APPENDIX B

Summary of Questionnaire Responses by Federal Agencies

1 Discuss your agency methods and extreme precipitation needs for decision making, assessments, and designs (extreme precipitation is defined as those events with a return period of 1,000-years or greater, up to and including PMP):

NRC: US NRC uses a "risk-informed" regulatory framework, although the manner and degree to which risks due to natural hazards are quantified varies. For example, the agency has used probabilistic seismic hazard analysis form many years. However, analysis of flooding hazards submitted for licensing of new facilities is almost entirely deterministic. Deterministic analysis via progressive refinement of conservative assumptions (called Hierarchical Hazard Assessment (HHA)) is commonly used. Concepts such as PMP and PMF are commonly used. On the other hand, a more explicitly risk-informed significance determination process (SDP) is being used for decision-making in light of new information that comes up after initial licensing. The SDP activities have often included attempts to quantify risks due natural hazards such as extreme precipitation and flooding.

More and more, applicants and licensee are submitting probabilistic flooding hazard assessments. US NRC is currently developing a research plan aimed at providing the technical basis for development of regulatory guidance for probabilistic flood hazard assessment (PFHA), including extreme precipitation. The goal is to develop an overall PFHA framework that can be used in both licensing and oversight activities.

NOTE-1: The types of sites and facilities for which extreme precipitation estimates are needed is varied: 1) nuclear power plant sites; 2) fuel cycle facilities; 3) interim spent fuel storage facilities; 4)nuclear waste repositories; 5) watersheds in which facilities are located; 6) reservoirs and dams upstream of nuclear facilities; and 6) tailings dams.

NOTE-2: The main question as written above appears predicated on cutting estimates off at the PMP. This does not seem to be compatible with a true probabilistic assessment.

NOTE-3: Many of the questions below refer to extreme precipitation "data", when, in reality, the values in question are model-based estimates derived from actual data. We sometimes use these estimates as if they are data, but one should not lose sight of the fact that they are estimates with considerable uncertainties. Methods applied to develop estimates from the actual data and attendant uncertainties need attention too.

NOTE-4: Many of the sub-questions below seem to be targeted at deterministic approaches. While advances in deterministic approaches may be usefully applied to current NRC methods, it's not the direction in which the agency is headed.

NWS: NOAA NWS generally isn't a user of this information. Rather, historically, we've created it for the users and we've made the key documents available to users.

APPENDIX B

1a What extreme precipitation data do you use in your decisions?

FERC: HMR based PMPs, site-specific PMPs, and NOAA Atlas 1000-yr 72hr values.

USACE: Probable Maximum Precipitation is used to develop the Inflow Design Flood for the design of spillways at USACE Dams. Dam safety studies require an estimate of the reservoir stage frequency curve defined out to the PMP/PMF event. One method for defining the frequency curve is rainfall-runoff simulation. Tools are being added to USACE software to sample precipitation data in a Monte Carlo analysis and then run hydrologic and reservoir models. Both estimates of magnitude and hyetograph temporal pattern are required. We use the HMR's along with site-specific studies to define the Probable Maximum Precipitation. Site specific studies require extreme historical storms to be transposed over a watershed. Sources of data include NOAA, USACE, USGS and CoCoRAS. Flood risk reduction project studies typically require precipitation frequency data from the 2-year to 500-year event. We typically use NOAA data from NOAA-14, NOAA 2, TP-40 and HYDRO-35 for this information.

USBR: Reclamation uses point and basin-average precipitation frequency relationships with AEPs ranging from 10-3 to 10-7, up to and including PMP. Spatial and temporal extreme storm patterns are used to distribute the extreme storm precipitation over specific watersheds.

NRCS: PMP, NOAA Atlas

TVA: PMP data published in: HMR-41 (1965) for the Tennessee River Basin above Chattanooga; HMR-47 (1973) for Tennessee River basins above Wheeler and Kentucky Dams; and HMR-56 (1986) for watershed areas up to 3000 mi2. In addition, TVA uses PMP estimates prepared by the National Weather Service in special studies conducted in the early 1980's for the watersheds above Douglas Dam (4541 mi2) and Cherokee Dam (3428 mi2).

TVA is currently funding a study being conducted by Applied Weather Associates to generate site specific estimates of PMP for a long list of critical watersheds in the Tennessee River Valley.

NRC: Consistent with US NRC's Hierarchical Hazard Assessment (HHA) approach and Standard Review Plan (SRP), US NRC relies primarily on the PMP data "product" represented by HMRs. However, US NRC is increasingly faced with licensee reports that involve site-specific PMPs for flood hazard re-evaluations at existing nuclear power plants that are currently underway [1]. In addition, US NRC has a risk informed regulatory framework and reviews of probabilistic flood hazard assessments (PFHA) are expected as part of flood hazard re-evaluations at some existing sites. Currently available precipitation data and "data products" does not readily support probabilistic approaches for extremely rare events or for reviews of site specific PMPs (both basin-wide and for highly localized flooding). It should be noted that both issues require greater focus on the probabilities associated with the PMPs in both the HMR and site-specific PMP studies. Site-specific PMP estimates are sometime considerably lower than values in the HMRs which naturally raises the question of the level of conservatism implied by earlier and new proposed estimates.

Loads on structures due to liquid and solid precipitation are derived from PMPs obtained from the HMRs.

The SDP activities have also included used of precipitation frequency estimates from NOAA Atlas 14 (or precursors).

[1] SECY-11-0124, "Recommended Actions to be Taken without Delay from the Near-Term Task Force Report," and SECY-11-0137, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned".

USGS: The most common extreme precipitation data that is used by the USGS is the 24-hour, 2-year precipitation and other similar depth-duration-frequency information, commonly obtained from NOAA Atlas 14, although some local and regional studies of depth-duration frequency of precipitation have be completed by USGS programs.

1b How is this extreme precipitation data used?

FERC: Used to estimate PMP and resulting PMF.

USACE: The extreme precipitation is used along with hydrologic modeling simulations to determine design floods for our reservoirs and levee projects.

USBR: Data are used as input to rainfall-runoff models.

NRCS: Flood hazard studies; Auxiliary spillway and Freeboard design storms for small watershed dams

TVA: PMP data are used to drive hydrologic simulations to define design basis flood levels at dams and various other critical locations such as nuclear power plants.

NRC: In new reactor licensing extreme precipitation estimates (generally PMPs) are used to construct extreme flood scenarios. Two typical scenarios are: 1) the probable maximum flood (PMF) for stream and river flooding; and 2) local intense precipitation (LIP) for evaluation of site drainage. These scenarios are applied within the HHA approach outlined above.

PMP values from the HMRs are also used to determine design basis loads on structures due to both liquid and solid precipitation.

The SDP activities have also included used of precipitation frequency estimates from NOAA Atlas 14 (or precursors). The focus here is on estimating the frequency of an initiating event. The initiating event frequency is combined with system fragility information to evaluate risk.

USGS: These data are used as precipitation or weather indices in USGS regional regression equations that link basin characteristics data to estimates of flood frequency quintiles.

1c What is the scale and resolution of this data (regional, site-specific, watershed-specific)?

FERC: Watershed-specific or site-specific

USACE: Multiple scales are necessary due to the various sizes of the watersheds being evaluated.

USBR: For moderate to detailed assessments, site-specific and watershed-specific information is developed. Regional information is used for PMP (HMRs) and depth-area relationships for screening-level assessments.

NRCS: Watershed specific; Site-specific if available

TVA: Watershed specific, although watershed sizes range from less than 100 mi2 to over 25,000 mi2. In addition, for nuclear plant site local drainage studies, PMP estimates for 1 mi2 areas are used.

NRC: The scale and resolution of "data" from the HMRs vary from very large watersheds (thousands of square miles) for river flooding down to 1-mi2 for evaluation of site drainage.

Licensees are also submitting "site-specific" PMP estimates for both large and small area sizes.

USGS: Watershed specific.

1d What is the spatial extent to which this data is applied?

FERC: Drainage areas associated with a dam.

USACE: The spatial extent is the watershed being modeled. Required information is area-reduction information. Typically, extreme historic storms are used to develop area-reduction factors.

