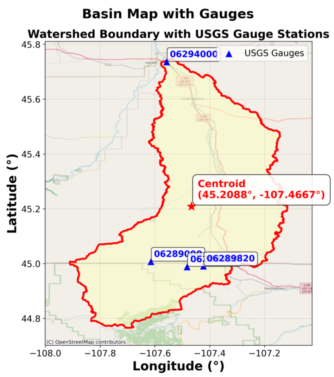
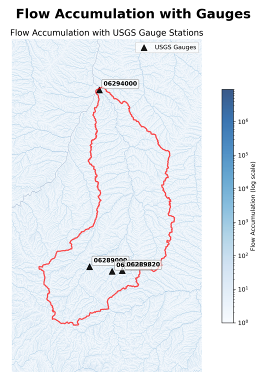
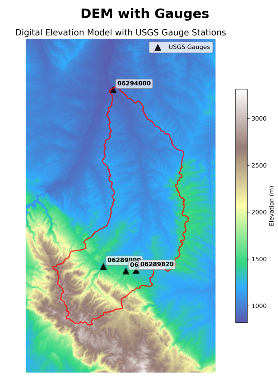
Hydrological Simulation Report: Little Bighorn Basin

1. Title and Basin Information

Basin & Gauge Map





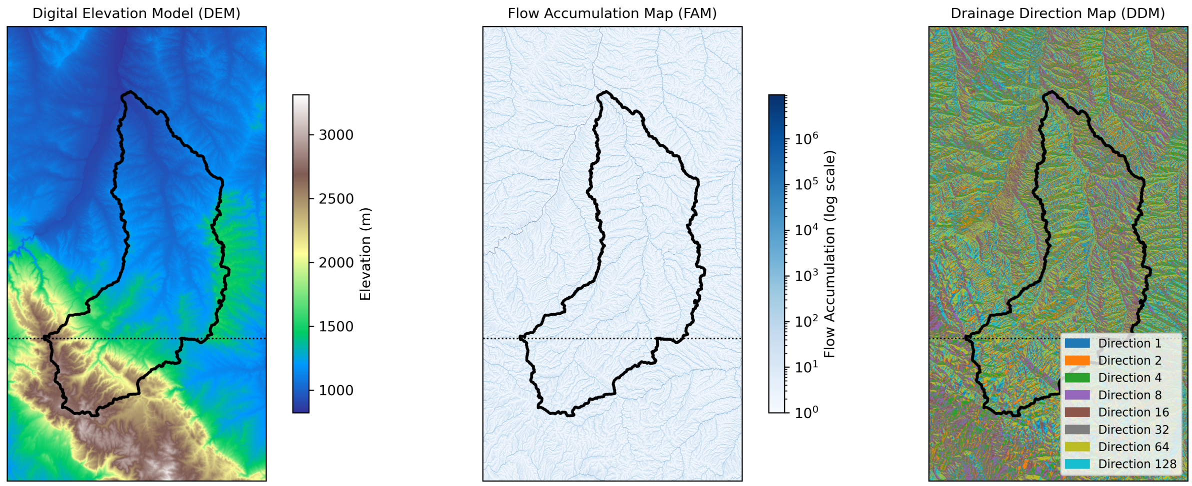


Basin Name: Little Bighorn
Area: 3359.4 km²
Location: USGS gauge #06294000 at (45.735812, -107.557305)
Period of Simulation: 2020-01-01 to 2022-12-31

Brief Introduction

The Little Bighorn basin features diverse hydrologic behavior, influenced by high-elevation headwaters in the north flowing toward lower elevations in the south. The USGS gauge #06294000 is the principal observation station used in this analysis. The map above highlights the basin boundary (red outline) and key gauges.

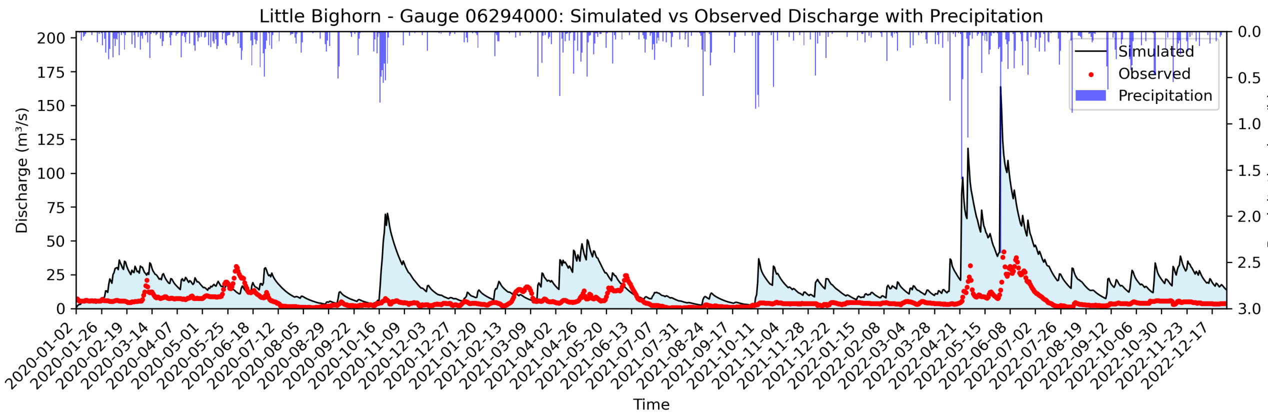
2. Fundamental Basin Data



- **DEM (Digital Elevation Model)**
  The color-ramped DEM indicates elevations ranging from roughly 1000 m near the outlet to over 3000 m in the mountainous headwaters. This topographic variability strongly affects runoff generation and timing.
- **Flow Accumulation (FAM)**
  The flow accumulation map reveals where runoff converges, delineating a well-developed drainage network. Major channels align with higher accumulation values, reflecting the mainstem and primary tributaries.
- **Drainage Direction Map (DDM)**
  Distinct color patterns show flow pathways from headwaters to the basin outlet. Steeper upstream terrains have denser channel formations, while flatter downstream areas have broader flow patterns.

