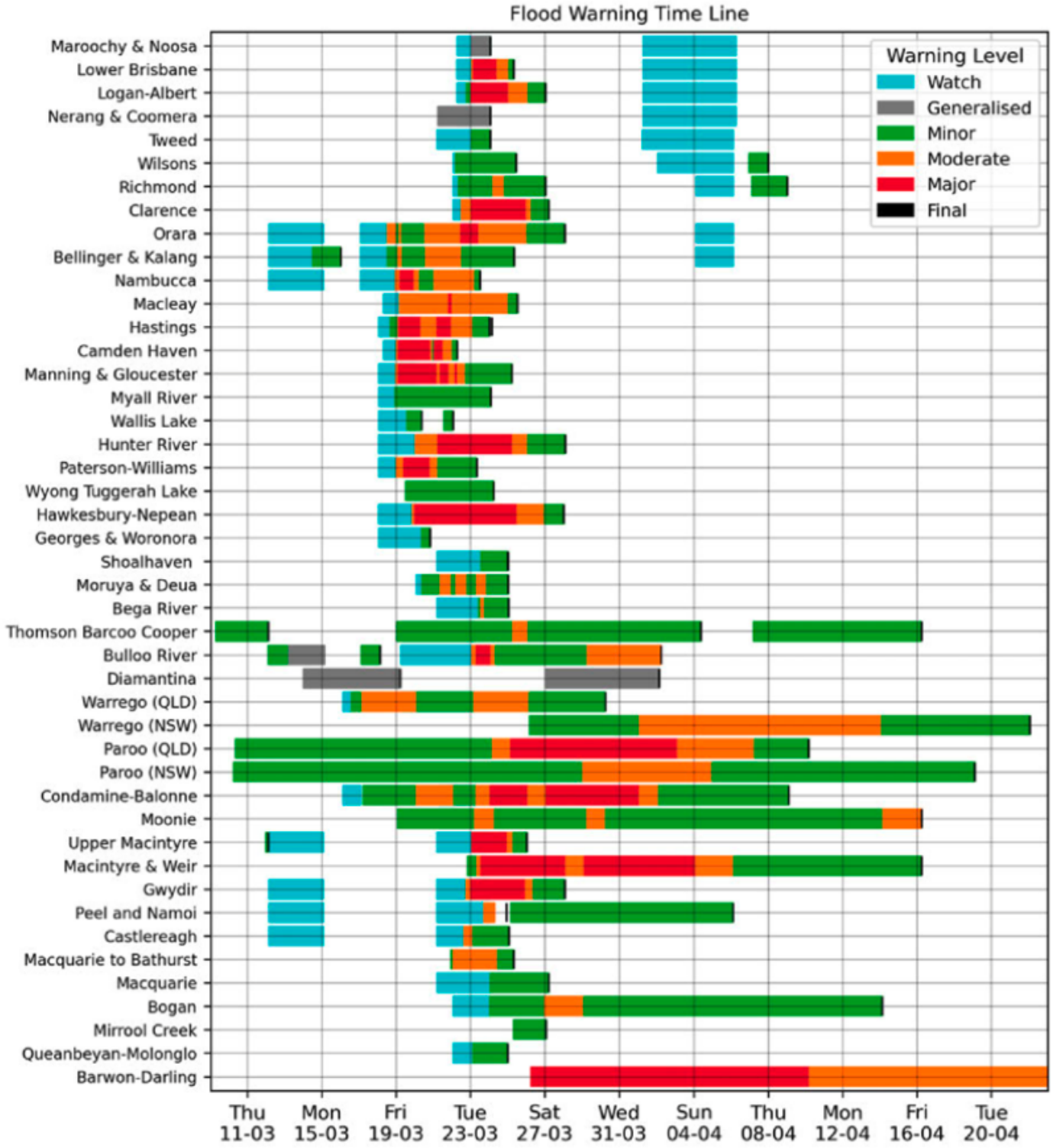


Figure 2d.1: *Timeline of Flood Warnings issued between 9 March and 23 April 2021. During this period, a total of 745 Flood Warnings were issued. (For the Barwon Darling, warnings continued until 24 May 2021)* . ***Source: BOM report "March-April 2021 flooding in QLD and NSW"***