USBR: Watershed scale, from point to > 10,000 mi2, usually at 4km2 or finer cell size. Custom information is developed for nearly all watersheds exceeding this scale.

NRCS: Drainage area above dams and below dams to assess effects of dams on downstream areas, flood hazard areas

TVA: For a given watershed, PMP is typically assumed to be centered over that watershed, with concurrent rainfall on adjacent watersheds also being considered and analyzed as necessary. Fixed patterns which define the spatial orientation of PMP for larger watersheds are used when specified in a given HMR.

NRC: Application falls under two categories: 1) LIP (local intense precipitation) on a resolution can be a small sub-watershed or even as small as tens of acres (approaching point precipitation) and 2) basin-wide riverine flooding and dam failure flooding for upstream

watersheds. This latter can have a spatial extent that varies dramatically sometimes going well beyond the area sizes in the NWS HMRs.

USGS: The data are used in regionalization work done at the state level for every state, but have been shown to be highly significant in only 18 states.

1e Would it be beneficial if this data were updated? And why is that?

FERC: Yes. Updating the HMR's would be beneficial to the dam engineering community. Potential changes to PMP values may impact the hydrologic safety and adequacy of the nations' high and significant hazard potential structures. An additional benefit would be unbiased and uniform PMP values developed by the NWS.

USACE: Yes, Up to date data means precipitation frequency estimates contain recent historic storms. This data should be updated periodically.

USBR: Yes, it would be beneficial if the data bases used for the regional information were updated. In this way, data for magnitudes and probabilities used in site-specific and watershed-scale estimates could be improved. Regional extreme estimates would also be improved, by updating the data and including uncertainty estimates.

NRCS: Yes. Current HMR data is dated. NRCS criteria allows the use of special site-specific PMP studies, however, having updated PMP would, in many cases negate the need for special studies and greatly expedite design and decision-making processes.

TVA: TVA design basis flood levels are based on rainfall databases and meteorologic analyses that are now approaching 50 years old. TVA believes regular updates to PMP estimates and extreme rainfall in general would be beneficial to state and federal agencies and to the engineering community.

NRC: Yes, an update to the HMRs, and particularly HMR51, which applies to the majority of our sites would be beneficial. The HMRs referenced in our general guidance documents are often criticized due their limitations on basin size, questionable applicability in "stippled" regions affected by orographic effects, by their lack of consistency in methodology, and generally by their age. We are currently being requested to review site-specific PMP values on an increasing basis creating a regulatory challenge. In addition to "updating" the data with new storms, radar related data and rigorous review of previous storms, more focus on the probabilities associated with PMP estimates is a critical component to risk informed decision making. Any update should include a review of potential storm model improvements that could be used to improve both "updates" to values and additional probabilistic analysis of the updates. Just plugging new data into an old method without considering adjustments to that method based on decades of experience (since the last update of the HMR 51-52, for example) doesn't seem appropriate. It's also important start thinking about probabilistic characterization as an essential element of such extreme precipitation estimates.

Additional attention to cool season precipitation would be useful for determining design basis snow and ice loads on structures.

USGS: The extreme precipitation data are used in regional regression equations that often yield estimates of flood frequency qualities used by many states in the design of routine transportation infrastructure such as culverts, bridges, and rural and urban drainage projects. The practical impact of an improvement in the precipitation data would be improved (more accurate) and reliable flood estimates for these projects.

1f What decisions are made by utilizing this data?

FERC: This data is used to make decisions concerning the safety and adequacy of existing or proposed spillways of jurisdictional dams.

USACE: Precipitation frequency data is used to access risk from USACE dams and for spillway design. It is also used in the design and analysis of new and existing flood risk reduction projects.

USBR: Risk-based dam safety decisions and designs, for Reclamation's dam safety program and other Department of Interior dams (BIA, NPS, FWS).

NRCS: Data are used to size auxiliary spillways and set top of dam elevations for small watershed dams constructed by NRCS. The data are also used to evaluate safety and adequacy of existing structures to determine rehabilitation designs. For flood hazard studies, NRCS uses data to estimate extents of inundation areas.

TVA: Use of PMP estimates to date has been driven by the need to show compliance with NRC and with TVA dam safety guidelines using a deterministic approach. Looking to the future, the development of extreme rainfall frequency data, and the use of improved hydrologic assessment capabilities will allow TVA to adopt a more rigorous approach to risk-informed analyses.

NRC: For proposed projects, the HMR data products are used to determine the suitability of specific sites and the design basis at those sites. The HMRs are used for design basis flood estimates as well as estimating design loads on structures due to both liquid and solid precipitation.

As part of the agency's response to the Fukushima accident, US NRC has issued a "Request for Information" instructing all operating nuclear power plants to develop and report updated flood risk information for comparison against original licensing information. For sites where flood elevations and associated effects exceed the original licensing basis, licensees are expected to perform an integrated assessment to evaluate their flood protection and mitigation features and procedures Licensees' evaluations use PMP values from the HMRs in some cases and in others, rely on site-specific PMPs. During the review period, licensees are actively engaging and revising protection and mitigation measures that depend in part on the HMR PMP estimates. The flooding reevaluations and integrated assessments will form the basis for regulatory decisions. The potential decisions range from changes in regulations regarding hazard assessment, protection and mitigation to modification of individual licenses.

In the SDP process (described above), decisions include the assigning a significance/severity to identified deficiencies. Depending on the severity, orders to modify facilities can be issued and fines can be assessed.

USGS: See response to question 1.e.

2 Describe your agency views on the recommendations and priorities from "Estimating Bounds on Extreme Precipitation Events" NRC 1994 report (pp 19-21), including: http://www.nap.edu/openbook.php?record_id=9195

NRC: The recommendations present probability-based standards as an alternative strategy particularly applicable to high-risk/high-complexity problems faced by U.S. NRC and other regulators. This strategy appears to have not advanced significantly since the 1994 report and obstacles are of key concern. The recommendations also focus on the need to find meaningful ways to apply PMP approaches to smaller geographic and shorter time scales. This should drive a focus on the "practices" of estimating intense rainfalls and the "processes" associated with reviewing the results. One obstacle that combines both probability based standards and practical applications is the paucity of practitioners for the work related to low probability/high events making the development and evaluation of technically defensible models a key constraint to this strategy. Advancements have clearly been made in the use of radar data, the extension of flood frequencies based on paleo-hydrology but the process of peer review needed for individual studies remains a key constraint.

The question regarding a national standard for consistency is complicated. There is a lack of consistency regarding both practices and peer review processes between Federal agencies, and it has created some problems. But the real question is consistency in what? And how would the consistency apply in light of differing risk tolerances? And could a standard be written without inhibiting innovation?

2a Continued use of PMP, or alternatives?

FERC: Continuously using PMP

USACE: Currently, the PMP is a design standard for USACE Dams. Alternative methods for developing PMP such as atmospheric modeling should be investigated, especially in the mountainous regions of the western U.S.

USBR: Reclamation uses alternatives to PMP, specifically including stochastic storm transposition and extreme precipitation frequency analysis.

NRCS: PMP will continue to be used as the design standard for NRCS dams.

TVA: The continued use of the development of Probable Maximum Precipitation is recommended. Advancements should be concentrated on a) ongoing maintenance of an extreme storms database, b) refinement of the mechanics of maximization and transposition, in

keeping with the spirit of the HMRs, and c) estimating the probability of extreme rainfall events over watersheds.

NWS: NWS supports the continued use of PMP as an upper limit. We also recognize the need for risk based approaches relying on annual exceedance probabilities between the limits of NOAA Atlas 14 and PMP. And that methods for estimating those probabilities are not yet within the realm of common practice.

USGS: The USGS takes no official position on this issue, but notes that many experts in the field advocate a middle ground in which PMP methods may be available, but that efforts should be used to develop frequency-based estimates of extreme precipitation.

2b Use of Numerical models?

FERC: No

USACE: It would be beneficial if we could incorporate regional atmospheric models in the estimation of PMP, in addition to methods used to originally develop PMP index maps. Particularly along the West Coast, we could look at varying the angle of attack and sea surface temperatures from historical storms which could expand our knowledge of maximum precipitation potential.

