

Warning Time for Extreme Precipitation Events

Rev 0 i, 6-4-14

1.0 Need and direction for warning time determination

Local Intense Precipitation (LIP) events postulated by using synthetic storms can project rainfall in excess of 19 inches for -1-hour over -1-mi². If a nuclear site's protection is not permanent and passive, a rainfall event of this magnitude may require actions to be taken prior to the storm to protect or mitigate flooding impacts on required Systems, Structures and Components (SSC's). As such, warning time is a key component in the planned response to the LIP rain event.

Historical data shows that while improvements in forecasting accuracy have been made, current forecasting methods and forecasting tools still cannot forecast extreme rain events accurately to consistently identify the location, timing, and amount of precipitation (Ralph et al. 2010, Olson et al 1995). This is due in part to extreme events occurring less frequently and modeling tool limitations.

Recognizing the limitations in forecasting accuracy for extreme events, the methods to establish warning time for extreme events will be based on:

1. Recognition that extreme precipitation events approaching the LIP level rainfalls would require substantial atmospheric moisture that is associated with large rain events which can be recognized and anticipated.
2. Setting warning thresholds conservatively based on less extreme (and more predictable) storms to assure that active protection or mitigation can be executed prior to consequential flooding.
3. Including additional conservatism to reduce uncertainty by setting monitoring and trigger thresholds that are a fraction of the precipitation level that would result in consequential flooding on site and also significantly less than the maximum LIP.

Using existing forecasting tools and addressing known forecast limitations with conservative measures can provide a reliable warning time to implement active defenses for a LIP event.

2.0 Basis for Local Intense Precipitation (LIP) extreme rain event

LIP events that are determined using NUREG/CR-7046 based on a 1-hour /over 1 mi² precipitation event. NUREG/CR-7046 recommends the use of the most recent hydrometeorological (HMR) report unless an approved site-specific HMR or Probable Maximum Precipitation (PMP) study is available. For most nuclear sites east of the 105th meridian, HMR-52, 1982 is the current HMR.

3.0 Sources of extreme rain events

The maximum recorded historical worldwide one hour rainfall event is 15.79" in Shangdi, Nei Monggol, China in 1975. The US maximum 1 hour rainfall event is 15" (interpolated from depth-area curves) in Smethport, PA in 1942. These record storms are significant but still less than the 19" maximum 1 hour storm predicted by HMR-52. Storms that have the potential to deliver rainfall approaching the world record rainfall would be detectable in advance with current forecasting methods/models based on the anomalously large amount of moisture and level of atmospheric instability required to generate precipitation of this magnitude. This precludes a typical isolated thunderstorm as a viable source of an extreme rain event of this magnitude. There are three basic types of storms that could lead to LIP magnitude events:

- Tropical Cyclones
- Synoptic Storms (General Storms)
- Mesoscale Convective Complexes (Thunderstorms)

The three basic types of storms that could lead to LIP magnitude events are briefly described below.

Comment [NRC Staff1]: There are numerous statements about storm types, their spatial and temporal structure, seasonality, etc. that should be backed up with references. Claims about accuracy and reliability of forecasts should include references.

Please add page numbers to the document.

Comment [NRC Staff2]: Adding conservatism does not reduce uncertainty. Adding additional margin or conservatism can be a legitimate way to address or account for uncertainty.

Comment [NRC Staff3]: Longer durations may be more realistic for some sites.

Comment [NRC Staff4]: HMR-52 provides guidance on application. The all-season PMP values are derived in HMR-51. Seasonal guidance is provided in HMR-53.

Comment [NRC Staff5]: Suggest using the English translation of "Inner Mongolia".

Comment [NRC Staff6]: Based on the "definition" of extreme rain event provided in section 6.2, this statement appears to be invalid in light of known rain events that occur without warning (a recent example being June 10, 2014, College Park, MD). Suggest using a term other than "extreme" for this discussion or provide stronger justification as to why an air mass thunderstorm could not produce an extreme rain event.

3.1 Tropical Cyclones

This storm type includes warm core systems with origins over the tropical waters of the Atlantic Ocean or Gulf of Mexico (including the Caribbean Sea). It should be noted that in extremely rare occasions modified tropical cyclones have made landfall over California and far southern Arizona. This storm type can produce PMP and LIP level rainfalls in these locations in a modified form where the storm has begun to transition into an extra tropical storm. High levels of tropical atmospheric moisture can produce extreme rainfall, especially when enhanced by convection/thunderstorms and slow movement.

