# Site Specific Probable Maximum Precipitation Estimates and Professional Judgement

**Barbara Hayes,** U.S. Nuclear Regulatory Commission

Co-authors:

**Shih-Chieh Kao**, Oak Ridge National Laboratory

**Joseph Kanney**, US Nuclear Regulatory Commission

**Kevin R. Quinlan**, US Nuclear Regulatory Commission

**Scott T. DeNeale**, Oak Ridge National Laboratory

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# NRC involvement in site specific PMP reviews

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- NRC's Recommendations from Fukushima Lessons Learned – Licensees performed immediate reviews followed by more in depth flood hazard "re-evaluation" reports
- Licensees used PMP estimates for basin wide riverine flooding, and local intense precipitation (LIP)

# Commercial Nuclear Power Plants in the U.S.

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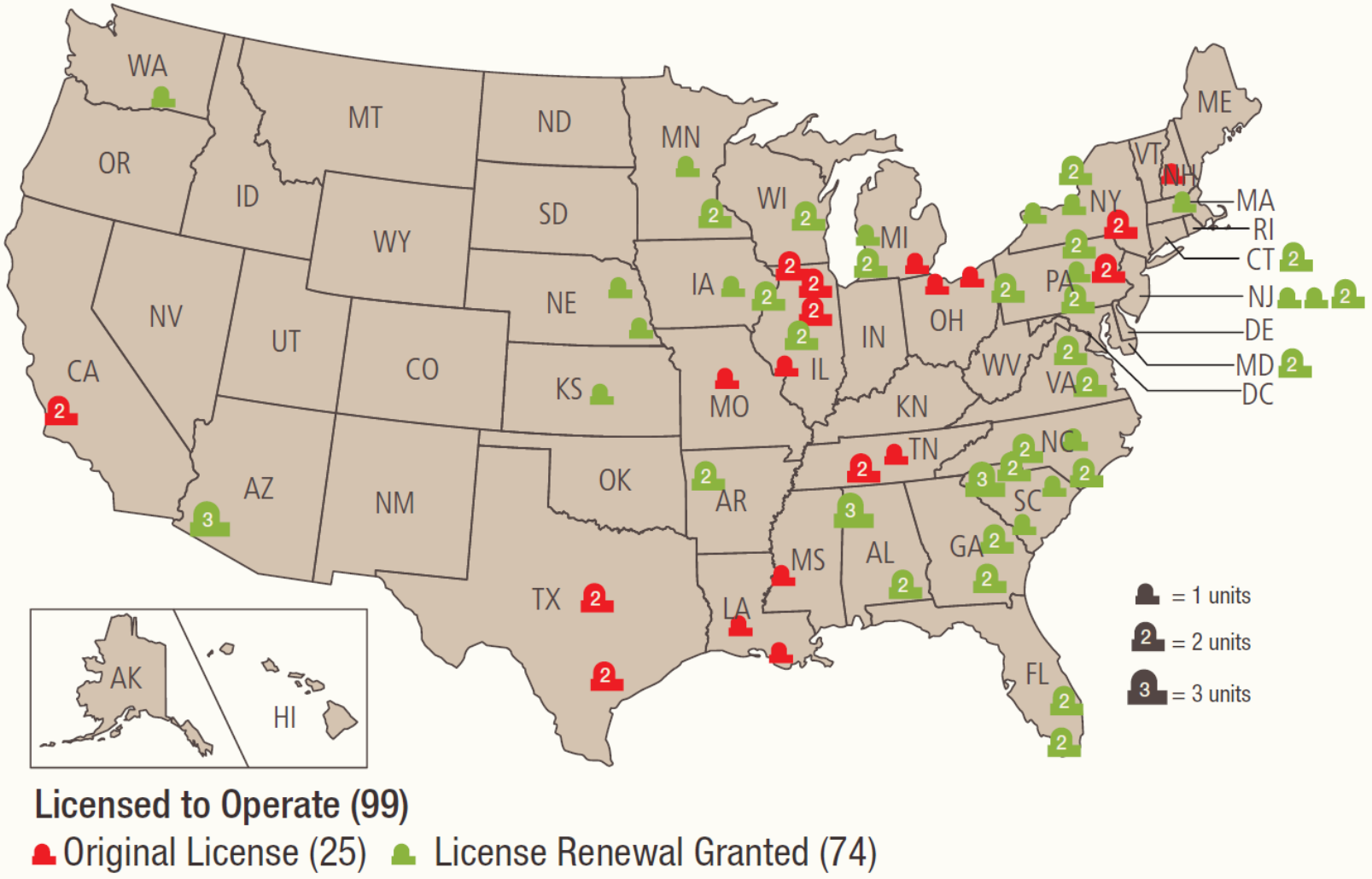