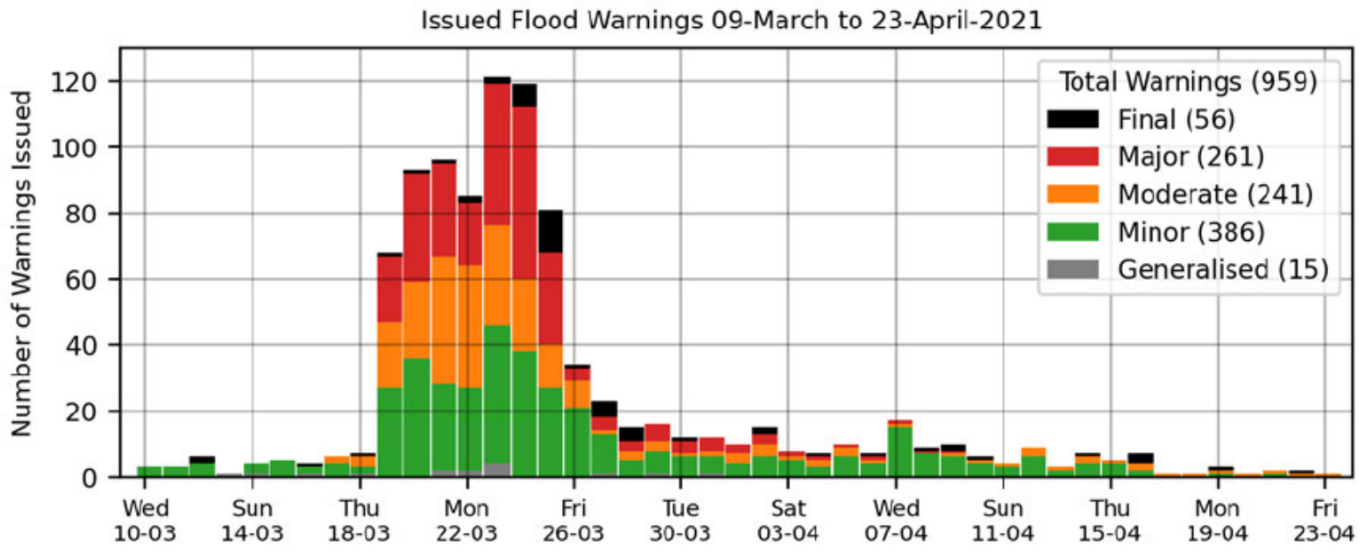


Figure 2d.2: *Flood warnings issues between 9 March and 23 April 2021 (in some case warnings continued until 24 May). Source: BOM report "March-April 2021 flooding in QLD and NSW"*

Comment on the use of uncertainty information in the warning i

- Timeliness when community needs to know but not all information is available yet starting with broader/general message and narrowing down from there
- Not issuing warnings regularly erodes credibility
- Cautious about over-warning

To what extent were communication systems in place and operating effectively? i

- Timeliness, lead time and accuracy the 3 KPIs to measure performance for flood forecast and warnings
    - NSW: 90%, 51%, 64% (Timeliness, lead time, accuracy); watches/warnings: 15/670
    - HNV: 80%, 88%, 71% (Timeliness, lead time, accuracy); watches/warnings: 4/57
        - Very good performance
- NSW SES website is not user friendly; not enough information on SES social media
- Not enough information prior and during the event – especially around evacuations (SES)
- There appears to be significant confusion in the community about where or how to find information (NSW SES community report)

To what extent were warning messages received and understood by the public? i

- State Emergency Services ran post-event community meetings in several towns in affected areas
- Some people were ill-prepared because they didn't understand the warning
- Others were well prepared, being a bit sceptic about accuracy and experienced flooding in the past
- Messages that were not impact-based, e.g., warning of forecast river height, were not very meaningful to the community even though emergency managers understand/expect that information

Comment on how the needs of specific communities and populations were addressed i

- Hawkesbury Nepean Valley near Sydney has a big community with English as a second language working with community leaders
- Multi-channel communication depending on target audience, e.g., Facebook on community of retirees not appropriate specified communications experts for that

Additional analysis i

- Water politics around releasing water from dams. Water is a precious resource and dam operators don't like to release water unnecessarily. However, leaving water release too late (i.e. failing to act on precipitation forecasts) causes greater flooding. Finding the right balance is tricky.