Forecasting the track, intensity, storm surge, and potential rainfall accumulation associated with a tropical system has improved dramatically in recent years (Needham and Keim, 2014, NHC Center, etc.). This has allowed lead times of forecast tracks to extend out 5-7 days with reliable accuracy. In all cases, as the time of potential landfall approaches, the forecast track and rainfall amounts become more refined. Three days out, the accuracy of these forecasts has become more certain with increasing accuracy each day until event occurrence. Therefore, protocol for monitoring and responding to potential PMP and LIP events should take advantage of the data and information available in making informed and accurate decisions.

3.2 Synoptic Storms

This storm type includes large scale frontal systems created by the interface between contrasting air masses. Synoptic storms can occur at any location across North America. These occur most often in the winter along the Gulf Coast and southern/mid-Atlantic region and along the West Coast. This pattern shifts northward through the spring and summer, before shifting south again in the fall. This is directly related to the climatologically preferred region of the jet stream (polar and sub-tropical). This storm type can produce PMP level rainfalls for locations where a 24-hour or longer event and 500-square mile or larger basin affects a given site. This storm type does not produce LIP level rainfall. However, the frontal system associated with the synoptic pattern can include imbedded convection in the form of thunderstorms. Thunderstorms related to strong synoptic scale events like deep mid-latitude low pressure systems or intense cold fronts can also produce heavy rainfall due to atmospheric instability and dynamic lifting. Rainfall amounts associated with these large scale frontal systems could produce a LIP event though they typically are too short lived or moving too quickly to produce rainfall amounts approaching LIP levels.

Forecasting the location, movement, and potential rainfall accumulation associated with synoptic storm systems has improved dramatically in recent years with the advancement of Numerical Weather Prediction. This has allowed lead times of forecast to extend out 5-7 days with reliable accuracy. In all cases, as the time of the potential storm affecting a given location comes closer, the forecasted movement and rainfall amounts become more refined. Within 3 days, the accuracy of these forecasts has become more certain, increasing each day until event occurrence. Therefore, protocol for monitoring and responding to potential PMP events can take advantage of the data and information available from which to make informed and accurate decisions. The accuracy of extreme rainfall forecast levels decreases as the projected levels exceed climatologically normal values. Therefore, monitoring and trigger levels need to be set at levels below the maximum PMP and LIP concerns. The model forecasts can be utilized to determine information such as specific Probabilistic Quantitative Precipitation Forecast (PQPF) and standard deviations from normal compared to a predefined threshold for a given site

In most cases, individual air mass thunderstorms (not associated with a synoptic scale event or mesoscale convective complex) do not contain sufficient moisture and lack the atmospheric lift required to produce LIP level rainfalls. Orographic effects are required to mechanically produce the constant

Comment [NRC Staff7]: Add citations to reference section

Comment [NRC Staff8]: Here and elsewhere the phrase "reliable accuracy" is used without any attempt to define or quantify and thus appears to be ambiguous. Adding a definition for this term would be helpful.

Comment [NRC Staff9]: This could be taken out of context. Since strong imbedded convection is a common feature of synoptic storms (as stated in the next sentence), especially during the warm season.

Additional justification should be provided, or alternatively, the sentence could be revised for clarification.

Comment [NRC Staff10]: The PMP concept is meant to account for the atypical. A more meaningful discussion may be focused on the atypical events where a LIP event is possible in a synoptic storm.

atmospheric lift to generate extreme precipitation in the absence of a synoptic scale event or mesoscale convective forcing. Terrain (e.g. located in or near mountainous regions) can serve as an immovable source of lifting which is the key in enabling an extreme precipitation scenario. This can be observed in the record US precipitation events such as Smethport, PA - 1942, Central West Virginia – 1943, and Simpson, KY – 1939, where strong orographic lift was present. As long as orographic lift is absent, individual air mass thunderstorms are not capable of producing extreme rain events as projected by HMR-52 due to a lack of a continuous sufficient lifting mechanism.

Comment [NRC Staff11]: See NRC Staff Comment #6 regarding the definition of “extreme” as presented in Section 6.2.

