FINAL REPORT

CONTINENTAL RESERVOIR FLOOD HYDROLOGY REPORT HINSDALE COUNTY, COLORADO SEO DAM ID 200110

Prepared for
Santa Maria Reservoir Co.
Monte Vista, CO

April 8, 2011

URS

URS Corporation
8181 E. Tufts Avenue
Denver, Colorado 80237
Project No. 22240908

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER RESOURCES

June 22, 2011

Mr. Ed Toms, P.E.
URS Corporation
8181 East Tufts Avenue
Denver, CO 80237

When replying, please refer to:
CONTINENTAL DAM
Water Division 3, DAMID: 200110

Subject: Approval of Flood Hydrology Report

Dear Ed:

Thank you for submitting for review by the State Engineer, the final Flood Hydrology Report for Continental Reservoir Dam, located in Hinsdale County, Colorado. This office has completed the review of the revised hydrology report, dated May11, 2011, in accordance with the State of Colorado's Rules and Regulations for Dam Safety and Dam Construction (Rules and Regulations). Upon review, it has been determined that report satisfies the criteria specified in the applicable Rules and the report is hereby accepted.

The Flood Hydrology Report identifies the Saguache Storm (EPAT Local Storm) as the basis for the Inflow Design Flood (IDF) for Continental Dam. The report also concludes that the spillway is inadequate for the General Storm developed using the procedures in HMR-55A, and that substantial overtopping would occur under this scenario. Based on the results presented in the report, it is apparent that the relatively small storm volumes associated with the EPAT and HMR-55A Local Storms result in substantial attenuation of the peak flows. Conversely, the larger storm volume associated with HMR-55A General Storm results in less attenuation and overtopping of the dam by some 3.7 feet. It is noted that this is a somewhat unusual situation in that the General Storm is the controlling event according to the HMR-55A procedures, whereas the Local Storm is the controlling event according to the EPAT. The intent of the submitted report was to verify the hydrologic adequacy of the existing spillway, and we concur that the spillway can pass the EPAT-based IDF, which satisfies the Rules and Regulations. However, in the event that the Owner pursues plans to rehabilitate the

spillway, the issue discussed above will be re-evaluated based on our evolving understanding of the reliability of EPAT results, particularly considering that the two methods (HMR & EPAT) indicate differing controlling storm types (General vs Local).

Thank you for your submittal, and if you have any questions or comments, please contact the local Dam Safety Field Engineer, Matthew Gavin, at (970) 247-1845, XT 7003.

Sincerely,

Mark R. Haynes

Mark R. Haynes, P.E.
Chief, Safety of Dams Program

cc: Craig Cotten, Division Engineer
Matthew Gavin, Dam Safety Engineer
Steve Baer, Water Commissioner, District 20

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List of Abbreviations

ac-ft	acre-feet
cfs	cubic feet per second
EPAT	Extreme Precipitation Analysis Tool
ESP	Extreme Storm Precipitation
ft/mi	feet per mile
GIS	Geographic Information System
HMR	Hydrometeorological Report
IDF	Inflow Design Flood
in/hr	inches per hour
NOAA	National Oceanic and Atmospheric Administration
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
Rules	Colorado State Engineer's Office Dam Safety Rules and Regulations
SEO	State Engineer's Office

mi^2	square miles
SMRC	Santa Maria Reservoir Company
SSPMP	Site Specific Probable Maximum Precipitation
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey

OVERVIEW

Continental Reservoir, in Hinsdale County, Colorado, is impounded by an embankment dam along its northeast side. The main dam is an earthen structure, approximately 310 feet long and 92 feet high, based on the Dam Safety Engineer's Inspection Report from June 4, 2009, available drawings, and reservoir storage data. The spillway consists of a 140-foot long, side channel spillway with a lined discharge chute and dissipation basin. The State Engineer's Office (SEO) classifies the main dam as a large, high-hazard structure. The dam and reservoir are owned and operated by the Santa Maria Reservoir Company (SMRC), of Monte Vista, Colorado.

The purpose of this report is to present the assumptions, criteria, and calculations for the development of the inflow design flood (IDF) for Continental Reservoir. The IDF will be used as the basis of design for future spillway improvements. The development of the IDF included estimating the inflow floods resulting from the 24-hour, 100-year storm; the Extreme Storm Precipitation (ESP) and Probable Maximum Precipitation (PMP) storms in order to define the critical storm event for the project. The ESP storms were developed using the Extreme Precipitation Analysis Tool (EPAT). The storm events were evaluated using United States Bureau of Reclamation's (USBR) dimensionless unit hydrograph procedure outlined in USBR's Flood Hydrology Manual (Cudworth, 1989).

URS modeled several ESP and PMP storm events to determine the IDF. USBR's methodology for development of the synthetic unit hydrograph was used for this study.

CONCLUSIONS AND RECOMMENDATIONS

After analyzing the flood values developed from the different storms, the recommended storm for the IDF was the EPAT local Saguache storm. The IDF produced a peak reservoir inflow of approximately 27,100 cfs resulting in a peak reservoir elevation of 10,285.3 feet, which is approximately 5.3 feet above the spillway crest and approximately 4.7 feet below the crest of the dam. The Hydrometerological Report (HMR)-55A storm could have been selected as the IDF, because it resulted in the largest outflow and overtopped the dam by approximately 3.7 feet. However, the EPAT results were considered more accurate due to the high elevation ranges of the watershed and dam. The existing spillway has adequate capacity to safely pass the IDF; therefore capacity enlargement is not required. Structural improvements will be required,

however, and the IDF will be used to size the new spillway. The replacement spillway will be sized to safely pass the IDF and will meet SEO Dam Safety Rules and Regulations (Rules).

Section 1

1.1 PURPOSE

The purpose of this report is to present the assumptions, criteria, and calculations for the development of the IDF for Continental Reservoir. The IDF will be used as the basis of design for future spillway improvements. The development of the IDF included estimating the inflow floods resulting from the 24-hour, 100-year storm and the ESP and HMR-55A storms in order to define the critical storm event for the dam and reservoir. The ESP storms were developed using the EPAT. The general and local storm events were both evaluated using USBR's dimensionless unit hydrograph procedure outlined in USBR's Flood Hydrology Manual (Cudworth, 1989).

1.2 EXISTING CONDITIONS

Continental Reservoir is impounded by an embankment dam along the northeast side of the reservoir. The main dam is an earthen structure, approximately 310 feet long and 92 feet high, based on the Dam Safety Engineer's Inspection Report from June 4, 2009, available drawings, and reservoir storage data. The spillway consists of a 140-foot long, side channel spillway with a lined discharge chute and dissipation basin. The main dam is currently classified as a high-hazard structure. The dam and reservoir are owned and operated by the SMRC.

Initially designed in 1911, the dam was re-designed and constructed between May 1925 and December 1928 (Inspection Memorandum November 7, 2003) as an irrigation storage reservoir. The upstream slope of the main dam varies from 2.5H:1V (horizontal:vertical) to 4H:1V, the downstream slope is 2H:1V, according to Drawing C-259A (Hydro-Triad 1990). The side channel spillway is located on the right abutment of the main dam crest. The side-channel spillway is a 12-inch wide weir with a crest 140 feet long, at elevation 10,280 feet. Historical drawings are presented in **Appendix A.**

1.3 SCOPE OF WORK

Under an agreement dated September 11, 2009, the SMRC authorized URS to develop the IDF that could be used for the basis of spillway capacity design (if required). The scope of work was divided into several tasks. This report presents the results of Task 1.1 – Hydrologic/Hydraulic Analysis.

The flood hydrology analysis included the development of the 100-year storm event and the general and local PMP storm events. The PMP storm events were prepared by two methods, EPAT and HMR-55A, so their results could be compared. The floods were routed through the reservoir and existing dam configuration to determine the critical storm event for the project. The critical storm event was selected for the basis for spillway design. URS used existing mapping for the project. Additional surveying or mapping was not performed. URS also used available reservoir storage data that was provided by the Dam Safety Engineer for the Colorado Division of Water Resources.

1.4 STUDY LIMITATIONS

Professional judgments in this report were based on evaluation of technical information and on our experience with similar projects. URS represents services that are performed within the limits prescribed by the client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation to the client, expressed or implied, and no warranty or guarantee is included or intended.

2.1 OVERVIEW

This section presents the flood hydrology developed for Continental Reservoir. The flood hydrology was prepared in conformance with the SEO Rules, dated January 1, 2007 (SEO, 2007). The flood hydrology was developed using precipitation values from the EPAT and HMR-55A for PMP storms, and the NOAA Atlas 2 for the 100-year storm.

2.2 INFLOW DESIGN FLOOD BASIS

The magnitude of the IDF is defined by the ESP or the HMR-55A storm event, and the size and hazard classification of the dam. The magnitude or percentage of the ESP or HMR-55A storm that is required to size the dam's spillway capacity was selected based on the characteristics of the watershed and the dam size and hazard classification.

Dam sizes are classified as minor, small, and large, based on the SEO Rules. SEO Rules define the dam classification based on the height and reservoir volume. Continental Dam is a 92-foot high embankment structure that impounds 22,825 ac-ft at the spillway crest, based on SEO storage data. SEO Rules state that a large size dam has a height greater than 50 feet and a capacity greater than 4,000 ac-ft. Therefore, the dam is classified as a "large" dam by SEO Rules.

The hazard classification is based on downstream hazard potential due to failure or improper operation of the dam. Presently, Continental Dam is classified as a "high" hazard structure. A high-hazard dam is one for which loss of human life is expected to result from a possible dam failure.

SEO Rules state that large, high-hazard dams shall safely pass 100% of the general or local ESP storm event, or 90% of the general or local HMR-55A PMP storm event, depending on the selected method to compute the IDF storm event.

2.3 DRAINAGE BASIN DESCRIPTION

The drainage basin contributing to Continental Reservoir is approximately 50.1 mi^2 in size and the reservoir area is approximately 0.72 mi^2 in size. The drainage basin ranges in elevation from approximately 10,280 feet at the spillway crest to approximately 12,845 feet at the Continental Divide. Vegetation cover varies throughout the basin due to the range in elevations and

transitions through ecological zones along the drainage flow path. The vegetation generally consists of high altitude, alpine vegetation. Currently, the basin is undeveloped.

The basin boundaries and watercourse were delineated from USGS 1:24,000 quadrangle maps. Runoff water will travel overland and through a course of tributaries, and ultimately flow into North Clear Creek and into the Continental Reservoir. The main watercourse flows generally west to east for approximately 12.5 miles at a slope of 207 ft/mi. **Figure 2-1** presents the watershed and primary watercourse of North Clear Creek.