# Regions covered by different NWS PMP documents (as of 2015)

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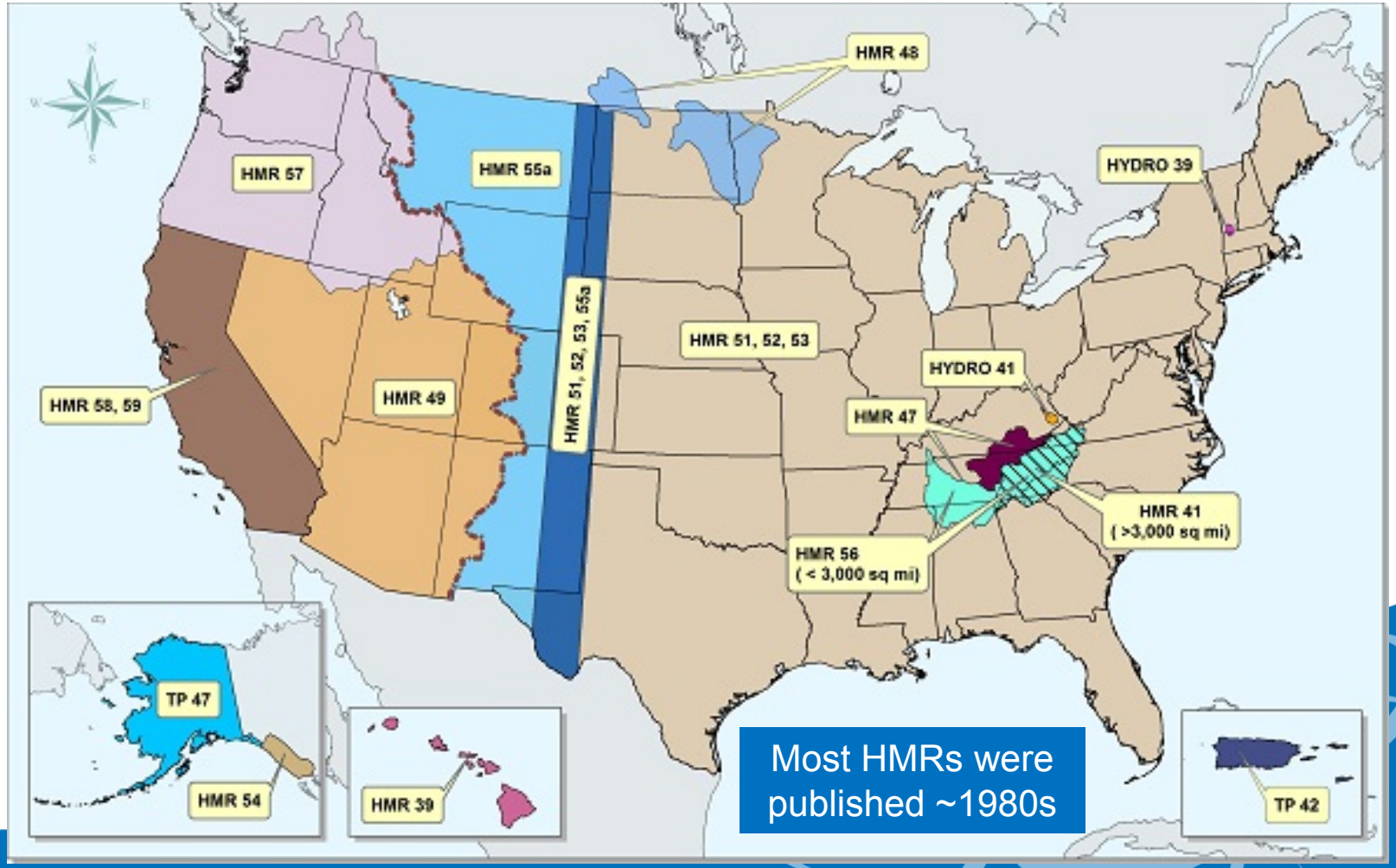
- **HMR 51: PMP Estimates, U.S. East of the 105th Meridian**
- **HMR 52: Application of PMP Estimates, U.S. East of the 105th Meridian**
- **HMR 53: Seasonal Variation of 10-Sq-Mi PMP Estimates , U.S. East of the 105th Meridian**



