JULESBURG (JUMBO) RESERVOIR

Jumbo Reservoir State Wildlife Area
Logan and Sedgwick Counties, Colorado

DAMIDs:
640212 – Julesburg #1
640213 – Julesburg #1a
640214 – Julesburg #2
640215 – Julesburg #3
640104 – Julesburg #4

JULESBURG RESERVOIR ENLARGEMENT
ALTERNATIVES ANALYSIS REPORT

Prepared for:

Julesburg Irrigation District
315 Cedar Street
Julesburg, CO 80737

Prepared by:

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources and Geotechnical Engineers
3700 S. Inca Street, Englewood, CO 80110
303-761-4130 • www.wheeler.com

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EXECUTIVE SUMMARY

This Alternatives Analysis Report for the enlargement of Julesburg Reservoir was prepared by W.W. Wheeler & Associates, Inc. (Wheeler) for the Julesburg Irrigation District. This Alternatives Analysis project was completed to develop feasibility level alternatives that address existing dam safety concerns and provide enlargement options for Julesburg Reservoir to recover its lost storage due to sedimentation. Detailed descriptions of each alternative are presented in section 5.3 and summarized below:

Alternative A – Alternative A focuses on rehabilitating the existing embankments while maintaining a similar reservoir configuration. This alternative raises each dam crest by five to six feet to meet the targeted reservoir capacity of 28,178 acre-feet. The existing spillway would be raised by approximately 3.5 feet. Toe drains would be installed along each downstream embankment to mitigate seepage. Constructing this alternative would require draining the reservoir pool and purchasing land or easements for the new inundated area. This alternative also includes rerouting the inlet canal which is a large cut and could be used for on-site embankment materials.

Alternative B – Alternative B involves a combination of rehabilitating and reconstructing the existing dams. This alternative proposes the reconstruction of Dams 1a, 2, and 3 into a single new dam located downstream, referred to as Julesburg Dam A. For Dam 1, the embankment crest would be slightly raised (0.8 foot), and a toe drain would be installed to mitigate seepage. For Dam 4, a toe drain would be installed along the northern embankment, and two spillways would be cut into the embankment and armored. The new alignment for Julesburg Dam A was located to obtain the targeted storage capacity while maintaining a similar normal high-water level compared to the current operating level. Constructing this alternative would require partially draining the reservoir and land acquisition or easements for the new dam inundated area.

Alternative C – Alternative C proposes the reconstruction of Dams 1, 1a, 2, and 3 into two new dams located downstream, referred to Julesburg Dam Band Julesburg Dam C. This alternative would optimize the alignments of new dams to minimize modifications at Dam 4 while meeting the targeted reservoir capacity and maintaining the existing operating level. For Dam 4, a toe drain would be installed along the northern embankment, and the existing spillway would be slightly modified and armored. Modification to the inlet channel will address slope issues by moving the reservoir inlet closer to the new Julesburg Dam C. Constructing this alternative would require partially draining the reservoir and land acquisition or easements for the new impoundment area associated with the footprints.

Table E.1: Opinion of Alternatives Probable Project Cost

Item Description	Alternative A Enlarge All Dams	Alternative B Replace Dams 1a, 2, and 3	Alternative C Replace 1, 1a, 2, and 3
Direct Construction Costs	$25,781,000	$37,249,000	$40,921,000
Indirect Construction Costs	$9,818,000	$19,171,000	$20,757,000
Total Construction Costs	**$35,599,000**	**$56,420,000**	**$61,678,000**

Note: All costs in projected 2025 dollars

JULESBURG RESERVOIR ENLARGMENT
ALTERNATIVES ANALYSIS REPORT
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1.0 INTRODUCTION

1.1 Project Objective

This Alternatives Analysis project was completed to develop feasibility level alternatives that address existing dam safety concerns and loss of storage. The reservoir is currently restricted to a lower operating level due to seepage and slope stability issues. And over time the reservoir has lost approximately 8,000 acre-feet of storage due to sedimentation.

1.2 Scope of Work

The Scope of Work for this project included the following major tasks:

Task 1: Background Data Review and Preliminary Investigation
Task 2: Hydrology
Task 3: Geotechnical Evaluation
Task 4: Feasibility Designs
Task 5: Alternatives Analysis Report

1.3 Authorization

The work documented in this report was authorized by an Agreement between the Julesburg Irrigation District and W. W. Wheeler & Associates, Inc. (Wheeler) that was executed on April 26, 2024.

1.4 Project Location

Julesburg Reservoir is located approximately twenty miles southwest of the Town of Julesburg, Colorado on the border between Logan County and Sedgwick County. The reservoir is an off-channel storage facility formed from four dams, all of which are owned and operated by Julesburg Irrigation District. The reservoir is filled primarily by water diverted from the South Platte River through the Harmony Ditch. Water from the reservoir is used to provide irrigation water to approximately 19,000 acres. A project location map is presented on Figure 1.1.

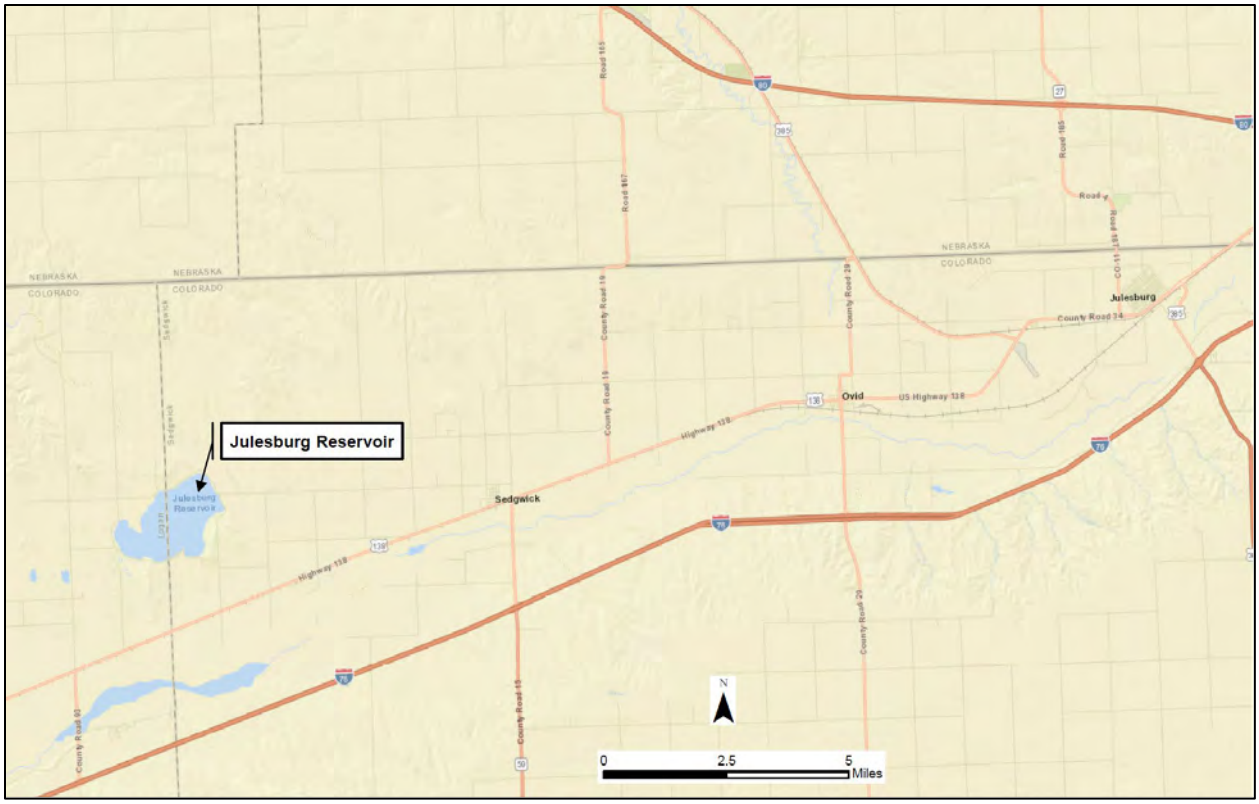

Figure 1.1: Project Location Map

1.5 Project Team

Key staff responsible for the preparation of this report included:

Larry Frame	Julesburg Irrigation District Manager
Todd Street, P.E.	Project Manager
Christine Mugele, P.E.	Water Resources Engineer
Jesse Reigle, P.E.	Geotechnical Engineer
Amin Ghorbanpour, P.E.	Geotechnical Engineer

2.0 BACKGROUND

2.1 Julesburg Reservoir

Julesburg Reservoir, also known as Jumbo Reservoir, as it is located within the Jumbo Reservoir State Wildlife Area, is formed by five separate embankments ranging from 23 to 66 feet in height. The dam outlet works and spillway are both located in Dam 4, the easternmost embankment section. The outlet works discharges directly into the Highline Canal and any spillway flow travels over the natural depression along County Road 28 and is captured in Cottonwood Creek.

Figure 2.1: Site Map

In the late 1970s, Julesburg Reservoir was placed on a restrictive water surface elevation order by the Colorado Division of Water Resources, due to observed seepage and slumps. Since that time, Julesburg Reservoir has been operated at a maximum gage height of 24 feet. In the early 2000s, the Julesburg Irrigation District Manager updated the reservoir capacity curve by manually measuring inflow and recording the associated gage height during a dry year. Through this process, it became apparent that the reservoir has partially filled with sediment over time. Originally, at gage height 24 feet, the reservoir capacity was 24,666 acre-feet of water storage; it has since been reduced to approximately 20,206 acre-feet. Per the Julesburg Reservoir water right Case No. CA0944, Julesburg Reservoir can store 28,178 acre-feet of water storage under a senior water right with an administrative priority number of 19765 and a 1908 Adjudication Date.

In addition to sedimentation, Julesburg Reservoir and associated dams have exhibited some dam safety concerns over time. The most concerning dam safety issue at Julesburg Reservoir appears to be the potential for seepage and piping, leading to a risk of dam failure. In 1910, Dam 2 failed, and the failure was attributed to piping of fines in the upper portion of the bedrock. It was hypothesized that piping allowed hydrostatic pressure to develop in the dam foundation, which became sufficient for uplift and subsequent failure. However, after further investigation into slope stability and seepage within this study, Wheeler hypothesized that a high phreatic surface along the toe of the dam lead to slope instability and failure. Currently, a self-imposed reservoir restriction is in place for Julesburg Reservoir due to these seepage and slope stability concerns.

Julesburg Reservoir is formed by five earthen embankment dams ranging from 23 feet to 66 feet in height and specific dam parameters summarized in Table 2.1. The dam crests also act as county roads or access roads. Dam 1, 1A, 2 and 3 dam crest access roads also serve as County Road 24.8. Dam 4 is crest access road is also County Road 3 and County Road 28. Dam 1 is located approximately 0.8 miles upstream of Little Jumbo Reservoir and Dam, which is owned and operated by Colorado Parks and Wildlife. Dam 4 embankment contains the updated 1996 outlet works conduit and tower and the broad crested overflow service spillway for Julesburg Reservoir.

Table 2.1: Dam Parameters

Dam No.	Dam Crest (NAVD 88)[1]	Dam Length (feet)[1]	Dam Crest Width (feet)[2]	Dam Height (feet)[1]	Upstream Slope (horizontal: vertical)[2]	Downstream Slope (horizontal: vertical)[2]
1	3715.2	2,722	20	23.4	2.8:1	1.7 to 2.6:1
1a	3715.9	743	20	18.2	1.5 to 1.7:1	1.5 to 2.5:1
2	3716.0	1,956	18	66	1.7:1	2.5:1
3	3716.0	1,917	20	40	3:1	1.5 to 2.5:1
4 (includes Dike / Dam 5)	3716.0	3,340	25 to 30	32.8	2.8:1	1.7 to 2.6:1

Notes: 1. Parameter was obtained from the existing 2-foot LiDAR data (Merrick & Co, 2019).
2. Parameter was obtained from the previous report (Wheeler, 1998).

2.2 Previous Studies

Several previous studies have been completed on Julesburg Reservoir including specific studies on each of the five dams. The studies of significance are summarized below.

2.2.1 *Fifteenth Biennial Report* (Colorado State Engineer, 1910)

On March 11, 1910, there was a sudden breach of Julesburg Reservoir Dam No. 2. On March 14, 1910, the Deputy State Engineer (Mr. J. W. Johnson) visited the site and completed a report regarding the breach. His report noted that the natural surface was underlaid with soft sandstone at 3 to 4 feet and the breach top width was approximately 400 feet wide with a bottom width of 300 feet wide and a breach height of approximately 20 feet. Per this report, the stratification under the failed dam was exceedingly porous and dangerous for the purposes of holding water. As water was stored in the reservoir, it eventually found a seepage path through the upper surface of the

underlying rock above the dam. The report concluded that gradually, the upward pressure exceeded the weight of the dam and underlying rock and was lifted from its bed and carried downstream at the toe of the dam. Under the major part of the dam, the super-incumbent load was enough to overcome the uplift pressure until the toe of the dam lifted, at which point the dam collapsed. It should be noted that during the current study, Wheeler could not replicate similar conditions through seepage and stability modeling.

The State Engineer recommended several test pits to be completed prior to reconstruction. A tight continuous curtain wall was also recommended to a depth that exceeded all loose insecure strata and penetrated well into the solid bedrock.

2.2.2 *Design Engineering Report Julesburg Reservoir Dam No. 3* (Wheeler, 1986)

This report noted that the stability of Julesburg Reservoir Dam No. 3 was unknown and there have been concerns regarding the presence of wet areas on the downstream slopes of Dams No. 2 and 3. A geotechnical investigation was completed as summarized above. This report proposed the construction of a sand filter on the downstream slope, covered by an earth berm, to protect the filter and to provide additional weight on the toe. It was recommended that the filter be connected to a trench drain designed to relieve pore pressure within the foundation. The filter was constructed to Elevation 3693 and designed to be extended to elevation 3710 in future years as funds become available.

2.2.3 *Geotechnical Investigation Rehabilitation of Julesburg Reservoir Dam No. 3* (Chen & Assoc., 1986)

A geotechnical investigation was completed in 1986 for Julesburg Reservoir Dam No. 3. The primary embankment fill was found to contain two to five feet of clayey sand overlaying 25 to 41 feet of sandy silt, and sandy clay, with lenses of slightly organic material. Bedrock was found between 27 and 45 feet below the existing dam crest and consisted of siltstone. Water was encountered at depths of 24.5 and 38.5 feet below the dam crest. During this measurement, the reservoir water surface elevation was 12 feet below the crest. A slope stability analysis was performed with the reservoir water surface elevation at varied elevations. The analyses indicated that a reservoir water surface at Elevation 3705 would have adequate factors of safety for static and pseudo-static cases; however, water surface elevations greater than 3705 would result in inadequate factors of safety. The factors of safety could be increased by placing a berm at the downstream toe of the embankment.

2.2.4 *Design Engineering Report Julesburg Reservoir Dam No. 2 Toe Drains and Embankment Stabilization* (Wheeler, 1988a)

Concerns were raised regarding seepage at the downstream toe of Dam No. 2 and the overall stability of the dam was determined to be marginal. Slope stability analyses show that, at a reservoir level of Elevation 3707.2[1], which is equal to gage height 25.5, the safety factors fall below recommended minimums unless a berm is constructed at the downstream toe. The 1998 report recommended to install a small sand filter blanket extending to Elevation 3676, with a toe

[1] All elevations in this report are reported in feet above the North American Vertical Datum of 1988 (NAVD88).

drain. Additionally, to prevent potential piping of fine-grained soils, a sand filter on the downstream slope was recommended to be constructed, covered by an earth berm, and connected to a trench drain for pore pressure relief. Engineering calculations confirmed that the proposed berms and filters can be built with locally available materials.

2.2.5 *Outlet Works Engineer Report* (Wheeler, 1992) and *Completion Report* (Wheeler, 1996)

The outlet works design and construction consisted of new outlet works structures and dam embankment constructed downstream of the existing dam to ensure the dam could fill during construction. The outlet works consisted of a cased-in-place, double box, and reinforced concrete conduit. Two large reservoir sluice gates are located at the inlet to the box conduits. The intake tower is equipped with movable fish screens and blind plates to contain game fish within the reservoir. The rehabilitated Dam 4 embankment is approximately 700 feet long with a maximum height of 33 feet. The embankment was designed with an eight-foot-wide cutoff trench constructed four feet into bedrock. The seepage control system, consisting of a drainage blanket, slotted drainage pipe, and outlet conduit filter diaphragm, was also constructed.

2.2.6 *Feasibility Study, Enlargement of Julesburg Reservoir* (Wheeler, 1998a)

Wheeler completed a feasibility study in 1998 with alternatives and costs to enlarge Julesburg Reservoir. The report included options to bring the dam embankments up to current standards and would provide up to 21,900 acre-feet of total reservoir storage. Three alternatives were developed with six different design options. Costs were estimated to range from $387,000 for limited improvements to Dam 1 and no storage increase, to $23 million for completed reconstruction program and maximum storage increase of 21,900 acre-feet.

The 1998 feasibility study was used as a starting point for this updated alternative analysis for the enlargement of Julesburg Reservoir.

2.2.7 *Comprehensive Dam Safety Evaluation Report, Dam 4* (DWR, 2024a)

A Comprehensive Dam Safety Evaluation (CDSE) of Julesburg Reservoir Dam No. 4 was completed by the Colorado Division of Water Resources (DWR) Dam Safety Branch on March 2024 to evaluate potential failure modes and risk to determine the safe storage level. The report concluded that the reconstructed outlet works, and channel was designed with a cutoff trench and blanket drain that performs as intended and is considered satisfactory. It was noted that the sand filter cutoff trench, which was installed with the 1992 construction, extended deep enough to provide a filtered exit for all seepage; therefore, at existing conditions, the southern portion of Dam 4 was considered conditionally satisfactory.

2.3 Previous Dam Modifications

Julesburg Reservoir was constructed between 1900 and 1905 for the purpose of providing irrigation water for local farmers. The reservoir was formed by the construction of five dams from local materials taken from the reservoir area. On March 11,1910, the Dam 2 embankment failed due to piping erosion at the toe of the embankment leading to slope failure. Since the failure, several modifications have been made to Julesburg Reservoir Dams 2, 3 and 4. The modifications are summarized below:

- Dam 2 was reconstructed in 1910, immediately after the failure. The rehabilitation of the embankment section included an additional 550 feet of curtain wall on the upstream toe of the embankment and 275 feet of core wall in the center of the embankment. The upstream embankment slope was 2H:1V (horizontal: vertical) and the downstream embankment slope was 3H:1V. A concrete facing and parapet wall were also constructed on the upstream face of the embankment at this time.
- In 1987, a downstream stabilizing berm and toe drain filter was constructed at Dam 3. The top stabilizing berm extended up to Elevation 3693 with the intention of future construction to bring the berm up to Elevation 3710. The future construction has not been completed at this time.
- As-built drawings were completed in 1988 (Wheeler, 1988a) showing the installation of a filter blanket, stabilizing berm, and toe drain completed at Dam 2.
- In 1996, design drawings were developed for the outlet work rehabilitation project completed at Dam 4 (Wheeler, 1996). The project consisted of new outlet works structure including outlet conduit, filter diaphragm, sluice gates, wall thimbles, and gate operations. The work also included 700 feet of reconstructed embankment with cutoff trench and a filter sand blanket with drain.

2.4 DWR Review/Site Visit

The most recent available DWR Dam Safety inspection of the Julesburg Reservoir Dams was completed on November 15, 2023 by the Dam Safety Engineer Kallie Baur (DWR, 2023a-c). Each of the dams was determined to be conditionally satisfactory at the restricted elevation level. Per the inspection reports, Dam 1 and 4 were identified as seeping excessively at full storage, and Dam 3 was observed to potentially have seepage through the foundation shale. It was recommended by the DWR to perform a comprehensive dam safety evaluation (CDSE) for all the dams and to maintain the reservoir restriction until further notice.

3.0 INFLOW HYDROLOGY ANALYSIS

The inflow hydrology was developed using guidelines and methods as recommended by DWR (DWR, 2020d; DWR, 2022). Completing the reasonableness checks and calibration portions of the guidance were excluded for this feasibility study. Those sections will be completed during the initial design phases. A hydrologic model was developed using HEC-HMS 4.12 software (USACE, 2024). Detailed descriptions of the development of key HEC-HMS model inputs are summarized in the following sections.

3.1 Basin and Reservoir Configuration

The 10.36 square mile drainage basin for Julesburg Reservoir was divided into four sub-basins, as shown on Figure 3.1. Wheeler did not modify the drainage basins based on the different alternatives discussed. It was assumed that the minor changes in the surface area related to the different alternatives would be negligible. Finalized drainage basins should be completed during the initial design phase of the preferred alternative. Sub-basin A represents inflow into the reservoir from the two local unnamed drainage ditches. Sub-basin B represents local runoff into Harmony Ditch No. 1 that could potentially drain into the reservoir. Sub-basin C represents a small area south of the reservoir between Dams 3 and 4 that topographically drains into the reservoir. Sub-basin D is the Julesburg Reservoir. For Sub-basin D, any precipitation that falls directly onto the reservoir is included as direct runoff.

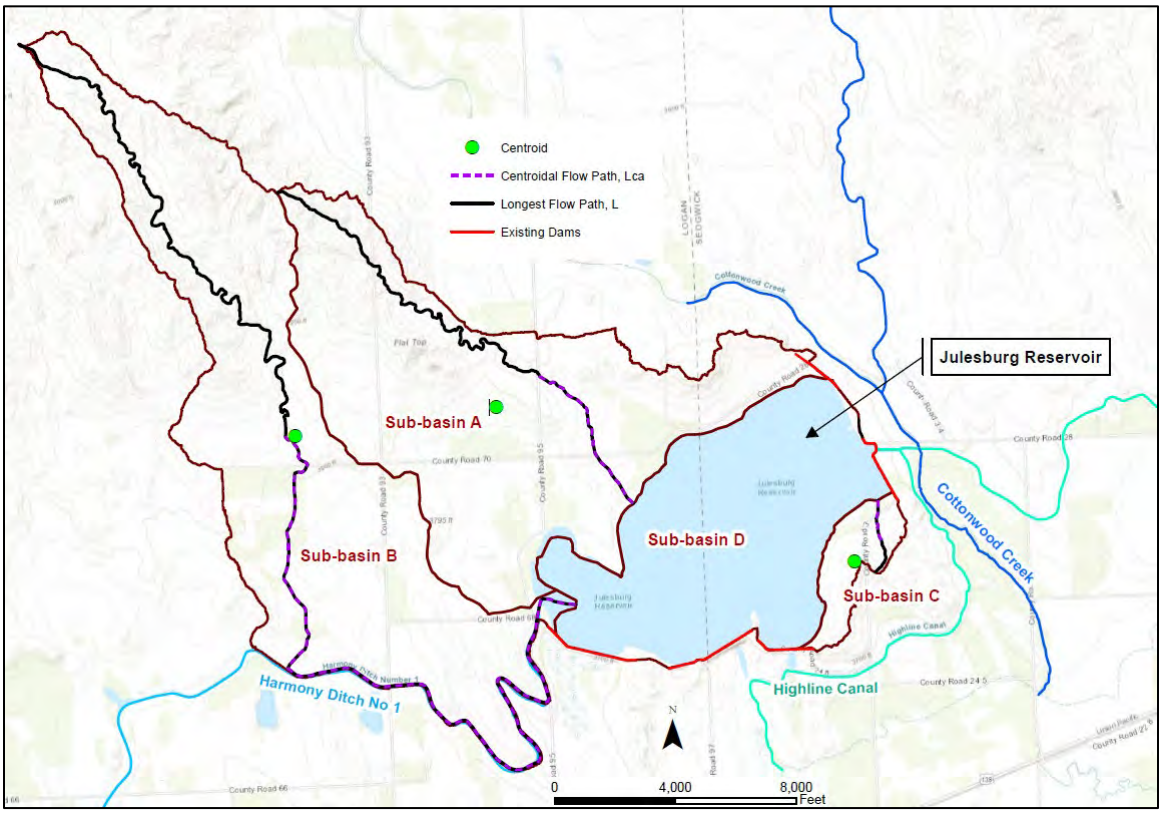

Figure 3.1: Julesburg Reservoir Sub-Basins

The Julesburg Reservoir drainage basin generally slopes northwest to southeast with predominately sandy loam soils. The vegetative cover consists primarily of farmland and shrubs. Table 3.1 provides a summary of key geometric characteristics of the modeled basin.

Table 3.1: Basin Geometric Characteristics

Sub-Basin	Area, A (square miles)	Drainage Length, L (mile)	Centroid Length, L_{ca} (mile)	Elevation Change, ΔZ (feet)	Watercourse Slope, S (feet / mile)
A	3.68	3.8	1.1	319	84
B	4.15	9.7	5.5	432	44
C	0.27	0.5	0.3	85	170
D - Reservoir	2.26	NA	NA	NA	NA

3.2 Precipitation

For this study, precipitation estimates of the "critical" storm were developed using the Regional Extreme Precipitation Study (REPS) tools (DWR, 2024c) for various precipitation Frequency Storms (FS) and Probable Maximum Precipitation (PMP) conditions. The web-based PMP and MetPortal tool were used to develop precipitation depths and temporal patterns for PMP and FS storms.

For Frequency Storms, the Annual Recurrence Intervals (ARIs) from 10 years to 10,000,000 years were estimated for the following storms:

- Local Storm (LS): 2-hour duration rainfall with a "Synthetic East" temporal distribution,
- Mesoscale with Embedded Convection (MEC): 6-hour duration rainfall with a "Front-Loaded Synthetic East" temporal distribution, and
- Mid-Latitude Cyclone / Tropical Storm Remnant (MLC / TSR): 48-hour duration rainfall with a "Center-Loaded Synthetic East" temporal distribution.

When a storm of a given frequency is used for assessing downstream flooding (e.g., 1,000-year event), the *REPS Guidelines* (DWR, 2024c) specifies that all three candidate Frequency Storm types be used with the basin hydrologic model to determine the critical storm for that frequency.

The best-estimate unscaled and scaled Frequency Storm (FS) totals for the potential storms are summarized in Table 3.2 over the range of Average Recurrence Intervals (ARI) assessed. Following Rule 7.2.4 (DWR, 2024), the unscaled precipitation depths for the Frequency Storms and Local and General PMP storms are multiplied by an atmospheric moisture factor (AMF) of 1.07 to determine the scaled Inflow Design Flood (IDF) for evaluating spillways. The precipitation depth values for the 2-hour and 48-hour storms given in the table are the cumulative values at exactly 2 and 48 hours. The temporal data obtained for HEC-HMS model entry extended beyond 2 and 48 hours, which resulted in the slightly higher total precipitation depths reflected in the HEC-HMS rainfall-runoff modeling.

Table 3.2: Precipitation Frequency Values for Analyzed Storms

ARI (years)	LS 2-hour Synthetic East Storm (inches)		MEC 6-hour Front-Loaded Synthetic East Storm (inches)		MLC / TSR 48-hour Center-Loaded Synthetic East Storm (inches)	
	Unscaled	Scaled	Unscaled	Scaled	Unscaled	Scaled
10	1.97	2.11	2.20	2.36	3.33	3.56
100	3.22	3.45	3.52	3.76	5.08	5.44
1,000	4.61	4.94	5.04	5.39	6.92	7.41
10,000	6.18	6.61	6.83	7.31	8.87	9.49
100,000	7.93	8.49	8.93	9.56	10.95	11.72
1,000,000	9.91	10.60	11.40	12.20	13.16	14.08
10,000,000	12.13	12.98	14.31	15.31	15.50	16.59

The unscaled and scaled Local and General storm PMP estimates and temporal distributions that were generated by the REPS tool are summarized in Table 3.3. The process resulted in the following three candidate site-specific PMP storms:

- General Storm PMP, 72-hour duration, with a “Synthetic East” temporal distribution and 15-minute timesteps.
- Local Storm PMP, 2-hour duration, with a “Stacked” temporal distribution and 5-minute timesteps.
- Local Storm PMP, 6-hour duration, with a “Synthetic East” temporal distribution and 5-minute timesteps.
- Local Storm PMP, 24-hour duration, with a “Synthetic Hybrid” temporal distribution and 5-minute timesteps.

Table 3.3: Unscaled Precipitation Frequency Values for PMP Candidate Storms

PMP Candidate Storms	Cumulative Storm Precipitation (inches)	
	Unscaled	Scaled
General Storm PMP, 72-hour duration	18.6	19.9
Local Storm PMP, 2-hour duration	14.9	15.9
Local Storm PMP, 6-hour duration	18.6	19.9
Local Storm PMP, 24-hour duration	20.1	21.5

3.3 Rainfall to Runoff Transformation Method

The combined basin loss and runoff response was developed following the Colorado State University Soil Moisture Accounting method (CSU-SMA) (DWR, 2022). To estimate the various soil loss parameters necessary to employ the SMA loss estimation approach in HEC-HMS, a GIS tool has been developed by DWR using the python scripting language of ArcGIS. This CSU-SMA python script requires several raster GIS aerial coverages of soils and surface data for the basin as listed below:

- Aerial coverage of % sand,
- Aerial coverage of % clay,
- Aerial coverage of % organic matter,
- Aerial coverage of depth to restrictive layer (measured in inches), and
- Aerial coverage of fractional vegetative cover.

The first four raster datasets (% sand, % clay, % organic matter, and depth to restrictive layer) have been obtained from the NRCS Gridded National Soil Survey Geographic Database (gNATSGO) by DWR, and subsequently tiled and clipped to cover the State of Colorado. DWR has provided online access to these raster datasets. The raster dataset of fractional vegetative cover is computed from USGS Landsat 5 B3 (red) and B4 (infrared) aerial images using methods detailed in the guidelines. The B3 and B4 Landsat images are also available online from the USGS (USGS, 2011).

The various raster datasets and basin delineation shapefile were compiled and used with the CSU-SMA python script to compute basin averages of the following soil parameters that are used with the SMA loss method in HEC-HMS:

- Maximum infiltration rate (inches / hour),
- Soil percolation rate (inches / hour),
- Soil storage (inches),
- Groundwater (GW) layer 1 storage (inches),
- Soil tension storage (inches), and
- Initial soil moisture content (%).

The SMA loss properties used in the hydrology model are summarized in Table 3.4. The soil properties in the Julesburg Reservoir basin are similar between the different basins. The largest difference between the basins is related to the infiltration and soil storage parameter. Sub-basin B has a slightly higher soil storage capacity, which means more water can be stored in the soil before direct runoff occurs. Sub-basin C has a slightly slower infiltration rate that would result in faster direct runoff. These differences are directly related to the time of concentration for each basin which is dependent on the shape, size and elevation changes in the basin. Sub-basin C is smaller with less elevation change, and Sub-basin B is larger with a longer flow path to reach the reservoir.

Table 3.4: Basin Properties

Property	Sub-basin A	Sub-basin B	Sub-basin C
% Soil	44.500	39.076	48.080
% Groundwater	0	0	0
Max Infiltration (inches/hour)	1.263	1.432	0.915
% Impervious	5	5	5
Soil Storage (inches)	18.677	20.529	18.518
Tension Storage (inches)	8.817	8.443	9.685
Soil Percolation (inches/hour)	0.181	0.485	0.111
Groundwater storage (inches)	2.075	2.281	2.058
Groundwater Percolation (inches/hour)	0.1	0.1	0.1
Groundwater Coefficient (1) (hours)	2.074	4.510	0.598

Note: (1) DWR guidance recommends that the groundwater coefficient is three times the storage coefficient, R, calculated below.

3.3.1 Clark Unit Hydrograph

The CSU-SMA method uses the Clark Unit Hydrograph in HEC-HMS for the rainfall-runoff transformation. Basin infiltration considers CSU-SMA losses such as the initial soil storage potential, ground water percolation, and subsurface stormflow as part of the direct losses. Once direct losses have been accounted for and rainfall excess is determined, the runoff response from rainfall excess may be estimated with a unit hydrograph, which is defined as the time distribution of one inch of direct runoff from a storm of a specified duration for a basin. The Clark dimensionless unit hydrograph technique is recommended by the State of Colorado as the preferred technique for performing rainfall to runoff transformation in natural basins.

The time of concentration (T_C) for the basin was computed from geometric measurements (area, drainage length, drainage length to centroid, and slope) and the storage coefficient as summarized in Table 3.5. For application to the CSU-SMA approach, DWR guidelines recommend that the ratio of the storage coefficient to the sum of the storage coefficient and the time of concentration ($K = R / (R + T_C)$) should lie in the range 0.2 to 0.3. The resultant ratio is then used as a tool to calibrate the model. The use of the lower end of the range of acceptable values (Ratio of 0.2) results in a smaller delay and higher peak runoff response, whereas the higher end of the range (Ratio of 0.3) produces a lower peak runoff response. Due to the sandy soils in this basin, Wheeler selected a ratio of 0.3 as an initial storage coefficient for each basin.

Table 3.5: Basin Clark Unit Hydrograph Parameters

Sub-basin	Time of Concentration (T_c) (hours)	Clark Storage Coefficient (R) (hours)	Ratio, $R / (T_c + R)$
A	1.61	0.69	0.3
B	3.51	1.51	0.3
C	0.47	0.20	0.3

The combined basin loss and runoff response was developed according to the Colorado State University Soil Moisture Accounting method (CSU-SMA) (DWR, 2022).

3.4 Baseflow

Baseflow values for Julesburg Reservoir were not applied since the reservoir is located off-channel on small, unnamed ditches. Wheeler also assumed the inlet ditch was empty except for the portion of the basin that flows into the ditch and drains into the reservoir (Sub-basin B). The inlet ditch typically flows from winter to early fall before these early spring and summer storms are expected.

3.5 Existing Spillway Rating Curve

An existing spillway rating curve was used as part of the reservoir routing of Julesburg Reservoir. Wheeler developed a two-dimensional hydraulic model of the existing broad crested weir service spillway flow that overtops the spillway crest located along County Road 28. Detailed hydraulic model development, assumptions and results are provided in Appendix B.

3.6 Existing Reservoir Capacity

An existing reservoir capacity curve was calculated for Julesburg Reservoir based on a combination of the 2019 two-foot LiDAR data collected for the Colorado Water Conservation Board (CWCB) by (Merrick, 2019) and the field measurements and recordings taken by the Julesburg Irrigation District Manager. Field measurements were taken during an extremely dry year by measuring inflow and recording the reservoir water surface elevation. This data was then used to develop an existing reservoir storage capacity that extended up to the operational high water line. The field measurements, where applicable, generally compared to the updated LiDAR capacity curve. Wheeler used the two-foot LiDAR data to develop a capacity curve above the reservoir level during the time when the LiDAR was flown. With develop a terrain surface in HEC-RAS 6.5 where volume was calculated using the 2D storage area feature. The LiDAR capacity curve does not include storage volume below Elevation 3704 (the reservoir level at the time when the LiDAR was flown). Therefore, for the existing reservoir capacity curve, Wheeler used the field measurement curve for elevations below 3704 and the 2019 LiDAR data for elevations above 3704. Details of the reservoir capacity curve derivation are provided in Appendix B.

3.7 Hydrologic Model Entry and SMA Parameter Summary

Tables 3.6 and 3.7 summarize the final CSU-SMA method parameters, sources, and values, and are organized by HEC-HMS component.

Table 3.6: CSU-SMA Method HEC-HMS Meteorological Model

HMS Method	Parameter (Units)	Hydrology Source	Recommended Parameter Value
Precipitation Specified Hyetograph	"Precipitation Gages" (incremental inch)	REPS PMP and MetPortal Frequency Storm	Temporal Data
Annual Evapotranspiration	Rate (inches/day)	Guidance (1)	0.098 inches/day

Note: (1) Recommended value taken from the *Guidelines for Hydrological Modeling and Flood Analysis* (DWR, 2022).

Table 3.7: CSU-SMA Method HEC-HMS Basin Model

HMS Method	Parameter (Units)	Hydrology Source	Recommended Parameter Value		
			Sub-basin A	Sub-basin B	Sub-basin C
Simple Canopy	Initial Storage (%)	Guidance (1)	0	0	0
	Max Storage (inches)	Guidance (1)	0.169	0.169	0.169
	Uptake Method	Guidance (1)	"Simple"	"Simple"	"Simple"
Soil Moisture Accounting (SMA) Loss	Soil (%)	"hms_initialsm_table"(2)	44.500	39.076	48.080
	Groundwater 1 (%)	Guidance (1)	0	0	0
	Groundwater 2 (%)	Guidance (1)	0	0	0
	Max Infiltration (inches/hour)	"hms_maxinfil_table" (2)	1.263	1.432	0.915
	Impervious (%)	Guidance (1)	5	5	5
	Soil Storage (inches)	"hms_soilstorage_table"(2)	18.677	20.529	18.518
	Tension Storage (inches)	"hms_tensionstore_table"(2)	8.817	8.443	9.685
	Soil Percolation (inches/hour)	"hms_soilperc_table"(2)	0.181	0.485	0.111
	GW1 Storage (inches)	"hms_gw1storage_table"(2)	2.075	2.281	2.058
	GW1 Percolation (inches/hour)	Guidance (1)	*0.1*	*0.1*	*0.1*
	GW1 Coefficient (hour)	Guidance (1),GW1 = 3 * R	2.074	4.510	0.598
	GW2 Storage (inches)	Guidance (1)	0	0	0
	GW2 Percolation (inches/hour)	Guidance (1)	0	0	0
	GW2 Coefficient (hours)	Guidance (1)	0	0	0
Clark Unit Hydrograph Transform	Method	Guidance (1)	Standard	Standard	Standard
	Time of Concentration, Tc (hours)	Guidance (1)	1.613	3.508	0.465
	Storage Coefficient, R (hours)	Guidance (1), R/(Tc+R) Ratio of 0.8	0.69	1.51	0.20
	Time-Area Method	Guidance (1)	Default	Default	Default
Linear Reservoir Baseflow	Layers	Guidance (1)	1	1	1
	Initial Type	Guidance (1)	Discharge	Discharge	Discharge
	GW1 Initial (cfs)	Guidance (1)	0	0	0
	GW1 Fraction	Guidance (1)	Blank	Blank	Blank
	GW Coefficient	Guidance (1), GW1 = 3 * R	2.074	4.510	0.598
	GW1 Reservoirs	Guidance (1)	1	1	1

Notes: (1) Recommended value from the Mountain Hydrology Guidance (DWR, 2022).
(2) Unique basin value calculated using the CSU-SMA method. The calculated "mean field" was used.

3.8 Hydrologic Model Results

The results listed in Tables 3.8 were used to determine the controlling storm event using the unscaled precipitation estimates. Figure 3.2 shows the flood frequency curve developed for Julesburg Reservoir with unscaled results. Figure 3.3 shows a reservoir stage probability curve based on the existing dam features. Figures 3.4 through 3.6 show the reservoir stage probability curve for each alternative. The alternative descriptions and design evaluation is provided in Section 5.

The results are based on reservoir routing analyses with the initial reservoir elevation at the service spillway crest elevation. The outlet works were assumed to be closed for each alternative in accordance with DWR guidance. The existing conditions routing results for the controlling storm show that the dams with crest elevations less than 3715.9 will overtop. For the three alternative conditions reservoir routing, the spillway crest and length and dam crest elevation were designed to meet the dam safety freeboard requirements discussed further in Section 5. And as the alternatives move into design, the spillway length and elevation can be adjusted to fine tune the target storage volumes and minimize the dam improvements that would be required.

Table 3.8: Peak Inflow and Reservoir Water Surface Elevation for the PMP Event (based on scaled precipitation)

	Scaled PMP (1)				
Design Storm	**Peak Inflow All Scenarios (cubic feet per second)**	**WSE Existing**	**WSE Alternative A**	**WSE Alternative B**	**WSE Alternative C**
REPS General Storm 72-Hour	6,899	3714.9 feet	3716.8 feet	3712.5 feet	3713.2 feet
REPS Local Storm 2-Hour	28,942	3715.7 feet	3718.0 feet	3713.5 feet	3714.0 feet
REPS Local Storm 6-Hour	23,990	3715.9 feet	3718.2 feet	3713.8 feet	3714.4 feet
REPS Local Storm 24-Hour	17,592	3715.8 feet	3718.0 feet	3713.6 feet	3714.3 feet

Note: (1) The REPS 6-hour Local Storm is the controlling PMP, as determined by the maximum reservoir water surface elevation and highlighted gray in the table.

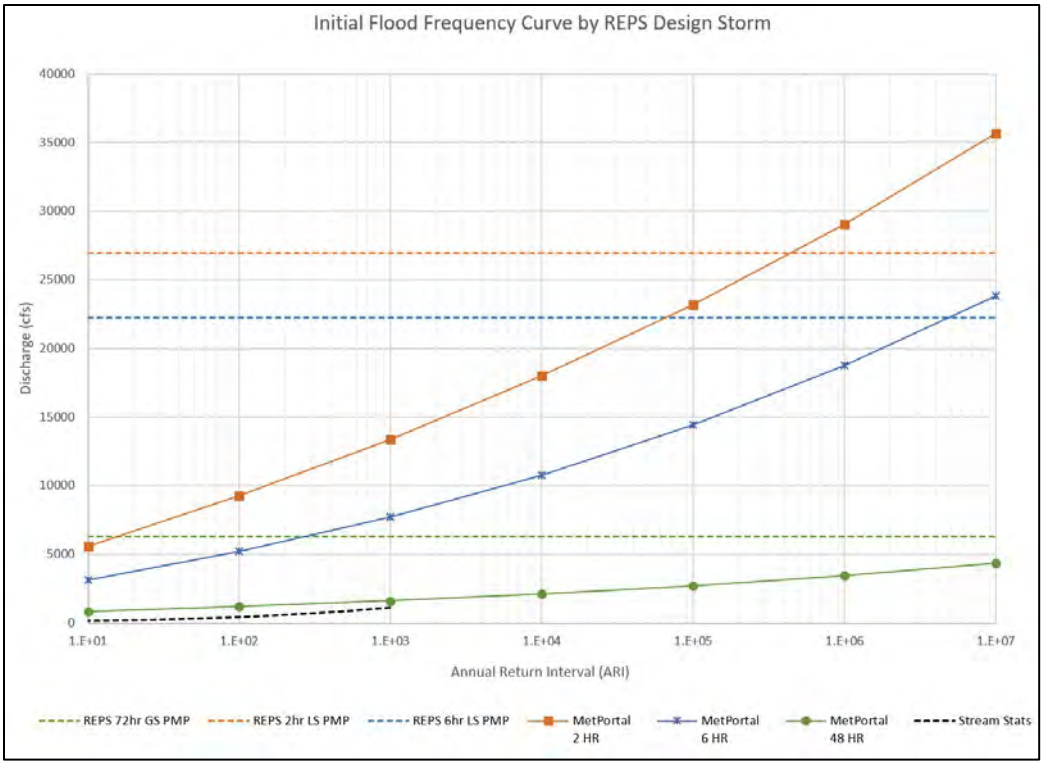

Figure 3.2: Flood Frequency Curve for Julesburg Reservoir (unscaled)

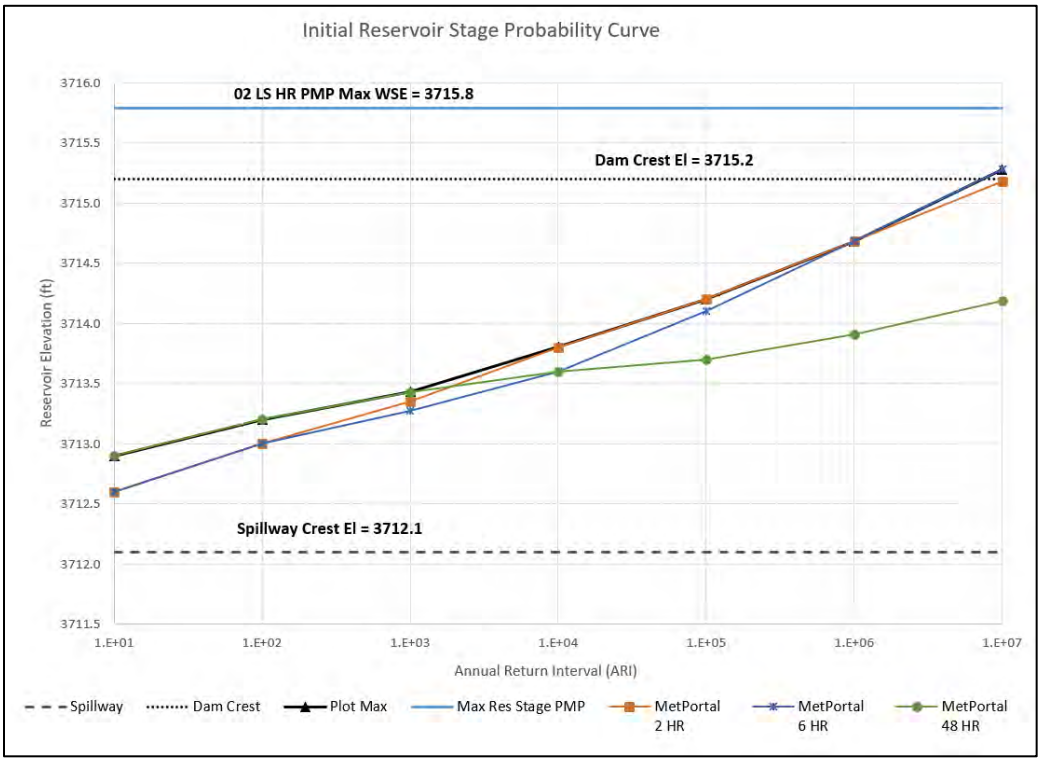

Figure 3.3: Julesburg Reservoir Existing Reservoir Stage Probability Curve (unscaled)

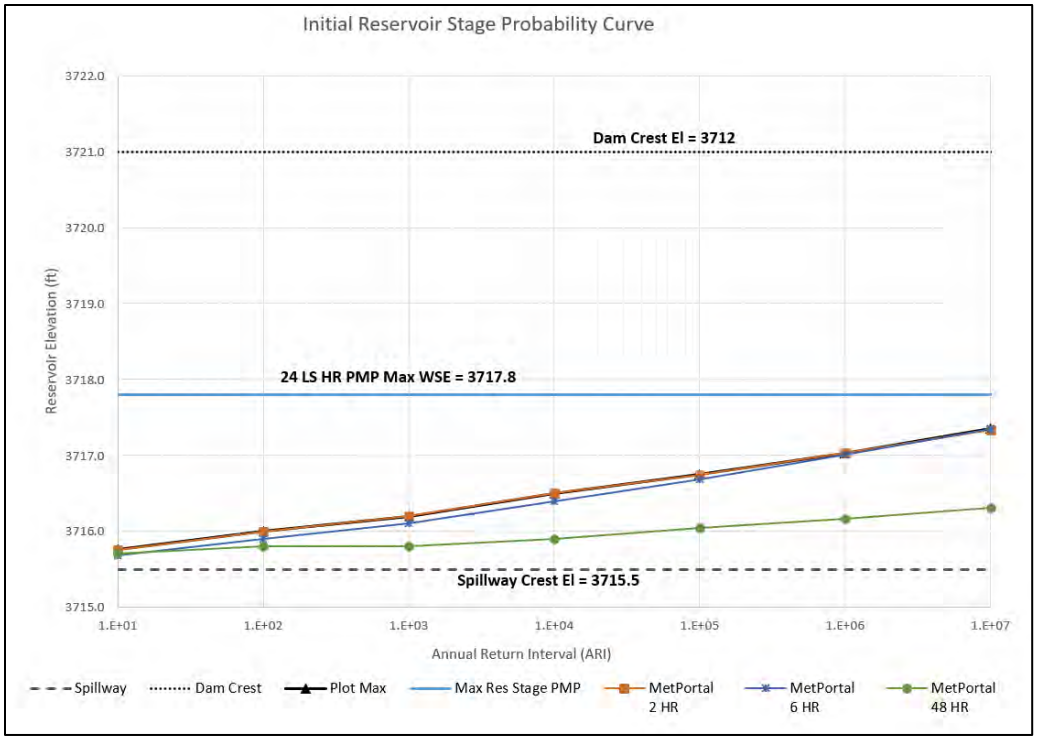

Figure 3.4: Julesburg Reservoir Alternative A Reservoir Stage Probability Curve (unscaled)

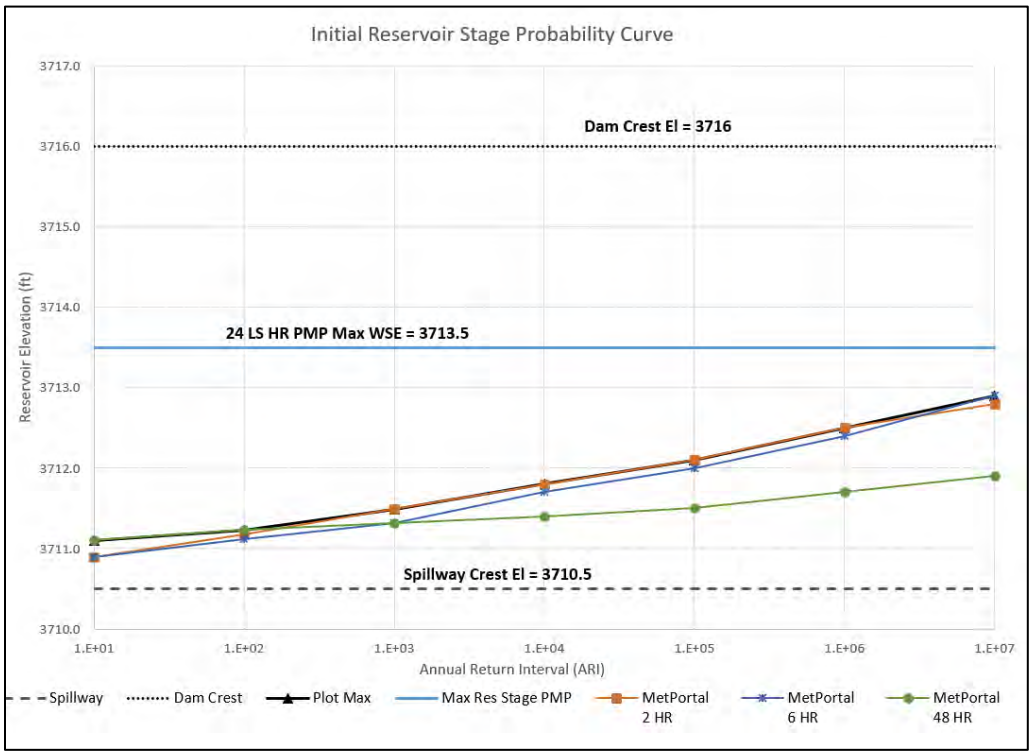

Figure 3.5: Julesburg Reservoir Alternative B Reservoir Stage Probability Curve (unscaled)

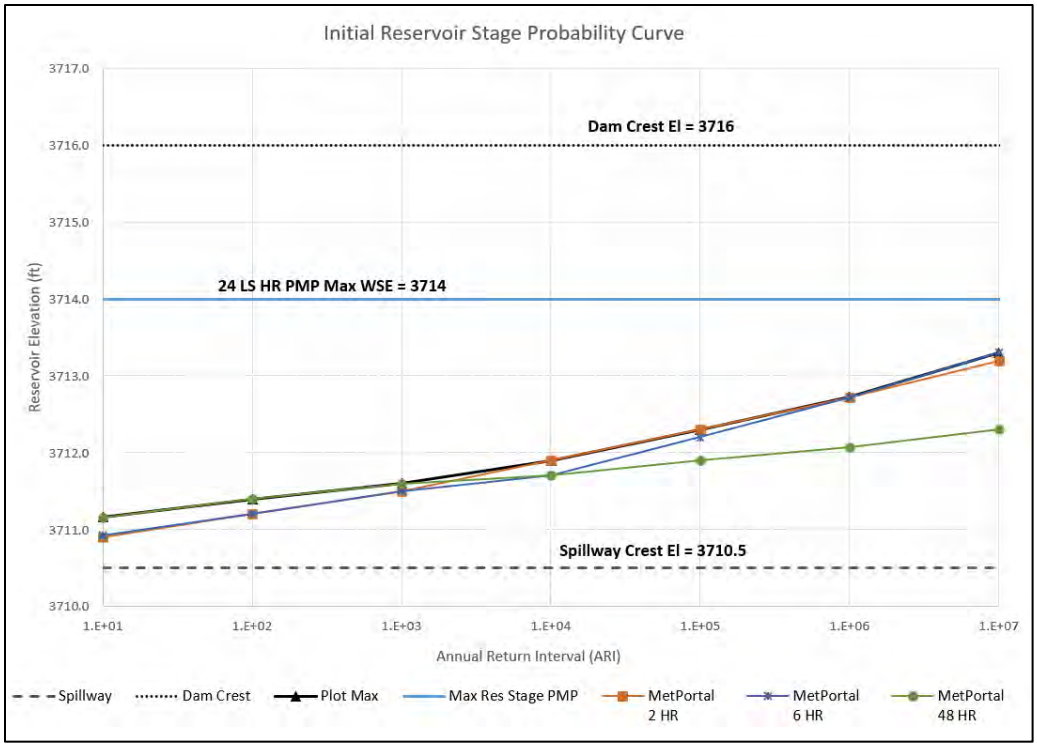

Figure 3.6: Julesburg Reservoir Alternative C Reservoir Stage Probability Curve (unscaled)

3.9 Reasonableness Checks

After the initial HEC-HMS model was constructed using the information developed in Sections 3.1 through 3.7, the guidance specifies performing a series of "reasonableness checks" on the hydrologic results to increase confidence in the model's capability to accurately reproduce observed local flood runoff behavior. Results of the "reasonableness checks" are used to establish a model "confidence level" that is used as part of the final calibration process. The specific checks given in the DWR guidance with the corresponding findings are summarized below.

1. Develop peak flow estimates (to check hydrologic model results against) at more frequent AEP's: the 100-, 200-, and 1,000-year ARI events, using alternate hydrologic methods: stream gage flood frequency analysis and regional regression flood frequency analysis.

   Following the guidance, peak flow estimates were obtained for the 100-year, 200-year, and 1,000-year ARIs using the regional regression flood frequency analysis from StreamStats (USGS, 2022). Additionally, Wheeler searched for nearby stream gages and found one on Goose Creek near Hoyt, CO. The gage flows would be further evaluated during the model calibration proposes in final design.

2. Review historical floods and determine the most likely storm type to control maximum runoff at the given location.

A search was completed to find any historical flood studies or paleoflood studies available in the vicinity of Julesburg Reservoir. No historical or paleoflood studies were found near the reservoir.

Based on initial hydrologic results for Julesburg Reservoir, the Probable Maximum Flood (PMF) controlling storm type is the Local 2-hour for peak inflow and the Local 48-hour storm for inflow volume. This matches the guidance based on the basin size from Table 11 (DWR, 2022).

3. Check on the seasonality of rainfall and see if the most assumed controlling storm type corresponds with local behavior.

   Using Figure 21 of (DWR, 2022), the Julesburg Reservoir basin is in the northeast storm seasonality zone in Colorado. The corresponding storm frequency histograms for this region show May and July as maximum seasonal rainfall months. This corresponds with historical water surface elevation fluctuations observed at the reservoir between May and July.

4. Plot estimated flood response at AEPs from more frequent storms, through extreme storms, all the way to controlling PMP on the appropriate peak flow envelope plot (DWR, 2022) to compare results with historical hydrologic data based on region and basin size.

   The PMF was plotted on the REPS Transposition Zones 1 and 3 for eastern plans and front range planes less than 7,500 feet in elevation. The figure shows that the PMF events are reasonable and within the 90-percent confidence bounds. This result also shows that the model-estimated peak flows for the frequent storms are larger than those calculated in StreamStats using regional equations.

   Figure 3.2 shows the initial flood frequency curve for the REPS design storm. The curves appear consistent with the expected behavior and indicate the short-duration (2-hour) storm governs at this site for inflow and the 48-hour governs for inflow volume.

   Figure 3.3 shows the reservoir stage probability curve based on the initial results. The figure shows the controlling storm as the 2-hour and 48-hour storm. The dam overtops between the 1,000,00-year ARI and 10,000,000-year ARI and the spillway is activated during any storm because the initial water surface elevation was set to the normal high water line at existing spillway crest Elevation 7312.1.

5. Check runoff coefficients for uncalibrated and unscaled model.

   Runoff coefficients were calculated for the largest drainage basin by taking the basin precipitation volume and dividing by the discharge volume for each storm event. Based on the results, the runoff coefficients averaged 75-percent for the more frequent storm events which is slightly higher than those calculated by CSU during the mountain hydrology research. The runoff coefficients averaged 95-percent for the less frequent storm events which are higher than those averaged in the guidance, but similar to examples seen by DWR.

6. Check the upper tail ratio and compare the result to the regional Upper Tail Ratio (UTR) data provided in the DWR guidance.

   The upper tail ratio for Julesburg Reservoir is 4.8, which is similar to the UTRs computed from the regional datasets for similar drainage basin sizes, which ranged between 5 and 6. However, the regional UTRs were all completed for drainage basins in the mountains and may not be applicable for this drainage basin.

Table 3-8: HEC-HMS Meteorological Model vs. Calibration Targets

Annual Return Interval (years)	Uncalibrated HEC-HMS Inflow (cfs)	Calibration Targets (cfs)		
		StreamStats	Regional Envelope Curve	90 Percent Confidence Bounds [1]
100	9,271	455	N/A	320, 645 [1]
1,000	13,376	1,136	N/A	840, 1,536 [1]
PMF	26,921	N/A	39,828	19,961, 79,467 [2]

(1) DWR, 2022, Section 9.3, calculate 90% confidence bounds based on StreamStats ASEp (equals 36 for 100-year and 31 for 1,000 year) and log10 cycle in Table 10 (using 36 equals 0.152 and 31 equals 0.131).
(2) DWR, 2022, calculate 90% confidence bounds based on 0.3log10 for probable maximum flood.

The 100-year and 1,000-year Annual Return Intervals and peak regional envelope value with the 90% uncertainty bounds were calculated as offsets from the guidance and summarized in Table 3-8. Review of the model results and reasonableness checks were performed to determine the model confidence which is used during the calibration process. The local Probable Maximum Flood (PMF) is aligned with the Colorado Dam Safety Envelope Curve without further calibration. However, the 100-year and 1,000-year peak discharges are significantly higher than the calculated regression values and are currently outside the 90-percent confidence bounds and will therefore require calibration.

3.10 Model Calibration and Confidence

The model confidence and calibration process were not completed as part of this alternatives analysis study. For final design, the model calibration may be used to adjust flows and optimize the preferred alternative. If the model were calibrated, the results would potentially show a decrease to the estimated inflow. Using uncalibrated results is therefore considered reasonably conservative. Results should be calibrated for the final design.

4.0 GEOTECHNICAL AND GEOLOGICAL ANALYSES

4.1 Geology

The Julesburg Reservoir is located at the boundary between the Colorado Piedmont and the High Plains physiographic province in Colorado. The area consists of gently rolling plains with extensive sedimentary deposits. Bedrock is generally not exposed in the project area, as it is overlain by surficial soils or man-placed fill. Lithological descriptions of subsurface units are based on regional geologic mapping and published data sources, specifically the Geologic Map of the Lower South Platte River Valley Between Hardin, Colorado and Paxton, Nebraska, Showing Topography of the Rocks Beneath the Quaternary Deposits (Brown, 1950).

4.1.1 Geologic Units

Near-surface bedrock and surficial deposits underlying the project area include the following:

- Twr – White River Group (Undifferentiated)

  This unit underlies the site and consists mainly of the Brule and Chadron Formations. The Brule Formation comprises silt, clay, and localized channel deposits. The Chadron Formation is primarily clay with some channel deposits.

- To – Ogallala Formation

  The Ogallala Formation underlies the area and consists of interbedded sand, gravel, silt, and clay, with local occurrences of hard calcareous sandstone and limestone.

- Qal – Quaternary Alluvium

  This unit comprises coarse gravel, sand, silt, and clay deposited along modern river channels and floodplains.

- Qds – Quaternary Dune Sand

  This unit consists of sand, silt, and clay deposited by wind, forming localized dune fields.

- Kp – Pierre Shale (Cretaceous Age)

  This unit comprises dark shale with sandstone lenses and underlies the Tertiary and Quaternary formations.

4.1.2 Seismicity and Faulting

The region surrounding the project area is generally considered to have low seismicity. The site is located in a region characterized by low to moderate earthquake hazard levels, as identified by the Colorado Geological Survey. The nearest mapped fault is the Golden Fault, approximately 200 miles to the southwest near Denver. Based on studies performed by the Colorado Geological Survey (Kirkham and Rodgers, 1981), the site is located within a low to moderate seismicity region. It is not near any active fault zones. The Seismotectonic Province in this region is estimated to generate maximum credible earthquakes (MCEs) ranging up to magnitude 6.6, as

evidenced by the largest known historical earthquake in Colorado, which occurred on November 8, 1882.

4.1.3 Site Conditions

The Julesburg Dam site is located within a rolling plains environment with a combination of surficial alluvial and aeolian deposits overlaying Tertiary and Cretaceous-age bedrock. The dam embankments and abutments are composed of compacted fill material, which was placed over natural deposits.

4.1.4 Borrow Source

The proposed borrow source for dam rehabilitation or construction is located within the White River Group (Twr), southwest of the Julesburg Reservoir. This unit consists primarily of the Brule and Chadron Formations, which contain fine-grained silts and clays. The Brule Formation is composed of silt with moderately plastic clay and localized channel deposits. The Chadron Formation consists primarily of clay with some channel deposits, which could serve as a low-permeability core material.

The suitability of these materials for construction will require a geotechnical site investigation, including field sampling and laboratory testing. The geotechnical properties of the borrow source materials will need to be studied to assess the suitability of these materials as embankment fill. The geotechnical site investigation will also provide necessary information to estimate the available quantity of the borrow source materials for the proposed alternatives.

4.2 Background Information

The subsurface conditions at Julesburg Reservoir were evaluated using historical reports and inspection records. This section summarizes the available data that informed the slope stability analyses, including embankment zoning, depth to bedrock, phreatic surface conditions, and material properties.