Remnants of tropical storms can interact with synoptic storms, especially slow-moving storm systems, and produce large amounts of rainfall. PMP level rainfalls and potentially LIP level rainfalls are possible in these situations. The weather forecasting community including the NWS has long recognized this set-up as a “classic” heavy rainfall and flooding situation and therefore anticipates these events well in advance with current forecasting models.

Comment [NRC Staff12]: This statement seems to imply that the only storms capable of producing LIP (or HMR-52 level) events in the mid-west (away from significant topography and the Gulf of Mexico) are due to MCCs. Is this accurate? Are any of the storms listed in HMR-52 away from the GoM or significant topography due to air mass thunderstorms?

3.3 Mesoscale Convective Complexes

This storm type includes mesoscale convective complexes (MCCs). A MCC is a complex (group) of thunderstorms organized on spatial scale that is larger than individual thunderstorms, but smaller than synoptic-scale storm systems. This storm type can occur at any location across North America, but is much more likely in regions away from the stabilizing effects of the cool waters of the Pacific Ocean. These storms are most common in the spring through early fall, though they are possible in the winter months as well. MCC development is directly related to availability of atmospheric moisture (mainly in the lowest 10,000 feet of the atmosphere) and excessive lift through a significant portion of the atmospheric column (instability). The atmospheric lift is created through thermodynamic or dynamic processes or a combination of both. This storm type can produce rainfall that could approach LIP levels. MCCs can produce large amounts of rainfall within heavy downpours. Excessive amounts of rainfall associated with MCCs will most typically occur when the system is moving very slowly. Typically, these systems move quickly, helping to limit extreme rainfall amounts.

Comment [NRC Staff13]: See NRC Staff Comment 10

Forecasting the location, movement, and potential rainfall accumulation associated with a MCC has also improved dramatically with the advancement of Numerical Weather Prediction. This has allowed lead times of forecast to extend out 3-5 days with reliable accuracy. In all cases, as the time of potential storm affecting a given location comes closer, the forecasted storm movement and rainfall amounts become more refined. Within 3 days, the accuracy of these forecasts has become more certain, increasing in accuracy each day until event occurrence. Therefore, protocol for monitoring and responding to potential PMP or LIP events can take advantage of the data and information available from which to make informed and accurate decisions. The parameters and physics involved in producing the model forecasts in the Numerical Weather Prediction are designed to best represent average or commonly expected conditions. The accuracy of extreme rainfall forecast levels decreases as the projected levels exceed climatologically normal values. Therefore, monitoring and trigger levels need to be set at levels below the maximum PMP and LIP concerns. The model forecasts can be utilized to determine information such as specific PMP and standard deviations from normal compared to a predefined threshold for a given site.

4.0 NOAA/National Weather Service Severe Weather Forecasting and Notification Tools – The National Weather Service (NWS) has central national monitoring and local branches that monitor developing weather conditions to detect and provide warning for severe weather prior to its arrival. The forecasting tools and services for severe rain events are described below:

Comment [NRC Staff14]: The qualification for making/assessing the products discussed in this section should be added since the products are key to planning. See NRC Staff Comment 15

4.1 Excessive Rainfall Forecast - The NWS **Weather Prediction Center (WPC)** mission is to forecast the potential for significant weather events dealing with heavy rainfall or snowfall, to discuss precipitation forecasts and model differences relating to general weather and precipitation forecasts. The WPC issues several focusing tools such as: Quantitative Precipitation Forecasts (QPFs), Probabilistic Quantitative Precipitation Forecasts (PQPFs), and Excessive Rainfall Outlooks.

The short range meteorologist prepares 6 through 60 hour forecasts for the continental U.S. These products are issued twice daily using numerical model output from the National Weather Service's (NWS) Global Forecast System (GFS) and North American Mesoscale model (NAM). Coordination with the surface analysis, model diagnostics, quantitative precipitation, winter weather, and tropical forecast desks is also performed during the forecast process. The short range forecast products include surface pressure patterns (isobars), circulation centers and fronts for 6-60 hours, and a depiction of the types and extent of precipitation that are forecast at the valid time of the chart. The primary goal is to depict accurately the evolution of major weather systems that will affect the continental U.S. during the next 60 hours. In addition, discussions are written on each shift and issued with the forecast packages that highlight the meteorological reasoning behind the forecasts and significant weather across the continental United States. Precipitation levels are not included on the 60-hour forecast chart