USBR: Reclamation uses numerical models (WRF, MM5-class) for exploring science-based questions on extreme precipitation. We have been doing this on occasion since the early 1990s under the US GCRP (PMP sensitivity), and site-specific studies. Through several recent published studies (i.e. Green Mountain Dam), and ongoing research, we are committed to using this class of models to study and eventually estimate extremes. We are embarking on some ensemble-based case studies this year with NOAA-CIRES.

NRCS: Modeling in mountainous regions is problematic. While PMP issues are a part of that picture, one of the other major challenges is modeling snowmelt runoff and particularly rain on snow events.

TVA: Numerical models should continue to be researched as to their use in modeling extreme storm events, and once they are validated as accurate compared to empirical observation should be considered an option in extreme storm analysis.

NWS: NWS recognizes that the methods used in the HMRs are empirical with empirical extrapolations. Some of the assumptions have been shown to be questionable in certain circumstances. This leads to need to better understand the physics of the rainfall producing mechanisms in order to produce better estimates. We support investigation of physics based numerical models as a means for making better estimates.

USGS: The USGS generally limits its use of numerical models of rainfall and runoff processes to situations for which there is an adequate means of calibrating the model for the specific study basin and range of flow or precipitation.

2c Assessment of radar accuracy?

FERC: No

USACE: Radar accuracy can be very poor to very good. Over the mountainous west, radar accuracy is poor. It can be very good over the eastern US particularly if the z-r relationships are calibrated to ground measurements. It is very beneficial for determining the spatial coverage of the storm. Radar accuracy has been improving and we should continue to use it over the eastern portion of the US

USBR: It is Reclamation's view that radar data (and more broadly gridded precipitation data) are essential to estimate extreme precipitation. We utilize multisensor estimates (MPE) in many studies. These blended products of gage (point) observations and radar reflectivity, with retrospective (reanalysis) processing with corrections (bias, bright band, AP, etc.) are essential. Recent work on accuracy and uncertainty estimates (done at Univ. of Iowa and Princeton) can really help in quantifying accurate estimates.

NRCS: Radar data is used within NRCS mainly as a way to evaluate effects of specific storm events. NRCS uses NEXRAD data as a major component of NRCS DamWatch software.

TVA: This is of particular interest to TVA, as ongoing reductions in our Operations and Maintenance budget effect the reality that fewer and fewer rainfall stations are maintained in the Valley. However, uncalibrated radar accuracy is a major problem in deriving rainfall accumulation and should not be used for analyses which are highly sensitive to these data. Private consultants and government agencies have been trying to improve the accuracy of radar data through post-analysis calibration of the information and this has shown to be reliable in determining rainfall accumulation.

NWS: Quantitative precipitation estimation (QPE) is fundamental to NWS operations. We have lots of experience, including multi-sensor precipitation estimation (MPE) which involves using other sensors to improve the quality of purely radar based QPE. There are several primary lessons learned from this experience:

i. The quality of radar based QPE without the use of other sensors is quite problematic. This also includes the use of model based land data assimilation systems.

ii. The effective coverage of NEXRAD radars is insufficient to provide full spatial coverage for QPE purposes, particularly in the west.

iii. Spatial resolution of the NEXRAD radars may not be sufficient to properly characterize PMP type events.

There are efforts under way to reconstruct rainfall estimates back in time, but they start to get problematic for years older than NEXRAD implementation.

USGS: The USGS takes no official position on this issue.

2d Estimating probabilities of extreme rainfall? Currently no, however Commission is developing procedures to consider risk in dam safety analyses.

USACE: It is more important to estimate the probability of the flow or reservoir stage.

USBR: As previously noted, Reclamation estimates extreme rainfall probabilities using some of the techniques mentioned in this NRC report (e.g. ARR), as well as others (Hosking and Wallis, 1997). We require these estimates for dam safety risk analysis.

NRCS: Used within NRCS to evaluate effects of specific storm events

TVA: Absolutely. TVA is currently funding an effort to develop regional precipitation frequency relationships for several critical watersheds in the Tennessee Valley as a critical component to the ability to assign frequencies to extreme hydrologic events. Ongoing research to validate the utility of efforts to regionalize data is needed.

NWS: Research is needed. Methods for estimating those probabilities are not yet within the realm of common practice

USGS: The USGS sees the merit of developing probability-based estimates of extreme precipitation, but notes the required necessity of using short records relative to the rarity of the events for which estimates are sought.

2e Storm-based analyses?

FERC: No

USACE: Publically available tools that do not rely on private software (ArcGIS) are needed to analyze historic storms. USACE is working on a tool called HEC-MetVue that will be extremely valuable in analyzing extreme storms.

USBR: Reclamation uses storm-based analyses based on older analyses, and conducts our own storm-based studies for individual watershed-scale studies. Newer storm-based studies are needed as well as studies that cover a wide geographic area to expand the data base. Reclamation's individual studies have limited coverage to transfer effectively to other sites.

NRCS Used within NRCS to estimate watershed scale project benefits and to evaluate effects of specific storm events

TVA: The availability of adequate storm-based data is perhaps the key element in conducting extreme rainfall analysis.

NWS: Storm based analysis is fundamental to understanding the physics of rare rainfall producing mechanisms. It’s therefor necessary to improving upon the methods used in the current HMRs.

USGS: The USGS takes no position on this issue.

2f Is there a need for a national standard for consistency?

FERC: Yes

USACE: Yes, but methods may need to vary by geographic location

USBR: Yes, national standards are needed on extreme storm methodologies and basic data.

NRCS: Yes. Having a national standard, particularly for site-specific PMP would be beneficial. NRCS needs confidence in PMP data and methods.

TVA: Yes. TVA's efforts to interpret the guidance in the various relevant HMRs have led to the conclusion that a clear national standard would be helpful to the hydrologic engineering community. TVA believes the development of a national standard should include efforts by all who have made valid contributions to the study of extreme rainfall, and not be limited to any one sector. TVA also believes that a national standard must recognize that variations in topography and meteorology cause large regional variations in extreme storm dynamics.

NWS: Yes, without a trusted national standard, users will be tempted to make independent estimates of PMP, and these may vary quite a bit in quality. Consistency is necessary to equitable funding among projects.

USGS: Yes. General guidelines are needed to drive application of analyst's judgment and permit the comparability of estimates from different sources.

3 Discuss your thoughts and views on the priorities – *risk analysis, standards, and meteorology*, from the "Hydrologic Research Needs for Dam Safety" FEMA workshop, USACE 2001 report (pp. 171-176) (also later published by FEMA in 2005), including these three from the top 10: http://www.hec.usace.army.mil/publications/SeminarProceedings/SP-29.pdf

NRC: Generally all three areas are important, however, a fourth area associated with U.S. NRC needs for extreme rainfall data is development of appropriate peer review processes to handling all three areas. This is relevant to needs at individual sites whether they be dams, flood prone sites, existing nuclear power plants, etc. It should be noted that considerable advancement has occurred related to both paleo-hydrology and use of NEX-RAD data since that report was prepared.

It should also be noted that there are differences in risk tolerances for nuclear facilities compared to dams, so that U.S. NRC has a somewhat different perspective on some of the priorities: 1) U.S. NRC is interested in hazard curves that extend significantly beyond the 1 in

10,000 year ARI; 2) simply extrapolating frequencies does not seem appropriate since this ignores potentially significant epistemic uncertainties

Also, for U.S. NRC's needs associated with high-risk/high-complexity issues, and the trend towards PFHA, greater focus on the peer review associated with these advancements is critical. The document's focus on risk analysis, rather than risk-informed decision making oversimplifies the challenges that U.S. NRC, and presumably other agencies, face.

3a Historical database of storms and floods?

FERC: Yes, but not for every project. FERC uses available publications issued by the NWS or any other credible supporting information published by other entities.

USACE: The USACE Extreme Storm Team is in the process of developing a storm database. When this is completed, a tool will be necessary to extract information from this database and apply it to a hydrologic model. Our current plan is to link the HEC-MetVue tool with the database and the HEC-HMS model.

