Rev 6, 4-8-15

Warning Time for Local Intense Precipitation Events

1.0 Introduction

Local Intense Precipitation (LIP) is a theoretical measure of extreme rainfall. This represents the upper limit of rainfall at a given location. LIP is typically assumed to be equivalent to the local probable maximum precipitation (PMP) derived from National Weather Service (NWS) Hydrometeorology Reports (HMRs) or from a site-specific PMP study. Even though LIP estimates in some locations can project rainfall in excess of 19 inches for 1-hour over one square mile, consequential flooding may occur from extreme precipitation events that fall below maximum LIP levels. A consequential rain event is the point at which flooding from rainfall (e.g., as determined by hydraulic analysis) rises above the permanent and passive flooding barriers (e.g., walls, door sills, dikes, berms, administratively closed openings, etc.) such that structures, systems, and components (SSC's) important to safety are impacted. If a nuclear site's flooding protection is not permanent and passive, a consequential rain event may require actions to be taken prior to the storm to protect or mitigate flooding impacts on required SSC's. As such, warning time is a key component in the planned response for a consequential rain event.

Despite improvements in forecasting accuracy of precipitation, the present state of the meteorological science's tools and techniques are not able to reliably predict extreme rain events explicitly in location, timing, or amount of precipitation (Ralph et al. 2010, Olson et al 1995, Sukovich et al 2014). This is due in part to limitations in weather model capabilities and is also due to the limited frequency of extreme rain events. Yet, despite these limitations, forecasting tools are available to identify atmospheric conditions that could lead to consequential rain events and to provide lead time to implement mitigation actions.

1.1 Basis for Methods - Recognizing the limitations in forecasting accuracy for extreme events, methods to establish warning time for consequential rain events are based on:

1. Recognition that consequential rain events require atmospheric conditions that include both substantial atmospheric moisture and a sustained atmospheric lifting mechanism, which can be recognized and forecast prior to the event occurring.
2. Setting warning thresholds conservatively based on less extreme (and more predictable) storms to assure that protection or mitigation can be executed prior to consequential flooding (see section 5.2.1 for a definition of consequential flooding).
3. Including additional conservatism to compensate for forecasting uncertainty by setting monitoring and trigger thresholds that are a fraction of the rain event that would result in consequential flooding.
4. Evaluating local thunderstorms for the nuclear site and assessing whether the maximum rainfall from a local thunderstorm is capable of producing consequential flooding for the site. A local thunderstorm is defined as an extreme rainfall event, not associated with widespread heavy precipitation, that produces rain for durations of 6 hours or less, and is concentrated over an area of 500 square miles or less (Riedel et al 1980).

Using existing forecasting tools and addressing known forecast limitations with conservative measures to compensate for uncertainty can provide an acceptable method for establishing warning time to implement flood protection or mitigation responses for consequential rain events.

2.0 Basis for Local Intense Precipitation (LIP) Events

NUREG/CR-7046 (USNRC 2011) recommends that LIP events be based on the 1-hr, 2.56-km2 (1-mi2) PMP at the location of the site. Some sites may consider different duration events if they result in more severe flooding than the 1-hr event. However such an analysis, if performed, should still include a maximum 1 hour rainfall within the assumed duration. NUREG/CR-7046 also recommends the use of the most recent Hydrometeorological Report (HMR) unless an approved site-specific PMP study is available. PMP is defined as, "…theoretically the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year" (Hansen et al., 1982). For most nuclear sites east of the 105th meridian, the current HMR's include: HMR-51 (all season PMP values), HMR-52 (application guidance), and HMR-53 (seasonal guidance). The National Weather Service (NWS) has also HMR's for west of the 105th meridian which can be accessed from their website (http://www.nws.noaa.gov/oh/hdsc/studies/pmp.html). As discussed in Section 1, consequential flooding may occur from extreme precipitation events that fall below maximum LIP levels.