4.1.1 Quantitative Precipitation Forecasts (QPF) – QPF's depict the amount of liquid precipitation expected to fall in a defined period of time. In the case of snow or ice, QPF represents the amount of liquid that will be measured when the precipitation is melted. Precipitation amounts can vary significantly over short distances, especially when thunderstorms occur, and for this reason QPFs issued by the WPC are defined as the expected "areal average" (on a 20 x 20 km grid) in inches. Methods for producing QPFs are similar to other meteorological forecasts. First, meteorologists analyze the current state of the atmosphere. Then they use model forecasts of pressure systems, fronts, jet stream intensity, etc., to form a conceptual model of how the weather will evolve. The WPC has unique access to the full suite of operational and ensemble model guidance from modeling centers in the U.S., Canada, and Europe (the foreign models are global models, so they also make predictions over the U.S.). The WPC also stores output from several consecutive runs of all of these models, allowing for trend analysis of model QPFs

WPC forecasters often engage in discussion with the local National Weather Service Forecast Offices (122 locations), River Forecast Centers (12 locations) in the Continental United States, and other national centers such as the Storm Prediction Center and National Hurricane Center. The WPC provides the rainfall forecast (known as a rainfall statement) that the National Hurricane Center inserts into each tropical cyclone advisory it issues. The WPC is also co-located with NOAA's National Environmental Satellite, Data, and Information Services (NESDIS) Synoptic Satellite Analysis Branch (SAB). The SAB provides information on satellite trends which helps refine short range QPFs. Together, the SAB and Day 1 QPF desk at the WPC are known as the National Precipitation Prediction Unit (NPPU). This collaborative process makes WPC forecasts generally more accurate than any individual model.

The QPF contours (isohyets) are drawn to encompass areal average amounts of 0.01, 0.25 inch, 0.50 inch, 1 inch, 1.50 inches, and 2.00 inches (see Attachment 1). Any values greater than 2.00 inches are drawn in one-inch increments. In addition, the location of QPF maxima are indicated on the chart by an "X", with the associated maximum value printed underneath. It is important to note the valid time period when viewing each product. Specifically, for the Day 1, 2, and 3

forecasts, QPFs are manually created for 6-hour periods and an accumulated 24-hour total QPF is also issued. For the Days 4/5 and Day 6/7 QPF, forecasters manually create a 48-hour accumulation of areal average rainfall. Computer programs then take advantage of model forecasts of the timing of precipitation to break the WPC forecast down into 6-hourly QPFs.

4.1.2 Probabilistic Quantitative Precipitation Forecasts (PQPF) - The WPC produces 6-hour QPF's for forecast projection days one through three at 6-hour intervals (72-hour duration). Deterministic forecast models, including the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS), the NCEP North American Mesoscale (NAM) model and the global model from the European Centre for Medium-Range Weather Forecasts (ECMWF), along with the NCEP Short-Range Ensemble Forecast (SREF) system produce forecasts covering this time period. These model runs constitute an ensemble from which uncertainty information is obtained to construct a probability distribution about the WPC QPF. This distribution is utilized to generate probabilistic forecasts of precipitation. The 6-hour QPFs are summed to obtain 24-h QPFs, which are the basis for 24-h probabilistic QPFs (PQPF's) generated using the same multi-model ensemble and the same method as for the 6-h probabilistic QPFs. The probabilistic QPF forecasts provide information in two different forms (see Attachment 1):

Probability of Precipitation of at Least a Specific Amount show filled contour levels of probability that the 6- or 24-hour accumulation of precipitation will equal or exceed the given threshold.

Precipitation Amount by Percentile show filled contour levels of precipitation amount associated with a given probability percentile in the distribution with a range of values from the 5th to 95th percentile.

4.1.3 Excessive Rainfall Outlooks - The Excessive Rainfall Outlooks provide a forecast of the risk of flash flooding across the continental United States. A closed contour with an arrowhead delineates the probability forecasts, with risk areas defined to the right of the direction of the arrowhead. The probability categories are based on calibration studies conducted at WPC. The calibration for the excessive rainfall graphics are based on the frequency of events for which observed rainfall exceeded flash flood guidance values for a given risk category. When forecasters outline risk areas they are expecting greater organization of excessive rainfall than would be observed under average conditions. As confidence of excessive rainfall increases the category respectively evolves from Slight to Moderate to High. Day-1 Excessive Rainfall Outlooks (graphic and associated discussion) are issued four times per day: 03, 06, 15, and 18 UTC. Day 2 and Day 3 excessive rainfall forecasts are issued only twice per day.