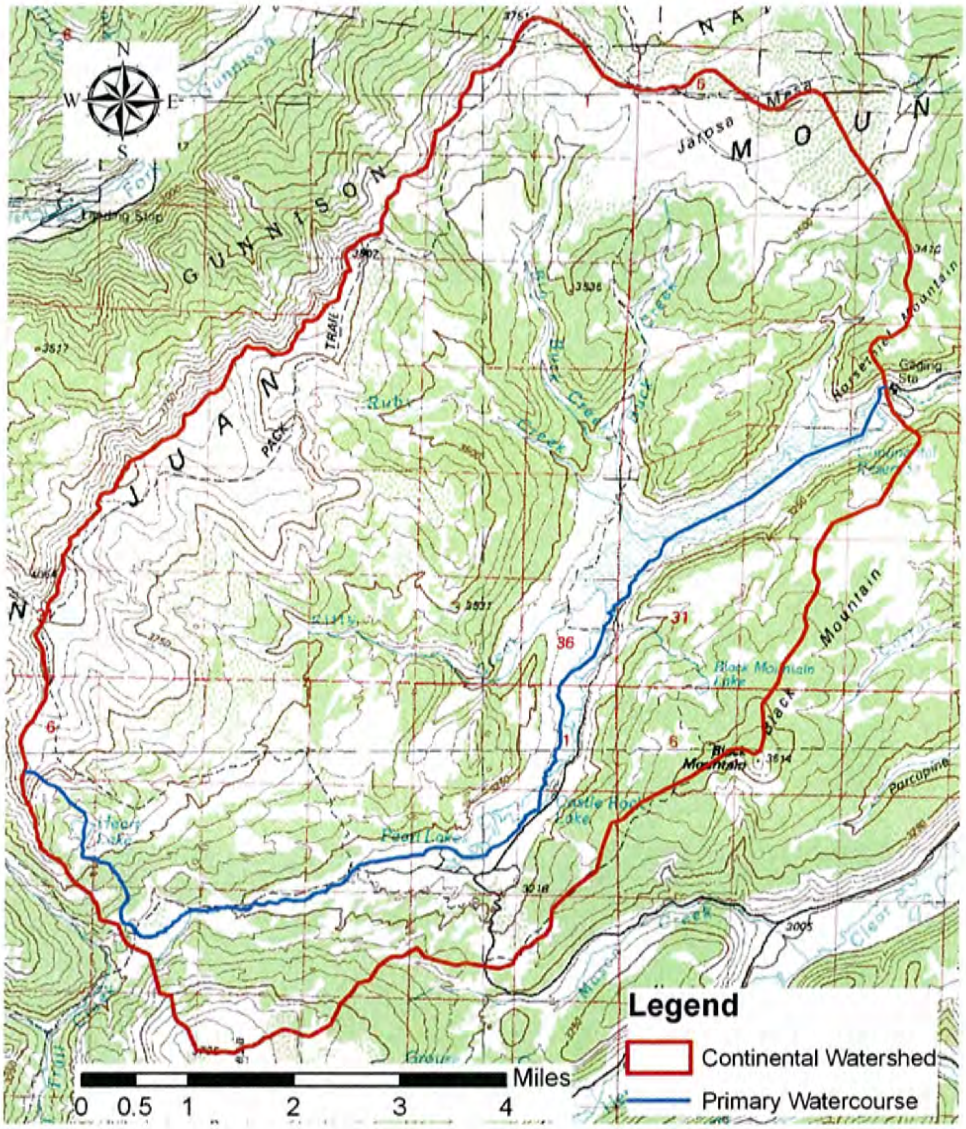

Figure 2-1
Watershed and Primary Watercourse

2.4 INFILTRATION

The State of Colorado's *Hydrologic Basin Response Parameter Estimation Guidelines* (SEO, 2008) recommends using Green and Ampt infiltration methodology for the 100-year frequency storm, and initial and constant methodology for PMP storms. Detailed infiltration calculations for both methodologies are included in **Appendix B**.

Using Green and Ampt methodology for the 100-year storm, an initial loss of 0.30 inches of runoff was estimated, assuming a vegetative cover between 40% and 80% and an average slope greater than 10% soil maps obtained from the USDA's Geospatial Data Gateway (USDA, 2010) indicate that the watershed is mostly composed of cobbly loams, silt loams, gravely loams, and a range of decomposed plant material. An estimated area weighted average of the first 6 inches of soil resulted in a bare ground hydraulic conductivity of 0.18 in/hr (SEO, 2008). This hydraulic conductivity value for bare soil was adjusted to account for vegetative cover, as described in SEO (2008). An adjustment ratio of 1.33 was obtained, making the hydraulic conductivity of the watershed approximately to 0.24 in/hr. It was assumed the 100-year storm could occur in the spring when snowmelt saturates the soil, and thus, no moisture deficit. The wetting front capillary suction was estimated to be 4.7 inches, based on the bare soil hydraulic conductivity rate. A comprising imperviousness for the watershed was estimated at 6.5% based on the USDA's reported standing water and rock outcropping areas.

The drainage basin was modeled assuming an initial loss of 0.6 inches for all PMP storms, with a constant loss rate of 0.13 in/hr. Using the same soil types described for the 100-year storm, a hydraulic conductivity for bare soils was estimated at 0.10 in/hr according to SEO (2008). This hydraulic conductivity value for bare soil was adjusted to account for vegetative cover, as described in SEO (2008). An adjustment ratio of 1.33 was obtained, making the hydraulic conductivity of the watershed approximately to 0.13 in/hr. The surface retention loss was estimated to be 0.30 inches using SEO (2008) for a vegetative cover between 40% and 80% with an average slope greater than 10%. The initial infiltration was estimated to be 0.3 inches for "normal" ground using SEO (2008). The sum of the retention loss and initial infiltration resulted in a total initial loss of 0.6 inches. **Table 2-1** provides a summary of all estimated losses corresponding with each design storm.

Table 2-1
Summary of the Continental Watershed Infiltration Parameters.

Design Storm	Approach	Capillary Suction (in.)	Vertical Hydraulic Conductivity (in/hr)	Initial Losses (in)
Local PMP (HMR-55A)	Initial and Constant	-	0.13	0.6
General PMP (HMR-55A)	Initial and Constant	-	0.13	0.6
EPAT	Initial and Constant	-	0.13	0.6
100-year, 24-hr	Green-Ampt	4.7	0.24	0.3

2.5 EXTREME STORM AND PROBABLE MAXIMUM PRECIPITATION

Two methods were used to develop extreme precipitation estimates for the project: the EPAT and HMR-55A methods. The EPAT results typically serve as the basis for evaluating the need for spillway improvements. The PMP storm event is developed, based on HMR-55A, for comparison purposes, to determine the reasonableness of the EPAT results. The EPAT was developed based on historical, site-specific PMP studies that were developed for dams over the past 10 years within Colorado, and therefore it is more representative of storm events within Colorado than HMR-55A.

2.5.1 Extreme Precipitation Analysis Tool

The ESP was estimated for the watershed by using EPAT, version 4.2. EPAT is a computer model that creates scientifically reproducible extreme precipitation results for Colorado. The ESP is a SSPMP that can be developed for areas within Colorado. The SSPMP is theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area, at a particular geographic location, at a certain time of the year, while acknowledging that storm sizes and intensities are specific to certain geographic locations.

EPAT only allows historical storms that occurred in the same geographic region as the watershed above the dam to be used when determining the SSPMP. The historic storms are transposed over the dam's watershed in a manner that makes the storm's spatial coverage consistent with what would occur in nature. The automated process follows certain calculations and procedures considered important in the HMR. These steps are then translated into GIS for transposing the

storm to the new location. EPAT develops both the general and local storm ESPs. EPAT results are presented in **Appendix C**.

The general storm ESP is considered a storm event that usually produces precipitation over an area larger than 500 mi^2 for durations longer than 6 hours. This type of storm is primarily caused by cyclonic precipitation associated with large-scale weather features such as pressure systems and fronts. EPAT produced four general storms for the Continental Reservoir drainage basin. All four storms were modeled, and the storm that produced the largest peak inflow and volume to Continental Reservoir was selected as the general ESP storm event. The general storms created by EPAT had relatively low rainfall intensities that were typically less than the constant soil infiltration rates. As a result, the majority of rainfall infiltrates the ground as opposed to becoming runoff for the EPAT general storms. For example, the historical storm used to develop the general ESP storm event was the Palisade Lake storm over southwest Colorado that occurred on June 26-29, 1927 and produced 5.9 inches of precipitation over 84 hours. The average precipitation intensity full duration of the storm is 0.08 in/hr, which is less than the constant infiltration rate of 0.13 in/hr. Although periods of higher rainfall intensities occur during this specific storm, the large majority of rainfall infiltrates into the soil.

The local ESP storm event is generally considered a storm event that is confined in duration and location. A local storm rarely occurs in areas exceeding 500 mi^2 and the duration is often 6 hours or less. This type of storm is primarily caused by convective precipitation associated with vertical upward motion within an extended mass of moist air, where the moist air is warmer than its environment. EPAT produced three local storms for the drainage basin of Continental Reservoir. All three storms were modeled. The storm that produced the largest peak inflow and volume to Continental Reservoir was chosen as the local ESP storm. The historical storm used to develop the local ESP storm event was Saguache storm on Saguache Creek that occurred on July 25, 1999, which produced 5.22 inches of precipitation over 2 hours. The precipitation used for the local ESP storm event, after transposing the historical storm over the Continental Reservoir watershed, produced 2.88 inches of precipitation over 2.7 hours.

2.5.2 Hydrometeorological Report 55A

The PMP storm event for the watershed was also estimated by using procedures presented in the HMR-55A, so the results could be compared against those estimated by the EPAT method. The

PMP storm event is theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area, at a particular geographic location, at a certain time of the year. HMR-55A includes the PMP for local and general storm events between the Continental Divide and east toward the 103rd Meridian.

The general PMP storm event is considered a storm event that usually produces precipitation over an area larger than 500 mi^2 for durations longer than 6 hours. This type of storm is primarily caused by cyclonic precipitation associated with large-scale weather features such as pressure systems and fronts. PMP depths for the general PMP storm event for Continental Reservoir were estimated from HMR-55A. Precipitation depths for the 5- and 15-minute durations were estimated using the SEO's "Dam Safety Project Review Guide" (SEO, 1994), and the 2-, 3-, 12-, and 48-hour precipitation depths were interpolated from the HMR-55A values (1-, 6-, 24-, and 72-hour depths).

The local PMP storm event is generally considered a storm event that is confined in duration and location. A local PMP storm event rarely occurs in areas exceeding 500 mi^2 and the duration is often 6 hours or less. This type of storm is primarily caused by convective precipitation associated with vertical upward motion within an extended mass of moist air, where the moist air is warmer than its environment.

The 15-minute to 6-hour PMP depths for the local PMP storm event were estimated from HMR-55A. The 5-minute PMP was estimated to be approximately 45% of the 15-minute value from HMR-55A. This estimate is based on the SEO "Dam Safety Project Review Guide" (SEO, 1994).

Due to the drainage basin having an average elevation of approximately 11400 feet, the PMP was reduced for elevation. According to the SEO Rules for high-hazard dams (SEO, 2007), both the general storm (east of the Continental Divide) and local storms were reduced to 90% of the PMP (0.9 PMP). The general and local PMP storm event estimates are shown in **Table 2-2**. Detailed calculations procedures and materials are presented in **Appendix C**.

Table 2-2
General and Local Storm PMP (HMR-55A)

Duration	General Storm Precipitation (inch)	Local Storm Precipitation (inch)
5-minute	0.63	0.77
15-minute	1.67	1.7
1-hour	3.7	3.3
2-hour	4.5	4.1
3-hour	5.4	4.5
6-hour	7.2	5.3
12-hour	11	-
24-hour	15.5	-
48-hour	18.2	-
72-hour	20.2	-

2.5.3 24-Hour, 100-Year Storm Event

The 24-hour, 100-year storm event from isopluvial maps located in NOAA Atlas 2, Volume III. Methodologies found in the NOAA Atlas 2 were used to develop precipitation depths for durations other than the 6-hour and 24-hour durations reported on the isopluvial maps. The areal adjusted 24-hour, 100-year storm precipitation depth was 3.14 inches. The 24-hour, 100-year storm estimates are presented in **Table 2-3**. Detailed calculation procedures and materials are presented in **Appendix C**.