3.0 Sources of Consequential Rain Events

The highest recorded worldwide one hour rainfall event is 15.79" in Shangdi, Inner Mongolia, China in 1975. The highest recorded U.S. rainfall event approaching 1 hour occurred at Holt, Missouri in 1947 with 12" of rain in 42 minutes. The highest estimated 1 hour event in the U. S. occurred in Burnsville, West Virginia in 1943 with an estimated rainfall of 13.8" (NOAA.gov "Record Point Precipitation Measurements for the World and the USA"). It has also been shown that there are instances in which PMP has been exceeded by or are very close in magnitude to observed events (Harrison 2006, J. T. Riedel et al., 1980). The present state of the meteorological science's tools and techniques are not able to reliably predict extreme rainfall events explicitly in location, timing, or amount of precipitation. However, atmospheric conditions that have the potential to deliver a consequential rain event would be detectable in advance with current forecasting methods/models based on the anomalously large amount of moisture and level of atmospheric instability (lift) required to generate precipitation of this magnitude.

Isolated, local thunderstorms typically do not have the capacity to produce a consequential rain event for most sites in the region covered by HMR 51 because of the short duration of sustained lift, lack of moisture, and transient nature of such storms (this must be verified for each site. See Section 1.1 Item 4). However, for areas west of the Continental Divide, HMRs provide local storm PMP values. This is a direct result of the meteorology which would produce these types of events in the various regions covered by each HMR. It was recognized in the HMRs that isolated, local thunderstorms are more likely to result in LIP-type rainfall in regions west of the Continental Divide, while LIP in regions covered by HMR 51 would result from rainfall associated with tropical systems, MCCs, and/or embedded convection within a synoptic event. Therefore, Section 6 of HMR 52 was developed subsequent to HMR 51 to address the different type of storm which would produce LIP-type rainfall versus the data used to derive the PMP values in HMR 51. This is a direct result of the meteorology (and specifically low-level moisture availability and source regions), which would produce these types of events in the various regions covered by each HMR.

General storms that have atmospheric conditions capable of producing consequential rain events would be detectable in advance utilizing current forecasting methods/models. The types of weather systems capable of producing consequential rainfall include:

- Tropical Systems
- Synoptic Storms with imbedded convection
- Mesoscale Convective Complexes (Organized Thunderstorms)

These three basic storms types (including combinations of these storms) are briefly described below including a discussion on the contribution of orographic effects.

3.1 Tropical Systems

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 transitioning tropical cyclones have impacted California and far southern Arizona (e.g. tropical cyclone Nora which arrived in Arizona in 1997 as a tropical storm). These rainfall events can also occur where the storm has begun to transition into an extratropical storm. High levels of tropical atmospheric moisture could produce consequential rainfall, especially when enhanced by convection/thunderstorms and slow movement.

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). Synoptic storms are not typically capable of producing consequential rainfall. However, the frontal systems associated with synoptic storms can include imbedded convection in the form of thunderstorms. These thunderstorms when related to strong synoptic scale events like deep mid- latitude low pressure systems or intense cold fronts can produce heavy rainfall due to atmospheric instability and dynamic lifting. Rainfall amounts associated with this form of large scale frontal systems with embedded thunderstorms could produce consequential rainfall if the system moves slower than normal, especially if there is some additional form of topographic or synoptic enhancement to the updraft.

Remnants of tropical storms can interact with synoptic storms, especially slow-moving storm systems, and produce large amounts of rainfall. Consequential rainfall is 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.

3.3 Mesoscale Convective Complexes

A Mesoscale Convective Complex (MCC) is an organized group of thunderstorms over a spatial scale larger than individual thunderstorms, but smaller than synoptic-scale storm systems. These systems can occur at any location across North America, but are 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 which is usually supplied by a low-level jet stream feature and lift through a significant portion of the atmospheric column (instability). The atmospheric lift is enhanced through thermodynamic or dynamic processes or a combination of both. Typically, these systems move quickly, helping to limit extreme rainfall amounts. However, this storm type can produce rainfall that could approach consequential rainfall. Excessive amounts of rainfall associated with MCCs will most typically occur when the system is moving very slowly producing large amounts of rainfall within heavy downpours.