Flash Flood Guidance values incorporate soil type, land coverage, and a host of other factors in an attempt to describe the rain rate necessary to yield significant surface runoff and flash flooding over a given area. The River Forecast Centers issue guidance values for 1-, 3-, and 6-hour periods. Flash Flooding is considered to be caused by rainfall occurring in 6 or fewer hours, whereas longer duration rainfall represents areal flooding or inundation. The WPC excessive rainfall products focus specifically on flash flooding.

4.2 Mesoscale Precipitation Discussions

The WPC provides short term guidance to the National Weather Service (NWS) Weather Forecast Offices during heavy rain events when there is a threat of flash flooding. These are also provided to the media, emergency managers and interested partners. Guidance is given in the form of Mesoscale Precipitation Discussions (MPDs), that are issued 1-6 hours ahead of time. Each MPD consists of a graphic indicating the area of concern and any pertinent meteorological features as

well as a brief text discussion focused on the mesoscale features supporting the anticipated heavy rainfall.

4.3 Tropical Public Advisories

The WPC will issue public advisories after the National Hurricane Center (NHC) discontinues its advisories on subtropical and tropical cyclones that have moved inland, but still pose a threat of heavy rain and flash floods in the conterminous United States or adjacent areas within Mexico which affect the drainage basins of NWS River Forecast Centers. The last NHC advisory will normally be issued when winds in an inland tropical cyclone drop below tropical storm strength, and the tropical depression is not forecast to regain tropical storm intensity or re-emerge over water. WPC advisories will terminate when the threat of flash flooding has ended.

4.4 Local Precipitation Climatological Studies

Local NWS offices often produce local climatology studies which focus on specific forecasting problems in the NWS office's specific county warning responsibility area. Some of these studies focus on precipitation forecasting and contain results based on years of accumulated knowledge of local climatology. These studies may be available from the internet, or upon request from the local NWS office. Local NWS forecasters often cite results from these local studies as part of their daily forecast discussions. Forecast discussions from local NWS offices are available on the internet. Results of local studies, and the additional comments provided by local NWS forecasters in the forecast discussions, can be quite useful when assessing potential and actual heavy rainfall situations for specific locations.

5.0 Severe Weather Forecast Process - the NWS **Storm Prediction Center (SPC)** employs meteorological forecasting tools and models to generate severe weather forecasting notifications. The Storm Prediction Center receives input from the WPC on excessive rainfall that could lead to flash flooding for severe weather forecast and warnings. SPC Forecast and Discussions are intended for use by qualified personnel such as state, local or commercial meteorologists. Forecasts provided include:

Day 4-8 Severe Weather Outlook - graphic and text issued daily

Day 3 Convective Outlook - issued daily

Day 2 Convective Outlook - issued twice daily

Day 1 Convective Outlook – narrative and graphics with timing and severity, issued 5 times daily

- Flash flooding watches – issued with projection for time, location, and rainfall amount

6.0 Excessive Rain Event Trigger & Warning Time

Rainfall projected for the LIP based on the maximum synthetic storm cannot be reliably forecasts using current models and forecasting methods which have been developed and validated based on historical rainfall. However, warning time for extreme events can be established based on less extreme events that occur infrequently but fall on the high end of normal rain events. These high precipitation forecast include the large storms systems that contain enough moisture with the potential for delivering LIP levels rainfalls without relying on the capability to accurately forecast specific extreme rainfall levels. This approach establishes monitoring and triggers based on less extreme events that will bound the maximum LIP extreme event. Locations without terrain that can produce orographic lift can have the longer warning time due to the significant size of the storms required to produce precipitation approaching the maximum LIP event.

Excessive rain event triggers and warning time mechanisms can be developed based on the time needed to implement any flooding protective or mitigation that are not passively based. Notification levels can be established using a single trigger or multiple triggers. Multiple triggers can be established if the

Comment [NRC Staff15]: Judging the feasibility of proposed triggers and warning times requires consideration of the skill in the forecasts which are being relied on. Quantitative skill metrics should be used. A recent assessment of NWS QPF for extreme precipitation is: Sukovich, E., F. Ralph, F. Barthold, D. Reynolds, and D. Novak, 2014: Extreme Quantitative Precipitation Forecast Performance at the Weather Prediction Center from 2001 to 2011. *Weather and Forecasting*. Early online release <http://dx.doi.org/10.1175/WAF-D-13-00061.1>

response to an extreme rain event is done in graduated steps (e.g. stage equipment at 48 hours, assemble equipment at 12 hours, and complete implementation at 6 hours).