4.2.1 Dam No. 1 Available Geotechnical Information

Dam No. 1 has a height of 23.4 feet and a crest length of 2,722 feet. No specific geotechnical data regarding the embankment zones, soil types, groundwater, or bedrock conditions are available for this dam.

4.2.2 Dam No. 1A Available Geotechnical Information

Dam No. 1A has a height of 18.2 feet and a crest length of 743 feet. No specific geotechnical data regarding embankment zones, soil types, groundwater, or bedrock conditions are available for this dam.

4.2.3 Dam No. 2 Available Geotechnical Information

Dam No. 2 is 66 feet high with a crest length of 1,956 feet and a crest width of 18 feet. The embankment is composed of silts and clays, with materials sourced locally during the original construction and subsequent repairs (Wheeler, 1988a). The upstream slope is protected with riprap, replacing a previous concrete slab. The downstream slope features a stability berm

constructed during seepage remedial measures. Chen & Associates performed a geotechnical investigation and installed piezometers at this dam in 1978.

Laboratory analyses classify the embankment materials as clayey silts to sandy clays, with liquid limits ranging from 43 to 46 and plasticity indices between 16 and 20. Foundation soils consist of fine-grained sandy clays and silts. Persistent seeps have been observed at or above the downstream toe of the dam. Chen & Associates (Chen & Assoc., 1988) used a conservative assumption of seepage outcrop at Elevation 3676.

Bedrock characteristics are not well documented. Following a failure in 1910, concrete cutoffs were installed into the underlying bedrock during reconstruction. More information on bedrock properties is unavailable (Chen & Assoc., 1988). Repairs in the 1980s included the installation of sand filter blankets and toe drains, along with stability berms to improve downstream stability. These berms have a minimum slope of 3:1 and include perforated drainpipes to address the seepage issues (Wheeler, 1988a).

4.2.4 Dam No. 3 Properties

Dam No. 3 is 40 feet high with a crest length of 1,917 feet and a crest width of 20 feet. The embankment consists of two- to five-foot-thick clayey sand overlying 25 to 41 feet of silts with interbedded sandy clay lenses and clayey silt lenses. Some clays near the foundation contain 2.8% to 3.7% organic content (Chen & Assoc., 1986).

Areas of the embankment that are composed of silts are cohesionless and prone to localized surface sloughing. Groundwater was encountered at 27.5 to 30 feet depths during drilling and fluctuated between 24.5 and 38.5 feet in subsequent monitoring. Perforated PVC pipes were installed in exploratory borings to facilitate long-term water level monitoring (Chen & Assoc., 1986). The siltstone bedrock was encountered at depths ranging from 27 to 45 feet.

4.2.5 Dam No. 4 Properties

Dam No. 4 has a structural height of 32.8 feet and a crest length of 3,340 feet, with a crest width of 25 feet. The upstream slope is approximately 3H:1V, while the downstream slope varies between 2.0H:1V and 2.5H:1V. The embankment includes clayey silt and sandy clay soils, with materials sourced locally during original construction and subsequent repairs. During rehabilitation, a blanket drain with a 24-inch sand filter and perforated pipes was installed to address seepage issues (Wheeler, 1987; Kumar, 1994). The embankment's as-built configuration includes a riprap section along the upstream slope to mitigate erosion (Kumar, 1994; Wheeler, 1990).

Geotechnical investigations indicate that the foundation consists of sandy siltstone bedrock encountered at varying depths beneath a sandy silt and silty sand alluvium layer. A cutoff trench, installed during the 1992 outlet channel reconstruction, extends four feet into the bedrock to intercept seepage through the foundation (Kumar, 1992). The lateral extent of this cutoff trench is unknown. Seepage was still occurring and there have been wet areas downstream of the cutoff trench following the installation of the cutoff trench.

4.3 Seepage Modeling

Wheeler assumed a reasonable phreatic surface for each dam to support the slope stability analyses. Historical piezometric level information is limited or absent for use in creating and validating a seepage model. Instead, phreatic surfaces were assumed based on recorded reservoir levels, observations at the downstream toe of the dam, and limited recorded piezometric data. The phreatic surfaces for each dam were developed by connecting the reservoir water surface on the upstream side of the dam to the downstream toe. There is a possibility of a higher phreatic surface at the downstream toe due to the presence of more pervious silt layers. For this alternatives analysis, Wheeler assumed the phreatic surface daylights at the downstream toe of each dam.

4.4 Slope Stability Modeling

To evaluate the existing slope stability and support the alternatives analysis, slope stability analyses were performed considering the long-term steady-state and rapid drawdown conditions for the maximum height embankment section for each dam. A slope stability analysis was performed for six locations as shown on Figure B-1 in Appendix B. The analyses were performed using Spencer's method and the computer program SLOPE/W (Seequent, 2021). The analysis considered minimum acceptable factors of safety as presented in Table 4.1.

Table 4.1: Acceptable Minimum Factors of Safety for Slope Stability

Loading Condition	Minimum Acceptable Factor of Safety	Reference
Long-Term Steady-State	1.5	USBR, 2011
Rapid Drawdown	1.2	USBR, 2011

The geotechnical information to develop material properties for the slope stability analyses is limited. Wheeler used conservative material properties based on the data presented in Section 4.1. Information from all the dams was used to develop a single set of material properties for the slope stability analysis of each dam. The material properties used in the slope stability analysis are presented in Table 4.2.

Table 4.2: Selected Material Properties

Material	Total Unit Weight (pcf)	Effective Stress Parameters		Total Stress Parameters	
		Φ (degrees)	Cohesion, c (psf)	Φ' (degress)	Cohesion, c' (psf)
Original Embankment Fill	110	31	25	20	100
Reconstructed Embankment Fill	110	31	25	20	100
Embankment Buttress	110	33	50	20	100
Embankment Raise Fill	110	31	25	20	100
Filter Sand	115	32	0	32	0
Alluvium	120	30	0	30	0
Weathered Bedrock	110	25	500	-	-
Bedrock	115	35	1000	-	-

Notes: pcf=pounds per cubic foot, deg=degree

Estimated drained and undrained shear strengths and unit weights for the dam embankment and foundation materials were developed using information obtained from previous field investigations and laboratory testing programs including in-situ Standard Penetration Testing (SPT), gradation, Atterberg, and triaxial test results.

4.4.1 Slope Stability Analysis Results for Existing Conditions

Estimated slope stability factors of safety for each dam using their existing condition and a restricted water level of Elevation 3708.5 are presented in Table 4.3. The slope stability models and results are provided in Figure B-1 to Figure B-19 in Appendix B.

Table 4.3: Calculated Factors of Safety for Existing Dams with Water Level at 3708.5 Feet

Condition	Long-Term Steady State (Minimum Acceptable FS=1.5)		Upstream Rapid Drawdown (Minimum Acceptable FS=1.2)
	Downstream Slope	Upstream Slope	Upstream Slope
Dam No. 1	**1.4**	1.7	1.3
Dam No. 1A	1.9	1.5	1.5
Dam No. 2 (Section C)[1]	**1.4**	1.9	1.0
Dam No. 2 (Section D)[1]	1.9	1.5	**0.7**
Dam No. 3	**1.3**	1.7	**0.9**
Dam No. 4	1.7	2.0	2.0

Notes: Numbers in red or bold fonts indicate an inadequate factor of safety.

1. Section C is located mid-slope on the valley side while Section D is the maximum height embankment section.

The downstream slopes of Dam No. 1, Dam No. 2 (Section C), and Dam No. 3 do not meet the minimum required factor of safety of 1.5 under the long-term, steady-state condition. The downstream slopes of Dam No. 1A, Dam No. 2 (Section D), and Dam No. 4 have adequate factors of safety.

The upstream slopes for all dams meet the minimum required factor of safety of 1.5 under the long-term, steady-state condition. The upstream slopes of Dam No. 2 (Section D) and Dam No. 3 do not meet the minimum required factor of safety of 1.2 under the rapid drawdown condition. The upstream slopes of Dam No. 1, Dam No. 1A, Dam No. 2 (Section C), and Dam No. 4 have adequate factors of safety.

4.4.2 Slope Stability Analysis Results for Alternatives A and B

Slope stability analyses were performed to support the design of Alternatives A and B, which are described more fully in Section 5.0. Stability analysis was only performed for existing dams and proposed dam raises. Reasonably conservative slopes were assumed for proposed new dams.

Under Alternative C all dams, except the rehabilitated Dam 4, will be new and stability analyses were not completed for Alternative C.

Dam raises for each alternative are based on design criteria discussed in Section 5.3. Alternative A includes raising the crest of all dams to Elevation 3721 with the reservoir level at Elevation 3715.5. Alternative B includes raising all dam crests to Elevation 3715.8 with the reservoir level at Elevation 3710.5. The crest width for each dam was modeled to be wide enough to satisfy the State's minimum crest width requirement. Based on the requirement, the crest widths ranged from 14 feet to 21 feet.

The slope stability analysis figures for Alternative A are provided in Figure B-20 to Figure B-37 in Appendix B. The slope stability analysis figures for Alternative B are provided in Figure B-38 to Figure B-43. A summary of the slope stability analysis for these alternatives is presented in Table 4.4. The slopes presented in Table 4.4 are the minimum slopes that would be required to meet the minimum acceptable stability factor of safety using the selected material properties.

Table 4.4: Minimum Required Slopes for Alternatives

Dam	Alternative A	Alternative B	Alternative C
Dam No. 1	Upstream 2.8:1 Downstream 2.5:1	Upstream 3:1, Downstream 2.5:1	N/A
Dam No. 1A	Upstream 2.8:1 Downstream 2.5:1	N/A	N/A
Dam No. 2[1]	Upstream 4:1 Downstream 2.5:1	N/A	N/A
Dam No. 3	Upstream 4:1 Downstream 3:1	N/A	N/A
Dam No. 4	Upstream 3:1 Downstream 3:1	Upstream 3:1, Downstream 2.5:1	Upstream 3:1, Downstream 2.5:1

Notes:

1. The minimum required upstream slope was estimated to be 4.5:1 for the maximum height section of the dam (Section D). The dam is built across a valley, an upstream slope of 4:1 is likely adequate based on the 3-dimensional effect of more stable abutments.

4.5 Wheelers Review of the Dam Failure

Wheeler reviewed the *Preliminary Report on the Reconstruction of the Julesburg Reservoir* by George Prince (Prince, 1910), which described the cause of the 1910 dam failure, as well as other historical reports with information on past seepage issues. The *Preliminary Report* found the 1910 dam failure to be caused by rupture of the porous bedrock beneath the dam at a depth of 30 feet due to the build-up of water pressure. The author mentioned that "seep" holes were observed in the downstream toe area; however, these "seep" holes did not have the capacity to relieve all the built-up pressure in the bedrock. The assessment of slope stability failures, however, requires substantial amounts of field data and analyses. In the absence of field data and engineering analyses, these historical assessments should be considered as opinions.

Seeps and slope failures have been observed and documented throughout the history of Julesburg Reservoir. Based on preliminary seepage analysis Wheeler performed for this project, the seepage and slope stability issues at Julesburg Reservoir are likely caused by internal erosion

mechanisms. Wheeler estimates the exit seepage gradients in the downstream toe area of Dam 2 to be in range of 0.3 feet. This seepage gradient is sufficient to initiate internation erosion. Laboratory test results to characterize the existing embankment fills and underlying alluvium are limited; however, the available geotechnical information indicates that cohesive clays and cohesionless silts are both present in the dam embankments. The alluvium is also composed of clayey sand to silty sand materials. The fine cohesionless materials such as the silt in the dam embankments or the silty sand in the dam foundation are more susceptible to internal erosion.

Based on the results of the seepage analysis, the uplift pressures in the bedrock beneath the dam are not sufficient to cause the bedrock rupture or uplift. A more plausible slope failure mechanism is the erosion of cohesionless materials in the embankment dam or the underlying alluvium, or weathered bedrock due to sufficient seepage gradients in the downstream toe area of the dam. This failure mechanism is supported by Wheeler's preliminary seepage analysis using limited available geotechnical information; it is also consistent with the historical observations.

In Wheeler's opinion, an effective solution to mitigate the risk of unfiltered seepage and slope stability failures in the downstream toe area of the dams is to build a toe drain system with a stability berm to provide a filtered exit at the location where the phreatic surface daylights in the downstream area of the dams. The historical observations of the seepage on the downstream face of the Dam 2 indicate the possibility of seepage exiting above the downstream toe on the downstream face of the dam. A toe drain system could be designed to include a chimney that extends above the toe along the downstream face to provide a filtered exit for seeps above the toe.

5.0 ALTERNATIVES ANALYSIS

5.1 Overview and Objective

The Julesburg Reservoir enlargement alternatives were developed to eliminate the water surface elevation restriction, to regain storage lost due to reservoir sedimentation, and to bring the five dams forming the reservoir into compliance with the DWR Dam Safety *Rules and Regulations* (DWR, 2020a).

5.2 Alternatives Options

Three alternatives were created to provide a range of options that meet the goals and objectives of the Julesburg Irrigation District as listed below. Conceptual design drawings for each alternative are presented in Appendix A and an opinion of cost for each alternative is presented in Appendix C. The three alternatives evaluated in this study are described in detail below.

Alternative A – Enlarge All Dams, substantial WSEL increase.

Alternative B – Downstream Replacement Dams 1A, 2, and 3, Minor WSEL increase.

Alternative C – Downstream Replacement 1, 1A, 2, and 3, Minor WSEL increase.

5.2.1 Alternative A – Enlarge All Dams

Alternative A focuses on rehabilitating the existing embankments while maintaining a similar reservoir configuration. This alternative includes modifications to both the upstream and downstream embankments to improve slope stability, as well as an increase in dam crest elevation by five to six feet. Additionally, the spillway crest would be raised to increase reservoir storage, and the inlet channel would be realigned. The dam crest raise/expansion would merge Dams 1A, 2, and 3 into a single crest that roughly follows the alignment of County Road 24.8. The dam crest raise/expansion would extend Dam 1 and 4 by several hundred feet. Toe drains would be installed along each downstream embankment to mitigate seepage.

To increase storage capacity, the spillway crest elevation would be raised to compensate for storage lost to sedimentation. The normal high water line would rise from a gage height of 27.5 (Elevation 3712.1) to gage height 30.9 (Elevation 3715.5), thus boosting the reservoir's storage capacity to 28,900 acre-feet.

The proposed increase in the normal high water line would require realigning the inlet canal. As a result, this alternative proposes a new inlet channel alignment above the normal high water line. Material from this channel could also provide on-site fill material needed for the dam expansions.

Constructing this alternative would require draining the reservoir pool to allow for modifications to the upstream embankment slope. Additionally, County Road 28, which runs along the north side of the reservoir, would need to be either rerouted or raised to prevent flooding during normal operations. This alternative would also require some land acquisition or easements due to the increased normal high water level and the rerouting of the inlet canal. Furthermore, it is assumed that Clean Water Act Section 404 permitting can be obtained under a Nationwide Permit and that

an individual permit would not be required for this Alternative. This assumption should be reevaluated if this alternative if the preferred design.

5.2.2 Alternative B – Replace Dams 1A, 2, and 3

Alternative B involves a combination of rehabilitating and reconstructing the existing dams. This alternative proposes the reconstruction of Dams 1a, 2, and 3 into a single new dam located downstream, referred to as Julesburg Dam A. The design of Julesburg Dam A would meet current DWR Dam Safety standards, including a cutoff trench and internal drainage systems. The reconstruction of these dams would address slope stability issues of existing dams, both upstream and downstream.

This alternative also includes rehabilitating Dams 1 and 4. For Dam 1, the embankment crest and both upstream and downstream slopes would be slightly raised, and a toe drain would be installed to mitigate seepage. For Dam 4, a toe drain would be installed along the northern embankment, and two spillways would be cut into the embankment and armored, as necessary. Since the Dam 4 crest alignment follows County Roads 3 and 28, spillway slopes would be limited to a maximum of 8% (12H:1V).

Alternative B would modify the reservoir configuration by relocating Dam Nos. 1a, 2 and 3 downstream, which would increase the storage capacity. The new alignment, known as Julesburg Dam A, would allow the normal high water line to decrease from a gage height of 27.5 (Elevation 3712.1) to 25.9 (Elevation 3710.5), and as a result, the reservoir's storage capacity would increase from 19,900 acre-feet to 28,300 acre-feet. A lower normal high water line also means the existing inlet channel could continue to be used without modifications, other than typical maintenance. Without modifications to the inlet channel, however, another on-site embankment fill source would be needed for this alternative.

Constructing this alternative would require partially draining the reservoir to allow for minor modifications to the upstream embankment slope and spillway. Additionally, land acquisition or easements would be needed for the expanded reservoir area and embankment alignment associated with Julesburg Dam A. Obtaining a Clean Water Act Section 404 permit is expected to be more challenging under this alternative due to the new dam alignment, as it would likely require an individual permit.

5.2.3 Alternative C – Replace Dams Nos. 1, 1A, 2, 3

Alternative C proposes the reconstruction of Dams 1, 1a, 2, and 3 into two new dams located downstream, referring to Julesburg Dam B and Julesburg Dam C. This alternative would optimize the alignments of the new Julesburg Dam B and C to minimize modifications at Dam 4. The new dam designs would meet current DWR Dam Safety standards, including a cutoff trench and internal drainage systems. The reconstruction of these dams would also address slope stability issues both upstream and downstream. For Dam 4, a toe drain would be installed along the northern embankment, and the existing spillway would be slightly modified and armored, as necessary. Since the Dam 4 crest alignment follows County Roads 3 and 28, the spillway cut slopes would be limited to a maximum of 8% (12H:1V).

Alternative C would modify the reservoir configuration by relocating the existing dams downstream and increasing the storage capacity. The alignments of new Julesburg Dam B and C would allow the normal high water line to decrease from a gage height of 27.5 (Elevation 3712.1) to 25.9 (Elevation 3710.5). As a result, the reservoir's storage capacity would increase from 19,900 acre-feet to 28,300 acre-feet. Because of the proposed location of Julesburg Dam C, the existing inlet channel could be modified to enter the reservoir approximately 1.6 miles upstream of the existing inlet location. Since minimal modifications to the inlet channel are proposed, another on-site embankment fill source would be needed for this alternative to be constructed.

Constructing this alternative would require partially draining the reservoir to allow for minor modifications to the spillway. Additionally, land acquisition or easements would be needed for the expanded reservoir storage area and embankment alignments associated with Julesburg Dam B and C. The land issue is particularly notable for Julesburg Dam C, which is proposed at the current location of Little Jumbo Reservoir and Dam, owned by Colorado Parks and Wildlife. Obtaining Clean Water Act Section 404 permitting is expected to be more challenging under this alternative compared to Alternative A and B. An individual permit is likely to be needed, and mitigation may be required for significant wetlands located downstream of Dam No. 1.

5.3 Alternative Design Criteria

To develop the three alternatives, several preliminary analyses and key assumptions were performed to meet DWR standards. Reservoir storage evaluation was required for each alternative to determine operating and normal high water line elevations. Inflow hydrology and spillway sizing analysis was conducted to provide dimensions for the conceptual spillway improvements. Wave run-up calculations were completed for each alternative to estimate freeboard and initial riprap sizing for erosion protection on the dam upstream slope. Slope stability analysis was performed for steady-state and rapid drawdown to address concerns regarding stability of the dams. Seepage modeling was performed to understand the need for downstream toe drains or cutoff trenches. The following sections further detail each of the analyses.

5.2.1 Hazard and Hydrologic Hazard Assumptions

For this alternatives analysis study, Wheeler assumed that each dam was classified as High Hazard and Extreme Hydrologic Hazard. Per DWR guidance for hazard classification and hydrologic hazard analysis (DWR, 2020c; DWR, 2020d), these classifications require the spillway and dam crest elevation to be sized for the PMP. Using the PMP meets the maximum inflow design flood requirement by DWR. This is a conservative assumption; the benefits of completing a full hydrologic hazard analysis for the highest dam should be considered once an alternative has been chosen.

5.2.2 Reservoir Storage Area

A reservoir storage capacity curve was updated for each of the alternatives. To calculate the existing capacity curve, a combination of the 2019 two-foot LiDAR data collected for the Colorado Water Conservation Board (CWCB) by (Merrick, 2019) and the field measurements and recordings taken by the Julesburg Irrigation District Manager. Field measurements were taken

during an extremely dry year by measuring inflow and recording the reservoir water surface elevation. This data was then used to develop an existing reservoir storage capacity that extended up to the operational high water line. The field measurements, where applicable, generally compared to the updated LiDAR capacity curve. A LiDAR capacity curve was developed by using the two-foot LiDAR data to develop a terrain surface in HEC-RAS 6.5 where volume was calculated using the 2D storage area feature. The LiDAR capacity curve does not include storage volume below Elevation 3704. Therefore, for the existing reservoir capacity curve, Wheeler used the field measurement curve for elevations below 3704 and the 2019 LiDAR data for elevations above 3704.

To determine the dam modifications needed for each alternative, Wheeler used an iterative approach to meet the reservoir storage requirement of 28,178 acre-feet. According to the Julesburg Irrigation District Manager, the reservoir is currently operated at a water surface elevation 3.2 feet below the service spillway crest. The District purposely operates lower than the service spillway crest to eliminate nuisance flows due to waves or small storm events. Therefore, for the purposes of this study, Wheeler has selected an operating high water line elevation that meets the storage requirement, then selected one foot higher as the normal high water line. Table 5.1 summarizes the reservoir capacity table for each alternative. Table 5.2 summarizes the operational high water level and normal high water level elevations used for each alternative.

Table 5.1: Reservoir Capacity Table

Gage Height (feet)	Elevation (feet, NAVD88)	Existing / Alternative A (acre-feet)	Alternative B (acre-feet)	Alternative C (acre-feet)	Notes
-39.6	3645.0	0	0	0	
5.0	3689.6	0	2,202	987	
7.0	3691.6	730	3,206	2,094	
9.0	3693.6	1,940	4,709	3,722	
11.0	3695.6	3,697	6,779	5,937	
13.0	3697.6	5,580	8,995	8,315	
15.0	3699.6	7,780	11,546	11,049	
17.0	3701.6	10,150	14,287	13,986	
19.0	3703.6	12,938	18,094	18,011	
21.0	3705.6	15,611	21,958	22,302	
23.0	3707.6	18,411	25,174	25,770	
24.0	3708.6	19,847	26,815	27,543	Exist OHWL
24.9	3709.5	21,154	28,316	29,171	Alt B / C OHWL
25.9	3710.5	22,662	30,030	31,022	Alt B / C NHWL
27.0	3711.6	24,336	31,965	33,113	
27.5	3712.1	25,105	32,831	34,054	Exist NHWL
29.0	3713.6	27,467	35,549	37,005	
29.9	3714.5	28,919	37,200	38,804	Alt A OHWL
30.9	3715.5	30,557	39,074	40,841	Alt A NHWL
31.4	3716.0	31,402	40,036	41,890	Alt B / C Dam Crest
33.0	3717.6	34,157	43,165	45,313	
36.4	3721.0	40,281	50,096	52,854	Alt A Dam Crest
38.4	3723.0	43,957	54,353	57,492	

Note: Operating High Water Line (OHWL) and Normal High Water Line (NHWL)

Table 5.2: Design Features

Parameter	Existing Elevation in feet, NAVD88 (Gage height)	Alternative A Elevation in feet, NAVD88 (Gage height)	Alternative B Elevation in feet, NAVD88 (Gage height)	Alternative C Elevation in feet, NAVD88 (Gage height)
Operating High Water Line (OHWL)	3708.6 (GH 24)	3714.5 (GH 29.9)	3709.5 (GH 24.9)	3709.5 (GH 24.9)
Normal High Water Line (NHWL)	3712.1 (GH 27.5)	3715.5 (GH 30.9)	3710.5 (GH 25.9)	3710.5 (GH 25.9)

5.2.3 Hydrology and Spillway Sizing

Inflow hydrology was completed for Julesburg Reservoir as summarized in Section 3. Per DWR guidance for spillway design, Wheeler applied the atmospheric moisture factor (AMF) of 1.07 to

the controlling PMP storm: the 6-hour Local Storm. The spillway crest elevation was determined in Section 5.2.2 based on the storage capacity. The spillway length was then adjusted to pass an inflow design storm plus one foot of freeboard, per the DWR *Rules* (DWR,2020a). The proposed spillways were designed to match the existing spillway at Julesburg Reservoir Dam No. 4. The existing spillway is a broad crested weir with a control section at County Road 28. The proposed spillway design also consists of a broad crested weir with a control section at County Road 28. Because the control section is a two-lane county road, design modifications included a minimum, width of 22 feet and a maximum longitudinal slope of 10H:1V. No local guidance for Logan County and Sedgwick County was available online; therefore, county road dimensions need to be verified by the county during the initial design phase.

Wheeler initially used the broad crested weir spillway feature in the hydrologic model described in Section 3 to determine a spillway length that would meet the DWR *Rules* (DWR, 2020a). Then, using the spillway length, crest elevation plus minimum county road widths and longitudinal slopes, Wheeler developed a two-dimensional hydraulic model to estimate the spillway rating curve for each alternative. Further details about the hydraulic model development are provided in Appendix B. Table 5.3 summarizes the spillway capacity tables for each alternative.

Table 5.3: Spillway Discharge

Gage Height	Elevation	Existing Discharge (cfs)	Alternative A Discharge (cfs)	Alternative B Discharge (cfs)	Alternative C Discharge (cfs)
25.9	3710.5	0	0	0	0
27.0	3711.6	0	0	1,292	421
27.5	3712.1	0	0	3,241	938
29.0	3713.6	565	0	13,998	4,128
29.9	3714.5	2,079	0	23,381	7,637
30.9	3715.5	5,280	0	36,059	13,026
31.4	3716.0	7,674	1,279	42,397	15,720
33.0	3717.6	NA	13,292	NA	NA
36.4	3721.0	NA	80,895	NA	NA

Note: cfs = cubic feet per second

5.2.4 Wave Run-up

Wave runup calculations were performed following DWR guidance for each of the Julesburg Reservoir dams. According to the guidance, normal freeboard is calculated as the vertical distance between the dam crest and the normal high water operating line and must be the greater of three feet or the calculated wave runup generated by sustained 100 mile per hour winds. The maximum wave runup depth of 5.3 feet was calculated at the northwest section of Dam 4. This wave runup depth was conservatively based on the steepest upstream existing and proposed slope of 2H:1V. Once a preferred alternative is selected, this calculation will be updated with final upstream slopes for each dam to minimize conservatism within the freeboard number.

5.2.5 Slope Stability and Seepage

Table 5.4 summarizes the minimum design slopes and identifies the need for a drainage system based on the geotechnical evaluations discussed in Section 4.0. The dam stability analysis

showed that some of the existing embankments do not meet the minimum acceptable factors of safety for the long-term steady-state stability loading. The existing models were utilized to add additional fill to upstream and/or downstream slopes to develop a stable embankment design. Further detailed calculations are provided in Appendix B.

Table 5.4: Embankment Design Slopes

Dam	Parameter	Alternative A	Alternative B	Alternative C
Dam 1	Upstream Slope	2.8H:1V	3H:1V (above reservoir)	3H:1V (Julesburg Dam C)
	Downstream Slope	2.5H:1V	2.5H:1V	3H:1V (Julesburg Dam C)
	Toe Drain Required?	Yes	Yes	Yes
Dam 1a	Upstream Slope	2.8H:1V	-	-
	Downstream Slope	2.5H:1V	-	-
	Toe Drain Required?	Yes	-	-
Dam 2	Upstream Slope	4H:1V	3H:1V (Julesburg Dam A)	3H:1V (Julesburg Dam B)
	Downstream Slope	2.5H:1V	3H:1V (Julesburg Dam A)	3H:1V (Julesburg Dam B)
	Toe Drain Required?	No	Yes	Yes
Dam 3	Upstream Slope	4H:1V	-	-
	Downstream Slope	3H:1V	-	-
	Toe Drain Required?	No	-	-
Dam 4	Upstream Slope	3H:1V	3H:1V	3H:1V
	Downstream Slope	3H:1V	3H:1V	3H:1V
	Toe Drain Required?	Yes - partially	Yes - partially	Yes - partially

5.2.6 Drawdown

With the proposed enlargement of the reservoir storage, Wheeler reviewed and evaluated the drawdown capacity of the existing outlet works structure at Julesburg Reservoir. The outlet works structure is located on Dam 4 and was reconstructed in 1996. The structure includes two 4.5-foot-wide by 5-foot-tall cast-in-place box culverts. The existing outlet works capacity curve, developed as part of the rehabilitation design and construction project, was used to evaluate the drawdown capacity for the three enlargement alternatives. Wheeler compared the results to Rule 7.8.2.1 which states, ‘Outlets shall be capable of releasing the top five feet of the reservoir capacity in five days,’ to verify whether the outlet works meets Colorado Dam Safety standards. Table 5.5 summarizes the results, which show that the existing outlet works structure is sufficient to meet the drawdown requirement of five feet in five days, except for Alternative C. Alternative C would require a waiver from DWR or a new outlet structure to be constructed since the drawdown period is less than five feet after five days.

Table 5.5: Drawdown Time

Reservoir Scenario	Drawdown Elevation (Gage Height)	Drawdown Time (days)
Existing	3707.1 (GH 22.5)	3.9
Alternative A	3710.5 (GH 25.9)	4.0
Alternative B	3705.5 (GH 20.9)	4.7
Alternative C	3705.5 (GH 20.9)	5.1

6.0 OPINION OF PROBABLE COST

6.1 Cost Development Approach

Wheeler developed feasibility-level opinions of probable project cost for the three alternatives for enlargement of Julesburg Reservoir. Wheeler's opinions of probable cost are reasonably conservative and considered to be equivalent to a Class 5, feasibility-level budget opinion (AACE, 2005). As project planning and the final design develops, the project budgets can change significantly due to the final configuration of the project and other unforeseen issues. The potential for these changes should be considered during planning and budgeting phases.

Preliminary construction quantities, preliminary project construction bid tabs, and project budget opinion costs were developed for the three alternatives. These direct construction costs were developed in 2025 construction dollars. The indirect project costs include budgets for non-construction items that are required to complete the project, such as design engineering; construction change order contingencies; permitting, legal and administrative costs; and construction administration and engineering. A summary of the opinion of probable direct construction and indirect project costs for each alternative is provided in Table 6.1. A summary of the key elements in the direct construction costs is provided in Table 6.2. A summary of the key elements in the indirect project costs are provided in Table 6.3. Additional details about Wheeler's feasibility-level opinions of probable project costs are provided in Appendix C.

Table 6.1: Opinion of Alternatives Probable Project Cost

Item Description	Alternative A Enlarge All Dams	Alternative B Replace Dams 1a, 2, and 3	Alternative C Replace 1, 1a, 2, and 3
Direct Construction Costs	$25,781,000	$37,249,000	$40,921,000
Indirect Construction Costs	$9,818,000	$19,171,000	$20,757,000
Total Construction Costs	**$35,599,000**	**$56,420,000**	**$61,678,000**

Note: All costs in projected 2025 dollars

6.2 Direct Construction Opinions of Cost

The key work elements that were developed to prepare an opinion of the direct construction costs are summarized as follows:

1. Preparatory work, including mobilization, bonds, insurance, stormwater management, clearing and grubbing, strip and stockpile topsoil, and reclamation and clean up.
2. Earthwork for each dam, including excavation, hauling, structural fill, and compaction.
3. Upstream embankment erosion protection for each dam, including riprap and bedding material.
4. Internal drainage systems for each dam, including filter sand and gravel material.
5. Inlet channel improvements.
6. Spillway improvements, including a concrete control section constructed upstream of County Road 28 and downstream armoring.

7. Enlargement of the outlet works tower including raising the tower and lengthening the bridge.
8. Dam safety instrumentation installation.
9. Miscellaneous earthwork.
10. Unlisted Items.

Unlisted items were estimated at 10 percent of the construction cost. Unlisted items are included to provide a contingency for additional design features that are typically included in the final design work that cannot be identified at this stage of project development. Contractor mobilization, bonds, general administration, and insurance were estimated at approximately 15 percent of the construction costs. Stormwater management, including erosion and sediment control, were estimated at approximately 5 percent of the construction costs with the assumption that the existing outlet works can be used to help maintain the reservoir at specified elevations during construction.

Table 6.2 provides a summary of the direct construction costs. A detailed listing of the anticipated construction items for each alternative is provided in Appendix C. The opinions of probable direct construction costs are reported in 2025 dollars.

Table 6.2: Alternatives Direct Construction Costs Summary

Item Description	Alternative A Enlarge All Dams	Alternative B Replace Dams 1a, 2, and 3	Alternative C Replace 1, 1a, 2, and 3
Preparatory Work	$5,134,000	$6,926,000	$7,500,000
Earthwork (Includes all dams)	$2,872,000	$14,773,000	$16,840,000
Upstream Embankment Projection (all dams)	$7,692,000	$9,001,000	$10,862,000
Internal Drainage Systems (all dams)	$2,437,000	$2,763,000	$2,293,000
Inlet channel improvements	$4,558,000	$0	$34,000
Spillway Work	$721,000	$867,000	$192,000
Enlargement of Outlet Works Tower	$328,000	$0	$0
Dam Safety Instrumentation	$119,000	$119,000	$119,000
Miscellaneous earthwork	$43,000	$43,000	$43,000
Unlisted Items	$1,877,000	$2,757,000	$3,038,000
Direct Construction Costs	**$25,781,000**	**$37,249,000**	**$40,921,000**

Note: All costs were escalated to 2025 dollars

6.3 Indirect Project Opinions of Cost

A summary of the indirect project cost elements is provided below.

1. **Land Acquisitions or Easement Purchases –** This is an approximate cost based on the increased surface area of the normal high water line for each alternative. The area also includes the new dam alignments. Wheeler used a flat amount of $1,000 per acre to estimate this cost.
2. **County Road Changes –** Cost associated with anticipated county road changes were estimated based on the earthwork and base course material needed to complete the work.

3. **Final Design and DWR Dam Safety Approval –** Final design engineering was assumed to be 10 percent of the construction cost. This work would include the preparation of detailed construction drawings, construction specifications, and a design summary report that documents the engineering analyses completed to support the design. These design documents will require review and approval by the DWR.
4. **Environmental Permitting –** A environmental permitting cost was estimated between 5 and 20 percent, depending on the type of CWA Section 404 permit required. For Alternative A, Wheeler assumed a nationwide permit would be required. For Alternatives B and C, an individual permit may be required and are typically more expensive. This percentage also includes other required permits to complete the project.
5. **Construction Administration and Engineering –** The construction administration and engineering costs were estimated as 10 percent of the sum of the direct construction cost. This budget would include the following activities that are normally required by the DWR, including:
    a. On-site resident engineering and preparation of daily construction reports;
    b. Materials testing;
    c. Routine progress meetings and preparation of meeting summaries;
    d. Monthly progress reports with photos and construction test results;
    e. Review and approval of contractor's monthly payment requests;
    f. Review of construction change orders;
    g. Responses to contractor requests for information (RFI);
    h. Preparation of a final construction report; and
    i. Preparation of Record Drawings to document the "as-built" condition of the project.
6. **Construction Contingency –** A change order contingency equivalent to 20 percent of the opinion of probable construction cost total was included. This change order contingency is included to address changes to construction quantities or unexpected changes that normally occur during a large heavy civil construction project.

Table 6.3 provides a summary of the indirect construction costs.

Table 6.3: Alternatives Indirect Project Cost Summary

Item Description	Alternative A Enlarge All Dams	Alternative B Replace Dams 1a, 2, and 3	Alternative C Replace 1, 1a, 2, and 3
Land Acquisition or Easement Purchases	$283,000	$355,000	$515,000
County Road Changes	$244,000	$624,000	$190,000
Final Design Engineering and DWR Dam Safety Approval (10%)	$2,065,000	$3,032,000	$3,342,000
Environmental Permitting	$1,032,000	$6,064,000	$6,684,000
Construction Administration and Engineering (10%)	$2,065,000	$3,032,000	$3,342,000
Construction Contingency (20%)	$4,129,000	$6,064,000	$6,684,000
Indirect Project Costs	**$9,818,000**	**$19,171,000**	**$20,757,000**

Note: All costs were escalated to 2025 dollars

7.0 RECOMMENDATIONS AND NEXT STEPS

Based on this Alternatives Analysis Report and Conceptual Designs for the enlargement of Julesburg Reservoir, Wheeler offers the following recommendations and next steps:

- Complete a geotechnical site investigation to verify the slope stability and seepage soil material assumptions and obtain the required data needed to complete a final design for the enlargement of Julesburg Reservoir.
- Select the preferred Alternative Design Concept and develop the 30-percent design package. Typically, the 30-percent design is sufficient to begin most permitting efforts.
- Evaluate and complete, if necessary, a hydrologic hazard and hazard classification for the preferred Alternative.

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Appendix B

Calculations

Appendix B.1

Drainage Basin Documentation

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Basin DEM and Parameters	Approved			

OBJECTIVE:

Document the source of the basin Digital Elevation Model (DEM).
Use the StreamStats basin as a starting point and calculate basin parameters using the DEM.
Develop Unit Hydrograph Parameters (A, L, Lca, S)

METHOD:

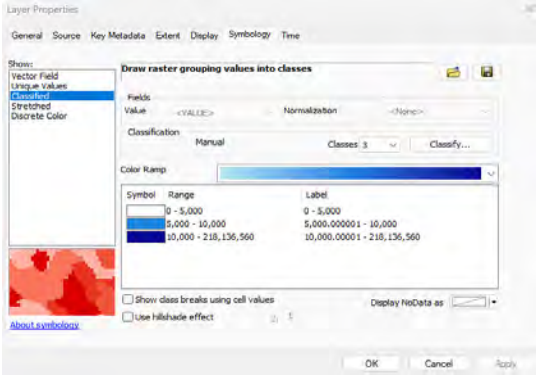
1. Download 1 meter DEM data. Data accessed through Colorado Hazard Mapping

Website: https://coloradohazardmapping.com/LidarDownload

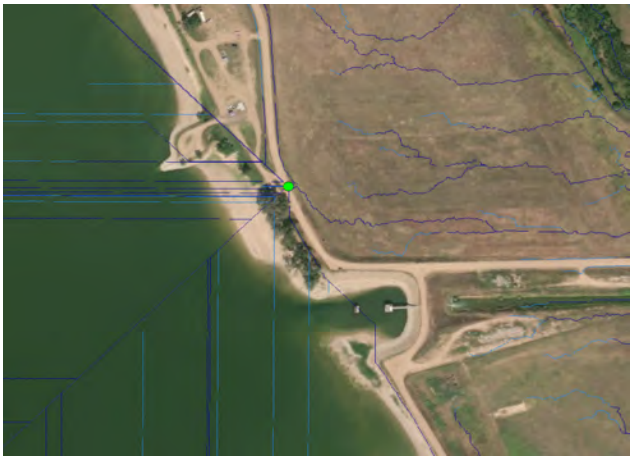
2. Record and verify DEM metadata
    a. Select "Info/Metadata": Print page to PDF and save in the same Original DEM Folder.
    b. Verify the following DEM metadata
        - Project geographic coordinates: North American Datum of 1983 2011 (NAD 83 11)
        - Elevation Datum: North American Vertical Datum of 1988 (NAVD 88)
        - Resolution: 2-ft LiDAR
        - Publication Date: 12/8/2021
        - Start Date: 7/31/2019
        - End Date: 9/8/2019

4. DEM Processing:
    a. Merge the geotiffs together.
    b. Clip the geotiff to include the subbain and downstream.
    c. final dem is located here.
        - File Location:
          R:\0900\0985\0985.04\08_GIS\LiDAR\DEM_f2.tif

5. Basin delineation using Arc Toolbox
    a. Spatial Analyst - Hydrology - Fill (Don't specify z limit)
        - File Location:
          R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\LargeDEM\fill.tif
    b. Spatial Analyst - Hydrology - Flow Direction ("fill_m" raster as the surface raster)
        - File Location:
          R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\LargeDEM\flowdirc2.tif
    c. Spatial Analyst - Hydrology - Flow Accumulation (Output type FLOAT)
        - File Location:
          R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\LargeDEM\Flowacc.tif
        - "Flo_accu_m" raster - Layer Properties - Classified - Visualize streamlines



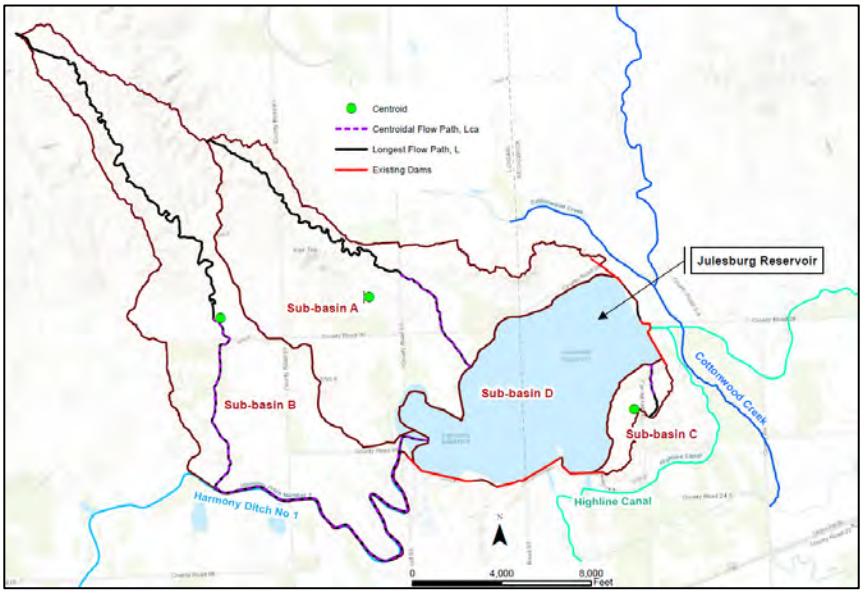
c. Spatial Analyst - Hydrology - Flow Accumulation, CONTINUED
- Create a delineation point based on "Flow_accu_m" raster.
- Delineation point:
  R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\DelineationPoint.shp



d. Spatial Analyst - Hydrology - Watershed (don't specify z limit) -
- File Location:
  R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\LargeDEM\watershed.tif

d. Converted Watershed into shapefile.
- File Location:
  R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\LargeDEM\watershed_large.shp

d. Split the basin into subbains. 1 - directly into the reservoir; 2 - runoff into the inlet canal or
- File Location:
  R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\Watershed.shp



6. Final basin parameters

a. Delineate Basin & Subbasins

- Basin Shapefile:
  R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\Watershed.shp

▪ Area Total:	6630.2 ac

- SubBasin Shapefile:

▪ Basin A:	2355.2 ac
▪ Basin B:	2654.3 ac
▪ Basin C:	174.0 ac
▪ Reservoir D:	1446.7 ac

b. Calculate Basin Centroid. Full basin was used in MetPortal

- Shapefile:
  R:\0900\0985\0985.04\08_GIS\SHP\Centroid.shp

	▪ X Coord:	▪ Y Coord:
▪ Basin A:	-102.67695	40.943638
▪ Basin B:	-102.70116	40.941605
▪ Basin C:	-102.63462	40.928612
▪ Reservoir D:	-102.65001	40.931352
▪Full Basin (used in	-102.67966	40.939749

c. Use the DEM contours to trace the longest flow path, L, and flow path along the centroid,.

- File Location
  R:\0900\0985\0985.04\08_GIS\SHP\LongestFlowPath.shp

	▪ L (feet) :
▪ Basin A:	20,016.5
▪ Basin B:	51,475.5
▪ Basin C:	2,629.0
▪ Reservoir D:	NA

- File Location
  R:\0900\0985\0985.04\08_GIS\SHP\LongestFlowPath.shp

	▪ Lca (feet) :
▪ Basin A:	5,854.4
▪ Basin B:	29,014.3
▪ Basin C:	1,540.4
▪ Reservoir D:	NA

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Basin DEM and Parameters	Approved			

RESULTS:

1. MXD Figure for final parameters
   - File Location:

     R:\0900\0985\0985.04\08_GIS\MXD\WorkMapLL.mxd

Area	Longest Flow path Length	Highest Elevation Along L (1)	Lowest Elevation Along L (2)	Longest Flow path Slope	Centroidal Flow path Length	Centroid X	Centroid Y	
A	L	El_{MAX}	El_{MIN}	S	L_{CA}	X	Y	
(Mile ^{2})	(Mile)	(Feet)	(Feet)	(Feet/ Mile)	(Mile)	(Decimal Deg)	(Decimal Deg)	Basin
3.680000	3.791000	4026.0	3707	84.14085993	1.108790	-102.67695	40.94364	A
4.147000	9.749140	4138.6	3707	44.26646863	5.495140	-102.70116	40.94161	B
0.271922	0.497915	3792.0	3707	170.7118685	0.291746	-102.63462	40.92861	C
2.260390	NA	3707.0	3707	NA	NA	-102.65001	40.93135	D-res

(1) Determined using contours created from the 1-meter DEM in GIS.
(2) Determined using contours created from the 1-meter DEM in GIS, elevation of the channel downstream of the outlet works; consistent with EIR crest El - dam height.

REFERENCES:

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Appendix B.2

Precipitation Documentation

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			

OBJECTIVE:

Document the precipitation development for the Probable Maximum Precipitation (PMP).

METHOD:

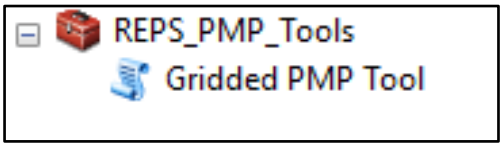
1. Follow Guidance from the Colorado Division of Water Resources:

   Colorado Division of Water Resources, Dam Safety Branch (DWR, 2020-3), ***Guidelines for the Use of Regional Extreme Precipitation Study (REPS) Rainfall Estimation Tools*** , January 21, 2020

   Colorado Division of Water Resources, Dam Safety Branch (DWR, 2020-3), ***Guidelines for the Use of Regional Extreme Precipitation Study (REPS) Rainfall Estimation Tools*** , August 22,2024

2. Download the CO-NM REPS (hereafter referred to as REPS).

   REPS is a GIS-based tool that runs as a toolbox script in ArcGIS.
   REPS PMP Tool (Version 1.10)
   Location on Network:
   S:\GIS_REPS\REPS_PMP_Tool_v1_10_Final_Nov 2018\PMP_Evaluation_Tool\Script\REPS_PMP_Tools.tbx



3. Add the representative watershed Polygon to ArcGIS
   - File Location, watershed SHP:
     R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\Watershed.shp
   - Check the basin area being evaluated. If the basin area exceeds thresholds of 100 miles, subdivision of the basin may be required for appropriate evaluation of the 2HR and 6HR Local Storm.
     Basin Area (sq mi) : 10.36 ,basin size OK
   - Check the basin area being evaluated. If the basin is located south of Latitude 38.5, then the tropical storm type technically also applies.
     Basin Centroid, Y, Latitude : 40.90 , south of Latitude 38.5º NA
   - File Location, MXD with REPS analysis and results:
     R:\0900\0985\0985.04\08_GIS\MXD\hydrology\04_REPS.mxd

4. Run the REPS GIS "Gridded PMP Tool" and checked the tool results with the new REPS web tool
   - File Location, RESULTS/OUTPUT FILES:
     R:\0900\0985\0985.04\08_GIS\REPS
   - The REPS tool was run for the Local Storm, General Storm, and Tropical Storm. Note that the basin is located north of Latitude 38.5 and the Tropical Storm does not apply.

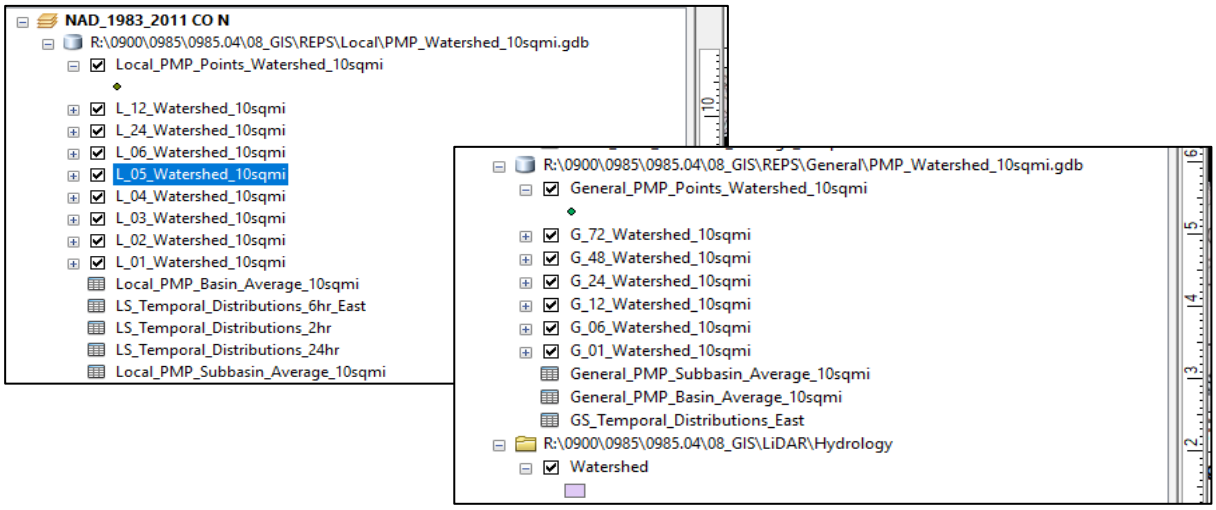
- The REPS tool creates separate folders for the selected storm durations which in this case were the Local, General Storm, and Tropical Storms. Each folder has a summary plot of computed depth duration based on the basin outline, and a geodatabase (.gdb) containing additional information.

- The REPS web tool provided the same values as the GIS tool

5. General Storm: Add the created ".gdb" to ArcMap, the two attribute tables (PMP Summary and Temporal Distribution) and 72 HR raster:

7. Local Storm: Add the created ".gdb" to ArcMap, the three attribute tables (PMP Summary, 2HR and 6HR Temporal Distribution) and 2HR, 6 HR and 24HR raster:

8. ArcMap Table of Contents containing REPS PMP Results for General, Tropical, and Local Storms:



9. General Storm tabular data from .gdb:

General_PMP_Basin_Average_10sqmi

OBJECTID *	Storm Type	PMP_01	PMP_06	PMP_12	PMP_24	PMP_48	PMP_72
1	General	3.33	8.3	12.39	15.78	17.93	18.58

General_PMP_Subbasin_Average_10sqmi

OBJECTID *	Storm Type	Subbasin	PMP_01	PMP_06	PMP_12	PMP_24	PMP_48	PMP_72
1	General	A	3.32	8.3	12.4	15.8	17.92	18.6
2	General	B	3.3	8.29	12.36	15.75	17.9	18.55
3	General	C	3.4	8.3	12.4	15.8	18	18.68
4	General	D - Res	3.39	8.3	12.4	15.8	17.99	18.61

Duration (hr)	REPS General Storm (in)	107% (1) REPS General Storm (in)
1	3.33	3.56
6	8.3	8.88
12	12.39	13.26
24	15.78	16.88
48	17.93	19.19
72	18.58	19.88

11. Local Storm tabular data from .gdb:

Local_PMP_Basin_Average_10sqmi

OBJECTID *	Storm Type	PMP_01	PMP_02	PMP_03	PMP_04	PMP_05	PMP_06	PMP_12	PMP_24
1	Local	9.48	14.86	18.31	18.31	18.31	18.57	20.02	20.05

Local_PMP_Subbasin_Average_10sqmi

OBJECTID *	Storm Type	Subbasin	PMP_01	PMP_02	PMP_03	PMP_04	PMP_05	PMP_06	PMP_12	PMP_24
1	Local	A	9.5	14.87	18.32	18.32	18.32	18.64	20.08	20.14
2	Local	B	9.45	14.82	18.29	18.29	18.29	18.36	19.79	19.82
3	Local	C	9.5	14.9	18.38	18.38	18.38	18.8	20.3	20.3
4	Local	D - Res	9.5	14.9	18.33	18.33	18.33	18.79	20.29	20.29

Duration (hr)	REPS Local Storm (in)	107% (1) REPS Local Storm (in)
1	9.48	10.14
2	14.86	15.90
3	18.31	19.59
4	18.31	19.59
5	18.31	19.59
6	18.57	19.87
12	20.02	21.42
24	20.05	21.45

NOTE

1. Analysis ultimately included a 7-percent augmentation factor for an increase in atmospheric moisture to account for climate change (added in HEC-HMS).

12. General Storm, temporal distribution, tabular data from .gdb:
Temporal results are provided for the 10th and 90th% Huff Distribution and Synthetic Storm. The Synthetic Storm was used. GIS excerpt show below.

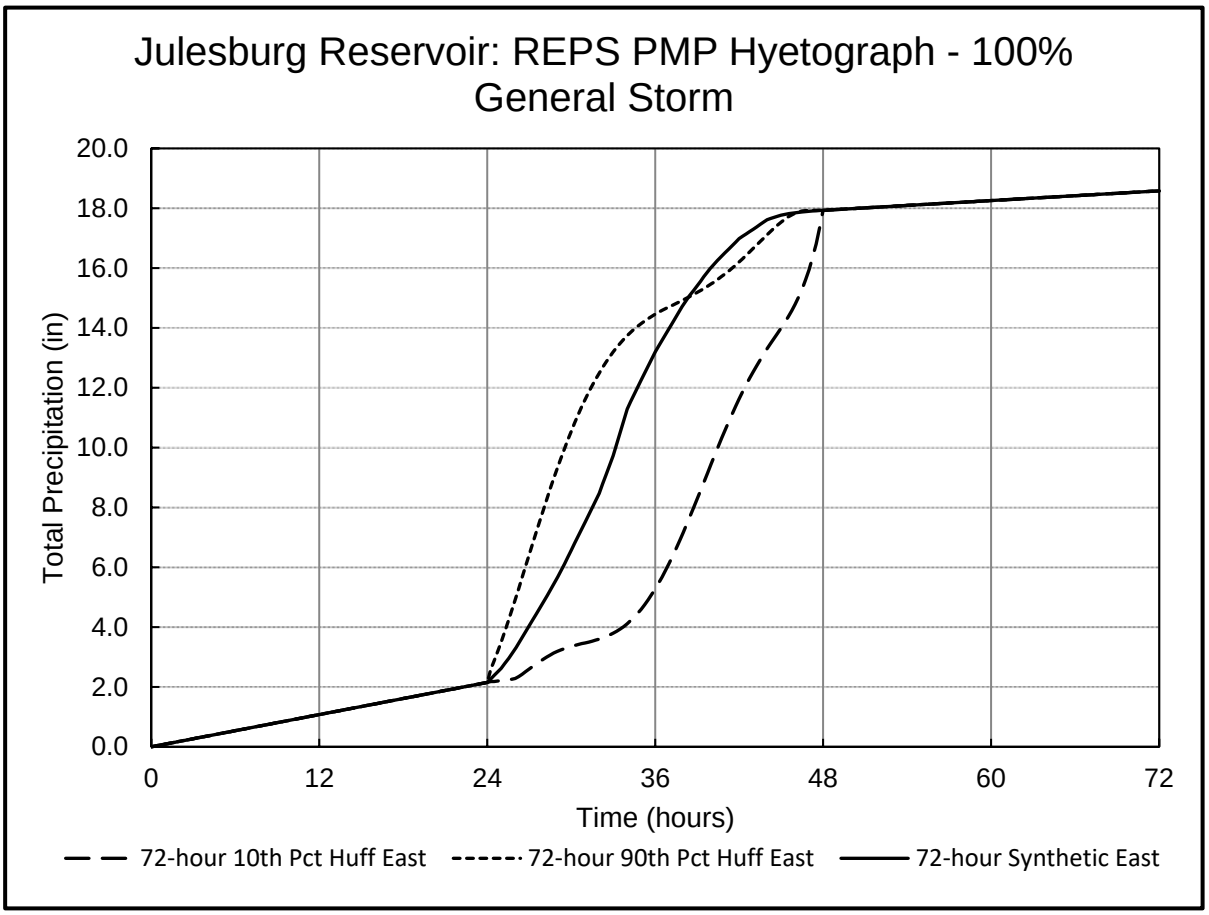
NOTE: Paste the full temporal data on the [REPS_PMP_TemporalData] tab. Printable temporal data is included at the end of this calculation. The figure below also exists in its own printable tab [Fig_PMP_GS].

GS_Temporal_Distributions_East

OBJECTID *	TIMESTEP	MINUTE	GS_24_hour_10th_Percentile_Huff_East	GS_24_hour_90th_Percentile_Huff_East	GS_24_hour_Synthetic_East
1	1	15	0.022	0.022	0.022
2	2	30	0.045	0.045	0.045
3	3	45	0.067	0.067	0.067
4	4	60	0.09	0.09	0.09
5	5	75	0.112	0.112	0.112
6	6	90	0.134	0.134	0.134
7	7	105	0.157	0.157	0.157

GS_Temporal_Distributions_East

OBJECTID *	TIMESTEP	MINUTE	GS_24_hour_10th_Percentile_Huff_East	GS_24_hour_90th_Percentile_Huff_East	GS_24_hour_Synthetic_East
282	282	4230	18.539	18.539	18.539
283	283	4245	18.546	18.546	18.546
284	284	4260	18.553	18.553	18.553
285	285	4275	18.56	18.56	18.56
286	286	4290	18.566	18.566	18.566
287	287	4305	18.573	18.573	18.573
288	288	4320	18.58	18.58	18.58



14. Local Storms, temporal distribution, tabular data from .gdb:
Temporal results are provided for the 2-hr, 6-hr, 24-hr 10th and 90th% Huff Distribution and Synthetic Storm

The 2-Hr, 6-hr, 24-hr Storms were used.

GIS excerpts shown below.

NOTE: Paste the full temporal data on the [REPS_PMP_TemporalData] tab. Printable temporal data is included at the end of this calculation. The figures below also exists in their own printable tabs [Fig_PMP_LS2hr] and [Fig_PMP_LS6hr] and [Fig_PMP_LS24hr] .

