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Chesapeake Bay Streamflow Base and Critical Period Diagnostics

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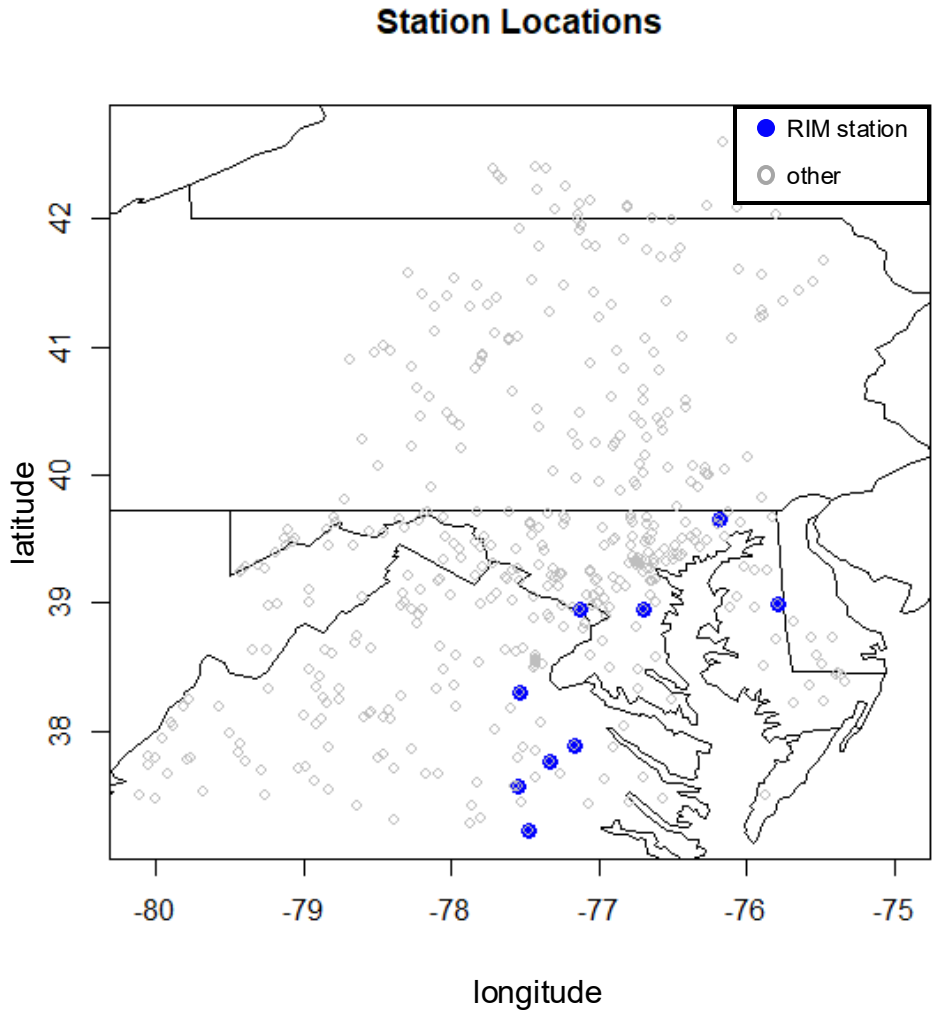
What Are the Hydrologic Base Period and Critical Period?

- **Base period:** A 10-year window of historical streamflow used to represent "typical" hydrology for the Bay watershed : the reference conditions against which nutrient and sediment loads are modeled

- **Critical period:** A 3-year window within the base period representing unusually high flow conditions : when nutrient and sediment delivery to the Bay is greatest and load reduction targets are most demanding (non-extreme)

Study area - RIM and tributary flow gages

- 9 River Input Monitoring (RIM) stations monitor direct inputs to the Bay - primary drivers of nutrient and sediment loading
- Interior tributary stations characterize watershed hydrology
- RIM stations weighted **95%** in composite score - consistent with their dominance of Bay inflow
- RIM weights applied using Phase 6 N adjusted ratios