3.4 Orographic Effects

Orographic effects can mechanically produce the constant atmospheric lift to generate extreme precipitation and consequential rainfall in the absence of a synoptic scale event or mesoscale convective forcing. This occurs when terrain (e.g. located in or near mountainous regions) serves as an immovable source of lifting which is the key in enabling an extreme precipitation scenario. Examples where strong orographic lift contributed to three extreme MCC precipitation events include Smethport, PA - 1942, Central West Virginia – 1943, and Simpson KY – 1939. Orographic effects have the potential to reduce warning time.

4.0 NOAA/National Weather Service Severe Weather Forecasting Tools

The 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. There are a number of different forecasting tools and services for severe rain events provided online by the NWS web site (http://www.hpc.ncep.noaa.gov/html/fam2.shtml). The recommended tool for a warning time trigger is a quantitative precipitation forecast which provides a specific amount of rain for a given time period. Additional tools are also discussed below which can be used to provide supporting information on the basis for the rainfall amount being forecasted. The NWS provides updates to the NWS forecasting tools and the NWS web site. Users of NWS tools should periodically review the applicable forecasting tools for changes and update the plant-specific triggers accordingly.

4.1 The NWS Weather Prediction Center (WPC) Products: The 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 WPC 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 (e.g. forecast of total rainfall for 6, 12, 24, and 48 hour periods). 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. 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 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 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 (see section 5.3 Forecasting Accuracy Limitations).

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-hour 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 which shows the tab selected for Precipitation Amount by Percentile for the 95th Percentile of a 24 hour forecast period):

- 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 for 6 or

24-hour accumulation.

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), which 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 tropical 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 from 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 useful when assessing site-specific considerations for potential and actual heavy rainfall for evaluating site-specific triggers.

5.0 Rain Event Trigger & Warning Time

Consequential rain events cannot be reliably forecast in location, timing, or amount of precipitation using current numerical models and forecasting methods which were developed and validated based on historical rainfall. However, warning time for consequential rain events can be established based on less extreme events that occur infrequently but still fall on the high end of normal rain events. Forecasts that identify the potential for consequential rainfall include the general storms systems that have atmospheric conditions with the potential for consequential rainfall without relying on the capability to accurately forecast location, timing, or amount of precipitation. Locations without terrain that produces orographic lift can support longer warning time due to the significant size of the storms required to produce precipitation approaching a consequential rain event. This approach establishes monitoring and triggers based on atmospheric conditions with the potential to cause a consequential rain event.

Rain event triggers and warning time mechanisms can be developed based on the time needed to implement any flood protection or mitigation measures. Notification levels can be established using a single trigger or multiple triggers. Multiple triggers can be established if the 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).

5.1 QPF Forecast for Monitoring and Triggers:

Medium Range Forecast (monitoring threshold)

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

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

Short Range Forecast (action trigger)

Day 2 – QPF and PQPF 6 and 24 hour forecast are issued twice a day (WPC forecast model updates every 6 hours) with a valid period of 24 hours. Additional information that can be used to supplement the PQPF includes Excessive Rainfall Outlook (ERO) forecasts and event driven updates. 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 at 0600 and 1800 UTC (Coordinated Universal Time) with a valid period of 24 hours.

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

5.2 Warning Time & Trigger: A method to establish warning time for consequential rain events can be established using NWS forecast tools. Warning thresholds should be set conservatively based on less extreme (and more predictable) events to assure that time is available to implement flood protection or mitigation measures prior to site specific consequential flooding (see 5.2.1 below) occurring. The warning time required should account for the time needed to implement flood protection or mitigation measures (e.g. closing doors, installing stop logs, staging equipment, etc.) and take into account other conditions (e.g. wind, lightning, personnel availability) that could impact the time required to execute the mitigating actions.

5.2.1 Consequential Flooding: Flooding from a consequential rain event may occur prior to the peak LIP flooding level. Consequential flooding (see Figure 1) is the point at which flooding (e.g., as determined by hydraulic analysis) rises above the permanent and passive flooding barriers (e.g., walls, door sills, dikes, berms, administratively closed openings, etc.) such that SSC's important to safely are impacted.

