USGS Peak-Flow Frequency Analyses

Recent developments

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PRESENTATION OUTLINE

1. Recent developments in USGS reporting methods
2. Overview of variability and uncertainty in frequency analysis in Montana
3. Overview of USGS regional regression equations

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A new USGS approach for reporting frequency analyses…

- An interpretive report (currently staged for final approvals) describes our methods for implementing Bulletin 17C guidelines
  - Definition of Bulletin 17C "standard procedures"
  - Discussion of "deviations" from the standard procedures in cases of regulated, mixed-population, and atypical lower-tail peak-flow datasets
  - Frequency analyses for 99 example streamgages illustrate application of the methods
  - The interpretive aspects of the frequency analyses are documented in tables and frequency-curve plots that are published in a separate data release---this provides a direct link from the interpretive report to the data release
- ScienceBase data releases (https://www.sciencebase.gov/catalog/)
  - Publication involves a streamlined focused review process
  - Less expensive and more timely delivery of frequency analyses

Currently, we are working out various details of making this new approach convenient for frequency users (ie., how do you find the current analysis for a streamgage of interest)…current fall-back is go to StreamStats for the correct data-release reference

Eventually, we hope to update frequency analyses for all Montana streamgages on an annual basis

Kathy Chase will discuss ScienceBase and accessing the frequency data releases in more detail later in this presentation

A new USGS approach for reporting frequency analyses…

- Open and view a data-release spreadsheet
  - Frequency analyses for selected streamgages in the Beaverhead River and Clark Fork Basins
  - Walk through the table format
  - View some of the frequency plots
  - Get a feel for navigating the spreadsheet
- Open and view PeakFQ files included in the data release
  - WATSTORE peak-flow input data
  - PeakFQ specifications file

This will be a quick overview of the data-release presentation

Thorough understanding of the data-release presentation requires thoughtful reading of the SIR

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Overview of variability/uncertainty in Montana frequency analysis…

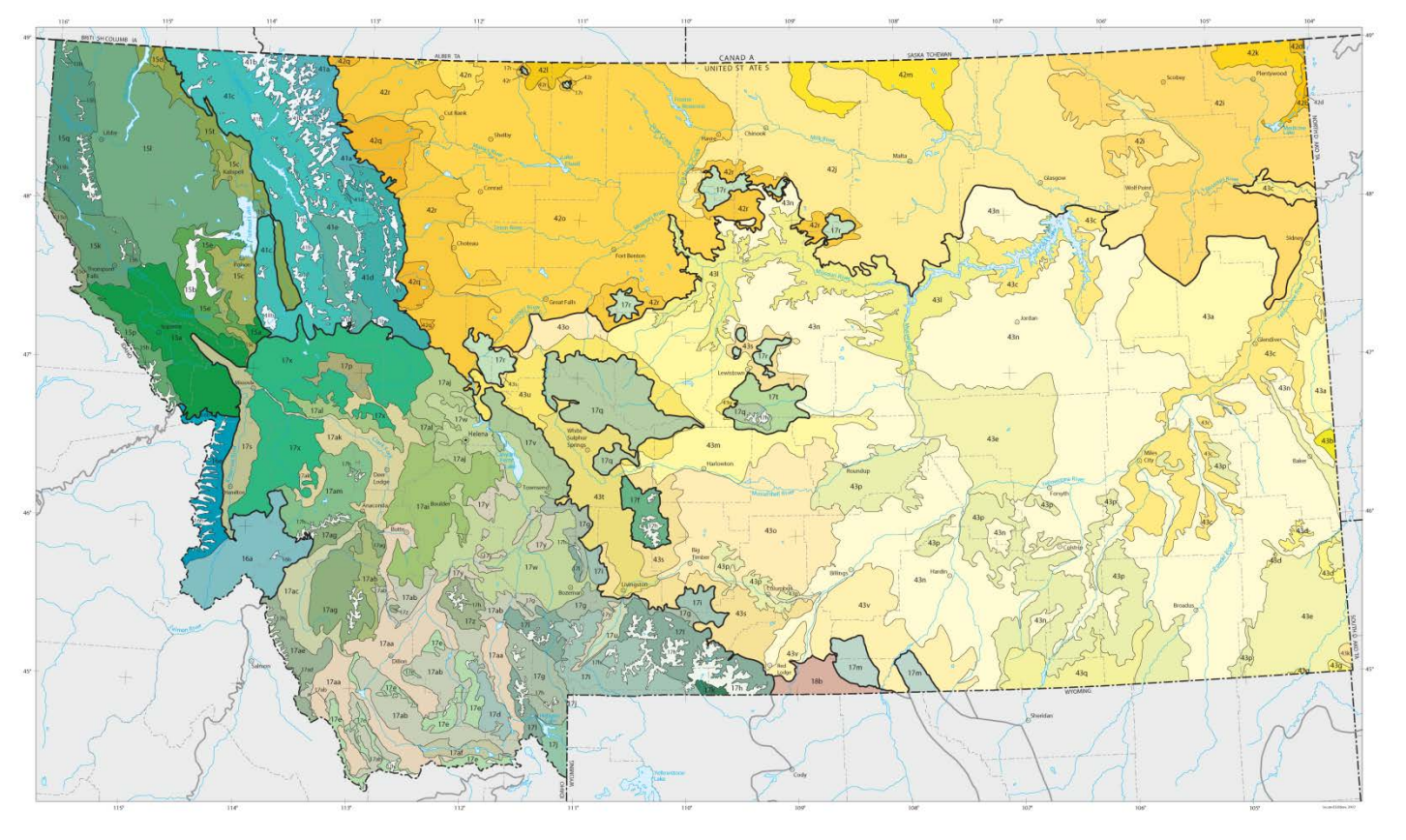
Montana ranks:

4th in size
46th in population

Ecoregions:

6 diverse Level III ecoregions
Numerous Level IV ecoregions

EPA Level III&IV Ecoregions of Montana



The environmental and socioeconomic setting of Montana poses large challenges in operating a statewide streamgage network that accurately captures the hydrologic variability.

Frequency analysis in Montana is more challenging than in most other states!

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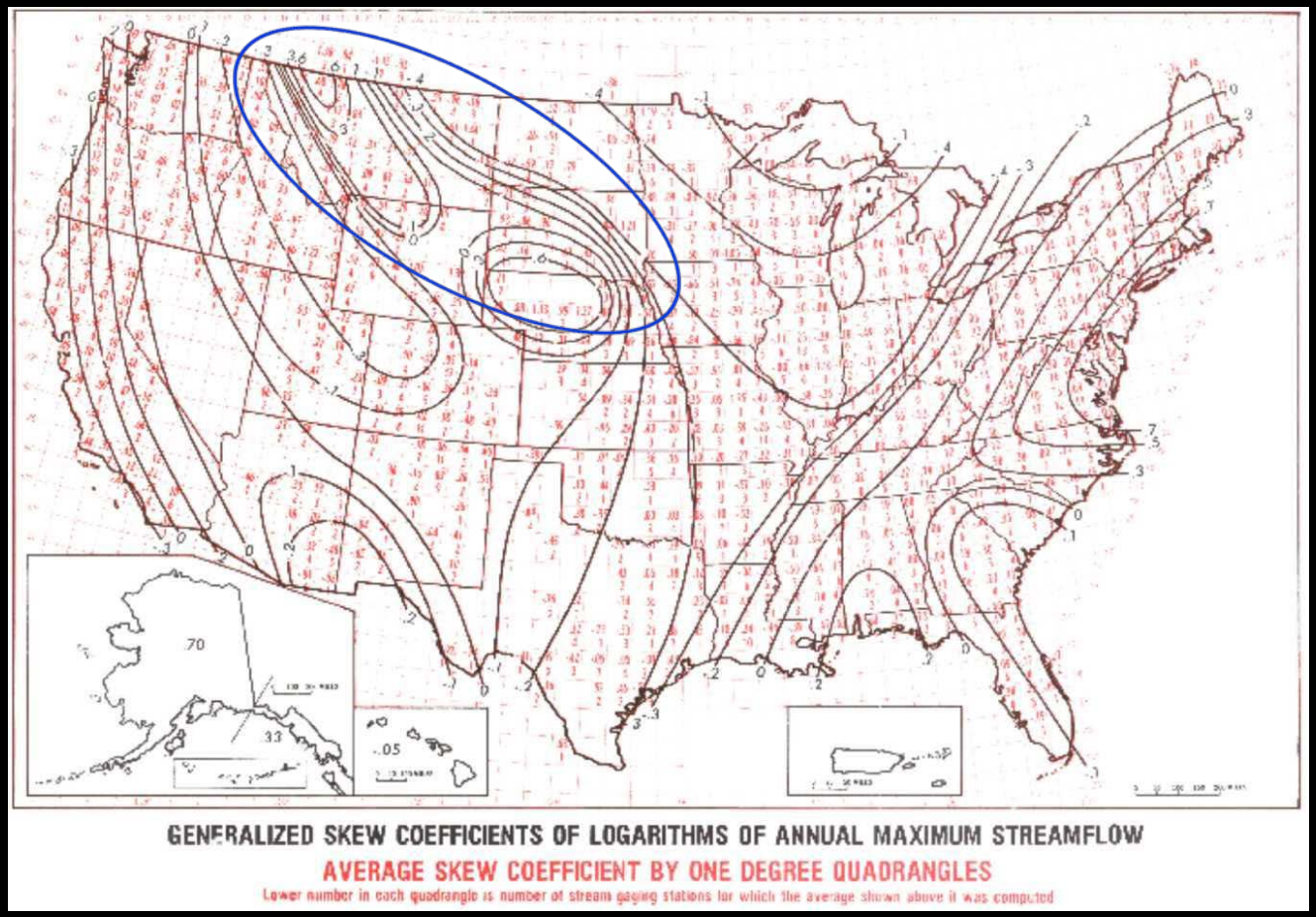
Overview of variability/uncertainty in Montana frequency analysis…

National scale flood-hydrology complexity

- North-central U.S. has the largest complexity
- Due to interaction of regional physiographic and continental hydroclimatic characteristics

Bulletin 17B regional skew map (antiquated)



Major points:

- MT has large complexity in flood hydrology
- National-scale methods don't always capture the variability

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Overview of variability/uncertainty in Montana frequency analysis…