# Comparison of ssPMP and HMR estimates for Local Intense Precipitation

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(using 1 hr- 1 sq. mi LIP determined from charts provided in HMR-52)

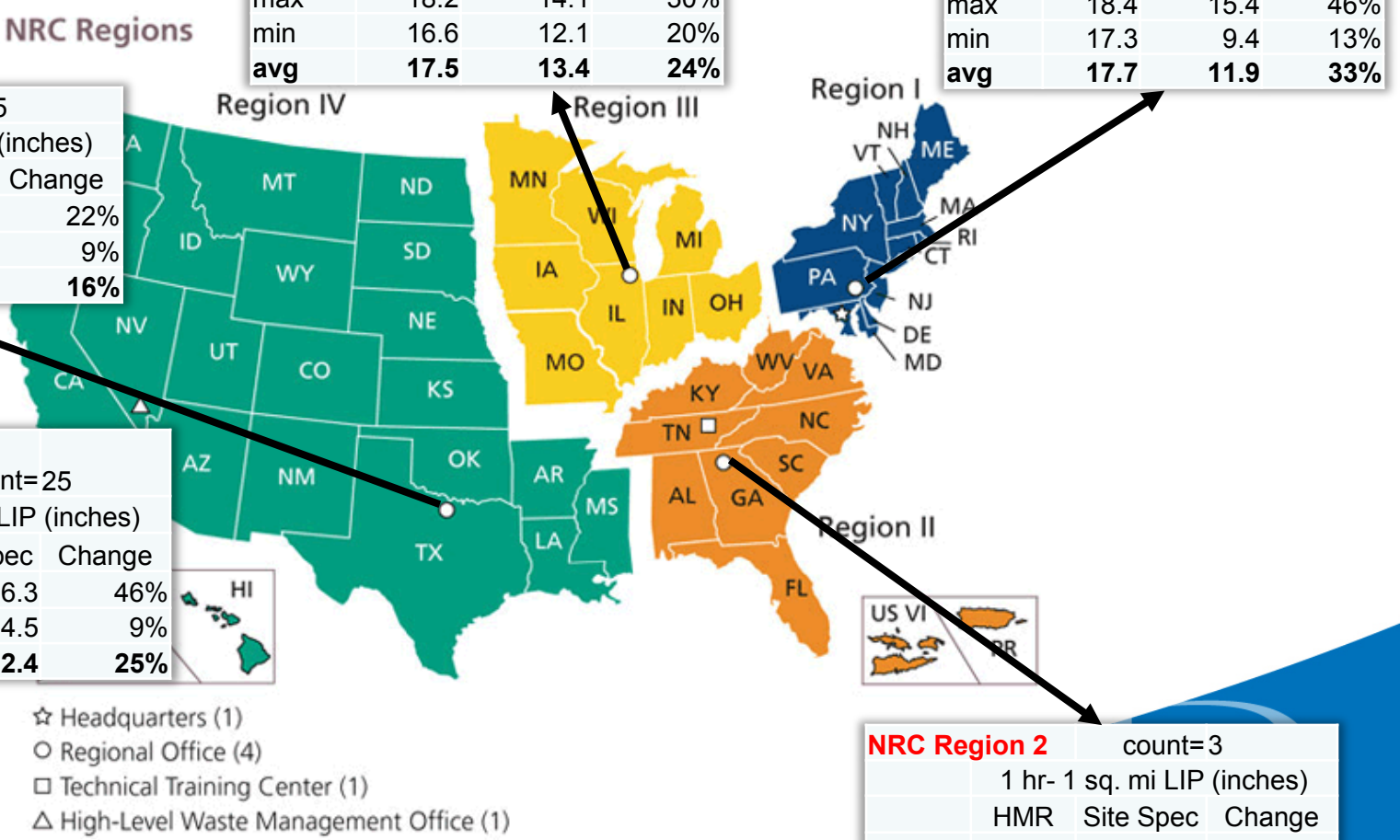
| NRC Region 3 | count= 13 | | |
|---|---|---|---|
| | 1 hr- 1 sq. mi LIP (inches) | | |
| | HMR | Site Spec | Change |
| max | 18.2 | 14.1 | 30% |
| min | 16.6 | 12.1 | 20% |
| **avg** | **17.5** | **13.4** | **24%** |