Table 2-3
24-Hour, 100-Year Storm Precipitation

Duration	Precipitation (inch)
15-minute	0.83
1-hour	1.46
2-hour	1.7
3-hour	1.86
6-hour	2.16
12-hour	2.65
24-hour	3.14

2.6 UNIT HYDROGRAPH

The general PMP, local PMP, and 24-hour, 100-year storm unit hydrographs were developed based on USBR's methods. The unit hydrographs using the methodology for development of a synthetic unit hydrograph as outlined in USBR's Flood Hydrology Manual (Cudworth, 1989).

Lag times were calculated as part of the procedure to obtain the unit hydrograph for the watershed. Lag time is the time between the peak rainfall intensity and the centroid of the runoff at the outlet of the watershed. It is influenced by the shape, steepness, and roughness of the watershed. The following USBR equation was used to estimate the lag time for the watershed:

$$L_g = 26\,K_n \left[\frac{L\,L_{ca}}{S^{0.5}}\right]^{0.33}$$

Where:

L_g = Lag time (hours)

K_n = Basin weighted Manning's roughness coefficient (dimensionless)

L = Length of longest watercourse from point of concentration to boundary of drainage watershed (mile)

L_{ca} = The distance along L from the base to a point nearest the centroid of the watershed (mile)

S = Overall channel slope (ft/mi)

The unit hydrograph was based on measurable and observed physical parameters of the watershed. Drainage area, length of longest watercourse (L), distance to centroid (L_{ca}), and slope (S), were estimated from the USGS quad maps. Unit hydrograph calculations are presented in **Appendix D**.

The K_n values suggested for the PMF and 24-hour, 100-year storm events are summarized in Table 7 of the *Hydrologic Basin Response, Parameter Estimation Guidelines* (SEO, 2008). Average values of the range of K_n values suggested by SEO (2008) were adopted. K_n values of 0.225, 0.065, and 0.25 were used for the general PMP, local PMP, and 24-hour, 100-year storms, respectively.

The values for the various unit hydrograph parameters are presented in **Table 2-4**.

Table 2-4
Unit Hydrograph Parameters

Parameter	Units	General Storm	Local Storm	24-hour, 100-year Storm
Unit Hydrograph Type		Rocky Mountain (General Storm)	Rocky Mountain (Thunderstorm)	Rocky Mountain (Thunderstorm)
Drainage Basin Area	mi^2	50.1	50.1	50.1
Watercourse Length	mile	12.5	12.5	12.5
Watercourse Length to Centroid	Mile	5.1	5.1	5.1
Channel Slope	ft/mi	207	207	207
Maximum Elevation	feet	12845	12845	12845
Minimum Elevation (at reservoir)	feet	10,280	10,280	10,280
K_n		0.225	0.065	0.250
Lag Time	hours	8.92	2.58	9.91

2.7 DAM AND RESERVOIR INFORMATION

Continental Reservoir Dam is an earthen dam consisting of the main dam and spillway. The main dam crest is located in the northeast side of the reservoir. The spillway is a side channel spillway with a concrete formed crest and chute. Construction drawings developed by others (Hydro-Triad, 1990), were utilized to obtain the dam crest and spillway dimensions used in the model. The values for the dam and spillway parameters are shown in **Table 2-5**, and the construction drawings are presented in **Appendix A**.

Table 2-5
Dam and Spillway Parameters

Feature	Units	Value
Dam Crest Elevation	feet	10,290
Dam Crest Length	feet	310
Dam Crest Width	feet	18
Dam Height	feet	92
Spillway Crest Elevation	feet	10,280
Spillway Crest Length	feet	140
Spillway Capacity(1)	cfs	11,511
Normal Pool Elevation (2)	feet	10,280
Volume at Normal Pool Elevation	ac-ft	22,825
Volume at Maximum Pool (3)	ac-ft	30,707

Notes: 1. Peak outflow when reservoir is at dam crest elevation 10,290 feet.
2. When reservoir is at spillway crest.
3. Volume at dam crest elevation 10,290 feet.

2.7.1 Storage Capacity Curve

Continental Reservoir has a storage capacity of approximately 30,707 ac-ft at the dam crest elevation 10,290 feet. The bottom of the reservoir is at elevation 10,203 feet. The storage capacity curve up to elevation 10,285 feet was given to URS by the Dam Safety Engineer for the Colorado Division of Water Resources. The remainder of the curve (between elevations 10,285 feet and 10,290 feet) was linearly extrapolated from the data. Storage capacity is shown on **Figure 2-2**, and calculation details and tabular data are presented in **Appendix E**.

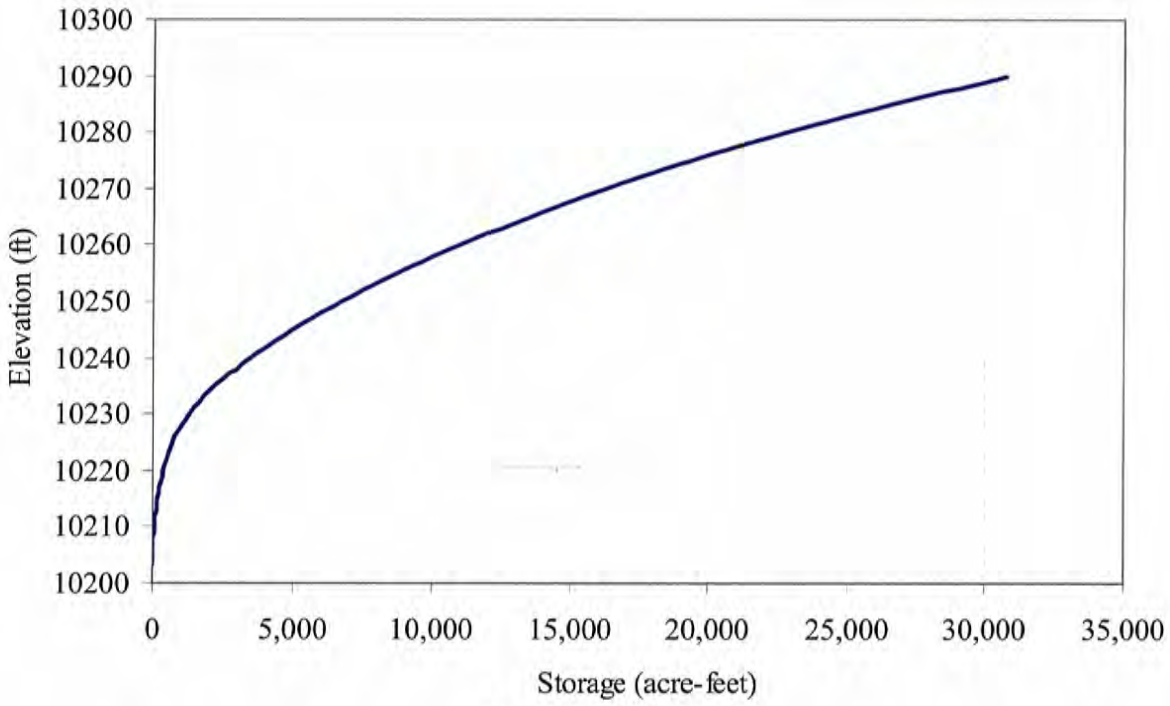

Figure 2-2
Storage Capacity Curve

2.7.2 Discharge Rating Curve

Initial hydrologic flood routings showed that the dam embankment may be overtopped during the general HMR-55A PMP event, therefore, the discharges attributable to overtopping of the dam embankment was estimated. It was also assumed that discharge through the low level outlet works is negligible during extreme precipitation events. Therefore only the spillway and the dam crest were considered for the elevation-discharge relationship. The spillway discharge rating curve up to elevation 10,291 feet was given to URS by the Dam Safety Engineer for the

Colorado Division of Water Resources which address the backwater effects resulting from the constriction in the side-channel below the spillway crest and the rating curve from a USACE, 1978 report. URS has reviewed this spillway discharge curve and adopted it for the this report. Discharges over the dam above elevation 10,291 feet were estimated using the broad-crested weir equation, presented below, with a discharge coefficient of 2.6:

$$Q = CLH^{3/2}$$

Where: Q = spillway discharge (cfs)

C = discharge coefficient = 2.6

L = spillway length = 310 feet

H = head above the dam crest (feet)

The discharge rating curve is shown on **Figure 2-3** and calculation details are presented in **Appendix E**.

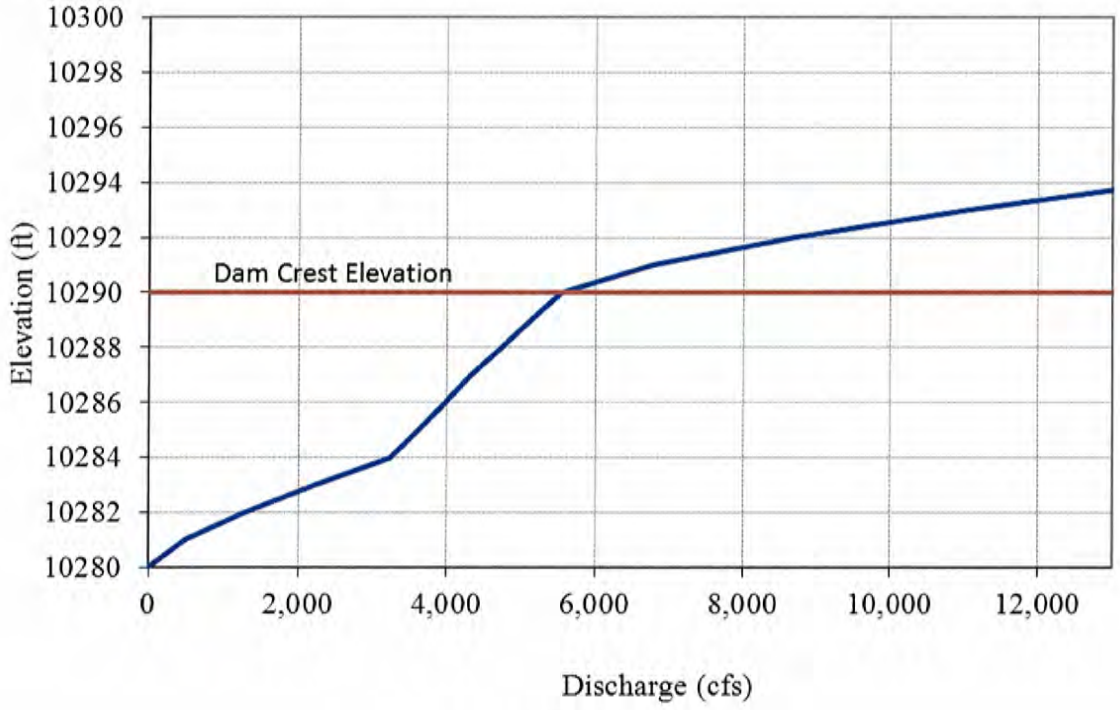

Figure 2-3
Discharge Rating Curve

2.8 HYDROLOGIC MODELING

URS completed the hydrologic modeling and reservoir routing using the Hydrologic Modeling System, version 3.4, (USACE, 2008) developed by the USACE, Hydrologic Engineering Center.