Montana streamgage network

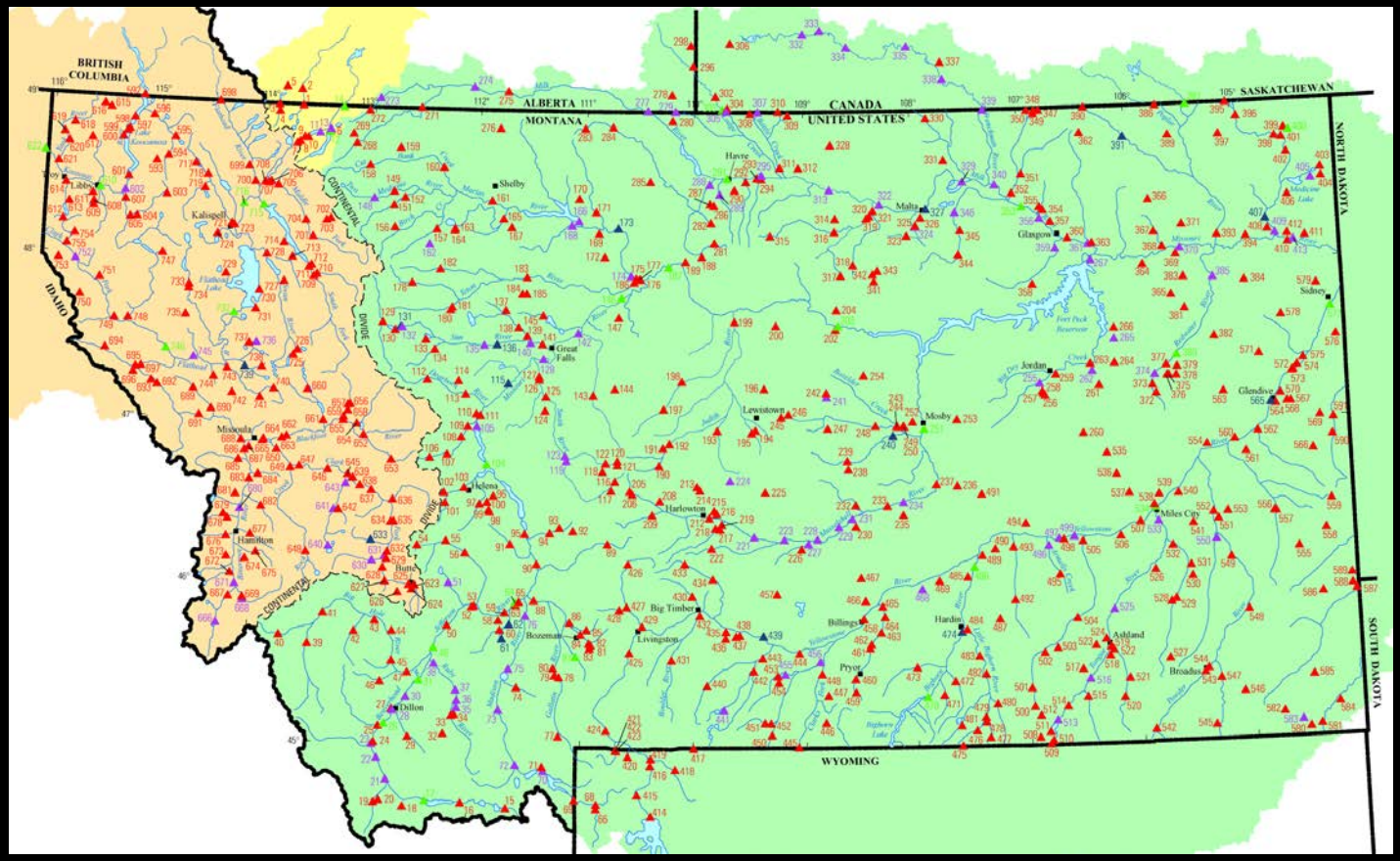
- Each streamgage dataset is different with respect to:
  1. Flood hydrology
  2. Length and timing of peak-flow records
- Large areas with poor streamgage coverage

Regional regression analysis combines the information from the streamgage network to:

1) Improve the understanding of flood-hydrology processes;
2) Adjust frequencies at streamgages; and
3) Estimate frequencies at ungaged sites

- WY-MT WSC reports frequency analyses for 726 streamgages in or near MT (average record length about 30-35 years; range of 10-126 years)

Reported streamgages



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Overview of Regional Regression Equations (RREs; SIR 2015-5019F)

- 8 hydrologic regions
- 28 candidate basin characteristics
- Generalized least squares (GLS) regression

The regression analyses produce best-fit models for 10 AEPs for each hydrologic region

- The complexity of Montana datasets and flood hydrology result in larger errors in RREs than in most states
- However, in most cases the RREs produce reasonably reliable results
- In some cases, the hydrologic setting of an ungaged site is not well represented by the RREs.