2-Hr Storm

LS_Temporal_Distributions_2hr

OBJECTID *	TIMESTEP	MINUTE	LS_2_hour_Stacked
1	1	5	1.389
2	2	10	2.612
3	3	15	3.686
4	4	20	4.628
5	5	25	5.455
6	6	30	6.185
7	7	35	6.835

LS_Temporal_Distributions_2hr

OBJECTID *	TIMESTEP	MINUTE	LS_2_hour_Stacked
19	19	95	12.618
20	20	100	13.067
21	21	105	13.515
22	22	110	13.963
23	23	115	14.412
24	24	120	14.86

6-Hr Storm

LS_Temporal_Distributions_6hr_East

OBJECTID *	TIMESTEP	MINUTE	LS_6_hour_10th_Percentile_Huff_East	LS_6_hour_90th_Percentile_Huff_East	LS_6_hour_Synthetic_East
1	1	5	0	0.505	0.464
2	2	10	0	0.99	0.927
3	3	15	0	1.53	1.391
4	4	20	0	2.059	1.853
5	5	25	0	2.579	2.318
6	6	30	0	3.092	2.78

LS_Temporal_Distributions_6hr_East

OBJECTID *	TIMESTEP	MINUTE	LS_6_hour_10th_Percentile_Huff_East	LS_6_hour_90th_Percentile_Huff_East	LS_6_hour_Synthetic_East
67	67	335	17.3	18.57	18.416
68	68	340	17.549	18.57	18.446
69	69	345	17.781	18.57	18.477
70	70	350	17.979	18.57	18.509
71	71	355	18.234	18.57	18.538
72	72	360	18.57	18.57	18.57

24-Hr Storm

LS_Temporal_Distributions_24hr

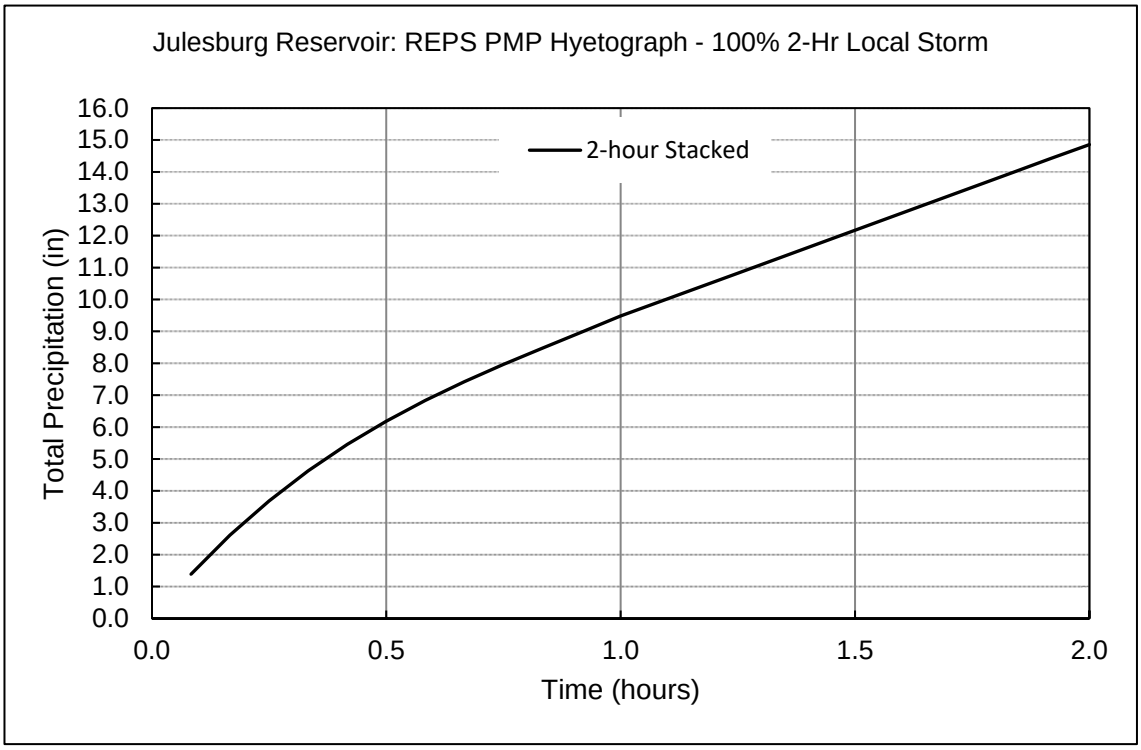
OBJECTID *	TIMESTEP	MINUTE	LS_24_hour_Synthetic_Hybrid
1	1	5	0.002
2	2	10	0.004
3	3	15	0.004
4	4	20	0.006
5	5	25	0.008
6	6	30	0.01

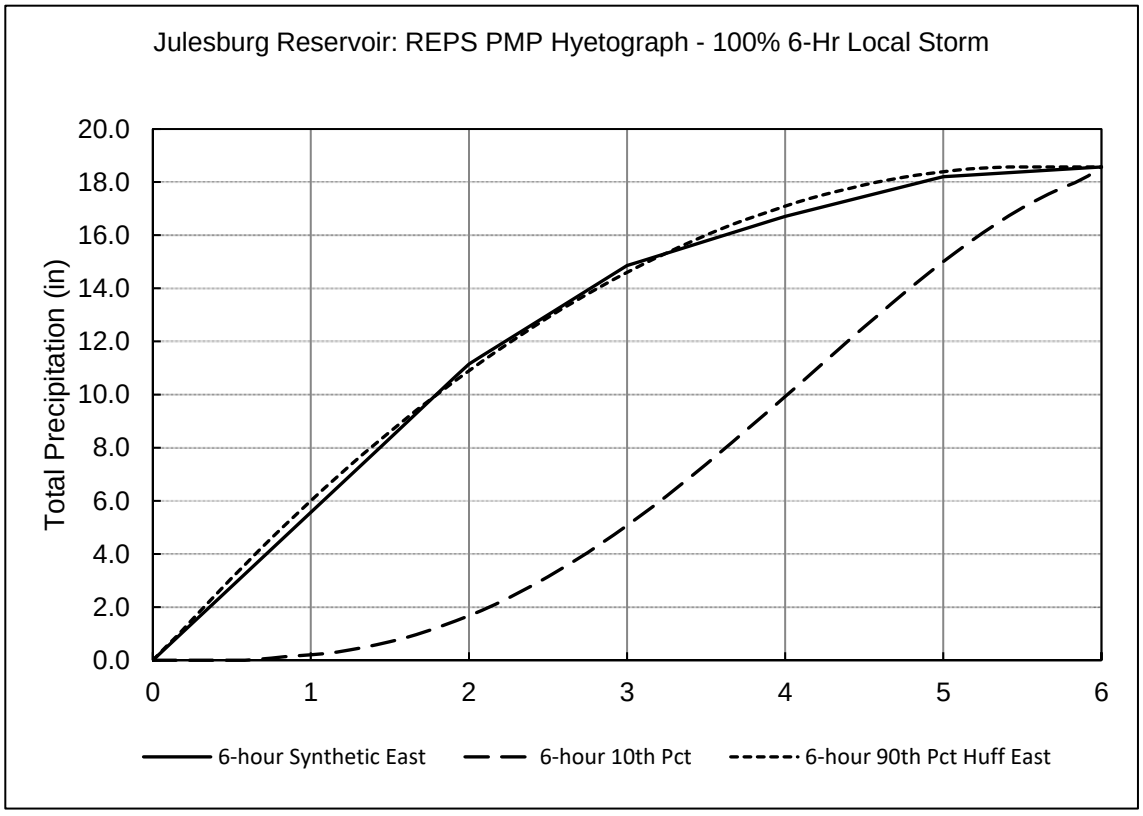
LS_Temporal_Distributions_24hr

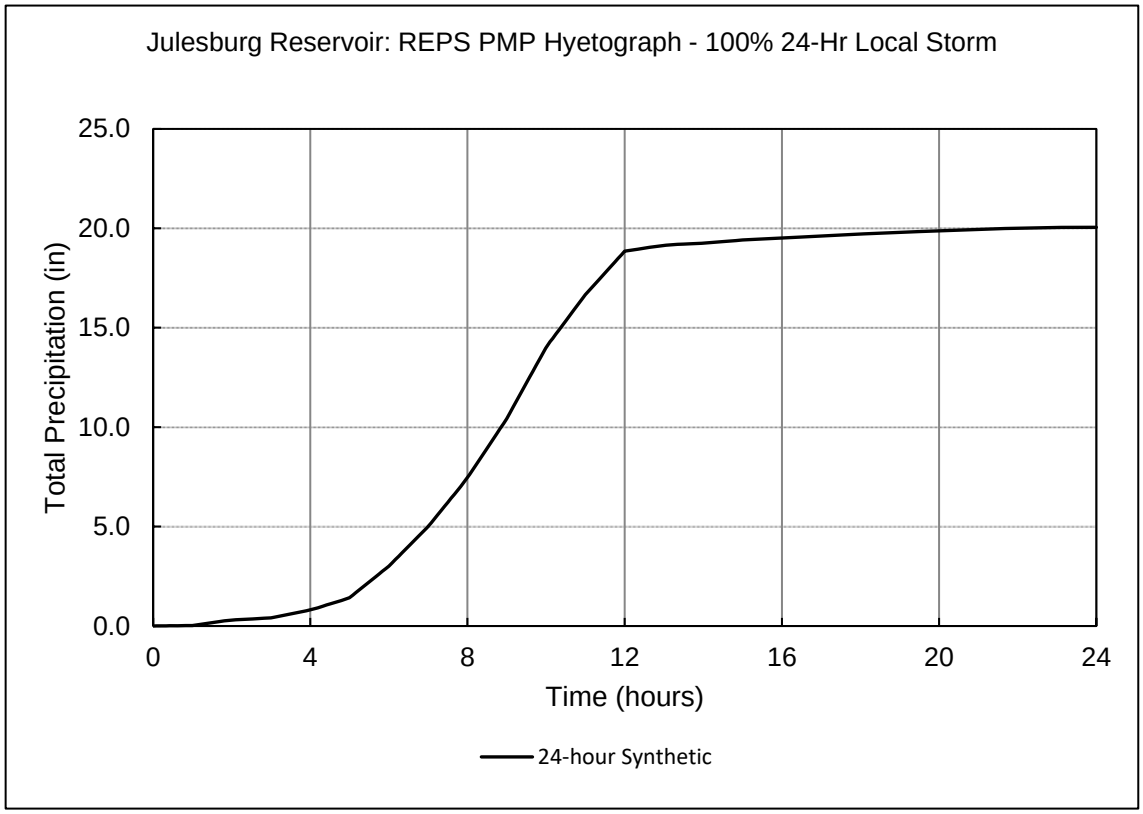
OBJECTID *	TIMESTEP	MINUTE	LS_24_hour_Synthetic_Hybrid
283	283	1415	20.042
284	284	1420	20.044
285	285	1425	20.046
286	286	1430	20.046
287	287	1435	20.048
288	288	1440	20.05

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			

Local Storms - Hyetograph Summary



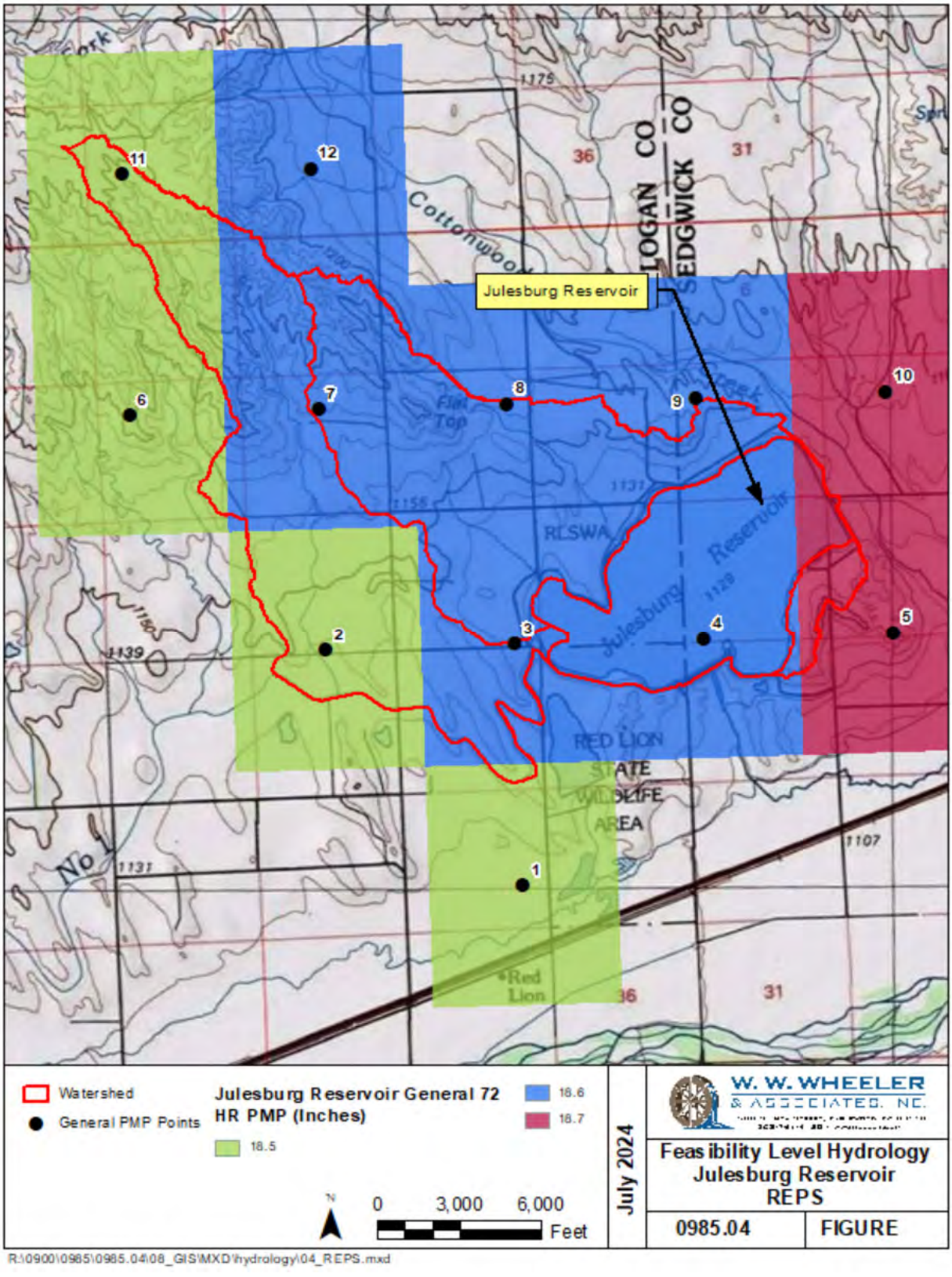




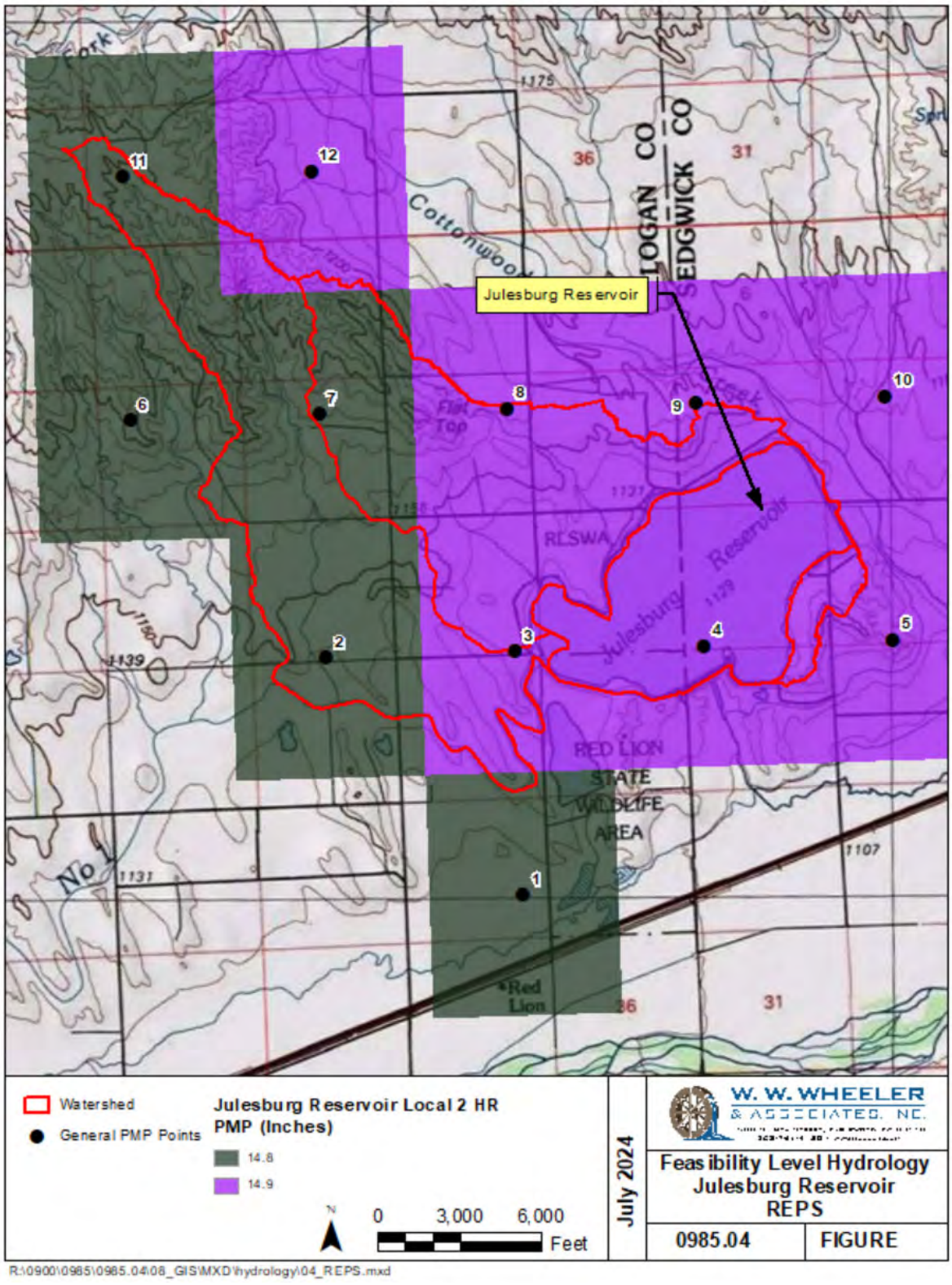
15. Gridded Precip Display:

a. Add 72 Hour REPS General Storm Raster:
GIS - Add data - General - PMP Geodatabase - Raster for 72 hour storm:
b. Add 2 Hour, 6 Hour, (and if applicable, 24 Hour) REPS Local Storm Raster:
GIS - Add data - Local - PMP Geodatabase - Raster for 72 hour storm:
c. Display the unique precip values:
Layer properties - Symbology - "Show:" Unique Values - Apply:
Layer properties - General - Layer Name - Identify Dam and Storm Type for Legend:
(Include storm duration (2, 6, 24, 72HR), Local or General, and units "Inches")
c. Format Legend
Legend properties - Items - select layer raster being displayed - Style :
d. Save new MXD - Print to PDF

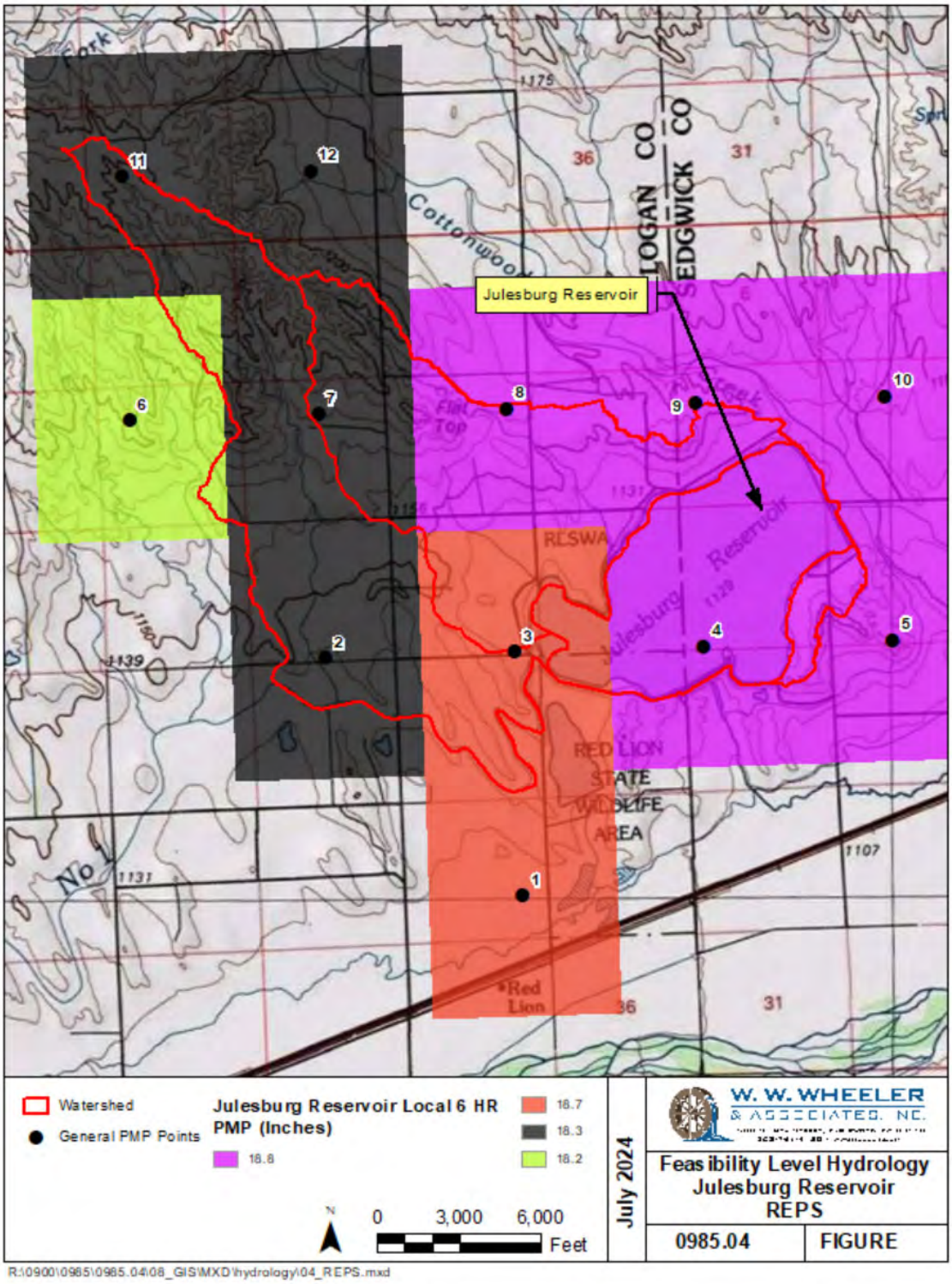
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers					
	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			



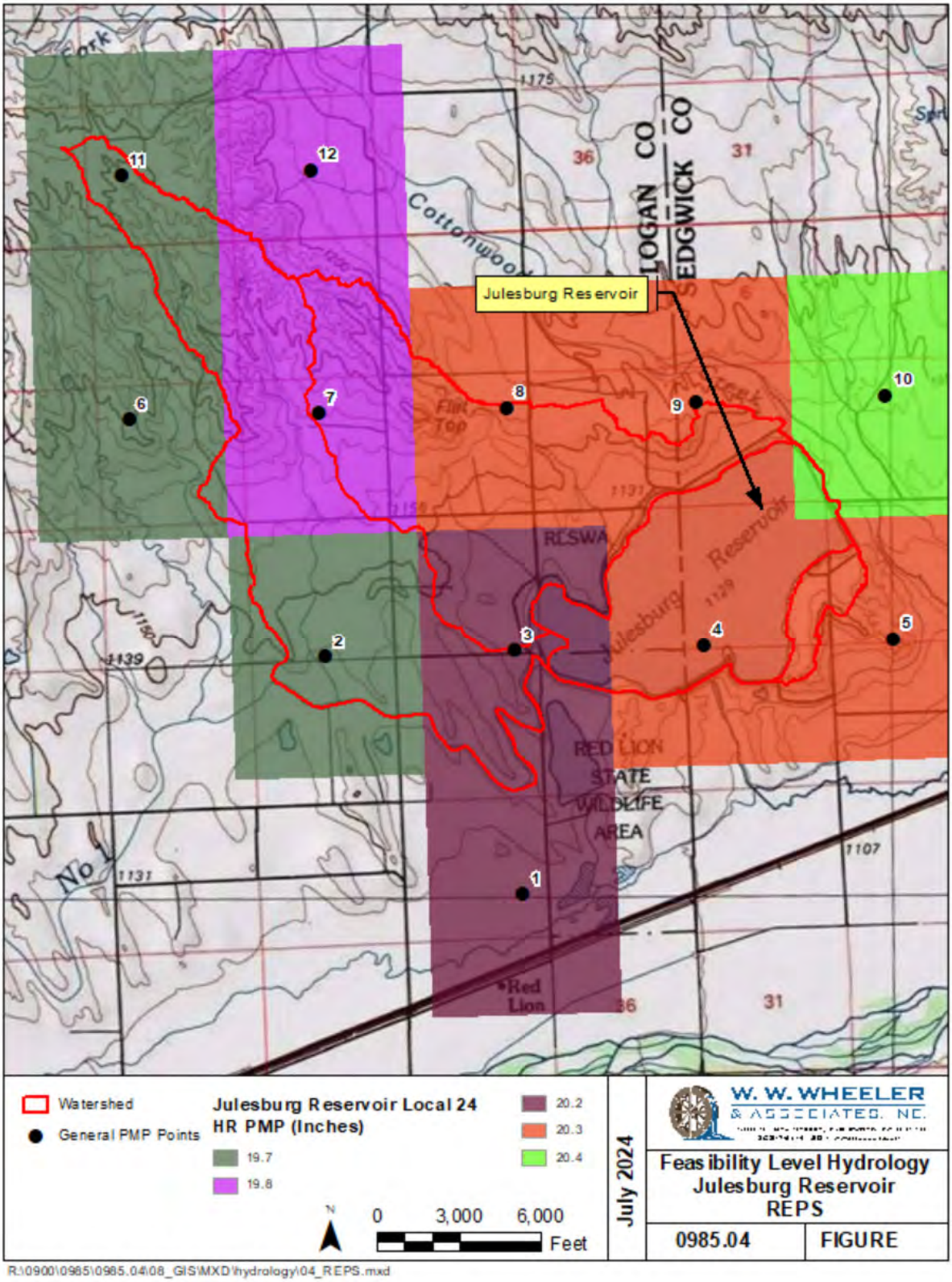
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers					
	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers					
	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers					
	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, REPS PMP	Approved			



16. Print PMP Points Attribute Tables for Each Storm Type:

Local_PMP_Points

LS PMP Points

OBJECTID *	Shape *	ID	POINT_X	POINT_Y	ELEV_FT	TRANS_ZONE	ELEV_ADJ	DIVIDE
1	Point	96146	-102.675	40.9	3648.294	1	1	East
2	Point	96491	-102.7	40.925	3734.894	1	1	East
3	Point	96492	-102.675	40.925	3716.55	1	1	East
4	Point	96493	-102.65	40.925	3707.553	1	1	East
5	Point	96494	-102.625	40.925	3709.493	1	1	East
6	Point	96837	-102.725	40.95	3941.893	1	1	East
7	Point	96838	-102.7	40.95	3862.453	1	1	East
8	Point	96839	-102.675	40.95	3802.887	1	1	East
9	Point	96840	-102.65	40.95	3780.913	1	1	East
10	Point	96841	-102.625	40.95	3734.048	1	1	East
11	Point	97185	-102.725	40.975	4073.666	1	1	East
12	Point	97186	-102.7	40.975	3892.403	1	1	East

PMP_01	PMP_02	PMP_03	PMP_04	PMP_05	PMP_06	PMP_12	PMP_24	Storm ID 01-hour
9.4	14.8	18.3	18.3	18.3	18.7	20.2	20.2	SPAS_1295_3
9.4	14.8	18.3	18.3	18.3	18.3	19.7	19.7	SPAS_1295_3
9.5	14.9	18.3	18.3	18.3	18.7	20.2	20.2	SPAS_1295_3
9.5	14.9	18.3	18.3	18.3	18.8	20.3	20.3	SPAS_1295_3
9.5	14.9	18.4	18.4	18.4	18.8	20.3	20.3	SPAS_1295_3
9.4	14.8	18.2	18.2	18.2	18.2	19.7	19.7	SPAS_1295_3
9.5	14.8	18.3	18.3	18.3	18.3	19.7	19.8	SPAS_1295_3
9.5	14.9	18.3	18.3	18.3	18.8	20.2	20.3	SPAS_1295_3
9.5	14.9	18.4	18.4	18.4	18.8	20.3	20.3	SPAS_1295_3
9.5	14.9	18.4	18.4	18.4	18.8	20.3	20.4	SPAS_1295_3
9.4	14.8	18.3	18.3	18.3	18.3	19.7	19.7	SPAS_1295_3
9.5	14.9	18.3	18.3	18.3	18.3	19.8	19.8	SPAS_1295_3

Storm ID 02-hour	Storm ID 03-hour	Storm ID 04-hour	Storm ID 05-hour	Storm ID 06-hour
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1036_1
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3
SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3	SPAS_1295_3

Local_PMP_Points (Cont)

Storm ID 12-hour	Storm ID 24-hour	Storm Name 01-hour	Storm Name 02-hour	Storm Name 03-hour
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935
SPAS_1036_1	SPAS_1036_1	Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935

Storm Name 04-hour	Storm Name 05-hour	Storm Name 06-hour	Storm Name 12-hour	Storm Name 24-hour
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997
Hale, CO - May, 1935	Hale, CO - May, 1935	Hale, CO - May, 1935	Pawnee Creek, CO - Jul, 1997	Pawnee Creek, CO - Jul, 1997

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	Precip Documentation, REPS PMP	Approved	

General Storm PMP Points

General PMP Points

OBJECTID *	Shape *	ID	POINT_X	POINT_Y	ELEV_FT	TRANS_ZONE	ELEV_ADJ	DIVIDE
1	Point	96146	-102.675	40.9	3648.294	1	1	East
2	Point	96491	-102.7	40.925	3734.894	1	1	East
3	Point	96492	-102.675	40.925	3716.55	1	1	East
4	Point	96493	-102.65	40.925	3707.553	1	1	East
5	Point	96494	-102.625	40.925	3709.493	1	1	East
6	Point	96837	-102.725	40.95	3941.893	1	1	East
7	Point	96838	-102.7	40.95	3862.453	1	1	East
8	Point	96839	-102.675	40.95	3802.887	1	1	East
9	Point	96840	-102.65	40.95	3780.913	1	1	East
10	Point	96841	-102.625	40.95	3734.048	1	1	East
11	Point	97185	-102.725	40.975	4073.666	1	1	East
12	Point	97186	-102.7	40.975	3892.403	1	1	East

PMP_01	PMP_06	PMP_12	PMP_24	PMP_48	PMP_72	Storm ID 01-hour	Storm ID 06-hour
3.3	8.3	12.3	15.7	17.9	18.5	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.3	15.7	17.9	18.5	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.4	15.8	17.9	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen
3.4	8.3	12.4	15.8	18	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen
3.4	8.3	12.4	15.8	18	18.7	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.2	12.3	15.7	17.9	18.5	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.4	15.8	17.9	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.4	15.8	17.9	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen
3.4	8.3	12.4	15.8	18	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen
3.4	8.3	12.4	15.9	18	18.7	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.4	15.7	17.9	18.5	SPAS_1560_1_gen	SPAS_1560_1_gen
3.3	8.3	12.4	15.8	17.9	18.6	SPAS_1560_1_gen	SPAS_1560_1_gen

Storm ID 12-hour	Storm ID 24-hour	Storm ID 48-hour	Storm ID 72-hour
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1
SPAS_1530_1	SPAS_1530_1	SPAS_1530_1	SPAS_1530_1

General Storm PMP Points (cont)

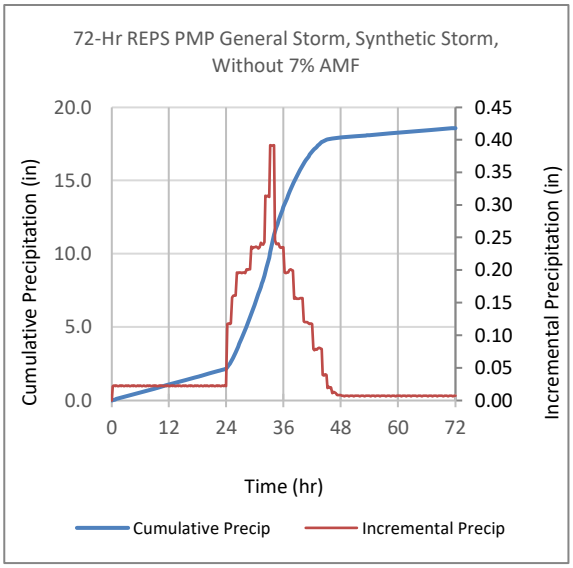
Storm ID 72-hour	Storm Name 01-hour	Storm Name 06-hour	Storm Name 12-hour
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013
SPAS_1530_1	Conway, TX - May, 1951	Conway, TX - May, 1951	Guadalupe Pass, TX - Sep, 2013

Storm Name 24-hour	Storm Name 48-hour	Storm Name 72-hour
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013
Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013	Guadalupe Pass, TX - Sep, 2013

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved			

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	--	**0.00000**
1	0.25	15	0.02200	**0.02200**
2	0.50	30	0.02300	**0.04500**
3	0.75	45	0.02200	**0.06700**
4	1.00	60	0.02300	**0.09000**
5	1.25	75	0.02200	**0.11200**
6	1.50	90	0.02200	**0.13400**
7	1.75	105	0.02300	**0.15700**
8	2.00	120	0.02200	**0.17900**
9	2.25	135	0.02300	**0.20200**
10	2.50	150	0.02200	**0.22400**
11	2.75	165	0.02200	**0.24600**
12	3.00	180	0.02300	**0.26900**
13	3.25	195	0.02200	**0.29100**
14	3.50	210	0.02300	**0.31400**
15	3.75	225	0.02200	**0.33600**
16	4.00	240	0.02200	**0.35800**
17	4.25	255	0.02300	**0.38100**
18	4.50	270	0.02200	**0.40300**
19	4.75	285	0.02300	**0.42600**
20	5.00	300	0.02200	**0.44800**
21	5.25	315	0.02200	**0.47000**
22	5.50	330	0.02300	**0.49300**
23	5.75	345	0.02200	**0.51500**
24	6.00	360	0.02300	**0.53800**
25	6.25	375	0.02200	**0.56000**
26	6.50	390	0.02200	**0.58200**
27	6.75	405	0.02300	**0.60500**
28	7.00	420	0.02200	**0.62700**
29	7.25	435	0.02200	**0.64900**
30	7.50	450	0.02300	**0.67200**
31	7.75	465	0.02200	**0.69400**
32	8.00	480	0.02300	**0.71700**
33	8.25	495	0.02200	**0.73900**
34	8.50	510	0.02200	**0.76100**
35	8.75	525	0.02300	**0.78400**
36	9.00	540	0.02200	**0.80600**



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
37	9.25	555	0.02300	**0.82900**
38	9.50	570	0.02200	**0.85100**
39	9.75	585	0.02200	**0.87300**
40	10.00	600	0.02300	**0.89600**
41	10.25	615	0.02200	**0.91800**
42	10.50	630	0.02300	**0.94100**
43	10.75	645	0.02200	**0.96300**
44	11.00	660	0.02200	**0.98500**
45	11.25	675	0.02300	**1.00800**
46	11.50	690	0.02200	**1.03000**
47	11.75	705	0.02300	**1.05300**
48	12.00	720	0.02200	**1.07500**
49	12.25	735	0.02200	**1.09700**
50	12.50	750	0.02300	**1.12000**
51	12.75	765	0.02200	**1.14200**
52	13.00	780	0.02300	**1.16500**
53	13.25	795	0.02200	**1.18700**
54	13.50	810	0.02200	**1.20900**
55	13.75	825	0.02300	**1.23200**
56	14.00	840	0.02200	**1.25400**
57	14.25	855	0.02300	**1.27700**
58	14.50	870	0.02200	**1.29900**
59	14.75	885	0.02200	**1.32100**
60	15.00	900	0.02300	**1.34400**
61	15.25	915	0.02200	**1.36600**
62	15.50	930	0.02300	**1.38900**
63	15.75	945	0.02200	**1.41100**
64	16.00	960	0.02200	**1.43300**
65	16.25	975	0.02300	**1.45600**
66	16.50	990	0.02200	**1.47800**
67	16.75	1005	0.02300	**1.50100**
68	17.00	1020	0.02200	**1.52300**
69	17.25	1035	0.02200	**1.54500**
70	17.50	1050	0.02300	**1.56800**
71	17.75	1065	0.02200	**1.59000**
72	18.00	1080	0.02300	**1.61300**
73	18.25	1095	0.02200	**1.63500**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
74	18.50	1110	0.02200	**1.65700**
75	18.75	1125	0.02300	**1.68000**
76	19.00	1140	0.02200	**1.70200**
77	19.25	1155	0.02200	**1.72400**
78	19.50	1170	0.02300	**1.74700**
79	19.75	1185	0.02200	**1.76900**
80	20.00	1200	0.02300	**1.79200**
81	20.25	1215	0.02200	**1.81400**
82	20.50	1230	0.02200	**1.83600**
83	20.75	1245	0.02300	**1.85900**
84	21.00	1260	0.02200	**1.88100**
85	21.25	1275	0.02300	**1.90400**
86	21.50	1290	0.02200	**1.92600**
87	21.75	1305	0.02200	**1.94800**
88	22.00	1320	0.02300	**1.97100**
89	22.25	1335	0.02200	**1.99300**
90	22.50	1350	0.02300	**2.01600**
91	22.75	1365	0.02200	**2.03800**
92	23.00	1380	0.02200	**2.06000**
93	23.25	1395	0.02300	**2.08300**
94	23.50	1410	0.02200	**2.10500**
95	23.75	1425	0.02300	**2.12800**
96	24.00	1440	0.02200	**2.15000**
97	24.25	1455	0.11700	**2.26700**
98	24.50	1470	0.11800	**2.38500**
99	24.75	1485	0.11700	**2.50200**
100	25.00	1500	0.11800	**2.62000**
101	25.25	1515	0.15800	**2.77800**
102	25.50	1530	0.16100	**2.93900**
103	25.75	1545	0.16100	**3.10000**
104	26.00	1560	0.16100	**3.26100**
105	26.25	1575	0.19600	**3.45700**
106	26.50	1590	0.19500	**3.65200**
107	26.75	1605	0.19600	**3.84800**
108	27.00	1620	0.19600	**4.04400**
109	27.25	1635	0.19500	**4.23900**
110	27.50	1650	0.19600	**4.43500**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
111	27.75	1665	0.19600	**4.63100**
112	28.00	1680	0.19500	**4.82600**
113	28.25	1695	0.20100	**5.02700**
114	28.50	1710	0.20000	**5.22700**
115	28.75	1725	0.20100	**5.42800**
116	29.00	1740	0.20100	**5.62900**
117	29.25	1755	0.23600	**5.86500**
118	29.50	1770	0.23300	**6.09800**
119	29.75	1785	0.23500	**6.33300**
120	30.00	1800	0.23500	**6.56800**
121	30.25	1815	0.23600	**6.80400**
122	30.50	1830	0.23500	**7.03900**
123	30.75	1845	0.23300	**7.27200**
124	31.00	1860	0.23500	**7.50700**
125	31.25	1875	0.24200	**7.74900**
126	31.50	1890	0.24000	**7.98900**
127	31.75	1905	0.23900	**8.22800**
128	32.00	1920	0.24300	**8.47100**
129	32.25	1935	0.31400	**8.78500**
130	32.50	1950	0.31300	**9.09800**
131	32.75	1965	0.31400	**9.41200**
132	33.00	1980	0.31200	**9.72400**
133	33.25	1995	0.39200	**10.11600**
134	33.50	2010	0.39100	**10.50700**
135	33.75	2025	0.39100	**10.89800**
136	34.00	2040	0.39200	**11.29000**
137	34.25	2055	0.24600	**11.53600**
138	34.50	2070	0.24000	**11.77600**
139	34.75	2085	0.24000	**12.01600**
140	35.00	2100	0.24100	**12.25700**
141	35.25	2115	0.23500	**12.49200**
142	35.50	2130	0.23400	**12.72600**
143	35.75	2145	0.23500	**12.96100**
144	36.00	2160	0.23500	**13.19600**
145	36.25	2175	0.19600	**13.39200**
146	36.50	2190	0.19500	**13.58700**
147	36.75	2205	0.19600	**13.78300**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
148	37.00	2220	0.19600	**13.97900**
149	37.25	2235	0.20000	**14.17900**
150	37.50	2250	0.20100	**14.38000**
151	37.75	2265	0.20000	**14.58000**
152	38.00	2280	0.19900	**14.77900**
153	38.25	2295	0.15600	**14.93500**
154	38.50	2310	0.15800	**15.09300**
155	38.75	2325	0.15600	**15.24900**
156	39.00	2340	0.15600	**15.40500**
157	39.25	2355	0.15600	**15.56100**
158	39.50	2370	0.15700	**15.71800**
159	39.75	2385	0.15700	**15.87500**
160	40.00	2400	0.15700	**16.03200**
161	40.25	2415	0.12100	**16.15300**
162	40.50	2430	0.12000	**16.27300**
163	40.75	2445	0.12000	**16.39300**
164	41.00	2460	0.12000	**16.51300**
165	41.25	2475	0.11800	**16.63100**
166	41.50	2490	0.11700	**16.74800**
167	41.75	2505	0.11800	**16.86600**
168	42.00	2520	0.11700	**16.98300**
169	42.25	2535	0.07900	**17.06200**
170	42.50	2550	0.07700	**17.13900**
171	42.75	2565	0.07900	**17.21800**
172	43.00	2580	0.07800	**17.29600**
173	43.25	2595	0.08000	**17.37600**
174	43.50	2610	0.08100	**17.45700**
175	43.75	2625	0.08000	**17.53700**
176	44.00	2640	0.07900	**17.61600**
177	44.25	2655	0.03900	**17.65500**
178	44.50	2670	0.03800	**17.69300**
179	44.75	2685	0.04000	**17.73300**
180	45.00	2700	0.03900	**17.77200**
181	45.25	2715	0.01900	**17.79100**
182	45.50	2730	0.02100	**17.81200**
183	45.75	2745	0.01900	**17.83100**
184	46.00	2760	0.02000	**17.85100**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
185	46.25	2775	0.01100	**17.86200**
186	46.50	2790	0.01300	**17.87500**
187	46.75	2805	0.01200	**17.88700**
188	47.00	2820	0.01100	**17.89800**
189	47.25	2835	0.00800	**17.90600**
190	47.50	2850	0.00800	**17.91400**
191	47.75	2865	0.00800	**17.92200**
192	48.00	2880	0.00800	**17.93000**
193	48.25	2895	0.00700	**17.93700**
194	48.50	2910	0.00700	**17.94400**
195	48.75	2925	0.00600	**17.95000**
196	49.00	2940	0.00700	**17.95700**
197	49.25	2955	0.00700	**17.96400**
198	49.50	2970	0.00700	**17.97100**
199	49.75	2985	0.00600	**17.97700**
200	50.00	3000	0.00700	**17.98400**
201	50.25	3015	0.00700	**17.99100**
202	50.50	3030	0.00700	**17.99800**
203	50.75	3045	0.00600	**18.00400**
204	51.00	3060	0.00700	**18.01100**
205	51.25	3075	0.00700	**18.01800**
206	51.50	3090	0.00700	**18.02500**
207	51.75	3105	0.00700	**18.03200**
208	52.00	3120	0.00600	**18.03800**
209	52.25	3135	0.00700	**18.04500**
210	52.50	3150	0.00700	**18.05200**
211	52.75	3165	0.00700	**18.05900**
212	53.00	3180	0.00600	**18.06500**
213	53.25	3195	0.00700	**18.07200**
214	53.50	3210	0.00700	**18.07900**
215	53.75	3225	0.00700	**18.08600**
216	54.00	3240	0.00700	**18.09300**
217	54.25	3255	0.00600	**18.09900**
218	54.50	3270	0.00700	**18.10600**
219	54.75	3285	0.00700	**18.11300**
220	55.00	3300	0.00700	**18.12000**
221	55.25	3315	0.00600	**18.12600**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
222	55.50	3330	0.00700	**18.13300**
223	55.75	3345	0.00700	**18.14000**
224	56.00	3360	0.00700	**18.14700**
225	56.25	3375	0.00600	**18.15300**
226	56.50	3390	0.00700	**18.16000**
227	56.75	3405	0.00700	**18.16700**
228	57.00	3420	0.00700	**18.17400**
229	57.25	3435	0.00700	**18.18100**
230	57.50	3450	0.00600	**18.18700**
231	57.75	3465	0.00700	**18.19400**
232	58.00	3480	0.00700	**18.20100**
233	58.25	3495	0.00700	**18.20800**
234	58.50	3510	0.00600	**18.21400**
235	58.75	3525	0.00700	**18.22100**
236	59.00	3540	0.00700	**18.22800**
237	59.25	3555	0.00700	**18.23500**
238	59.50	3570	0.00600	**18.24100**
239	59.75	3585	0.00700	**18.24800**
240	60.00	3600	0.00700	**18.25500**
241	60.25	3615	0.00700	**18.26200**
242	60.50	3630	0.00700	**18.26900**
243	60.75	3645	0.00600	**18.27500**
244	61.00	3660	0.00700	**18.28200**
245	61.25	3675	0.00700	**18.28900**
246	61.50	3690	0.00700	**18.29600**
247	61.75	3705	0.00600	**18.30200**
248	62.00	3720	0.00700	**18.30900**
249	62.25	3735	0.00700	**18.31600**
250	62.50	3750	0.00700	**18.32300**
251	62.75	3765	0.00600	**18.32900**
252	63.00	3780	0.00700	**18.33600**
253	63.25	3795	0.00700	**18.34300**
254	63.50	3810	0.00700	**18.35000**
255	63.75	3825	0.00700	**18.35700**
256	64.00	3840	0.00600	**18.36300**
257	64.25	3855	0.00700	**18.37000**
258	64.50	3870	0.00700	**18.37700**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - General Storm, 72 HR Synthetic West	Approved	

72-Hr General Storm, Synthetic Storm, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

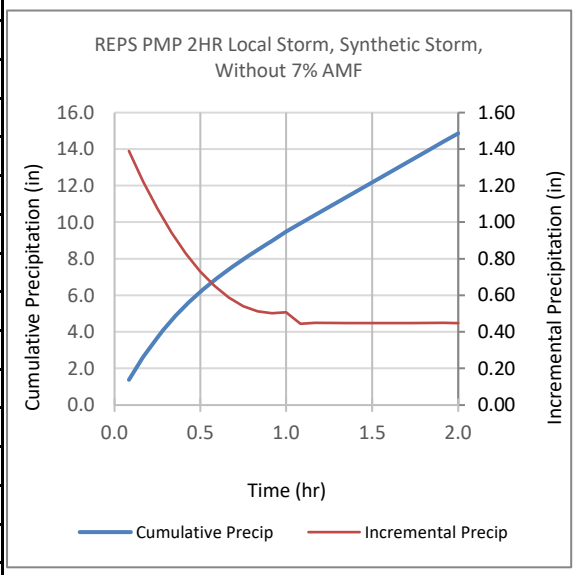
Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
259	64.75	3885	0.00700	**18.38400**
260	65.00	3900	0.00600	**18.39000**
261	65.25	3915	0.00700	**18.39700**
262	65.50	3930	0.00700	**18.40400**
263	65.75	3945	0.00700	**18.41100**
264	66.00	3960	0.00700	**18.41800**
265	66.25	3975	0.00600	**18.42400**
266	66.50	3990	0.00700	**18.43100**
267	66.75	4005	0.00700	**18.43800**
268	67.00	4020	0.00700	**18.44500**
269	67.25	4035	0.00600	**18.45100**
270	67.50	4050	0.00700	**18.45800**
271	67.75	4065	0.00700	**18.46500**
272	68.00	4080	0.00700	**18.47200**
273	68.25	4095	0.00600	**18.47800**
274	68.50	4110	0.00700	**18.48500**
275	68.75	4125	0.00700	**18.49200**
276	69.00	4140	0.00700	**18.49900**
277	69.25	4155	0.00700	**18.50600**
278	69.50	4170	0.00600	**18.51200**
279	69.75	4185	0.00700	**18.51900**
280	70.00	4200	0.00700	**18.52600**
281	70.25	4215	0.00700	**18.53300**
282	70.50	4230	0.00600	**18.53900**
283	70.75	4245	0.00700	**18.54600**
284	71.00	4260	0.00700	**18.55300**
285	71.25	4275	0.00700	**18.56000**
286	71.50	4290	0.00600	**18.56600**
287	71.75	4305	0.00700	**18.57300**
288	72.00	4320	0.00700	**18.58000**

72-Hr REPS PMP General Storm, Synthetic Storm, Without 7% AMF

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - Local Storm, 2 HR Stacked	Approved	

2-Hr Local Storm, Stacked, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

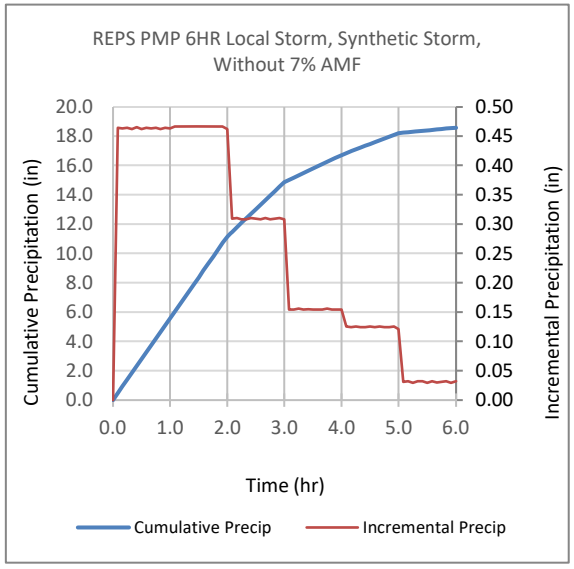
Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	--	**0.00000**
1	0.08	5	1.38900	**1.38900**
2	0.17	10	1.22300	**2.61200**
3	0.25	15	1.07400	**3.68600**
4	0.33	20	0.94200	**4.62800**
5	0.42	25	0.82700	**5.45500**
6	0.50	30	0.73000	**6.18500**
7	0.58	35	0.65000	**6.83500**
8	0.67	40	0.58700	**7.42200**
9	0.75	45	0.54100	**7.96300**
10	0.83	50	0.51300	**8.47600**
11	0.92	55	0.50100	**8.97700**
12	1.00	60	0.50700	**9.48400**
13	1.08	65	0.44400	**9.92800**
14	1.17	70	0.44900	**10.37700**
15	1.25	75	0.44800	**10.82500**
16	1.33	80	0.44800	**11.27300**
17	1.42	85	0.44900	**11.72200**
18	1.50	90	0.44800	**12.17000**
19	1.58	95	0.44800	**12.61800**
20	1.67	100	0.44900	**13.06700**
21	1.75	105	0.44800	**13.51500**
22	1.83	110	0.44800	**13.96300**
23	1.92	115	0.44900	**14.41200**
24	2.00	120	0.44800	**14.86000**



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	REPS Temporal - Local Storm, 6 HR Synthetic West	Approved			

6-Hr Local Storm, Synthetic, REPS Probable Maximum Precipitation
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	--	**0.00000**
1	0.08	5	0.46400	**0.46400**
2	0.17	10	0.46300	**0.92700**
3	0.25	15	0.46400	**1.39100**
4	0.33	20	0.46200	**1.85300**
5	0.42	25	0.46500	**2.31800**
6	0.50	30	0.46200	**2.78000**
7	0.58	35	0.46400	**3.24400**
8	0.67	40	0.46300	**3.70700**
9	0.75	45	0.46400	**4.17100**
10	0.83	50	0.46200	**4.63300**
11	0.92	55	0.46400	**5.09700**
12	1.00	60	0.46300	**5.56000**
13	1.08	65	0.46600	**6.02600**
14	1.17	70	0.46600	**6.49200**
15	1.25	75	0.46600	**6.95800**
16	1.33	80	0.46600	**7.42400**
17	1.42	85	0.46600	**7.89000**
18	1.50	90	0.46700	**8.35700**
19	1.58	95	0.46600	**8.82300**
20	1.67	100	0.46600	**9.28900**
21	1.75	105	0.46600	**9.75500**
22	1.83	110	0.46600	**10.22100**
23	1.92	115	0.46600	**10.68700**
24	2.00	120	0.46200	**11.14900**
25	2.08	125	0.30900	**11.45800**
26	2.17	130	0.31000	**11.76800**
27	2.25	135	0.30800	**12.07600**
28	2.33	140	0.30800	**12.38400**
29	2.42	145	0.31000	**12.69400**
30	2.50	150	0.30900	**13.00300**
31	2.58	155	0.30800	**13.31100**
32	2.67	160	0.31000	**13.62100**
33	2.75	165	0.30800	**13.92900**
34	2.83	170	0.30900	**14.23800**
35	2.92	175	0.31000	**14.54800**
36	3.00	180	0.30800	**14.85600**



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - Local Storm, 6 HR Synthetic West	Approved	

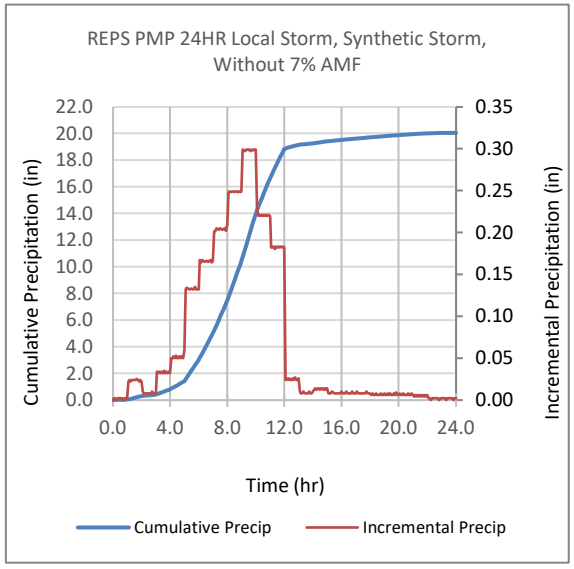
6-Hr Local Storm, Synthetic, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
37	3.08	185	0.15400	**15.01000**
38	3.17	190	0.15400	**15.16400**
39	3.25	195	0.15600	**15.32000**
40	3.33	200	0.15400	**15.47400**
41	3.42	205	0.15500	**15.62900**
42	3.50	210	0.15400	**15.78300**
43	3.58	215	0.15400	**15.93700**
44	3.67	220	0.15400	**16.09100**
45	3.75	225	0.15600	**16.24700**
46	3.83	230	0.15400	**16.40100**
47	3.92	235	0.15400	**16.55500**
48	4.00	240	0.15400	**16.70900**
49	4.08	245	0.12500	**16.83400**
50	4.17	250	0.12400	**16.95800**
51	4.25	255	0.12500	**17.08300**
52	4.33	260	0.12400	**17.20700**
53	4.42	265	0.12400	**17.33100**
54	4.50	270	0.12500	**17.45600**
55	4.58	275	0.12400	**17.58000**
56	4.67	280	0.12500	**17.70500**
57	4.75	285	0.12400	**17.82900**
58	4.83	290	0.12400	**17.95300**
59	4.92	295	0.12500	**18.07800**
60	5.00	300	0.12100	**18.19900**
61	5.08	305	0.03100	**18.23000**
62	5.17	310	0.03200	**18.26200**
63	5.25	315	0.02900	**18.29100**
64	5.33	320	0.03200	**18.32300**
65	5.42	325	0.03200	**18.35500**
66	5.50	330	0.02900	**18.38400**
67	5.58	335	0.03200	**18.41600**
68	5.67	340	0.03000	**18.44600**
69	5.75	345	0.03100	**18.47700**
70	5.83	350	0.03200	**18.50900**
71	5.92	355	0.02900	**18.53800**
72	6.00	360	0.03200	**18.57000**

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	REPS Temporal - Local Storm, 6 HR Synthetic West	Approved			

6-Hr Local Storm, Synthetic, REPS Probable Maximum Precipitation
Without 7% "Atmospheric Moisture Factor"

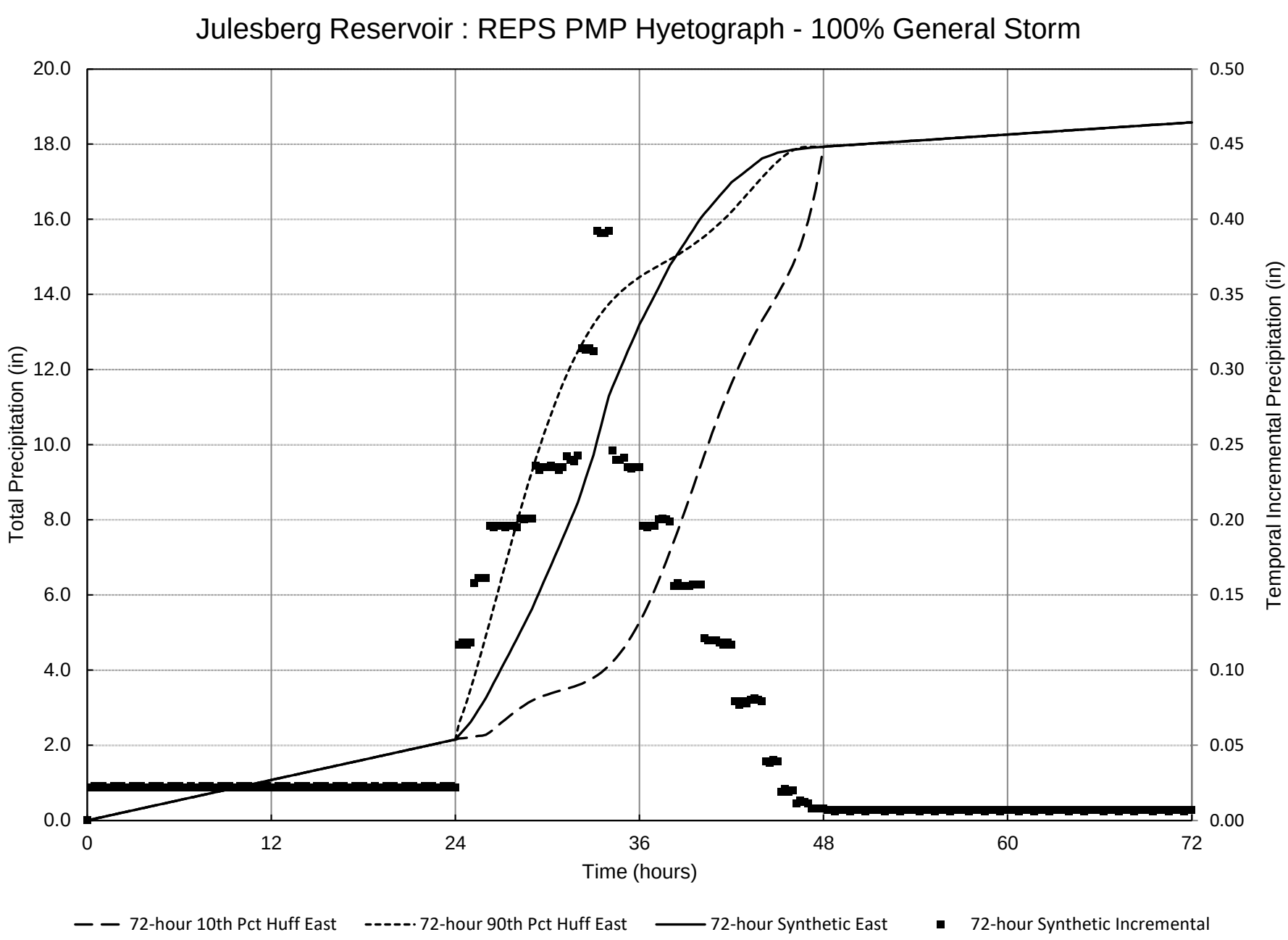
Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	--
1	0.08	5	0.00200	**0.00200**
2	0.17	10	0.00400	**0.00200**
3	0.25	15	0.00400	**0.00000**
4	0.33	20	0.00600	**0.00200**
5	0.42	25	0.00800	**0.00200**
6	0.50	30	0.01000	**0.00200**
7	0.58	35	0.01200	**0.00200**
8	0.67	40	0.01400	**0.00200**
9	0.75	45	0.01400	**0.00000**
10	0.83	50	0.01600	**0.00200**
11	0.92	55	0.01800	**0.00200**
12	1.00	60	0.02000	**0.00200**
13	1.08	65	0.04200	**0.02200**
14	1.17	70	0.06600	**0.02400**
15	1.25	75	0.08800	**0.02200**
16	1.33	80	0.11200	**0.02400**
17	1.42	85	0.13600	**0.02400**
18	1.50	90	0.16000	**0.02400**
19	1.58	95	0.18400	**0.02400**
20	1.67	100	0.20900	**0.02500**
21	1.75	105	0.23300	**0.02400**
22	1.83	110	0.25500	**0.02200**
23	1.92	115	0.27900	**0.02400**
24	2.00	120	0.30100	**0.02200**
25	2.08	125	0.31100	**0.01000**
26	2.17	130	0.31900	**0.00800**
27	2.25	135	0.32700	**0.00800**
28	2.33	140	0.33500	**0.00800**
29	2.42	145	0.34300	**0.00800**
30	2.50	150	0.35100	**0.00800**
31	2.58	155	0.35900	**0.00800**
32	2.67	160	0.36700	**0.00800**
33	2.75	165	0.37700	**0.01000**
34	2.83	170	0.38500	**0.00800**
35	2.92	175	0.39300	**0.00800**
36	3.00	180	0.40100	**0.00800**

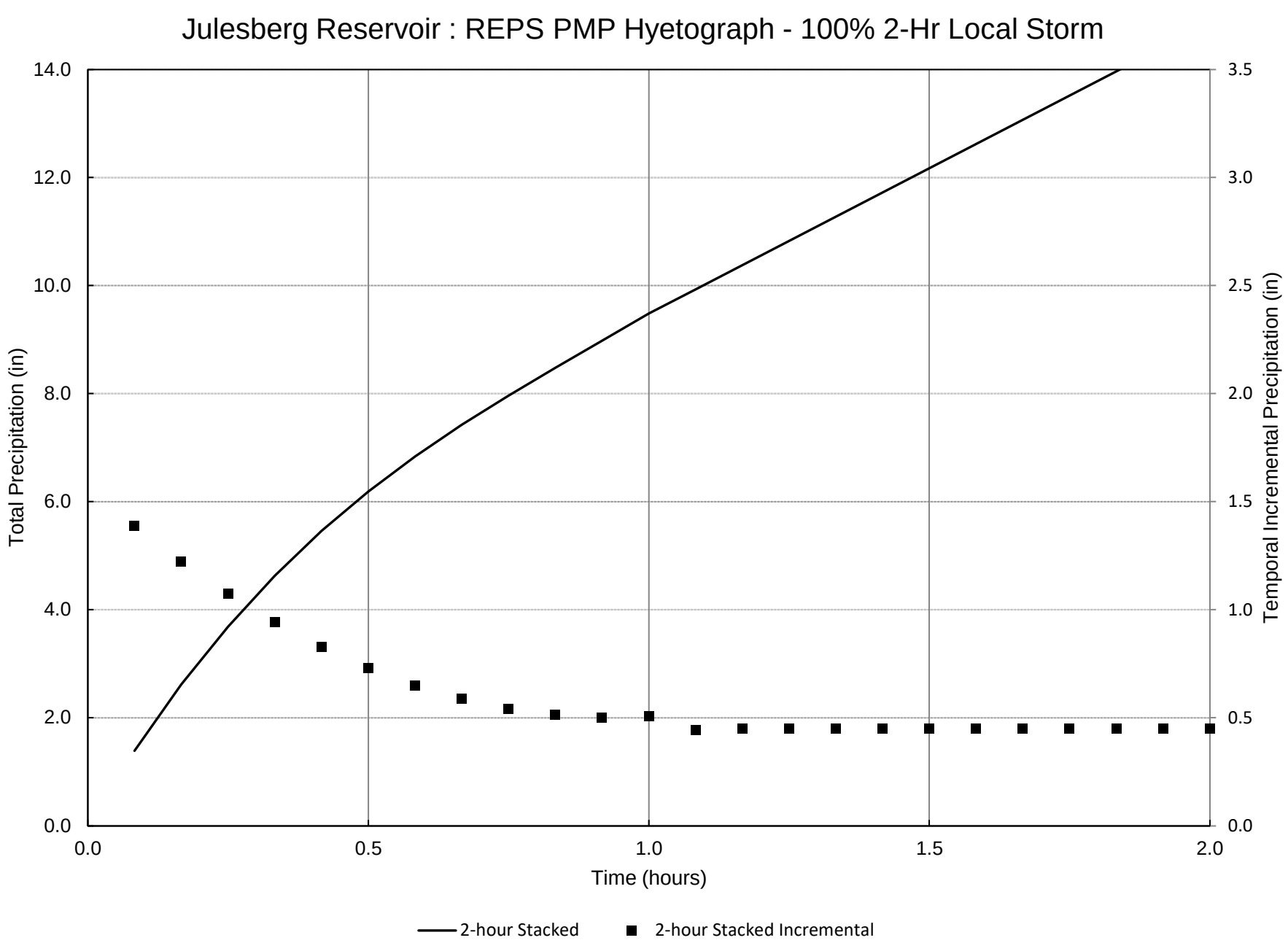


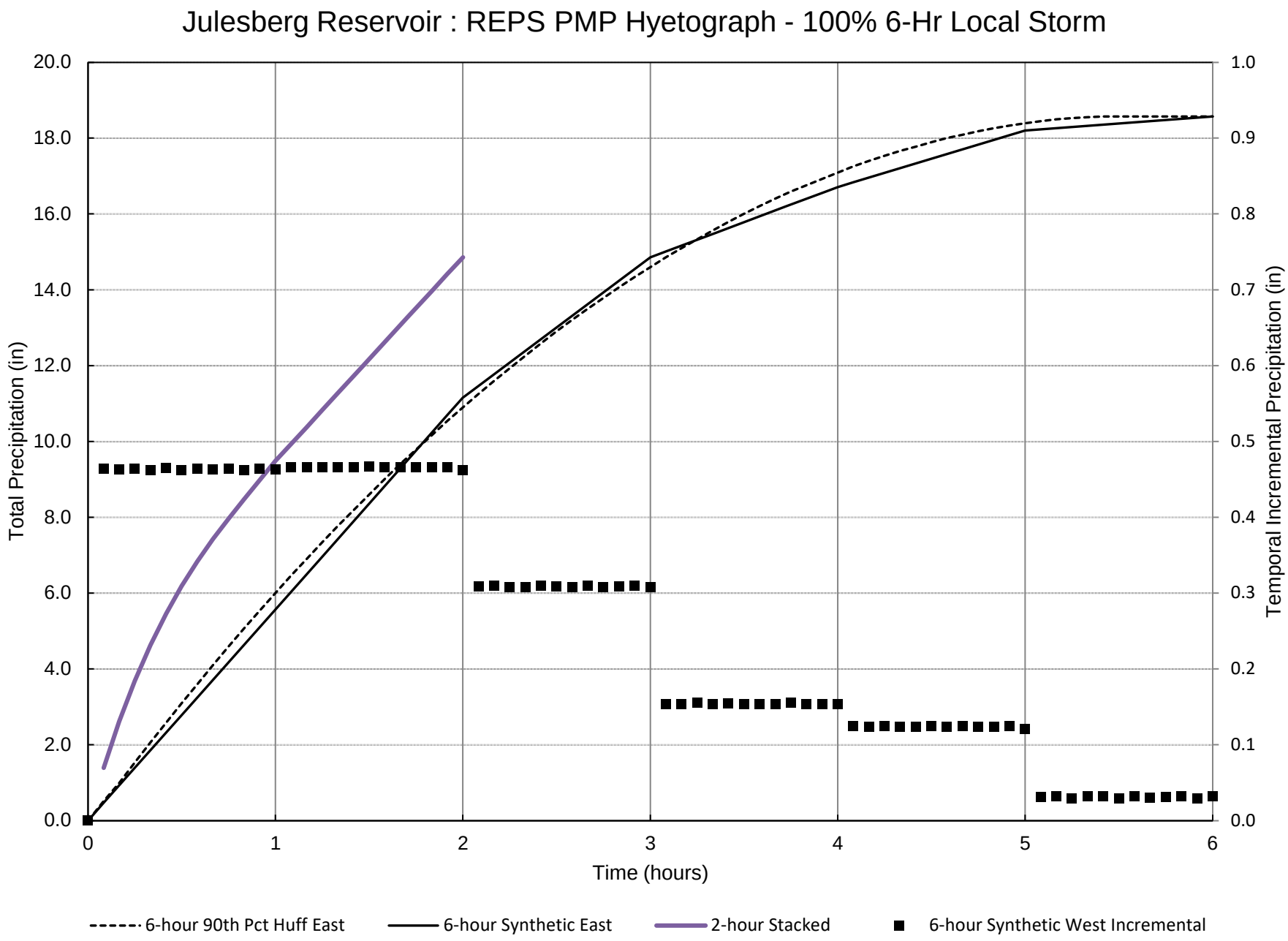
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	REPS Temporal - Local Storm, 6 HR Synthetic West	Approved	