Ten storms were modeled, the 48-hour PMP General storm, the 6-hour PMP Local storm, the four EPAT general storms, the three EPAT local storms, and the 24-hour, 100-year storm. Both the PMP and the 24-hour, 100-year storms were distributed in the HEC-HMS model using the balanced storm feature.

The reservoir was assumed to start at the maximum normal pool elevation (spillway elevation) of 10,280 feet for the reservoir routing analysis.

The local HMR-55A PMP storm produced the largest peak runoff rate (41,900 cfs) of the storms that were considered, however, the storm that resulted in the highest reservoir water surface elevation and dam outflow was the general PMP storm. The general PMP storm produced a peak outflow rate of 20,500 cfs and a peak reservoir waters surface at elevation 10,293.7 feet, which is 3.7 foot above the dam crest elevation 10,290 feet.

The local EPAT storms produced outflow rates and volumes significantly than the general EPAT storms, due to the low rainfall intensities produced from the general EPAT storms in relation to the constant soil infiltration rate. The Saguache local EPAT storm was determined to be the critical EPAT event, thus it was determined to be the ESP.

The 24-hour, 100-year event produced a peak inflow of 4,510 cfs, a peak outflow of 910 cfs, and a peak reservoir surface at elevation 10,281.5 feet, which is 1.5 feet above the spillway crest.

The results of the hydrologic modeling and reservoir routing analyses are summarized in **Table 2-5.** HEC-HMS model descriptions, screen captures, and results are presented in **Appendix F.** All electronic HEC-HMS files are in **Appendix G.b**

Table 2-6
Hydrologic and Reservoir Routing Results

Storm Event	Local PMP	General PMP	ESP*	24-hour,100-year
Total Precipitation (inches)†	4.77	16.38	2.88	3.14
Storm Duration (hour)	6	48	2.7	24
Peak Inflow (cfs)	41,900	20,500	27,100	4,510
Peak Outflow (cfs)	5,260	12,900	3,730	910
Total Inflow (ac-ft)	9,743	29,900	5,210	1,790
Peak Reservoir Surface Elevation (feet)	10,289.3	10,293.7	10,285.3	10,281.5
Spillway Overtopping Depth (feet)	9.3	13.7	5.3	1.5

*The ESP is the Saguache local EPAT storm.
†A precipitation ratio of 0.90 was applied to the HMR-55A PMP values.

Inflow and outflow hydrographs for the Local PMP, General PMP, ESP, and 24-hour, 100-year storm events are presented in **Figures 2-4** through **2-7**, respectively.

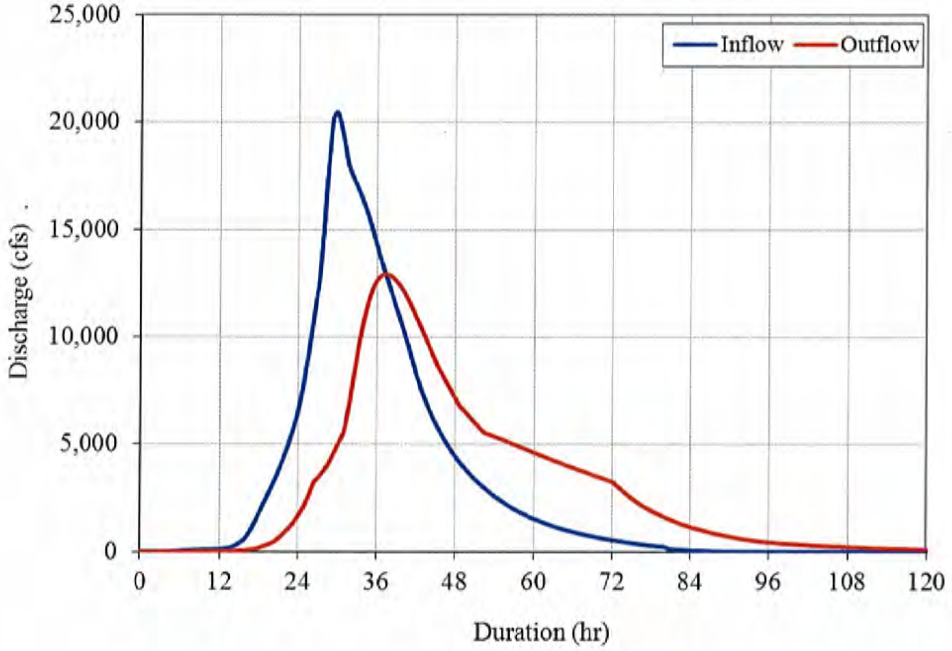

Figure 2-4
Inflow and Outflow Hydrograph for the General PMP Storm Event

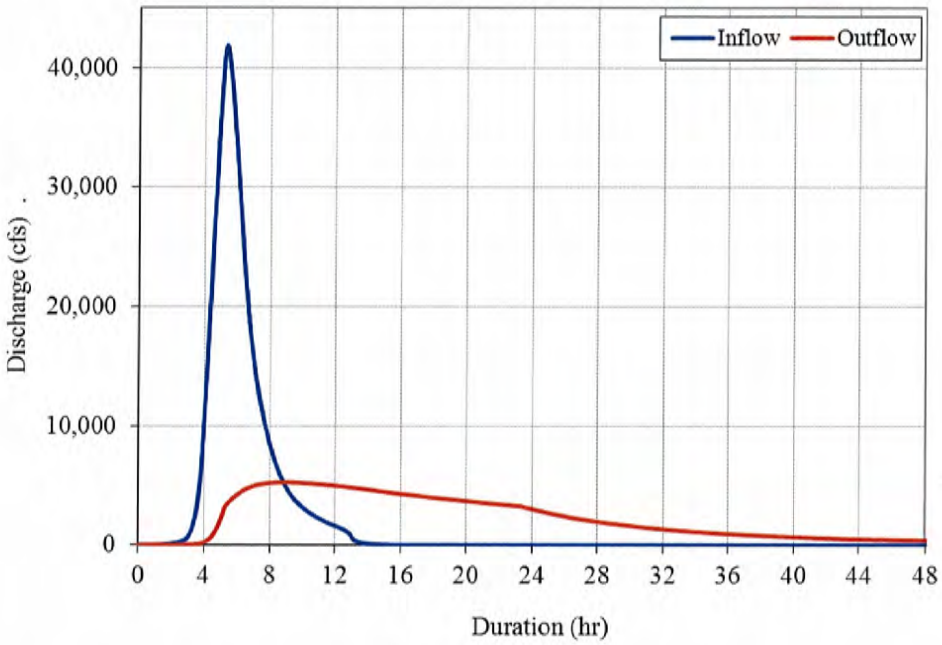

Figure 2-5
Inflow and Outflow Hydrograph for the Local PMP Storm Event

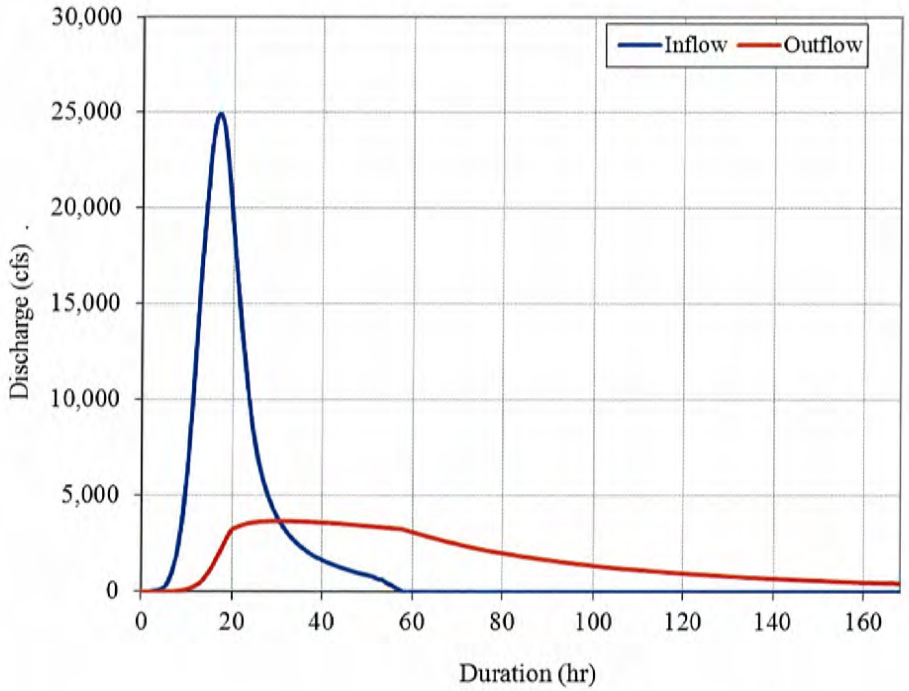

Figure 2-6
Inflow and Outflow Hydrograph for the ESP Storm Event

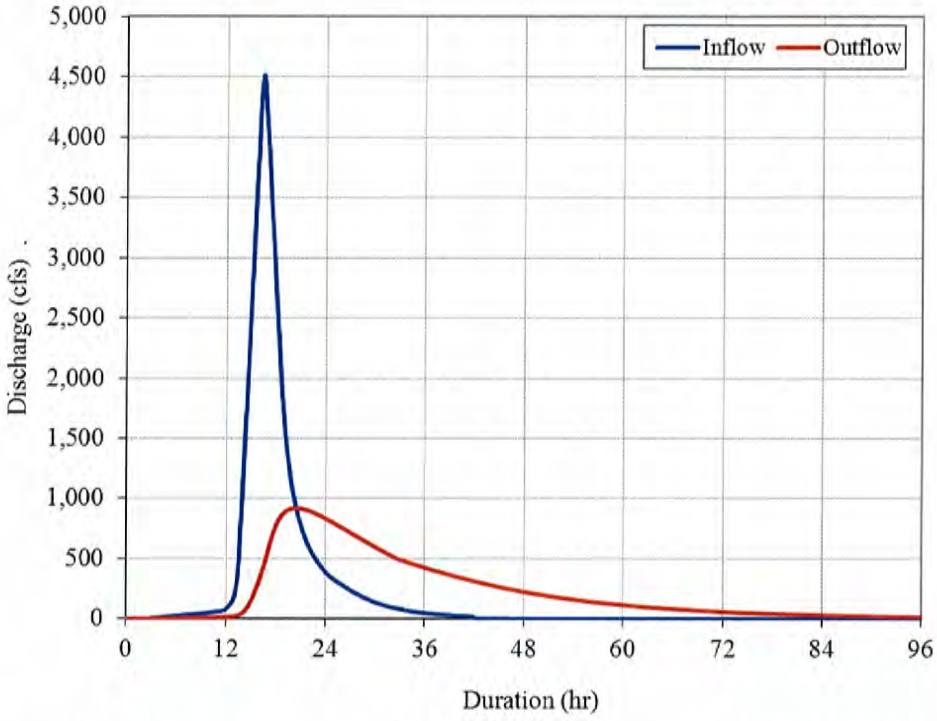

Figure 2-7
Inflow and Outflow Hydrograph for the 24-hour, 100-year Storm Event

2.9 SUMMARY

The SEO Rules state that several methods can be used to compute the IDF for a reservoir. URS used two methods to compute the IDF for Continental Reservoir: HMR-55A and EPAT. The EPAT was developed based on historical, site-specific PMP studies that were developed for dams over the past 10 years within Colorado, therefore is more representative of storm events within Colorado, compared with HMR-55A.