| NRC Region 1 | count= 5 | | |
|---|---|---|---|
| | 1 hr- 1 sq. mi LIP (inches) | | |
| | HMR | Site Spec | Change |
| max | 18.4 | 15.4 | 46% |
| min | 17.3 | 9.4 | 13% |
| **avg** | **17.7** | **11.9** | **33%** |

| NRC Region 4 | count= 5 | | |
|---|---|---|---|
| | 1 hr- 1 sq. mi LIP (inches) | | |
| | HMR | Site Spec | Change |
| max | 19.4 | 16.3 | 22% |
| min | 5.5 | 4.5 | 9% |
| **avg** | **12.7** | **10.7** | **16%** |

| Summary: All Sites | count= 25 | | |
|---|---|---|---|
| | 1 hr- 1 sq. mi LIP (inches) | | |
| | HMR | Site Spec | Change |
| max | 19.4 | 16.3 | 46% |
| min | 5.5 | 4.5 | 9% |
| **avg** | **16.7** | **12.4** | **25%** |

| NRC Region 2 | count= 3 | | |
|---|---|---|---|
| | 1 hr- 1 sq. mi LIP (inches) | | |
| | HMR | Site Spec | Change |
| max | 19.1 | 12.4 | 38% |
| min | 18.4 | 11.8 | 33% |
| **avg** | **18.7** | **12.0** | **36%** |



# NRC February 2015 Generic Audit[1] of vendor's PMP Approach

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- Approach generally a logical extension of HMRs
- Enhanced storm database
  - More recent and larger number of storms (compared to HMRs)
  - GIS tools to facilitate analysis (not available for most HMRs)
- General enhancements such as moving storms, larger basins, simpler chunking of the database
- Professional judgement used differed from the HMRs on a number of points, some of which had a significant impacts on the resulting estimates, most notably:
  - 1993 EPRI heuristic for storm representative dew point adjustment to harmonize historic storms with only 12 hour dew point data and more recent storms in a single database.
  - Use of self-derived 100-year dew point climatology maps instead of the maximum persisting 12-hr dew point maps published by NOAA.

[1] NRC 2015, "Report for the Audit of Applied Weather Associates, LLC, Regarding Site Specific Probable Maximum Precipitation Development in Support of Near-Term Task Force Recommendation 2.1 Flood Hazard Reevaluations," May 19, 2015, ADAMS Accession No. ML15113A029

# Approach for Estimating PMP

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Vendor's approach attempts to maintain as much consistency as possible with the general method used in the NOAA HMRs.