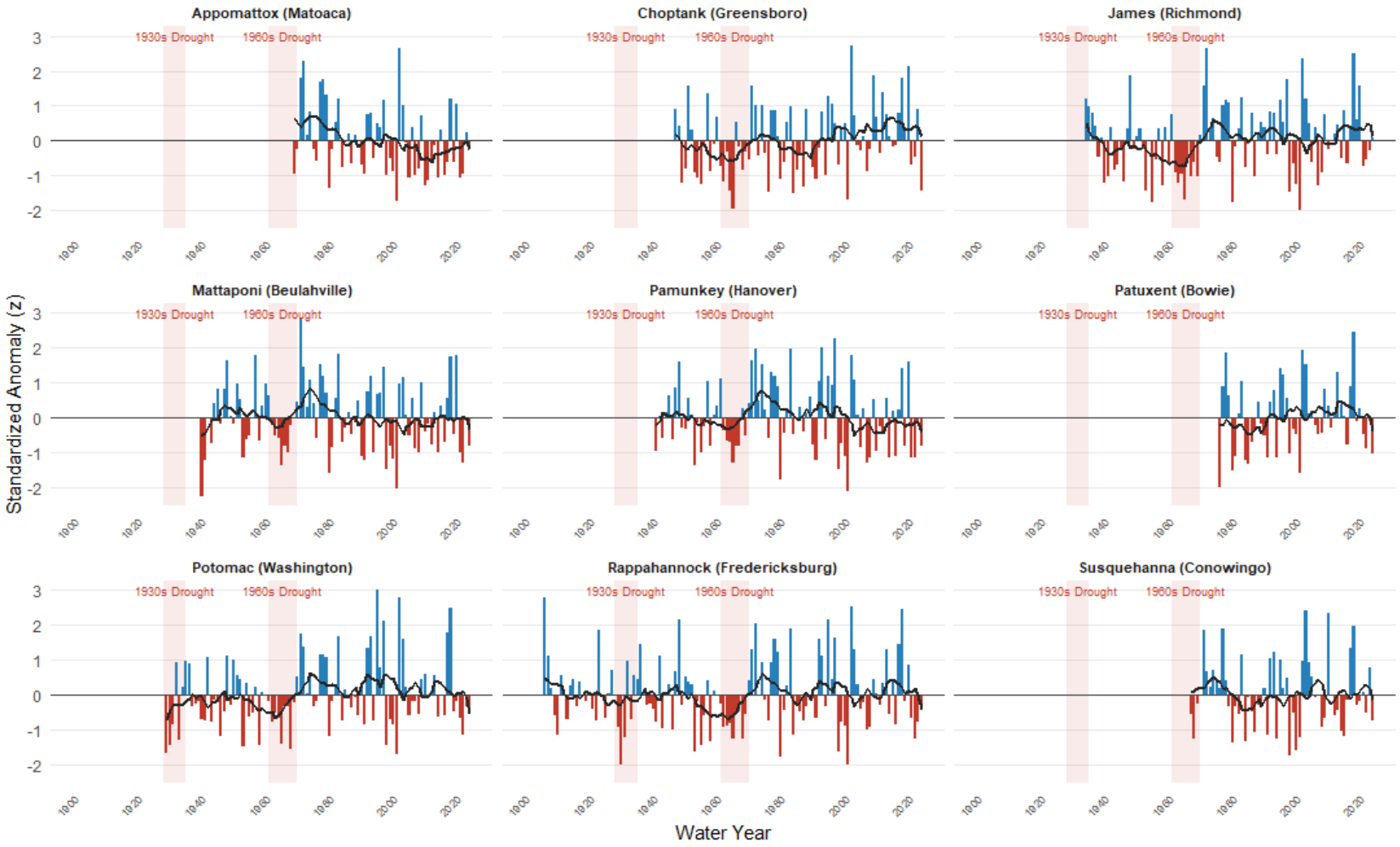


RIM station periods of record

Annual streamflow anomaly

1960s drought- largest recorded departure from normal freshwater flows

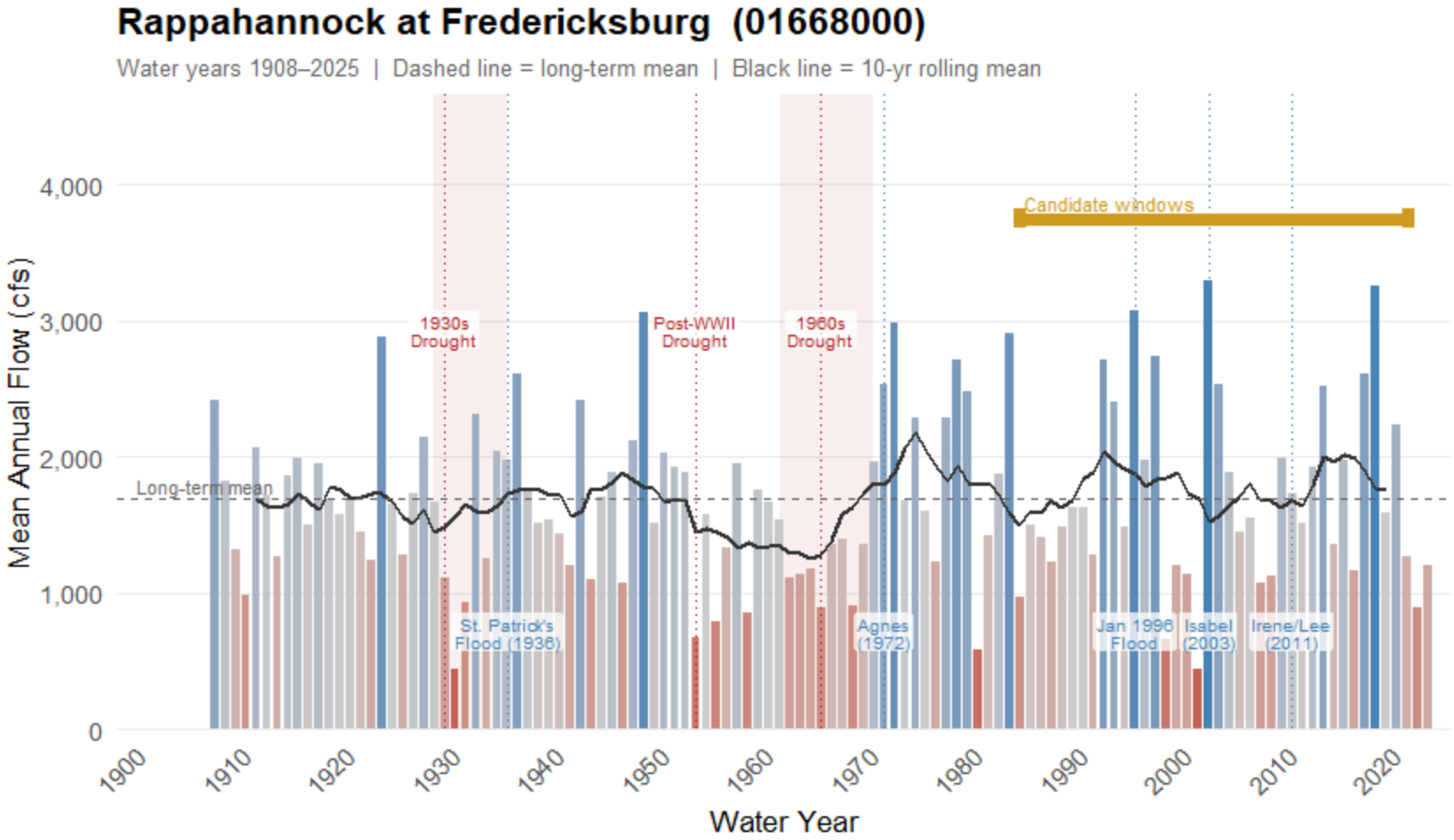
Longest sustained dry period in the Chesapeake's instrumental record



A closer look: Annual flows

Candidate windows will likely be limited to modeling constraints (1985-2022)