Communication success/issues/challenges experienced i

- Mixed feedback on warnings
    - Negative feedback arises in the press since mostly negative experience take a stand in community meetings
    - Warning fatigue due to previous bushfire events (e.g. Black Summer) and pandemic
    - Conflicting messages in back-to-back communication
- Flood forecasting team was overwhelmed
    - Putting out more than 50 warnings per shift
    - Staffing issues

Part 2e. Supplementary information about responses to warnings

Wherever possible, please include references to information you provide.

Editors (Name & Institute): David Hoffmann (BOM

Brief overview of the response to the hazard by emergency services and other partners [i]

In the NSW SES Northern Zone an Incident Control Centre and Incident Management Team (IMT) were established at Metford to manage the storm and flood response. Three divisions were established under the IMT–Northern Rivers (Goonellabah), Mid North Coast (Taree) and Hunter-Central Coast (Metford). The area of operations outlines in this report is the Mid North Coast Division. This Division covered six local government areas (Coffs Harbour LGA, Bellingen LGA, Nambucca LGA, Kempsey LGA, Port Macquarie–Hastings LGA, Mid-Coast LGA).
Throughout the emergency response there were 11 Incident Action Plans (IAPs) issued by the Northern Zone IMT. A Deputy Incident Controller –Recovery was appointed to the IMT on 21st March 2021. This role covered transition to recovery activities in all 3 Divisions in the Zone. On 27th March an Annex to the IAP focussed on Rapid Damage Assessment. The final IAP issued on 31st March focussed on concluding response operations, undertaking community liaison, resupply and immediate relief tasks in the flood affected areas.

The State Command Centre (SCC) was opened on 14th March 2021 to undertake pre-planning for the severe weather which was forecast to occur on the east coast from 13th March 2021.The SCC team coordinated the priority of effort and undertook strategic planning and public information, including the issuing of Evacuation Orders and Warnings via Emergency Alert. National Resource Sharing Centre (NRSC) arrangements were activated on 20th March2021 increasing the capacity of specialist resources across NSW. This was co-ordinated through the SCC. The SCC aided in planning, resourcing requirements and providing flood intelligence in support of the Incident Management Team, maintaining overall monitoring of the management of the incident, strategic coordination, and supporting information flow to state level stakeholders. State level and national media coverage was coordinated by the Public Information Unit in the SCC. *(Source: NSW SES EVENT SUMMARY REPORT – Event 144/2021, Severe Weather NSW – Mid North Coast Division (Northern Zone))*

- 14,368 requests for assistance (RFA)
- 1052 flood rescues
- 24 evacuation orders (25,500 people)
- Multi agency efforts post impact in the clean-up and recovery
- Emotional support provided to residents by emergency service personnel
- In the NSW SES Northern Zone an Incident Control Centre and Incident Management Team (IMT) were established at Metford to manage the storm and flood response. Three divisions were established under the IMT–Northern Rivers (Goonellabah), Mid North Coast (Taree) and Hunter-Central Coast (Metford).
- Evacuation centres (see NSW SES Event 144/2021 summary report)
- Emergency response centres (Kempsey, Mid-Coast, Port Macquarie-Hastings, Coffs Harbour)
- Natural disaster declarations (declared in LGAs Nambucca, Coffs Harbour City, Kempsey, Mid-Coast, Port Macquarie-Hastings)

What were the main response actions by the public to the warnings? [i]

- The Bureau embedded a hydrologist at the NSW SES state headquarters from the 19 to 29 March. The embedded hydrologist provided additional customer decision support including multiple briefings during the event and provided an integral link between the Bureau and NSW SES

Institutional responses to the warnings [i]