- Storm search from updated database organized by storm types
- For each storm: Depth-Area-Duration and Mass Curves, Isohyets, trajectory analysis
- Maximize each storm
  - Backtrack along the storm trajectories moisture source for representative storm dew point temperature ($T_d$)
  - Use maximum $T_d$ climatology data at same location
  - Ratio of Precipitable Water (PW) is used as maximization factor
- Transposition each storm to point(s) of interest
- Final envelopment of transposed, maximized storms for different durations and areas

# EPRI heuristic[1] for representative $T_d$

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- Representative $T_d$ for older storms used 12-hour persisting $T_d$ due to limited data, instead of the 6-, 12-, and 24-hour average $T_d$ used by the vendor for newer, more data-rich storms. The vendor uses a simple heuristic developed for the Electric Power Research Institute by North American Weather Consultants in 1993.
- For basin wide PMP, 2 degree F is added on the 12-hour persisting dew point to approximate 12- or 24-hour average dew point. A larger 7 degree F conversion factor is used for LIP-PMP to approximate 6- or 12-hour average dew point.
- The EPRI heuristic reflects storms in the central United States and its applicability to storms along the Gulf and Atlantic coasts has not been investigated

[1] EPRI, 1993, TR-101554-V1 and TR-101554-V2; Probable Maximum Precipitation Study for Wisconsin and Michigan: Volumes 1 and 2, prepared by North American Weather Consultants. http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-101554-V1

# EPRI heuristic

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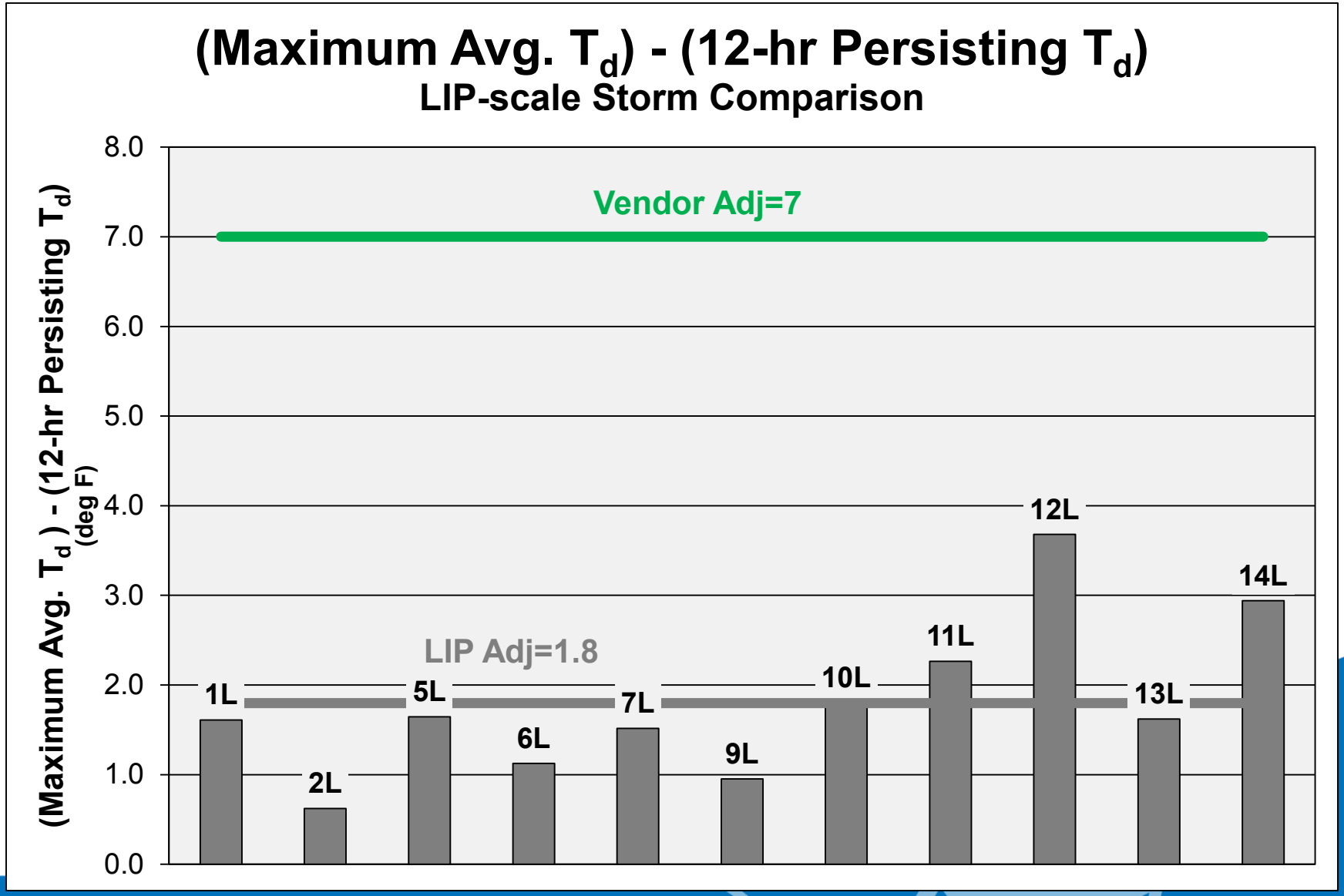