USBR: This is still priority 1, and needs to be completed. The historical storms should be digitized and made available in an electronic format. More current storm analyses also need to be included. We are performing individual storm studies for this effort, but do not yet have a repository. USACE is making progress on a larger data base, and has a prototype. We will be sharing data with USACE and anticipate using their data base.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data and tools were they available to us.

TVA: There is no substitute for good observational data of historic storms and floods. A historical database should be continually updated and made available to all in the engineering community.

NWS: A historical database is necessary to the storm based analysis mentioned above

USGS: The database on which the extreme precipitation estimates are based should be updated to include more recent storms. In particular, the database should include the storms for which estimates of aerial distributions and intensities can be developed using Doppler radar and other remotely sensed sources, as well as, point or gaged estimates

3b Precipitation Analysis needs?

FERC: Yes

USACE: The Corps is developing a GIS based meteorological software tool (HEC-Methuen) that can be used to catalog historic storms and apply the storms to a geographical area to create different alternatives (what-if scenarios). HEC-Methuen will be linked to HEC-HMS to develop flow estimates for the precipitation events.

USBR: This is an important priority and work needs to be done in this area. If precipitation analysis and hydrometeorology is done on a finer regional scale, and cover the entire nation, it could help refine critical storm types, durations, spatial scales, define homogeneous regions, and transposition zones and probabilities.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data and tools were they available to us.

TVA: The systematic analysis of major storms should be preserved, and continually built upon. Much work has been done in this area over the last couple of decades by private consultants, and TVA believes this has resulted in a contribution to the profession that should be recognized by the entire community.

NWS: Storm based analysis mentioned above includes precipitation analysis.

USGS: The USGS has no position on the topic.

3c Extend frequencies?

FERC: Yes

USACE: The USACE has a draft document for extending frequency curves out to the PMF event. Currently under development are software tools that will provide the ability to follow recommendations in the draft document.

USBR: We have methods to do this, and are happy to share them. More efforts are certainly needed.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data and tools were they available to us.

TVA: TVA believes this is a critical element to establishing probabilities of, and reducing the uncertainty associated with, flood discharges and elevations for extreme events, and should be a high priority for ongoing research and development.

NWS: As mentioned above, NWS recognizes the need for risk-based approaches relying on annual exceedance probabilities between the limits of NOAA Atlas 14 and PMP. And that methods for estimating those probabilities are not yet within the realm of common practice.

USGS: The USGS has no position on the topic.

4 Describe what your agency would like to incorporate and support that came out of the Probabilistic Flood Hazard Workshop held at the Nuclear Regulatory Commission in January 2013 http://www.nrc.gov/reading-rm/doc-collections/nuregs/conference/cp0302/ (pp. 10-4 to 10-7)

NRC: The list that follows seems limited. Development of a more global framework (similar to the framework used for other hazards such as seismic) for specific flood hazards (in this case PMP) that can be used more consistently should be pursued.

NWS: The PFHA provided broad coverage of potential state of the art approaches. Most all of them should be further examined as part of the research necessary to improve the science.

USGS: The USGS would endeavor to support these activities through participation in any advisory or oversight committee that ACWI wishes to form. In particular, the USGS could offer some expertise in the regionalization and stochastic modeling process but any such support would either be limited in scope or duration or require funding assistance.

4a Focus on extreme rainfall observations and improve databases

FERC: Yes

USACE: The USACE extreme storm team is developing a database of historic extreme storms. This will provide a common database for all agencies to share extreme storm data. Long term plans need to be developed to determine which agency maintains and updates the database once it is complete.

USBR: We can contribute our existing data to this, and other ongoing data analyses.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data were they available to us.

NRC: This is necessary but not sufficient. The database of extreme storms will always be sparse and in need of supplemental approaches. Simply updating the storm catalogue and applying 40-year old methods does not seem like a technically defensible approach.

4b Explore advances in data-processing methods

FERC: Yes

USACE: Currently, USACE is using Arc-GIS along with other tools to analyze and process historical storm information. We are also developing a tool called HEC-MetVue to streamline the data processing.

USBR: We can share our current methodologies, and collaborate on efforts using numerical models. Our focus is on gridded precipitation data at a fine resolution.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data were they available to us.

NRC: We don’t know what this means.

4c Develop regionalized techniques

FERC: Yes

USACE: The USACE Hydrologic Engineering Center (HEC) is in the process of adding a regional frequency analysis tool to HEC-SSP.

USBR: We are happy to share techniques we are using and discuss ways to improve them.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data were they available to us.

NRC: Regionalized approaches for estimating precipitation frequency exist and are commonly used, although not for "PMP-scale" precipitation. It seems reasonable that regionalization would play some role in estimating magnitude and frequency for extreme precipitation.

4d Stochastic methods

FERC: Yes

USACE: HEC is also adding Monte Carlo simulation capabilities to sample meteorologic, hydrologic, and reservoir operation parameters. These tools can be used to extend flow and reservoir stage frequency curves out to the PMF event.

USBR: We are also happy to share techniques we are using and ways to improve them.

NRCS: NRCS relies upon other federal agencies for precipitation estimates and extreme storm event data; and could make good use of such data were they available to us.

TVA: TVA is certainly not philosophically opposed to any of the above research areas. In a world characterized by shrinking budgets, it is critical that funding to support the development of these and perhaps other techniques be justified by reasonable expectations of cost savings and efficiencies. Sharing "success stories" associated with the application of these methodologies may benefit the entire community.

NRC: Stochastic methods (both event-based and continuous modeling) should be pursued. In order to apply a more risk-informed regulatory approach to flooding (an agency priority) better estimation of the probabilities associated with extreme events is needed.

However, a risk-informed regulatory approach also requires the development of processes to rigorously evaluate controversial and ambiguous information associated with both data and methodologies. The need to address uncertainty regarding the interpretation and use of such data is equal to the uncertainty of the data itself.

Right now, it seems like probabilistic evaluations are performed in rather ad hoc ways. It also seems that different individuals are doing PFHA rather differently and there's not much focus on developing an overall framework. This doesn't seem like an appropriate approach to developing a broadly accepted methodology that reflects the collective community of knowledge.

APPENDIX B

5 Discuss applicability of current Federal extreme precipitation publications, databases and tools:

5a HydroMeteorological Reports (HMR)

5a.i What information do you glean from the HMRs? And how do you use this information exactly?

FERC: PMP values. Following FERC Engineering Guidelines, PMF Determinations use the PMP value for hydrologic modeling to determine the PMF value.

USACE: Within USACE, the HMR reports are used to develop the PMP storm. We follow the procedures outlined in the HMR to develop the PMP storm in 1 to 6 hour time increments. The storm data are used with a hydrologic model to develop the PMF hydrograph.

USBR: We use PMP estimates, DAD tables and ancillary storm data used in the PMP estimates, depth-area curves, area reduction factors, and snowpack information (where available). Focus is usually on general storms. We utilize the individual storm analyses (and DAD tables) used in estimating PMP for historic storm spatial and temporal patterns for scaling up from basin-average precipitation frequency relationships.

NRCS: PMP values.

TVA: Rainfall data and techniques on how to develop and apply PMP rainfall over basin sizes ranging from point (1 mi2) to large (over 25,000 mi2) watersheds. Rainfall data thus derived are used to drive hydrologic and hydraulic simulation models to determine PMF levels at critical locations.

NRC: PMP values and guidance. PMP values at watershed scale are used to develop PMF estimates. 10-square mile PMP values are used with HMR 52 to estimate local intense precipitation.

The 48-hour probable maximum winter precipitation (PMWP) is used for design ice and snow loads on structures.

USGS: The response to question 1B.

5a.ii Which information is most useful?

FERC: General/local PMP values

USACE: The PMP Index maps, DAD tables, temporal distribution, examples

USBR: The individual storms that are the basis of PMP

NRCS: Estimates of PMP

TVA: Rainfall depths and application guidance.

NRC: PMP values and HMR52 guidance.

USGS: Site-specific and watershed estimates of the depth-duration-frequency estimates. The most commonly used duration is 24 hours, but the frequency interval ranges typically are from 2–100 year events.