3. Analysis Sections

3.1 Simulation vs Observation



- **Simulated Discharge (black line + shaded area)**
  The model reproduces the general seasonal flow pattern — higher flows in spring from snowmelt and moderate rises following precipitation events.
- **Observed Discharge (red dots)**
  Observational data track a similar pattern but reveal mismatches in peak flow magnitude and timing. Overestimation of some high flows and slight underestimation of low flows are evident.
- **Precipitation (blue bars)**
  Precipitation events typically align with short-term discharge increases. In some instances, timing differences between precipitation inputs and peak flows indicate potential lags or deficiencies in the model's quick-response components.

3.2 Model Performance Metrics

Metric	Value
NSCE	-12.956
KGE	-2.279
Correlation Coefficient	0.583
Bias (m^3/s)	14.24 (237.6%)
RMSE (m^3/s)	21.12

Interpretation
- **Nash-Sutcliffe Coefficient (NSCE)** is negative, indicating that the mean observed flow would have been a better predictor than the model in terms of variance explanation.

- **Kling-Gupta Efficiency (KGE)** is also negative, reinforcing the notion that the simulation falls short of capturing observed flow dynamics.
- **Bias** is strongly positive, signifying a notable overprediction of flow.
- **RMSE** of 21.12 m^3/s quantifies the magnitude of overall errors, which is substantial relative to typical flows in this basin.

3.3 CREST Parameters

Below are the key model parameters used in this CREST (Coupled Routing and Excess Storage) simulation.

Water Balance Parameters

Parameter	Value	Description
Water capacity ratio (WM)	180.0	Maximum soil water capacity (mm)
Infiltration exponent (B)	8.0	Governs runoff/infiltration partitioning
Impervious area ratio (IM)	0.05	Urbanized fraction generating direct runoff
PET adjustment factor (KE)	0.7	Scales reference evapotranspiration
Soil saturated K (FC)	40.0	Saturated hydraulic conductivity (mm/hr)
Initial soil water (IWU)	25.0	Initial soil moisture content (mm)

Kinematic Wave (Routing) Parameters

Parameter	Value	Description
Drainage threshold (TH)	100.0	Flow accumulation threshold (km^2) for channel definition
Interflow speed multiplier (UNDER)	1.0	Adjusts subsurface flow velocity
Interflow reservoir leakage (LEAKI)	0.05	Rate of reservoir drainage to channels
Initial interflow reservoir (ISU)	0.0	Initial water in interflow storage

Parameter	Value	Description
Channel flow multiplier (ALPHA)	1.5	Kinematic wave coefficient; higher = slower wave
Channel flow exponent (BETA)	0.6	Flow area exponent; controls velocity variation
Overland flow multiplier (ALPHA0)	1.0	Overland flow equivalent of ALPHA

4. Data Tables

4.1 Run Arguments (Basin Details)

Argument	Value
Basin Name	Little Bighorn
Basin Area (km^2)	3359.4
Gauge	#06294000
Latitude	45.735812
Longitude	-107.557305
Simulation Period	2020-01-01 to 2022-12-31

4.2 Performance Metrics (Reiterated)

Metric	Value
Nash-Sutcliffe (NSCE)	-12.956
Kling-Gupta (KGE)	-2.279
Correlation	0.583
Bias (m^3/s)	14.24 (237.6%)
RMSE (m^3/s)	21.12

4.3 CREST Parameters (Reiterated)

Parameter	Value
WM (Water Capacity Ratio)	180.0
B (Infiltration Exponent)	8.0
IM (Impervious Area Ratio)	0.05
KE (PET Adjustment)	0.7
FC (Saturated Conductivity)	40.0
IWU (Initial Soil Water)	25.0

Parameter	Value
TH (Drainage Threshold)	100.0
UNDER (Interflow Speed)	1.0
LEAKI (Interflow Leakage)	0.05
ISU (Initial Interflow)	0.0
ALPHA (Channel Flow)	1.5
BETA (Channel Exponent)	0.6
ALPHA0 (Overland Flow)	1.0

5. Conclusion and Discussion

Despite capturing the seasonal discharge envelope reasonably, high biases and negative efficiency metrics indicate that model calibration and parameter refinement are necessary. The following points stand out:

1. **Model Performance Evaluation**
    - NSCE and KGE values are both negative, suggesting that the current parameterization has limited predictive skill relative to observation averages. More robust parameter calibration or refined input data may be needed.
2. **Warmup Period Considerations**
    - Although the computed bias is not less than -90%, it is significantly positive, indicating potential storage misalignment or data/parameter inconsistencies. A longer calibration or warmup period might be explored to stabilize soil moisture and initial states.
3. **Recommendations for Simulation Period & Next Steps**
    - Revisit precipitation inputs (magnitude and distribution).

    - Adjust water balance parameters (e.g., infiltration exponent, impervious area, and PET factor) to reduce the large overall bias.

    - Explore additional model calibration focusing on snowmelt dynamics in high-elevation areas.

    - Validate the model in alternative flow regimes or sub-basins to pinpoint model structure issues.

Overall, while the baseline simulation reveals the basin's hydrologic response patterns, improvements are required in process representation, calibration strategy, and input data accuracy to achieve better alignment with observed flows.