Response actions	Taken by whom	When taken	On the basis of what information?	Benefit (if any)	Cost
Evacuation order	NSW SES	Laurieton, North Haven and Dungoban	19/3/21 @ 2:30	Rainfall forecast, predicted flood peaks, flood inundation maps	
Evacuation order	NSW SES	Lower Macleay	19/3/21 @ 18:50	As above	

Evacuation order	NSW SES	Port Macquarie (Hibbard Settlement Point North Shore)	19/3/21 @ 16:00	As above	
Evacuation order	NSW SES	Kings Point and Macksville CBD	20/3/21 @ 0:00	As above	
Evacuation order	NSW SES	Kempsey CBD	19/3/21 @ 22:30	As above	
Evacuation order	NSW SES	Wauchope and Rawdon Island	19/3/21 @ 23:00	As above	
Evacuation order	NSW SES	Bulahdelah	19/3/21 @ 23:30	As above	
Evacuation order	NSW SES	Taree, Dumaresq Island, Cundletown	20/3/21 @ 6:30	As above	
Evacuation order	NSW SES	Central Wingham	20/3/21 @ 6:40	As above	

How did the overall response to this event compare to similar previous events? i

- No major loss of life

How knowledgeable was the community about the hazard? i

- Some people have experience and local flood knowledge to help others
- People warned others in the community late on the Friday that the flood situation was critical

Comment on the existence and use of disaster preparedness and response plans i

- Council emergency preparedness workshops before the event. E.g., Nambucca Shire Council
- Evacuation centres (see NSW SES Event 144/2021 summary report)
- Emergency response centres (Kempsey, Mid-Coast, Port Macquarie-Hastings, Coffs Harbour)

What capacity did the community have to respond to warnings? i

- Communities created their own community emergency management hubs at halls and other facilities such as RFS stations
- Residents rescuing others in their own boats/vehicles
- Community evacuating other residents and animals
- Physical help in property protection and clean up
- People organising shelter for evacuees in their own homes or help organising other accommodation
- Some areas created their own Facebook page to share information. E.g., Stuart Point
- Communities often used community-based Facebook pages rather than SES/BoM/Council as their primary source of information

Additional analysis i

Success/issues/challenges experienced i

Part 2f. Analysis of the warning chain

Wherever possible, please include references to information you provide.

Editors (Name & Institute): Beth Ebert (BOM)

Information flow through the warning chain i

Warning chain	Was all necessary input information available? (yes/partially/no)	If not or partially available, what input information was missing?	Who should have provided the missing information?
Weather forecast	Yes		
Hazard forecast	Yes, according to SOPs	Flood forecasters would have liked more ensemble rainfall forecasts	BoM operational area
Impacts forecast			
Warning communication	Yes		
Warning response	Partially	Initial flood warnings were made "out of hours", making it more difficult for local government to respond	BoM

Tools and operational workflows for sharing information between partners i
BoM meteorologist embedded at State Emergency Services has access to BoM's visualisations and forecasting tools, enabling rapid direct communication of the weather and flood situation. BoM makes both weather and flood forecasts so weather and flood forecasters and comms specialists can consult with each other and work together.

How were social media used in the warning chain? i
Continuous and targeted use of social media channels (including Twitter, Facebook and YouTube) together with the Bureau's weather app. Agencies retweet each other's information to reinforce the message.

Evidence that warning chain was effective in reducing fatalities, injuries, damage, and/or disruption i

What were the strongest links in the warning chain? i
- Excellent relationship between weather bureau, emergency services and media to share intelligence and convey a consistent warning message (communications team won a national award for excellence).
- Real-time support from climatologists to put the rainfall into context

What were the weakest links in the warning chain? i
Weather and flood forecasters felt the NWP didn't provide enough early warning of the severity of the event, which meant that downstream partners in the warning chain had less time to mobilise than they would have liked.

What procedures were used to identify lessons learned from the event? i
- Bureau conducted a post-event review management (PERM) to review performance of all operational areas, and overall how the event was handled.
- The event was written up as a report by the Flood team, with a second draft report on the weather forecasts.
- Internal Value Chain workshop held in September involving a broader cross section of the Bureau.
- Community engagement post-event, led by State Emergency Services.