6.1 Monitoring for Precipitation (by NWS):

Medium Range Forecast

Days 4-7 –QPF forecast are issued twice a day with valid periods of 48 hours

Day 3 – QOF and PQPF forecast are issued twice a day with valid periods of 24 hours

Short Range Forecast

Day 2 – QPF and PQPF forecast are issued twice a day (WPC forecast model updates every 6 hours) with a valid period of 24 hours. Excessive Rainfall Outlook forecast are issued twice a day with a valid period of 24 hours.

Day 1 - PQPF forecast are issued twice a day (WPC forecast model updates every 6 hours) with a valid period of 24 hours. Excessive Rainfall Outlook forecast are issued twice a day with a valid period of 24 hours. Excessive Rainfall Outlook forecast are issued four times a day with a valid period of 21 to 30 hours. Unscheduled, event driven updates may be issued as determined by NWS/WPC

Other Monitoring Data Sources include: (NWS) Storm Prediction Center, National Hurricane Center, local National Weather Service Forecast Offices (122 locations nationally), Internal licensee meteorologist, private weather forecasting consulting organizations, and other sources.

6.2 LIP Warning Time & Trigger: Warning time needed to provide a reliable response time to prepare for an extreme precipitation LIP event as predicted by HMR-52 (or a location specific HMR) can be established using NWS forecast. LIP warning thresholds should be set conservatively based on less extreme (and more predictable) events to assure that active protection or mitigation can be executed prior to consequential flooding (point at which required SSC's are impacted by flooding levels) occurring. Consequential flooding may occur prior to the peak LIP flooding level (see Figure 1).

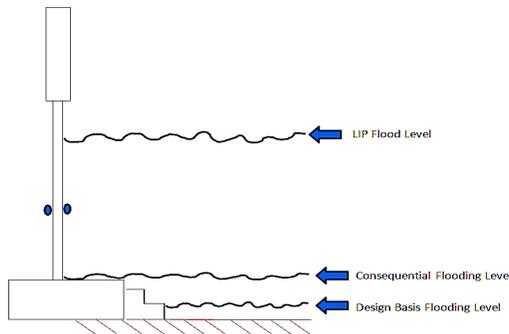


Figure 1 Consequential Flooding Illustration

LIP warning time should be based on the three types of storms (Tropical, Synoptic, Mesoscale Convective Complexes) that can produce the LIP level rainfall for a given nuclear facility location. Mesoscale Convective Complexes (thunderstorms) for sites with local terrain that can provide orographic lift, may have the shorter warning times. A qualified meteorologist can determine what storm types apply to a given location including whether terrain has the potential to produce orographic lift. An acceptable method that provides a conservative and

Comment [NRC Staff16]: The determination of what is consequential should be based on a site-specific basis. Consideration of aspects other than the SSCs being directly impacted by flood waters may be needed. Examples include but are not limited to: 1) ability to stage equipment or move around the site; 2) associated affects such as wind, lighting, and other factors such as personnel availability.

Comment [NRC Staff17]: A better criteria for determining who is a qualified meteorologist should be discussed. Certifications such as the AMS certification as a consulting meteorologist should be addressed in light of what is an acceptable level for the "qualified meteorologist" described in this paper.

Comment [NRC Staff18]: This appears to be an unnecessary step if the LIP warning time will be coming from WPC forecasts for all sites anyway.

reliable warning time is to establish a monitoring threshold followed by a mitigation action trigger. The recommended precipitation forecasting tools are QPF's for monitoring during medium range forecast, and PQPF's for the mitigation action trigger for short range forecast for Day 1 and Day 2. This approach can be developed as follows:

A monitoring threshold can be set by establishing a level of extreme rainfall for the basin where the nuclear facility is located. For most locations east of the 105th meridian a value of 3.7 to 5.7 inches in 24 hours would be considered an extreme rainfall based on a threshold of 0.001 frequency (the top 0.1% of days with rainfall) (Ralph et al 2009). This threshold can be set using the medium range forecast 3 to 7 days prior to the event. If this threshold still is met based on short range forecast on Day 2, the nuclear site would be notified (unless an earlier notification is desired) which would initiate site monitoring once per shift as directed by site procedure.