# EPRI heuristic

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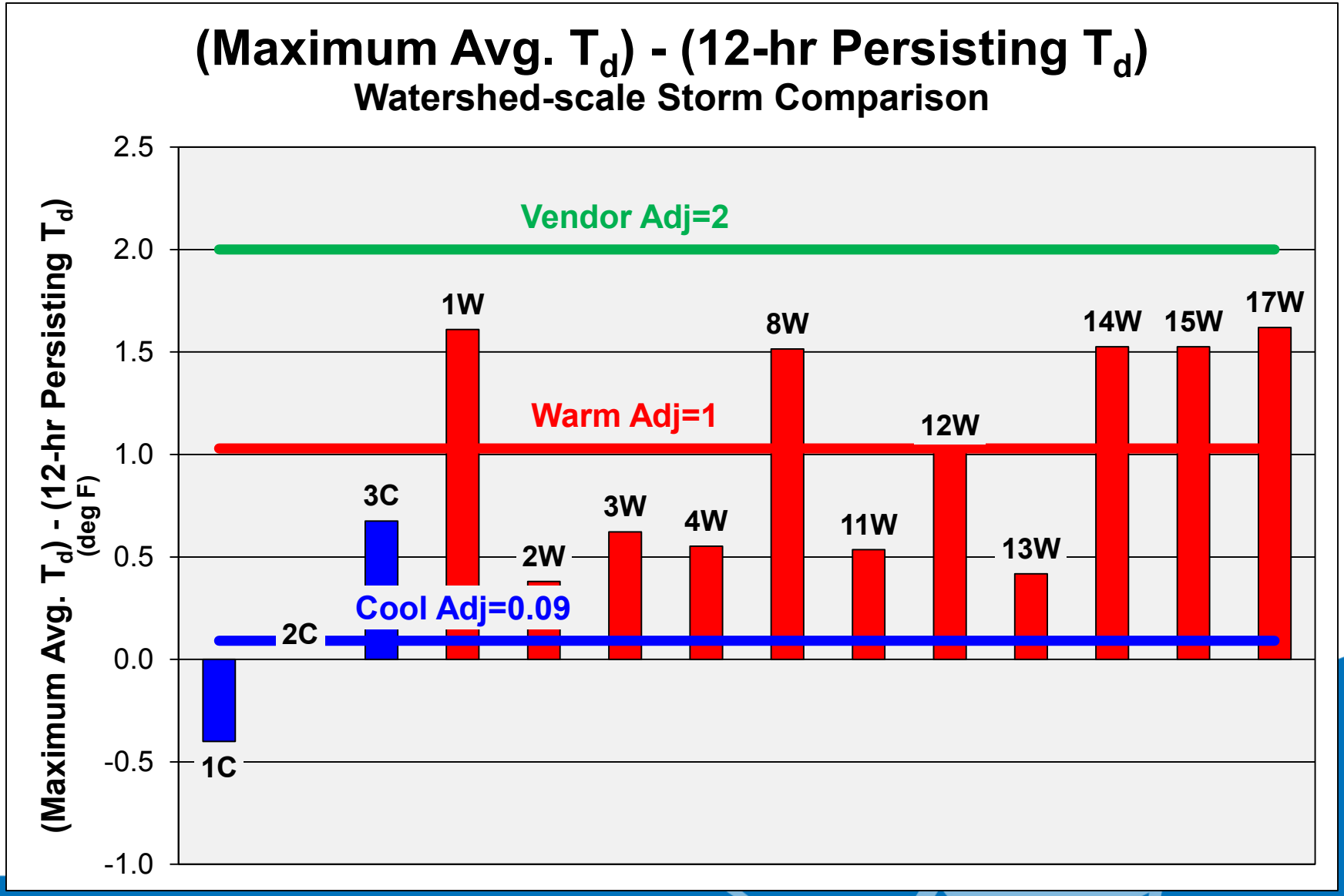