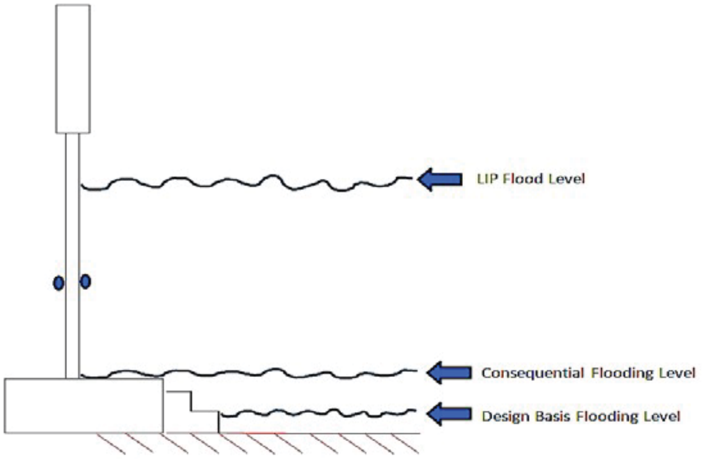


Figure 1. Consequential Flooding Illustration

5.2.2 Monitoring and Action Triggers: Warning time should be based on the storms (Tropical, Synoptic, and Mesoscale Convective Complexes) that can produce the maximum or consequential rainfall for a given nuclear site location. This assumes that local thunderstorms (see definition in Section 1.1) have been evaluated for the nuclear site and it has been confirmed that the maximum rainfall will not result in consequential flooding for the site. Mesoscale convective complexes for sites with local terrain that can provide orographic lift may have the shorter warning times. A 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 warning time is to establish a Monitoring Threshold followed by an Action Trigger. This approach can be developed (assuming any specific site limitations have been evaluated as described in Sections 1.1 and 5.2.2 D) as follows:

A. Select a Forecasting Tool: The recommended precipitation forecasting tools are the NWS QPF and PQPF as described in section 4.1. For the Monitoring Threshold use the NWS QPF for monitoring during medium range forecast from Day 3 to Day 7. For the Action Trigger, the NWS PQPF (selecting the 95th Percentile forecast) for short range forecast for Day 1 and Day 2 is recommended. The PQPF can also be used for both the Monitoring Threshold and the Action Trigger if desired.

B. Establish a Monitoring Threshold: a monitoring threshold should be set by establishing a level of consequential rainfall for the basin where the nuclear facility is located. For most locations east of the 105th meridian a value of 2.0 to 3.1 inches in 24 hours would be considered an extreme rainfall based on a threshold of 0.01 frequency (the top 1% of days with rainfall) (Ralph et al 2010). See Ralph et al 2010 for 0.01 frequency extreme rainfall values that apply to the specific region where the nuclear site is located. This threshold should 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 required based on site-specific factors such as time required for flood protection implementation. This would initiate site monitoring once per shift as directed by site procedure. Notification to the site should be provided by either internal meteorological services or by external contract meteorological services as long as the meteorological coverage is provided seven days a week and the notification process is formalized. Depending on the threshold selected, there may be a low probability of detection associated with the QPFs. In these cases, alternate products (e.g., convective outlook on conditions in the area) should also be considered for specifying monitoring thresholds, in addition to the QPFs. Monitoring should be initiated based on *either* the results of the QPF or the alternate tool (e.g., convective outlook).

C. Select an Action Trigger:

1. **Define consequential rainfall depth:** Determine the smallest precipitation amount that, when distributed over one hour, may lead to consequential flooding at the site (e.g., as determined by hydraulic analysis). Consideration should also be given to whether precipitation amounts less than the above values may be consequential to the site (brief but high- intensity rainfall events not covered by 1.1.4, prolonged lower-intensity events).
2. **Define Trigger Value**: The "trigger value" is set at the minimum of the following:
    - one-half of the consequential 1hr rainfall depth (amount)
    - one half (or other fraction as justified based on time required to conduct actions) of other consequential rainfall amounts (this would be tied to prediction capability)
    - the saturation point of the PQPF (i.e., the largest rainfall amount considered by the PQPF; as shown in Figure 2 of Attachment 1, is 9 inches of rainfall)
3. **Define conditions to initiate actions**: Actions are initiated when the Day 1 or 2 (or longer depending on time required for plant response) 95th percentile PQPF projects cumulative rainfall amount greater than the trigger value over the next 24 hours.