Long-term reference period: constrain by record length and hydrologic regime



Scoring Candidate Windows: A Two-Stage Process

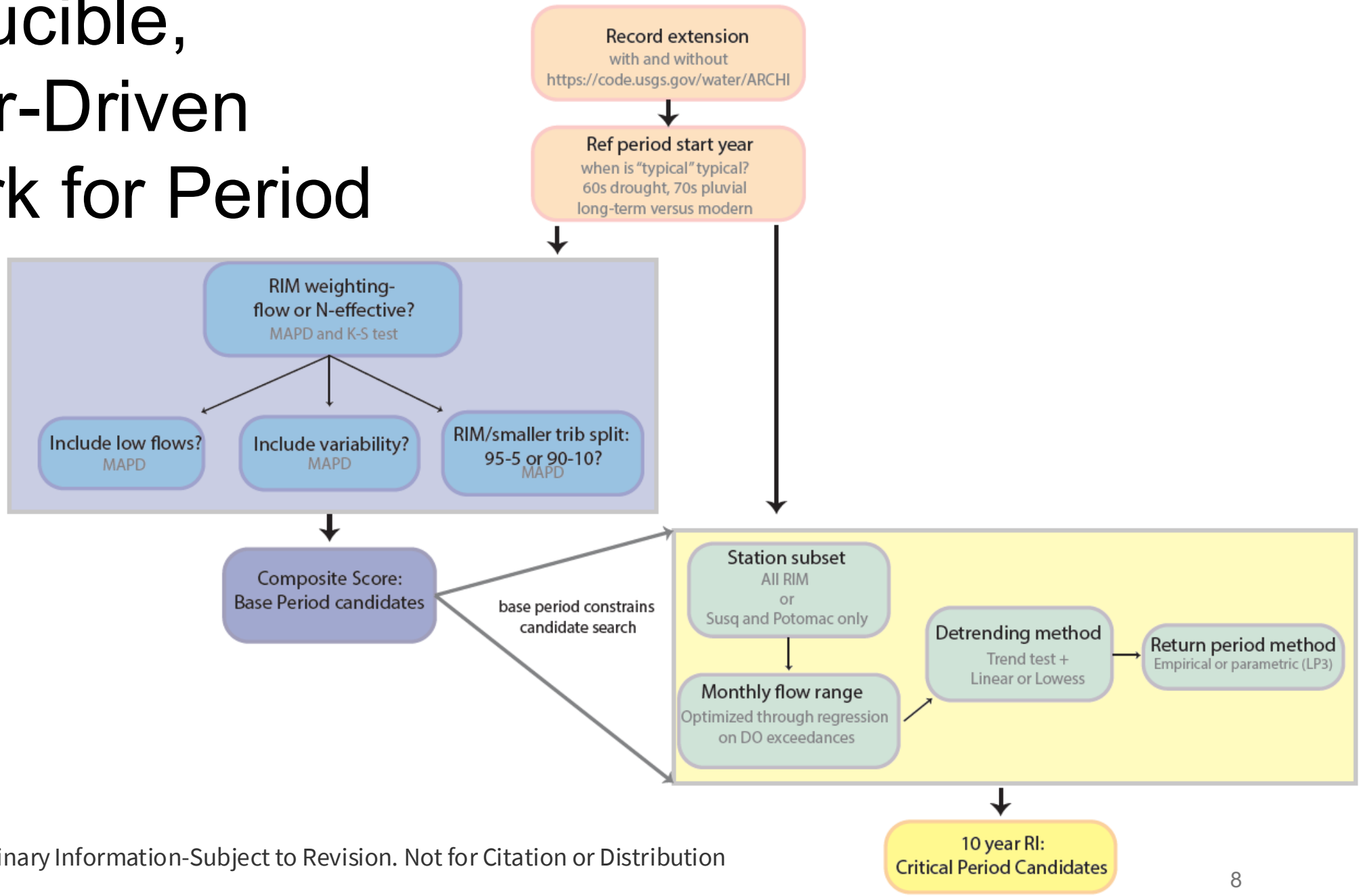
Base Period Scoring

- MAPD : mean absolute percent difference
- Statistics include mean flow, flow variability (CV), high flows (Q95), and optionally low flows (Q05)
- Kolmogorov-Smirnov (K-S) test evaluates whether the full flow distribution matches the reference period
- MAPD and K-S scores are normalized and combined into a composite score; RIM stations weighted by Phase 6 load effectiveness