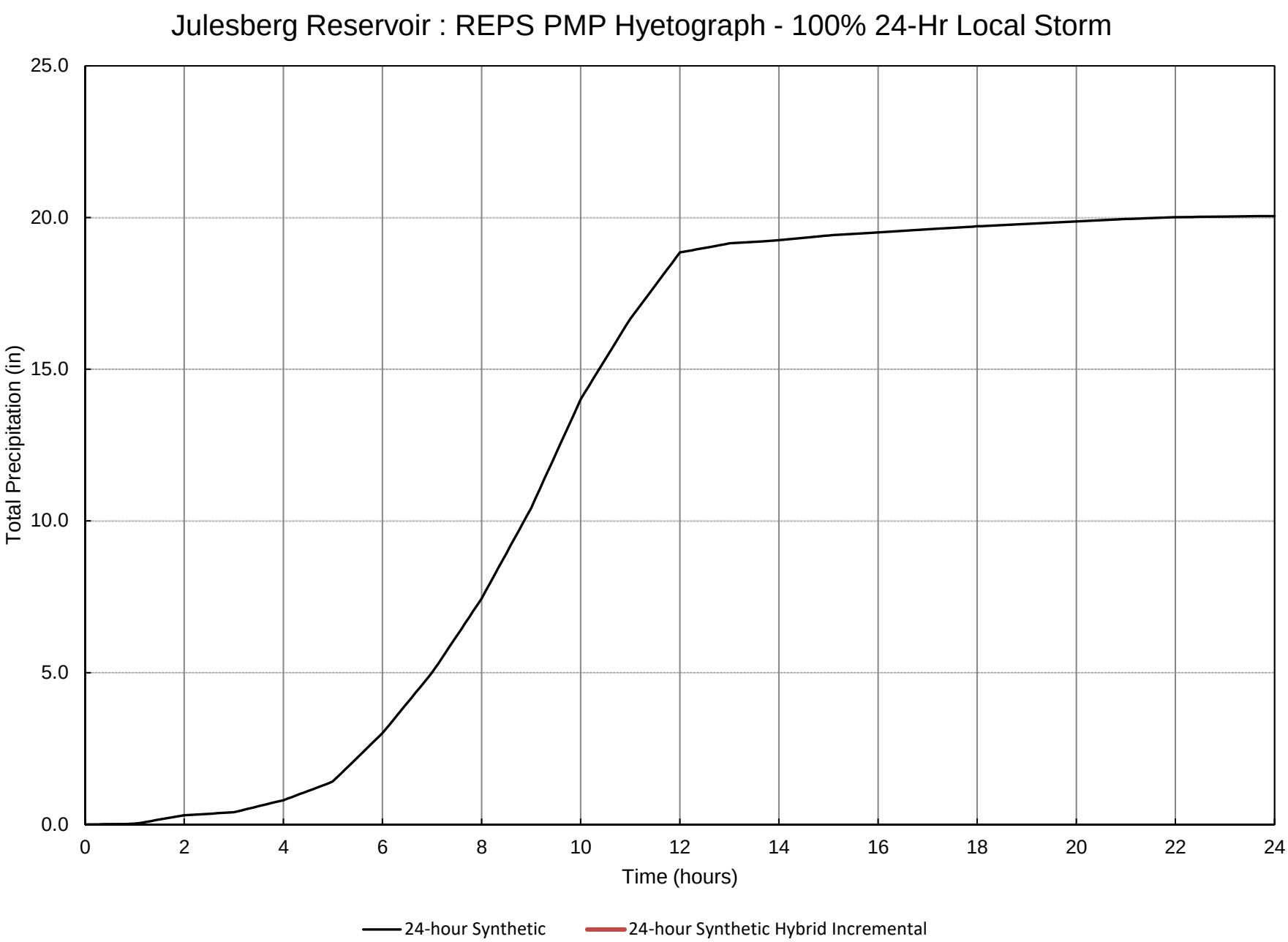
6-Hr Local Storm, Synthetic, REPS Probable Maximum Precipitation Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
37	3.08	185	0.43500	**0.03400**
38	3.17	190	0.46700	**0.03200**
39	3.25	195	0.50100	**0.03400**
40	3.33	200	0.53300	**0.03200**
41	3.42	205	0.56700	**0.03400**
42	3.50	210	0.59900	**0.03200**
43	3.58	215	0.63400	**0.03500**
44	3.67	220	0.66600	**0.03200**
45	3.75	225	0.70000	**0.03400**
46	3.83	230	0.73200	**0.03200**
47	3.92	235	0.76600	**0.03400**
48	4.00	240	0.79800	**0.03200**
49	4.08	245	0.84800	**0.05000**
50	4.17	250	0.89800	**0.05000**
51	4.25	255	0.95000	**0.05200**
52	4.33	260	1.00000	**0.05000**
53	4.42	265	1.05300	**0.05300**
54	4.50	270	1.10300	**0.05000**
55	4.58	275	1.15300	**0.05000**
56	4.67	280	1.20500	**0.05200**
57	4.75	285	1.25500	**0.05000**
58	4.83	290	1.30700	**0.05200**
59	4.92	295	1.35700	**0.05000**
60	5.00	300	1.41600	**0.05900**
61	5.08	305	1.54800	**0.13200**
62	5.17	310	1.68200	**0.13400**
63	5.25	315	1.81500	**0.13300**
64	5.33	320	1.94700	**0.13200**
65	5.42	325	2.07900	**0.13200**
66	5.50	330	2.21200	**0.13300**
67	5.58	335	2.34400	**0.13200**
68	5.67	340	2.47600	**0.13200**
69	5.75	345	2.61100	**0.13500**
70	5.83	350	2.74300	**0.13200**
71	5.92	355	2.87500	**0.13200**
72	6.00	360	3.00700	**0.13200**


Julesberg Reservoir : REPS PMP Hyetograph - 100% General Storm
Total Precipitation (in)
Temporal Incremental Precipitation (in)
Time (hours)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
12
24
36
48
60
72
72-hour 10th Pct Huff East
72-hour 90th Pct Huff East
72-hour Synthetic East
72-hour Synthetic Incremental


Julesberg Reservoir : REPS PMP Hyetograph - 100% 2-Hr Local Storm
Total Precipitation (in)
Temporal Incremental Precipitation (in)
Time (hours)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
0.5
1.0
1.5
2.5
3.0
3.5
2-hour Stacked
2-hour Stacked Incremental


Julesberg Reservoir : REPS PMP Hyetograph - 100% 6-Hr Local Storm
Total Precipitation (in)
Temporal Incremental Precipitation (in)
Time (hours)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
6-hour 90th Pct Huff East
6-hour Synthetic East
2-hour Stacked
6-hour Synthetic West Incremental


Julesberg Reservoir : REPS PMP Hyetograph - 100% 24-Hr Local Storm
Total Precipitation (in)
25.0
20.0
15.0
10.0
5.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (hours)
24-hour Synthetic
24-hour Synthetic Hybrid Incremental

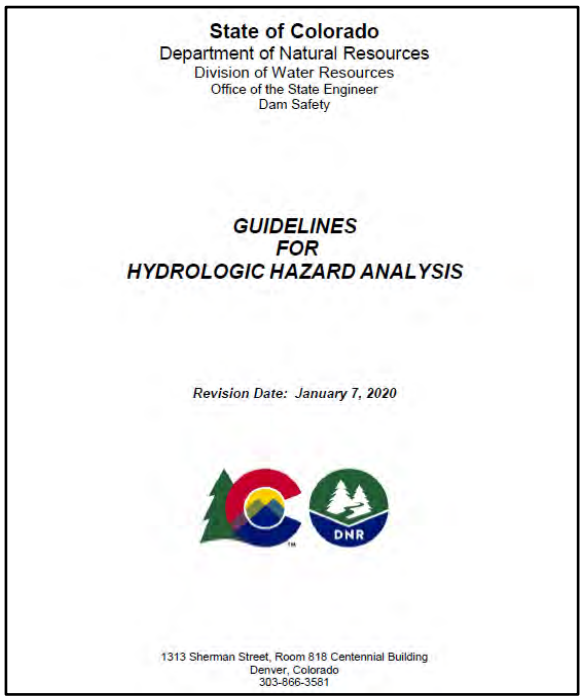
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal F	Approved			

OBJECTIVE:

Document the precipitation development for the Frequency Storms (FS) using MetPortal.

METHOD:

1. Follow Guidance from the DWR's Guidelines for Hydrologic Hazard, Section 2.
   Colorado Division of Water Resources, Dam Safety Branch (DWR, 2020-3), ***Guidelines for Hydrologic Hazard Analysis*** , January 7, 2020.

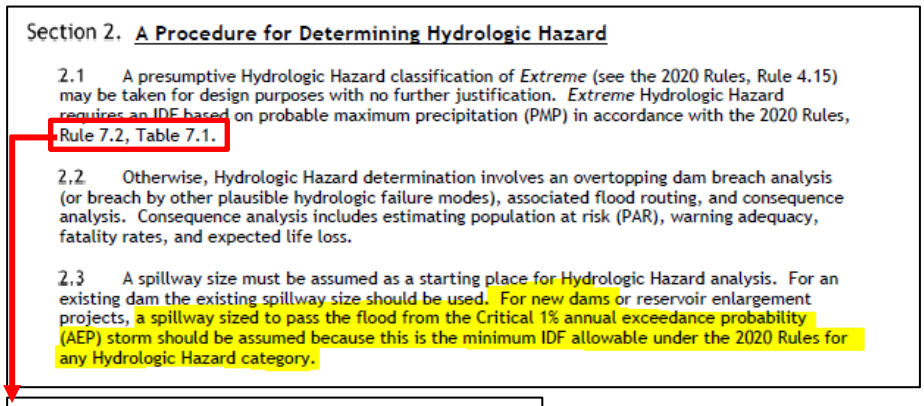


State of Colorado
Department of Natural Resources
Division of Water Resources
Office of the State Engineer
Dam Safety

GUIDELINES
FOR
HYDROLOGIC HAZARD ANALYSIS

Revision Date: January 7, 2020

1313 Sherman Street, Room 818 Centennial Building
Denver, Colorado
303-866-3581



Section 2. **A Procedure for Determining Hydrologic Hazard**

2.1 A presumptive Hydrologic Hazard classification of *Extreme* (see the 2020 Rules, Rule 4.15) may be taken for design purposes with no further justification. *Extreme* Hydrologic Hazard requires an IDF based on probable maximum precipitation (PMP) in accordance with the 2020 Rules, Rule 7.2, Table 7.1.

2.2 Otherwise, Hydrologic Hazard determination involves an overtopping dam breach analysis (or breach by other plausible hydrologic failure modes), associated flood routing, and consequence analysis. Consequence analysis includes estimating population at risk (PAR), warning adequacy, fatality rates, and expected life loss.

2.3 A spillway size must be assumed as a starting place for Hydrologic Hazard analysis. For an existing dam the existing spillway size should be used. For new dams or reservoir enlargement projects, a spillway sized to pass the flood from the Critical 1% annual exceedance probability (AEP) storm should be assumed because this is the minimum IDF allowable under the 2020 Rules for any Hydrologic Hazard category.

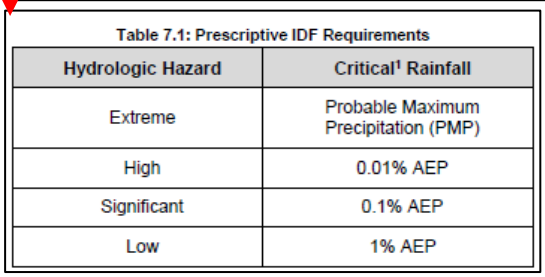


Table 7.1: Prescriptive IDF Requirements

Hydrologic Hazard	Critical[1] Rainfall
Extreme	Probable Maximum Precipitation (PMP)
High	0.01% AEP
Significant	0.1% AEP
Low	1% AEP

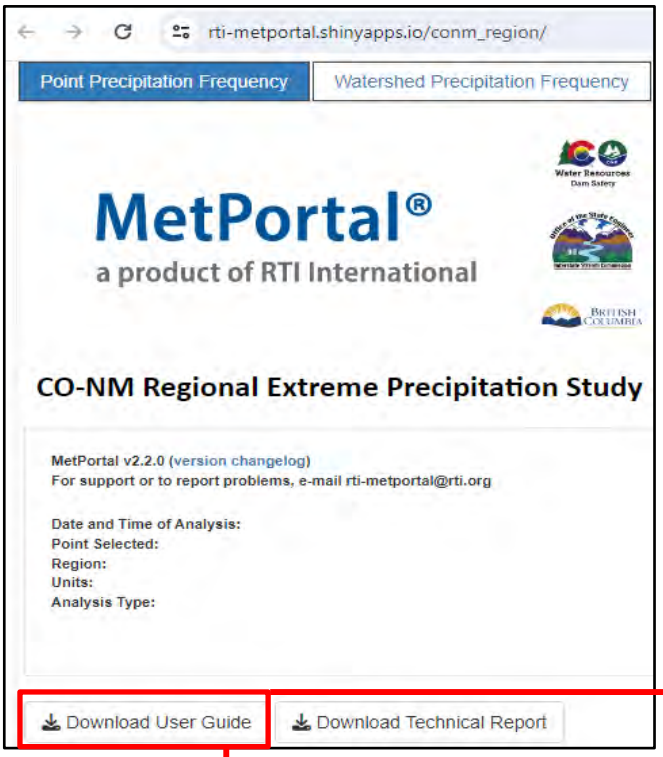
Other Notation

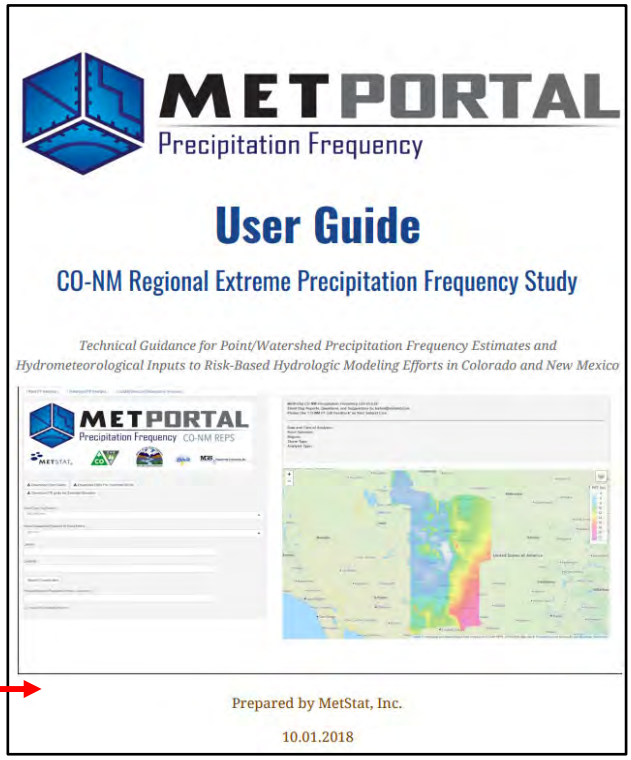
AEP		ARI (yr)
10^-4	1E-04	10,000
10^-3	1E-03	1,000
10^-2	1E-02	100

2. Launch the CO-NM REPS Precipitation Frequency on-line tool MetPortal.

MetPortal Online Tool: Version 2.2.0

Website: https://rti-metportal.shinyapps.io/conm_region/





User Guide:

MetStat, Inc., (MetStat, 2018) ***MetPortal Precipitation Frequency User Guide CO-NM Regional Extreme Precipitation Frequency Study*** , Revised 01/01/2018.

MetPortal is a web-based tool that generates point and watershed precipitation frequency estimates for the following storm types:

- Local Storms (LS), calculated from annual maximum series at 2-hr durations
- Mesoscale with Embedded Convection (MEC) storms, calculated from annual maximum series at 6-hr durations
- Midlatitude Cyclone/Tropical Storm Remnants (MLC/TSR), calculated from annual maximum series at 48-hr durations

For Julesberg Reservoir, the Point Precipitation Frequency was used, which does not apply an Areal Reduction Factor (ARF). The point based precipitation frequency interface is intended for watersheds of 50 mi^2 or less, which applies to this basin with a total basin area of 10.36 mi^2 .

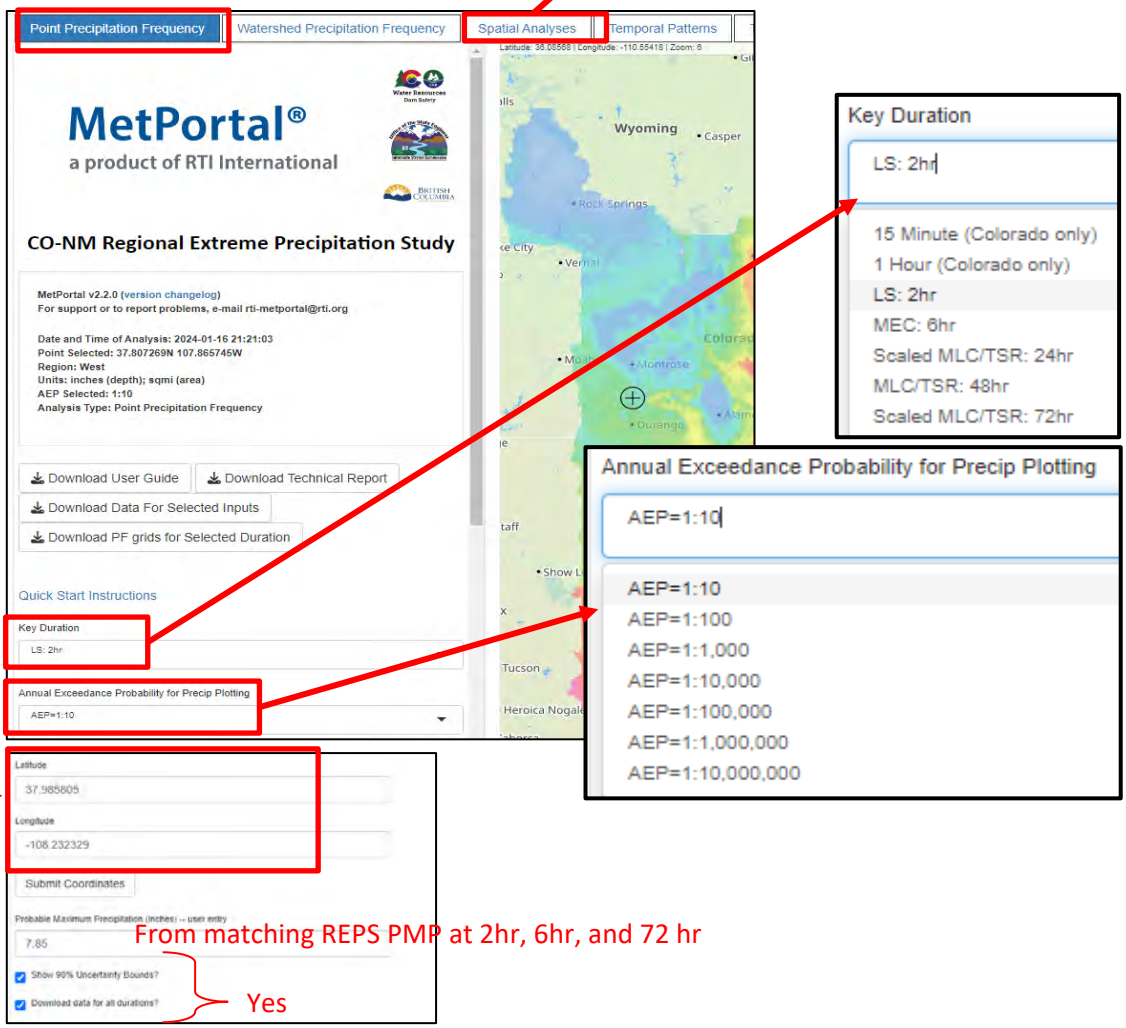
3. Provide the required GUI entries and run the on-line MetPortal tool.
   a. The calculated centroid of the whole watershed was used for the point precipitation estimate:

Latitude	40.93975
Longitude	-102.67966

Results were obtained for seven (unscaled) storm types and subsequent Annual Exceedance Probabilities (AEP) shown in the expanded dropdown menus below:

AEP		ARI (yr)
10^1	1E-01	10
10^-2	1E-02	100
10^-3	1E-03	1,000
10^-4	1E-04	10,000
10^-5	1E-05	100,000
10^-6	1E-06	1,000,000
10^-7	1E-07	10,000,000

See Step 5.



From matching REPS PMP at 2hr, 6hr, and 72 hr

Yes

4. MetPortal Watershed Precipitation Frequency Results
   a. The table summary below was re-created directly from the MetPortal "Point Precipitation Frequency Interface".

NOTE: The values for the 2-hr and 48-hr storms are the cumulative values at exactly **2 and 48 hrs**. The temporal analysis which provides the Hyetograph for HEC-HMS entry extended beyond 2 and 48 hrs, resulting in slightly higher total precipitation depths which are reflected in the HEC-HMS rainfall-runoff modeling.

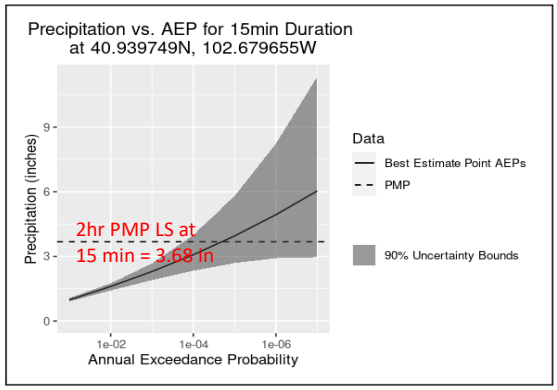
MetPortal **Point Precipitation Frequency** Summary Table

AEP (yr)	ARI (yr)	15-min Storm (in)	1-hr Storm (in)	2-hr Local Storm[1] (in)	6-hr MEC storm[2] (in)	48-hr MLC/TSR (in)
1E-01	10	0.98	1.72	1.97	2.20	3.33
1E-02	100	1.61	2.82	3.22	3.52	5.08
1E-03	1,000	2.30	4.03	4.61	5.04	6.92
1E-04	10,000	3.08	5.39	6.18	6.83	8.87
1E-05	100,000	3.95	6.93	7.93	8.93	10.95
1E-06	1,000,000	4.93	8.65	9.91	11.40	13.16
1E-07	10,000,000	6.04	10.59	12.129	14.306	15.50

NOTE
1. LS areal coverage is typically less than 50 mi^2 , ***approximately 10X Total Basin***
2. MEC storm types can produce large floods on intermediate size watersheds of less than 1,000 mi^2

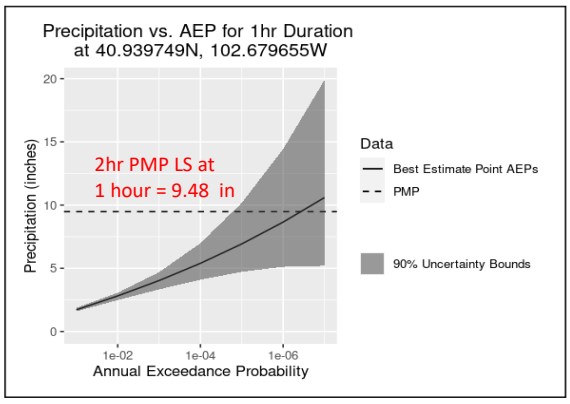
Precipitation (inches) for 15min Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	0.91	0.98	1.07
AEP=1:100	1.42	1.61	1.75
AEP=1:1,000	1.90	2.30	2.67
AEP=1:10,000	2.34	3.08	3.98
AEP=1:100,000	2.69	3.95	5.80
AEP=1:1,000,000	2.92	4.93	8.23
AEP=1:10,000,000	2.96	6.04	11.34



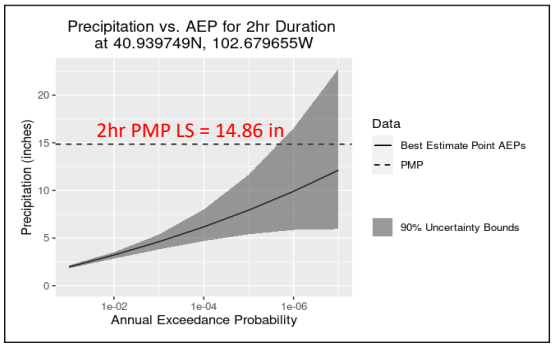
Precipitation (inches) for 1hr Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	1.60	1.72	1.87
AEP=1:100	2.49	2.82	3.07
AEP=1:1,000	3.33	4.03	4.69
AEP=1:10,000	4.10	5.39	6.99
AEP=1:100,000	4.72	6.93	10.18
AEP=1:1,000,000	5.12	8.65	14.43
AEP=1:10,000,000	5.20	10.59	19.89



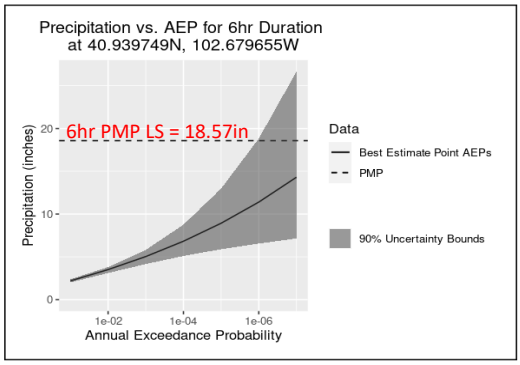
Precipitation (inches) for 2hr Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	1.83	1.97	2.14
AEP=1:100	2.85	3.22	3.51
AEP=1:1,000	3.81	4.61	5.37
AEP=1:10,000	4.69	6.18	8.00
AEP=1:100,000	5.40	7.93	11.65
AEP=1:1,000,000	5.86	9.91	16.52
AEP=1:10,000,000	5.95	12.13	22.77



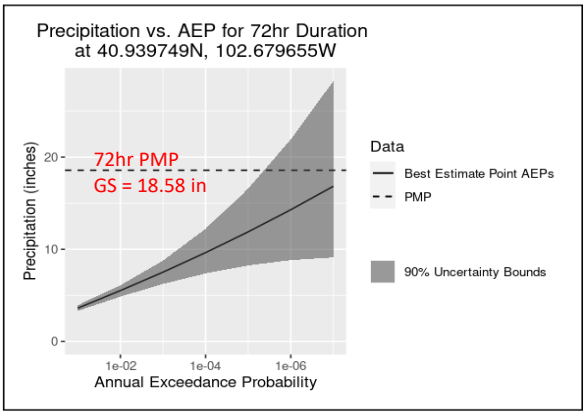
Precipitation (inches) for 6hr Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	2.02	2.20	2.38
AEP=1:100	3.12	3.52	3.81
AEP=1:1,000	4.16	5.04	5.82
AEP=1:10,000	5.10	6.83	8.76
AEP=1:100,000	5.90	8.93	12.98
AEP=1:1,000,000	6.55	11.40	18.82
AEP=1:10,000,000	7.16	14.31	26.64



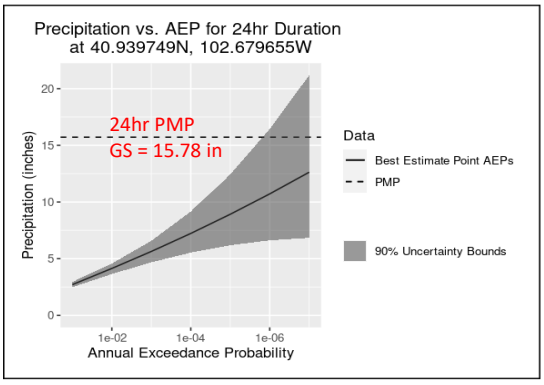
Precipitation (inches) for 72hr Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	3.31	3.62	3.93
AEP=1:100	4.87	5.52	6.09
AEP=1:1,000	6.24	7.52	8.77
AEP=1:10,000	7.39	9.64	12.22
AEP=1:100,000	8.25	11.90	16.58
AEP=1:1,000,000	8.83	14.30	21.93
AEP=1:10,000,000	9.12	16.85	28.26



Precipitation (inches) for 24hr Duration and Given AEP at 40.939749N, 102.679655W

	Lower Bound - 5% (inches)	Best Estimate (inches)	Upper Bound - 95% (inches)
AEP=1:10	2.48	2.71	2.95
AEP=1:100	3.65	4.14	4.57
AEP=1:1,000	4.68	5.64	6.58
AEP=1:10,000	5.54	7.23	9.16
AEP=1:100,000	6.19	8.92	12.43
AEP=1:1,000,000	6.62	10.72	16.44
AEP=1:10,000,000	6.84	12.63	21.18



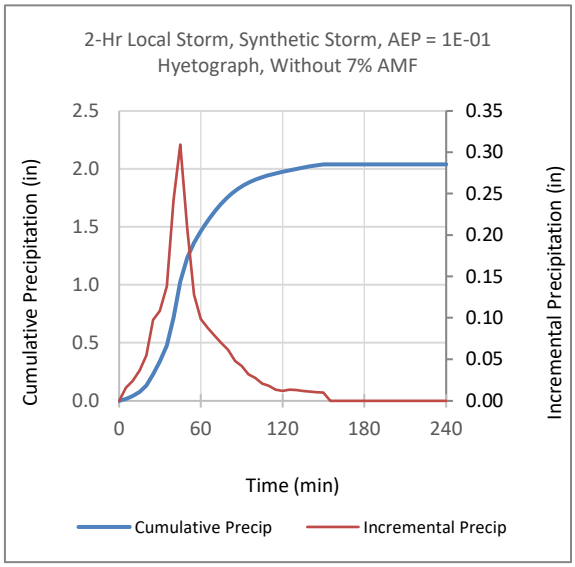
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-01 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.01557	**0.01557**
2	0.17	10	0.02385	**0.03942**
3	0.25	15	0.03646	**0.07588**
4	0.33	20	0.05440	**0.13028**
5	0.42	25	0.09756	**0.22785**
6	0.50	30	0.10840	**0.33625**
7	0.58	35	0.13797	**0.47422**
8	0.67	40	0.24243	**0.71666**
9	0.75	45	0.30945	**1.02610**
10	0.83	50	0.20695	**1.23306**
11	0.92	55	0.12811	**1.36117**
12	1.00	60	0.09875	**1.45992**
13	1.08	65	0.08830	**1.54822**
14	1.17	70	0.07864	**1.62686**
15	1.25	75	0.06977	**1.69664**
16	1.33	80	0.06169	**1.75833**
17	1.42	85	0.04790	**1.80622**
18	1.50	90	0.04179	**1.84801**
19	1.58	95	0.03173	**1.87974**
20	1.67	100	0.02759	**1.90734**
21	1.75	105	0.02070	**1.92803**
22	1.83	110	0.01794	**1.94597**
23	1.92	115	0.01340	**1.95937**
24	2.00	120	0.01163	**1.97100**
25	2.08	125	0.01340	**1.98440**
26	2.17	130	0.01281	**1.99721**
27	2.25	135	0.01183	**2.00904**
28	2.33	140	0.01104	**2.02008**
29	2.42	145	0.01025	**2.03033**
30	2.50	150	0.00966	**2.03998**
31	2.58	155	0.00000	**2.03998**
32	2.67	160	0.00000	**2.03998**
33	2.75	165	0.00000	**2.03998**
34	2.83	170	0.00000	**2.03998**
35	2.92	175	0.00000	**2.03998**
36	3.00	180	0.00000	**2.03998**
37	3.08	185	0.00000	**2.03998**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-01 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**2.03998**
39	3.25	195	0.00000	**2.03998**
40	3.33	200	0.00000	**2.03998**
41	3.42	205	0.00000	**2.03998**
42	3.50	210	0.00000	**2.03998**
43	3.58	215	0.00000	**2.03998**
44	3.67	220	0.00000	**2.03998**
45	3.75	225	0.00000	**2.03998**
46	3.83	230	0.00000	**2.03998**
47	3.92	235	0.00000	**2.03998**
48	4.00	240	0.00000	**2.03998**

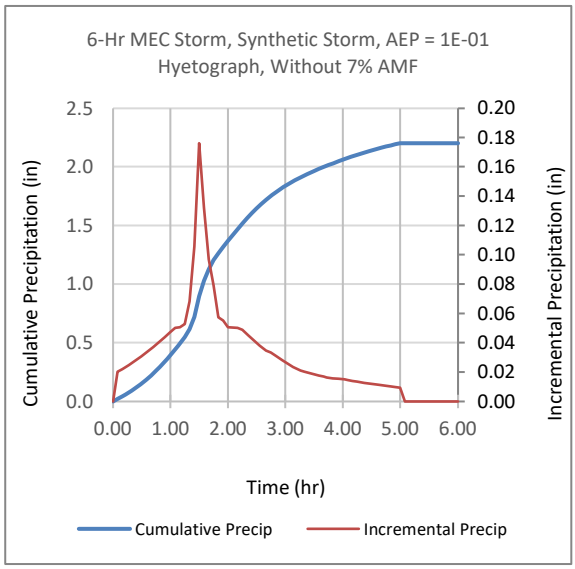
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-01 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.02025	**0.02025**
2	0.17	10	0.02201	**0.04226**
3	0.25	15	0.02421	**0.06647**
4	0.33	20	0.02619	**0.09266**
5	0.42	25	0.02839	**0.12105**
6	0.50	30	0.03081	**0.15187**
7	0.58	35	0.03324	**0.18510**
8	0.67	40	0.03588	**0.22098**
9	0.75	45	0.03852	**0.25950**
10	0.83	50	0.04138	**0.30088**
11	0.92	55	0.04424	**0.34512**
12	1.00	60	0.04732	**0.39244**
13	1.08	65	0.05018	**0.44262**
14	1.17	70	0.05062	**0.49324**
15	1.25	75	0.05282	**0.54607**
16	1.33	80	0.06823	**0.61430**
17	1.42	85	0.10565	**0.71995**
18	1.50	90	0.17608	**0.89603**
19	1.58	95	0.13206	**1.02809**
20	1.67	100	0.09684	**1.12493**
21	1.75	105	0.07924	**1.20417**
22	1.83	110	0.05723	**1.26139**
23	1.92	115	0.05502	**1.31642**
24	2.00	120	0.05062	**1.36704**
25	2.08	125	0.05040	**1.41744**
26	2.17	130	0.05018	**1.46763**
27	2.25	135	0.04886	**1.51649**
28	2.33	140	0.04578	**1.56227**
29	2.42	145	0.04270	**1.60497**
30	2.50	150	0.03984	**1.64481**
31	2.58	155	0.03720	**1.68200**
32	2.67	160	0.03456	**1.71656**
33	2.75	165	0.03324	**1.74979**
34	2.83	170	0.03103	**1.78083**
35	2.92	175	0.02861	**1.80944**
36	3.00	180	0.02685	**1.83629**
37	3.08	185	0.02487	**1.86117**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic St



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-01 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.02289	**1.88406**
39	3.25	195	0.02113	**1.90519**
40	3.33	200	0.02025	**1.92543**
41	3.42	205	0.01937	**1.94480**
42	3.50	210	0.01849	**1.96329**
43	3.58	215	0.01761	**1.98090**
44	3.67	220	0.01695	**1.99785**
45	3.75	225	0.01607	**2.01391**
46	3.83	230	0.01563	**2.02954**
47	3.92	235	0.01541	**2.04495**
48	4.00	240	0.01519	**2.06014**
49	4.08	245	0.01453	**2.07466**
50	4.17	250	0.01387	**2.08853**
51	4.25	255	0.01343	**2.10195**
52	4.33	260	0.01277	**2.11472**
53	4.42	265	0.01233	**2.12705**
54	4.50	270	0.01189	**2.13893**
55	4.58	275	0.01145	**2.15038**
56	4.67	280	0.01100	**2.16138**
57	4.75	285	0.01056	**2.17195**
58	4.83	290	0.01012	**2.18207**
59	4.92	295	0.00968	**2.19176**
60	5.00	300	0.00924	**2.20100**
61	5.08	305	0.00000	**2.20100**
62	5.17	310	0.00000	**2.20100**
63	5.25	315	0.00000	**2.20100**
64	5.33	320	0.00000	**2.20100**
65	5.42	325	0.00000	**2.20100**
66	5.50	330	0.00000	**2.20100**
67	5.58	335	0.00000	**2.20100**
68	5.67	340	0.00000	**2.20100**
69	5.75	345	0.00000	**2.20100**
70	5.83	350	0.00000	**2.20100**
71	5.92	355	0.00000	**2.20100**
72	6.00	360	0.00000	**2.20100**

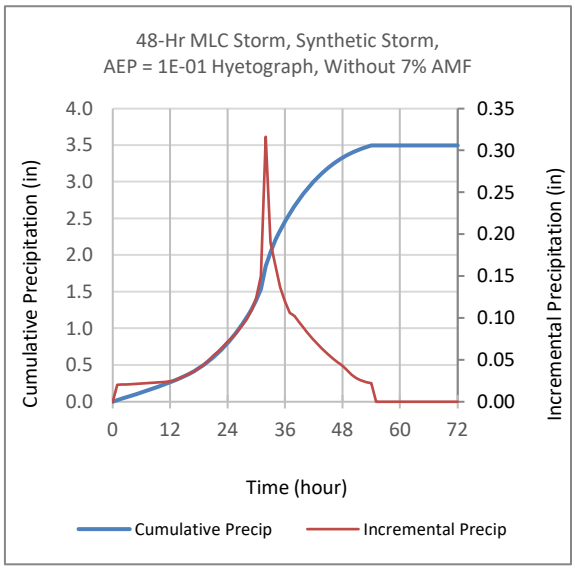
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-01 Hyetograph Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.01997	**0.01997**
2	2.00	120	0.02030	**0.04027**
3	3.00	180	0.02063	**0.06090**
4	4.00	240	0.02097	**0.08187**
5	5.00	300	0.02130	**0.10317**
6	6.00	360	0.02163	**0.12480**
7	7.00	420	0.02196	**0.14676**
8	8.00	480	0.02230	**0.16906**
9	9.00	540	0.02263	**0.19169**
10	10.00	600	0.02296	**0.21466**
11	11.00	660	0.02363	**0.23828**
12	12.00	720	0.02429	**0.26258**
13	13.00	780	0.02496	**0.28754**
14	14.00	840	0.02796	**0.31549**
15	15.00	900	0.03028	**0.34578**
16	16.00	960	0.03328	**0.37906**
17	17.00	1020	0.03628	**0.41533**
18	18.00	1080	0.03994	**0.45527**
19	19.00	1140	0.04393	**0.49920**
20	20.00	1200	0.04925	**0.54845**
21	21.00	1260	0.05491	**0.60337**
22	22.00	1320	0.05990	**0.66327**
23	23.00	1380	0.06556	**0.72883**
24	24.00	1440	0.07155	**0.80038**
25	25.00	1500	0.07688	**0.87726**
26	26.00	1560	0.08353	**0.96079**
27	27.00	1620	0.09085	**1.05165**
28	28.00	1680	0.09851	**1.15016**
29	29.00	1740	0.10949	**1.25965**
30	30.00	1800	0.12314	**1.38278**
31	31.00	1860	0.14976	**1.53254**
32	32.00	1920	0.31616	**1.84870**
33	33.00	1980	0.18970	**2.03840**
34	34.00	2040	0.16307	**2.20147**
35	35.00	2100	0.13645	**2.33792**
36	36.00	2160	0.11981	**2.45773**
37	37.00	2220	0.10616	**2.56389**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic S



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-01 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.10217	**2.66606**
39	39.00	2340	0.09452	**2.76058**
40	40.00	2400	0.08719	**2.84777**
41	41.00	2460	0.08020	**2.92797**
42	42.00	2520	0.07355	**3.00152**
43	43.00	2580	0.06756	**3.06908**
44	44.00	2640	0.06190	**3.13098**
45	45.00	2700	0.05624	**3.18723**
46	46.00	2760	0.05125	**3.23848**
47	47.00	2820	0.04692	**3.28540**
48	48.00	2880	0.04260	**3.32800**
49	49.00	2940	0.03727	**3.36527**
50	50.00	3000	0.03162	**3.39689**
51	51.00	3060	0.02762	**3.42451**
52	52.00	3120	0.02496	**3.44947**
53	53.00	3180	0.02296	**3.47244**
54	54.00	3240	0.02196	**3.49440**
55	55.00	3300	0.00000	**3.49440**
56	56.00	3360	0.00000	**3.49440**
57	57.00	3420	0.00000	**3.49440**
58	58.00	3480	0.00000	**3.49440**
59	59.00	3540	0.00000	**3.49440**
60	60.00	3600	0.00000	**3.49440**
61	61.00	3660	0.00000	**3.49440**
62	62.00	3720	0.00000	**3.49440**
63	63.00	3780	0.00000	**3.49440**
64	64.00	3840	0.00000	**3.49440**
65	65.00	3900	0.00000	**3.49440**
66	66.00	3960	0.00000	**3.49440**
67	67.00	4020	0.00000	**3.49440**
68	68.00	4080	0.00000	**3.49440**
69	69.00	4140	0.00000	**3.49440**
70	70.00	4200	0.00000	**3.49440**
71	71.00	4260	0.00000	**3.49440**
72	72.00	4320	0.00000	**3.49440**

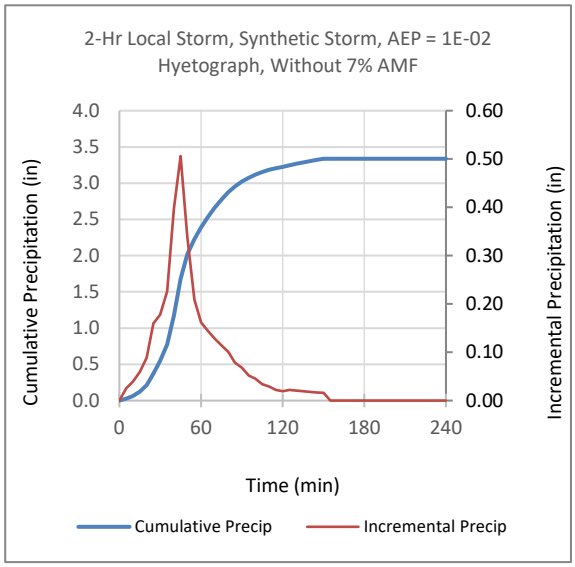
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-02 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.02547	**0.02547**
2	0.17	10	0.03901	**0.06448**
3	0.25	15	0.05964	**0.12412**
4	0.33	20	0.08898	**0.21311**
5	0.42	25	0.15959	**0.37269**
6	0.50	30	0.17732	**0.55001**
7	0.58	35	0.22568	**0.77569**
8	0.67	40	0.39655	**1.17225**
9	0.75	45	0.50617	**1.67841**
10	0.83	50	0.33852	**2.01693**
11	0.92	55	0.20956	**2.22649**
12	1.00	60	0.16152	**2.38802**
13	1.08	65	0.14444	**2.53245**
14	1.17	70	0.12864	**2.66109**
15	1.25	75	0.11413	**2.77522**
16	1.33	80	0.10091	**2.87613**
17	1.42	85	0.07834	**2.95447**
18	1.50	90	0.06835	**3.02282**
19	1.58	95	0.05191	**3.07473**
20	1.67	100	0.04514	**3.11986**
21	1.75	105	0.03385	**3.15372**
22	1.83	110	0.02934	**3.18306**
23	1.92	115	0.02192	**3.20498**
24	2.00	120	0.01902	**3.22400**
25	2.08	125	0.02192	**3.24592**
26	2.17	130	0.02096	**3.26688**
27	2.25	135	0.01934	**3.28622**
28	2.33	140	0.01805	**3.30428**
29	2.42	145	0.01676	**3.32104**
30	2.50	150	0.01580	**3.33684**
31	2.58	155	0.00000	**3.33684**
32	2.67	160	0.00000	**3.33684**
33	2.75	165	0.00000	**3.33684**
34	2.83	170	0.00000	**3.33684**
35	2.92	175	0.00000	**3.33684**
36	3.00	180	0.00000	**3.33684**
37	3.08	185	0.00000	**3.33684**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-02 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**3.33684**
39	3.25	195	0.00000	**3.33684**
40	3.33	200	0.00000	**3.33684**
41	3.42	205	0.00000	**3.33684**
42	3.50	210	0.00000	**3.33684**
43	3.58	215	0.00000	**3.33684**
44	3.67	220	0.00000	**3.33684**
45	3.75	225	0.00000	**3.33684**
46	3.83	230	0.00000	**3.33684**
47	3.92	235	0.00000	**3.33684**
48	4.00	240	0.00000	**3.33684**

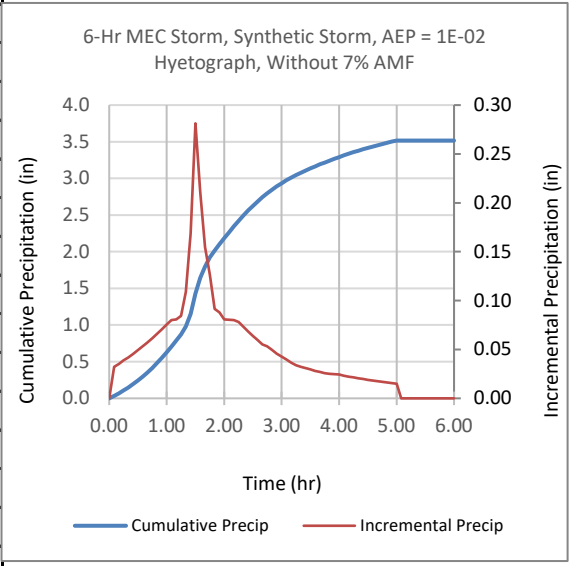
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.03235	**0.03235**
2	0.17	10	0.03516	**0.06751**
3	0.25	15	0.03868	**0.10618**
4	0.33	20	0.04184	**0.14802**
5	0.42	25	0.04536	**0.19338**
6	0.50	30	0.04922	**0.24260**
7	0.58	35	0.05309	**0.29570**
8	0.67	40	0.05731	**0.35301**
9	0.75	45	0.06153	**0.41454**
10	0.83	50	0.06610	**0.48064**
11	0.92	55	0.07067	**0.55131**
12	1.00	60	0.07559	**0.62690**
13	1.08	65	0.08016	**0.70707**
14	1.17	70	0.08087	**0.78794**
15	1.25	75	0.08438	**0.87232**
16	1.33	80	0.10900	**0.98132**
17	1.42	85	0.16877	**1.15008**
18	1.50	90	0.28128	**1.43136**
19	1.58	95	0.21096	**1.64232**
20	1.67	100	0.15470	**1.79703**
21	1.75	105	0.12658	**1.92360**
22	1.83	110	0.09142	**2.01502**
23	1.92	115	0.08790	**2.10292**
24	2.00	120	0.08087	**2.18379**
25	2.08	125	0.08052	**2.26430**
26	2.17	130	0.08016	**2.34447**
27	2.25	135	0.07806	**2.42252**
28	2.33	140	0.07313	**2.49566**
29	2.42	145	0.06821	**2.56387**
30	2.50	150	0.06364	**2.62751**
31	2.58	155	0.05942	**2.68693**
32	2.67	160	0.05520	**2.74213**
33	2.75	165	0.05309	**2.79522**
34	2.83	170	0.04958	**2.84480**
35	2.92	175	0.04571	**2.89050**
36	3.00	180	0.04290	**2.93340**
37	3.08	185	0.03973	**2.97313**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.03657	**3.00970**
39	3.25	195	0.03375	**3.04345**
40	3.33	200	0.03235	**3.07580**
41	3.42	205	0.03094	**3.10674**
42	3.50	210	0.02953	**3.13627**
43	3.58	215	0.02813	**3.16440**
44	3.67	220	0.02707	**3.19147**
45	3.75	225	0.02567	**3.21714**
46	3.83	230	0.02496	**3.24210**
47	3.92	235	0.02461	**3.26672**
48	4.00	240	0.02426	**3.29098**
49	4.08	245	0.02321	**3.31418**
50	4.17	250	0.02215	**3.33633**
51	4.25	255	0.02145	**3.35778**
52	4.33	260	0.02039	**3.37817**
53	4.42	265	0.01969	**3.39786**
54	4.50	270	0.01899	**3.41685**
55	4.58	275	0.01828	**3.43513**
56	4.67	280	0.01758	**3.45271**
57	4.75	285	0.01688	**3.46959**
58	4.83	290	0.01617	**3.48576**
59	4.92	295	0.01547	**3.50123**
60	5.00	300	0.01477	**3.51600**
61	5.08	305	0.00000	**3.51600**
62	5.17	310	0.00000	**3.51600**
63	5.25	315	0.00000	**3.51600**
64	5.33	320	0.00000	**3.51600**
65	5.42	325	0.00000	**3.51600**
66	5.50	330	0.00000	**3.51600**
67	5.58	335	0.00000	**3.51600**
68	5.67	340	0.00000	**3.51600**
69	5.75	345	0.00000	**3.51600**
70	5.83	350	0.00000	**3.51600**
71	5.92	355	0.00000	**3.51600**
72	6.00	360	0.00000	**3.51600**

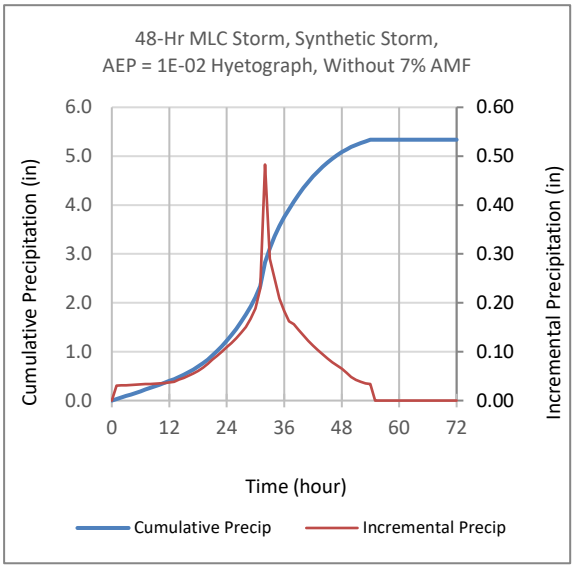
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.03050	**0.03050**
2	2.00	120	0.03101	**0.06150**
3	3.00	180	0.03151	**0.09302**
4	4.00	240	0.03202	**0.12504**
5	5.00	300	0.03253	**0.15757**
6	6.00	360	0.03304	**0.19061**
7	7.00	420	0.03355	**0.22416**
8	8.00	480	0.03406	**0.25822**
9	9.00	540	0.03456	**0.29278**
10	10.00	600	0.03507	**0.32785**
11	11.00	660	0.03609	**0.36394**
12	12.00	720	0.03711	**0.40105**
13	13.00	780	0.03812	**0.43917**
14	14.00	840	0.04270	**0.48187**
15	15.00	900	0.04626	**0.52812**
16	16.00	960	0.05083	**0.57895**
17	17.00	1020	0.05540	**0.63436**
18	18.00	1080	0.06100	**0.69535**
19	19.00	1140	0.06710	**0.76245**
20	20.00	1200	0.07523	**0.83768**
21	21.00	1260	0.08387	**0.92155**
22	22.00	1320	0.09149	**1.01304**
23	23.00	1380	0.10014	**1.11318**
24	24.00	1440	0.10928	**1.22246**
25	25.00	1500	0.11742	**1.33988**
26	26.00	1560	0.12758	**1.46746**
27	27.00	1620	0.13877	**1.60623**
28	28.00	1680	0.15046	**1.75668**
29	29.00	1740	0.16723	**1.92392**
30	30.00	1800	0.18807	**2.11199**
31	31.00	1860	0.22874	**2.34072**
32	32.00	1920	0.48289	**2.82361**
33	33.00	1980	0.28973	**3.11334**
34	34.00	2040	0.24907	**3.36240**
35	35.00	2100	0.20840	**3.57081**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
36	36.00	2160	0.18299	**3.75380**
37	37.00	2220	0.16215	**3.91594**
38	38.00	2280	0.15605	**4.07199**
39	39.00	2340	0.14436	**4.21635**
40	40.00	2400	0.13317	**4.34952**
41	41.00	2460	0.12250	**4.47202**
42	42.00	2520	0.11233	**4.58436**
43	43.00	2580	0.10318	**4.68754**
44	44.00	2640	0.09454	**4.78209**
45	45.00	2700	0.08590	**4.86799**
46	46.00	2760	0.07828	**4.94627**
47	47.00	2820	0.07167	**5.01794**
48	48.00	2880	0.06506	**5.08300**
49	49.00	2940	0.05693	**5.13993**
50	50.00	3000	0.04829	**5.18822**
51	51.00	3060	0.04219	**5.23041**
52	52.00	3120	0.03812	**5.26853**
53	53.00	3180	0.03507	**5.30360**
54	54.00	3240	0.03355	**5.33715**
55	55.00	3300	0.00000	**5.33715**
56	56.00	3360	0.00000	**5.33715**
57	57.00	3420	0.00000	**5.33715**
58	58.00	3480	0.00000	**5.33715**
59	59.00	3540	0.00000	**5.33715**
60	60.00	3600	0.00000	**5.33715**
61	61.00	3660	0.00000	**5.33715**
62	62.00	3720	0.00000	**5.33715**
63	63.00	3780	0.00000	**5.33715**
64	64.00	3840	0.00000	**5.33715**
65	65.00	3900	0.00000	**5.33715**
66	66.00	3960	0.00000	**5.33715**
67	67.00	4020	0.00000	**5.33715**
68	68.00	4080	0.00000	**5.33715**
69	69.00	4140	0.00000	**5.33715**
70	70.00	4200	0.00000	**5.33715**
71	71.00	4260	0.00000	**5.33715**
72	72.00	4320	0.00000	**5.33715**

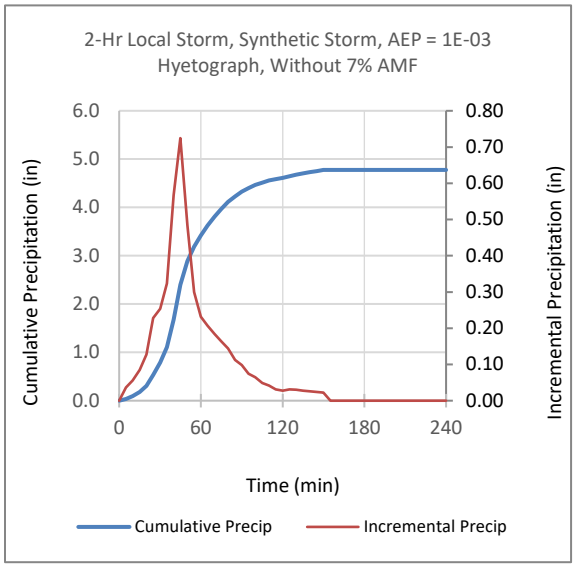
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-03 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.03646	**0.03646**
2	0.17	10	0.05584	**0.09230**
3	0.25	15	0.08538	**0.17768**
4	0.33	20	0.12737	**0.30505**
5	0.42	25	0.22844	**0.53349**
6	0.50	30	0.25382	**0.78732**
7	0.58	35	0.32305	**1.11037**
8	0.67	40	0.56764	**1.67801**
9	0.75	45	0.72455	**2.40257**
10	0.83	50	0.48457	**2.88714**
11	0.92	55	0.29997	**3.18712**
12	1.00	60	0.23121	**3.41833**
13	1.08	65	0.20675	**3.62508**
14	1.17	70	0.18414	**3.80922**
15	1.25	75	0.16337	**3.97259**
16	1.33	80	0.14445	**4.11704**
17	1.42	85	0.11214	**4.22919**
18	1.50	90	0.09784	**4.32702**
19	1.58	95	0.07430	**4.40133**
20	1.67	100	0.06461	**4.46594**
21	1.75	105	0.04846	**4.51439**
22	1.83	110	0.04200	**4.55639**
23	1.92	115	0.03138	**4.58777**
24	2.00	120	0.02723	**4.61500**
25	2.08	125	0.03138	**4.64638**
26	2.17	130	0.03000	**4.67638**
27	2.25	135	0.02769	**4.70407**
28	2.33	140	0.02584	**4.72991**
29	2.42	145	0.02400	**4.75391**
30	2.50	150	0.02261	**4.77652**
31	2.58	155	0.00000	**4.77652**
32	2.67	160	0.00000	**4.77652**
33	2.75	165	0.00000	**4.77652**
34	2.83	170	0.00000	**4.77652**
35	2.92	175	0.00000	**4.77652**
36	3.00	180	0.00000	**4.77652**
37	3.08	185	0.00000	**4.77652**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-03 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**4.77652**
39	3.25	195	0.00000	**4.77652**
40	3.33	200	0.00000	**4.77652**
41	3.42	205	0.00000	**4.77652**
42	3.50	210	0.00000	**4.77652**
43	3.58	215	0.00000	**4.77652**
44	3.67	220	0.00000	**4.77652**
45	3.75	225	0.00000	**4.77652**
46	3.83	230	0.00000	**4.77652**
47	3.92	235	0.00000	**4.77652**
48	4.00	240	0.00000	**4.77652**