5a.iii Do you use the spatial and temporal storm patterns provided?

FERC: Yes

USACE: Yes for PMP, Sometimes the spatial patterns are also used for frequency based storms for large watersheds.

USBR: Yes, typically for screening-level studies and comparisons. For more detailed studies, we derive these relationships.

NRCS: Typically for NRCS small watersheds, point values are used. Temporal storm patterns are evaluated, but NRCS criteria provides guidance on temporal distributions used within NRCS.

TVA: Yes

NRC: Yes

USGS: Only to estimate watershed specific precipitation estimates per the response to questions 5A-ii.

5a.iv Do you use the Depth-Area-Duration (DAD) tables?

FERC: Yes

USACE: Yes, we also use them for developing depth-area reduction factors for frequency based storms for large watersheds.

USBR: Yes

NRCS: Yes

TVA: Yes

NRC: No

USGS: No

5a.v Do you use the HMRs to compute PMP?

FERC: Yes

USACE: YES, unless we do a site-specific PMP study.

USBR: Yes, in most situations.

NRCS: Yes. Unless more current special studies are available.

TVA: Yes

NRC: Yes

USGS: No

5a.vi Do you use the HMRs to compute a percentage of PMP? Which percentage?

FERC: No

USACE: Yes, in the western US we use 50% of PMP to represent the Standard Project Storm.

USBR: We do not use PMP percentages.

NRCS: Yes. Most often when evaluating state-specific criteria compared with NRCS criteria for freeboard design storms. (Generally 0.5PMP or 0.75 PMP).

TVA: No

NRC: No

USGS: No, N/A.

5a.vii Do you use the areal reduction factors provided in the HMRs?

FERC: Yes

USACE: Yes

USBR: Yes. For detailed studies, we usually derive a site-specific relationship.

NRCS: Yes.

TVA: Yes.

NRC: Yes.

USGS: No.

5a.viii Do you consider storm seasonality in your studies?

FERC: Yes

USACE: Yes, for some areas that may have a combination of snowmelt and rainfall for the probable maximum flood.

USBR: Yes. This factor is critical in the western US.

NRCS: Yes. Mainly in areas where snowmelt and rain on snow are factors.

TVA: Yes - primarily due to the variation in seasonal flood storage allocation at TVA reservoirs.

NRC: Yes.

USGS: No.

5a.ix Which HMR do you consult the most often?

FERC: HMR 51/52 and HMR 58/59

USACE: HMR51/52 since 80 percent of USACE dams are located in this region.

USBR: We use HMR 49, 55A, 57 and 59 equally in the western US, and HMR 51 to a lesser extent.

NRCS: HMR 51 and 52. Most NRCS dams are located in this region. However, all are used.

TVA: 41 and 56.

NRC: We rely most heavily on PMP values in HMR 51 and HMR 52 guidance which cover regions applicable to the majority of the sites US NRC regulates. Other HMRs are used for sites outside of the HMR51 regional coverage.

For snow and ice loads on structures, our Standard Review Plan references HMR 49, 53, 55A, 57 and 59.

USGS: Atlas 14.

5a.x Are the HMRs easy to use? If not, why?

FERC Yes, except snowmelt estimations.

USACE: No, they are all slightly different in application. We are developing tools to perform the calculations to simplify. Currently we have a tool for HMR51/52 and HMR57.

USBR: No. The lack of gridded, electronic versions of the plates, maps, etc. impedes efforts to import the plates, maps, etc. into a GIS environment. The challenges with portions of HMR 49 are somewhat involved.

NRCS: No. Procedures vary somewhat region to region.

TVA: No. TVA's experience is that the HMRs contain little information on how data were analyzed and used, and the available guidance is such that replication of results from one analyst to another is problematic.

NRC: Yes though HMR52 is less so.

USGS: Yes.

5a.xi Do you use the digitized HMR 51 plates? Or the shapefiles available for HMR 58 and 59?

FERC: Yes

USACE: We use the HMR 58/59 shapefiles. It would have been helpful to have the shapefiles for all of the figures in HMR 59 available (and not just the index PMP). However, we have had success in digitizing the figures that we do need that aren't available.

USBR: Yes we use both.

NRCS: Yes.

TVA: No.

NRC: No.

USGS: No.

5a.xii What would you change about the HMRs when/if updated?

FERC: Updating PMP value, clarifying snowmelt procedures, additional work and methods to address orographic effects, etc.

USACE: Have an automated tool to work with each HMR.

USBR: Complete numerical database to reproduce results. All gridded information, on a much finer scale than the generalized estimates. Full uncertainty, and estimates of exceedance probabilities blending with full precipitation frequency curves. Enhanced spatial patterns for orographic regions.

NRCS: Update PMP values. Expand database. Make HMR shapefiles available for the entire nation.

TVA: Carefully review and include all relevant work done since the HMRs were published, whether done in the public or private sector, incorporating advancements and updated storm data bases. Ensure the updated HMRs are clearly written, produced in coordination with the user community, and make available all background data/information/materials for verification and understanding of results.

NRC: Address "stippled areas" in HMR 51

Address area limitations

- Large watersheds (e.g., Missouri, Mississippi rivers)

- Bridge gap between point estimates and existing 10-sqaure mile estimates

Provide precipitation estimates that are more suitable for design snow and ice load calculations in relevant regions (i.e. cool season, or winter months; 48-hour durations)

NWS: We'd like, as much as possible, to see standard tools or "services" that automate the procedures in the HMRs

USGS: The USGS has specific suggestions to offer.

5a.xiii What additional information would you want to see included?

FERC: Remove subjectivity that is in most of the HMR's.

USACE: We should look at atmospheric modeling particularly along the western US for aiding development of PMP estimates.

USBR: See previous answer.

NRCS: Automated procedures

TVA: More consistent guidance on a) the development of antecedent and subsequent rainfall amounts, including a discussion of resulting combined probabilities, and b) the existence and location of the zero rainfall isohyet.

NRC: An online digital product similar to the NOAA Atlas 14 Precipitation Frequency Data Server. Probabilities and confidence intervals associate with estimates

USGS: The USGS has specific suggestions to offer.

5a.xiv Do you use any other studies besides the HMRs for PMP?

FERC: Yes, site specific PMP studies, particularly in the stippled regions.

USACE: Yes, site specific PMP studies.

USBR: Yes, we use Reclamation's design storm studies for individual dams (if available, as these past studies were used for design (in most cases), rather than PMP. These estimates are used for comparisons.

NRCS: Special studies for site-specific PMP as available. Regional PMP studies developed by others if available and generally accepted by state dam safety agencies.

TVA: No.

NRC: We are currently faced with reviewing site-specific PMPs developed by licensees (i.e., by their consultants).

USGS: N/A.

5a.xv Do you estimate PMP probabilities? If so, how?

FERC: Currently, no.

USACE: No, but we do estimate probabilities of the PMF using several different methods including 1) extrapolation of volume probability curve, 2) rainfall runoff modeling to the 1000 yr event to guide extrapolation, 3) regional precipitation method, 4) GRADEX method, 5) Stochastic Extreme Flood Modeling.

USBR: Yes, using ARR, regional precipitation frequency analysis for the dam and region of interest, and stochastic storm transposition (in a few cases).

NRCS: No.

TVA: TVA does not currently attempt to define PMP probabilities.

NRC: No but we occasionally have licensee's attempt doing this without established guidance or methodologies.

USGS: No.

5b NOAA Atlas 14

NWS: As the producer of NOAA Atlas 14, we're looking forward to user comments here.

5b.i NOAA Atlas 14 is being updated to include the Northeastern states (from TP40). Funding has not yet been found to update estimates for Texas (from TP40) or the Northwestern states (from NOAA Atlas 2). How important is it to your organization to have NOAA Atlas 14 volumes for Texas and the Northwestern states?

FERC: NOAA Atlas 14 is important to FERC, especially to those projects in the northwestern part of US to help determine reasonableness of a PMP or site-specific PMP estimate. Frequency estimates are compared to PMP/PMF determinations to determine reasonableness of computed values.