Critical Period Scoring

- Compute composite Oct - June flow across RIM stations for each water year within the base period
- Calculate 3-year running averages; test for and optionally remove trend
- Fit a frequency distribution (Weibull) to identify the 10-year recurrence interval flow — the threshold for "anomalously high" conditions
- 3-year windows exceeding this threshold are critical period candidates

A Reproducible, Parameter-Driven Framework for Period Selection



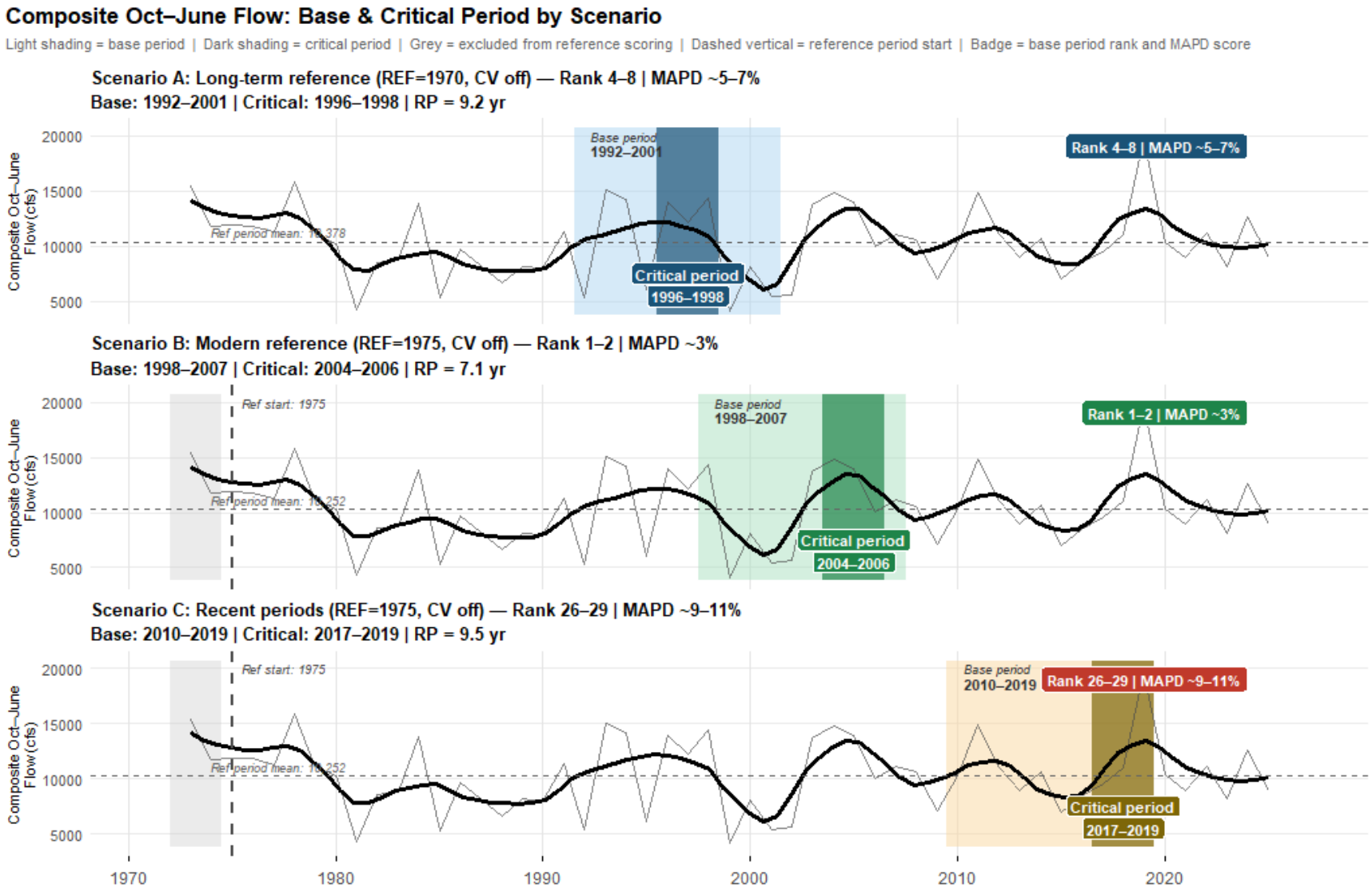
Decision space- base period

Parameter	Options
Reference start year	1900, 1968, 1970, 1975, 1985
MAPD metrics	Mean, CV, Q05, Q95 (on/off)
MAPD metric weights	Equal or differential (1.0 default)
Station weighting	Load effectiveness vs. raw flow
RIM/tributary split	95/5 or 90/10
Record extension	Standard or ARCHI-extended

Decision space- critical period

Parameter	Options
Composite flow months	Oct–Jun (default; pending DO data)
Station subset	All 9 RIM vs. Susquehanna + Potomac
Detrending	None, linear, LOWESS
Return period method	Weibull (LP3 pending)
Target return period	10 years (±2 tolerance)
Window type	Overlapping vs. non-overlapping

What Does "Typical" Mean? Example Solutions Under Different Assumptions



Summary

What the analysis does:

- Scores all 10-year candidate windows on how well they match long-term reference flow statistics (MAPD) and flow distribution shape (K-S test) across 9 weighted RIM stations
- Identifies 3-year critical period candidates by fitting a Weibull return period to the full reference record and flagging windows near the 10-year target (±2 years)

What we found:

- Top-ranked base periods cluster around 1997–2007; critical period consistently points to mid-2000s under modern reference assumptions
- Reference period start year is the dominant lever : it shifts both the MAPD benchmark and the 10-year return period flow threshold simultaneously