A mitigation action trigger can be set at $\frac{1}{2}$ of the 1 hour LIP rainfall amount that requires mitigation action by the site. For example if the site LIP is determined to be 18" but consequential flooding on site occurs with an 8" per hour rain event, the action trigger would be set based on the more limiting event at 4". This trigger value from a 1 hour rainfall event would be applied to a 24 hour rainfall projection based on the Day 1 or 2 PQPF. Using $\frac{1}{2}$ of the 1 hour LIP (or the more limiting event) would provide a conservative trigger value when applied to a 24 hr rainfall 95th Percentile PQPF. The 1 hour LIP used in developing the trigger should be based on the LIP for the location of the nuclear site using the appropriate HMR (e.g. HMR-52). A site or region specific updated HMR could also be used to develop the basis for the trigger value.

The accuracy of extreme rainfall forecast levels decreases as the projected levels exceed climatologically normal values and longer lead times. Using 24 hour value based on $\frac{1}{2}$ of the 1 Hour LIP (e.g., 6" to 9" for HMR-52) is still in the range of reasonable forecast accuracy using short range forecast. Rainfalls in the range of these values also provides a low threshold of expected occurrence with low return rates of less than 1 in 1000 years for most locations east of the 105th meridian. Based on the desired warning time, the 95th Percentile PQPF can be selected from the 24 hour short range forecast on Day 1 or Day 2. When this trigger is reached, action would be taken to put active protection or mitigation measures into place.

It is important that a qualified meteorologist evaluate the nuclear site location to validate the acceptability of the monitoring threshold, trigger, and warning time based on the meteorological impacts of the local terrain and a review of weather history for the region associated with the nuclear site.

The above method represents one approach that can applied apply. Forecasting uncertainty is compensated by using a trigger value based on a combination of $\frac{1}{2}$ of the 1 hour consequential rainfall, applied to a 24 hour storm as forecasted by the 95th Percentile PQPF. The conservative bias of this approach increases the likelihood of false alarms. However, the consequence of a false alarm are minimal assuming the trigger actions are limited to reversible actions such as securing doors/gates or staging equipment.

Other methods can also be used based on government and private forecasting models. Sites located within 50 miles of coastal areas should include monitoring of hurricane and tropical

Comment [NRC Staff19]: Clearly defining who will do the monitoring, issue the notifications, and how the warning will be communicated is an essential element of the procedure.

Since most NPP sites no longer employ meteorologists, agreements with private weather forecasting firms may become necessary.

Comment [NRC Staff20]: Consider a site specific value instead of recommending a set value (1/2) for the trigger that would depend on site specific variables (like time needed to implement any actions taken, the time it takes for water to accumulate, etc.). Also, consider including more than the 1-hour storm because licensees have submitted FHRRs with a range of storm durations.

Comment [NRC Staff21]: While it is practical to base warnings and triggers on rainfall rates, it is the rate of water level rise on the site or some portion of the site that is controlling. For some sites, this might be quite different than the rainfall rate.

Comment [NRC Staff22]: If it's important, then criteria for qualification are needed. Other documents that refer to this terminology should also have acceptance criteria for what a "qualified meteorologist" is.

Comment [NRC Staff23]: 3 paragraphs up, it says that the trigger value is based on $\frac{1}{2}$ of the 1 hour LIP. Please clarify.

storm advisories from the National Hurricane Center in addition to the Weather Prediction Center precipitation forecasts. Western plant sites- need to consider atmospheric streaming as a significant source of moisture based on location and historic data.

Attachments:

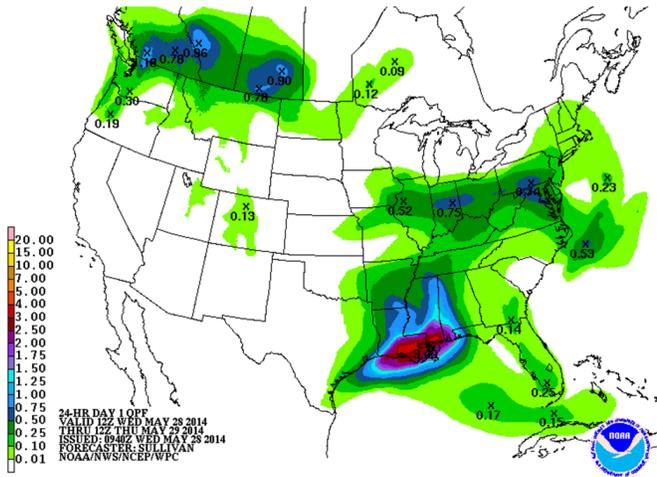
- Attachment 1 - Probabilistic Quantitative Precipitation Forecast, Excessive Rainfall Outlooks
- Attachment 2 - NWS Web Sites (Source Material), References