USACE: It is extremely important that NOAA update frequency precipitation for remaining areas. Otherwise, engineers will continue to use outdated information. The NWS is a better alternative to private consultants and other state/local agencies for performing frequency precipitation updates due to experience, practice in other regions, and independence from the application of the updated frequency precipitation data.

USBR: It is important to have NOAA 14 for the Northwestern states, as we have many facilities in that region. We are less interested in Texas, because there are very few DOI facilities in that state.

NRCS: NRCS uses Precipitation-frequency data for design of engineering based conservation practices as well as dam designs. In those areas where NOAA Atlas 14 is updated, we are using those values. In areas where NOAA Atlas 14 is not updated, we still rely

upon the old TP-40 data, NOAA Atlas 2 data or data developed by others than NWS, if available.

TVA: Not important to TVA as these areas lie outside the Tennessee River watershed.

NRC: This would be of low to medium importance for US NRC (but could change based on what applications are submitted). There are a number of licensed facilities operating in Texas and Northwestern states. However, for the applications of interest for operating large commercial U.S. nuclear reactors, the ranges of precipitation needed may be outside those justified for extrapolation by NOAA and other entities. Hence, while the information can be useful up to 1000 years to justify that less intense, more frequent precipitation events not impact a site severely, most ranges of interest may exceed 1000 years and, therefore, may need additional methodologies/data for full use in risk assessment. However, US NRC would be very interested in the result of additional NOAA Atlas 14 studies.

USGS: The USGS has conducted an extensive Texas-specific analysis of depth-duration frequency with data through 1994. The results are published in two USGS Scientific Investigations Reports. The USGS is trying to fund a study into coefficients by county in Texas to implement intensity-duration estimation into framework used by Texas Department of Transportation (TxDOT). Other agencies or investigators have periodically looked at more modern time periods and have found agreement with existing depth-duration frequency. Whereas, the USGS cannot speak directly for TxDOT, it seems a lack of interest exists for funding further statistical studies of precipitation.

5b.ii What information do you glean from NOAA Atlases 2 and 14? And how do you use this information exactly?

FERC: 100-year precipitation from both NOAA Atlases 2/14; 100-yr and 1000-year values from NOAA Atlas 14. The ratio of the NOAA 14 to NOAA 2 (100-yr, 24 hr) values can be considered as an important index to update HMR-59 PMP estimates.

USACE: Typically, USACE studies obtain the depth-duration frequency precipitation data and develop hypothetical design storms (generally less than 400 square miles). If the storm is greater than 400 square miles then area reduction is a big concern and depth area reduction factors are based on historical storms or from the HMR's. The NWS depth area reduction factor study currently under way will be valuable for us.

USBR: We use the published point precipitation frequency (1/50, 1/100, 1/1000 if available) for each site, and use ARR or other methods to extrapolate. We also extensively use the time series data behind NOAA 14 to conduct site-specific or regionalized precipitation frequency for an individual dam or project.

NRCS: Point values for 1- to 100-year return intervals. Used as design storms for hydrologic sizing of engineering based conservation practices

TVA: Occasional reference to NOAA Atlas 14 is made to estimate the probability of observed rainfall events.

In addition, TVA's PMP consultant uses data from NOAA Atlas 14 as part of the site-specific PMP study to help define the effects of topography on rainfall and in defining transposition limits. In addition, the PMP values are compared to the NOAA Atlas 14 values as one of several comparisons to help define reasonableness of PMP values.

NRC: As mentioned above, for risk assessment purposes, NOAA Atlas 14 data may provide an initial assessment of the potential impact of precipitation on an area surrounding a licensed facility, such as a nuclear reactor. The information would not be used as a final answer for decision-making since most ranges of interest for flooding events impacting nuclear reactors exceed 1,000 years, but may be used in a risk-informed manner. If an issue is identified where NOAA Atlas 14 may indicate an area of additional regulatory oversight is warranted, this information would be used to then couple any precipitation impact with an evaluation of plant response in an integrated system/human probabilistic risk assessment model for follow-up regulatory activities.

USGS: See response to question 1b.

5b.iii Which return period is most useful to your studies?

FERC: 100-yr for a low hazard dam; 1000-yr for a high/significant dams.

USACE: Typically we look at full range of frequency storms from 2-yr to 500-yr or 1000-yr.

USBR: We focus on a full distribution, rather than individual return periods. AEPs of most interest are 10-3 to 10-6.

NRCS: Point values for 1- to 100-year return intervals.

TVA: 100- and 500- year frequencies are most important because of their relevance to floodplain management.

NRC: The full hazard curve, usually in excess of 1000 years (up to and beyond 1,000,000 years) is of interest.

USGS: 2-100 year.

5b.iv Do you extrapolate beyond the 1,000-year return period (not recommended by NWS)? If so, how?

FERC: No

USACE: Extrapolation beyond the 1000yr might be necessary when running Stochastic models simulations to define flow and stage frequency curves out to the PMF event.

USBR: Yes. See presentations at the NRC PFHA workshop, Reclamation's Hydrologic Hazard Guidelines, and previous answers. Our current preferred way is basin-average regional precipitation frequency.

NRCS: No.

TVA: No.

NRC: In a limited basis and as a risk-informed exercise to evaluate information submitted to the NRC, since multiple licensees have performed such extrapolations on NOAA Atlas 14 and other hydrologic databases, as a way to respond to NRC regulatory activities. In this sense, the NRC is not necessarily interested in pursuing these limited credibility extrapolations, but rather responding to requests to consider risk insights based on submitted information. The NRC is aware of the limited technical justification for doing so and therefore uses significant caution in these cases.

USGS: USGS does not extrapolate precipitation estimates.

5b.v Which duration(s) is most useful to your studies? 6/24/72-hour durations.

USACE: All durations are necessary, shorter duration drive the peak flow for smaller watersheds and longer durations are important for volume.

USBR: Typically general storms (48 hrs to 72 hours); we also examine storm sequences over longer (12 day) periods. In some cases, thunderstorms (<6 hours) are of interest. Duration is highly dependent upon the conditions specific to the watershed.

NRCS: 6-hour and 24-hour

TVA: N/A.

NRC: All durations (short, long) are of interest.

USGS: 24-hour.

5b.vi How do you determine your storm duration(s)?

FERC: 72-hr for general storm or 6-hr for local storms.

USACE: Storm durations are typically determined by evaluating the critical duration of the study area (time of concentration, reservoir characteristics, downstream operation).

USBR: Analysis of historical extreme storms, and integrate watershed and reservoir characteristics.

NRCS: NRCS criteria specifies use of 24-hour durations for most conservation engineering based practices (typically designed on the 10-year to 50-year return interval). NRCS criteria for dam designs specifies use of 6-hour and 24-hour durations in evaluation of auxiliary spillways. However, NRCS criteria for dam designs also requires checking of other durations to assure that the critical storm duration is used for design.

TVA: N/A.

NRC: For new facility license applications use:

1) time of concentration for watershed; 2) analysis of historical events. For operating facilities usually evaluated against an existing design bases or other flooding scenario.

USGS: USGS primary hydrologic computations involving storm duration are associated with concepts such as the characteristic time of a watershed for modeling purpose. The USGS does not engage in site-specific design computations so seldom is a need to use administratively incorporated storm durations in "design manuals."

5b.vii NOAA Atlases 2 and 14 contain point-based precipitation. Do you need areal information?

FERC: Yes

USACE: Yes, area reduction information is necessary.

USBR: Yes, areal estimates are required for most of our projects.

NRCS: Occasionally. NRCS includes guidance on making areal adjustments (based on old TP-40 recommendations).

TVA: Yes.

NRC: Yes, areal information has become an issue of discussion in recent regulatory activities.

USGS: Yes, for specific watersheds.

5b.viii Do you currently compute areal estimates based on the point values from NOAA Atlas 2 or 14? If so, how? And where/how do you obtain your areal reduction factors if you use that method?

USACE: Yes, for watersheds less than 400 sq mi area reduction comes from TP40. For larger watersheds we use area-reduction information from historic storms or as contained in the HMR documents.