# Maximum $T_d$ climatology

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Vendor used maximum 6-, 12-, and 24-hour average $T_d$ based on 100-year return interval to produce monthly $T_d$ maps:

1. Extract/calculate annual maximum series of monthly max $T_d$ at each station
2. Calculate L-moment statistics
3. Use L-moment ratios as guide to choose GEV distribution
4. Extraction of 20, 50, and 100 return period maximum monthly dew points
5. Adjust for max $T_d$ at 15$^{th}$ of the month
6. Adjust to 1000 mb (i.e., adding 2.7 °F per 1000 ft elevation).
7. Spatially interpolate the monthly max using PRISM[1] gridded 30-year average monthly dew point data as a base map
8. Smooth using block filter
9. Manual smoothing using professional judgement

[1] PRISM Climate Group (www.prism.oregonstate.edu)

# Maximum $T_d$ Climatology alternative gauge-based approach

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Alternate approach developed upon gauge-based data for final determination rather than data from in-house manually smoothed maps. Key differences were as follows:

- No spatial smoothing of $T_d$ climatology values.
- The Kolmogorov–Smirnov goodness-of-fit test (under 5% significance level) used to filter out ill-fitted results.
- Maximum likelihood is used to estimate the parameters of generalized extreme value (GEV) distributions.

Using the NCDC-ISD database the 100-year, 6-, 12-, and 24-hour duration maximum $T_d$ are calculated for all stations.

