Executive summary

The St. Paul District of the US Army Corps of Engineers (USACE) is studying the feasibility of a number of proposed flood risk reduction measures for the Fargo, ND-Moorhead, MN metropolitan area. These communities are exposed to flooding from the Red River of the North. Data show a trend of increasing magnitude and frequency of flooding in recent decades. A review of pertinent research suggests that this increase in flooding magnitude and frequency is consistent with projections of possible effects of climate change.

Given this, the Corps asked for an expert opinion elicitation (EOE) to serve two purposes: (1) to provide general guidance on how to account for climate change in the hydrologic and hydraulic analyses that support the Fargo-Moorhead feasibility study, and (2) to identify specific actions, if any, that should be taken to account for future probability and uncertainty in flood flows in the quantification of flood risk in the project area.

The topic of climate change was emphasized in the first question posed to the EOE expert panel: "Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND-Moorhead, MN?"

Following the first question, the experts and observers discussed the meaning of the phrase "climate change," particularly in the context of the Fargo-Moorhead flood risk reduction project. There was consensus among the experts that the recent data show a clear trend toward greater magnitudes and frequency of flooding in the Fargo-Moorhead area. It was also generally agreed among the experts and observers that current evidence is insufficient to determine whether or not anthropogenic greenhouse gases are contributing to the trend. However, the experts agreed that it was not necessary to determine the cause of the trend in order to address the Corps' second objective for the EOE (determining how to account for increased uncertainty).

In responding to the subsequent questions posed during the EOE meeting, the experts rather quickly moved away from a discussion of climate change, per se, and focused instead on the apparent lack of stationarity in the flood flow frequency and magnitude data over the period of record (the last 110 years or so).

Taken together, points made during the group discussions and the experts' written responses suggest that the following steps should be taken to adjust the flood frequency curve used in the hydrologic analysis supporting the Fargo-Moorhead feasibility study:

1. Develop, and use as the basis for the frequency analysis, an unregulated time series. Prior to the addition of significant regulation in the system, the series will be the recorded flows. After regulation was added, the recorded flows must be adjusted to "remove" the effects of regulation in the system. This can be done with the reservoir and channel routing models that the District has available.
2. Develop and use a transform function to convert the derived unregulated frequency function to the regulated frequency function that is required for the risk analysis. This transform function can be developed by simulating system behavior without and with regulation for floods from the period of record (POR). As the historical floods may fail to cover adequately the

range of flows needed to define the frequency curve well, historical events can be scaled to simulate larger floods. This is consistent with guidance in EM 1110-2-1415.

3. Analyze the unregulated flow series, and divide the current POR into two portions. Suggestions for identifying the "break" between the wet period and the dry period included:

   - Using qualitative judgment, e.g., define the dry period as 1901-1941 and the wet period as 1942-2009; or define the dry period as 1901-1960 and the wet period as 1961-2009.
   - Use statistical tests for homogeneity to determine where to divide the POR. The expert panel did not agree on the statistical tests, but did note work by Villarini, et al.

4. Fit a log Pearson III distribution separately to the dry components of the split record and the wet component, following generally the guidance in *Bulletin 17B*. Some members of the panel suggested using the total record to estimate the skew coefficient to be used for both components. Others suggested determining the skew coefficients for each portion of the POR separately. If the skew coefficients are close, an appropriately rounded average of the two could be used.

5. Combine the "wet" and "dry" curves, and weight the probabilities for continued wet conditions versus a reemergence of dry conditions. Two schemes emerged from the majority of the experts' responses:

   - Transition from wet to dry over time. For example, begin with p(wet)=1 and p(dry)=0 in year 1 of the project, moving to p(wet)=0.5 and p(dry)=0.5 in year 50, or move p(wet) from 1 to 0 over the life of the project.
   - Do not change the probabilities over time, e.g., p(wet)=0.8 and p(dry)=0.2 over the entire 50-year project life.

6. Account for greater uncertainty. One suggestion was to use an equivalent POR in the Corps Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) equal to the number of years of the smaller portion of the POR (either the wet portion or the dry portion).

Overview of Fargo-Moorhead EOE

The Fargo-Moorhead EOE, which was held on September 28-29, 2009, in St. Paul, MN, was planned and implemented according to these three guidance documents:

- *Technical guide for use of expert opinion elicitation for U.S. Army Corps of Engineers risk assessments*, USACE Dam Safety Risk Management Center (2009).
- *A practical guide on conducting expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 01-R-01 (2001).
- *Methods for expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 00-R-10 (2000).

The *Technical guide* requires a Level II EOE when the specific information sought is not available from historical records, prediction methods, or literature review. Therefore, the Fargo-Moorhead EOE was a Level II EOE.

Why this EOE was needed

The Fargo, ND-Moorhead, MN metropolitan area has a relatively high risk of flooding from the Red River of the North and relies on emergency responses to ensure safety of the community. Given the high flood risk, the St. Paul District of the US Army Corps of Engineers is completing a feasibility study of alternative measures to reduce flood risk in the Fargo-Moorhead area.

The highest river stages usually occur as a result of spring snowmelt, but summer rainfall events have also caused significant flood damages. In fact, the Red River of the North has exceeded the National Weather Service flood stage of 17 feet in 50 of the past 106 years, and every year from 1993 through 2009.

A review of Red River flow data verifies the increase in flood magnitude and frequency in the relatively recent decades of the period of record (1901-2009). A time series of natural annual maximum mean daily flow for the Red River at Fargo is shown in Figure 1 (Source: David Ford Consulting Engineers, Inc., using USACE data). As can be seen, both the magnitude and variability of the flows have increased since the beginning of record. A review of pertinent research suggests that this increase in flooding magnitude and frequency is consistent with projections of possible effects of climate change.

The Fargo-Moorhead feasibility study follows Corps planning study guidelines, which require that "[r]isk-based analysis… be used to compare plans in terms of the likelihood and variability of their physical performance, economic success and residual risks" (ER 1105-2-100). The annual maximum discharge-probability function (also known as the flood flow frequency curve) at the location of interest is a key input to the risk analysis. For the Fargo-Moorhead project, the Red River frequency was developed following Corps guidelines in EM 1110-2-1415, *Hydrologic frequency analysis,* and EM 1110-2-1417, *Flood-runoff analysis*.