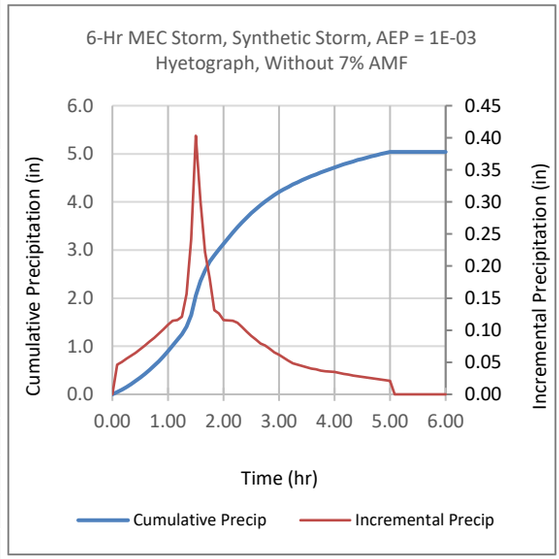
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-03 Hyetograph Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.04636	**0.04636**
2	0.17	10	0.05039	**0.09675**
3	0.25	15	0.05543	**0.15218**
4	0.33	20	0.05996	**0.21214**
5	0.42	25	0.06500	**0.27715**
6	0.50	30	0.07055	**0.34769**
7	0.58	35	0.07609	**0.42378**
8	0.67	40	0.08214	**0.50592**
9	0.75	45	0.08818	**0.59410**
10	0.83	50	0.09473	**0.68883**
11	0.92	55	0.10128	**0.79012**
12	1.00	60	0.10834	**0.89845**
13	1.08	65	0.11489	**1.01334**
14	1.17	70	0.11590	**1.12924**
15	1.25	75	0.12094	**1.25018**
16	1.33	80	0.15621	**1.40638**
17	1.42	85	0.24187	**1.64826**
18	1.50	90	0.40312	**2.05138**
19	1.58	95	0.30234	**2.35372**
20	1.67	100	0.22172	**2.57543**
21	1.75	105	0.18140	**2.75684**
22	1.83	110	0.13101	**2.88785**
23	1.92	115	0.12598	**3.01383**
24	2.00	120	0.11590	**3.12972**
25	2.08	125	0.11539	**3.24512**
26	2.17	130	0.11489	**3.36001**
27	2.25	135	0.11187	**3.47187**
28	2.33	140	0.10481	**3.57668**
29	2.42	145	0.09776	**3.67444**
30	2.50	150	0.09121	**3.76564**
31	2.58	155	0.08516	**3.85080**
32	2.67	160	0.07911	**3.92992**
33	2.75	165	0.07609	**4.00601**
34	2.83	170	0.07105	**4.07705**
35	2.92	175	0.06551	**4.14256**
36	3.00	180	0.06148	**4.20404**
37	3.08	185	0.05694	**4.26098**
38	3.17	190	0.05241	**4.31338**
39	3.25	195	0.04837	**4.36176**
40	3.33	200	0.04636	**4.40812**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-03 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
41	3.42	205	0.04434	**4.45246**
42	3.50	210	0.04233	**4.49479**
43	3.58	215	0.04031	**4.53510**
44	3.67	220	0.03880	**4.57390**
45	3.75	225	0.03678	**4.61069**
46	3.83	230	0.03578	**4.64646**
47	3.92	235	0.03527	**4.68173**
48	4.00	240	0.03477	**4.71650**
49	4.08	245	0.03326	**4.74976**
50	4.17	250	0.03175	**4.78151**
51	4.25	255	0.03074	**4.81225**
52	4.33	260	0.02923	**4.84147**
53	4.42	265	0.02822	**4.86969**
54	4.50	270	0.02721	**4.89690**
55	4.58	275	0.02620	**4.92310**
56	4.67	280	0.02520	**4.94830**
57	4.75	285	0.02419	**4.97249**
58	4.83	290	0.02318	**4.99566**
59	4.92	295	0.02217	**5.01784**
60	5.00	300	0.02116	**5.03900**
61	5.08	305	0.00000	**5.03900**
62	5.17	310	0.00000	**5.03900**
63	5.25	315	0.00000	**5.03900**
64	5.33	320	0.00000	**5.03900**
65	5.42	325	0.00000	**5.03900**
66	5.50	330	0.00000	**5.03900**
67	5.58	335	0.00000	**5.03900**
68	5.67	340	0.00000	**5.03900**
69	5.75	345	0.00000	**5.03900**
70	5.83	350	0.00000	**5.03900**
71	5.92	355	0.00000	**5.03900**
72	6.00	360	0.00000	**5.03900**

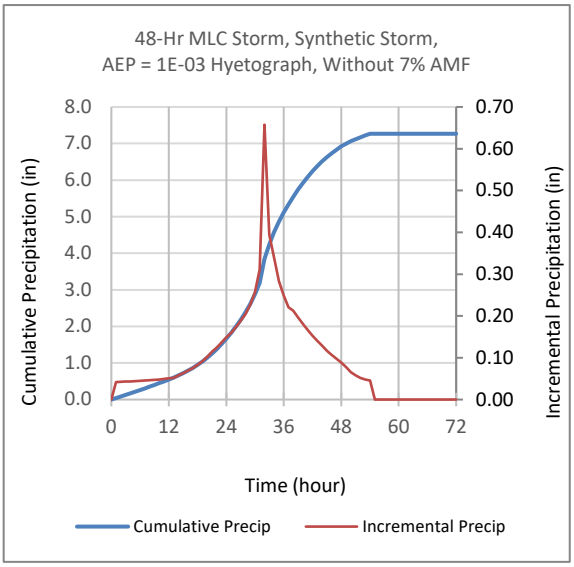
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-03 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.04153	**0.04153**
2	2.00	120	0.04222	**0.08374**
3	3.00	180	0.04291	**0.12665**
4	4.00	240	0.04360	**0.17026**
5	5.00	300	0.04429	**0.21455**
6	6.00	360	0.04499	**0.25954**
7	7.00	420	0.04568	**0.30522**
8	8.00	480	0.04637	**0.35159**
9	9.00	540	0.04706	**0.39865**
10	10.00	600	0.04775	**0.44640**
11	11.00	660	0.04914	**0.49554**
12	12.00	720	0.05052	**0.54607**
13	13.00	780	0.05191	**0.59797**
14	14.00	840	0.05814	**0.65611**
15	15.00	900	0.06298	**0.71909**
16	16.00	960	0.06921	**0.78830**
17	17.00	1020	0.07544	**0.86374**
18	18.00	1080	0.08305	**0.94679**
19	19.00	1140	0.09136	**1.03815**
20	20.00	1200	0.10243	**1.14058**
21	21.00	1260	0.11420	**1.25478**
22	22.00	1320	0.12458	**1.37936**
23	23.00	1380	0.13634	**1.51570**
24	24.00	1440	0.14880	**1.66450**
25	25.00	1500	0.15988	**1.82438**
26	26.00	1560	0.17372	**1.99809**
27	27.00	1620	0.18894	**2.18704**
28	28.00	1680	0.20486	**2.39190**
29	29.00	1740	0.22770	**2.61960**
30	30.00	1800	0.25608	**2.87568**
31	31.00	1860	0.31145	**3.18712**
32	32.00	1920	0.65750	**3.84462**
33	33.00	1980	0.39450	**4.23911**
34	34.00	2040	0.33913	**4.57824**
35	35.00	2100	0.28376	**4.86200**
36	36.00	2160	0.24916	**5.11116**
37	37.00	2220	0.22078	**5.33194**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-03 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.21247	**5.54441**
39	39.00	2340	0.19656	**5.74097**
40	40.00	2400	0.18133	**5.92230**
41	41.00	2460	0.16680	**6.08910**
42	42.00	2520	0.15295	**6.24205**
43	43.00	2580	0.14050	**6.38255**
44	44.00	2640	0.12873	**6.51128**
45	45.00	2700	0.11696	**6.62824**
46	46.00	2760	0.10658	**6.73483**
47	47.00	2820	0.09759	**6.83241**
48	48.00	2880	0.08859	**6.92100**
49	49.00	2940	0.07752	**6.99852**
50	50.00	3000	0.06575	**7.06426**
51	51.00	3060	0.05744	**7.12171**
52	52.00	3120	0.05191	**7.17362**
53	53.00	3180	0.04775	**7.22137**
54	54.00	3240	0.04568	**7.26705**
55	55.00	3300	0.00000	**7.26705**
56	56.00	3360	0.00000	**7.26705**
57	57.00	3420	0.00000	**7.26705**
58	58.00	3480	0.00000	**7.26705**
59	59.00	3540	0.00000	**7.26705**
60	60.00	3600	0.00000	**7.26705**
61	61.00	3660	0.00000	**7.26705**
62	62.00	3720	0.00000	**7.26705**
63	63.00	3780	0.00000	**7.26705**
64	64.00	3840	0.00000	**7.26705**
65	65.00	3900	0.00000	**7.26705**
66	66.00	3960	0.00000	**7.26705**
67	67.00	4020	0.00000	**7.26705**
68	68.00	4080	0.00000	**7.26705**
69	69.00	4140	0.00000	**7.26705**
70	70.00	4200	0.00000	**7.26705**
71	71.00	4260	0.00000	**7.26705**
72	72.00	4320	0.00000	**7.26705**

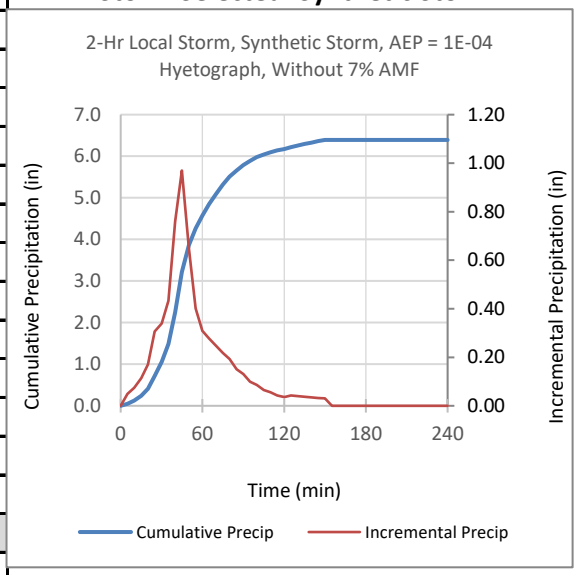
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.04879	**0.04879**
2	0.17	10	0.07473	**0.12352**
3	0.25	15	0.11426	**0.23778**
4	0.33	20	0.17046	**0.40823**
5	0.42	25	0.30571	**0.71395**
6	0.50	30	0.33968	**1.05363**
7	0.58	35	0.43232	**1.48595**
8	0.67	40	0.75965	**2.24559**
9	0.75	45	0.96963	**3.21523**
10	0.83	50	0.64848	**3.86371**
11	0.92	55	0.40144	**4.26515**
12	1.00	60	0.30942	**4.57456**
13	1.08	65	0.27668	**4.85125**
14	1.17	70	0.24642	**5.09767**
15	1.25	75	0.21863	**5.31630**
16	1.33	80	0.19331	**5.50961**
17	1.42	85	0.15008	**5.65969**
18	1.50	90	0.13093	**5.79062**
19	1.58	95	0.09943	**5.89005**
20	1.67	100	0.08646	**5.97652**
21	1.75	105	0.06485	**6.04136**
22	1.83	110	0.05620	**6.09756**
23	1.92	115	0.04200	**6.13956**
24	2.00	120	0.03644	**6.17600**
25	2.08	125	0.04200	**6.21800**
26	2.17	130	0.04014	**6.25814**
27	2.25	135	0.03706	**6.29520**
28	2.33	140	0.03459	**6.32978**
29	2.42	145	0.03212	**6.36190**
30	2.50	150	0.03026	**6.39216**
31	2.58	155	0.00000	**6.39216**
32	2.67	160	0.00000	**6.39216**
33	2.75	165	0.00000	**6.39216**
34	2.83	170	0.00000	**6.39216**
35	2.92	175	0.00000	**6.39216**
36	3.00	180	0.00000	**6.39216**
37	3.08	185	0.00000	**6.39216**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**6.39216**
39	3.25	195	0.00000	**6.39216**
40	3.33	200	0.00000	**6.39216**
41	3.42	205	0.00000	**6.39216**
42	3.50	210	0.00000	**6.39216**
43	3.58	215	0.00000	**6.39216**
44	3.67	220	0.00000	**6.39216**
45	3.75	225	0.00000	**6.39216**
46	3.83	230	0.00000	**6.39216**
47	3.92	235	0.00000	**6.39216**
48	4.00	240	0.00000	**6.39216**

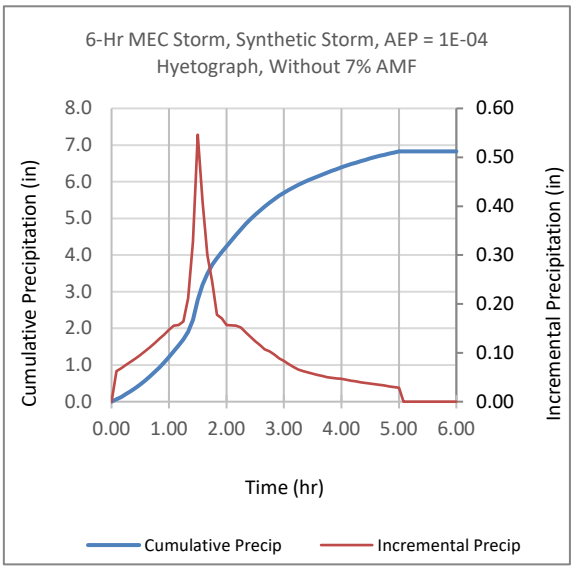
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.06282	**0.06282**
2	0.17	10	0.06828	**0.13110**
3	0.25	15	0.07511	**0.20621**
4	0.33	20	0.08125	**0.28746**
5	0.42	25	0.08808	**0.37554**
6	0.50	30	0.09559	**0.47113**
7	0.58	35	0.10310	**0.57423**
8	0.67	40	0.11130	**0.68553**
9	0.75	45	0.11949	**0.80502**
10	0.83	50	0.12837	**0.93339**
11	0.92	55	0.13724	**1.07063**
12	1.00	60	0.14680	**1.21743**
13	1.08	65	0.15568	**1.37311**
14	1.17	70	0.15704	**1.53015**
15	1.25	75	0.16387	**1.69403**
16	1.33	80	0.21167	**1.90569**
17	1.42	85	0.32774	**2.23344**
18	1.50	90	0.54624	**2.77968**
19	1.58	95	0.40968	**3.18936**
20	1.67	100	0.30043	**3.48979**
21	1.75	105	0.24581	**3.73560**
22	1.83	110	0.17753	**3.91313**
23	1.92	115	0.17070	**4.08383**
24	2.00	120	0.15704	**4.24087**
25	2.08	125	0.15636	**4.39723**
26	2.17	130	0.15568	**4.55291**
27	2.25	135	0.15158	**4.70449**
28	2.33	140	0.14202	**4.84651**
29	2.42	145	0.13246	**4.97898**
30	2.50	150	0.12359	**5.10256**
31	2.58	155	0.11539	**5.21796**
32	2.67	160	0.10720	**5.32516**
33	2.75	165	0.10310	**5.42826**
34	2.83	170	0.09627	**5.52453**
35	2.92	175	0.08876	**5.61330**
36	3.00	180	0.08330	**5.69660**
37	3.08	185	0.07716	**5.77376**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.07101	**5.84477**
39	3.25	195	0.06555	**5.91032**
40	3.33	200	0.06282	**5.97313**
41	3.42	205	0.06009	**6.03322**
42	3.50	210	0.05736	**6.09058**
43	3.58	215	0.05462	**6.14520**
44	3.67	220	0.05258	**6.19778**
45	3.75	225	0.04984	**6.24762**
46	3.83	230	0.04848	**6.29610**
47	3.92	235	0.04780	**6.34389**
48	4.00	240	0.04711	**6.39101**
49	4.08	245	0.04506	**6.43607**
50	4.17	250	0.04302	**6.47909**
51	4.25	255	0.04165	**6.52074**
52	4.33	260	0.03960	**6.56034**
53	4.42	265	0.03824	**6.59858**
54	4.50	270	0.03687	**6.63545**
55	4.58	275	0.03551	**6.67096**
56	4.67	280	0.03414	**6.70510**
57	4.75	285	0.03277	**6.73787**
58	4.83	290	0.03141	**6.76928**
59	4.92	295	0.03004	**6.79932**
60	5.00	300	0.02868	**6.82800**
61	5.08	305	0.00000	**6.82800**
62	5.17	310	0.00000	**6.82800**
63	5.25	315	0.00000	**6.82800**
64	5.33	320	0.00000	**6.82800**
65	5.42	325	0.00000	**6.82800**
66	5.50	330	0.00000	**6.82800**
67	5.58	335	0.00000	**6.82800**
68	5.67	340	0.00000	**6.82800**
69	5.75	345	0.00000	**6.82800**
70	5.83	350	0.00000	**6.82800**
71	5.92	355	0.00000	**6.82800**
72	6.00	360	0.00000	**6.82800**

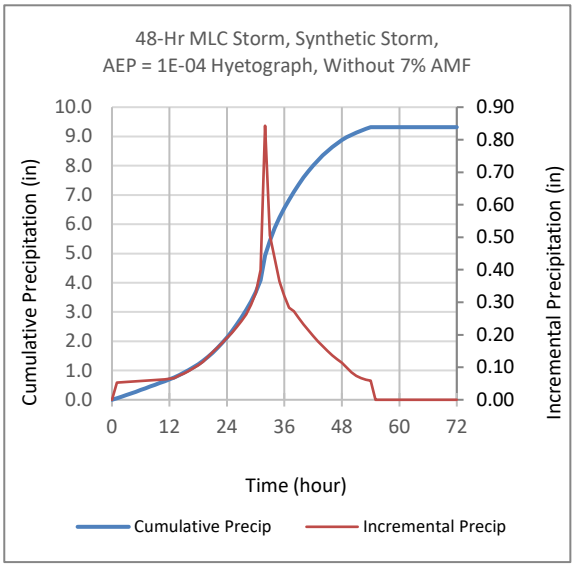
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.05324	**0.05324**
2	2.00	120	0.05413	**0.10736**
3	3.00	180	0.05501	**0.16238**
4	4.00	240	0.05590	**0.21828**
5	5.00	300	0.05679	**0.27506**
6	6.00	360	0.05767	**0.33274**
7	7.00	420	0.05856	**0.39130**
8	8.00	480	0.05945	**0.45075**
9	9.00	540	0.06034	**0.51108**
10	10.00	600	0.06122	**0.57231**
11	11.00	660	0.06300	**0.63531**
12	12.00	720	0.06477	**0.70008**
13	13.00	780	0.06655	**0.76663**
14	14.00	840	0.07453	**0.84116**
15	15.00	900	0.08074	**0.92190**
16	16.00	960	0.08873	**1.01063**
17	17.00	1020	0.09672	**1.10735**
18	18.00	1080	0.10648	**1.21383**
19	19.00	1140	0.11712	**1.33095**
20	20.00	1200	0.13132	**1.46227**
21	21.00	1260	0.14640	**1.60867**
22	22.00	1320	0.15971	**1.76839**
23	23.00	1380	0.17480	**1.94319**
24	24.00	1440	0.19077	**2.13396**
25	25.00	1500	0.20497	**2.33892**
26	26.00	1560	0.22271	**2.56164**
27	27.00	1620	0.24223	**2.80387**
28	28.00	1680	0.26264	**3.06651**
29	29.00	1740	0.29192	**3.35843**
30	30.00	1800	0.32830	**3.68673**
31	31.00	1860	0.39929	**4.08602**
32	32.00	1920	0.84294	**4.92895**
33	33.00	1980	0.50576	**5.43471**
34	34.00	2040	0.43478	**5.86949**
35	35.00	2100	0.36379	**6.23328**
36	36.00	2160	0.31943	**6.55271**
37	37.00	2220	0.28305	**6.83576**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.27240	**7.10816**
39	39.00	2340	0.25199	**7.36015**
40	40.00	2400	0.23247	**7.59263**
41	41.00	2460	0.21384	**7.80647**
42	42.00	2520	0.19609	**8.00256**
43	43.00	2580	0.18012	**8.18268**
44	44.00	2640	0.16504	**8.34772**
45	45.00	2700	0.14995	**8.49767**
46	46.00	2760	0.13664	**8.63432**
47	47.00	2820	0.12511	**8.75943**
48	48.00	2880	0.11357	**8.87300**
49	49.00	2940	0.09938	**8.97238**
50	50.00	3000	0.08429	**9.05667**
51	51.00	3060	0.07365	**9.13032**
52	52.00	3120	0.06655	**9.19686**
53	53.00	3180	0.06122	**9.25809**
54	54.00	3240	0.05856	**9.31665**
55	55.00	3300	0.00000	**9.31665**
56	56.00	3360	0.00000	**9.31665**
57	57.00	3420	0.00000	**9.31665**
58	58.00	3480	0.00000	**9.31665**
59	59.00	3540	0.00000	**9.31665**
60	60.00	3600	0.00000	**9.31665**
61	61.00	3660	0.00000	**9.31665**
62	62.00	3720	0.00000	**9.31665**
63	63.00	3780	0.00000	**9.31665**
64	64.00	3840	0.00000	**9.31665**
65	65.00	3900	0.00000	**9.31665**
66	66.00	3960	0.00000	**9.31665**
67	67.00	4020	0.00000	**9.31665**
68	68.00	4080	0.00000	**9.31665**
69	69.00	4140	0.00000	**9.31665**
70	70.00	4200	0.00000	**9.31665**
71	71.00	4260	0.00000	**9.31665**
72	72.00	4320	0.00000	**9.31665**

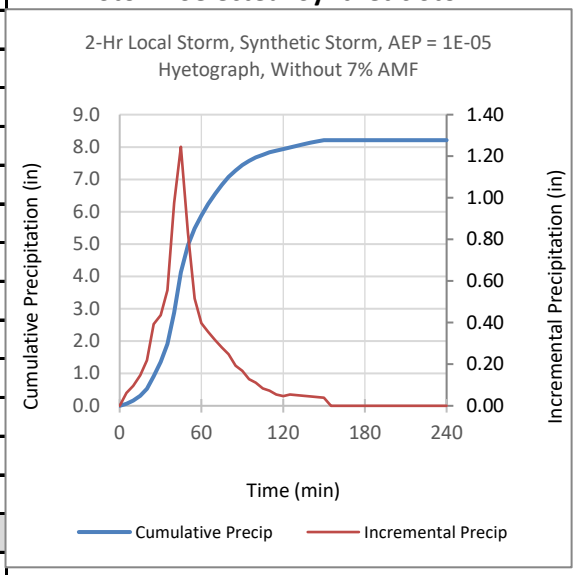
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.06267	**0.06267**
2	0.17	10	0.09599	**0.15866**
3	0.25	15	0.14676	**0.30542**
4	0.33	20	0.21895	**0.52437**
5	0.42	25	0.39268	**0.91705**
6	0.50	30	0.43632	**1.35337**
7	0.58	35	0.55531	**1.90868**
8	0.67	40	0.97576	**2.88444**
9	0.75	45	1.24548	**4.12992**
10	0.83	50	0.83297	**4.96288**
11	0.92	55	0.51565	**5.47853**
12	1.00	60	0.39744	**5.87597**
13	1.08	65	0.35540	**6.23137**
14	1.17	70	0.31653	**6.54790**
15	1.25	75	0.28083	**6.82873**
16	1.33	80	0.24830	**7.07703**
17	1.42	85	0.19277	**7.26980**
18	1.50	90	0.16818	**7.43798**
19	1.58	95	0.12772	**7.56570**
20	1.67	100	0.11106	**7.67676**
21	1.75	105	0.08330	**7.76006**
22	1.83	110	0.07219	**7.83225**
23	1.92	115	0.05394	**7.88620**
24	2.00	120	0.04680	**7.93300**
25	2.08	125	0.05394	**7.98694**
26	2.17	130	0.05156	**8.03851**
27	2.25	135	0.04760	**8.08611**
28	2.33	140	0.04442	**8.13053**
29	2.42	145	0.04125	**8.17178**
30	2.50	150	0.03887	**8.21066**
31	2.58	155	0.00000	**8.21066**
32	2.67	160	0.00000	**8.21066**
33	2.75	165	0.00000	**8.21066**
34	2.83	170	0.00000	**8.21066**
35	2.92	175	0.00000	**8.21066**
36	3.00	180	0.00000	**8.21066**
37	3.08	185	0.00000	**8.21066**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**8.21066**
39	3.25	195	0.00000	**8.21066**
40	3.33	200	0.00000	**8.21066**
41	3.42	205	0.00000	**8.21066**
42	3.50	210	0.00000	**8.21066**
43	3.58	215	0.00000	**8.21066**
44	3.67	220	0.00000	**8.21066**
45	3.75	225	0.00000	**8.21066**
46	3.83	230	0.00000	**8.21066**
47	3.92	235	0.00000	**8.21066**
48	4.00	240	0.00000	**8.21066**

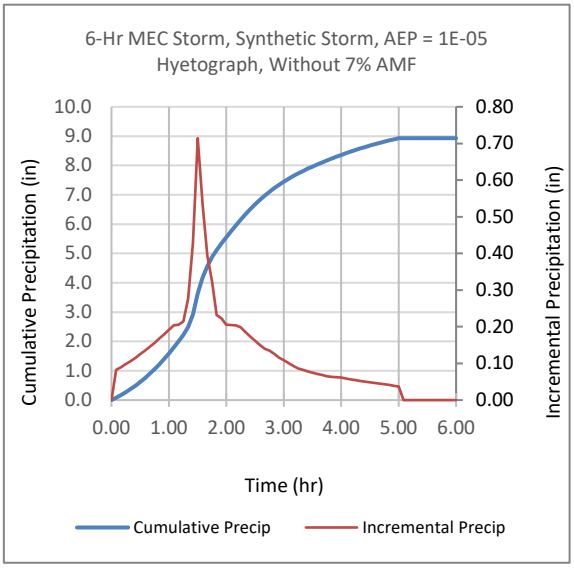
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.08216	**0.08216**
2	0.17	10	0.08930	**0.17146**
3	0.25	15	0.09823	**0.26969**
4	0.33	20	0.10627	**0.37595**
5	0.42	25	0.11520	**0.49115**
6	0.50	30	0.12502	**0.61617**
7	0.58	35	0.13484	**0.75101**
8	0.67	40	0.14556	**0.89657**
9	0.75	45	0.15628	**1.05285**
10	0.83	50	0.16788	**1.22073**
11	0.92	55	0.17949	**1.40022**
12	1.00	60	0.19200	**1.59222**
13	1.08	65	0.20360	**1.79582**
14	1.17	70	0.20539	**2.00121**
15	1.25	75	0.21432	**2.21553**
16	1.33	80	0.27683	**2.49236**
17	1.42	85	0.42864	**2.92100**
18	1.50	90	0.71440	**3.63540**
19	1.58	95	0.53580	**4.17120**
20	1.67	100	0.39292	**4.56412**
21	1.75	105	0.32148	**4.88560**
22	1.83	110	0.23218	**5.11778**
23	1.92	115	0.22325	**5.34103**
24	2.00	120	0.20539	**5.54642**
25	2.08	125	0.20450	**5.75092**
26	2.17	130	0.20360	**5.95452**
27	2.25	135	0.19825	**6.15277**
28	2.33	140	0.18574	**6.33851**
29	2.42	145	0.17324	**6.51176**
30	2.50	150	0.16163	**6.67339**
31	2.58	155	0.15092	**6.82431**
32	2.67	160	0.14020	**6.96451**
33	2.75	165	0.13484	**7.09935**
34	2.83	170	0.12591	**7.22526**
35	2.92	175	0.11609	**7.34135**
36	3.00	180	0.10895	**7.45030**
37	3.08	185	0.10091	**7.55121**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.09287	**7.64408**
39	3.25	195	0.08573	**7.72981**
40	3.33	200	0.08216	**7.81196**
41	3.42	205	0.07858	**7.89055**
42	3.50	210	0.07501	**7.96556**
43	3.58	215	0.07144	**8.03700**
44	3.67	220	0.06876	**8.10576**
45	3.75	225	0.06519	**8.17095**
46	3.83	230	0.06340	**8.23435**
47	3.92	235	0.06251	**8.29686**
48	4.00	240	0.06162	**8.35848**
49	4.08	245	0.05894	**8.41742**
50	4.17	250	0.05626	**8.47368**
51	4.25	255	0.05447	**8.52815**
52	4.33	260	0.05179	**8.57994**
53	4.42	265	0.05001	**8.62995**
54	4.50	270	0.04822	**8.67817**
55	4.58	275	0.04644	**8.72461**
56	4.67	280	0.04465	**8.76926**
57	4.75	285	0.04286	**8.81212**
58	4.83	290	0.04108	**8.85320**
59	4.92	295	0.03929	**8.89249**
60	5.00	300	0.03751	**8.93000**
61	5.08	305	0.00000	**8.93000**
62	5.17	310	0.00000	**8.93000**
63	5.25	315	0.00000	**8.93000**
64	5.33	320	0.00000	**8.93000**
65	5.42	325	0.00000	**8.93000**
66	5.50	330	0.00000	**8.93000**
67	5.58	335	0.00000	**8.93000**
68	5.67	340	0.00000	**8.93000**
69	5.75	345	0.00000	**8.93000**
70	5.83	350	0.00000	**8.93000**
71	5.92	355	0.00000	**8.93000**
72	6.00	360	0.00000	**8.93000**

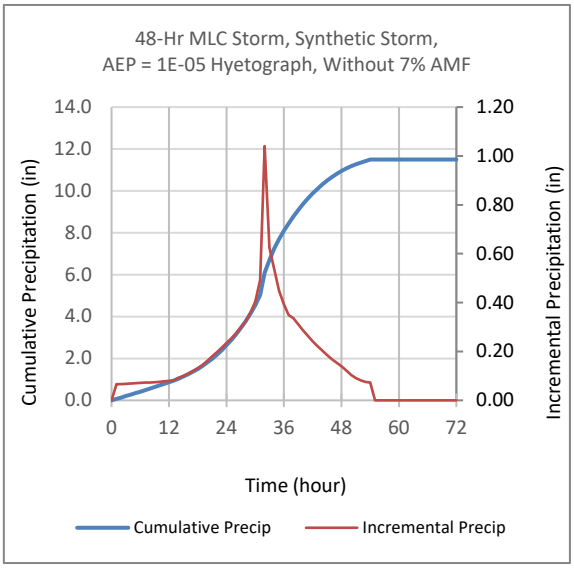
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.06569	**0.06569**
2	2.00	120	0.06679	**0.13248**
3	3.00	180	0.06788	**0.20037**
4	4.00	240	0.06898	**0.26935**
5	5.00	300	0.07007	**0.33942**
6	6.00	360	0.07117	**0.41059**
7	7.00	420	0.07226	**0.48285**
8	8.00	480	0.07336	**0.55621**
9	9.00	540	0.07445	**0.63066**
10	10.00	600	0.07555	**0.70621**
11	11.00	660	0.07774	**0.78395**
12	12.00	720	0.07993	**0.86388**
13	13.00	780	0.08212	**0.94599**
14	14.00	840	0.09197	**1.03797**
15	15.00	900	0.09964	**1.13760**
16	16.00	960	0.10949	**1.24709**
17	17.00	1020	0.11934	**1.36644**
18	18.00	1080	0.13139	**1.49782**
19	19.00	1140	0.14453	**1.64235**
20	20.00	1200	0.16205	**1.80440**
21	21.00	1260	0.18066	**1.98505**
22	22.00	1320	0.19708	**2.18214**
23	23.00	1380	0.21570	**2.39783**
24	24.00	1440	0.23540	**2.63323**
25	25.00	1500	0.25292	**2.88616**
26	26.00	1560	0.27482	**3.16098**
27	27.00	1620	0.29891	**3.45988**
28	28.00	1680	0.32409	**3.78397**
29	29.00	1740	0.36022	**4.14420**
30	30.00	1800	0.40511	**4.54931**
31	31.00	1860	0.49271	**5.04201**
32	32.00	1920	1.04016	**6.08217**
33	33.00	1980	0.62409	**6.70626**
34	34.00	2040	0.53650	**7.24276**
35	35.00	2100	0.44891	**7.69167**
36	36.00	2160	0.39416	**8.08584**
37	37.00	2220	0.34927	**8.43511**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.33613	**8.77124**
39	39.00	2340	0.31095	**9.08220**
40	40.00	2400	0.28686	**9.36906**
41	41.00	2460	0.26387	**9.63293**
42	42.00	2520	0.24197	**9.87490**
43	43.00	2580	0.22226	**10.09717**
44	44.00	2640	0.20365	**10.30082**
45	45.00	2700	0.18504	**10.48586**
46	46.00	2760	0.16861	**10.65447**
47	47.00	2820	0.15438	**10.80885**
48	48.00	2880	0.14015	**10.94900**
49	49.00	2940	0.12263	**11.07163**
50	50.00	3000	0.10402	**11.17564**
51	51.00	3060	0.09088	**11.26652**
52	52.00	3120	0.08212	**11.34864**
53	53.00	3180	0.07555	**11.42419**
54	54.00	3240	0.07226	**11.49645**
55	55.00	3300	0.00000	**11.49645**
56	56.00	3360	0.00000	**11.49645**
57	57.00	3420	0.00000	**11.49645**
58	58.00	3480	0.00000	**11.49645**
59	59.00	3540	0.00000	**11.49645**
60	60.00	3600	0.00000	**11.49645**
61	61.00	3660	0.00000	**11.49645**
62	62.00	3720	0.00000	**11.49645**
63	63.00	3780	0.00000	**11.49645**
64	64.00	3840	0.00000	**11.49645**
65	65.00	3900	0.00000	**11.49645**
66	66.00	3960	0.00000	**11.49645**
67	67.00	4020	0.00000	**11.49645**
68	68.00	4080	0.00000	**11.49645**
69	69.00	4140	0.00000	**11.49645**
70	70.00	4200	0.00000	**11.49645**
71	71.00	4260	0.00000	**11.49645**
72	72.00	4320	0.00000	**11.49645**

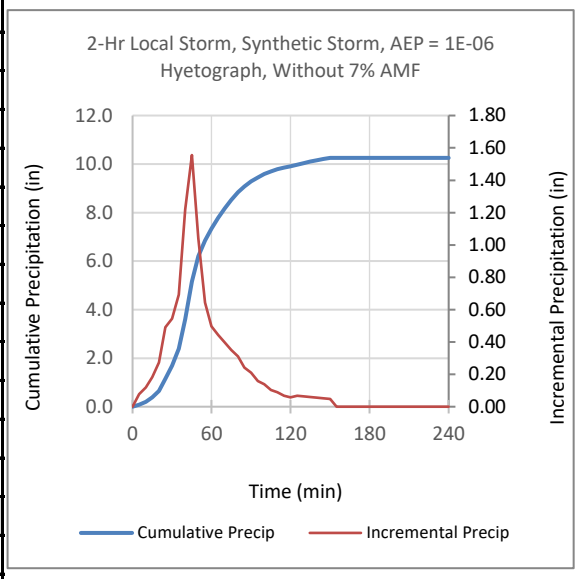
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.07827	**0.07827**
2	0.17	10	0.11989	**0.19816**
3	0.25	15	0.18330	**0.38146**
4	0.33	20	0.27346	**0.65492**
5	0.42	25	0.49045	**1.14536**
6	0.50	30	0.54494	**1.69030**
7	0.58	35	0.69356	**2.38386**
8	0.67	40	1.21868	**3.60255**
9	0.75	45	1.55556	**5.15810**
10	0.83	50	1.04034	**6.19844**
11	0.92	55	0.64402	**6.84246**
12	1.00	60	0.49639	**7.33886**
13	1.08	65	0.44388	**7.78273**
14	1.17	70	0.39533	**8.17806**
15	1.25	75	0.35074	**8.52881**
16	1.33	80	0.31012	**8.83893**
17	1.42	85	0.24076	**9.07969**
18	1.50	90	0.21005	**9.28974**
19	1.58	95	0.15952	**9.44926**
20	1.67	100	0.13871	**9.58797**
21	1.75	105	0.10403	**9.69201**
22	1.83	110	0.09016	**9.78217**
23	1.92	115	0.06737	**9.84954**
24	2.00	120	0.05846	**9.90800**
25	2.08	125	0.06737	**9.97537**
26	2.17	130	0.06440	**10.03978**
27	2.25	135	0.05945	**10.09922**
28	2.33	140	0.05548	**10.15471**
29	2.42	145	0.05152	**10.20623**
30	2.50	150	0.04855	**10.25478**
31	2.58	155	0.00000	**10.25478**
32	2.67	160	0.00000	**10.25478**
33	2.75	165	0.00000	**10.25478**
34	2.83	170	0.00000	**10.25478**
35	2.92	175	0.00000	**10.25478**
36	3.00	180	0.00000	**10.25478**
37	3.08	185	0.00000	**10.25478**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**10.25478**
39	3.25	195	0.00000	**10.25478**
40	3.33	200	0.00000	**10.25478**
41	3.42	205	0.00000	**10.25478**
42	3.50	210	0.00000	**10.25478**
43	3.58	215	0.00000	**10.25478**
44	3.67	220	0.00000	**10.25478**
45	3.75	225	0.00000	**10.25478**
46	3.83	230	0.00000	**10.25478**
47	3.92	235	0.00000	**10.25478**
48	4.00	240	0.00000	**10.25478**

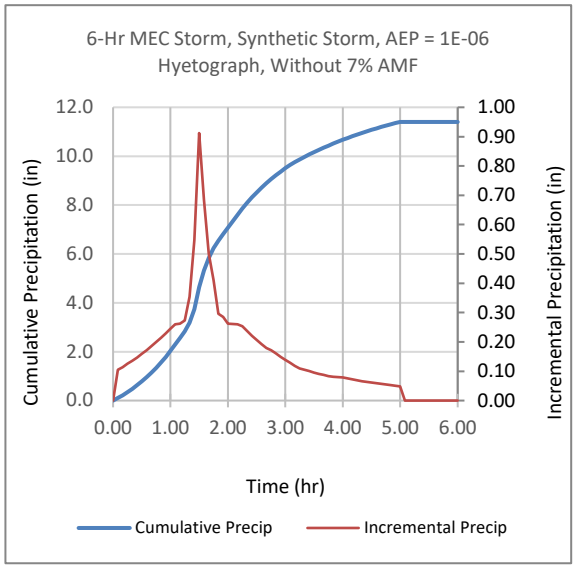
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.10489	**0.10489**
2	0.17	10	0.11401	**0.21890**
3	0.25	15	0.12541	**0.34431**
4	0.33	20	0.13567	**0.47998**
5	0.42	25	0.14707	**0.62706**
6	0.50	30	0.15961	**0.78667**
7	0.58	35	0.17216	**0.95882**
8	0.67	40	0.18584	**1.14466**
9	0.75	45	0.19952	**1.34418**
10	0.83	50	0.21434	**1.55852**
11	0.92	55	0.22916	**1.78768**
12	1.00	60	0.24512	**2.03280**
13	1.08	65	0.25994	**2.29274**
14	1.17	70	0.26222	**2.55496**
15	1.25	75	0.27362	**2.82859**
16	1.33	80	0.35343	**3.18202**
17	1.42	85	0.54725	**3.72927**
18	1.50	90	0.91208	**4.64135**
19	1.58	95	0.68406	**5.32541**
20	1.67	100	0.50164	**5.82705**
21	1.75	105	0.41044	**6.23749**
22	1.83	110	0.29643	**6.53391**
23	1.92	115	0.28503	**6.81894**
24	2.00	120	0.26222	**7.08116**
25	2.08	125	0.26108	**7.34224**
26	2.17	130	0.25994	**7.60219**
27	2.25	135	0.25310	**7.85529**
28	2.33	140	0.23714	**8.09243**
29	2.42	145	0.22118	**8.31361**
30	2.50	150	0.20636	**8.51997**
31	2.58	155	0.19268	**8.71264**
32	2.67	160	0.17900	**8.89164**
33	2.75	165	0.17216	**9.06380**
34	2.83	170	0.16075	**9.22455**
35	2.92	175	0.14821	**9.37276**
36	3.00	180	0.13909	**9.51185**
37	3.08	185	0.12883	**9.64069**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.11857	**9.75926**
39	3.25	195	0.10945	**9.86871**
40	3.33	200	0.10489	**9.97359**
41	3.42	205	0.10033	**10.07392**
42	3.50	210	0.09577	**10.16969**
43	3.58	215	0.09121	**10.26090**
44	3.67	220	0.08779	**10.34869**
45	3.75	225	0.08323	**10.43192**
46	3.83	230	0.08095	**10.51286**
47	3.92	235	0.07981	**10.59267**
48	4.00	240	0.07867	**10.67134**
49	4.08	245	0.07525	**10.74658**
50	4.17	250	0.07183	**10.81841**
51	4.25	255	0.06955	**10.88796**
52	4.33	260	0.06613	**10.95408**
53	4.42	265	0.06385	**11.01793**
54	4.50	270	0.06157	**11.07949**
55	4.58	275	0.05929	**11.13878**
56	4.67	280	0.05701	**11.19578**
57	4.75	285	0.05472	**11.25051**
58	4.83	290	0.05244	**11.30295**
59	4.92	295	0.05016	**11.35312**
60	5.00	300	0.04788	**11.40100**
61	5.08	305	0.00000	**11.40100**
62	5.17	310	0.00000	**11.40100**
63	5.25	315	0.00000	**11.40100**
64	5.33	320	0.00000	**11.40100**
65	5.42	325	0.00000	**11.40100**
66	5.50	330	0.00000	**11.40100**
67	5.58	335	0.00000	**11.40100**
68	5.67	340	0.00000	**11.40100**
69	5.75	345	0.00000	**11.40100**
70	5.83	350	0.00000	**11.40100**
71	5.92	355	0.00000	**11.40100**
72	6.00	360	0.00000	**11.40100**

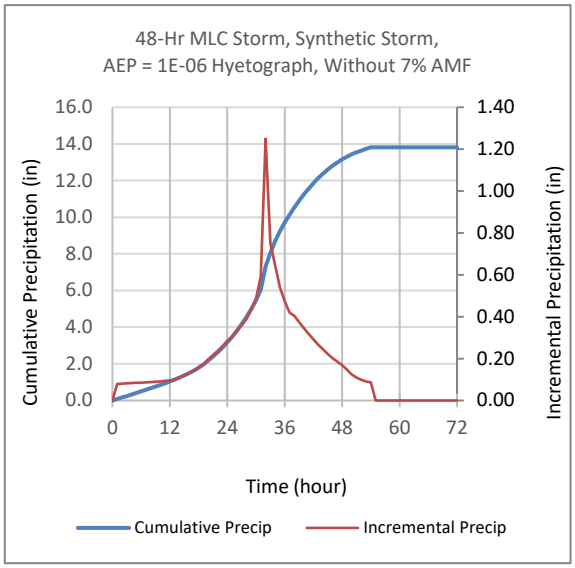
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.07894	**0.07894**
2	2.00	120	0.08025	**0.15919**
3	3.00	180	0.08157	**0.24075**
4	4.00	240	0.08288	**0.32364**
5	5.00	300	0.08420	**0.40784**
6	6.00	360	0.08551	**0.49335**
7	7.00	420	0.08683	**0.58018**
8	8.00	480	0.08815	**0.66832**
9	9.00	540	0.08946	**0.75779**
10	10.00	600	0.09078	**0.84856**
11	11.00	660	0.09341	**0.94197**
12	12.00	720	0.09604	**1.03801**
13	13.00	780	0.09867	**1.13668**
14	14.00	840	0.11051	**1.24719**
15	15.00	900	0.11972	**1.36691**
16	16.00	960	0.13156	**1.49847**
17	17.00	1020	0.14340	**1.64187**
18	18.00	1080	0.15787	**1.79974**
19	19.00	1140	0.17366	**1.97340**
20	20.00	1200	0.19471	**2.16811**
21	21.00	1260	0.21707	**2.38518**
22	22.00	1320	0.23681	**2.62199**
23	23.00	1380	0.25917	**2.88116**
24	24.00	1440	0.28285	**3.16402**
25	25.00	1500	0.30390	**3.46792**
26	26.00	1560	0.33022	**3.79814**
27	27.00	1620	0.35916	**4.15730**
28	28.00	1680	0.38942	**4.54671**
29	29.00	1740	0.43283	**4.97955**
30	30.00	1800	0.48677	**5.46632**
31	31.00	1860	0.59202	**6.05834**
32	32.00	1920	1.24982	**7.30816**
33	33.00	1980	0.74989	**8.05805**
34	34.00	2040	0.64464	**8.70269**
35	35.00	2100	0.53940	**9.24209**
36	36.00	2160	0.47362	**9.71571**
37	37.00	2220	0.41968	**10.13538**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.40389	**10.53927**
39	39.00	2340	0.37363	**10.91290**
40	40.00	2400	0.34469	**11.25759**
41	41.00	2460	0.31706	**11.57465**
42	42.00	2520	0.29075	**11.86540**
43	43.00	2580	0.26707	**12.13246**
44	44.00	2640	0.24470	**12.37716**
45	45.00	2700	0.22234	**12.59950**
46	46.00	2760	0.20260	**12.80210**
47	47.00	2820	0.18550	**12.98760**
48	48.00	2880	0.16840	**13.15600**
49	49.00	2940	0.14735	**13.30335**
50	50.00	3000	0.12498	**13.42833**
51	51.00	3060	0.10919	**13.53752**
52	52.00	3120	0.09867	**13.63619**
53	53.00	3180	0.09078	**13.72697**
54	54.00	3240	0.08683	**13.81380**
55	55.00	3300	0.00000	**13.81380**
56	56.00	3360	0.00000	**13.81380**
57	57.00	3420	0.00000	**13.81380**
58	58.00	3480	0.00000	**13.81380**
59	59.00	3540	0.00000	**13.81380**
60	60.00	3600	0.00000	**13.81380**
61	61.00	3660	0.00000	**13.81380**
62	62.00	3720	0.00000	**13.81380**
63	63.00	3780	0.00000	**13.81380**
64	64.00	3840	0.00000	**13.81380**
65	65.00	3900	0.00000	**13.81380**
66	66.00	3960	0.00000	**13.81380**
67	67.00	4020	0.00000	**13.81380**
68	68.00	4080	0.00000	**13.81380**
69	69.00	4140	0.00000	**13.81380**
70	70.00	4200	0.00000	**13.81380**
71	71.00	4260	0.00000	**13.81380**
72	72.00	4320	0.00000	**13.81380**

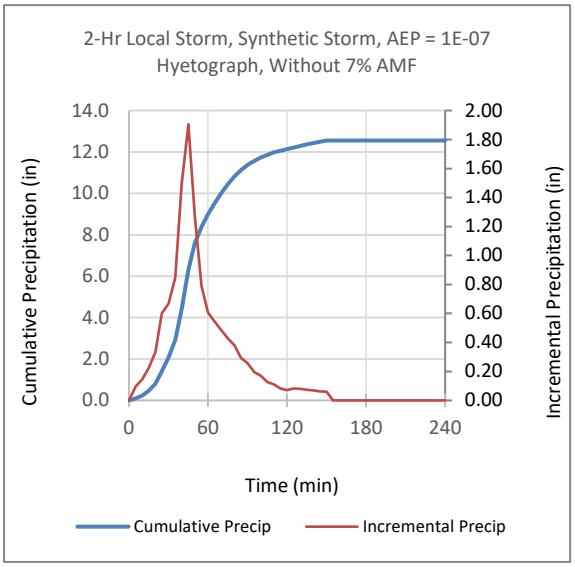
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-07 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.09582	**0.09582**
2	0.17	10	0.14676	**0.24258**
3	0.25	15	0.22439	**0.46697**
4	0.33	20	0.33476	**0.80173**
5	0.42	25	0.60039	**1.40211**
6	0.50	30	0.66709	**2.06921**
7	0.58	35	0.84903	**2.91824**
8	0.67	40	1.49187	**4.41010**
9	0.75	45	1.90425	**6.31436**
10	0.83	50	1.27354	**7.58790**
11	0.92	55	0.78838	**8.37629**
12	1.00	60	0.60766	**8.98395**
13	1.08	65	0.54338	**9.52733**
14	1.17	70	0.48395	**10.01128**
15	1.25	75	0.42937	**10.44064**
16	1.33	80	0.37964	**10.82028**
17	1.42	85	0.29473	**11.11502**
18	1.50	90	0.25713	**11.37215**
19	1.58	95	0.19528	**11.56743**
20	1.67	100	0.16981	**11.73723**
21	1.75	105	0.12735	**11.86459**
22	1.83	110	0.11037	**11.97496**
23	1.92	115	0.08248	**12.05744**
24	2.00	120	0.07156	**12.12900**
25	2.08	125	0.08248	**12.21148**
26	2.17	130	0.07884	**12.29032**
27	2.25	135	0.07277	**12.36309**
28	2.33	140	0.06792	**12.43101**
29	2.42	145	0.06307	**12.49408**
30	2.50	150	0.05943	**12.55351**
31	2.58	155	0.00000	**12.55351**
32	2.67	160	0.00000	**12.55351**
33	2.75	165	0.00000	**12.55351**
34	2.83	170	0.00000	**12.55351**
35	2.92	175	0.00000	**12.55351**
36	3.00	180	0.00000	**12.55351**
37	3.08	185	0.00000	**12.55351**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:46

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: Local Storm
Analysis Type: Temporal
ARF applied: No
Storm Selected: Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

2-Hr Local Storm, Synthetic Storm, AEP = 1E-07 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.00000	**12.55351**
39	3.25	195	0.00000	**12.55351**
40	3.33	200	0.00000	**12.55351**
41	3.42	205	0.00000	**12.55351**
42	3.50	210	0.00000	**12.55351**
43	3.58	215	0.00000	**12.55351**
44	3.67	220	0.00000	**12.55351**
45	3.75	225	0.00000	**12.55351**
46	3.83	230	0.00000	**12.55351**
47	3.92	235	0.00000	**12.55351**
48	4.00	240	0.00000	**12.55351**

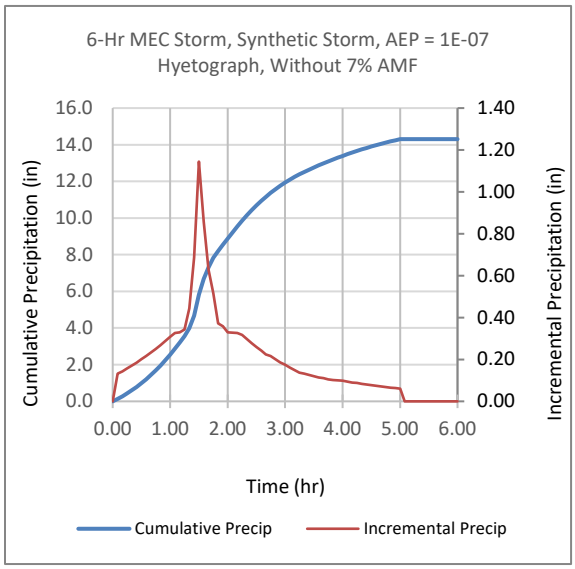
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-07 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	0.08	5	0.13162	**0.13162**
2	0.17	10	0.14306	**0.27468**
3	0.25	15	0.15737	**0.43204**
4	0.33	20	0.17024	**0.60228**
5	0.42	25	0.18455	**0.78683**
6	0.50	30	0.20028	**0.98711**
7	0.58	35	0.21602	**1.20313**
8	0.67	40	0.23319	**1.43632**
9	0.75	45	0.25035	**1.68668**
10	0.83	50	0.26895	**1.95563**
11	0.92	55	0.28755	**2.24318**
12	1.00	60	0.30758	**2.55076**
13	1.08	65	0.32618	**2.87694**
14	1.17	70	0.32904	**3.20597**
15	1.25	75	0.34334	**3.54932**
16	1.33	80	0.44349	**3.99280**
17	1.42	85	0.68669	**4.67949**
18	1.50	90	1.14448	**5.82397**
19	1.58	95	0.85836	**6.68233**
20	1.67	100	0.62946	**7.31180**
21	1.75	105	0.51502	**7.82681**
22	1.83	110	0.37196	**8.19877**
23	1.92	115	0.35765	**8.55642**
24	2.00	120	0.32904	**8.88546**
25	2.08	125	0.32761	**9.21306**
26	2.17	130	0.32618	**9.53924**
27	2.25	135	0.31759	**9.85683**
28	2.33	140	0.29756	**10.15440**
29	2.42	145	0.27754	**10.43194**
30	2.50	150	0.25894	**10.69087**
31	2.58	155	0.24177	**10.93265**
32	2.67	160	0.22460	**11.15725**
33	2.75	165	0.21602	**11.37327**
34	2.83	170	0.20171	**11.57498**
35	2.92	175	0.18598	**11.76096**
36	3.00	180	0.17453	**11.93550**
37	3.08	185	0.16166	**12.09715**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:57:03

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MEC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Front-Loaded Synthetic Storm



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

6-Hr MEC Storm, Synthetic Storm, AEP = 1E-07 Hyetograph
Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	3.17	190	0.14878	**12.24594**
39	3.25	195	0.13734	**12.38327**
40	3.33	200	0.13162	**12.51489**
41	3.42	205	0.12589	**12.64078**
42	3.50	210	0.12017	**12.76095**
43	3.58	215	0.11445	**12.87540**
44	3.67	220	0.11016	**12.98556**
45	3.75	225	0.10443	**13.08999**
46	3.83	230	0.10157	**13.19156**
47	3.92	235	0.10014	**13.29170**
48	4.00	240	0.09871	**13.39042**
49	4.08	245	0.09442	**13.48484**
50	4.17	250	0.09013	**13.57496**
51	4.25	255	0.08727	**13.66223**
52	4.33	260	0.08297	**13.74520**
53	4.42	265	0.08011	**13.82532**
54	4.50	270	0.07725	**13.90257**
55	4.58	275	0.07439	**13.97696**
56	4.67	280	0.07153	**14.04849**
57	4.75	285	0.06867	**14.11716**
58	4.83	290	0.06581	**14.18297**
59	4.92	295	0.06295	**14.24591**
60	5.00	300	0.06009	**14.30600**
61	5.08	305	0.00000	**14.30600**
62	5.17	310	0.00000	**14.30600**
63	5.25	315	0.00000	**14.30600**
64	5.33	320	0.00000	**14.30600**
65	5.42	325	0.00000	**14.30600**
66	5.50	330	0.00000	**14.30600**
67	5.58	335	0.00000	**14.30600**
68	5.67	340	0.00000	**14.30600**
69	5.75	345	0.00000	**14.30600**
70	5.83	350	0.00000	**14.30600**
71	5.92	355	0.00000	**14.30600**
72	6.00	360	0.00000	**14.30600**

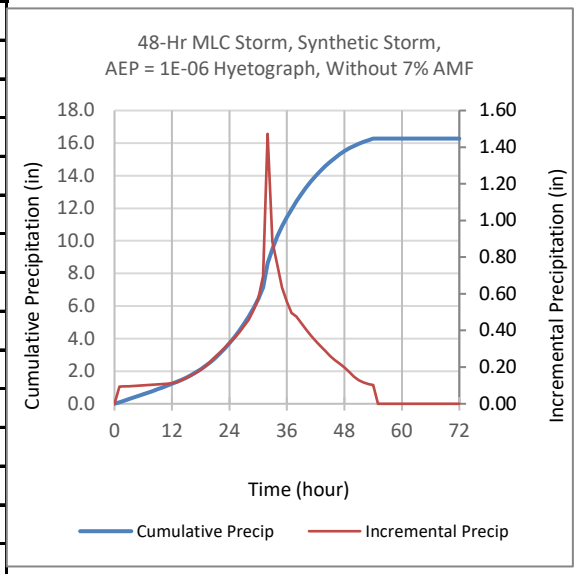
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-07
Hyetograph Without 7% "Atmospheric Moisture Factor"

Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
0	0.00	0	0.00000	**0.00000**
1	1.00	60	0.09302	**0.09302**
2	2.00	120	0.09457	**0.18759**
3	3.00	180	0.09612	**0.28370**
4	4.00	240	0.09767	**0.38137**
5	5.00	300	0.09922	**0.48059**
6	6.00	360	0.10077	**0.58136**
7	7.00	420	0.10232	**0.68368**
8	8.00	480	0.10387	**0.78755**
9	9.00	540	0.10542	**0.89297**
10	10.00	600	0.10697	**0.99994**
11	11.00	660	0.11007	**1.11001**
12	12.00	720	0.11317	**1.22319**
13	13.00	780	0.11627	**1.33946**
14	14.00	840	0.13023	**1.46968**
15	15.00	900	0.14108	**1.61076**
16	16.00	960	0.15503	**1.76579**
17	17.00	1020	0.16898	**1.93477**
18	18.00	1080	0.18604	**2.12081**
19	19.00	1140	0.20464	**2.32545**
20	20.00	1200	0.22944	**2.55489**
21	21.00	1260	0.25580	**2.81069**
22	22.00	1320	0.27905	**3.08975**
23	23.00	1380	0.30541	**3.39516**
24	24.00	1440	0.33331	**3.72847**
25	25.00	1500	0.35812	**4.08659**
26	26.00	1560	0.38913	**4.47572**
27	27.00	1620	0.42323	**4.89895**
28	28.00	1680	0.45889	**5.35784**
29	29.00	1740	0.51005	**5.86789**
30	30.00	1800	0.57361	**6.44150**
31	31.00	1860	0.69764	**7.13913**
32	32.00	1920	1.47279	**8.61192**
33	33.00	1980	0.88367	**9.49559**
34	34.00	2040	0.75965	**10.25523**
35	35.00	2100	0.63562	**10.89086**
36	36.00	2160	0.55811	**11.44897**
37	37.00	2220	0.49455	**11.94351**

MetPortal v2.2.0
Date and Time of Analysis: 2024-07-10 20:56:32

Point Selected: 40.939749N 102.679655W
Region: East
Units: inches (depth); sqmi (area)
Storm Type: MLC
Analysis Type: Temporal
ARF applied: No
Storm Selected: Center-Loaded Synthetic Storm

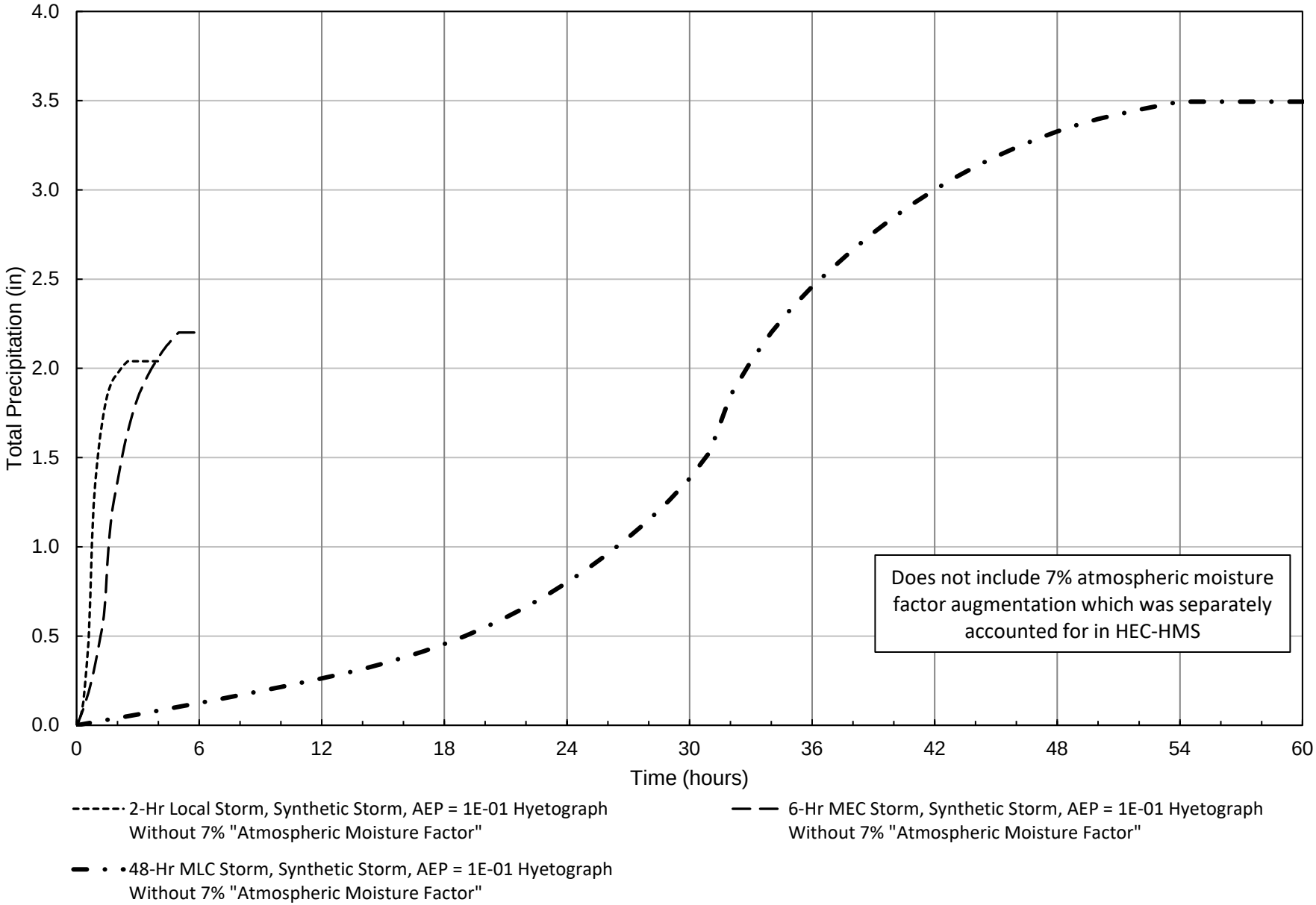


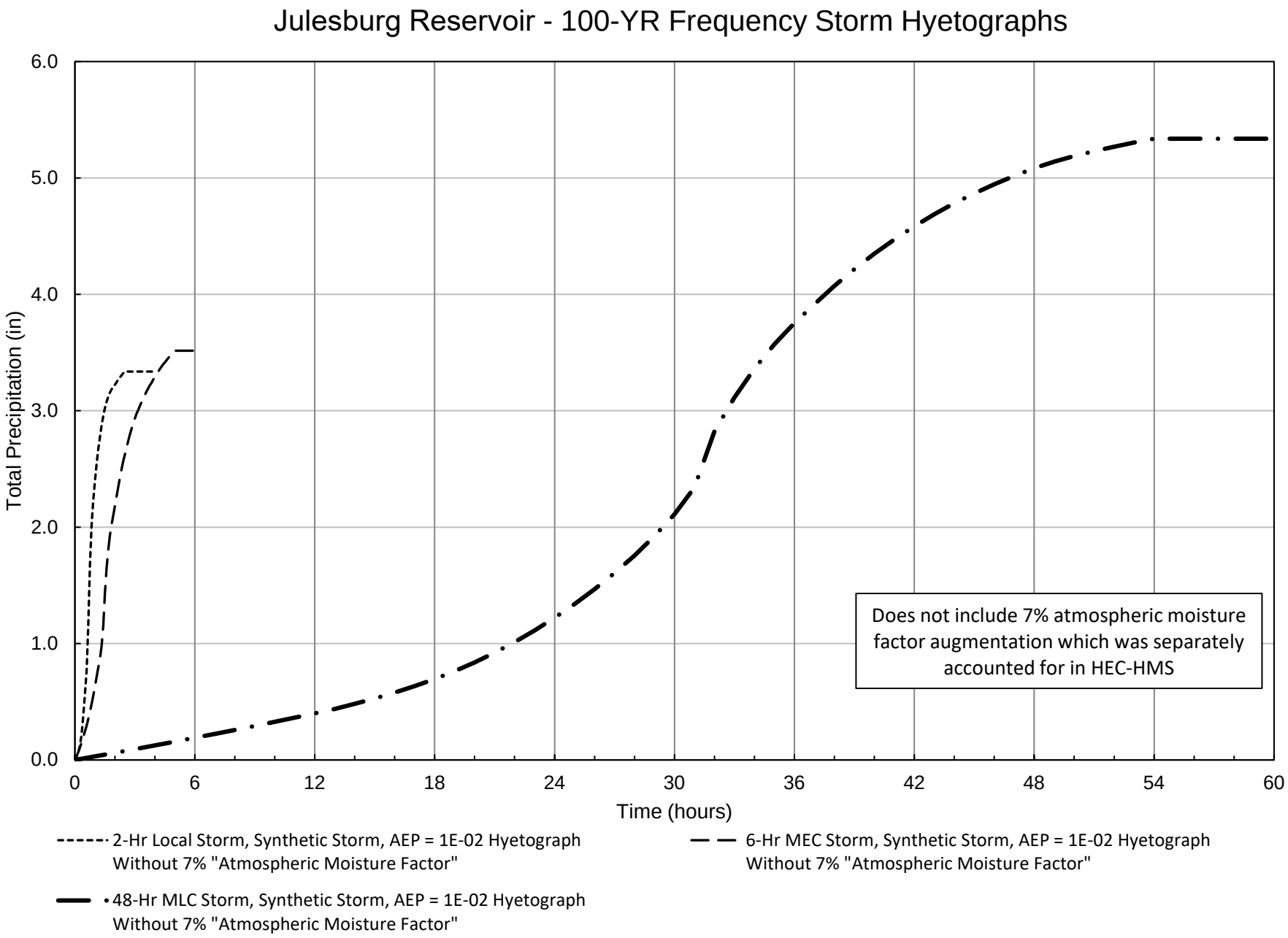
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Precip Documentation, MetPortal FS	Approved	0		