Alternate Action Trigger: If the rate of return for the Trigger Value as described in C. 2. above is too high (i.e. results in excessive false triggers), an alternative approach can be considered based on historical storms for the drainage basin where the site is located. The use of the alternate action trigger could result in trigger levels approaching the consequential rainfall level for the site. Alternative trigger points developed on a plant-specific basis should include justification to show that the trigger point is conservative.

D. Validation of Monitoring and Action Trigger:

A meteorologist should 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. For example, sites located near coastal areas should include as part of their monitoring process the use of hurricane and tropical storm advisories from the National Hurricane Center in addition to the Weather Prediction Center precipitation forecasts. Plant sites west of the Continental Divide should consider atmospheric river events where heavy bursts of rain can occur within an overall synoptic storm. Sites affected by the North American Monsoon, should consider the Gulf of California surge events.

The conservative bias of this approach increases the likelihood of false alarms. However, the consequence of a false alarm should be minimal assuming the trigger actions are limited to reversible actions such as securing doors/gates or staging equipment.

5.3 Forecast Accuracy Limitations: The accuracy of extreme rainfall forecast decreases as the projected levels exceed climatologically normal values and longer lead times. 24-hour precipitation values of 1/2 of the 1-hour LIP (e.g. 6"-9" from HMR-52) correspond to precipitation return rates on the order of 1/1000 (0.001 or 0.1%), or less, for most sites east of the 105th meridian. In Sukovich et al. 2014, Figure 6 shows a Probability of Detection for the WPC QPF forecasts of the top 0.1% of precipitation events near 0.25 (25%) for the CONUS (continental United States) in 2011. This qualitatively low level of detection is partially a function of the grading metric (full credit or no credit only), but is also a function of the inherent low bias that occurs when forecasting extreme events. The use of "1/2" of the 1 hour LIP or consequential event provides a level of conservatism intended to compensate for uncertainties in the precipitation forecast. Additionally, the use of the 24-hour 95th percentile PQPF as opposed to the QPF (comparable to the 50th percentile PQPF) builds in further conservatism to the methodology. The 95th percentile PQPF is designed such that an event has only a 5 percent chance of exceeding the forecast value, based on an ensemble of QPF model forecasts.

Attachments:

Attachment 1 - NWS Weather Prediction Center (WPC) Forecast Tools

Attachment 2 - NWS Web Sites (Source Material), References, Contributing Authors

Attachment 1

NWS Weather Prediction Center (WPC) Forecast Tools

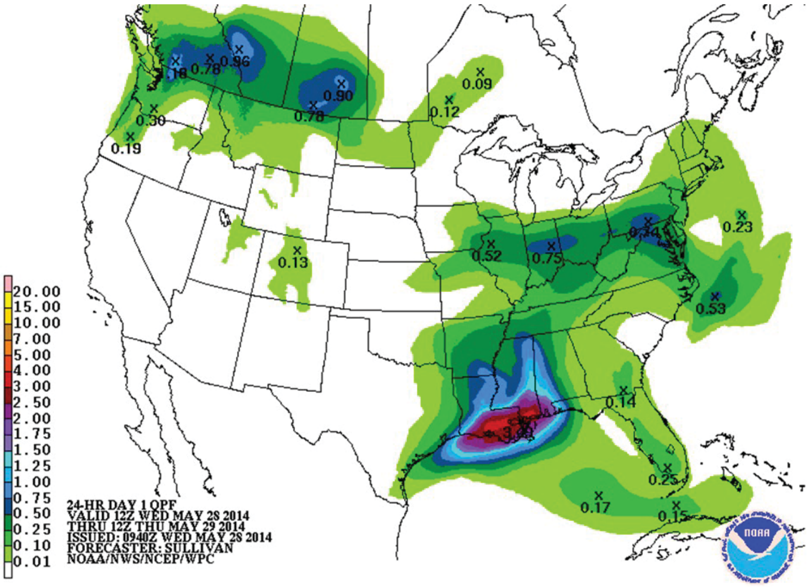
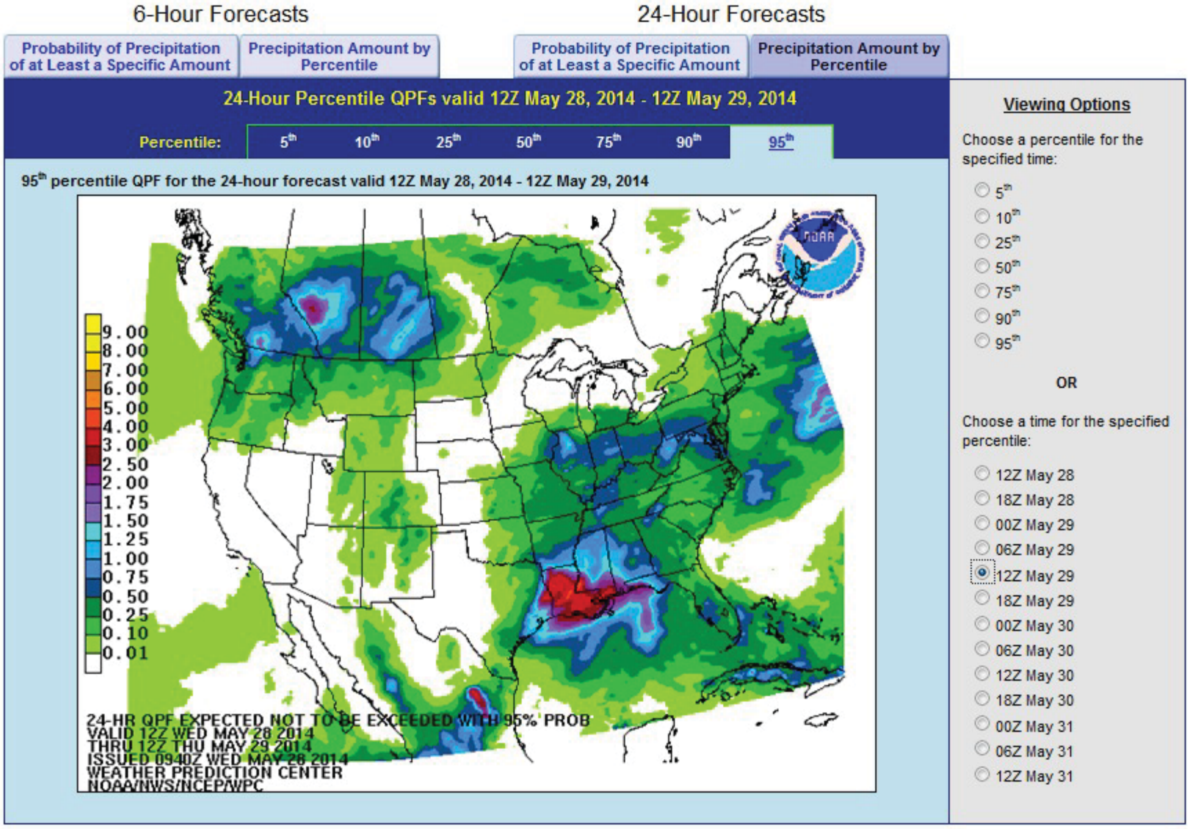


Figure 1 Quantitative Precipitation Forecasts (QPF) – EXAMPLE
(http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml**)**



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

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

Figure 2 Probabilistic Quantitative Precipitation Forecasts (PQPF) – EXAMPLE
(http://www.hpc.ncep.noaa.gov/pqpf/conus_hpc_percentile.php?fpd=24)

Attachment 2

NWS Web Sites (Source Material)

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

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Contributing Authors

1. William Henson, PhD, AMEC
2. William D. Kappel, President/Chief Meteorologist, Applied Weather Associates
3. Brian Kolts, Meteorologist - First Energy
4. Stanton Lanham, Meteorologist - Duke Energy
5. Peter C. Manousos, Meteorologist - First Energy
6. Erwin T. Prater, PhD, MBA, CCM, CFA, Certified Consulting Meteorologist