Generally, the results reflect this comparison between EPAT and HMR-55A, with the exception of the EPAT general storm. Since the infiltration rate exceeded the rainfall depth a large section of the entire storm event, the results showed very low discharges and volumes compared to the HMR-55A results. The EPAT results for the local storm do show a good comparison to the HMR-55A results. The EPAT was developed for just these types of cases, as the accuracy of HMR-55A at higher elevations is considered unreliable due to the methodology used to develop the HMR-55A.

3.1 CONCLUSIONS AND RECOMMENDATIONS

After analyzing the flood values developed from the different storms, URS recommends the EPAT local storm event at Saguache to be used as the IDF storm. The IDF produced a peak reservoir inflow of approximately 27,100 cfs, and a peak reservoir at elevation 10,285.3 feet, which was approximately 5.3 feet over the spillway and 4.7 feet below the crest of the Continental Reservoir Dam. The HMR-55A storm was considered for selection as the IDF because it resulted in the largest outflow and highest water level in the reservoir, overtopping the dam by approximately 3.7 feet. However, the EPAT results more accurate due to the higher elevations within the watershed. The spillway capacity is adequate to pass the IDF. The spillway will need to be replaced due to the poor condition of the structural concrete. The replaced spillway capacity will need to pass the IDF with no dam residual freeboard based on OSE Rules.

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U. S. Department of Commerce, National Oceanic and Atmospheric Administration, and the United States Department of Army, Corps of Engineers. 1988. Hydrometeorological Report No. 55A. "Probable Maximum Precipitation Estimates, United States Between the Continental Divide and the 103rd Meridian."

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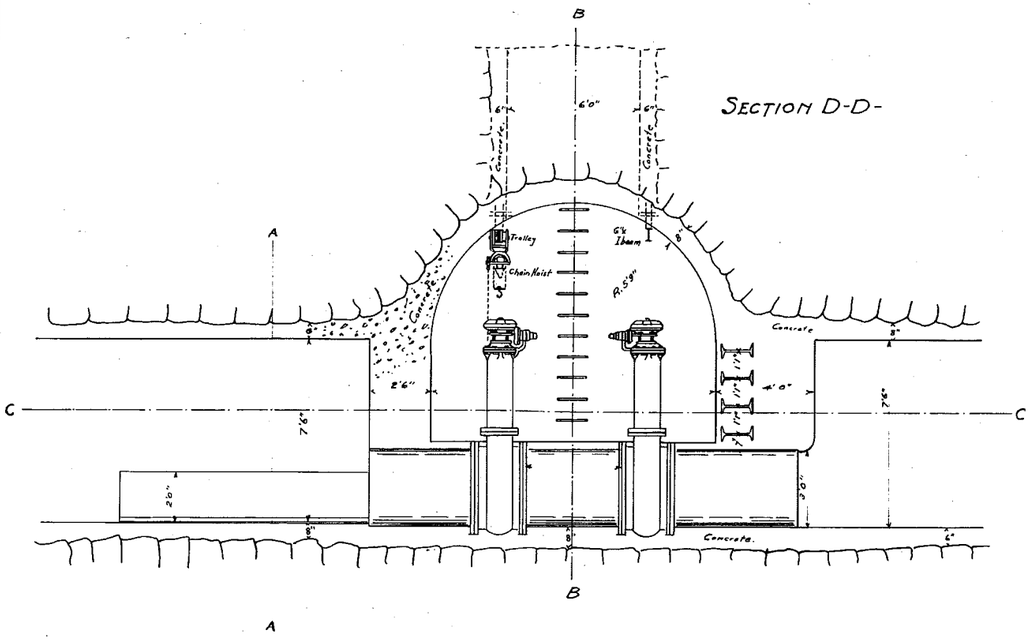
Appendix A

Appendix A
Drawings



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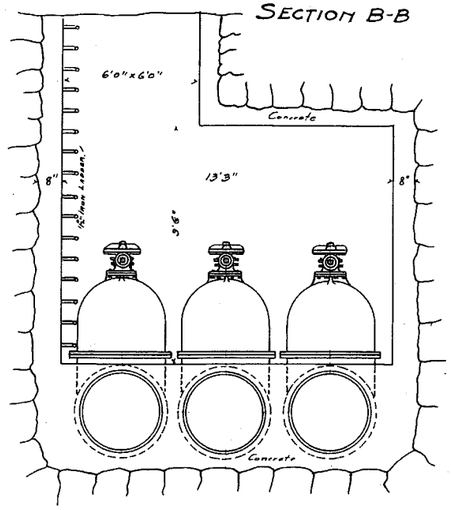

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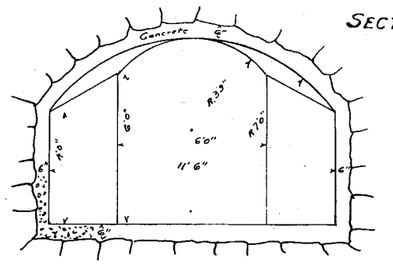

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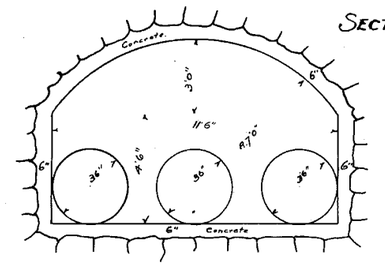
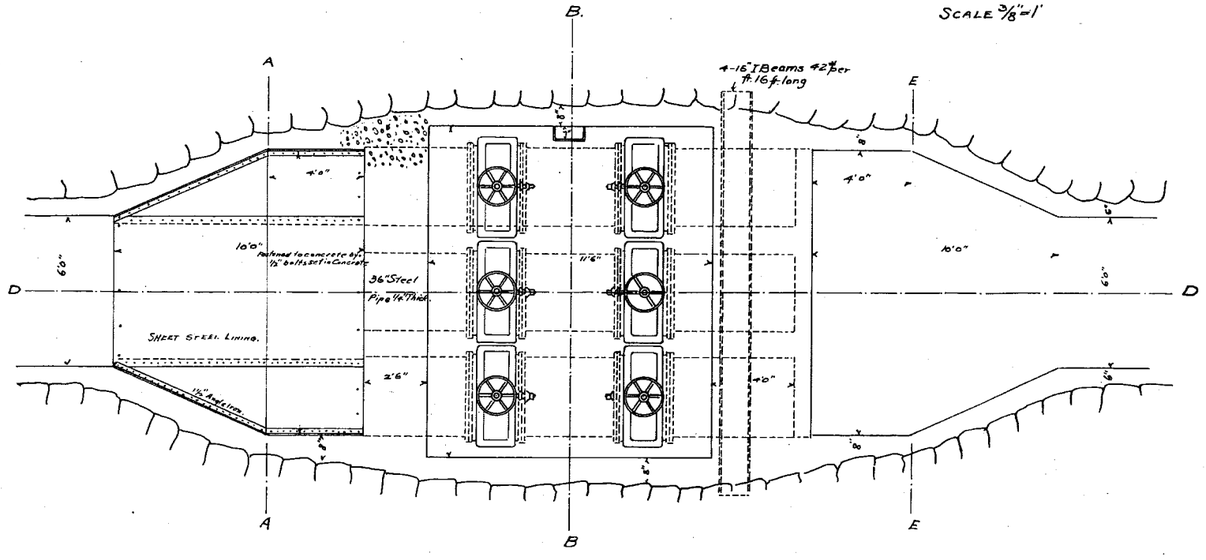
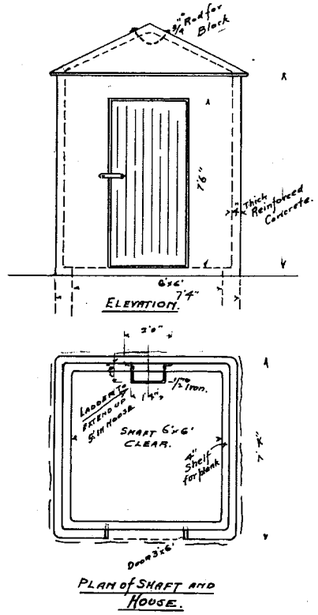


SECTION AA

SECTION C-C.

SCALE 3/8"=1'





Approved on the 31st day of October 1911.

Charles W. Comstock
State Engineer.

CONTINENTAL RESERVOIR
THE CONTINENTAL LAND AND IRRIGATION CO.
HINSDALE COUNTY COLO.
VALVE CHAMBER AND SHAFT.

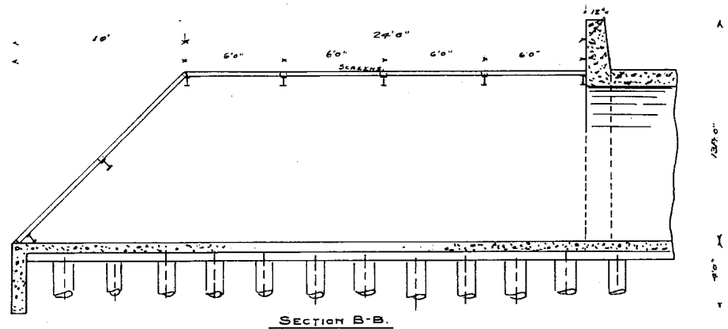
Scale 3/8"=12"

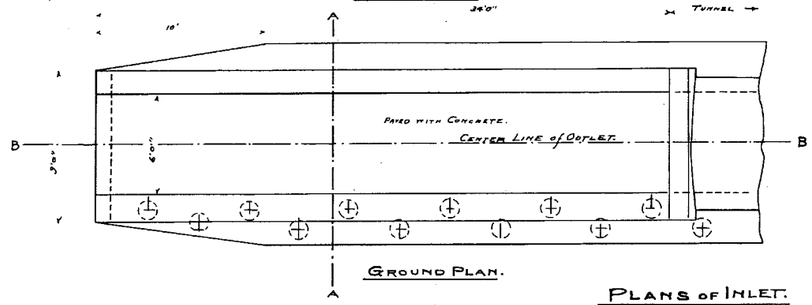
Irr. Div. No. 3 Water Dist No. 20 —

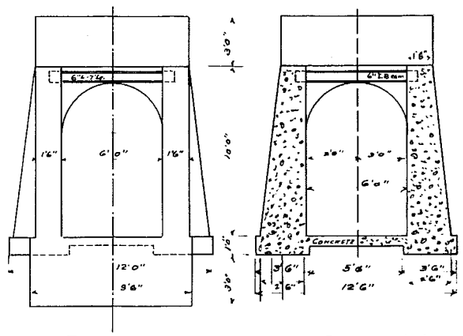
Thos. W. Jaycox C.E.