USBR: Yes, we compute areal estimates. We use ARFs from other NOAA published reports, HMRs, USDA-ARS research watersheds (e.g. Walnut Gulch, Reynolds Creek), and site-specific estimates we prepare for individual studies. Storm data, DAD tables, analysis of new storms, and transposed storms are used in making basin-average precipitation estimates. Some details were presented at the NRC PFHA workshop.

NRCS: Currently based on old TP-40 recommendations.

TVA: No.

NRC: Licensees have submitted areal estimates on point values from NOAA Atlas 14 and the NRC had to evaluate the implications of this information for reactor oversight purposes. ARF guidance from NOAA Atlas 14, NOAA Atlas 2, NOAA TP-40, state and federal drainage manuals, as well as various studies reported in literature.

USGS: Use the plates in and interpolate to center of watershed or rely on USGS publications on areal reduction factors.

5b.ix Which region of the United States is of most interest to you for precipitation frequency estimates?

FERC: Entire country

USACE: We have projects in all regions of the US so all areas are important. The highest priority now would be the areas not covered by NOAA14, the northwest, northeast and Texas.

USBR: The 17 western states are of most interest. Other states (coterminous) are of secondary interest, and are needed for assessing DOI facilities.

NRCS: All.

TVA: The southeast.

NRC: The NRC licenses and regulates licensees throughout the U.S., hence, all regions are of interest. However, current nuclear facilities, such as large commercial nuclear reactors, are concentrated on the East Coast, South, Northeast, and West Coast.

USGS: All regionals are equally important now, but going forward those regionals near coasts and subject to hurricanes will likely gain in importance.

5b.x Did you use NOAA Atlas 2 or TP40 before NOAA Atlas 14 volumes were published?

FERC: Yes for 100-yr precipitation

USACE: Yes, we used both NOAA 2 and TP40, also HYDRO-35 for short duration storms.

USBR: Yes, extensively. NOAA Atlas 2 provides the base spatial pattern in HMRs 57 and 59, and was useful for isopercentile analysis.

NRCS: Yes.

TVA: Yes.

NRC: Used TP40 before NOAA Atlas 14 was available.

USGS: Yes.

5b.xi Do you still use NOAA Atlas 2 or TP40? Where for? And for what purpose?

FERC: Yes, for the areas not covered by NOAA Atlas 14 for dam safety analyses.

USACE: We still used NOAA 2 for the northwest, TP40 for the northeast and Texas

USBR: Yes. We use Atlas 2 and TP-40 on occasion for point frequency estimates at sites not covered by NOAA 14. Estimates are made and extrapolated (usually with ARR) for dam safety screening-level studies.

NRCS: NOAA Atlas 2 still used for the Northwest (those states not yet updated). TP-40 still used for Texas (not yet updated). For design of engineering based conservation practices and for dam design.

TVA: No.

NRC: No.

USGS: No.

5b.xii To what extent is NOAA Atlas 14 information incorporated into design guidance or regulations that govern what you do?

FERC: 100-yr storm

USACE: We typically use the most recent precipitation frequency information from NOAA.

USBR: Reclamation design guidance is flexible and not prescriptive. We mention NOAA 14 as useful and show examples in our Hydrologic Hazard Guidelines for dam safety.

NRCS: NRCS engineering policy requires use of available existing hydrometeorological data for planning, design, and operation of water-related structures and systems; and provides a prioritized list of data sources. In policy, that list is as follows:

(1) NRCS National Water and Climate Center (NWCC).

(2) U.S. Geological Survey (USGS).

(3) National Oceanic and Atmospheric Administration (NOAA).

(i) National Weather Service (NWS).

(ii) National Climatic Data Center (NCDC).

(4) Regional climate centers (RCCs).

(5) State climatologists.

(6) USDA sister agencies.

(i) Agricultural Research Service

(ii) Forest Service

(7) Other Federal, State, and local agencies having planning responsibilities for water-related projects, operational responsibilities, or both.

NRCS dam design criteria (TR-60) specifies use of NWS data unless special studies are used.

TVA: N/A.

NRC: It is not. Limited information has been used for oversight of current operating nuclear reactors. NOAA Atlas 14 was not available during original licensing in almost all cases.

USGS: N/A.

5b.xiii Are there elements in NOAA Atlas 2 or TP 40 missing in NOAA Atlas 14?

FERC: Unknown

USBR: Nothing of major substance.

NRCS: Unknown

TVA: Areal adjustment factors.

NRC: Don't know.

USGS: No.

5b.xiv Is NOAA Atlas 14 easy to use? How could it be improved?

FERC: Yes

USBR: It is very easy to use. Improvements could be made to include realistic, storm-based temporal and spatial patterns, and extrapolation to AEPs of interest. Distribution choices could be refined for specific durations. The inclusion of distribution uncertainty would be an improvement, as extrapolation estimates are largely a function of distribution choice.

NRCS: NRCS uses NOAA Atlas 14 downloaded data to derive temporal rainfall distributions for the 1- through 100-year return intervals. Maintaining a consistent format for that downloaded data would be extremely beneficial.

TVA: Yes.

NRC: Availability and flexibility of using original data, including publication of parameters for fitted extrapolations would be useful.

5b.xv Do you input latitude/longitude values into the web interface?

USACE: Yes

USBR: Yes, on occasion.

NRCS: Yes.

TVA: Rarely.

NRC: Sometimes.

USGS: Yes.

5b.xvi Do you consult the isopluvial maps of precipitation frequency estimates for a particular exceedance probability and duration? If so, what value do they provide beyond the GIS compatible grids of the same information?

FERC: Yes. The maps can provide quick rough estimates.

USACE: Yes, sometimes they are simpler to use for quick estimates.

USBR: We use the GIS grids. The maps are not very helpful, other than to have a quick look at a regional pattern or some drainage.

NRCS: Occasionally.

TVA: No.

NRC: No.

USGS: No.

5b.xvii Of what value are the temporal distribution curves in NOAA Atlas 14?

FERC: Unknown

USACE: This area needs to be improved. The temporal distributions are not valuable because they wash out the intensity of actual rainfall events. Averaging a number of precipitation events together to get a generalized pattern results in lower intensities. Instead, time-patterns from historic events would be more useful.

USBR: They are a somewhat useful starting point for temporal patterns. We typically rely on individual gages or patterns from an individual extreme storm (or ensemble of storms).

NRCS: NRCS procedures were developed for deriving temporal distributions from the rainfall values. These procedures differ from the procedures used by NWS to develop temporal distributions. We do not typically use the temporal distribution curves in NOAA Atlas 14.

TVA: N/A.

NRC: They are of value in terms of comparing different contributors from a combined risk perspective (i.e., as opposed to evaluating a single extreme storm of very low exceedance probability).

USGS: N/A.

5b.xviii Of what value are the seasonal curves in NOAA Atlas 14?

FERC: Unknown

USACE: They are useful for rain on snow events.

USBR: They are somewhat helpful for a starting point to examine the maximum extreme storm/flood season. We don't use them in much detail.

NRCS: We not use them. They may be helpful for evaluating rain on snow events.

TVA: N/A.

NRC: They are of value, since many licensees have submitted information assessing the probability of flooding impacts based on seasonal information arguments. Having this information available in advance is greatly beneficial.

USGS: N/A.

5b.xix There is a difference between precipitation frequency estimates more frequency than about 15-20 years ARI for estimates derived from annual maximum series and estimates derived from annual maximum series and estimates derived from partial duration series. How important is it for NOAA Atlas 14 to provide both? Which of the two is your preference and why?

FERC: It is important to provide both for which the conservative one is chosen.

USACE: We typically do not use the partial duration series unless we are computing agricultural flood damages.

USBR: Given PDS and AMS estimates typically converge at about 1/20 AEP, and our estimates are 10-3 to 10-6, we prefer AMS for tradition and simplicity. Site-specific and custom studies can alleviate any potential issues, if there is a cluster of extreme storms within a year.

NRCS: In general partial duration series estimates are more valuable to us for design of engineering based conservation practices because these designs rely upon the 10- to 50-year return interval events.

TVA: Important. 100- and 500- year frequencies are most important because of their relevance to floodplain management.