Comment [NRC Staff24]: "Atmospheric streaming" is not a commonly used or understood phrase. Consider replacing with "atmospheric rivers," or something along the lines of, "Western plants need to consider significant atmospheric moisture from the Pacific Ocean interacting with complex terrain as a significant source of precipitation..."

Attachment 1

Quantitative Precipitation Forecasts (QPFs) – EXAMPLE

(<http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml>)



Probabilistic Quantitative Precipitation Forecasts (PQPFs) – EXAMPLE

(http://www.hpc.ncep.noaa.gov/pQPF/conus_hpc_percentile.php?fpd=24)

6-Hour Forecasts

Probability of Precipitation of at Least a Specific Amount

Precipitation Amount by Percentile

24-Hour Forecasts

Probability of Precipitation of at Least a Specific Amount

Precipitation Amount by Percentile

24-Hour Percentile QPFs valid 12Z May 28, 2014 - 12Z May 29, 2014

Percentile:

5th
10th
25th
50th
75th
90th
95th

95th percentile QPF for the 24-hour forecast valid 12Z May 28, 2014 - 12Z May 29, 2014

24-HR QPF EXPECTED NOT TO BE EXCEEDED WITH 95% PROB
 VALID 12Z WED MAY 28 2014
 THRU 12Z THU MAY 29 2014
 ISSUED 0940Z WED MAY 28 2014
 WEATHER PREDICTION CENTER
 NOAA/NWS/NCEP/WPC

Viewing Options

Choose a percentile for the specified time:

- 5th
- 10th
- 25th
- 50th
- 75th
- 90th
- 95th

OR

Choose a time for the specified percentile:

- 12Z May 28
- 18Z May 28
- 00Z May 29
- 06Z May 29
- 12Z May 29
- 18Z May 29
- 00Z May 30
- 06Z May 30
- 12Z May 30
- 18Z May 30
- 00Z May 31
- 06Z May 31
- 12Z May 31

Attachment 2

NWS Web Sites (Source Material)

Comment [NRC Staff25]: Direct links to NOAA websites could be problematic as they change from time to time. These links could quickly become outdated / broken.

NWS Weather Prediction Center (WPC)

<http://www.hpc.ncep.noaa.gov/html/fam2.shtml> - Website describing the WPC Products
<http://www.hpc.ncep.noaa.gov/index.shtml> - Website with QPC's and Excessive Rain Forecast
http://www.hpc.ncep.noaa.gov/pqpf/conus_hpc_percentile.php?fpd=24 – Website for Probabilistic QPF's

NWS National Hurricane Center (NHC)

<http://www.nhc.noaa.gov/> - Home page for NHC

NWS Storm Prediction Center (SPC)

<http://www.spc.noaa.gov/misc/aboutus.html>
<http://www.spc.noaa.gov/misc/about.html#Day 1 Convective Outlook>

NWS Weather Alerts

<http://alerts.weather.gov/>

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)¹
(includes recurrence intervals up to 1000 years and includes a 1 hour storm – listed by state)

<http://hdsc.nws.noaa.gov/hdsc/pfds/index.html>

NWS and Non-NWS listings of Weather Service Providers

<http://www.nws.noaa.gov/im/metdir.htm>

References

1. F. M. Ralph, E. Sukovich, D. Reynolds, M. Dettinger, S. Weagle, W. Clark, And P. J. Neiman (November 2009). "Assessment of Extreme Probabilistic Quantitative Precipitation Forecasts and Development of Regional Extreme Event Thresholds Using Data from HMT-2006 and COOP Observers"
2. D. A. Olson, N. W. Junker, And B Korty (February 1995). "Evaluation of 33 Years of Quantitative Precipitation Forecasting at the NMC", Weather Forecast Branch, Meteorological Operations Division, National Meteorological Center

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