Comment on lessons learnt from previous events and their contributions to greater warning success for this event i

Additional analysis i

Part 3. Assessment of the end-to-end warning chain

Your profession: Researcher
Please rate your level of expertise on a scale of 1 (no expertise) to 5 (established expert) for:

Weather:	3
Hazard:	2
Impact:	2
Warning/communication:	2
Response:	1
High-impact weather event evaluation:	3

HOW SUCCESSFUL WERE THE FORECASTS, WARNINGS AND RESPONSES?

How well do you think the event was observed? *Scale of 1 (poor) to 5 (excellent) 4*
Reason for this rating i
Networks functioned as expected. The event occurred in a relatively well observed part of Australia. Could always do with even more observations.

How well do you think the weather was forecast? *Scale of 1 (poor) to 5 (excellent) 3*
Reason for this rating i
The ECMWF model did a very good job, the ACCESS model not quite as good ("typical" performance according to modellers) and didn't converge on an intense event until a few days out. Operational forecasters didn't feel sufficiently confident to rely on the NWP

How well do you think the hazards were forecast? *Scale of 1 (poor) to 5 (excellent) 4*
Reason for this rating i
Flood forecasts were good quality but extent and duration of event meant that even with staff working as fast as they could the warnings didn't always get updated in time

How well do you think the impacts were predicted? *Scale of 1 (poor) to 5 (excellent) 2*
Reason for this rating i
Can currently only anticipate qualitative impacts – don't yet have flood inundation modelling capability or sufficient knowledge of vulnerability

How well do you think warnings were communicated? *Scale of 1 (poor) to 5 (excellent) 5*
Reason for this rating i
Won an award for excellent warning communication. Well coordinated and consistent messaging

How well do you think the warnings were used? *Scale of 1 (poor) to 5 (excellent) 3?*
Reason for this rating i

How well do you think the entire warning chain performed overall? *Scale of 1 (poor) to 5 (excellent) 4*

Thank you very much for contributing to the WWRP Warning Value Chain Project database!

Acknowledgements of information providers (optional):

Annex 1: *List of hazards adapted from the UNDRR-ISC Hazard Information Profiles*

1. Convective-related
   - Downburst
   - Lightning (Electrical Storm) Thunderstorm
2. Flood
   - Coastal Flood
   - Estuarine (Coastal) Flood
   - Flash Flood
   - Fluvial (Riverine) Flood
   - Groundwater Flood
   - Ice-Jam Flood Including Debris Ponding (Drainage)
   - Snowmelt Flood
   - Surface Water Flooding
   - Glacial Lake Outburst Flood
3. Lithometeors
   - Black Carbon (Brown Clouds)
   - Dust storm or Sandstorm
   - Fog
   - Haze
   - Polluted Air
   - Sand haze
   - Smoke
4. Marine
   - Ocean Acidification
   - Rogue Wave
   - Sea Water Intrusion
   - Sea Ice (Ice Bergs)
   - Ice Flow
   - Seiche
   - Storm Surge
   - Storm Tides
   - Tsunami
5. Pressure-related
   - Depression or Cyclone (Low Pressure Area)
   - Extra-tropical Cyclone
   - Sub-Tropical Cyclone
6. Precipitation-related
   - Acid Rain
   - Rain
   - Blizzard
   - Drought
   - Hail
   - Ice Storm
   - Snow
   - Snow Storm
7. Temperature-related
   - Cold Wave
   - Dzud
   - Freeze
   - Frost (Hoar Frost)
   - Freezing Rain (Supercooled Rain)
   - Glaze
   - Ground Frost
   - Heatwave
   - Icing (Including Ice)
   - Thaw
8. Terrestrial
   - Avalanche
   - Mud Flow
   - Rockslide
   - Landslide
9. Wind-related
   - Derecho
   - Gale (Strong Gale)
   - Squall
   - Subtropical Storm
   - Tropical Cyclone (Cyclonic Wind, Rain [Storm] Surge)
   - Tropical Storm
   - Tornado
   - Wind
10. Environmental
    - Wildfires
    - Coastal Erosion