48-Hr MLC Storm, Synthetic Storm, AEP = 1E-07
Hyetograph Without 7% "Atmospheric Moisture Factor"

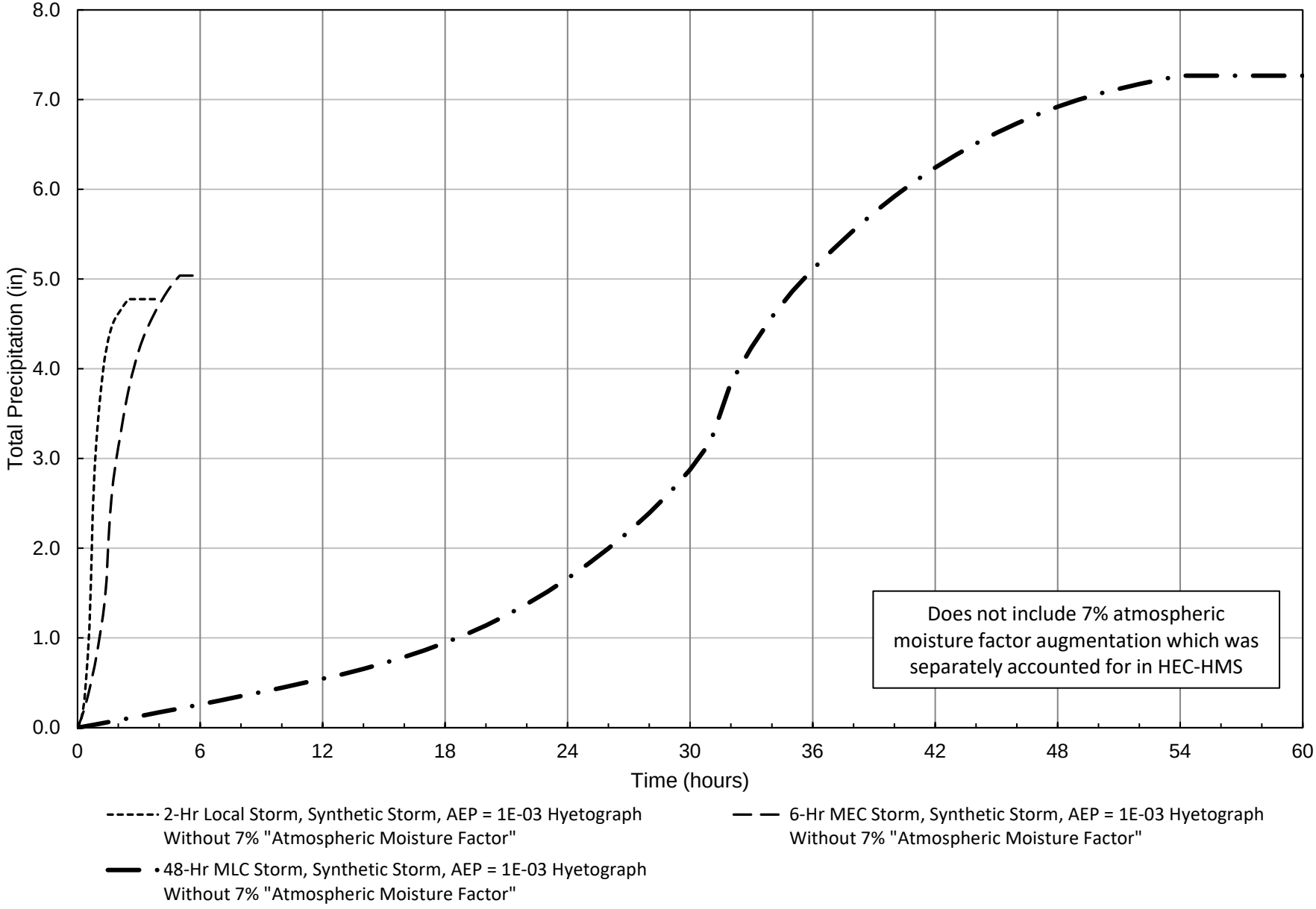
Time Step (#)	Elapsed Time (h)	Elapsed Time (min)	Incremental Precip (in)	Cumulative Precip (in)
38	38.00	2280	0.47594	**12.41945**
39	39.00	2340	0.44029	**12.85974**
40	40.00	2400	0.40618	**13.26592**
41	41.00	2460	0.37362	**13.63954**
42	42.00	2520	0.34262	**13.98216**
43	43.00	2580	0.31471	**14.29687**
44	44.00	2640	0.28836	**14.58522**
45	45.00	2700	0.26200	**14.84722**
46	46.00	2760	0.23875	**15.08597**
47	47.00	2820	0.21859	**15.30456**
48	48.00	2880	0.19844	**15.50300**
49	49.00	2940	0.17363	**15.67663**
50	50.00	3000	0.14728	**15.82391**
51	51.00	3060	0.12867	**15.95259**
52	52.00	3120	0.11627	**16.06886**
53	53.00	3180	0.10697	**16.17583**
54	54.00	3240	0.10232	**16.27815**
55	55.00	3300	0.00000	**16.27815**
56	56.00	3360	0.00000	**16.27815**
57	57.00	3420	0.00000	**16.27815**
58	58.00	3480	0.00000	**16.27815**
59	59.00	3540	0.00000	**16.27815**
60	60.00	3600	0.00000	**16.27815**
61	61.00	3660	0.00000	**16.27815**
62	62.00	3720	0.00000	**16.27815**
63	63.00	3780	0.00000	**16.27815**
64	64.00	3840	0.00000	**16.27815**
65	65.00	3900	0.00000	**16.27815**
66	66.00	3960	0.00000	**16.27815**
67	67.00	4020	0.00000	**16.27815**
68	68.00	4080	0.00000	**16.27815**
69	69.00	4140	0.00000	**16.27815**
70	70.00	4200	0.00000	**16.27815**
71	71.00	4260	0.00000	**16.27815**
72	72.00	4320	0.00000	**16.27815**

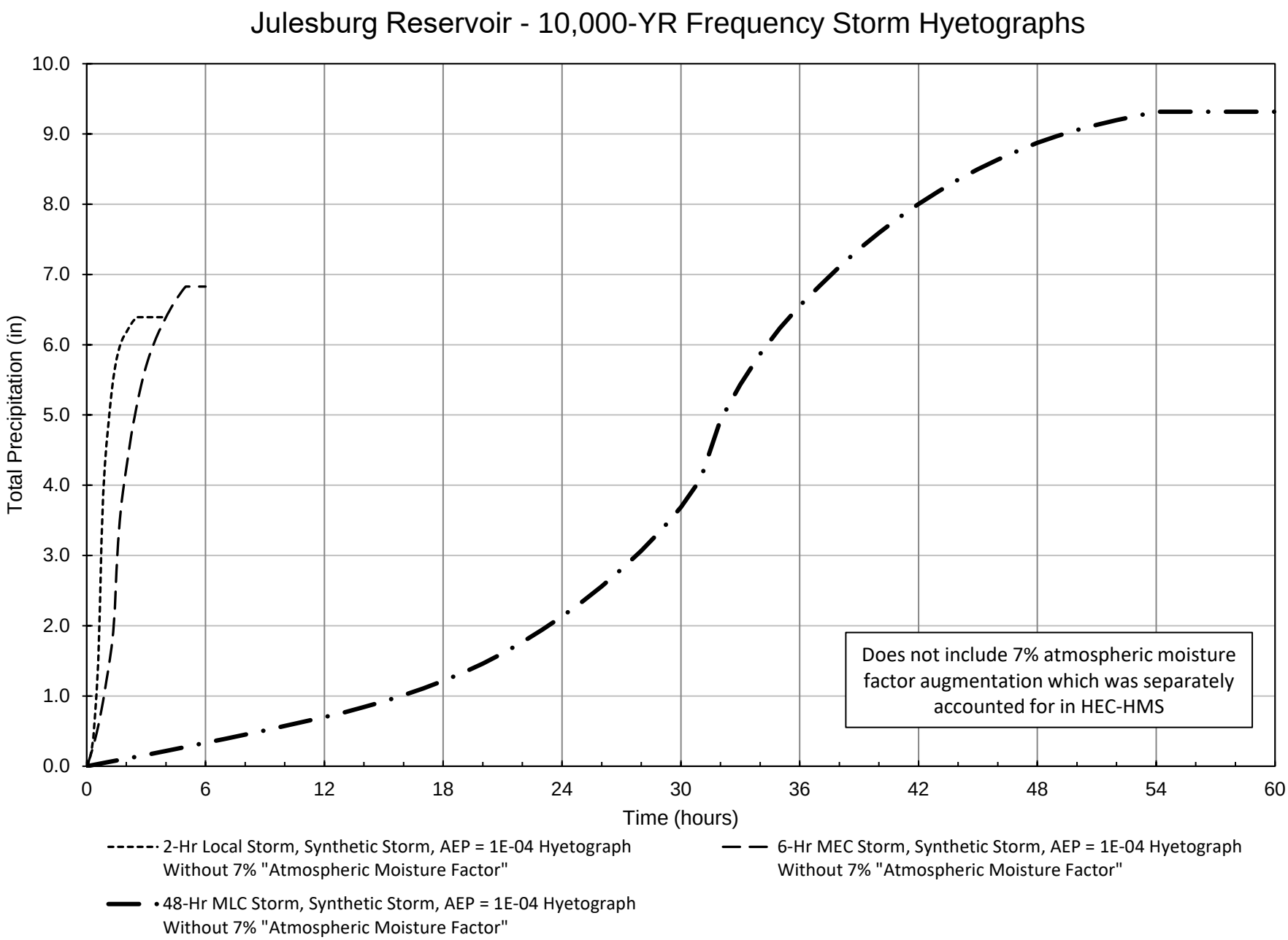
Julesburg Reservoir - 10-YR Frequency Storm Hyetographs

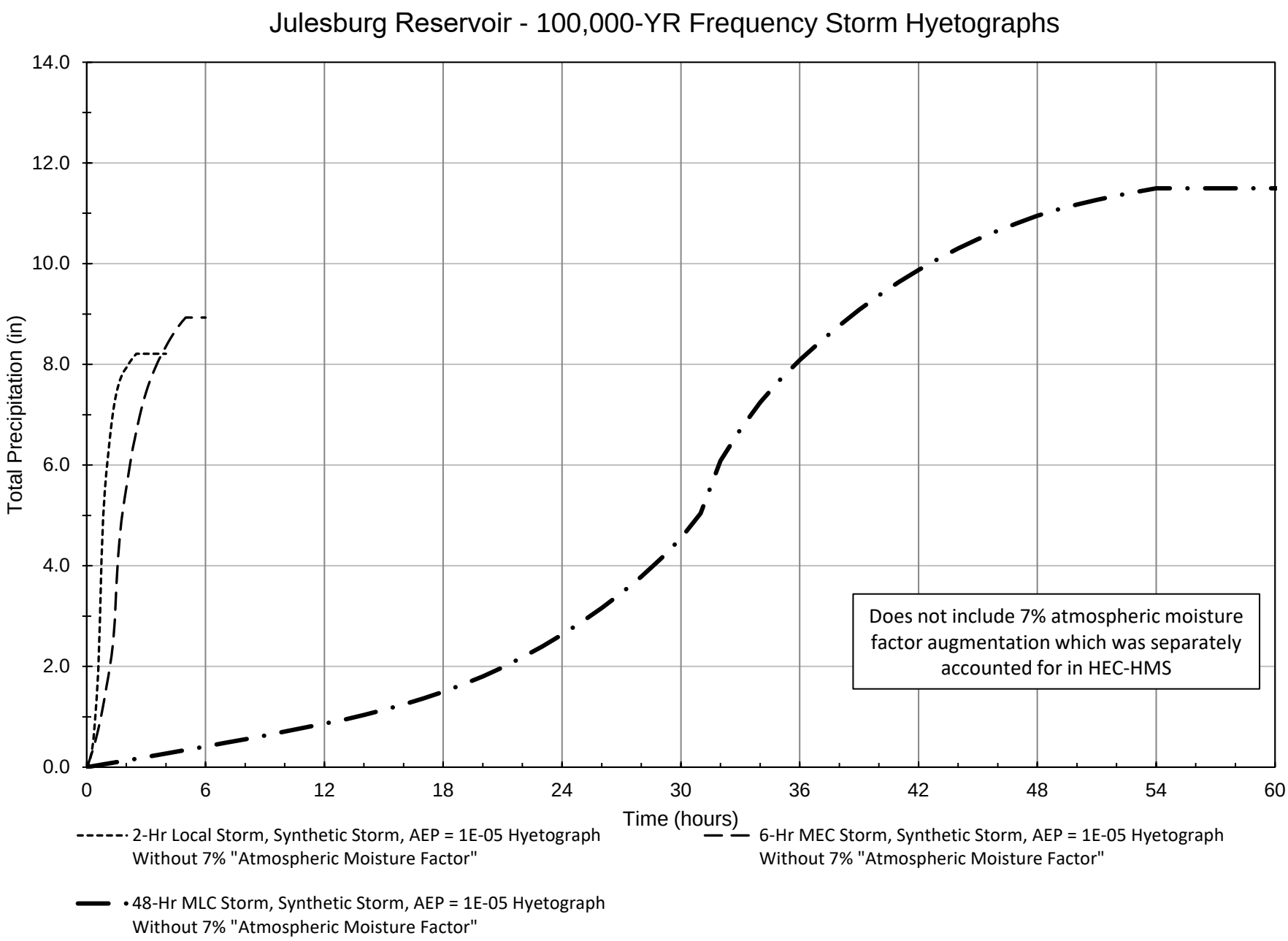


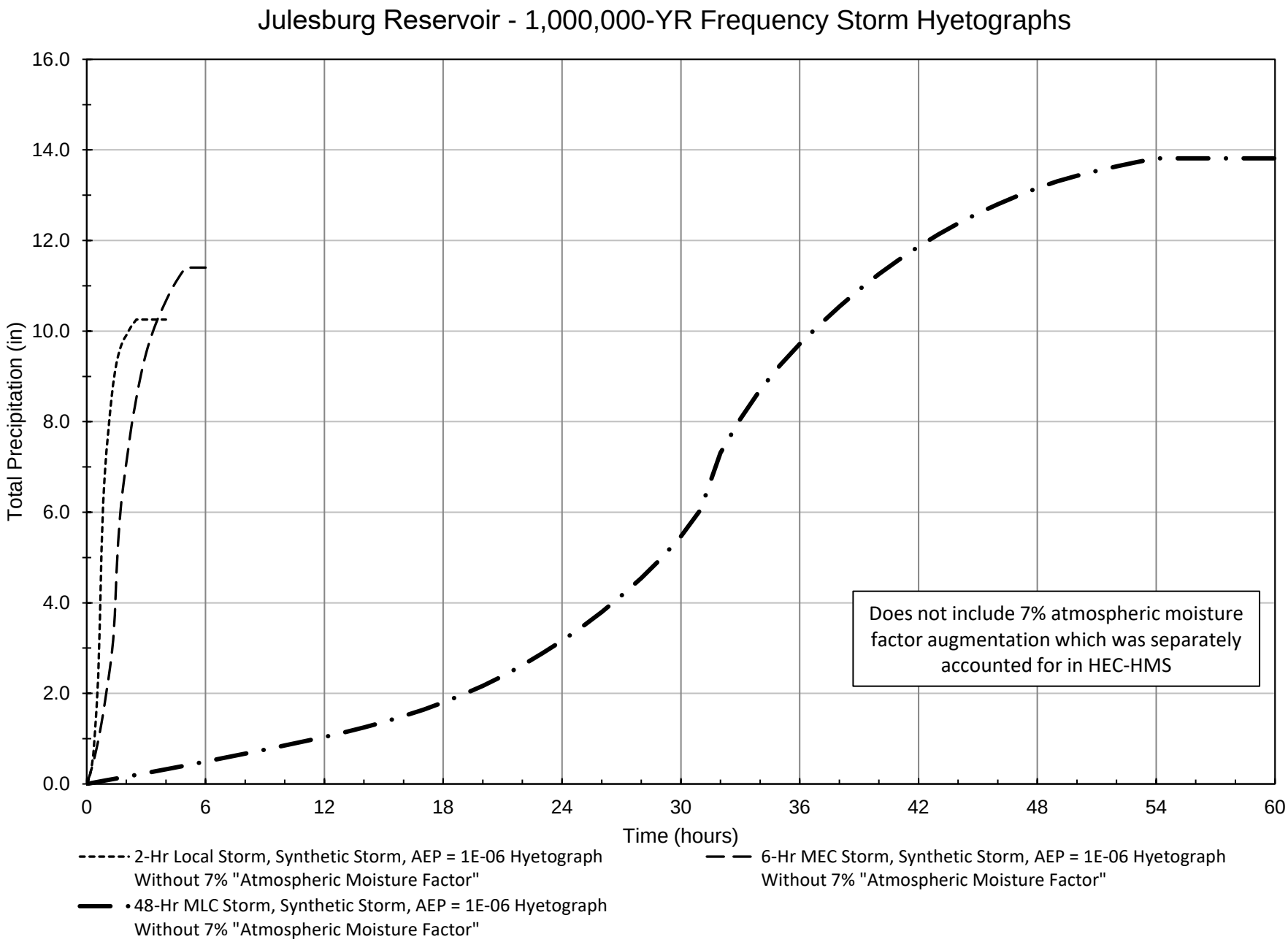

Julesburg Reservoir - 100-YR Frequency Storm Hyetographs
Total Precipitation (in)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
6
12
18
24
30
36
42
48
54
60
Time (hours)
Does not include 7% atmospheric moisture factor augmentation which was separately accounted for in HEC-HMS
2-Hr Local Storm, Synthetic Storm, AEP = 1E-02 Hyetograph Without 7% "Atmospheric Moisture Factor"
6-Hr MEC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph Without 7% "Atmospheric Moisture Factor"
48-Hr MLC Storm, Synthetic Storm, AEP = 1E-02 Hyetograph Without 7% "Atmospheric Moisture Factor"

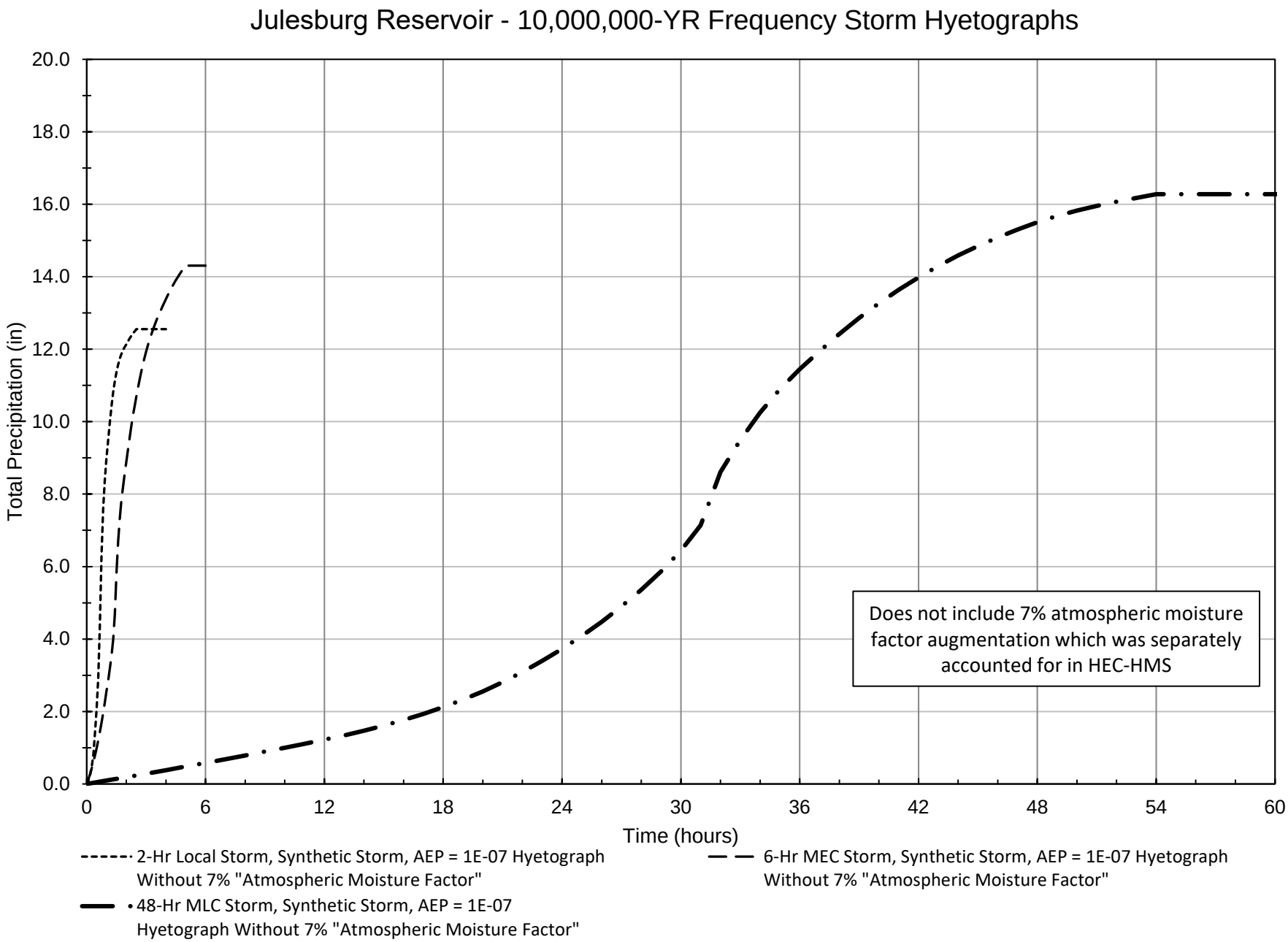
Julesburg Reservoir - 1,000-YR Frequency Storm Hyetographs




Julesburg Reservoir - 10,000-YR Frequency Storm Hyetographs
Total Precipitation (in)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
6
12
18
24
30
36
42
48
54
60
Time (hours)
Does not include 7% atmospheric moisture factor augmentation which was separately accounted for in HEC-HMS
2-Hr Local Storm, Synthetic Storm, AEP = 1E-04 Hyetograph Without 7% "Atmospheric Moisture Factor"
6-Hr MEC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph Without 7% "Atmospheric Moisture Factor"
48-Hr MLC Storm, Synthetic Storm, AEP = 1E-04 Hyetograph Without 7% "Atmospheric Moisture Factor"


Julesburg Reservoir - 100,000-YR Frequency Storm Hyetographs
Total Precipitation (in)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
Time (hours)
Does not include 7% atmospheric moisture factor augmentation which was separately accounted for in HEC-HMS
2-Hr Local Storm, Synthetic Storm, AEP = 1E-05 Hyetograph Without 7% "Atmospheric Moisture Factor"
6-Hr MEC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph Without 7% "Atmospheric Moisture Factor"
48-Hr MLC Storm, Synthetic Storm, AEP = 1E-05 Hyetograph Without 7% "Atmospheric Moisture Factor"


Julesburg Reservoir - 1,000,000-YR Frequency Storm Hyetographs
Total Precipitation (in)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
Time (hours)
Does not include 7% atmospheric moisture factor augmentation which was separately accounted for in HEC-HMS
2-Hr Local Storm, Synthetic Storm, AEP = 1E-06 Hyetograph Without 7% "Atmospheric Moisture Factor"
6-Hr MEC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph Without 7% "Atmospheric Moisture Factor"
48-Hr MLC Storm, Synthetic Storm, AEP = 1E-06 Hyetograph Without 7% "Atmospheric Moisture Factor"


Julesburg Reservoir - 10,000,000-YR Frequency Storm Hyetographs
Total Precipitation (in)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
6
12
18
24
30
36
42
48
54
60
Time (hours)
Does not include 7% atmospheric moisture factor augmentation which was separately accounted for in HEC-HMS
2-Hr Local Storm, Synthetic Storm, AEP = 1E-07 Hyetograph Without 7% "Atmospheric Moisture Factor"
6-Hr MEC Storm, Synthetic Storm, AEP = 1E-07 Hyetograph Without 7% "Atmospheric Moisture Factor"
48-Hr MLC Storm, Synthetic Storm, AEP = 1E-07 Hyetograph Without 7% "Atmospheric Moisture Factor"

Appendix B.3

Soil and Infiltration Documentation

W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			

OBJECTIVE:

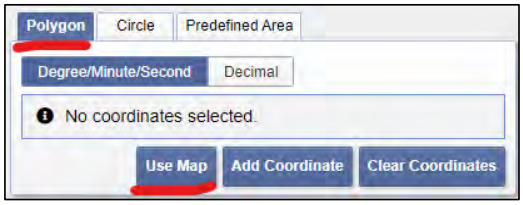
Document the obtainment and processing of the input data required to run the CSU-SMA GIS tool.
Note, regardless of how many basins are in the analysis, the CSU-SMA tool only needs to be run once.

METHOD:

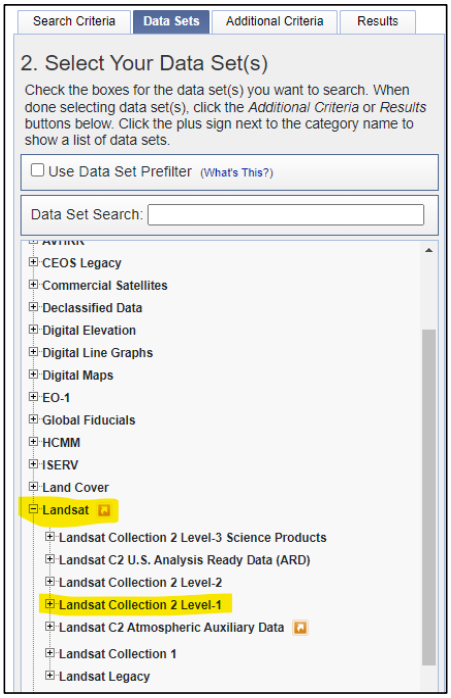
1. The *Guidelines for Hydrological Modeling and Flood Analysis* (DWR, 2022), Section 4 and Section 5 describe the process which was followed below.

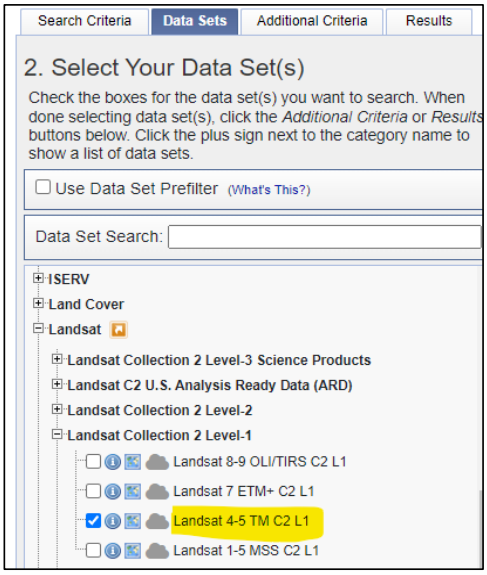
2. Download "Landsat" images for the "Normalized Difference Vegetation Index" (NDVI) raster calculation which is then used to calculate the "Fractional Vegetative Cover", or Fg.
   a. Download the "Landsat red and infrared band images" for the basin with USGS EarthExplorer:
   USGS Website: https://earthexplorer.usgs.gov/

   b. (Guidance, Section 4.4) Set Search Criteria: Polygon - Use Map



   c. Select Tab **"Data Sets":**
   Landsat -> Landsat Collection 2 Level-1
   Landsat 4-5 TM C2 Level-1 or Level-2.

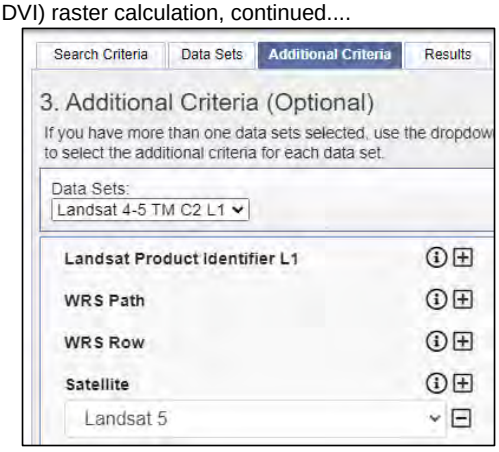




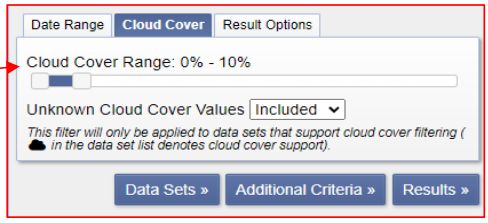
2. Download "Landsat" images for the (NDVI) raster calculation, continued....

d. Select Tab **"Additional Criteria":**

Land Cloud Cover -> "0 to 10"
Satellite -> Landsat5
Results

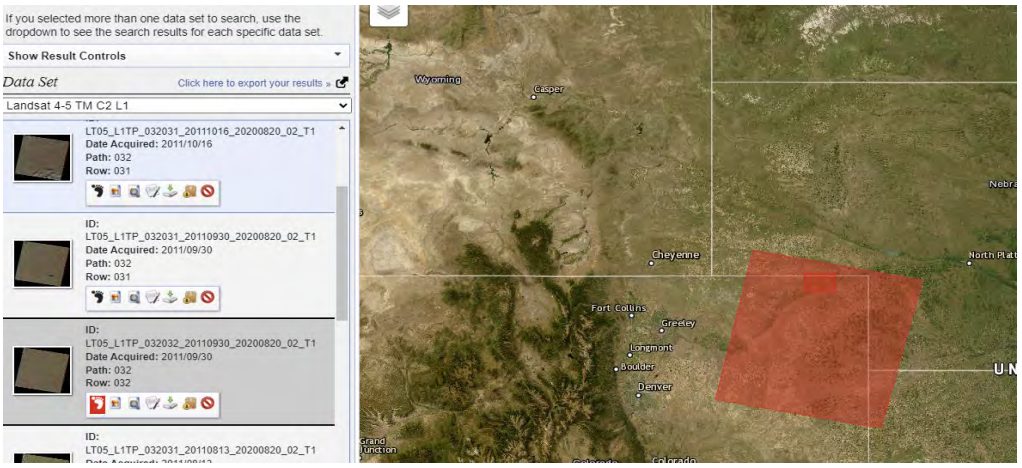


Note 1/17/2024:, Land Cover is now on the first tab, "Search Criteria"



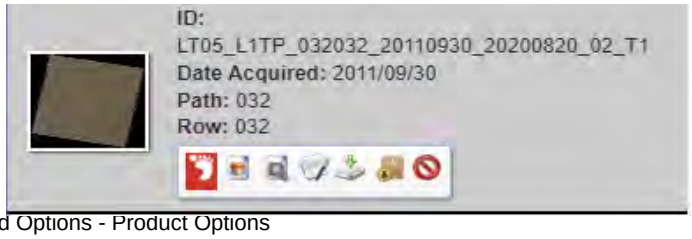
e. Look at result imagery from September or October.

Select the “footprint” icon and chose a flight path(s) that covers the entire basin-of-interest.

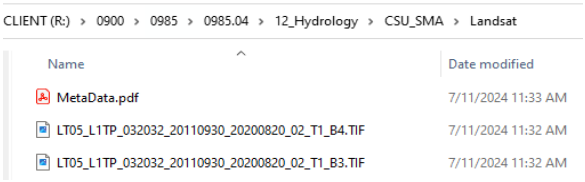


2. Download "Landsat" images for the (NDVI) raster calculation, continued....
Record the Metadata for the selected aerial:

- Save to network: R:\0900\0985\0985.04\12_Hydrology\CSU_SMA\Landsat
- Landsat Product Identifier L1: LT05_L1TP_032032_20110930_20200820_02_T1
- Coordinate System: UTM Zone 13 WGS 84
- Date Acquired: 9/30/2011



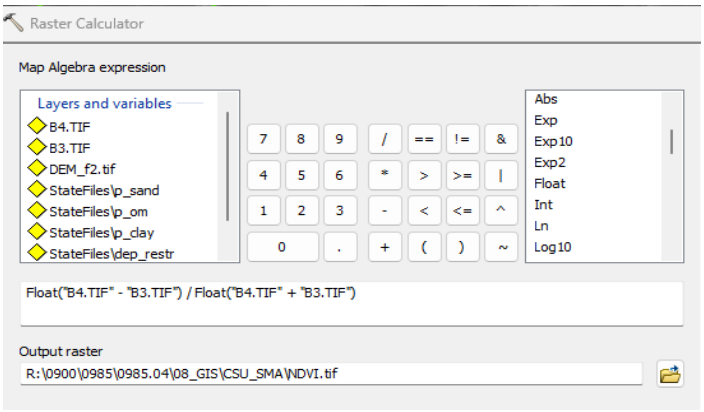
f. Download Options - Product Options
Select and Download the Landsat GeoTiff "B3.TIF" (red) and "B4.TIF" (near-infrared)



3. Calculate NDVI raster in GIS.
a. Arc ToolBox: Spatial Analyst Tools - Map Algebra - "Raster Calculator". Raster file name abbreviated in GIS Table of Contents.

$$NDVI_{Raster} = \frac{FLOAT(B4 - B3)}{FLOAT(B4 + B3)}$$

Where:
B3 = Landsat 5 band raster for "red"
B4 = Landsat 5 band raster for "near infrared"



- Result File Location:
R:\0900\0985\0985.04\08_GIS\CSU_SMA\NDVI.tif

3. Calculate NDVI raster in GIS, continued…
b. Clip to general basin area. Create a "Clip" shapefile (do in the same coordinate system as NDVI Raster). Include a buffer around basin (don't use the basin outline exclusively).

- File Location:
R:\0900\0985\0985.04\08_GIS\CSU_SMA\NDVI_clp.tif

Arc ToolBox: Data Management tools - Raster - Raster Processing - Clip (Yes "Use Input Features for Clipping Geometry") - Raster Created "NDVI_Clip"

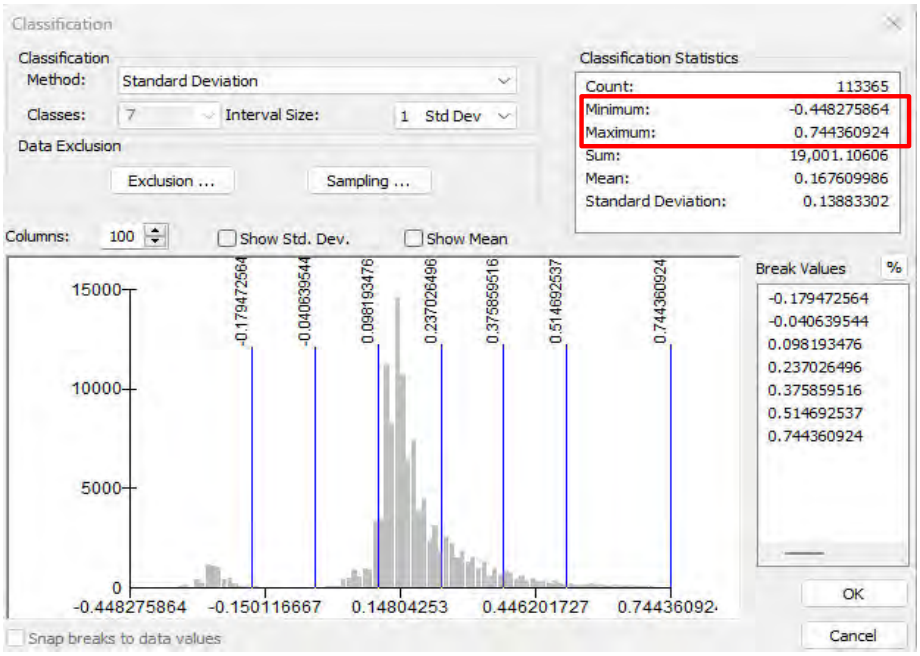
4. Determine $NDVI_{inf}$ and NDV_0 , which represent the range of NDVI values for the basin.

a. NDVI raster ranges in value from -1 to 1:

NDVI -1 to 0 : Negative NDVI correlates with open water, snow, and some rock outcrops

NDVI 0 < to 1 : Bare soil to "1" represents full vegetation

b. Find the range of raster values for the basin of interest by using GIS Raster Properties: Raster "NDVI_i" - Layer Properties - Symbology - Classified - Look at Histogram -



$NDVI_0$ = -0.448276 Min classification statistic

$NDVI_{inf}$ = 0.744361 Max classification statistic

5. Develop the fractional vegetative cover (Fg) for the basin.

$$Fg = \frac{(FLOAT(NDVI_i) - NDVI_0) * (FLOAT(NDVI_i) - NDVI_0)}{(NDVI_{inf} - NDVI_0) * (NDVI_{inf} - NDVI_0)}$$

Where:

$NDVI_0$ = -0.448276 Determined above, Min classification statistic

$NDVI_{inf}$ = 0.744361 Determined above, Max classification statistic

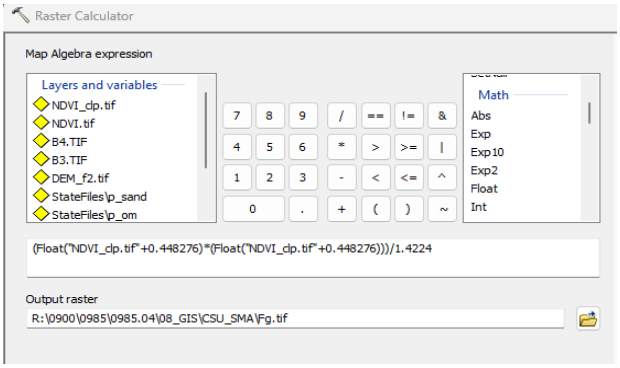
$NDVI_i$ = Raster Raster calculated above and clipped

$NDVI_{inf} - NDVI_0$ = 1.192637 Simplify Fg equation terms

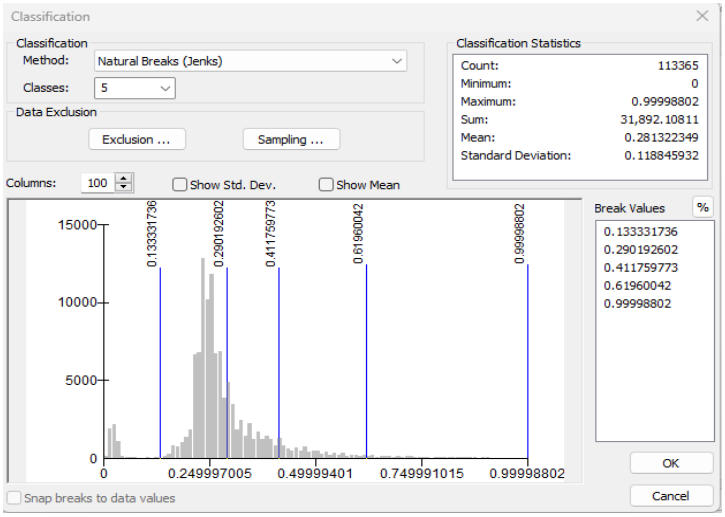
$(NDVI_{inf} - NDVI_0)^2$ = 1.4224 Simplify Fg equation terms

$$Fg = \frac{(FLOAT(NDVI_i) - -0.448276) * (FLOAT(NDVI_i) - -0.448276)}{1.4224}$$

a. Arc ToolBox: Spatial Analyst Tools - Map Algebra - "Raster Calculator".



b. Fg check: raster values should be between 0 and 1:



6. Clip the statewide soil property raster datasets.
   - Network copy of soil data (from: https://dnrftp.state.co.us/#/DWR/DamSafety/Colorado_Soils/) S:\GIS_CSU_SMA\SOIL_NRCS
   - Note, these are large files, so copy to project folder, clip, and remove the copy keeping only the clipped soil data in the project folder.

   a. Start with MXD containing statewide rasters. Note, select appropriate UTM Zone. Statewide soil data rasters are in NAD_1983_UTM_Zone_13N. XX Dam is in Zone (12 or 13)N
   - File Location: R:\0900\0985\0985.04\08_GIS\MXD\hydrology\05_CSU_SMA_NAD_1983_UTM_Zone_13N.mxd

   b. Clip the "originals", "p_sand", p"om", "p_clay", and "dep_restr" using the same boundary from the Fg generation.

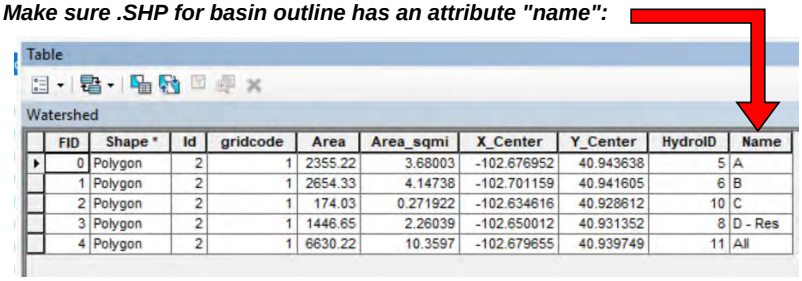
   Arc ToolBox: Data Management tools - Raster - Raster Processing - Clip (Yes "Use Input Features for Clipping Geometry"):
   R:\0900\0985\0985.04\08_GIS\CSU_SMA\clip

b. Add "Fg" raster, DEM raster, and convert all into NAD_1983_UTM_Zone_13N

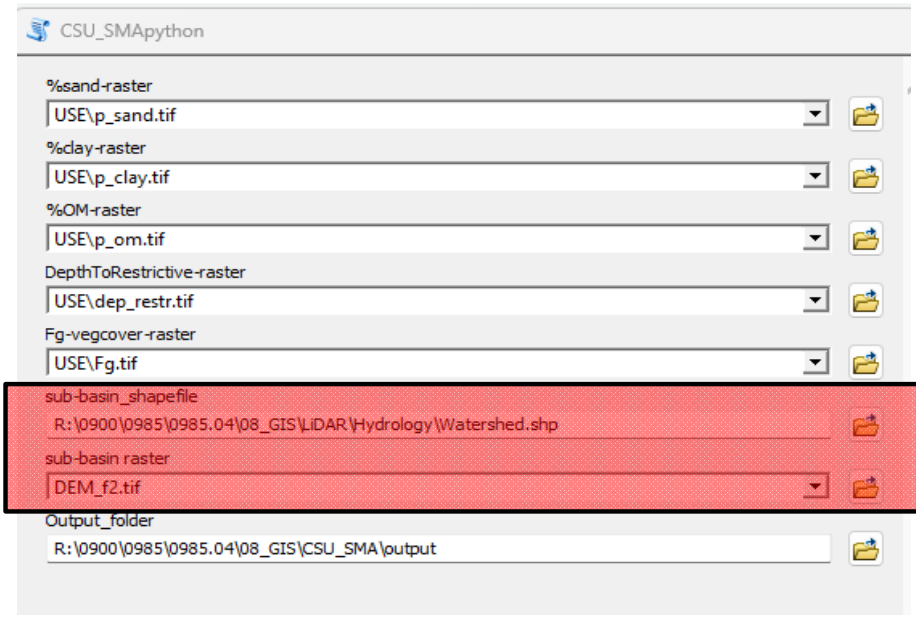
ASSUMPTIONS / INPUTS:

1. Run the CSU Python Script
   - Network location of python tool:
     S:\GIS_CSU_SMA\CSU_SMA_Python_Script\CSU_SMApython2.tbx
     Downloaded from: https://drive.google.com/drive/folders/1nuF3Oj8UTfgLm7YRZQS4lvKVAJbf69UV
   - Note, as of 1/18/2024 and according to Google Drive version, this python tool "CSU_SMApython2.tbx" was last modified Jan 25, 2022 by Mark Perry.

a. Make sure .SHP for basin outline has an attribute "name":



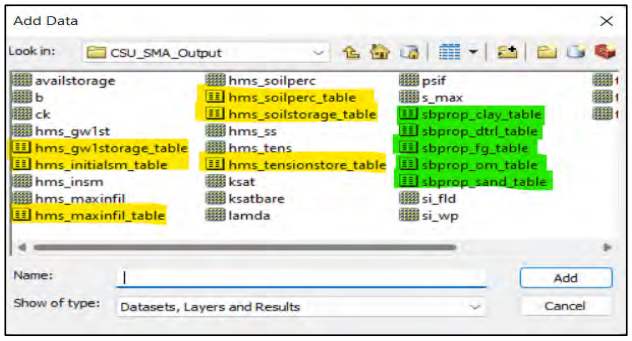
FID	Shape *	Id	gridcode	Area	Area_sqmi	X_Center	Y_Center	HydroID	Name
0	Polygon	2	1	2355.22	3.68003	-102.676952	40.943638	5	A
1	Polygon	2	1	2654.33	4.14738	-102.701159	40.941605	6	B
2	Polygon	2	1	174.03	0.271922	-102.634616	40.928612	10	C
3	Polygon	2	1	1446.65	2.26039	-102.650012	40.931352	8	D - Res
4	Polygon	2	1	6630.22	10.3597	-102.679655	40.939749	11	All



W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			

RESULTS:

1. GIS - Add Data - Navigate to the Output Folder from the last step - Add tables:



2. Print Summary Statistics Tables from Step 1, Summarize in table below

sbprop_sand_table

sbprop_sand_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.182	0.95	0.768	0.449599	0.150096	1068901.818937
2	B	2	2683921	10735684	0.221	0.95	0.729	0.52451	0.162488	1407743.175444
3	C	3	175062	700248	0.36	0.706	0.346	0.422534	0.123115	73969.665672
4	D - Res	4	62722	250888	0.182	0.775	0.593	0.333136	0.083385	20894.954237

sbprop_clay_table

sbprop_clay_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.017	0.297	0.28	0.195542	0.060357	464892.183179
2	B	2	2683921	10735684	0.017	0.33	0.313	0.181055	0.075254	485937.85206
3	C	3	175062	700248	0.12	0.29	0.17	0.239338	0.053774	41899.008643
4	D - Res	4	62722	250888	0.081	0.297	0.216	0.217627	0.059821	13650.020895

sbprop_om_table

sbprop_om_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.0031	0.0383	0.0352	0.015553	0.006392	36975.773376
2	B	2	2683921	10735684	0.0031	0.0383	0.0352	0.014644	0.00559	39304.085351
3	C	3	175062	700248	0.0047	0.0192	0.0145	0.016474	0.003674	2883.909302
4	D - Res	4	62722	250888	0.0036	0.0239	0.0203	0.010814	0.004318	678.299299

sbprop_dtrl_table ***(Units in inches)***

sbprop_dtrl_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN
1	A	1	2383001	9532004	11	79	68	74.431484	15.947885	177370301	4	79	11	79
2	B	2	2685567	10742268	79	79	0	79	0	212159793	1	79	79	79
3	C	3	176096	704384	79	79	0	79	0	13911584	1	79	79	79
4	D - Res	4	1463755	5855020	11	79	68	78.578848	5.190724	115020182	4	79	11	79

sbprop_fg_table

sbprop_fg_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2383001	9532004	0.128951	0.788287	0.659336	0.282542	0.078846	673297.68489
2	B	2	2685567	10742268	0.137614	0.848011	0.710396	0.260736	0.05504	700225.304646
3	C	3	176096	704384	0.129489	0.67831	0.548821	0.310447	0.095074	54668.490109
4	D - Res	4	1463755	5855020	0.000796	0.943759	0.942963	0.113173	0.20531	165657.265913

Subbasin Soil Property Summary						
Sub-Basin	% Sand	% Clay	% Organic Matter	Depth to Restrictive Layer (in)	Depth to Restrictive Layer (cm)	Fractional Vegetative Cover
A	45.0%	19.6%	1.6%	74.4	189.0	28.3%
B	52.5%	18.1%	1.5%	79	200.7	26.1%
C	42.3%	23.9%	1.6%	79	200.7	31.0%
D	33.3%	21.8%	1.1%	78.6	199.6	11.3%

3. Compare Subbasin Soil Properties to StreamStats Basin Properties, Soil Survey Geographic Database (SSURGO)

Basin	SSURGO A	SSURGO B	SSURGO C	SSURGO D	STATS CLAY
Full Basin	**18.9**	**27.2**	**18**	**1.79**	**9.89**

Soil data from StreamStats is limited for the full basin. However, the % Clay and % Sand values match close
Based on this comparison, the CSU-SMA Soil properties appear to be reasonable for the basin.

4. Compare Subbasin Soil Properties to the USGS Web Soil Survey (WSS), based on a weighted average calculation of the "soil physical property" percent for the top 20 inches of each soil map unit for the whole basin.

Website: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

SHP : (The same as what was used in the GIS Tool)
R:\0900\0985\0985.04\08_GIS\LiDAR\Hydrology\Watershed.shp

Obtain WSS Results: Soil Data Explorer tab --> Soil Properties and Qualities tab --> Soil Physical Properties tab --> Percent Sand / Clay / Organic Matter

Aggregation Method: Weighted Average
Tie Break Rule: Higher
Layer Options: Depth Range, Top Depth 0, Bottom Depth 20, Inches

Obtain WSS Results: Soil Data Explorer tab --> Soil Properties and Qualities tab --> Soil Qualities and Features --> Depth to Any Soil Restrictive Layer

Aggregation Method: Weighted Average
Tie Break Rule: Higher (I don't think this matters if using weighted average)
Nulls as Zero: N/A

R:\0900\0985\0985.04\12_Hydrology\CSU_SMA\SoilSurveyClay.pdf

R:\0900\0985\0985.04\12_Hydrology\CSU_SMA\SoilSurveyDepth.pdf

R:\0900\0985\0985.04\12_Hydrology\CSU_SMA\SoilSurveyOM.pdf

W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			

WSS Summary Table for percent sand, clay and organic matter, and depth to restrictive layer:

Map Unit Symbol	Map Unit Name	Acres AOI (Acres)	Sand Rating (%)	Clay Rating (%)	OM Rating (%)	D to Soil Restrictive (cm)
1	Albinas loam, 0 to 3 percent slopes	151.3	39	22.9	3.68	200.0
4	Altvan-Eckley sandy loams, 3 to 5	12.2	59.8	23.6	1.04	200.0
5	Altvan-Eckley sandy loams, 5 to 9	24.7	59.8	23.6	1.04	200.0
6	Aquolls	0.6	55.1	23.8	2.28	200.0
14	Ellicott-Ellicott sandy-skeletal	126.7	95	1.6	0.3	200.0
16	Bridgeport loam	5.3	31.4	21.5	1.61	200.0
18	Chappell sandy loam	193.2	65.2	11.5	0.97	200.0
24	Dix-Altvan complex, 10 to 30	0	79.2	7.4	0.96	71.0
25	Dix-Eckley complex, 5 to 25	239.6	74.3	7	0.64	200.0
27	Epping loam, 3 to 9 percent slopes	24.1	43	17.5	0.75	28.0
61	Manter, sandy loam, 0 to 3 percent	106.1	66.5	14.2	2.24	200.0
69	Mitchell-Keota loams, 0 to 3	17.5	21.2	14.5	0.75	61.0
70	Mitchell-Keota loams, 3 to 9	163	21.2	14.5	0.75	71.0
86	Peetz gravelly sandy loam, 5 to 25	908.5	67.9	10.5	1.63	200.0
89	Platner loam, 0 to 3 percent slopes	40.6	33.7	33.8	1.5	200.0
92	Rago loam, 0 to 3 percent slopes	87.9	36.3	30.8	1.5	200.0
99	Satanta loam, 0 to 1 percent	118.7	40	21.7	1.34	200.0
100	Satanta loam, 1 to 3 percent	852.6	39.3	22.6	1.31	200.0
103	Satanta loam, wet	0.8	37.8	24.9	1.21	200.0
118	Wages loam, 0 to 3 percent slopes	123	44	27	0.72	84.0
119	Wages loam, 3 to 5 percent slopes	168.5	44.1	22.7	1.57	200.0
120	Wages loam, 5 to 9 percent slopes	0.8	44.1	22.7	1.57	200.0
122	Wages-Manter complex, 3 to 9	547.7	44.1	22.7	1.57	200.0
123	Wages-Rosebud loams, 3 to 5	141.7	44.1	22.7	1.57	84.0
124	Wages-Rosebud loams, 5 to 9	805.8	44.1	22.7	1.57	84.0
132	Water	562				200.0
133	Ellicott-Glenberg complex, 0 to 3	7	95	1.6	0.3	200.0
EcE	Eckley-Chappell complex, 9 to 20	28	73.5	10.9	1.13	200.0
EpE	Epping gravelly loam, 5 to 15	40.9	40.4	22	0.75	38.0
KyD	Keota-Epping loams, 3 to 9	124.4	17.4	25.5	0.35	50.0
Ls	Las loam	1.7	37.6	25	0.45	200.0
RcB	Richfield loam, 0 to 3 percent	59.9	36.8	27.8	0.99	200.0
W	Water	830.7				200.0
WaC	Wages gravelly loam, 3 to 5	0.6	37.3	25.3	1.75	200.0
WaD	Wages gravelly loam, 5 to 9	113.6	37.3	25.3	1.75	200.0

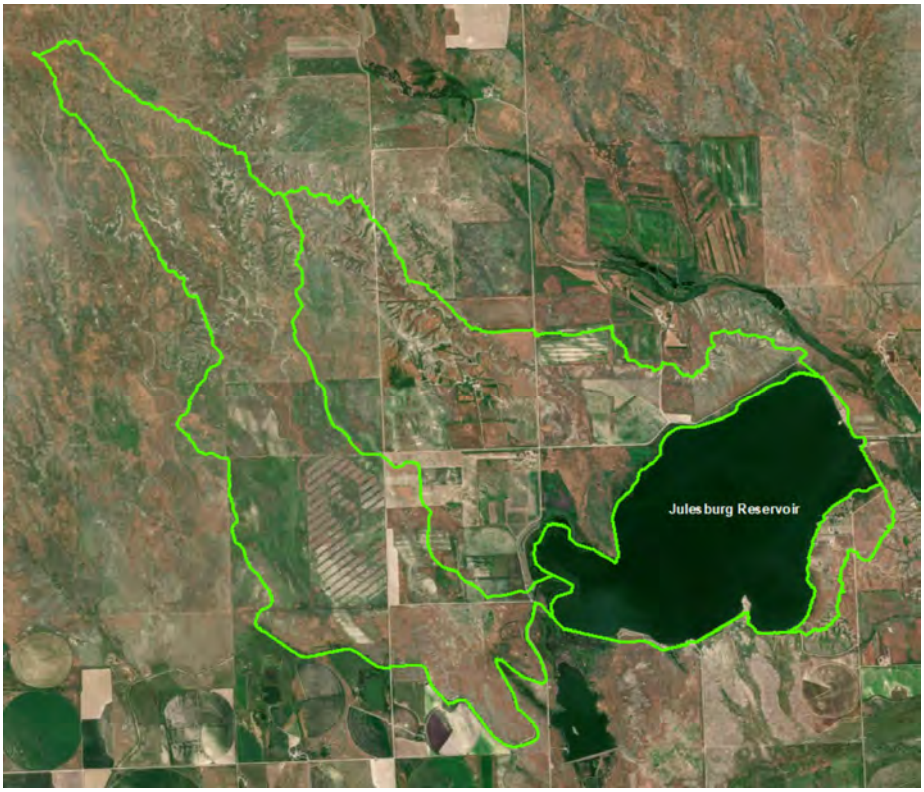
Total	% Sand	% Clay	%OM	Depth (cm)
	39.1%	14.9%	1.1%	173.29

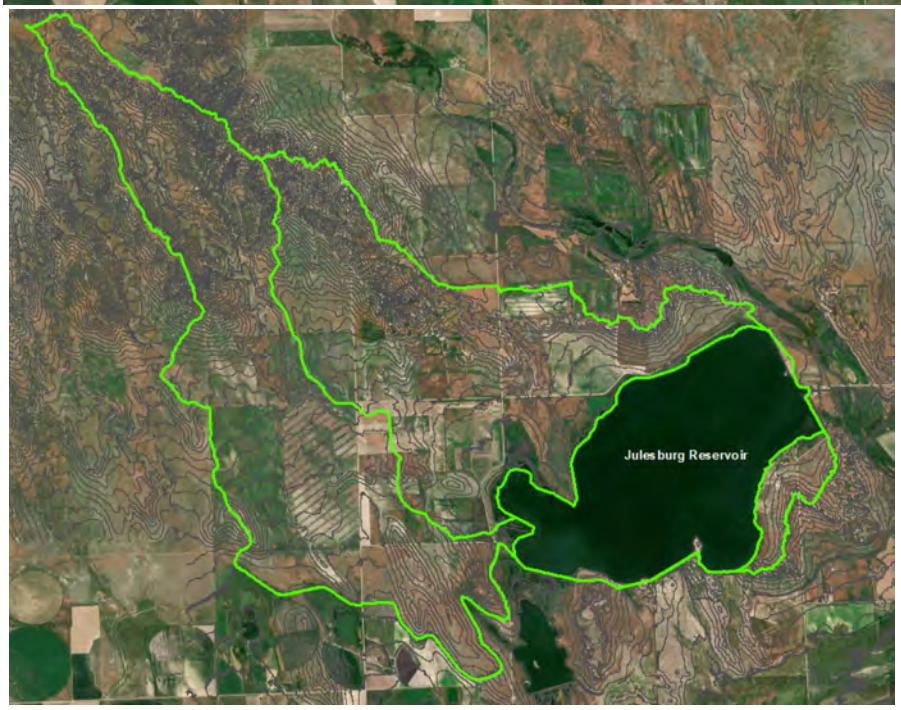
Subbasin Soil Property Summary (Mean Values)

Sub-Basin	% Sand	% Clay	% Organic Matter	Depth to Restrictive Layer (cm)	Fractional Vegetative Cover
Average, SMA	43.2%	20.8%	1.4%	197.47	24.2%
Average, WSS	39.1%	14.9%	1.1%	173.29	N/A

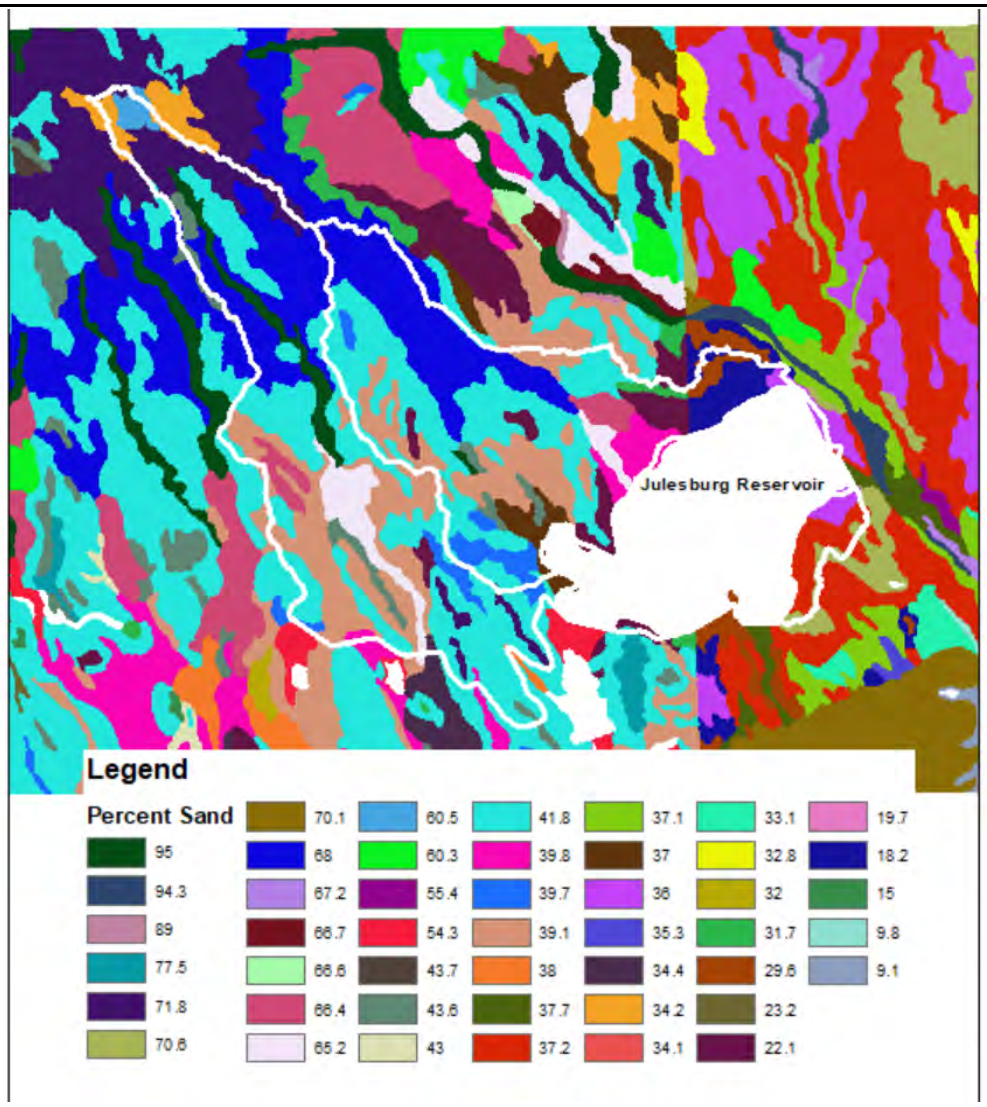
The CSU-SMA vs WSS-weighted-average for basin soil properties of percent sand, percent clay and percent organic matter had a difference of 4.2%, 5.9%, 0.3% and 24 cm, respectively. All within a reasonable amount of diffrence.