# Max $T_d$ Climatology

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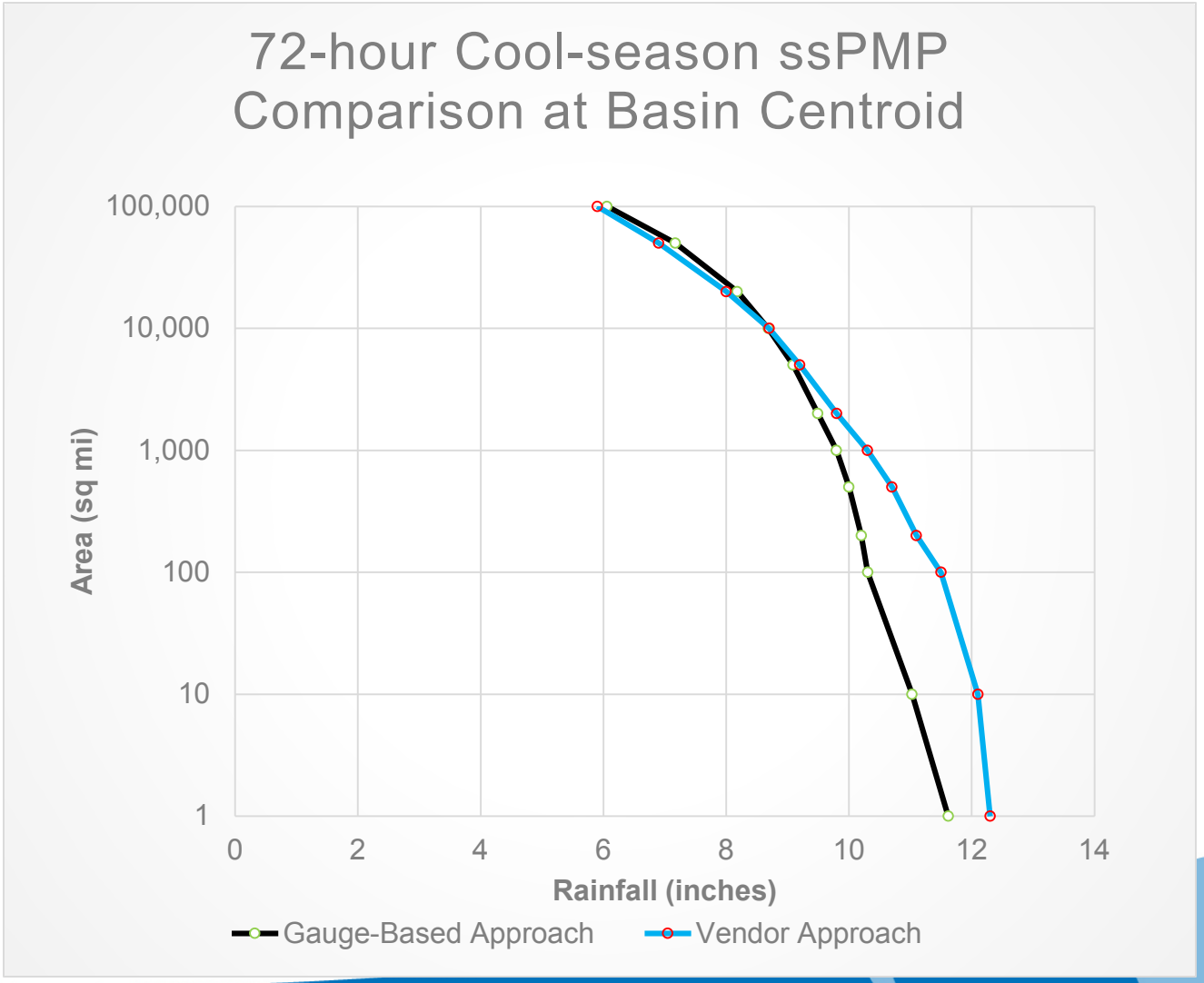


| Area (sq. mi) | Deviation (GB-vendor) |
|---|---|
| 100000 | 3% |
| 50000 | 4% |
| 20000 | 2% |
| 10000 | 0% |
| 5000 | -1% |
| 2000 | -3% |
| 1000 | -5% |
| 500 | -7% |
| 200 | -9% |
| 100 | -12% |
| 10 | -10% |
| 1 | -6% |

# Summary

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- NRC conducted a generic audit of a vendor's approach to PMP estimation
- The approach generally followed HMR and WMO approaches with an expanded database and computational power
- Key points of professional judgement were investigated more fully for one location using 25 storms
- A heuristic for related to representative $T_d$ was not supported by the analysis as applied to LIP
- Smoothing used to develop Max $T_d$ climatology had significantly different results relative to a more gauge-based approach

# Related Research in Progress

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- NRC Probabilistic Flood Hazard Assessment (PFHA) Research Program – Extreme Precipitation projects
  - Adapt structured assessment approaches used in seismic hazard assessment community
    - Use of expert judgement in face of large uncertainties
    - Initial focus on LIP flooding events
  - High-resolution numerical simulation of LIP events using mechanistic models (e.g. numerical weather prediction codes)
    - Simulate observed extreme events to understand uncertainties and sensitivities
      - Convective parameterization, microphysics, long and short wave radiation, land surface, etc.
      - MCS and TC evens for which Stage IV precipitation data available
    - Perturb boundary and initial conditions to investigate changes in precipitation due to changes in
      - Moisture inflow
      - Regional climate forcing