- Recent windows (2010–2022) score poorest in the candidate set on both metrics : double-penalized on MAPD and K-S

What remains open:

- Full sensitivity analysis across all 26 parameters : planned for September deliverable
- DO exceedance correlation to optimize monthly flow window (pending data)
- Formal uncertainty quantification via bootstrapping
- Whether post-2010 hydrology represents a new regime or a transient wet-dry cycle

Discussion

- Long-term historical hydrology or modern conditions : which better serves Phase 7 planning targets?

- Is post-2010 hydrology a new regime driven by large-scale climate forcing (AMO, NAO, climate change), or a transient cycle, and should that question be resolved before we select a period?

- Given the nonstationarity question, is a 10-year return period still the right critical period criterion?

- Are there additional hydrologic or climate factors the group wants incorporated into the analysis before a recommendation is brought forward in September?

Base Period Scoring: Methodology

- Windows scored by Mean Absolute Percent Difference (MAPD) from long-term statistics

$$MAPD = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{S_w - S_{LT}}{S_{LT}}\right|100$$

where:

S_w = statistic for 10-year window

S_{LT} = long-term mean statistic

n = number of metrics and gages

- Builds on previous analysis (appendix F):
- Extended candidate period (1985-2024)
- Added Q05, Q95, CV

Computed across: mean Q, SD, CV, Q05, Q95

Basins	Symbol	N relative effectiveness	N&P relative effectiveness	N adjusted ratio	N&P adjusted ratio
Appomattox	JmsA	2.647	4.067	0.035	0.044
Choptank	EshMid	11.244	18.773	0.150	0.202
James	JmsA	2.647	4.067	0.035	0.044
Mattaponi	YrkA	4.630	5.334	0.062	0.057
Pamunkey	YrkA	4.630	5.334	0.062	0.057
Patuxent	PxtA	10.931	13.355	0.145	0.144
Potomac	PotA	14.045	14.835	0.187	0.160
Rappahannock	RapA	8.065	8.707	0.107	0.094
Susquehanna	Susq	16.325	18.370	0.217	0.198
sum		75.163	92.844	1.000	1.000

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