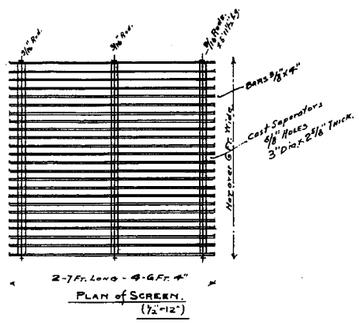
3 Sheets No. 3

C-75

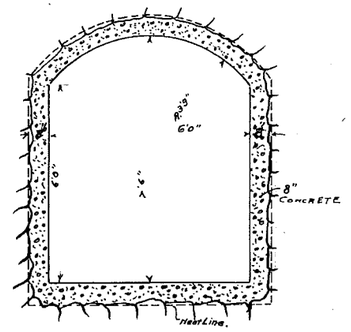


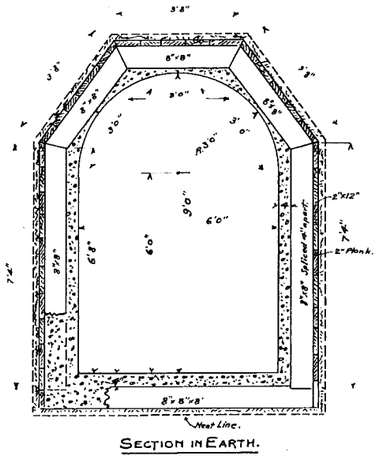






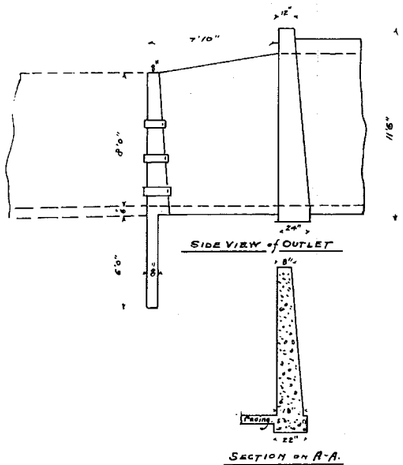
Plans of Inlet.

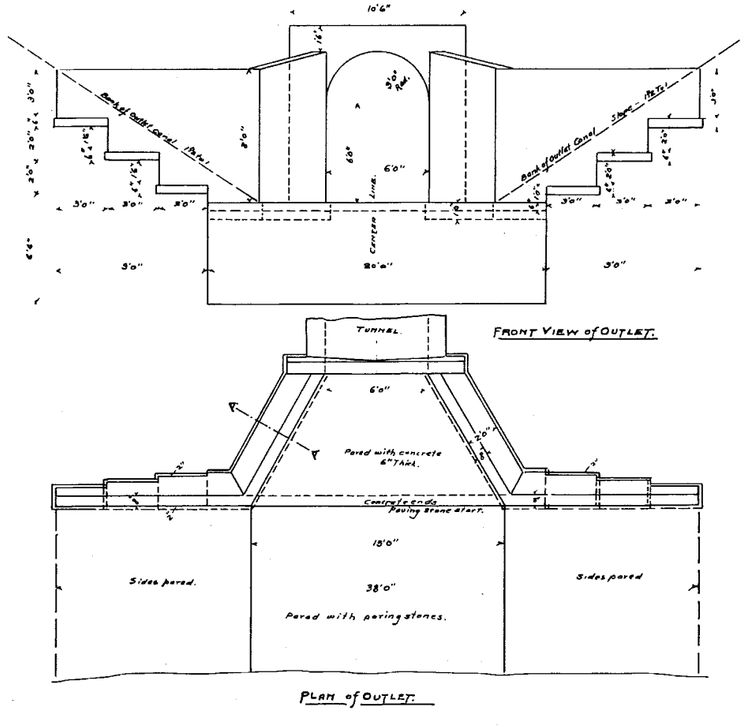




Tunnel Sections

Scale - 1/2"=1'2"





Approved on the 31st day of October 1911.

Charles W. Comstock

State Engineer.

Continental Reservoir

The Continental Land and Irrigation Co.

Hinsdale County Colo.

Tunnel Sections

Inlet and Outlet Ends.

Irr. Div. No. 3 — Water Dist. No. 20

Scale 1/4" and 1/2"= 1'0" — Thos. W. Jaycox C.E.

3 Sheets No. 2

C-75

CONTINENTAL RESERVOIR

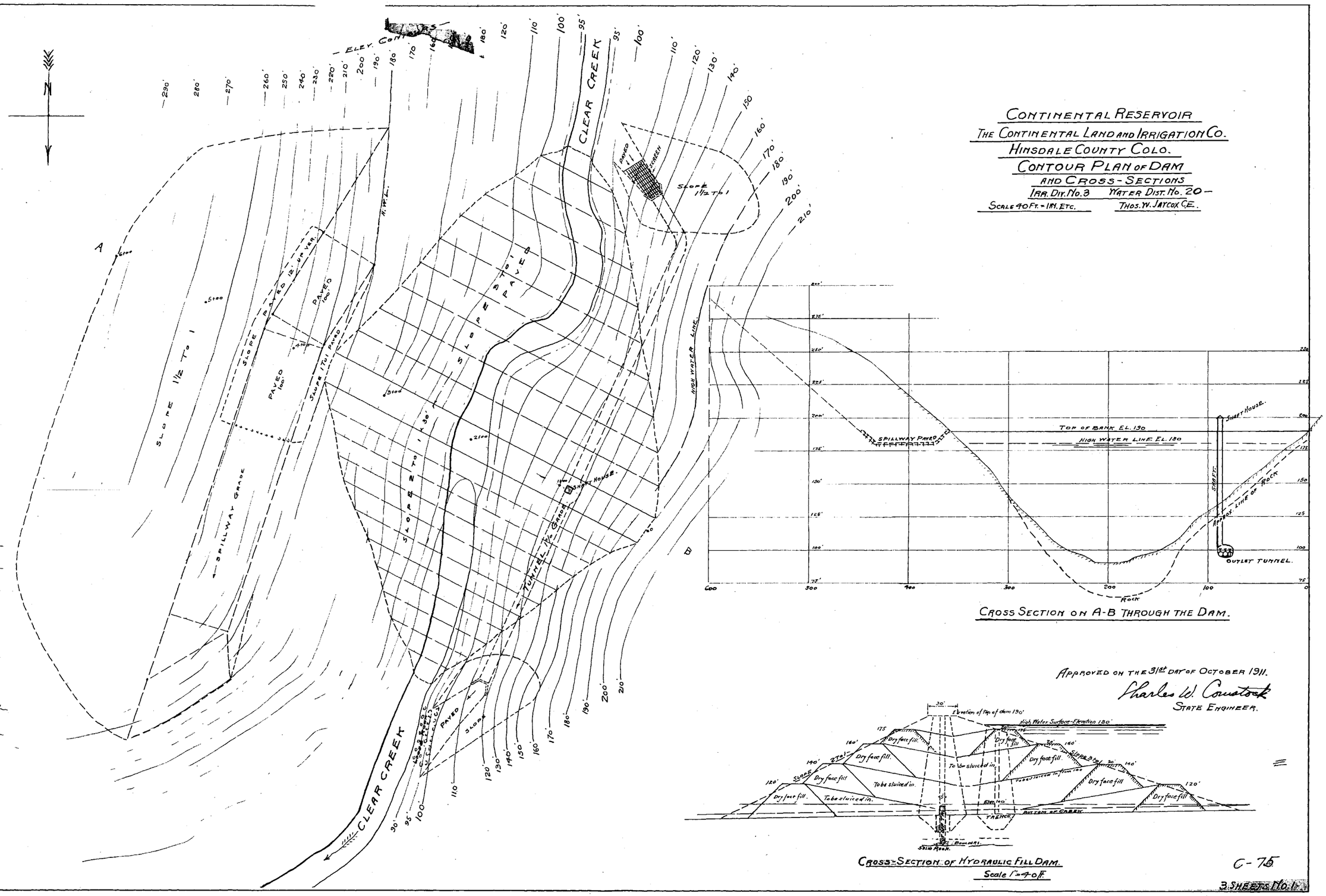
THE CONTINENTAL LAND AND IRRIGATION CO.

HINSDALE COUNTY COLO.

CONTOUR PLAN OF DAM AND CROSS-SECTIONS

IRR. DIV. No. 3 — WATER DIST. No. 20 —

SCALE 40 FT. = 1 IN. ETC. — THOS. W. JAYCOX C.E.



CROSS SECTION ON A-B THROUGH THE DAM.

APPROVED ON THE 31st DAY OF OCTOBER 1911.

Charles W. Comstock

STATE ENGINEER.

CROSS-SECTION OF HYDRAULIC FILL DAM.

Scale 1"=40 F.

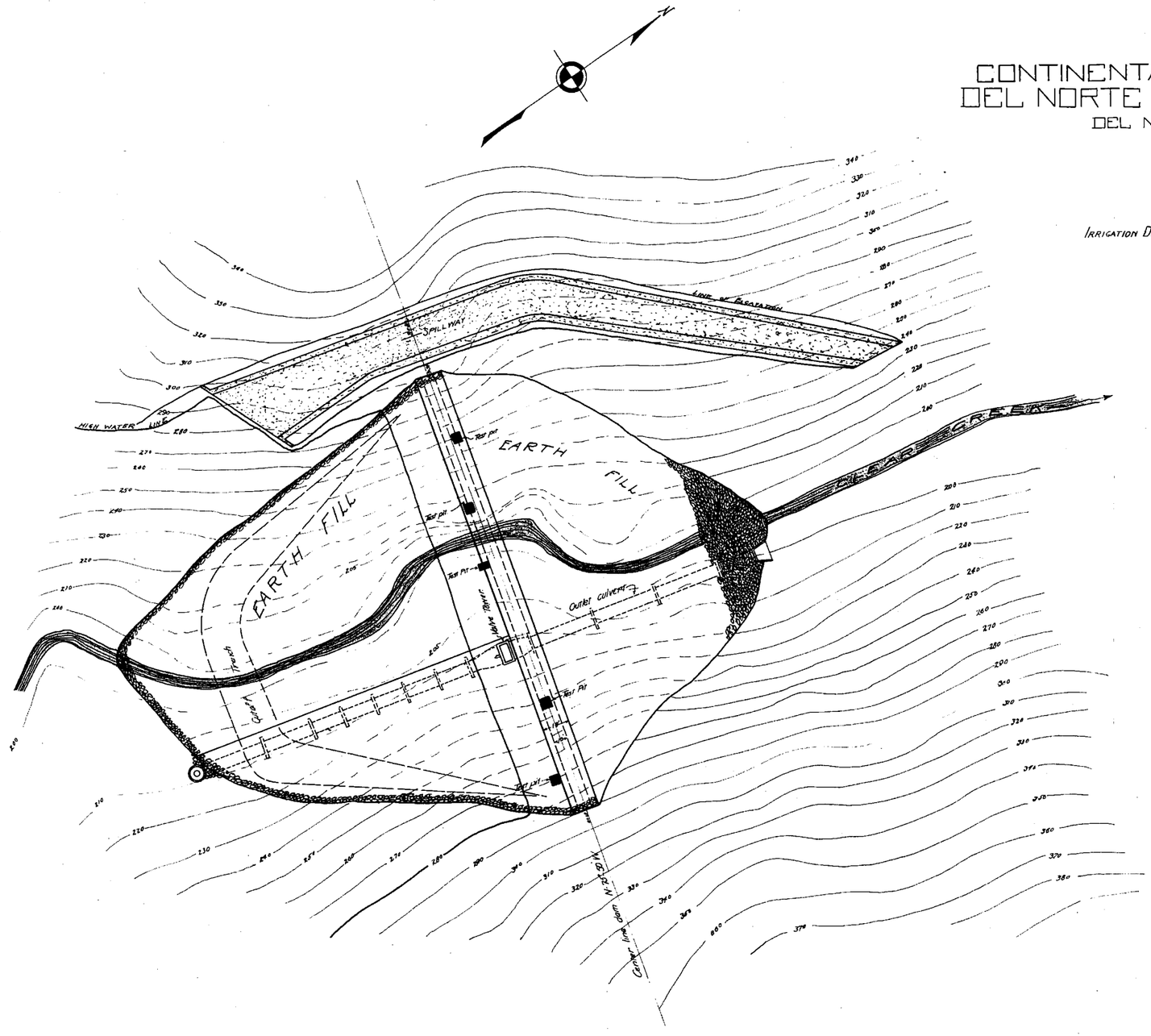
C-75

3 SHEETS No. 1

CONTINENTAL RESERVOIR DAM
DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLORADO

PLAN
OF
DAM

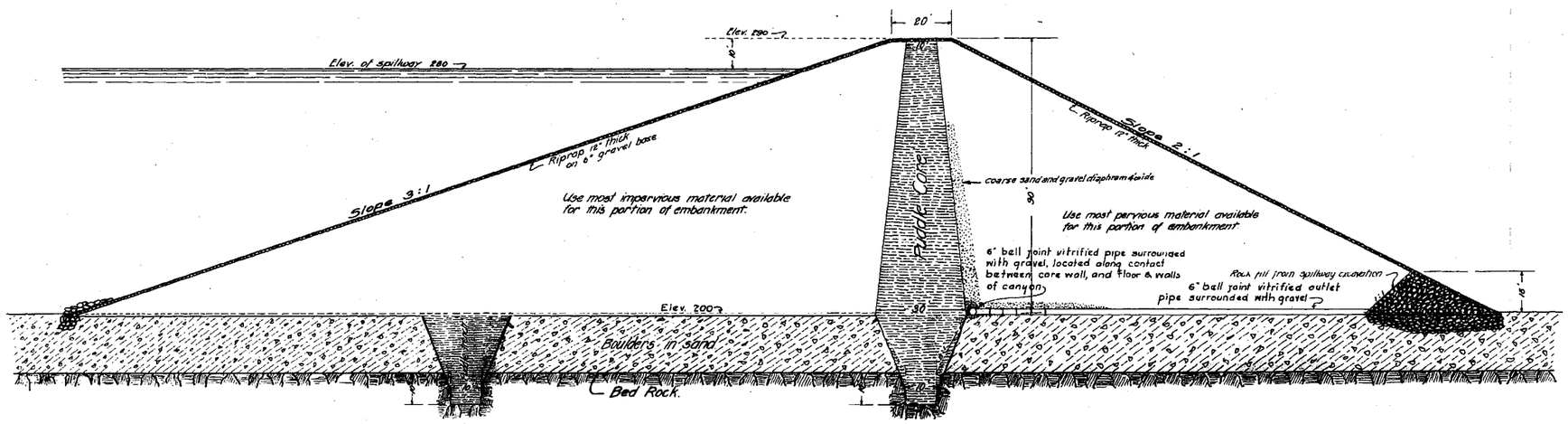
IRRIGATION DIVISION No.3 WATER DISTRICT No.20



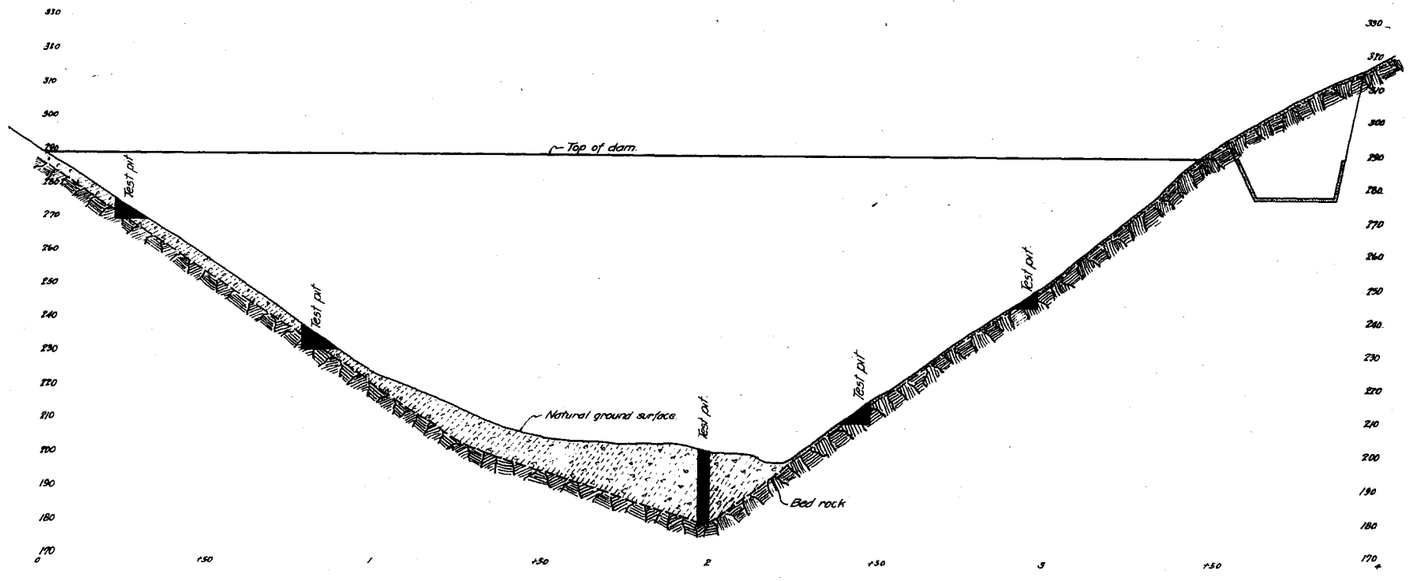
Scale 1" = 40'

APPROVED ON THE 10th DAY OF
September A.D. 1925
M. C. Hinderlider
STATE ENGINEER.

C-179



CROSS-SECTION OF DAM
Scale 1in = 20ft



PROFILE OF DAM.
Scale 1in = 20ft.

Sup. order 1..
Revised Sht. Nr. 3 of 5

DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLO.
DETAILS OF DAM.

Approved on the 2nd day of February
A. D. 1926

W. O. Hendricks
State Engineer.

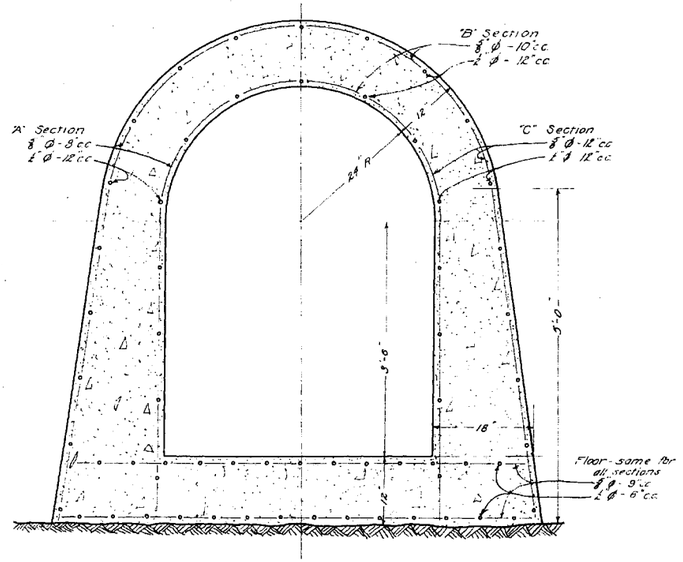
Deputy.

C-179

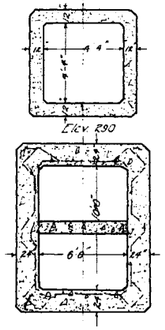
CONTINENTAL RESERVOIR DAM
DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLORADO

DETAIL OF OUTLET CULVERT

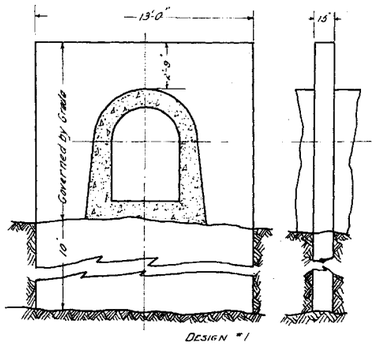
IRRIGATION DIVISION No. 3 WATER DISTRICT No. 20



CULVERT SECTION
Scale 1" = 1'



TOWER SECTIONS



CUTOFF WALLS
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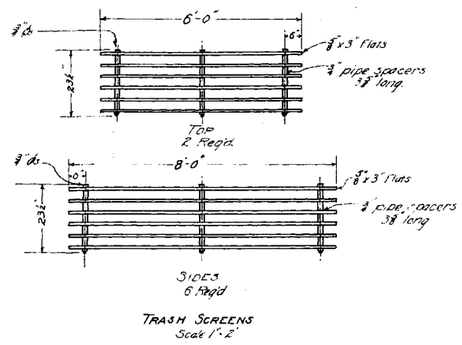
Note. Use Design "1" for wall 206' upstream & Design "2" for balance.



TRASH SCREENS
Scale 1" = 2'

SECTION

PLAN

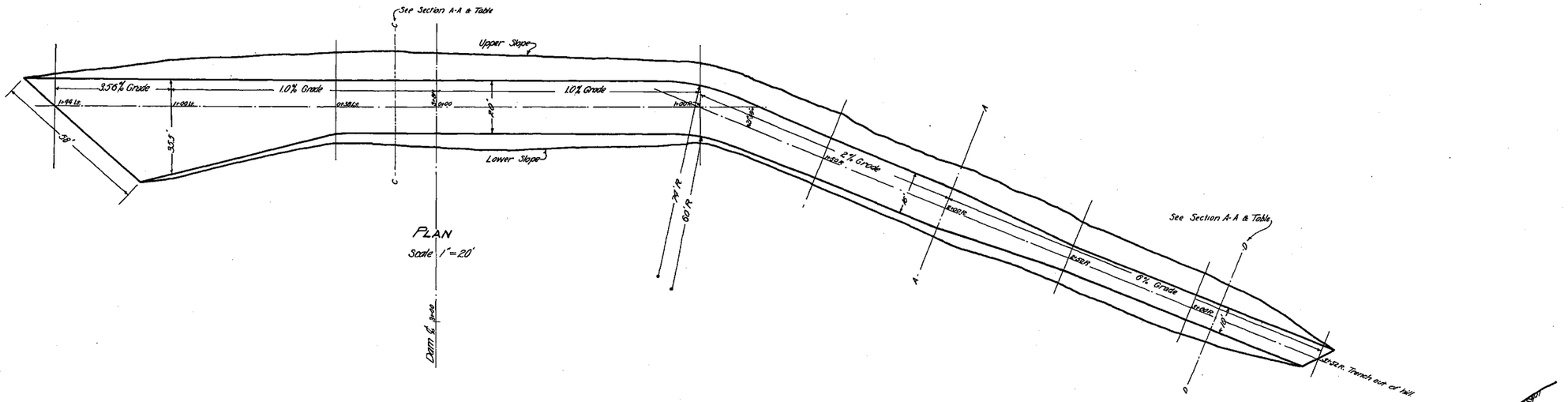
OUTLET CULVERT
Scale 1" = 6'

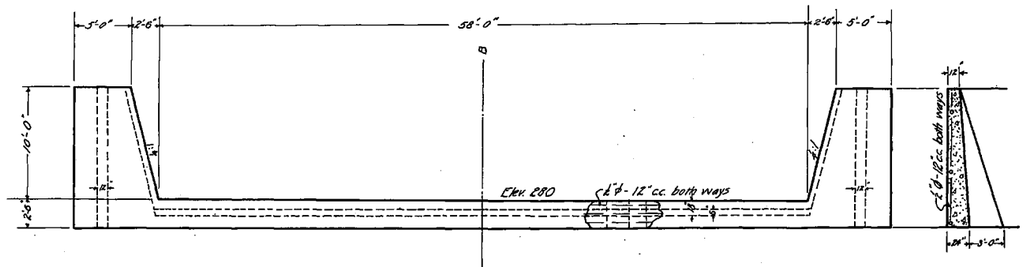
APPROVED ON THE 10th DAY OF September A.D. 1925
M. C. Hinderlider
STATE ENGINEER.