4. Print GIS Subbasin Property Maps (next pages)
   1 Aerial Imagery
   2 Topography
   3 Percent Sand
   4 Percent Clay
   5 Percent Organic Material
   6 Depth to Restrictive Layer (inches)
   7 Fractional Vegetative Cover

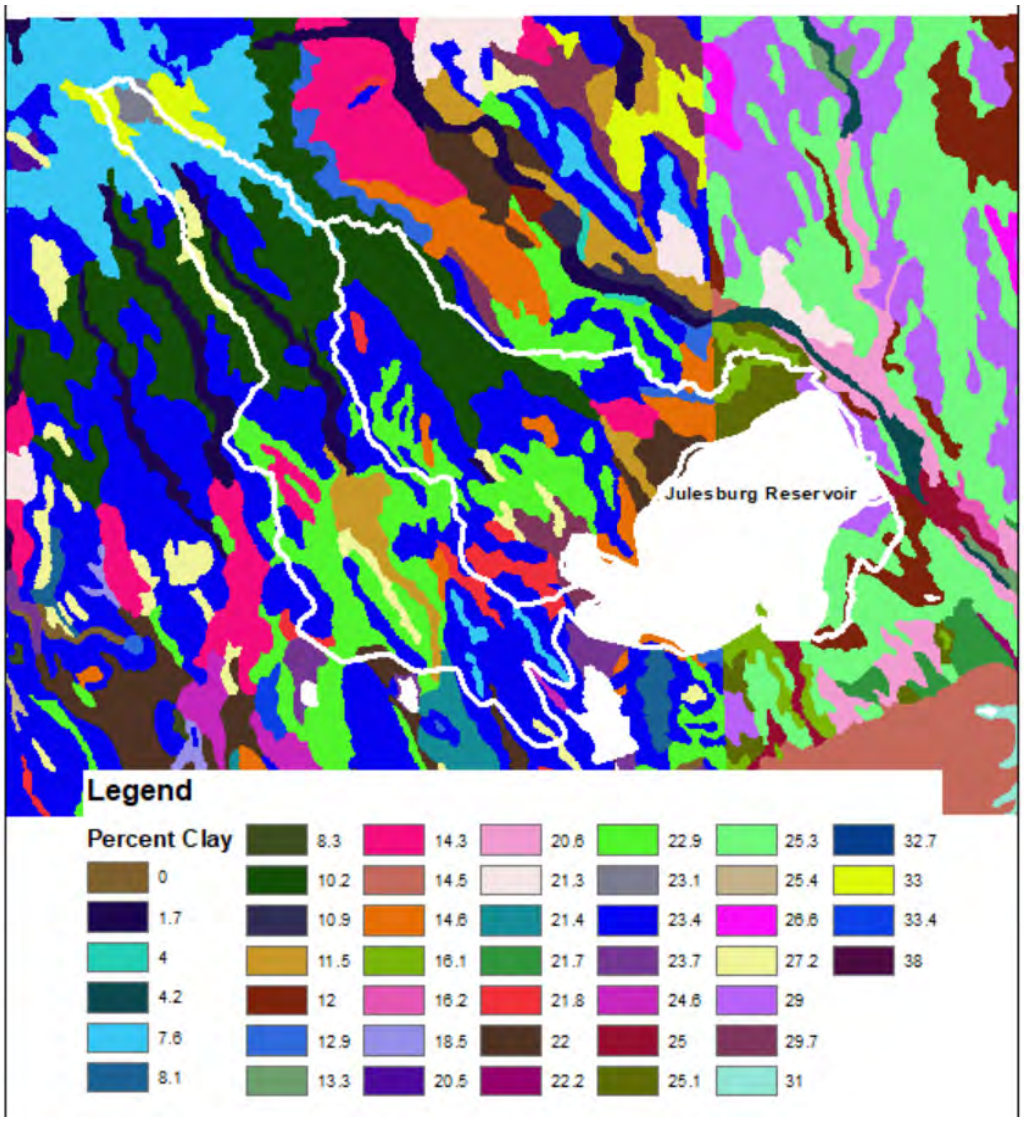




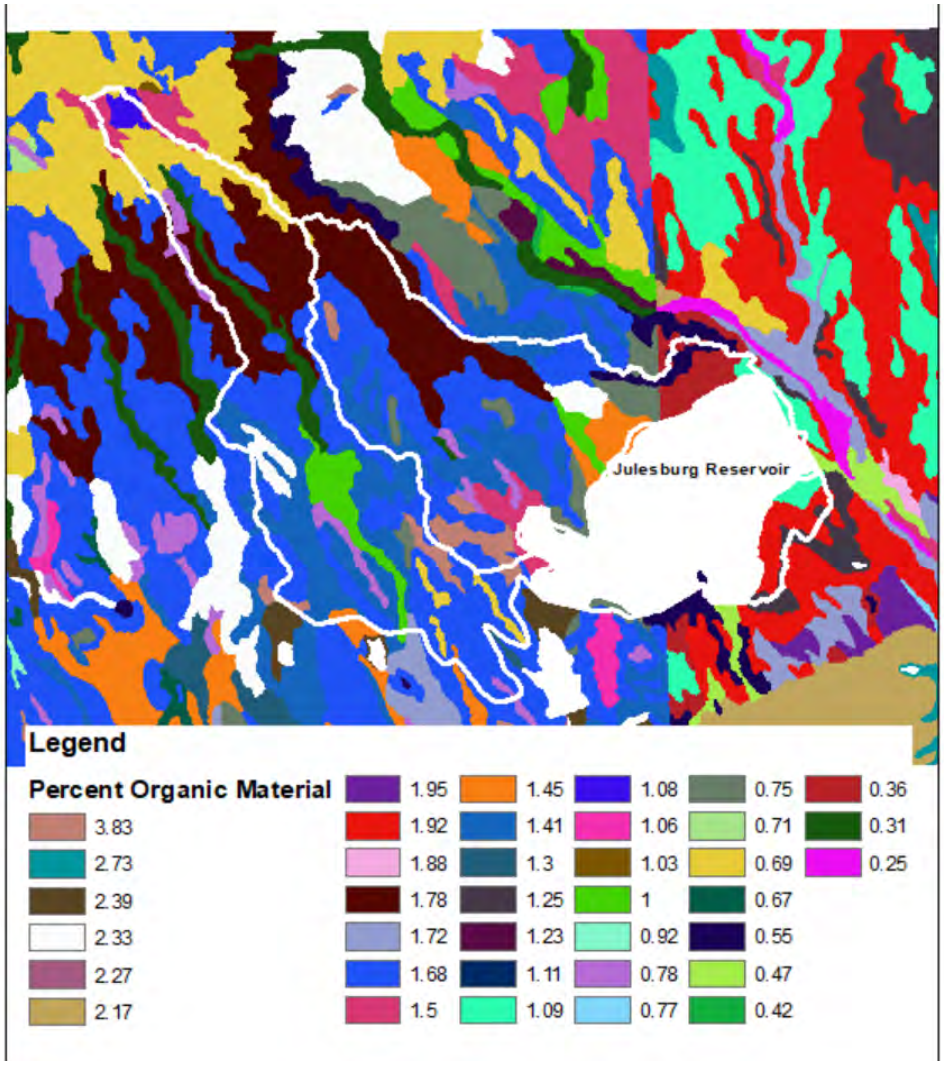
W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			



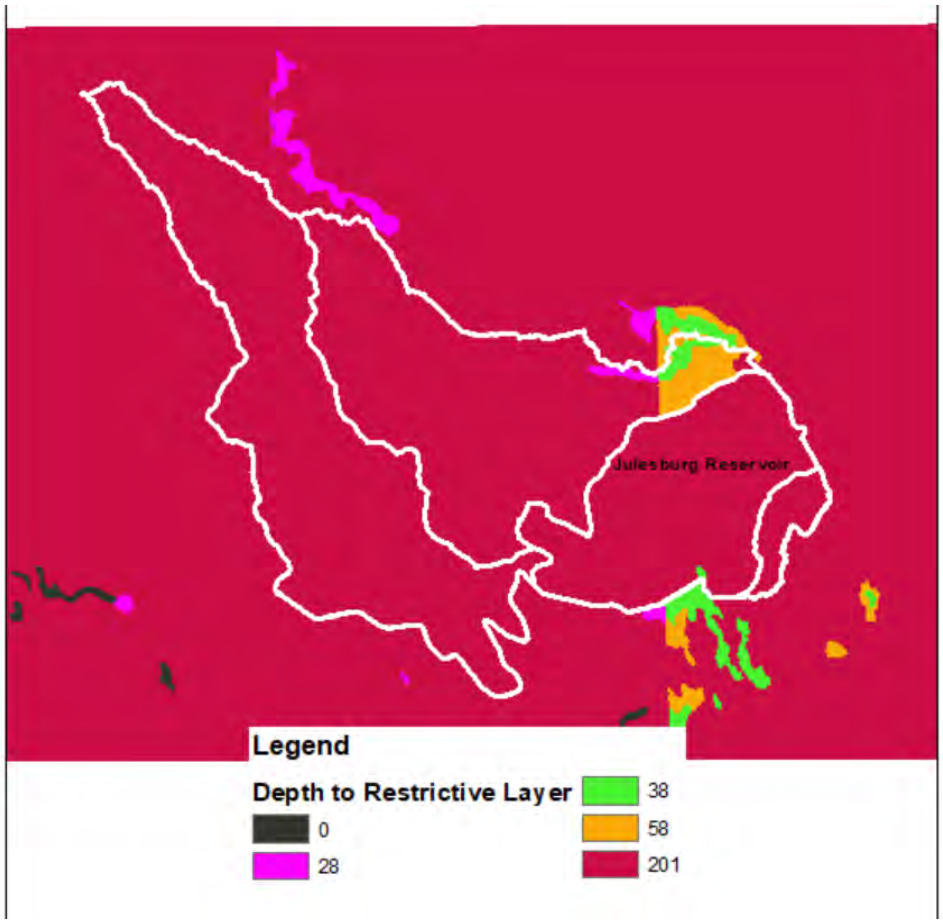
W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			

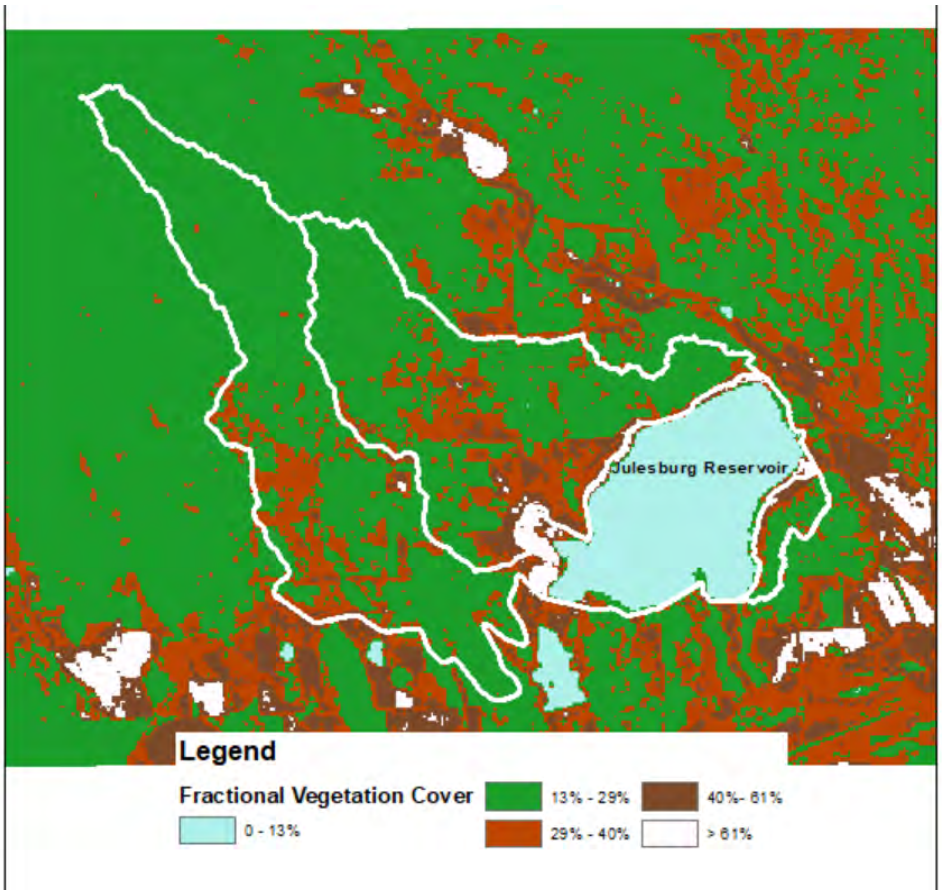


W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			



W. W. WHEELER & ASSOCIATES, INC.	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/11/2024
	CSU-SMA Input Data	Approved			





4. Print SMA Output Tables from Step 1, Summarize in table below

hms_initialsm_table

hms_initialsm_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	8.471975	62.850224	54.378248	44.500262	12.203708	105797371.437492
2	B	2	2683921	10735684	8.471975	59.56102	51.089045	39.076235	13.597922	104877527.888292
3	C	3	175062	700248	23.387081	54.633144	31.246063	48.080304	10.761282	8417034.237698
4	D - Res	4	62722	250888	17.949392	62.850224	44.900831	53.811848	5.290683	3375186.703444

hms_maxinfil_table

hms_maxinfil_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.513261	7.10556	6.592299	1.263134	0.469298	3003045.40879
2	B	2	2683921	10735684	0.398364	6.70811	6.309746	1.431567	1.041458	3842212.12703
3	C	3	175062	700248	0.585586	1.461187	0.875601	0.914971	0.199983	160176.714804
4	D - Res	4	62722	250888	0.491374	2.80532	2.313946	1.361171	0.593171	85375.373755

hms_soilstorage_table

hms_soilstorage_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	2.99281	30.222893	27.230083	18.676961	4.56028	44403634.990531
2	B	2	2683921	10735684	16.202959	30.222893	14.019934	20.528664	3.264113	55097311.704943
3	C	3	175062	700248	17.073444	22.465631	5.392187	18.518013	1.750627	3241800.426352
4	D - Res	4	62722	250888	2.99281	24.743111	21.750301	16.494038	5.621391	1034539.020868

hms_tensionstore_table

hms_tensionstore_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	1.727553	13.980151	12.252598	8.817038	2.594273	20962111.221417
2	B	2	2683921	10735684	2.844974	13.980151	11.135178	8.442847	2.193555	22659934.375072
3	C	3	175062	700248	5.83784	10.423696	4.585856	9.684885	1.669795	1695455.31511
4	D - Res	4	62722	250888	1.727553	13.980151	12.252598	9.84756	3.589719	617658.687912

hms_soilperc_table

hms_soilperc_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.032154	7.295838	7.263684	0.181498	0.372205	431502.774485
2	B	2	2683921	10735684	0.02568	6.887745	6.862065	0.485075	1.245286	1301902.58782
3	C	3	175062	700248	0.038241	0.450127	0.411886	0.111014	0.12909	19434.338478
4	D - Res	4	62722	250888	0.032089	0.692108	0.660019	0.078342	0.058378	4913.785827

hms_gw1storage_table

hms_gw1storage_table

Rowid	NAME	ZONE-CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	A	1	2377455	9509820	0.332534	3.358099	3.025565	2.075218	0.506698	4933737.538714
2	B	2	2683921	10735684	1.800329	3.358099	1.557771	2.280963	0.362679	6121923.858948
3	C	3	175062	700248	1.897049	2.496181	0.599132	2.057557	0.194514	360200.044313
4	D - Res	4	62722	250888	0.332534	2.749235	2.4167	1.832671	0.624599	114948.783853

Soil Properties for HEC-HMS HEC-HMS	CSU SMA Python Script Output Table	Basin A Average Value *	Basin B Average Value *	Basin C Average Value *	Basin D Average Value *
HEC-HMS Max Infiltration	hms_maxinfil_table	1.263	1.432	0.915	1.361
HEC-HMS Soil Percolation	hms_soilperc_table	0.181	0.485	0.111	0.078
HEC-HMS Soil Storage	hms_soilstorage_table	18.677	20.529	18.518	16.494
HEC-HMS Parameter GW1 Storage	hms_gw1storage_table	2.075	2.281	2.058	1.833
HEC-HMS Tension Storage	hms_tensionstore_table	8.817	8.443	9.685	9.848
HEC-HMS Initial Soil Moisture	hms_initialsm_table	44.500	39.076	48.080	53.812

* Note, only report to the 1,000th of an inch

REFERENCES:

1. Colorado Division of Water Resources, Dam Safety Branch (DWR, 2022), *Guidelines for Hydrological Modeling and Flood Analysis* , September 12, 2022.
2. U.S. Geological Survey (USGS) Landsat Imagery. (USGS Landsat, 2011), ***LT05_L1TP_035034_20110919_20200820_02_T1,*** Acquired 9/19/2011, obtained online 4/18/2022.

Appendix B.4

Clark Unit Hydrograph Documentation

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by CBM	Job No. 985.04
	Dam 1, 2, 3, 4 and 1a	Checked JTC	Date 7/2/2024
	Clark UH Parameters	Approved	

OBJECTIVE:

Document the Unit Hydrograph (UH) approach used in the CSU Soil Moisture Accounting (CSU-SMA) method (DWR, 2022). The UH parameters are entered directly in to the HEC-HMS model.

METHOD:

1. The *Guidelines for Hydrological Modeling and Flood Analysis* (DWR, 2022), Section 6.3 indicate the Clark UH approach is used. The two parameter variables are the "Time of Concentration", Tc, and "Storage Coefficient", R.

   Table 5 of the Guidance provides a starting point depending on the basin region and elevation:

Table 5: Summary of guidance for Clark UH Tc and R parameter estimation by region(1)

Region	Tc, time of concentration (hrs)	R, storage coefficient (hrs)
Mountains > 7,500 ft	$T_c = 2.4A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.2}$ (Sabol, 2008)	Sub-basin<10sqmi: R/(Tc+R)=0.6-0.8 Sub-basin>10sqmi: 7 hours
Front Range foothills, Eastern Plains, and West Slope Canyons(2)	$T_c = 2.4A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.2}$ (Sabol, 2008)	R/(Tc+R) = 0.2-0.3 or $R=0.37T_c^{1.11}L^{0.8}A^{-0.57}$ (Sabol, 2008)
Agricultural	$T_c=7.2A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.2}$ (Sabol, 2008)	$R=0.37T_c^{1.11}L^{0.8}A^{-0.57}$ (Sabol, 2008)
Urban/developed	$T_c=3.2A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.14}RTIMP^{-0.36}$ (Sabol, 2008)	$R=0.37T_c^{1.11}L^{0.8}A^{-0.57}$ (Sabol, 2008)

(1) These estimates should be used as a starting place; Tc and R should be checked and calibrated as needed based on reasonableness checks against peak flow envelopes and flood frequency estimates, as discussed in Sections 9 & 10 below.

(2) HEC-HMS's Clark UH Variable method for estimating Tc and R may help in model calibration per Section 10 below

Section 10.3 of the Guidance on model calibration and application of Tc and R:

- **Clark Unit Hydrograph Time of Concentration (hr):** T_c generally represents channel storage and travel time through the basin stream network. Decreasing T_c will produce larger peak flows and flashier surface runoff hydrographs. See discussions above about use of Clark Variable method to produce non-linear runoff response, i.e., flashier runoff response with increasing rainfall intensity and excess precipitation.
- **Clark Unit Hydrograph Storage Coefficient (hr):** *R* generally represents hillslope storage in the basin. Decreasing *R* will have a similar effect as decreasing T_c, producing larger peak flows and flashier surface runoff hydrographs.

2. The first calculated parameter is the "Time of Concentration" Tc, which is calculated according to Sabol (2008) for the Rocky Mountain, Great Planes, and CO Plateau Regions:

$$T_C = 2.4 * A^{0.1} * L^{0.25} * L_{ca}^{0.25} * S^{-0.2}$$

Where:

A = The total (sub)basin area in square miles
L = The longest flow path length in miles
S = The longest flow path slope in feet per mile
L_{ca} = The centroidal flow path length in miles

3. The second calculated parameter is the "Storage Coefficient" R. The Storage Coefficient represents basin storage, and is a recommended calibration parameter for the model to obtain HEC-HMS results that align more closely with the StreamStats Peak Flow Statistics. Larger values of "R" according to the Guidance "lead to lower predictions of peak flow and more attenuated hydrographs".

   Based on Table 5 reproduced above, the following decision sequence was used to determine a starting value of "R":

   a. Is the elevation above 7,500 feet, and is the area greater than 10 mi^2?

      If "Yes", the Guidance recommends using a constant value of R = 7 based on a general average of Colorado mountain basins investigated by CSU (Irvin, 2021)

Not applicable in this case, Elev < 7,500 ft

   b. Is the elevation above 7,500 feet, and is the area less than 10 mi^2?

      If "Yes", the Guidance indicates the ratio of "R / (Tc+R)" is within a range of 0.6 to 0.8:

$$0.6 < \frac{R}{T_c + R} < 0.8$$

$$R = 1.5\, T_c \; to \; 4T_c$$

Not applicable in this case, Elev < 7,500 ft

   c. Is the basin in the Front Range foothills, Eastern Plains, or West Slope Canyons

      If "Yes", the Guidance indicates the ratio of "R / (Tc+R)" is within a range of 0.2 to 0.3:

$$0.2 < \frac{R}{T_c + R} < 0.3$$

$$R = 0.25\, T_c \; to \; 0.43T_c$$

Use 0.43Tc as a starting place for R

   d. It is noted that "R" can be calculated according to Sabol (2008):

$$R = 0.37 \; * T_c^{1.11} * L^{0.80} * A^{-0.57}$$

      "R" according to Sabol was also calculated for comparison against the range indicated from the Guidance and may be relevant when calibrating the model.

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	Clark UH Parameters	Approved			

ASSUMPTIONS / INPUTS:

Note: Values below are from the **RESULTS** of Step No. 2, Basin DEM Parameters. The Area "A" and Length "L" and "Lca" values below were obtained in meters, calculated using GIS, and recorded to 6 decimal places. The Max and Min elevation were recorded to the nearest whole meter.

Area	Longest Flow path Length	Highest Elevation Along L (1)	Lowest Elevation Along L (2)	Longest Flow path Slope	Centroidal Flow path Length	Centroid X	Centroid Y	
A	L	El_{MAX}	El_{MIN}	S	L_{CA}	X	Y	
(Mile ^{2})	(Mile)	(Feet)	(Feet)	(Feet/ Mile)	(Mile)	(Decimal Deg)	(Decimal Deg)	Basin
3.680000	3.791000	4026.0	3707.0	84.14085993	1.108790	-102.676952	40.943638	A
4.147000	9.749140	4138.6	3707.0	44.26646863	5.495140	-102.701159	40.941605	B
0.271922	0.497915	3792.0	3707.0	170.7118685	0.291746	-102.634616	40.928612	C
2.260390	NA	3707.0	3707.0	NA	NA	-102.650012	40.931352	D-res

(1) Determined using contours created from the 1-meter DEM in GIS.
(2) Determined using contours created from the 1-meter DEM in GIS, elevation of the channel downstream of the outlet works; consistent with EIR crest El - dam height.

CALCULATIONS:

Time of Concentration	Storage Coefficient, Min Range	Storage Coefficient, Max Range	Storage Coefficient (Sabol)	
T_c	$R_{Ratio\ 0.2}$ (1)	$R_{Ratio\ 0.3}$ (2)	R_{SABOL}	
(Hour)	(Hour)	(Hour)	(Hour)	Basin
1.61	0.40	0.69	0.87	A
3.51	0.88	1.50	4.09	B
0.47	0.12	0.20	0.19	C
Na	NA	NA	NA	D-res

RESULTS:

The following Time of Concentration (Tc), and Storage Coefficient (R) as summarized in the table below was entered into Calculation 7 as the initial condition for HEC-HMS entry. Additional refinement /calibration are completed in Calculation to determine the final Storage Coefficient value.

	Time of Concentration	Storage Coefficient (Sabol)
	T_c	$R_{0.43*Tc}$
Basin	(Hour)	(Hour)
A	1.613	0.69
B	3.508	1.51
C	0.465	0.20
D-res	NA	NA

REFERENCES:

1. Colorado Division of Water Resources, Dam Safety Branch (DWR, 2022), *Guidelines for Hydrological Modeling and Flood Analysis* , September 12, 2022.

2. Irvin, Ben Christopher, IV (Irvin, 2021), Parameter Estimation Methods for Models of Major Flood Events in Ungaged Mountain Basins of Colorado, Master's Thesis, Colorado State University, Dept. of Civil and Environmental Engineering, Fall 2021.

3. Sabol, George V. (Sabol, 2008), *Hydrologic Basin Response Parameter Estimate Guidelines* , prepared for the State of Colorado Office of the State Engineer Dam Safety Branch, May 2008.

4. U.S. Geological Survey (USGS). (USGS, 2022), StreamStats v4.21.0, obtained online 7/1/2024

Appendix B.6

USGS StreamStats Report

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	StreamStats Documentation	Approved			

OBJECTIVE:

1. Document StreamStats "Peak-Flow" Statistics for Envelope Curve Calibration.

2. Extrapolate stream stats for the 1000 year Annual Return Event. Include a summary on the SEO Confidence Checklist "Reasonableness & Checks", Item No. 2.

METHOD:

1. Use StreamStats to obtain an initial basin area, basin shapefile, and basin report.

   StreamStats Website : https://streamstats.usgs.gov/ss/

   Delineate the basin by clicking on a blue stream cell at the dam location. Download the basin (ShapeFile), as well as "Build a Report". The report builder includes both Regression Based Scenarios and Basin Characteristics. Select the Regression Based Scenarios for Peak-Flow, Flood-Volume, Annual Flow, Monthly Flow, and "Select All Basin Characteristics"

2. Plot the StreamStats "Peak Flow" values from the reported range of Annual Return Intervals (ARIs). Include the range of values based on the Stream Stats Average Standard Error of Prediction, ASEp, if provided,%). If not, include a range that is +/- 20% (for calibration/reasonable checks)

3. Extrapolate the StreamStats "Peak Flow" for the 1000 year Annual Return Event. Include a summary on the SEO Confidence Checklist "Reasonableness & Checks", Item No. 2.

ASSUMPTIONS/INPUTS:

1. Abbreviations:

   Annual Exceedance Probability (AEP) of event, Percent
   Annual Return Interval (ARI) of event, Years
   Cubic Feet Per Second (CFS) discharge of the event

2. Download StreamStats Report and basin shapefile for reservoir basin.

   StreamStats Version: V.4.21.0
   Regression Based Scenarios: Peak-Flow, Flood-Volume, Annual Flow, Monthly Flow
   Basin Characteristics: All

   Location of Report PDF: R:\0900\0985\0985.04\12_Hydrology
   File Name of Report PDF: StreamStats_JulesburgRes.pdf

   Location of Basin SHP: R:\0900\0985\0985.04\08_GIS\SHP\streamstats
   File Name of Basin SHP: globalwatershed.shp

3. StreamStats Peak Flow from PDF Report:

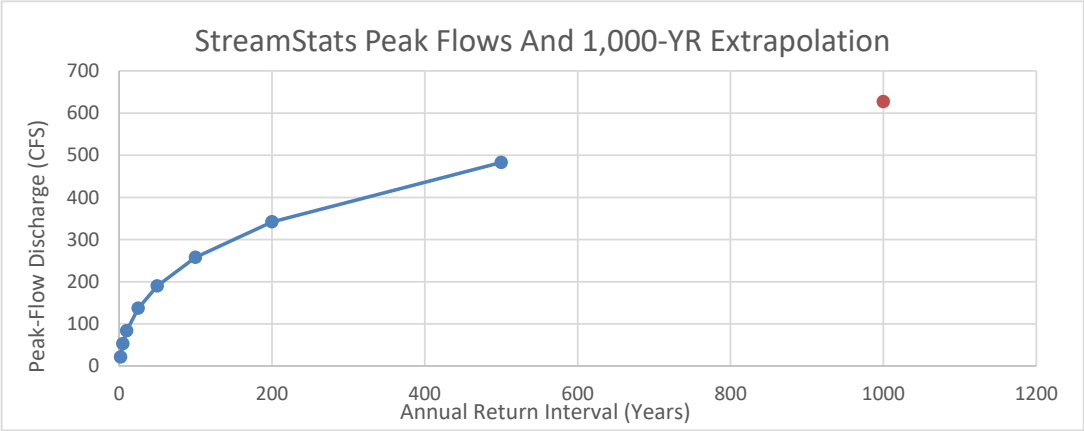
Statistic	AEP (%)	ARI (YEARS)	Value (CFS)
50-percent AEP flood	50%	2	21.4
20-percent AEP flood	20%	5	52.9
10-percent AEP flood	10%	10	83.6
4-percent AEP flood	4%	25	137
2-percent AEP flood	2%	50	190
1-percent AEP flood	1%	100	258
0.5-percent AEP flood	0.5%	200	342
0.2-percent AEP flood	0.2%	500	483

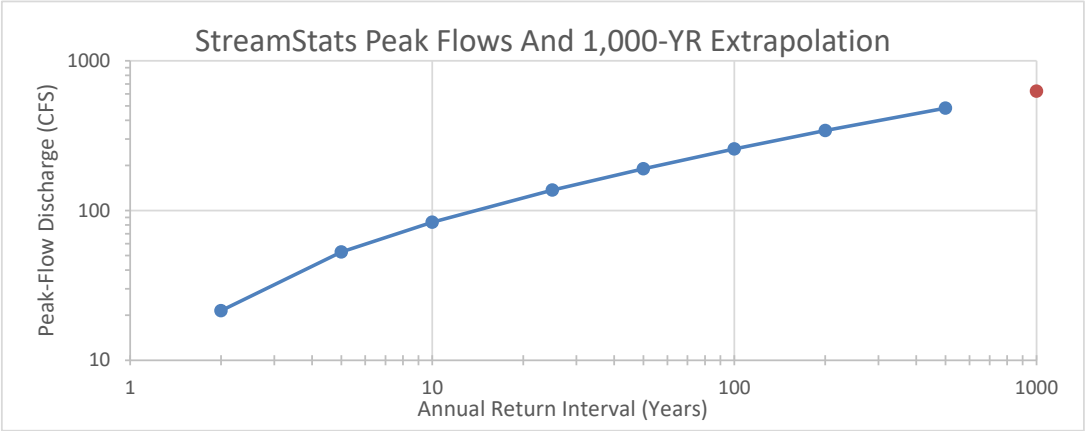
4. StreamStats Extrapolation for the 1,000-YR uses a natural log extrapolation of the entire StreamStats dataset.

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 2, 3, 4 and 1a	Checked	JTC	Date	7/2/2024
	StreamStats Documentation	Approved			

CALCULATIONS:

1. Plot and Extrapolate StreamStats Peak Flow





Using Logarithmic Extrapolation for the 1,000 yr ARI Storm Event

Statistic	AEP (%)	ARI (YEARS)	Value (CFS)
0.1-percent AEP flood	0.1%	1000	627

RESULTS:

StreamStats 1,000 Year Discharge By Extrapolation:

X =	**1000**	**ARI, Years**
Y =	**627.13**	**CFS**

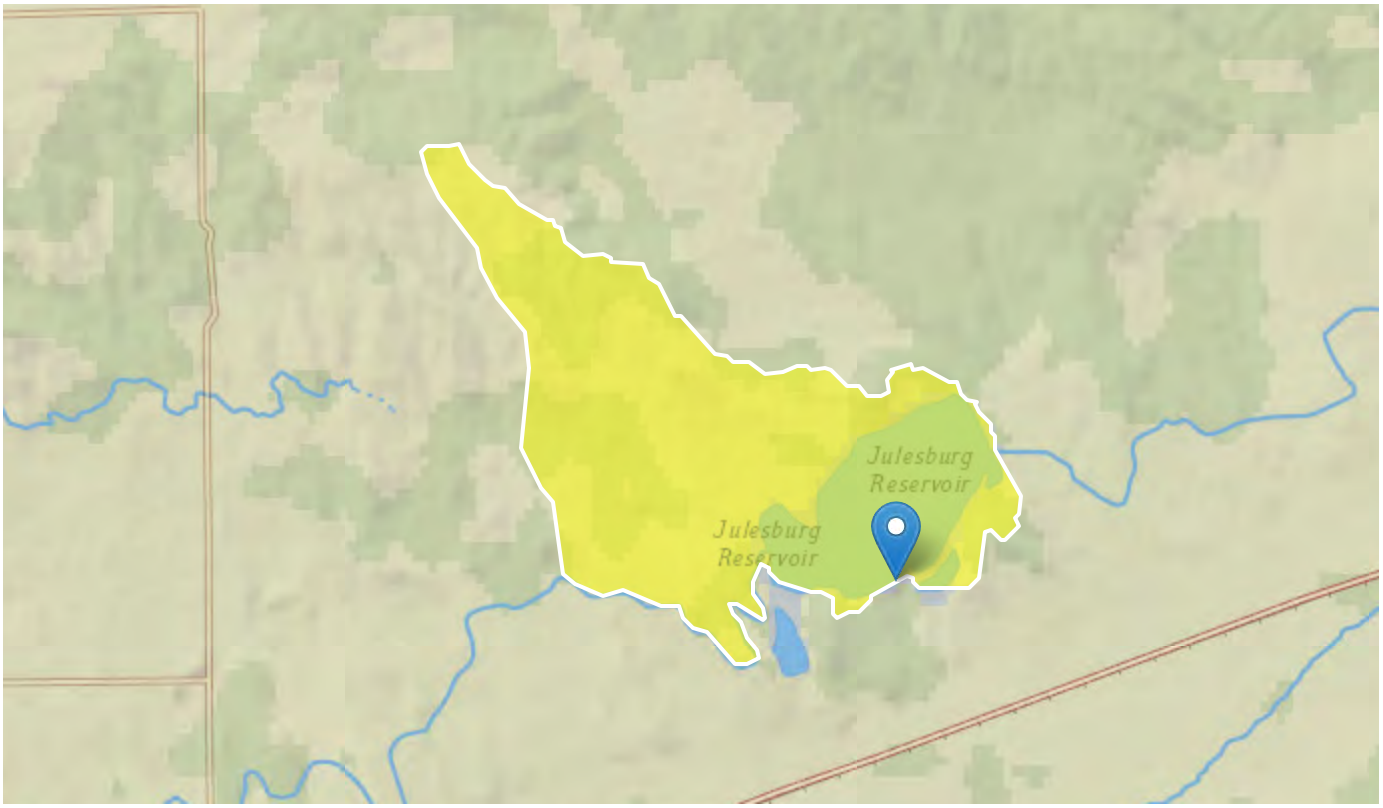
REFERENCES:

1. Capesius, J.P., and Stephens, V. C.,2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p.

2. U.S. Geological Survey (USGS). (USGS, 2022), ***StreamStats v4.21.0,*** obtained online 7/2/2024.

StreamStats Report - Updated Basin

Region ID: CO
Workspace ID: CO20250218044908097000
Clicked Point (Latitude, Longitude): 40.92190, -102.64959
Time: 2025-02-17 21:49:51 -0700



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BSLDEM10M	Mean basin slope computed from 10 m DEM	3	percent
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	53.5	feet per
DRNAREA	Area that drains to a point on a stream	10.4	square r
EL7500	Percent of area above 7500 ft	0	percent
ELEV	Mean Basin Elevation	3760	feet

Parameter Code	Parameter Description	Value	Unit
ELEVMAX	Maximum basin elevation	4130	feet
I24H100Y	Maximum 24-hour precipitation that occurs on average once in 100 years	4.78	inches
I24H2Y	Maximum 24-hour precipitation that occurs on average once in 2 years - Equivalent to precipitation intensity index	2.12	inches
I6H100Y	6-hour precipitation that is expected to occur on average once in 100 years	4.41	inches
I6H2Y	Maximum 6-hour precipitation that occurs on average once in 2 years	1.64	inches
LAT_OUT	Latitude of Basin Outlet	40.92188	degrees
LC11BARE	Percentage of barren from NLCD 2011 class 31	0.3	percent
LC11CRPHAY	Percentage of cultivated crops and hay, classes 81 and 82, from NLCD 2011	13.7	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	3	percent
LC11FOREST	Percentage of forest from NLCD 2011 classes 41-43	0.1	percent
LC11GRASS	Percent of area covered by grassland/herbaceous using 2011 NLCD	61	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	3	percent
LC11SHRUB	Percent of area covered by shrubland using 2011 NLCD	0	percent
LC11SNOIC	Percent snow and ice from NLCD 2011 class 12	0	percent
LC11WATER	Percent of open water, class 11, from NLCD 2011	16.7	percent
LC11WETLND	Percentage of wetlands, classes 90 and 95, from NLCD 2011	5.3	percent
LFPLENGTH	Length of longest flow path	4.84	miles
LONG_OUT	Longitude of Basin Outlet	-102.649581	degrees
MINBELEV	Minimum basin elevation	3680	feet
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88	3707	feet
PRECIP	Mean Annual Precipitation	17.89	inches
RCN	Runoff-curve number as defined by NRCS (http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17758.wba)	62.91	dimensi

Parameter Code	Parameter Description	Value	Unit
RUNCO_CO	Soil runoff coefficient as defined by Verdin and Gross (2017)	0.26	dimensi
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	26.7	percent
SSURGOB	Percentage of area of Hydrologic Soil Type B from SSURGO	31.8	percent
SSURGOC	Percentage of area of Hydrologic Soil Type C from SSURGO	19.6	percent
SSURGOD	Percentage of area of Hydrologic Soil Type D from SSURGO	1.1	percent
STATSCLAY	Percentage of clay soils from STATSGO	11.49	percent
STORNHD	Percent storage (wetlands and waterbodies) determined from 1:24K NHD	21.2	percent
TOC	Time of concentration in hours	6.57	hours

General Disclaimers

This watershed has been edited, computed flows and basin characteristics may not apply. For more information, submit a support request from the 'Help' button in the upper-right of the screen, attach a pdf of this report and request assistance from your local StreamStats regional representative.

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Plains Region Peak Flow 2016 5099]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
BSLDEM10M	Mean Basin Slope from 10m DEM	3	percent	0.41	21.9
DRNAREA	Drainage Area	10.4	square miles	0.26	3560
STATSCLAY	STATSGO Percentage of Clay Soils	11.49	percent	5.2	38.5

Peak-Flow Statistics Flow Report [Plains Region Peak Flow 2016 5099]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	ASEp
50-percent AEP flood	33.4	ft^3/s	131
20-percent AEP flood	86.7	ft^3/s	102
10-percent AEP flood	140	ft^3/s	103
4-percent AEP flood	235	ft^3/s	113
2-percent AEP flood	331	ft^3/s	123
1-percent AEP flood	455	ft^3/s	136
0.5-percent AEP flood	608	ft^3/s	150
0.2-percent AEP flood	868	ft^3/s	170

Peak-Flow Statistics Citations

Kohn, M.S., Stevens, M.R., Harden, T.M., Godaire, J.E., Klinger, R.E., and Mommandi, A.,2016, Paleoflood investigations to improve peak-streamflow regional-regression equations for natural streamflow in eastern Colorado, 2015: U.S. Geological Survey Scientific Investigations Report 2016–5099, 58 p. (http://dx.doi.org/10.3133/sir20165099)

Bankfull Statistics

Bankfull Statistics Parameters [Interior Plains D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	10.4	square miles	0.19305	59927.7393

Bankfull Statistics Parameters [Great Plains P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	10.4	square miles	0.598455	30899.82624

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	10.4	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Interior Plains D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	26.7	ft
Bieger_D_channel_depth	2.34	ft
Bieger_D_channel_cross_sectional_area	65.2	ft^2

Bankfull Statistics Flow Report [Great Plains P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	13.3	ft
Bieger_P_channel_depth	1.72	ft
Bieger_P_channel_cross_sectional_area	49.1	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	28.2	ft
Bieger_USA_channel_depth	1.99	ft
Bieger_USA_channel_cross_sectional_area	60.5	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	26.7	ft
Bieger_D_channel_depth	2.34	ft
Bieger_D_channel_cross_sectional_area	65.2	ft^2
Bieger_P_channel_width	13.3	ft
Bieger_P_channel_depth	1.72	ft
Bieger_P_channel_cross_sectional_area	49.1	ft^2
Bieger_USA_channel_width	28.2	ft
Bieger_USA_channel_depth	1.99	ft
Bieger_USA_channel_cross_sectional_area	60.5	ft^2

Bankfull Statistics Citations

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_cam

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [Crippen Bue Region 12]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	10.4	square miles	0.1	7000

Maximum Probable Flood Statistics Flow Report [Crippen Bue Region 12]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	51400	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

Application Version: 4.27.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Appendix B.7

HEC-HMS Entry Documentation

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/23/2024
	Initial HEC-HMS Entry and Results	Approved			

OBJECTIVE:

This calculation documents the development of the HEC-HMS Basin Runoff Model.

METHOD:

1. Develop a HEC-HMS model of the basin, HEC-HMS model Version 4.12 (USACE, 2024).
    a. HMS input parameters using the new mountain hydrology approach which incorporates Soil Moisture Accounting (SMA), see the *Guidelines for Hydrological Modeling and Flood Analysis,* March 28th 2022 (DWR, 2022).

2. HMS Entry:
    a. Basin Model - Reservoir Creation Tool - Add Reservoir:
        - Method: Outflow Structures
        - Storage Method: Elevation-Storage
        - Initial Condition: NHWL Ele\

	Existing	Alt A	Alt B	Alt C
-- Elevation (FT):	3712.10	3715.50	3710.50	3710.50

        - Main Tailwater: Assume None
        - Time Step Method: Automatic Adaptation
        - Spillways: 1

-- Method:	Specified Spillway
-- Rating Curve:	Created in HEC-RAS, based on LiDAR and Reservoir Options Calc 6

        - Dam Tops: 1

	-- Method:	Level Overflow			
	Existing	Alt A	Alt B	Alt C	
-- Elevation (FT):	3715.2 (Dam1)	3721.0	3716.0	3716.0	LiDAR
-- Length (FT):	2722 (Dam1) 7956 (Dam2)	10678.0	10678.0	10678.0	LiDAR
-- Coefficient:	2.68	2.68	2.68	2.68	Broad Crested Weir

    b. Basin Model - Subbasin Creation Tool (In this case the "subbasin" is all one basin)
        - Downstream: Reservoir created in Step 2.a.

	Basin A	Basin B	Basin C	Basin D	
- Area: (Mi^2)	3.68	4.15	0.27	2.26	
-- Initial Storage (%):	0	0	0	0	Recommended Value (DWR, 2022)
-- Max Storage (IN):	0.169	0.169	0.169	0.169	Recommended Value (DWR, 2022)
-- Crop Coefficient:	1	1	1	1	HEC-HMS default
-- Evapotranspiration:	Only Dry Periods	Only Dry Periods	Only Dry Periods	Only Dry Periods	HEC-HMS default
-- Uptake Method:	Simple	Simple	Simple	Simple	Recommended Value (DWR, 2022)

        - Surface Method: --None--

b. Basin Model - Continued…

▪ Loss Method: Soil Moisture Accounting

	Basin A	Basin B	Basin C	Basin D	
-- Soil (%) :	44.500	39.076	48.080	53.812	CSU-SMA Tool, "hms_initialsm_table", mean
-- Groundwater 1 (%):	0	0	0	0	Recommended Value (DWR, 2022)
-- Groundwater 2 (%):	0	0	0	0	Recommended Value (DWR, 2022)
-- Max Infiltration (IN/HR):	1.263	1.432	0.915	1.361	CSU-SMA Tool, "hms_maxinfil_table",
-- Impervious (%):	5	5	5	5	***calibration potential*** (DWR, 2022)
-- Soil Storage (IN) :	18.677	20.529	18.518	16.494	"hms_soilstorage_table", mean, ***calibration***
-- Tension Storage (IN) :	8.817	8.443	9.685	9.848	"hms_tensionstore_table", mean
-- Soil Percolation (IN/HR) :	0.181	0.485	0.111	0.078	CSU-SMA Tool,
-- GW 1 Storage (IN) :	2.075	2.281	2.058	1.833	"hms_gw1storage_table", mean, ***calibration***
-- GW 1 Percolation (IN/HR) :	***0.1***	***0.1***	***0.1***	***0.1***	Recommended Range 0.02 in/hr (San Juans) to 0.1 in/hr (Front Range), ***calibration***
-- GW 1 Coefficient (HR) :	**2.074**	**4.51**	**0.598**	**NA**	3 X R (from Clark UH), Recommended Value (DWR, 2022)
-- GW 2 Storage (IN) :	0	0	0	0	Recommended Value (DWR, 2022)
-- GW 2 Percolation (IN/HR) :	0	0	0	0	Recommended Value (DWR, 2022)
-- GW 2 Coefficient (HR) :	0	0	0	0	Recommended Value (DWR, 2022)

▪ Transform Method: Clark Unit Hydrograph

	Basin A	Basin B	Basin C	Basin D	
-- Method :	Standard	Standard	Standard		
-- Time of Concentration, ***Tc*** (HR) :	1.61	3.51	0.47	NA	Tc from Clark UH Worksheet: $T_c = 2.4 * A^{0.1} * L^{0.25} * L_{ca}^{0.25} * S^{-0.2}$
-- Storage Coefficient, ***R*** (HR) :	**0.69**	**1.51**	**0.20**	**NA**	Use a Storage Coefficient based on a ratio of: R/(Tc+R) = 0.3

R/(Tc+R):	***0.30***	***0.30***	***0.30***	***NA***	Initial HEC-HMS, Start with 0.43TC

▪ Baseflow Method: Linear Reservoir

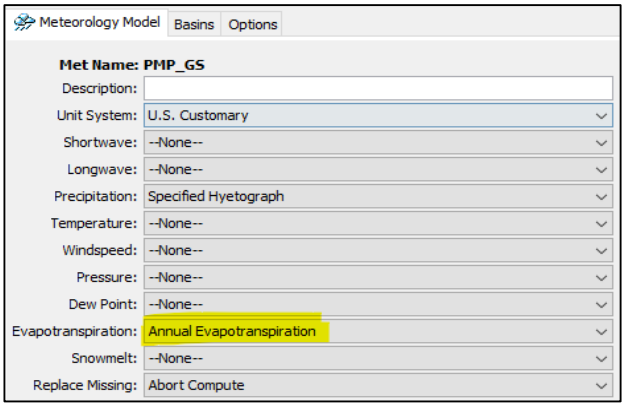
-- Layers :	1	1	1	1	(previous versions of HEC-HMS/Guidance calls this "Reservoirs")
-- Initial Type :	Discharge	Discharge	Discharge	Discharge	Recommended Value (DWR, 2022)
-- GW 1 Initial (CFS) :	0	0	0	0	
-- GW 1 Fraction :	(blank)	(blank)	(blank)	(blank)	
-- GW 1 Coefficient (HR) :	**2.074**	**4.510**	**0.598**	**NA**	3 X R (from Clark UH), Recommended Value (DWR, 2022)
-- GW 1 Reservoirs :	1	1	1	1	(previous versions of HEC-HMS/Guidance calls this "Steps")

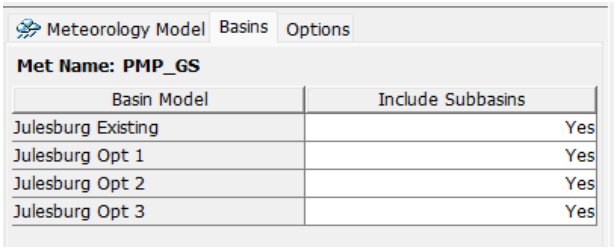
c. Meteorologic Models - 25 Total, including (Remnant) Tropical Storm

▪ Naming Convention

-- PMP_GS : Probable Maximum Precipitation, General Storm
-- PMP_TS : Probable Maximum Precipitation, (Remnant) Tropical
-- PMP_LS_02HR : Probable Maximum Precipitation, Local Storm 2 HR
-- PMP_LS_06HR : Probable Maximum Precipitation, Local Storm 6 HR
-- 1E01_10YR_02HR_LS: 10YR Frequency Storm, 2 HR Local Storm
-- 1E01_10YR_06HR_MEC: 10YR Frequency Storm, 6 HR Mesoscale Storms with Embedded Convection
-- 1E01_10YR_48HR_MLC: 10YR Frequency Storm, 48 HR Mid-Latitude Cyclones

▪ First Meteorologic Model: All defaults except for "Evapotranspiration", and set Basin - Include Subbasins - to "Yes".



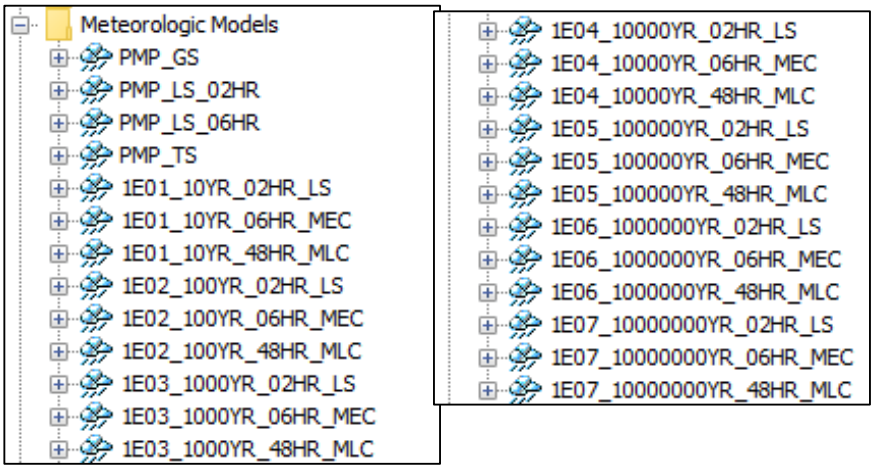


-- "Annual Evapotranspiration" :

Rate (IN/DAY):	0.098	Recommended Value (DWR, 2022)
Percent Pattern:	--None--	Recommended Value (DWR, 2022)

c. Meteorologic Models, continued….

▪Then create 20 copies and rename according to naming convention:



d. Time-Series Data - Precipitation gages - 25 Total.

▪ Naming Convention (same as Meteorologic Models)

-- PMP_GS : Probable Maximum Precipitation, General Storm
-- PMP_LS_02HR : Probable Maximum Precipitation, Local Storm 2 HR
-- PMP_LS_06HR : Probable Maximum Precipitation, Local Storm 6 HR
-- 1E01_10YR_02HR_LS: 10YR Frequency Storm, 2 HR Local Storm
-- 1E01_10YR_06HR_MEC: 10YR Frequency Storm, 6 HR Mesoscale Storms with Embedded
-- 1E01_10YR_48HR_MLC: 10YR Frequency Storm, 48 HR Mid-Latitude Cyclones

-- "PMP_GS", and "PMP_TS" :

Units:	Cumulative Inches	Recommended (DWR, 2022)
Time Interval:	15 minutes	Recommended Value (DWR, 2022)
Time Window:	10 days	Recommended Value (DWR, 2022)

-- "PMP_LS_02HR", "PMP_LS_06HR" and if applicable "PMP_LS_24hr":

Units:	Cumulative Inches	
Time Interval:	5 minutes	Recommended Value (DWR, 2022)
Time Window:	2 days	Recommended Value (DWR, 2022)

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/23/2024
	Initial HEC-HMS Entry and Results	Approved			

For faster entry, copy these three Precipitation Frequency events for the 10YR storm and use as a template for the subsequent 100 - 10,000,000YR Frequency Storms.

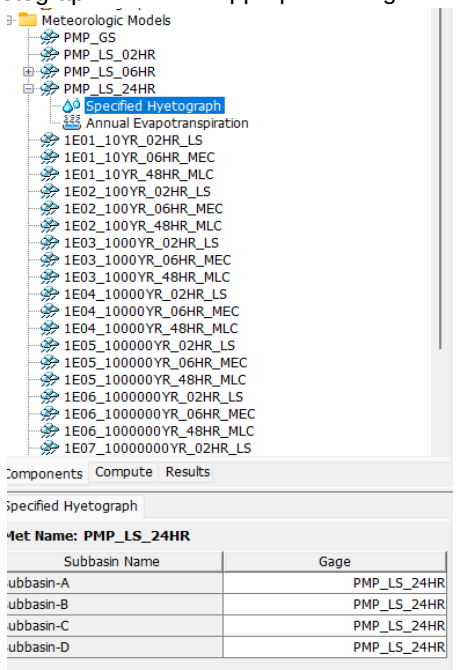
-- "1E01_10YR_02HR_LS"
"1E01_10YR_06HR_MEC":

Units:	Cumulative Inches	
Time Interval:	5 minutes	Recommended Value (DWR, 2022)
Time Window:	2 days	Recommended Value (DWR, 2022)

-- "1E01_10YR_48HR_MLC" :

Units:	Cumulative Inches	
Time Interval:	1 hour	Recommended Value (DWR, 2022)
Time Window:	10 days	Recommended Value (DWR, 2022)

Go back and pair correct precipitation gage with matching meteorologic model:
-- "Specified Hyetograph" : Select appropriate Gage based on "Time-Series Data" - Precipitation



e. Control Specifications

-- 02day_1min :

Start/End Date and Time:	Span same 2 days as Precipitation Gage
Time Interval:	1 minute

-- 10day_5min :

Start/End Date and Time:	Span same 10 days as Precipitation Gage
Time Interval:	5 minute

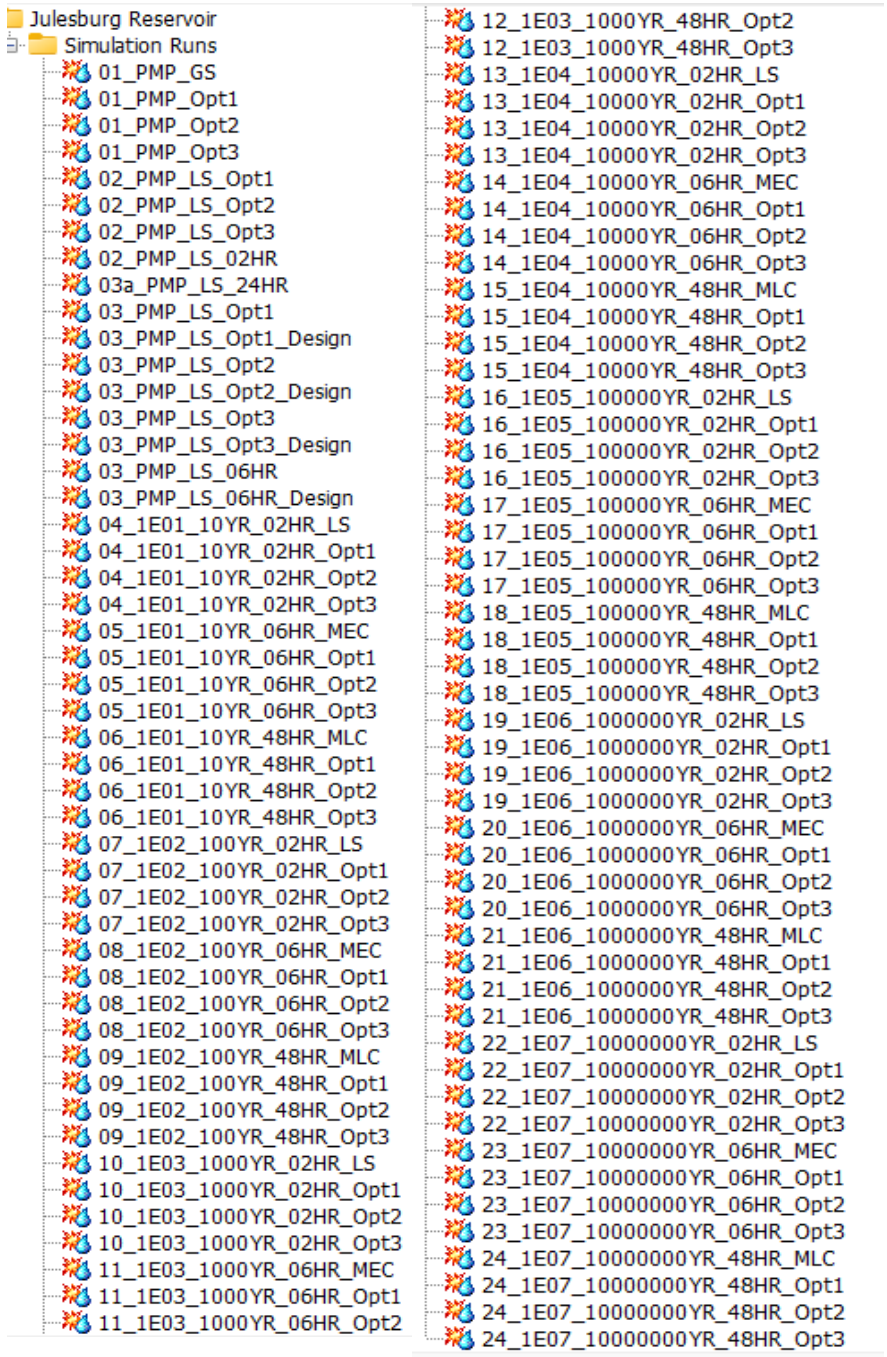
f. Paired Data - "Elevation-Storage Functions"
-- Reservoir Volume : From LiDAR, see Calc 06 Pertinent Data Update

Go back and pair with Basin Model, Reservoir "Elev-Stor Function"

g. Paired Data - "Elevation-Discharge Functions"
-- Spillway Capacity : From LiDAR, see Calc 06 Pertinent Data Update

Go back and pair with Basin Model, Specified Spillway, "Elevation Discharge"

3. HMS Create Compute:
   a. Create computes for each of the runs, 25 total (including GS_TS, noting either the GS or TS will control, so between the two they are "Run 1")
   b. For initial calibration, do not apply the 7% Atmospheric Moisture Factor. (Ratio - Ratio Method - Precipitation - Ratio 1.07)



W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Julesburg Reservoir	Made by	CBM	Job No.	985.04
	Dam 1, 1a, 2, 3, and 4	Checked	JTC	Date	7/23/2024
	Initial HEC-HMS Entry and Results	Approved			

CALCULATIONS:

1. Run HEC-HMS model with frequency storm rainfall distributions to determine which is controlling the 2-, 6-, or 48-hour duration frequency storm. Also run the HEC-HMS model with rainfall for the REPS General/(Residual) Tropical and Local PMP Storms.
   a. The controlling storm duration for each frequency storm event will be the inflow event with the maximum routed reservoir water surface elevation.
   b. For the controlling storm, record the maximum inflow (CFS). Compare to StreamStats 100YR (within 20% or standard error of prediction) and compare REPS PMP to CO Envelope Curve and calibrate if required.

HMS Model - Organize Simulation Runs

Design Storm:	**Annual Return Event**							
	PMP	10	100	1,000	10,000	100,000	1,000,000	10,000,000
	N/A	1E+01	1E+02	1E+03	1E+04	1E+05	1E+06	1E+07
REPS GS/TS 72 HR	01							
REPS LS 2 HR	02							
REPS LS 6 HR	03							
REPS LS 24 HR	03a							
MetPortal 2 HR		04	07	10	13	16	19	22
MetPortal 6 HR		05	08	11	14	17	20	23
MetPortal 48 HR		06	09	12	15	18	21	24

Appendix B.8

Wave-Runup Documentation

W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Objective: Calculate normal and residual freeboard requirement for Julesburg Reservoir in the Existing and Option 1 conditions

Methods: Use US Bureau of Reclamation Design Manual 13, Chapter 6: Freeboard, DS-13(6)-2 to estimate normal freeboard and residual freeboard (required minimum freeboard during peak IDF water surface).
Rule 7.4.2.2.1 of Colorado Rules and Regulations for Dam Safety and Dam Construction, 2-CCR 402-1 (January, 2020) indicates that minimum normal freeboard must be the greater of three feet or the wave setup and runup generated by a sustained 100 mph wind.
Rule 7.4.2.2.2 of 2-CCR 402-1 (January, 2020) indicates that minimum residual freeboard must be the greater of one foot or the wave setup and runup generated by a sustained 10 percent Hourly Exceedance Probability (HEP) wind.

Assumptions: Inflow design flood is 23,990 **cfs** based on a PMP, 6-hour Local Storm (incl. 7% AMF)
Upstream Embankment Slope varies for each dam and is provided below. The slope is equivalent to 1 / (tangent of the slope angle, α)
USBR DS 13 Chapter 6, Figure 6.2.2-1 is used to provide freeboard for 100 mph wind runup + setup
Average reservoir depth along the central fetch radius is calculated for each dam on tab 'Average Depth'

Design:

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	
Design Dam Crest Elevation Existing =	3715.20	3715.90	3715.90	3715.90	3716.00	3716.00	feet
Maximum IDF Water Surface Elevation Exising =	3715.80	3715.80	3715.80	3715.80	3715.80	3715.80	feet [1]
Design Normal Reservoir Water Surfae Elevation Existing=	3712.10	3712.10	3712.10	3712.10	3712.10	3712.10	feet
Design Dam Crest Elevation Option 1 =	3721.00	3721.00	3721.00	3721.00	3721.00	3721.00	feet
Maximum IDF Water Surface Elevation Option 1 =	3717.70	3717.70	3717.70	3717.70	3717.70	3717.70	feet [1]
Design Normal Reservoir Water Surfae Elevation Option 1 =	3715.50	3715.50	3715.50	3715.50	3715.50	3715.50	feet

Note: 1 - Water surface elevation from flood routing results of IDF through design spillway.