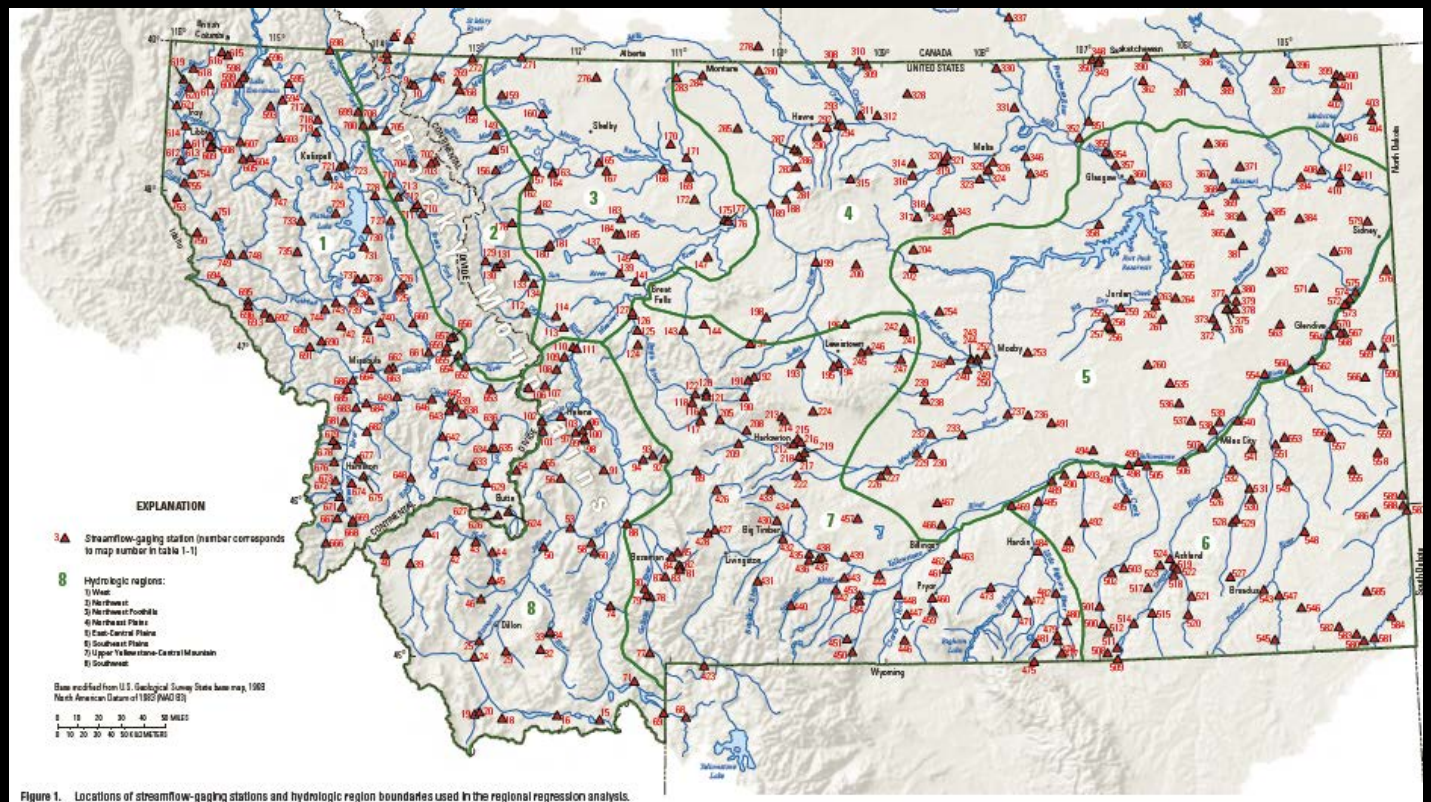

Figure 1. Locations of streamflow-gaging stations and hydrologic region boundaries used in the regional regression analysis.

RRE users need to give thoughtful consideration to the hydrologic setting of an ungaged site. The RRE results should be investigated with respect to as much other relevant information as possible.