NRC: NOAA should provide both estimates for short ARIs. For short ARI's, PDS would provide more complete risk information (i.e., the threshold set in the PDS could be set with the facility fragility in mind).

USGS: Use of partial duration series analysis remains in the realm of individual investigation circumstances.

5b.xx Do you consult the report documentation of NOAA Atlas 14 for any purpose?

FERC: Yes, for 100-yr storm and procedures.

USACE: Yes – It is important to understand the data used and methodology for developing index precipitation maps

USBR: Absolutely; the documentation is invaluable and required in order to extrapolate any of the regional distributions.

NRCS: Yes. It is important to understand how the data was developed in order to use it properly.

TVA: No.

NRC: Occasionally. For the basis on the extrapolated precipitation curves in the NOAA Atlas 14 interface website

USGS: Yes, it provides background needed to select specific frequencies.

5b.xxi Do you use any of the background information that the NWS used to compute the precipitation frequency estimates? If so, what exactly? (e.g., gauge data, clusters)

FERC: No

USACE: We use extreme storm data in site specific PMP studies and will be using it to update our Standard Project Storm criteria.

USBR: We extensively use the gage data that are the basis for the estimates. We also use the regions, for those studies that relied on geographically-fixed regions (as opposed to the newer ROI estimates).

NRCS: Yes. The background information, particularly gage data, is important for us in calibrating models.

TVA: No.

NRC: No.

USGS: N/A.

5c National Storm Catalog (USACE big black book of storms)

5c.i Do you have a copy of this book?

FERC: No

USACE: Yes

USBR: Yes. Hard copy and electronic (pdf) versions.

NRCS: No.

TVA: No.

NRC: Yes, but seldom consulted.

USGS: No.

5c.ii What information from this book do you use?

FERC: N/A

USACE: Primarily the Depth Area Duration tables.

USBR: DAD tables, storm orientation, maximization factors, etc.

TVA: N/A.

NRC: Not really used.

USGS: N/A.

5c.iii If the book was digitized, would you use the information?

FERC: N/A

USACE: We have scanned the book and have a digital copy. We also have the 2-page summaries for each storm as a pdf in our Extreme Strom database. We plan to enter the DAD tables in the database so they can be searched and exported by duration and area for specific regions.

USBR: Yes. We already are, for the most part. Individual DAD tables are digitized as needed. We are collaborating with USACE on this, and supplying many of Reclamation's storm DAD tables that are not in the National Storm Catalog.

NRCS: Probably.

TVA: N/A

NRC: Not sure.

USGS: N/A.

5c.iv Do you consult DAD tables in your safety analyses?

FERC: N/A

USACE: Yes

USBR: Yes.

TVA: N/A

NRC: Seldom.

USGS: N/A.

5c.v Are storm spatial patterns needed in your safety analyses?

FERC: N/A

USACE: Yes

USBR: Yes, and are required for most watersheds.

TVA: N/A

NRC: Yes.

USGS: N/A.

6 What other extreme precipitation resources does your agency utilize?

NRC: U.S. NRC is seeing a rapidly increasing trend of licensee's sponsoring "site-specific" PMP studies that involve all of the above. US NRC is faced with reviewing these submittals.

6a Non-Federal technical documents on extreme storms or PMP?

FERC: No except FERC approved site-specific PMP study results

USACE: For site specific PMP studies, we use the World Meteorologic Organization (WMO) Manual for the Estimate of the Probable Maximum Precipitation.

USBR: We use much of the past and new published literature (journal articles) for methods, ideas, and techniques. We use WMO publications. We use state publications for basic data.

NRCS: Special site specific PMP studies – if accepted by state dam safety agency.

TVA: TVA is currently using extreme storm analyses and site-specific PMP estimates from private consultants.

USGS: There are other studies of storm statistics available for some parts of the country and some studies by USGS. These are used on an individual investigation basis.

6b Other non-Federal documents?

FERC: No

USACE: Academic research and studies particularly on atmospheric rivers and atmospheric modeling.

USBR: See above answer.

TVA: TVA is currently using extreme storm analyses and site-specific PMP estimates from private consultants.

USGS: There are some studies of storm statistics by USGS. These are used on an individual investigation basis.

6c Data?

FERC: No

USACE: Precipitation data from USACE, NWS, USGS, CoCoRAS

USBR: We use much data from NCAR, NOAA (CFS-R, other reanalysis), NCDC, and some CoCoRAHs.

TVA: TVA is currently using extreme storm analyses and site-specific PMP estimates from private consultants.

NWS: For developing NOAA Atlas 14, we try to capture precipitation information from as many sources as possible. We then QC the data to derive data sets to be used in analysis. We publish the QC's data sets on the web.

USGS: Mostly commonly NWS data is used in USGS studies but some local or regional precipitation networks operated by USGS or others could be used.

6d Software?

FERC: No

USACE: USACE uses the HEC-HMR52 program to develop PMP storm events in the Eastern U.S. We also have developed a new tool to provide HMR57 calculations for the Pacific Northwest. Working a new tool called HEC-MetVue to perform storm analysis and combine the HMR computations for various regions of the US. HEC-MetVue will be linked with the HEC-HMS model and the Extreme Storm database.

USBR: We use scripts and capabilities in R, custom FORTRAN programs, etc.

TVA: TVA is currently using extreme storm analyses and site-specific PMP estimates from private consultants.

USGS: There are various software tools and libraries available for analysis of extreme events. The choice of software is a made on an individual investigation basis.

7 Discuss any gaps or further needs

7a What precipitation/extreme storm information do you need that you don't have now?

FERC: Updated HMRs

USACE: Need to update the extreme storm database to include more recent extreme storms. We are currently working on this. It would also be good if more atmospheric modeling studies were performed to improve our understanding of the Probable Maximum Precipitation, particularly in the mountainous west.

USBR: We could use an updated extreme storm data base with spatial information, such as an update to Shipe and Riedel (1976). We could use improved methods for combining estimates from atmospheric models (e.g. WRF) with gage-based techniques. Uncertainty of the precipitation field (magnitudes and probabilities) in space and time would be a nice enhancement. Hydrometeorological definition of explicit and implicit stochastic storm transposition would be valuable.

NRCS: Updated PMP estimates.

NRC: U.S. NRC faces several challenges that include: 1) age and limitations of NWS's HMR reports that are referenced in our general guidance, 2) lack of an overall framework and practical experience for PFHA given the diversity of data and approaches (see below) and 3) a lack of established approaches to appropriate peer review of individual studies given the paucity of experts in the field.

In our view an overall framework for extreme precipitation estimates (and PFHA in general) is lacking. By framework, we mean a structured approach that includes formal consideration of both aleatory and epistemic uncertainties and formal consideration of all technically defensible interpretations of data, models, and methods.

Lastly, we are being pushed to consider the potential for accelerated climate change to affect hazard assessments (for specific facilities), including hazards due to extreme precipitation. There seems to be little definitive information at the site or even regional scale upon which to base guidance.

USGS: The USGS has no official position.

7b For data gaps, what is the most pressing piece of information that needs to be created or updated?

FERC: The historical extreme storms that have occurred after the HMRs were published.

USACE: Depth-Area-Reduction curves in TP40 are typically applied across the U.S. and are often applied to watersheds greater than 400 square miles. Up-to-date area-reduction information is needed as well as guidance for developing hypothetical storm events.

USBR: Improved techniques for spatial patterns in orographic terrain, and defining extreme storm moisture pathways within the intermountain west.

NRCS: Updated PMP estimates and accompanying background information such as historical extreme storms database.

TVA: Critical review and evaluation of historic extreme storm analysis performed by others, with usage of such as deemed appropriate.

NRC: Data collection and analysis of significant storms seems to be the most pressing data gap. Such information would be needed to 1) simply update PMPs using existing methods; 2) update PMPs with modified methods; or 3) develop a probabilistic alternative to PMP.

USGS: The USGS has no official position.

8 Please identify Agency representatives and other attendees willing to participate in the Extreme Storm Events Work Group's Writing Workshop, currently scheduled for May 15-16, 2014, in Washington, D.C., either on-site or remotely via webinar. Please include contact information.

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APPENDIX B

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