1) Design Normal Freeboard - For Existing and Option 1
Normal Freeboard = vertical distance between the NHWL and the lowest point on the dam crest

Design Normal Freeboard Exising =	3.10	3.80	3.80	3.80	3.90	3.90	feet
Design Normal Freeboard Option 1 =	5.50	5.50	5.50	5.50	5.50	5.50	feet

2) Design Residual Freeboard - For Existing and Option 1
Residual Freeboard = vertical distance between the maximum WSEL during the IDF and the lowest point on the dam crest

Design Residual Freeboard Existing =	-0.60	0.10	0.10	0.10	0.20	0.20	feet
Design Residual Freeboard Option 1 =	2.20	2.20	2.20	2.20	2.20	2.20	feet

Calculations: Calculation 1: Normal and Residual Freeboard

Results: Calculation 1: Design Freeboard of 7 Feet, and Residual Freeboard of 1.31 feet are both acceptable

Calculation 1: Normal and Residual Freeboard

Step 1 Calculate Reservoir Fetch using nine radii on three degree spacing to each side of the central radius, which is perpendicular to the dam
Note that in cases where it is not clear which Central Radius Location will yield the greatest Average Radius Length, multiple locations should be tested.

Radius ID	Angle (degrees)	Dam 1 Length (feet)	Dam 2 Length (feet)	Dam 3 Length (feet)	Dam 4 Length (feet)	Dam 5 Length (feet)	Dam 1a Length (feet)
Upstream Slope (1 V: X H)		2.8	1.5; 1.7; 2	1.7	2.73	3	2.8
Average Reservoir Depth		20.75	23.20	24.39	24.94	25.65	23.30
Average Radius Length (feet)		5655	5857	7543	7945	8660	6,079
Average Radius Length (miles)		1.1	1.1	1.4	1.5	1.6	1.15

Average Radius is equal to the **Reservoir Fetch**, as defined by DS-13(6)-2. Refer to attached reservoir fetch figure.

Step 2 Use Figure 6.2.2-1 from DS-13(6)-2 to determine wave runup + setup for 100 mph wind. Wheeler assuemd a slope of 2:1 for a representative of all upstream slopes for each dam. During final design, a less conservative slope should be used to reduce the estimated freeboard.

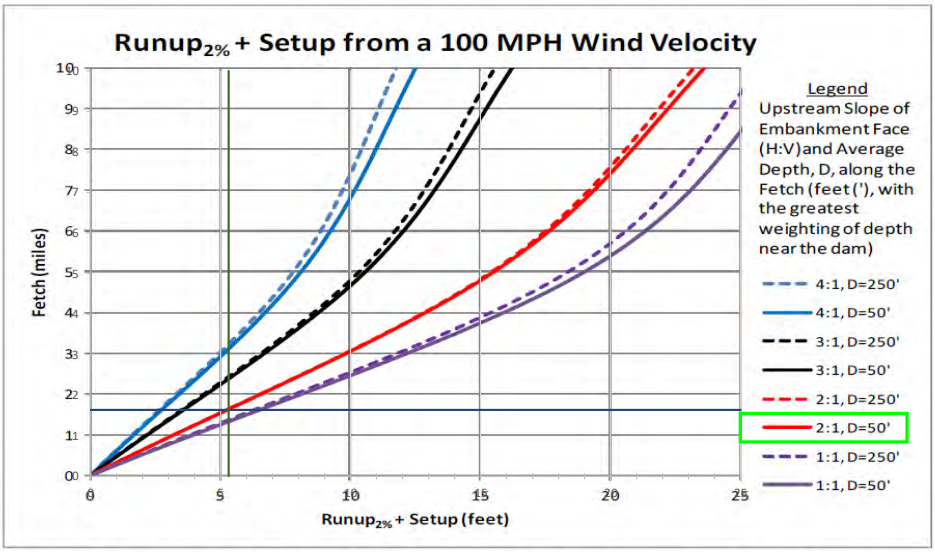


Figure 6.2.2-1. $Runup_{2\%}$ + setup from a 100-mi/h sustained wind velocity on a surface protected by riprap.

Runup + Setup for 100 mi/h sustained wind velocity =

Dam 1	3.40	feet
Dam 1a	3.65	feet
Dam 2	3.50	feet
Dam 3	4.60	feet
Dam 4	4.80	feet
Dam 5	5.30	feet

Step 3

Use Probabilistic Freeboard and Riprap Analysis (PFARA) software as referenced in DS-13(6)-2 to generate a 10% Hourly Exceedance Probability Over-Water Wind Velocity plot for the dam site in question. Then use the plot to determine the 10% HEP Over-Water Wind Velocity ($VMPH_{10\%}$). Alternatively, use the computed table of PFARA results provided by the CODWR in their design spreadsheet.

Table 1: 10% Probability of Non-Excedence (PWH)

PFARA Station	*Station I.D.*	*Over Water Wind Velocity (mph) 10% Probability of Non-Excedence (P_{WH}) Fetch Length*			
		0.5 mile	*1.0 mile*	*1.5 mile*	*2 mile*
Aurora/Buckley	CO23036	18.0	18.5	19.0	19.0
Alamosa	CO23061	22.5	23.0	23.5	24.0
Denver/Sta Gage	CO23062	22.0	23.0	24.6	26.0
Eagle	CO23062	23.0	24.0	25.0	26.0
Grand Junction	CO23066	19.5	20.0	21.0	22.0
La Junta	CO23067	18.0	19.0	20.0	21.0
Pueblo	CO23068	18.0	19.0	20.0	20.0
Trinidad	CO23070	22.0	23.0	24.0	24.0
Akron	CO24015	26.0	27.0	28.0	29.0
Denver	CO93032	19.0	20.0	21.0	21.0
Colorado Springs	CO93037	20.0	21.0	23.0	23.0
Pueblo	CO93058	20.0	20.2	21.0	22.0
USAFA	CO93065	21.0	22.0	22.5	23.0
Fort Carson	CO93065	20.0	20.5	21.0	22.0

** Wind Velocity Calucated using PRARA Program by the Colorado Division of Water Resources, Dam Safety*

P_{WH} = 1.0E-01 $VMPH_{10\%}$ = **27.5** mph

Step 4 Calculate Wind-Generated Significant Wave Height at P_{WH} = 10% using Equation 2 from Appendix B, Section B.4.1 of DS-13(6)-2

where:

H_S = Wind Generated Significant Wave Height (feet),
F = Fetch (miles) and
VMPH = Over-Water Wind Velocity (mph) at selected HEP.

$$H_s = 0.0245 \cdot F^{1/2} \cdot VMPH \cdot (1.1 + 0.0156 \cdot VMPH)^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.07	1.15	1.43	1.50	1.64	1.11
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.1	27.3	27.9	25.0	28.3	27.2
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.85	0.89	1.01	0.92	1.10	0.87

Step 5 Calculate Wave Period at P_{WH} = 10% using Equation 4 from Appendix B, Section B.4.2 of DS-13(6)-2

where:

T = Wave Period (seconds).

$$T = 0.464 \cdot F^{1/3} \cdot VMPH^{1/3} \cdot (1.1 + 0.0156 \cdot VMPH)^{1/6}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.07	1.15	1.43	1.50	1.64	1.11
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.1	27.3	27.9	25.0	28.3	27.2
10% HEP Wave Period, T	seconds	0.38	0.41	0.52	0.48	0.61	0.40

Step 6 Calculate Surf Similarity Factor at P_{WH} = 10% using Equation 7 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

ξ_P = Surf Similarity Factor and
tan(α) = slope of the upstream face of the dam embankment (V:1H).

$$\xi_p = (2.26 \cdot T \cdot \tan(\alpha)) / H_s^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
10% HEP Wave Period, $T_{10\%}$	seconds	0.38	0.41	0.52	0.48	0.61	0.40
tan(α) = Upstream Slope	V:1H	0.4	0.4	0.6	0.6	0.4	0.3
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.85	0.89	1.01	0.92	1.10	0.87
Surf Similarity Factor, ξ_P	---	0.33	0.35	0.69	0.67	0.48	0.32

Step 7 Calculate Wave Runup at P_{WH} = 10% using Equation 8 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

R = Wave runup on relatively impermeable slope (feet),
A, C = Coefficients dependent on ξ_P = (see Table B-4 of Appendix B, DS-13(6)-2),
γ_r = Surface roughness reduction factor (see Table B-3 of Appendix B, DS-13(6)-2),
γ_b = Berm influence reduction factor (1.0 for non-bermed profiles),
γ_h = Shallow-water reduction factor (1.0 for Rayleigh distributed waves),
B = Angle between the Fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to computed fetch, which is directly perpendicular to the dam axis.), and
γ_β = Reduction factor for direction of fetch relative to dam axis (see Figure B-4 of Appendix B, DS-13(6)-2).

$$R = H_s \cdot (A \cdot \xi_P + C) \cdot \gamma_r \cdot \gamma_b \cdot \gamma_h \cdot \gamma_\beta$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wave Height, $H_{S\text{-}10\%}$	0.85	0.89	1.01	0.92	1.10	0.87	feet
Surf Similarity Factor, ξ_P	0.33	0.35	0.69	0.67	0.48	0.32	---
Runup Coefficient A	1.60	1.60	1.60	1.60	1.60	1.60	---
Runup Coefficient C	0.00	0.00	0.00	0.00	0.00	0.00	---
Surface roughness reduction factor, γ_r	0.55	0.55	0.55	0.55	0.55	0.55	---
Berm influence reduction factor, γ_b	1.00	1.00	1.00	1.00	1.00	1.00	---
Shallow-water reduction factor, γ_h	1.00	1.00	1.00	1.00	1.00	1.00	---
Fetch incidence angle reduction factor, γ_β	1.00	1.00	1.00	1.00	1.00	1.00	---
10% HEP Wave Runup, $R_{10\%}$	0.249	0.276	0.617	0.540	0.470	0.244	feet

Step 8 Calculate Wind Setup at P_{WH} = 10% using Equation 9 from Appendix B, Section B.4.4 of DS-13(6)-2

where:

S = Wind Setup (feet) and

D = Average depth of water (feet) along computed Fetch.

$$S = (VMPH_{10\%}^{2} \cdot F) / (1400 \cdot D)$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wind Speed, $VMPH_{10\%}$	27.1	27.3	27.9	25.0	28.3	27.2	mph
Fetch, F	1.07	1.15	1.11	1.43	1.50	1.64	miles
Average Depth Along Fetch, D	20.8	23.3	23.2	24.4	24.9	25.6	feet
10% HEP Wind Setup, $S_{10\%}$	0.027	0.026	0.027	0.026	0.034	0.034	feet

Step 9 Check Design values of Normal and Residual Freeboard for **Existing Conditions**

Per Rule 7.4.2.2.1, the minimum normal freeboard shall be the greater of 3 feet or the wave setup and runup generated by a sustained 100 mph wind.

		Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Normal Freeboard =	feet	3.10	3.80	3.80	3.80	3.90	3.90
Wave Runup + Setup for 100 mph sustained wind =	feet	3.40	3.65	3.50	4.60	4.80	5.30
Minimum Normal Freeboard =	feet	3.40	3.65	3.50	4.60	4.80	5.30
Design Normal Freeboard value is:		Not Acceptable	Acceptable	Acceptable	Not Acceptable	Not Acceptable	Not Acceptable

Per Rule 7.4.2.2.2, the minimum residual freeboard shall be the greater of 1 foot or the wave setup and runup generated by a sustained 10% HEP wind.

		Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Residual Freeboard =	feet	-0.60	0.10	0.10	0.10	0.20	0.20
Wave Runup + Setup for 22 mph sustained wind =	feet	0.28	0.30	0.64	0.57	0.50	0.28
Minimum Residual Freeboard =	feet	1.00	1.00	1.00	1.00	1.00	1.00
Design Residual Freeboard value is:		Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable

Step 10 Check Design values of Normal and Residual Freeboard for **Alternative A**

Per Rule 7.4.2.2.1, the minimum normal freeboard shall be the greater of 3 feet or the wave setup and runup generated by a sustained 100 mph wind.

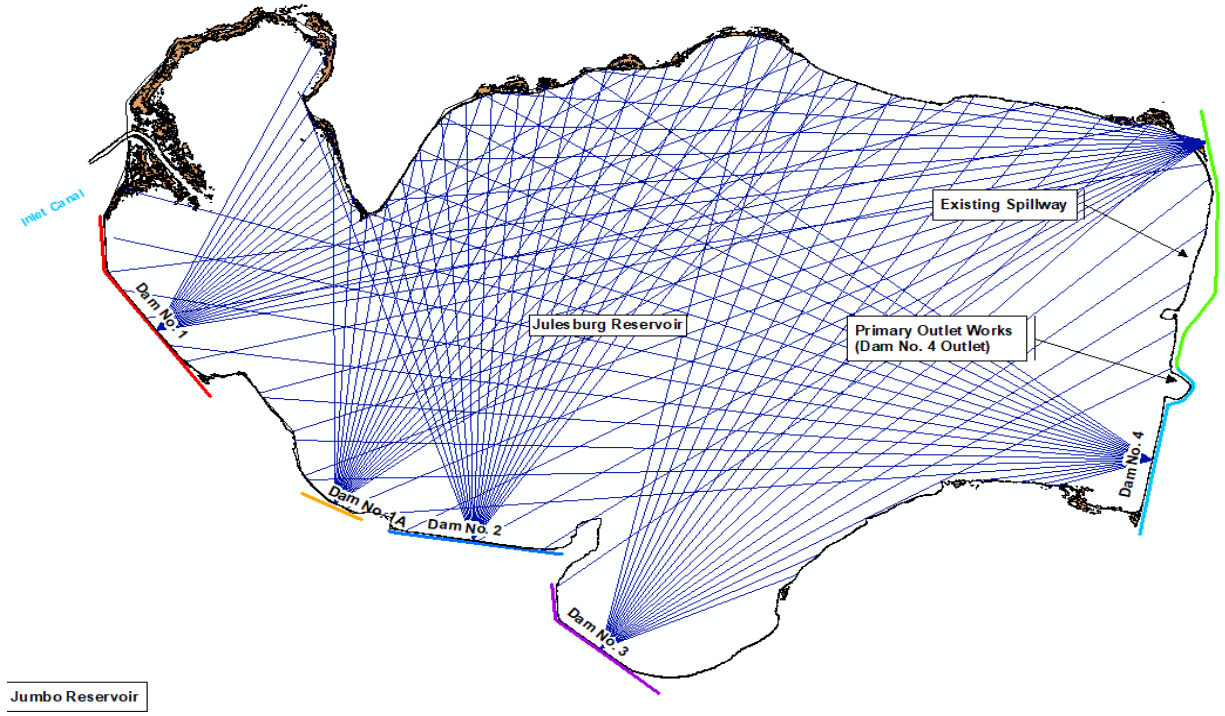
		Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Normal Freeboard =	feet	5.50	5.50	5.50	5.50	5.50	5.50
Wave Runup + Setup for 100 mph sustained wind =	feet	3.40	3.65	3.50	4.60	4.80	5.30
Minimum Normal Freeboard =	feet	3.40	3.65	3.50	4.60	4.80	5.30
Design Normal Freeboard value is:		Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Per Rule 7.4.2.2.2, the minimum residual freeboard shall be the greater of 1 foot or the wave setup and runup generated by a sustained 10% HEP wind.

		Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Residual Freeboard =	feet	2.20	2.20	2.20	2.20	2.20	2.20
Wave Runup + Setup for sustained wind 10% HEP =	feet	0.28	0.30	0.64	0.57	0.50	0.28
Minimum Residual Freeboard =	feet	1.00	1.00	1.00	1.00	1.00	1.00
Design Residual Freeboard value is:		Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Attachment 1: Reservoir Fetch Figure



W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Objective: Calculate normal and residual freeboard requirement for Julesburg Reservoir in the Existing and Option 1 conditions

Methods: Use US Bureau of Reclamation Design Manual 13, Chapter 6: Freeboard, DS-13(6)-2 to estimate normal freeboard and residual freeboard (required minimum freeboard during peak IDF water surface).
Rule 7.4.2.2.1 of Colorado Rules and Regulations for Dam Safety and Dam Construction, 2-CCR 402-1 (January, 2020) indicates that minimum normal freeboard must be the greater of three feet or the wave setup and runup generated by a sustained 100 mph wind.
Rule 7.4.2.2.2 of 2-CCR 402-1 (January, 2020) indicates that minimum residual freeboard must be the greater of one foot or the wave setup and runup generated by a sustained 10 percent Hourly Exceedance Probability (HEP) wind.

Assumptions: Inflow design flood is 23,990 **cfs** based on a PMP, 6-hour Local Storm (incl. 7% AMF)
Upstream Embankment Slope varies for each dam and is provided below. The slope is equivalent to 1 / (tangent of the slope angle, α)
USBR DS 13 Chapter 6, Figure 6.2.2-1 is used to provide freeboard for 100 mph wind runup + setup
Average reservoir depth along the central fetch radius is calculated for each dam on tab 'Average Depth'

Design:

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	
Design Dam Crest Elevation Alternative B =	3716.00	3716.00	3716.00	3716.00	3716.00	3716.00	feet
Maximum IDF Water Surface Elevation Alternative B =	3713.50	3713.50	3713.50	3713.50	3713.50	3713.50	feet [1]
Design Normal Reservoir Water Surfae Elevation Alternative B =	3710.50	3710.50	3710.50	3710.50	3710.50	3710.50	feet

Note: 1 - Water surface elevation from flood routing results of IDF through design spillway.

1) Design Normal Freeboard - For Alternative B
Normal Freeboard = vertical distance between the NHWL and the lowest point on the dam crest

Design Normal Freeboard Alternative B =	5.50	5.50	5.50	5.50	5.50	5.50	feet

2) Design Residual Freeboard - For Alternative B
Residual Freeboard = vertical distance between the maximum WSEL during the IDF and the lowest point on the dam crest

Design Residual Freeboard Alternative B =	2.50	2.50	2.50	2.50	2.50	2.50	feet

Calculations: Calculation 1: Normal and Residual Freeboard

W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
		Julesburg Reservoir	Checked	JTC	Date	8/29/2024
		Freeboard Estimation & Wave Runup	Approved			

Results: Calculation 1: Design Freeboard of 7 Feet, and Residual Freeboard of 1.31 feet are both acceptable

Calculation 1: Normal and Residual Freeboard

Step 1 Calculate Reservoir Fetch using nine radii on three degree spacing to each side of the central radius, which is perpendicular to the dam Note that in cases where it is not clear which Central Radius Location will yield the greatest Average Radius Length, multiple locations should be tested. For Dam No. 2, it was conservatively assumed that the existing dams were removed during construction and wave runoff could occur accoss the whole reservoir.

Radius | ID	Angle (degrees)	Dam 1 Length (feet)	Dam2_new Length (feet)	Dam 3 Length (feet)	Dam 4 Length (feet)	Dam 5 Length (feet)	Dam 1a Length (feet)
Upstream Slope (1 V: X H)		**2.8**	**2.5**		**2.73**	**3**	
Average Reservoir Depth		**16.37**	**53.64**		**20.09**	**20.11**	
+27°	27	4059	7326		1123	9124	
+24°	24	4085	7736		1265	8965	
+21°	21	3218	8019		1499	9525	
+18°	18	3185	8114		1945	10154	
+15°	15	3194	8064		8635	10605	
+12°	12	3073	8188		9396	10868	
+9°	9	2941	8344		9526	10805	
+6°	6	2851	8354		9916	10994	
+3°	3	2791	8648		11010	11694	
Central Radius (0°)	0	2742	8920		11634	11992	
-3°	-3	2767	8912		11862	12319	
-6°	-6	6327	8707		11928	9144	
-9°	-9	7752	8640		9219	8843	
-12°	-12	7970	8640		9057	8560	
-15°	-15	8291	8713		9016	7952	
-18°	-18	8826	9030		8964	6939	
-21°	-21	10203	9211		8711	2885	
-24°	-24	11364	9435		8281	2112	
-27°	-27	11806	9648		7964	1064	
Average Radius Length (feet)		**5655**	**8560**		**7945**	**8660**	
Average Radius Length (miles)		**1.1**	**1.6**		**1.5**	**1.6**	

Average Radius is equal to the **Reservoir Fetch**, as defined by DS-13(6)-2. Refer to attached reservoir fetch figure.

Step 2 Use Figure 6.2.2-1 from DS-13(6)-2 to determine wave runup + setup for 100 mph wind. Wheeler assuemd a slope of 2:1 for a representative of all upstream slopes for each dam. During final design, a less conservative slope should be used to reduce the estimated freeboard.

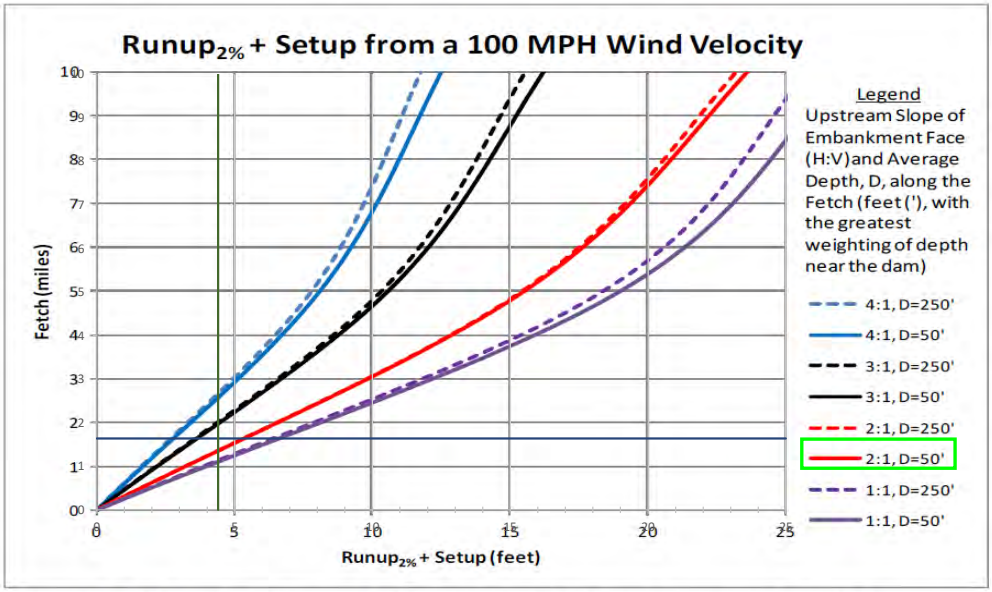


Figure 6.2.2-1. Runup$_{2\%}$ + setup from a 100-mi/h sustained wind velocity on a surface protected by riprap.

Runup + Setup for 100 mi/h sustained wind velocity =

Dam 1 **3.40** **feet**

Dam 2 **3.60** **feet**

Dam 4 **4.80** **feet**

Dam 5 **4.40** **feet**

Step 3 Use Probabilistic Freeboard and Riprap Analysis (PFARA) software as referenced in DS-13(6)-2 to generate a 10% Hourly Exceedance Probability Over-Water Wind Velocity plot for the dam site in question. Then use the plot to determine the 10% HEP Over-Water Wind Velocity ($VMPH_{10\%}$). Alternatively, use the computed table of PFARA results provided by the CODWR in their design spreadsheet.

Table 1: 10% Probability of Non-Excedence (PWH)

PFARA Station	*Station I.D.*	*Over Water Wind Velocity (mph) 10% Probability of Non-Excedence (P_{WH}) Fetch Length*			
		0.5 mile	*1.0 mile*	*1.5 mile*	*2 mile*
Aurora/Buckley	**CO23036**	18.0	18.5	19.0	19.0
Alamosa	**CO23061**	22.5	23.0	23.5	24.0
Denver/Sta Gage	**CO23062**	22.0	23.0	24.6	26.0
Eagle	**CO23062**	23.0	24.0	25.0	26.0
Grand Junction	**CO23066**	19.5	20.0	21.0	22.0
La Junta	**CO23067**	18.0	19.0	20.0	21.0
Pueblo	**CO23068**	18.0	19.0	20.0	20.0
Trinidad	**CO23070**	22.0	23.0	24.0	24.0
Akron	**CO24015**	26.0	27.0	28.0	29.0
Denver	**CO93032**	19.0	20.0	21.0	21.0
Colorado Springs	**CO93037**	20.0	21.0	23.0	23.0
Pueblo	**CO93058**	20.0	20.2	21.0	22.0
USAFA	**CO93065**	21.0	22.0	22.5	23.0
Fort Carson	**CO93065**	20.0	20.5	21.0	22.0

**** Wind Velocity Calucated using PRARA Program by the Colorado Division of Water Resources, Dam Safety***

P_{WH} = 1.0E-01 $VMPH_{10\%}$ = **27.5** **mph**

Step 4 Calculate Wind-Generated Significant Wave Height at P_{WH} = 10% using Equation 2 from Appendix B, Section B.4.1 of DS-13(6)-2

where:

H_S = Wind Generated Significant Wave Height (feet),

F = Fetch (miles) and

VMPH = Over-Water Wind Velocity (mph) at selected HEP.

$$H_s = 0.0245 \cdot F^{1/2} \cdot VMPH \cdot (1.1 + 0.0156 \cdot VMPH)^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.07		1.62		1.50	1.64
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.1		28.2		28.0	28.3
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.85		1.09		1.04	1.10

Step 5 Calculate Wave Period at P_{WH} = 10% using Equation 4 from Appendix B, Section B.4.2 of DS-13(6)-2

where:

T = Wave Period (seconds).

$$T = 0.464 \cdot F^{1/3} \cdot VMPH^{1/3} \cdot (1.1 + 0.0156 \cdot VMPH)^{1/6}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.07		1.62		1.50	1.64
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.1		28.2		28.0	28.3
10% HEP Wave Period, T	seconds	0.38		0.61		0.56	0.61

Step 6 Calculate Surf Similarity Factor at P_{WH} = 10% using Equation 7 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

ξ_P = Surf Similarity Factor and

tan(α) = slope of the upstream face of the dam embankment (V:1H).

$$\xi_p = (2.26 \cdot T \cdot \tan(\alpha)) / H_s^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
10% HEP Wave Period, $T_{10\%}$	seconds	0.38		0.61		0.56	0.61
tan(α) = Upstream Slope	V:1H	0.4		0.6		0.4	0.3
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.85		1.09		1.04	1.10
Surf Similarity Factor, ξ_P	---	0.33		0.77		0.45	0.44

Step 7 Calculate Wave Runup at P_{WH} = 10% using Equation 8 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

R = Wave runup on relatively impermeable slope (feet),

A, C = Coefficients dependent on ξ_P = (see Table B-4 of Appendix B, DS-13(6)-2),

γ_r = Surface roughness reduction factor (see Table B-3 of Appendix B, DS-13(6)-2),

γ_b = Berm influence reduction factor (1.0 for non-bermed profiles),

γ_h = Shallow-water reduction factor (1.0 for Rayleigh distributed waves),

B = Angle between the Fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to computed fetch, which is directly perpendicular to the dam axis.), and

γ_β = Reduction factor for direction of fetch relative to dam axis (see Figure B-4 of Appendix B, DS-13(6)-2).

$$R = H_s \cdot (A \cdot \xi_P + C) \cdot \gamma_r \cdot \gamma_b \cdot \gamma_h \cdot \gamma_\beta$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wave Height, $H_{S\text{-}10\%}$	0.85		1.09		1.04	1.10	feet
Surf Similarity Factor, ξ_P	0.33		0.77		0.45	0.44	---
Runup Coefficient A	1.60		1.60		1.60	1.60	---
Runup Coefficient C	0.00		0.00		0.00	0.00	---
Surface roughness reduction factor, γ_r	0.55		0.55		0.55	0.55	---
Berm influence reduction factor, γ_b	1.00		1.00		1.00	1.00	---
Shallow-water reduction factor, γ_h	1.00		1.00		1.00	1.00	---
Fetch incidence angle reduction factor, γ_β	1.00		1.00		1.00	1.00	---
10% HEP Wave Runup, $R_{10\%}$	0.249		0.742		0.414	0.427	feet

Step 8 Calculate Wind Setup at P_{WH} = 10% using Equation 9 from Appendix B, Section B.4.4 of DS-13(6)-2

where:

S = Wind Setup (feet) and

D = Average depth of water (feet) along computed Fetch.

$$S = (VMPH_{10\%}^2 \cdot F) / (1400 \cdot D)$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wind Speed, $VMPH_{10\%}$	27.1		28.2		28.0	28.3	mph
Fetch, F	1.07		1.62		1.50	1.64	miles
Average Depth Along Fetch, D	16.4		53.6		20.09	20.11	feet
10% HEP Wind Setup, $S_{10\%}$	0.034		0.017		0.042	0.047	feet

Step 9 Check Design values of Normal and Residual Freeboard for Alternative B

Per Rule 7.4.2.2.1, the minimum normal freeboard shall be the greater of 3 feet or the wave setup and runup generated by a sustained 100 mph wind.

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Normal Freeboard = feet	5.50		5.50		5.50	5.50
Wave Runup + Setup for 100 mph sustained wind = feet	3.40		5.30		4.80	5.30
Minimum Normal Freeboard = feet	3.40		5.30		4.80	5.30
Design Normal Freeboard value is:	Acceptable		Acceptable		Acceptable	Acceptable

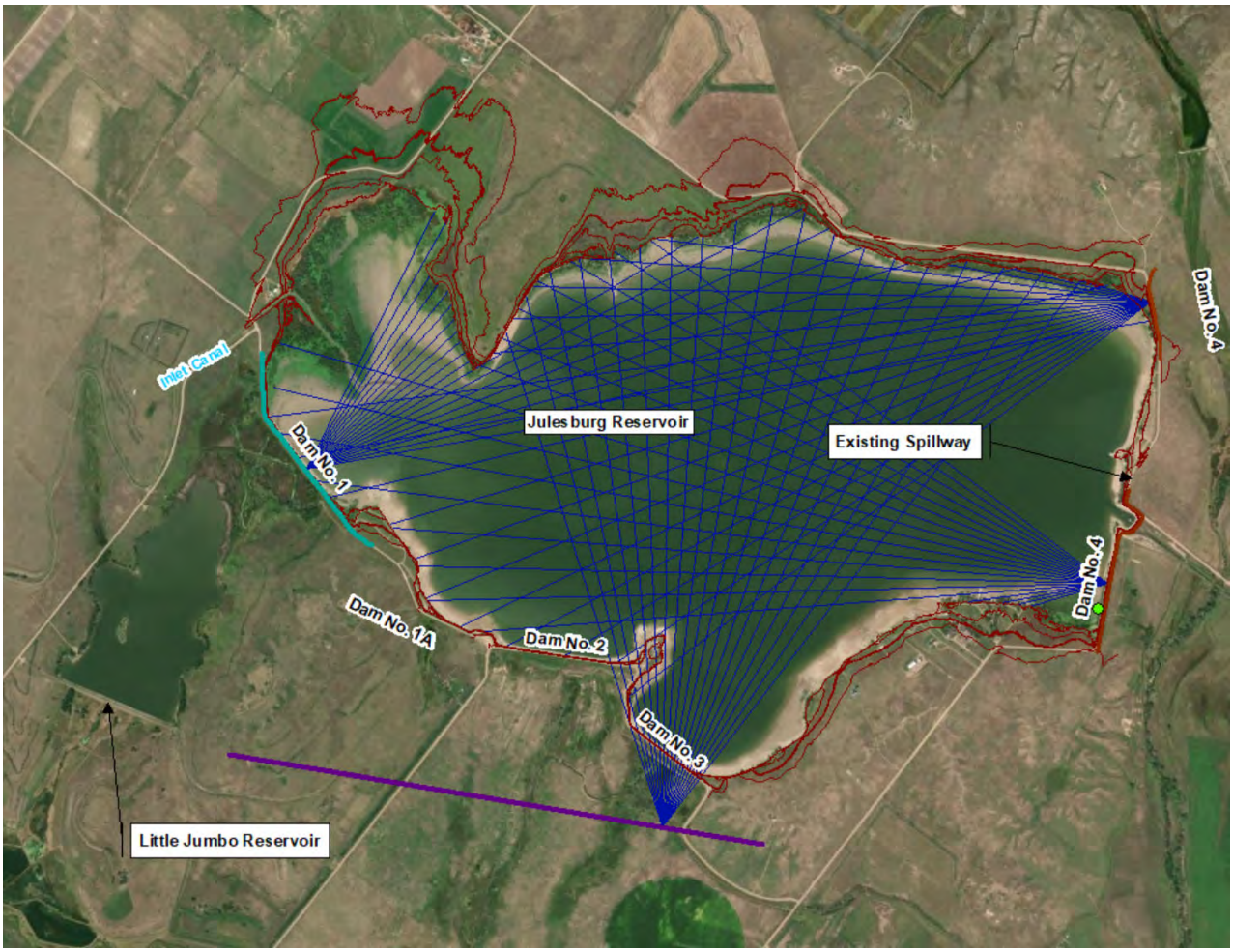
W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Per Rule 7.4.2.2.2, the minimum residual freeboard shall be the greater of 1 foot or the wave setup and runup generated by a sustained 10% HEP wind.

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Residual Freeboard = feet	2.50		2.50		2.50	2.50
Wave Runup + Setup for 22 mph sustained wind = feet	0.28		0.76		0.46	0.47
Minimum Residual Freeboard = feet	1.00		1.00		1.00	1.00
Design Residual Freeboard value is:	Acceptable		Acceptable		Acceptable	Acceptable

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Attachment 1: Reservoir Fetch Figure



W. W. WHEELER & ASSOCIATES, INC.	Subject: Julesburg Irrigation Ditch	Made by: CBM	Job No.: 985.04
	Julesburg Reservoir	Checked: JTC	Date: 8/29/2024
	Freeboard Estimation & Wave Runup	Approved:	

Objective: Calculate normal and residual freeboard requirement for Julesburg Reservoir in the Existing and Option 1 conditions

Methods: Use US Bureau of Reclamation Design Manual 13, Chapter 6: Freeboard, DS-13(6)-2 to estimate normal freeboard and residual freeboard (required minimum freeboard during peak IDF water surface).
Rule 7.4.2.2.1 of Colorado Rules and Regulations for Dam Safety and Dam Construction, 2-CCR 402-1 (January, 2020) indicates that minimum normal freeboard must be the greater of three feet or the wave setup and runup generated by a sustained 100 mph wind.
Rule 7.4.2.2.2 of 2-CCR 402-1 (January, 2020) indicates that minimum residual freeboard must be the greater of one foot or the wave setup and runup generated by a sustained 10 percent Hourly Exceedance Probability (HEP) wind.

Assumptions: Inflow design flood is 23,990 **cfs** based on a PMP, 6-hour Local Storm (incl. 7% AMF)
Upstream Embankment Slope varies for each dam and is provided below. The slope is equivalent to 1 / (tangent of the slope angle, α)
USBR DS 13 Chapter 6, Figure 6.2.2-1 is used to provide freeboard for 100 mph wind runup + setup
Average reservoir depth along the central fetch radius is calculated for each dam on tab 'Average Depth'

Design:

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	
Design Dam Crest Elevation Alternative C =	3716.00	3716.00	3716.00	3716.00	3716.00	3716.00	feet
Maximum IDF Water Surface Elevation Alternative C =	3714.20	3714.20	3714.20	3714.20	3714.20	3714.20	feet [1]
Design Normal Reservoir Water Surfae Elevation Alternative C =	3710.50	3710.50	3710.50	3710.50	3710.50	3710.50	feet

Note: 1 - Water surface elevation from flood routing results of IDF through design spillway.

1) Design Normal Freeboard - For Alternative C
Normal Freeboard = vertical distance between the NHWL and the lowest point on the dam crest

Design Normal Freeboard Alternative C =	5.50	5.50	5.50	5.50	5.50	5.50	feet

2) Design Residual Freeboard - For Alternative C
Residual Freeboard = vertical distance between the maximum WSEL during the IDF and the lowest point on the dam crest

Design Residual Freeboard Alternative C =	1.80	1.80	1.80	1.80	1.80	1.80	feet

Calculations: Calculation 1: Normal and Residual Freeboard

Results: Calculation 1: Design Freeboard of 7 Feet, and Residual Freeboard of 1.31 feet are both acceptable

Calculation 1: Normal and Residual Freeboard

Step 1 Calculate Reservoir Fetch using nine radii on three degree spacing to each side of the central radius, which is perpendicular to the dam
Note that in cases where it is not clear which Central Radius Location will yield the greatest Average Radius Length, multiple locations should be tested. For new Dams No. 1 and 2, it was conservatively assumed that the existing dams were removed during construction and wave runoff could occur accoss the whole reservoir.

Opt3_Dm1

Radius | ID	Angle (degrees)	Opt3_Dm1 Length (feet)	Opt3Dam2 Length (feet)	Dam 3 Length (feet)	Dam 4 Length (feet)	Dam 5 Length (feet)	Dam 1a Length (feet)
Upstream Slope (1 V: X H)		**2.5**	**2.5**		**2.73**	**3**	
Average Reservoir Depth		**44.21**	**56.69**		**20.09**	**20.11**	
+27°	27	4600	6463		1123	9124	
+24°	24	3922	6637		1265	8965	
+21°	21	3442	6704		1499	9525	
+18°	18	3200	6924		1945	10154	
+15°	15	3028	7049		8635	10605	
+12°	12	3059	7328		9396	10868	
+9°	9	4957	7297		9526	10805	
+6°	6	5161	7741		9916	10994	
+3°	3	5588	8055		11010	11694	
Central Radius (0°)	0	7557	8110		11634	11992	
-3°	-3	7937	8023		11862	12319	
-6°	-6	8301	8042		11928	9144	
-9°	-9	8239	8137		9219	8843	
-12°	-12	8142	8305		9057	8560	
-15°	-15	7505	8731		9016	7952	
-18°	-18	7269	9051		8964	6939	
-21°	-21	7027	9404		8711	2885	
-24°	-24	9235	9770		8281	2112	
-27°	-27	10515	10031		7964	1064	
Average Radius Length (feet)		**6247**	**7990**		**7945**	**8660**	
Average Radius Length (miles)		**1.2**	**1.5**		**1.5**	**1.6**	

Average Radius is equal to the **Reservoir Fetch**, as defined by DS-13(6)-2. Refer to attached reservoir fetch figure.

Step 2 Use Figure 6.2.2-1 from DS-13(6)-2 to determine wave runup + setup for 100 mph wind. Wheeler assuemd a slope of 2:1 for a representative of all upstream slopes for each dam. During final design, a less conservative slope should be used to reduce the estimated freeboard.

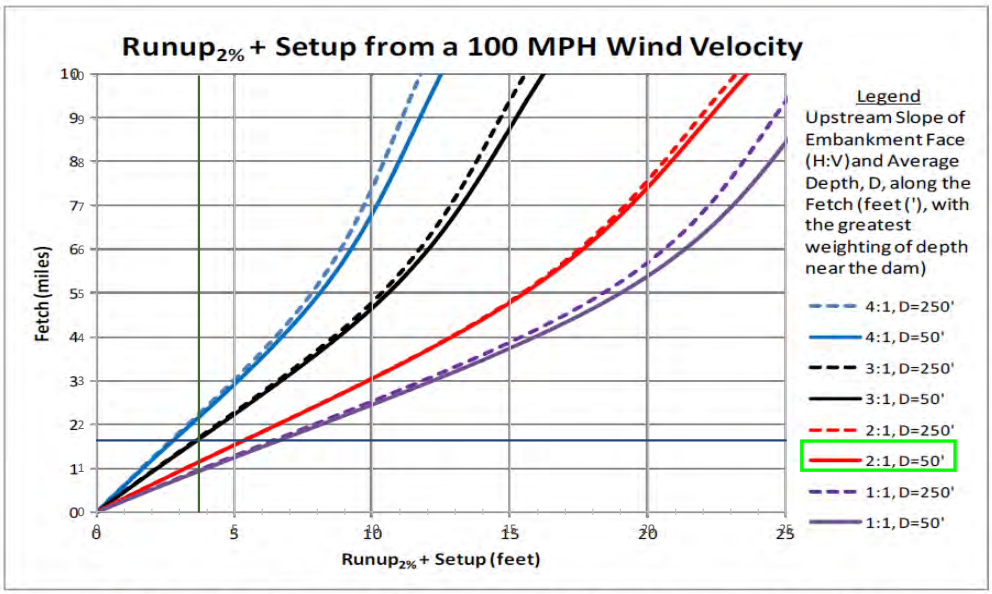


Figure 6.2.2-1. Runup$_{2\%}$ + setup from a 100-mi/h sustained wind velocity on a surface protected by riprap.

Runup + Setup for 100 mi/h sustained wind velocity =

Dam 1 **3.80** **feet** (This is an estimate, should be conservative enough)

Dam 2 **4.10** **feet**

Dam 4 **4.80** **feet**

Dam 5 **3.70** **feet**

Step 3 Use Probabilistic Freeboard and Riprap Analysis (PFARA) software as referenced in DS-13(6)-2 to generate a 10% Hourly Exceedance Probability Over-Water Wind Velocity plot for the dam site in question. Then use the plot to determine the 10% HEP Over-Water Wind Velocity (VMPH$_{10\%}$). Alternatively, use the computed table of PFARA results provided by the CODWR in their design spreadsheet.

Table 1: 10% Probability of Non-Excedence (PWH)

PFARA Station	*Station I.D.*	*Over Water Wind Velocity (mph) 10% Probability of Non-Excedence (P_{WH}) Fetch Length*			
		0.5 mile	*1.0 mile*	*1.5 mile*	*2 mile*
Aurora/Buckley	**CO23036**	18.0	18.5	19.0	19.0
Alamosa	**CO23061**	22.5	23.0	23.5	24.0
Denver/Sta Gage	**CO23062**	22.0	23.0	24.6	26.0
Eagle	**CO23062**	23.0	24.0	25.0	26.0
Grand Junction	**CO23066**	19.5	20.0	21.0	22.0
La Junta	**CO23067**	18.0	19.0	20.0	21.0
Pueblo	**CO23068**	18.0	19.0	20.0	20.0
Trinidad	**CO23070**	22.0	23.0	24.0	24.0
Akron	**CO24015**	26.0	27.0	28.0	29.0
Denver	**CO93032**	19.0	20.0	21.0	21.0
Colorado Springs	**CO93037**	20.0	21.0	23.0	23.0
Pueblo	**CO93058**	20.0	20.2	21.0	22.0
USAFA	**CO93065**	21.0	22.0	22.5	23.0
Fort Carson	**CO93065**	20.0	20.5	21.0	22.0

**** Wind Velocity Calucated using PRARA Program by the Colorado Division of Water Resources, Dam Safety***

P_{WH} = 1.0E-01 **VMPH$_{10\%}$ =** **27.5** **mph**

Step 4 Calculate Wind-Generated Significant Wave Height at P_{WH} = 10% using Equation 2 from Appendix B, Section B.4.1 of DS-13(6)-2

where:

H_S = Wind Generated Significant Wave Height (feet),

F = Fetch (miles) and

VMPH = Over-Water Wind Velocity (mph) at selected HEP.

$$H_s = 0.0245 \cdot F^{1/2} \cdot VMPH \cdot (1.1 + 0.0156 \cdot VMPH)^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.18		1.51		1.50	1.50
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.4		28.0		28.0	28.0
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.90		1.05		1.04	1.04

Step 5 Calculate Wave Period at P_{WH} = 10% using Equation 4 from Appendix B, Section B.4.2 of DS-13(6)-2

where:

T = Wave Period (seconds).

$$T = 0.464 \cdot F^{1/3} \cdot VMPH^{1/3} \cdot (1.1 + 0.0156 \cdot VMPH)^{1/6}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Fetch, F	miles	1.18		1.51		1.50	1.50
10% HEP Wind Speed, $VMPH_{10\%}$	mph	27.4		28.0		28.0	28.0
10% HEP Wave Period, T	seconds	0.42		0.56		0.56	0.56

Step 6 Calculate Surf Similarity Factor at P_{WH} = 10% using Equation 7 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

ξ_P = Surf Similarity Factor and

tan(α) = slope of the upstream face of the dam embankment (V:1H).

$$\xi_p = (2.26 \cdot T \cdot \tan(\alpha)) / H_s^{1/2}$$

Variable	Unit	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
10% HEP Wave Period, $T_{10\%}$	seconds	0.42		0.56		0.56	0.56
tan(α) = Upstream Slope	V:1H	0.4		0.6		0.4	0.3
10% HEP Wave Height, $H_{S\text{-}10\%}$	feet	0.90		1.05		1.04	1.04
Surf Similarity Factor, ξ_P	---	0.40		0.73		0.45	0.41

Step 7 Calculate Wave Runup at P_{WH} = 10% using Equation 8 from Appendix B, Section B.4.3 of DS-13(6)-2

where:

R = Wave runup on relatively impermeable slope (feet),

A, C = Coefficients dependent on ξ_P = (see Table B-4 of Appendix B, DS-13(6)-2),

γ_r = Surface roughness reduction factor (see Table B-3 of Appendix B, DS-13(6)-2),

γ_b = Berm influence reduction factor (1.0 for non-bermed profiles),

γ_h = Shallow-water reduction factor (1.0 for Rayleigh distributed waves),

B = Angle between the Fetch and the dam axis (degrees). (0° is normal incidence and is commonly used to computed fetch, which is directly perpendicular to the dam axis.), and

γ_β = Reduction factor for direction of fetch relative to dam axis (see Figure B-4 of Appendix B, DS-13(6)-2).

$$R = H_s \cdot (A \cdot \xi_P + C) \cdot \gamma_r \cdot \gamma_b \cdot \gamma_h \cdot \gamma_\beta$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wave Height, $H_{S\text{-}10\%}$	0.90		1.05		1.04	1.04	feet
Surf Similarity Factor, ξ_P	0.40		0.73		0.45	0.41	---
Runup Coefficient A	1.60		1.60		1.60	1.60	---
Runup Coefficient C	0.00		0.00		0.00	0.00	---
Surface roughness reduction factor, γ_r	0.55		0.55		0.55	0.55	---
Berm influence reduction factor, γ_b	1.00		1.00		1.00	1.00	---
Shallow-water reduction factor, γ_h	1.00		1.00		1.00	1.00	---
Fetch incidence angle reduction factor, γ_β	1.00		1.00		1.00	1.00	---
10% HEP Wave Runup, $R_{10\%}$	0.321		0.671		0.414	0.377	feet

Step 8 Calculate Wind Setup at P_{WH} = 10% using Equation 9 from Appendix B, Section B.4.4 of DS-13(6)-2

where:

S = Wind Setup (feet) and

D = Average depth of water (feet) along computed Fetch.

$$S = (VMPH_{10\%}^{2} \cdot F) / (1400 \cdot D)$$

Variable	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5	Unit
10% HEP Wind Speed, $VMPH_{10\%}$	27.4		28.0		28.0	28.0	mph
Fetch, F	1.18		1.51		1.50	1.50	miles
Average Depth Along Fetch, D	44.2		56.7		20.09	20.11	feet
10% HEP Wind Setup, $S_{10\%}$	0.014		0.015		0.042	0.042	feet

Step 9 Check Design values of Normal and Residual Freeboard for Alternative C

Per Rule 7.4.2.2.1, the minimum normal freeboard shall be the greater of 3 feet or the wave setup and runup generated by a sustained 100 mph wind.

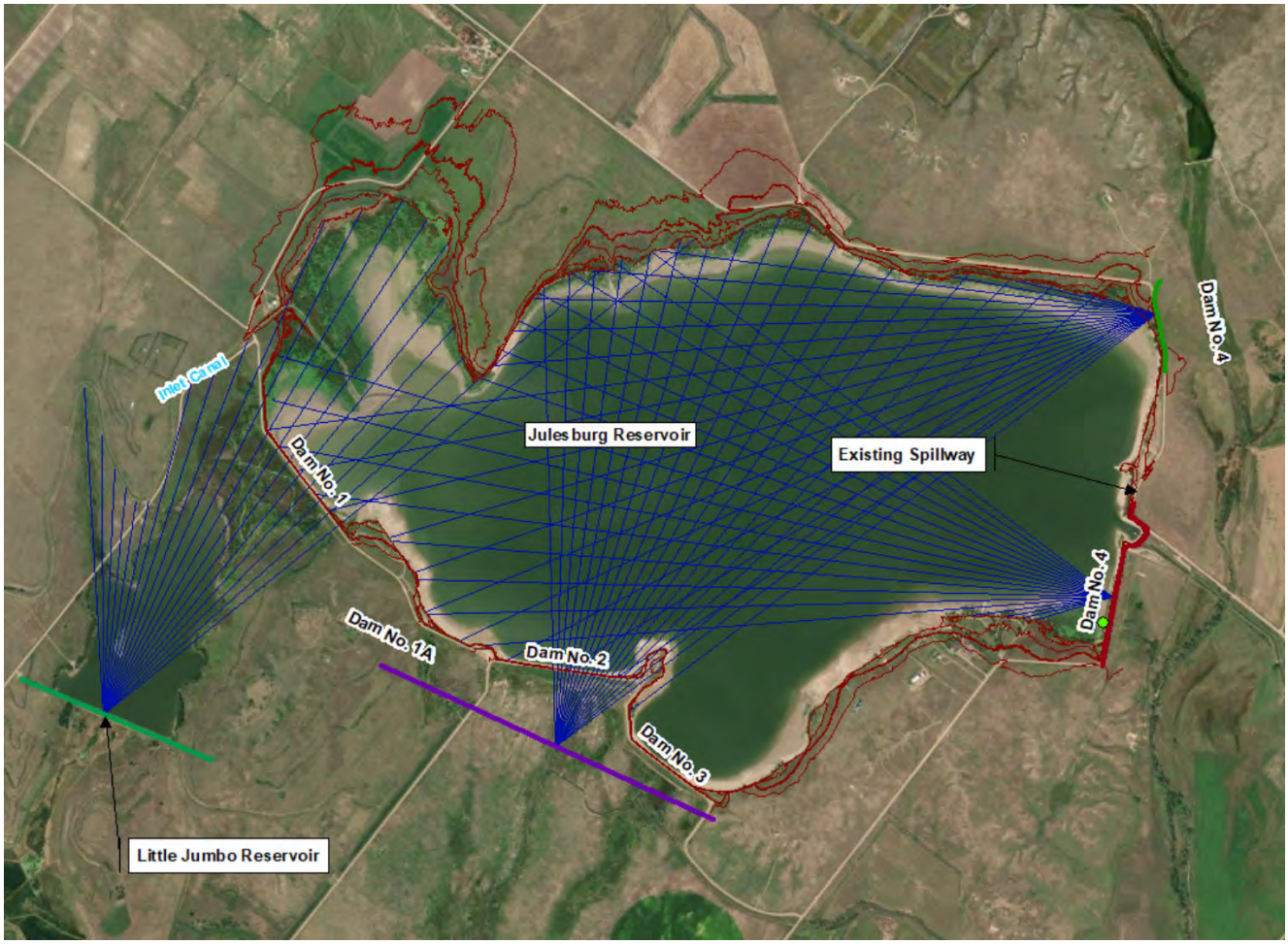
	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Normal Freeboard = feet	5.50		5.50		5.50	5.50
Wave Runup + Setup for 100 mph sustained wind = feet	3.80		4.10		4.80	3.70
Minimum Normal Freeboard = feet	3.80		4.10		4.80	3.70
Design Normal Freeboard value is:	Acceptable		Acceptable		Acceptable	Acceptable

Per Rule 7.4.2.2.2, the minimum residual freeboard shall be the greater of 1 foot or the wave setup and runup generated by a sustained 10% HEP wind.

	Dam 1	Dam 1a	Dam 2	Dam 3	Dam 4	Dam 5
Design Residual Freeboard = feet	1.80		1.80		1.80	1.80
Wave Runup + Setup for 22 mph sustained wind = feet	0.34		0.69		0.46	0.42
Minimum Residual Freeboard = feet	1.00		1.00		1.00	1.00
Design Residual Freeboard value is:	Acceptable		Acceptable		Acceptable	Acceptable

W. W. WHEELER & ASSOCIATES, INC.	Subject	Julesburg Irrigation Ditch	Made by	CBM	Job No.	985.04
	Julesburg Reservoir		Checked	JTC	Date	8/29/2024
	Freeboard Estimation & Wave Runup		Approved			

Attachment 1: Reservoir Fetch Figure



Appendix C

Alternative Opinions of Probable Cost

CLASS 5 OPINION OF PROBABLE COST
JULESBURG RESERVOIR - ENLARGEMENT ALTERNATIVE A
Julesberg Irrigation District

Item No.	Description	Quantity	Unit	Unit Price	Total
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (15% of construction costs)	15%			$3,096,700
2	Storm Water Management - Erosion and Sediment Control (5% of construction costs)	5%			$1,032,200
3	Clearing and Grubbing	68	AC	$2,271	$154,100
4	Strip and Stockpile Topsoil	54,752	CY	$4.50	$246,400
5	Reclamation and Cleanup	1	LS	$604,660	$604,700
	Subtotal				**$5,134,100**
Construction Components					
6	Dam 1 Fill Borrow and Placement	74,785	CY	$8.50	$635,700
7	Dam 1 Drainage System	1	LS	$728,600	$728,600
8	Dam 1 US Erosion Protectoin	1	LS	$1,594,200	$1,594,200
9	Dam 1a Borrow and Placement	8,658	CY	$8.50	$73,600
10	Dam 1a Drainage System	1	LS	$279,000	$279,000
11	Dam 1a US Erosion Protectoin	1	LS	$296,200	$296,200
12	Dam 2 Borrow and Placement	104,240	CY	$8.50	$886,000
13	Dam 2 Drainage System Extended	1	LS	$574,100	$574,100
14	Dam 2 US Erosion Protectoin	1	LS	$2,050,500	$2,050,500
15	Dam 3 Borrow and Placement	89,474	CY	$8.50	$760,500
16	Dam 3 Drainage System Extended	1	LS	$488,600	$488,600
17	Dam 3 US Erosion Protectoin	1	LS	$1,870,500	$1,870,500
18	Dam 4 Borrow and Placement (includes northeast dike)	60,665	CY	$8.50	$515,700
19	Dam 4 Drainage System	1	LS	$366,500	$366,500
20	Dam 4 US Erosion Protectoin	1	LS	$1,880,600	$1,880,600
21	Inlet Canal Improvments	557,147	CY	$8.00	$4,457,200
22	Inlet Canal Access Road	1,568	CY	$64.20	$100,700
23	Enlarge Outlet Works Tower and Bridge	1	LS	$327,503	$327,500
24	Misc. Earthwork (undefined)	5,000	CY	$8.50	$42,500
25	Misc. Reinforced Concrete (Appurtenant Structures, Spillway, etc.)	396	CY	$1,602	$633,900
26	Spillway Armor	1	LS	$86,563	$86,600
27	Dam Safety Instrumentation	1	LS	$119,057	$119,100
28	Unscheduled Items (10% of other construction components)	10%			$1,876,800
	Subtotal				**$20,644,600**
	TOTAL DIRECT CONSTRUCTION COSTS				**$25,778,700**
Indirect Construction Costs					
29	Land Acquisitions based on NHWL	283	AC	$1,000	$282,900
30	Reroute County Road 28	1	LS	$243,716	$243,700
31	Final Design and SEO Dam Safety Approval (10% Direct Construction Costs)	10%			$2,064,500
32	Construction Administration and Engineering (10% Direct Construction Costs)	10%			$2,064,500
33	Environmental Permtting (404, T&E, etc.)	5%			$1,032,200
34	Construction Contingency (20% of DCS)	20%			$4,128,900
	TOTAL INDIRECT CONSTRUCTION COSTS				**$9,816,700**
	TOTAL ESTIMATED PROJECT COSTS (2025)				**$35,595,400**

Assumptions and Notes:
1) Totals rounded up to nearest $100 for simplification.
2) To account for approximate inflation, the total estimated project costs should be increased by 3 percent for each year beyond 2025.

CLASS 5 OPINION OF PROBABLE COST
JULESBURG RESERVOIR - ENLARGEMENT ALTERNATIVE B
Julesberg Irrigation District

Item No.	Description	Quantity	Unit	Unit Price	Total
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (15% of construction costs)	15%			$4,548,200
2	Storm Water Management - Erosion and Sediment Control (5% of construction costs)	5%			$1,516,100
3	Clearing and Grubbing	64	AC	$2,271	$145,600
4	Strip and Stockpile Topsoil	51,719	CY	$4.50	$232,700
5	Reclamation and Cleanup	1	LS	$483,396	$483,400
	Subtotal				**$6,926,000**
Construction Components					
6	Dam 1 Fill Borrow and Placement	15,440	CY	$8.5	$131,200
7	Dam 1 Drainage System	1	LS	$659,700	$659,700
8	Dam 1 US Erosion Protection	1	LS	$674,300	$674,300
9	Dam 1A Breach	12,426	CY	$16.2	$201,300
10	Dam 2 Breach	30,139	CY	$16.2	$488,300
11	Dam 3 Breach	44,250	CY	$16.2	$716,900
12	Juesburg Dam A Borrow and Placement	1,539,977	CY	$8.5	$13,089,800
13	Juesburg Dam A Cutoff Constructoin	17,109	CY	$8.5	$145,400
14	Juesburg Dam A Internal Drainage System	1	LS	$1,736,370	$1,736,400
15	Juesburg Dam A US Erosion Protection	1	LS	$8,326,493	$8,326,500
16	Juesburg Dam A Outlet (Optional)	1	LS	$3,926,031	$0
17	Dam 4 Drainage System	1	LS	$366,478	$366,500
18	Misc. Earthwork	5,000	CY	$8.5	$42,500
19	Misc. Reinforced Concrete (Appurtenant Structures, Spillway, etc.)	476	CY	$1,602	$762,600
20	Spillway Armor	1	LS	$104,151	$104,200
21	Dam Safety Instrumentation	1	LS	$119,057	$119,100
22	Unscheduled Items (10% of other construction components)	10%			$2,756,500
	Subtotal				**$30,321,200**
	TOTAL DIRECT CONSTRUCTION COSTS				**$37,247,200**
Indirect Construction Costs					
23	Land Acquisitions - (Purchase or Easement - Decide, consider increased NHWL and canal)	355	AC	$1,000	$355,300
24	Reroute County Road 1 and County Road 24.8	1	LS	$623,593	$623,600
25	Final Design and SEO Dam Safety Approval (10% Direct Construction Costs)	10%			$3,032,100
26	Construction Administration and Engineering (10% Direct Construction Costs)	10%			$3,032,100
27	Environmental Permtting (404, T&E, etc.)	20%			$6,064,200
28	Construction Contingency (20% of DCS)	20%			$6,064,200
	TOTAL INDIRECT CONSTRUCTION COSTS				**$19,171,500**
	TOTAL ESTIMATED PROJECT COSTS (2024)				**$56,418,700**

Assumptions and Notes:
1) Totals rounded up to nearest $100 for simplification.
2) To account for approximate inflation, the total estimated project costs should be increased by 3 percent for each year beyond 2025.

CLASS 5 OPINION OF PROBABLE COST
JULESBURG RESERVOIR - ENLARGEMENT ALTERNATIVE C
Julesberg Irrigation District

Item No.	Description	Quantity	Unit	Unit Price	Total
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (15% of construction costs)	15%			$5,013,200
2	Storm Water Management - Erosion and Sediment Control (5% of construction costs)	5%			$1,671,100
3	Clearing and Grubbing	65	AC	$2,271	$147,900
4	Strip and Stockpile Topsoil	52,517	CY	$4.50	$236,300
5	Reclamation and Cleanup	1	LS	$431,364	$431,400
	Subtotal				**$7,499,900**
Construction Components					
6	Juesburg Dam C Borrow and Placement	861,716	CY	$8.5	$7,324,600
7	Juesburg Dam C Cutoff Construction	7,179	CY	$8.5	$61,000
8	Juesburg Dam C Internal Drainage System	1	LS	$686,500	$686,500
9	Juesburg Dam C US Erosion Protection	1	LS	$5,431,200	$5,431,200
10	Dam 1 Breach	38,250	CY	$16.2	$619,700
11	Dam 1A Breach	12,426	CY	$16.2	$201,300
12	Dam 2 Breach	30,139	CY	$16.2	$488,300
13	Dam 3 Breach	44,250	CY	$16.2	$716,900
14	Juesburg Dam B Borrow and Placement	861,716	CY	$8.5	$7,324,600
15	Juesburg Dam B Cutoff Constructoin	12,218	CY	$8.5	$103,800
16	Juesburg Dam B Internal Drainage System	1	LS	$1,239,916	$1,239,900
17	Juesburg Dam B US Erosion Protection	1	LS	$5,431,162	$5,431,200
18	Juesburg Dam B Outlet (Optional)	1	LS	$3,679,608	$0
19	Dam 4 Drainage System	1	LS	$366,478	$366,500
20	Misc. Earthwork	5,000	CY	$8.5	$42,500
21	Misc. Reinforced Concrete (Appurtenant Structures)	106	CY	$1,602	$169,100
22	Spillway Armoring	1	LS	$23,100	$23,100
23	Inlet Canal Reroute	3,450	CY	$8.0	$27,600
24	Inlet Canal Armoring	93	CY	$64.2	$5,900
25	Dam Safety Instrumentation	1	LS	$119,057	$119,100
26	Unscheduled Items (10% of other construction components)	10%			$3,038,300
	Subtotal				**$33,421,100**
	TOTAL DIRECT CONSTRUCTION COSTS				**$40,921,000**
Indirect Construction Costs					
27	Land Acquisitions - (Purchase or Easement - Decide, consider increased NHWL and canal)	515	AC	$1,000	$515,200
28	Reroute County Road 95	1	LS	$190,403	$190,400
29	Final Design and SEO Dam Safety Approval (10% Direct Construction Costs)	10%			$3,342,100
30	Construction Administration and Engineering (10% Direct Construction Costs)	10%			$3,342,100
31	Environmental Permtting (404, T&E, etc.)	20%			$6,684,200
32	Construction Contingency (20% of DCS)	20%			$6,684,200
	TOTAL INDIRECT CONSTRUCTION COSTS				**$20,758,200**
	TOTAL ESTIMATED PROJECT COSTS (2024)				**$61,679,200**

Assumptions and Notes:
1) Totals rounded up to nearest $100 for simplification.
2) To account for approximate inflation, the total estimated project costs should be increased by 3 percent for each year beyond 2025.