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Additional thoughts on GLS regression and RREs

- Two basic assumptions of ordinary least squares (OLS) regression are often violated in hydrologic regional regression studies:
  - Constant variance (problem: the variance is dependent on length and timing of the peak-flow records, which is different among streamgages)
  - Inter-streamgage independence (problem: spatial correlation among the streamgages)

- GLS regression compensates for the violations of the OLS assumptions

- The USGS regional GLS regression analyses follow standard documented procedures for developing valid best-fit models for predicting peak-flow quantiles at ungaged sites

- The RREs need to be periodically updated to incorporate additional peak-flow data and to accommodate advances in frequency analysis and basin-characteristics datasets

- Transitioning from one set of RREs to an updated set of RREs can pose questions

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Considerations concerning the use of updated RREs

- The updated RREs (SIR 2015-5019F):
  - were developed using the same fundamental approaches as previous RREs
  - incorporate additional peak-flow data and advances in frequency analysis and basin-characteristics datasets

- Interpretation of changes in mean standard errors of prediction (SEP) between previous and updated RREs
  - Error is not necessarily bad!
  - MT SEPs for 1-percent AEP peak-flow quantiles generally range from about 55 to 75 percent (generally large)
  - The SEP is not an absolute index of the quality of the prediction
  - SEPs can increase or decrease between previous and updated RREs
  - More/better information was used in the updated RREs

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Evaluation of RRE results for ungaged sites

- Compile and investigate any available information on flood events
- Investigate nearby streamgages with hydrologically similar drainage basins
- Investigate the basin characteristics of the ungaged site with respect to the streamgages in the hydrologic region
- Investigate the channel-geometry equations from WRIR 2003-4308
- Investigate rainfall/runoff models

In some cases, there can be substantial differences between the RRE results and other estimation methods or relevant information. This provides indication of larger than typical uncertainty in determination of the estimated 1-percent AEP.

In such cases, due diligence is required for appropriate determination of the estimated 1-percent AEP quantile.

Consider that greater uncertainty might warrant selection of a more conservative hydrologic procedure.

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FEMA prioritization of hydrologic procedures

FEMA's Appendix C[1] clearly establishes a hierarchy of hydrologic procedures for flood-plain mapping studies:

- Use streamgage data if a streamgage is along or near the study reach;
- Use USGS regression equations if no streamgage is on the studied stream and the regression equations are applicable to the site of interest; and
- Use rainfall-runoff models for ungaged streams if the regression equations are not applicable

Consider that the FEMA hierarchy should be followed wherever possible.

[1]Federal Emergency Management Agency, 2009, ***Guidelines and Specification for Flood Hazard Mapping Partners, Appendix C: Guidance for Riverine Flooding Analyses and Mapping***, November 2009. (https://www.fema.gov/media-library/assets/documents/13948)

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Considerations on the use of custom/local regression analyses

- **MY UNDERSTANDING**: custom/local regression analyses are not directly covered in the FEMA hierarchy of hydrologic procedures
- Any regression analysis should follow accepted methods for valid regression analysis
- Minimum of 20 streamgages
- Start from scratch; compile a thorough basin characteristics data set and evaluate various regression models
- Consider potential effects of time-sampling error and inter-streamgage correlation
- Thorough evaluation of regression diagnostics

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Ongoing and potential USGS activities to advance frequency analysis and the RREs

- Published revisions to SIR 2015-5019D and SIR 2015-5019F relating to the RREs for the NW hydrologic region
- Ongoing activities to improve definition of regulation status for Montana streamgages
- Ongoing activities to investigate incorporation of hydroclimatic persistence into frequency analyses
- Update of channel geometry regression equations (in progress)
- Potential revisitation of application of the “Region of Influence” (ROI) approach in Montana
- Potential investigation of machine-learning approaches (eg., Random Forest regression)

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THE END

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