CONTINENTAL RESERVOIR DAM
DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLORADO

DETAIL OF SPILLWAY

IRRIGATION DIVISION No. 3 WATER DISTRICT No. 20





ELEVATION - INTAKE
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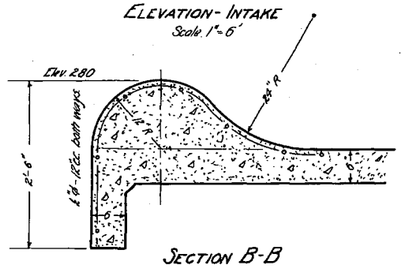
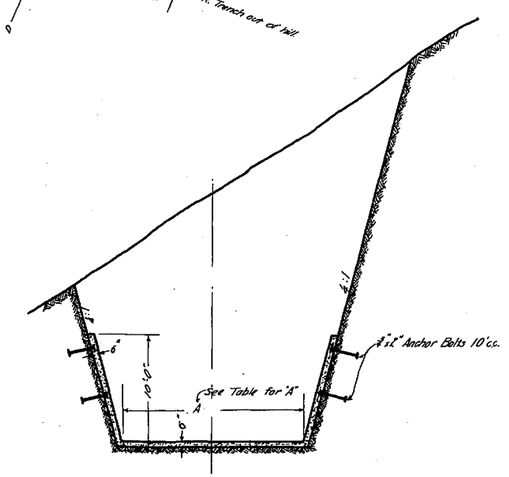


SECTION B-B
Scale 1"=1'

VALUES OF "A"

SECTION	A
A-A	16'-0"
C-C	20'-0"
D-D	10'-0"



SECTION A-A
Scale 1"=6'

APPROVED ON THE 10th DAY
OF September A.D. 1925
M. C. Hinderlider
STATE ENGINEER.

RUBY CREEK.

BUCK CREEK.

CLEAR CREEK.

DAM

Borrow Pits

N

SURFACE AREA OF RESERVOIR
APPROX. 800 ACRES.

DRAINAGE AREA APPROX 50 SQ. M.

CREEK.

T. 42 N.
T. 41 N.

HITTY CREEK.

CLEAR CREEK.

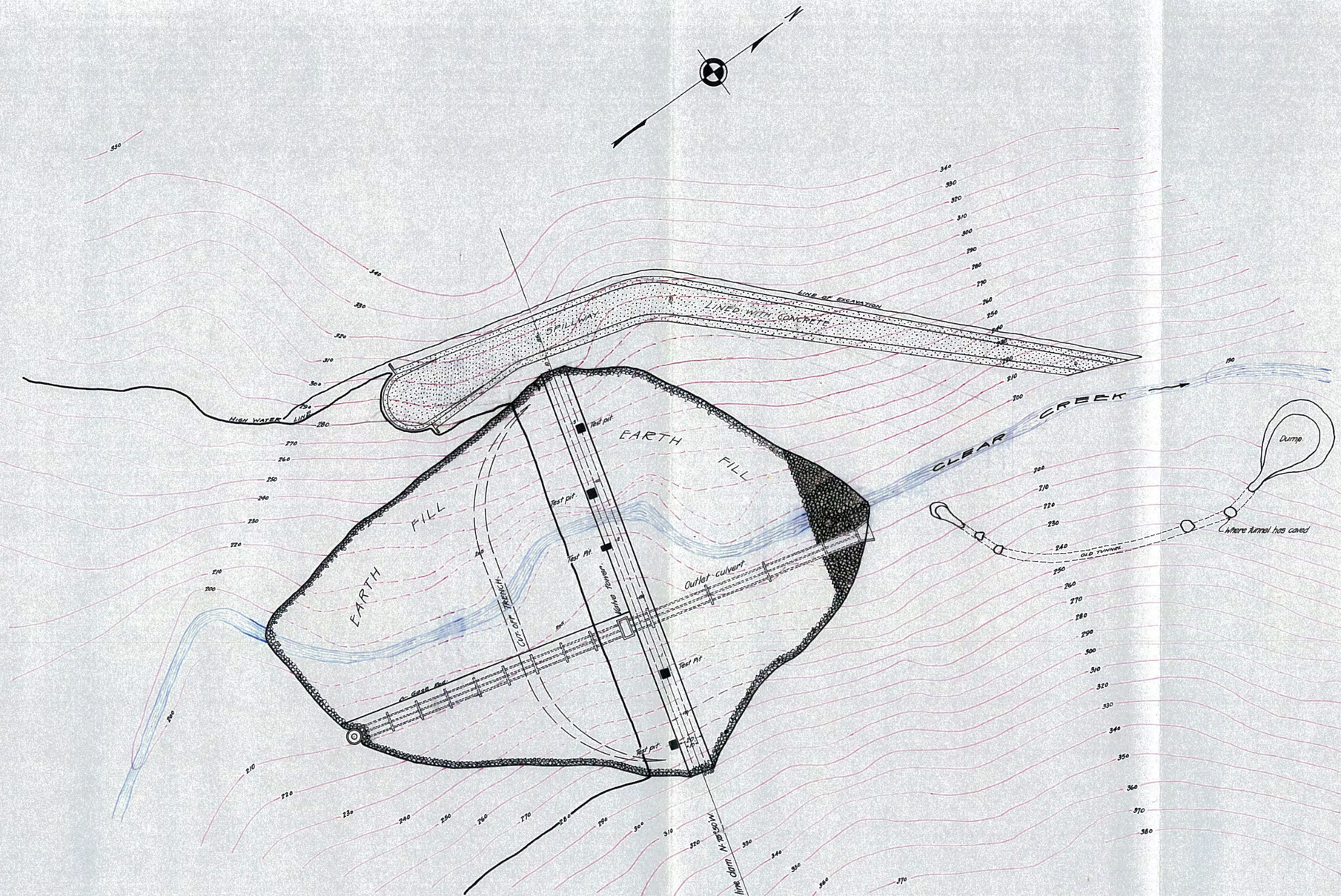
R. 4 W.
R. 3 W.

DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLO.

TOPOGRAPHIC MAP OF RESERVOIR

Approved on the 3rd day of February
A.D. 1925

C-179



Scale 1 in = 40 ft

Superceded by
Revised Sheet No 2 of 5

DEL NORTE IRRIGATION DISTRICT
DEL NORTE, COLO.

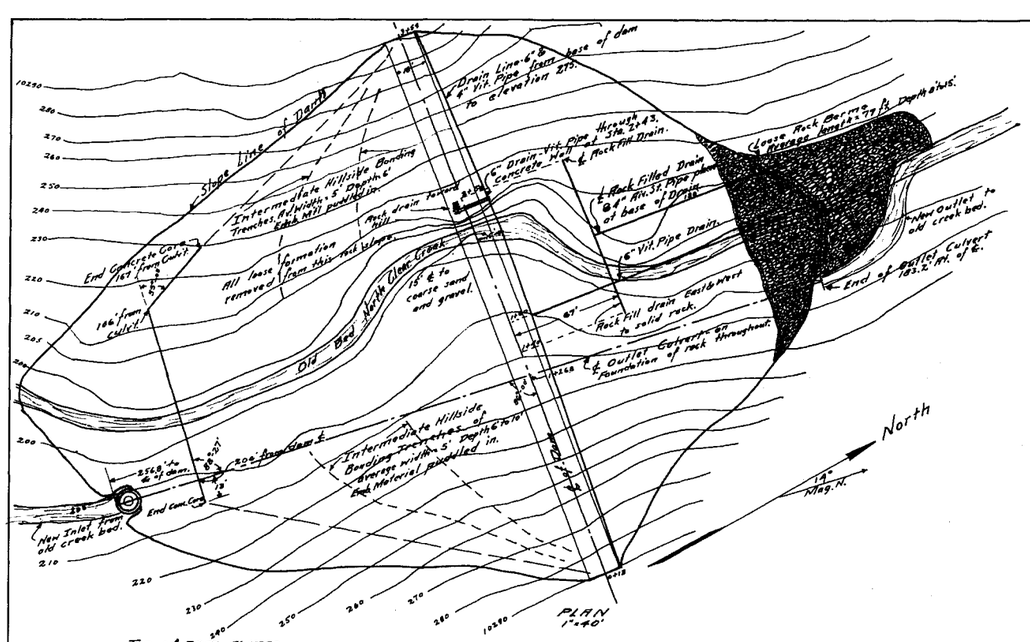
PLAN OF DAM.

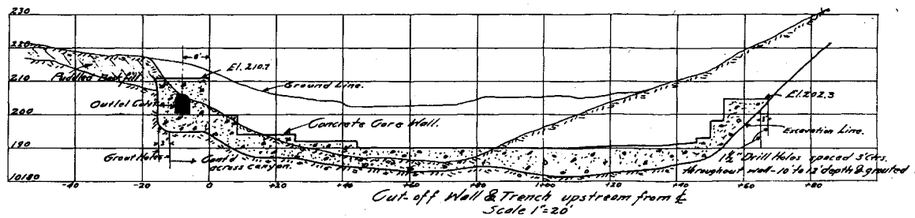
Approved on the 2nd day of February
A. D. 1925

M. O. Hinderlider
State Engineer.

Deputy

C-179





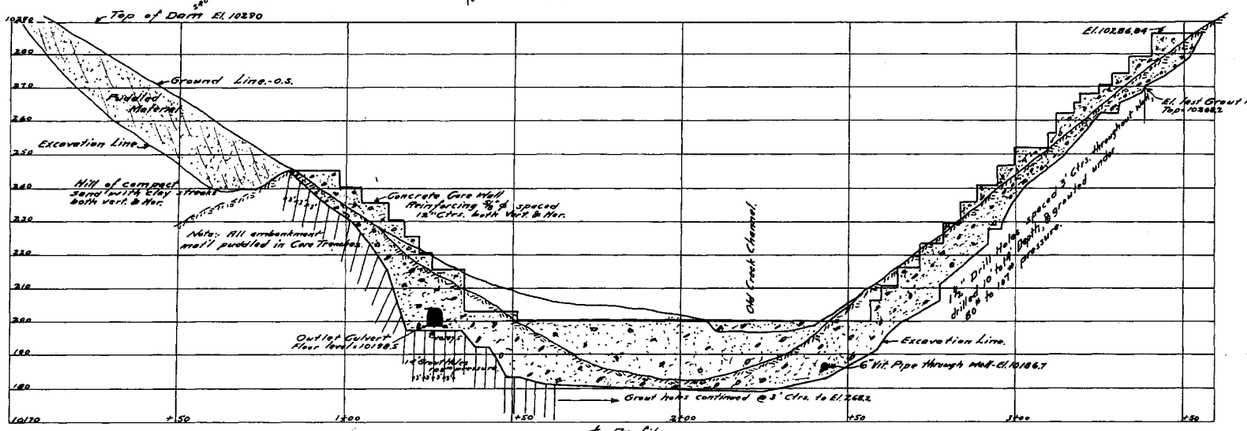
Cut. off Wall & Trench upstream from ℄
Scale 1"=20'

STATE OF COLORADO } ss.
City & County of Denver }

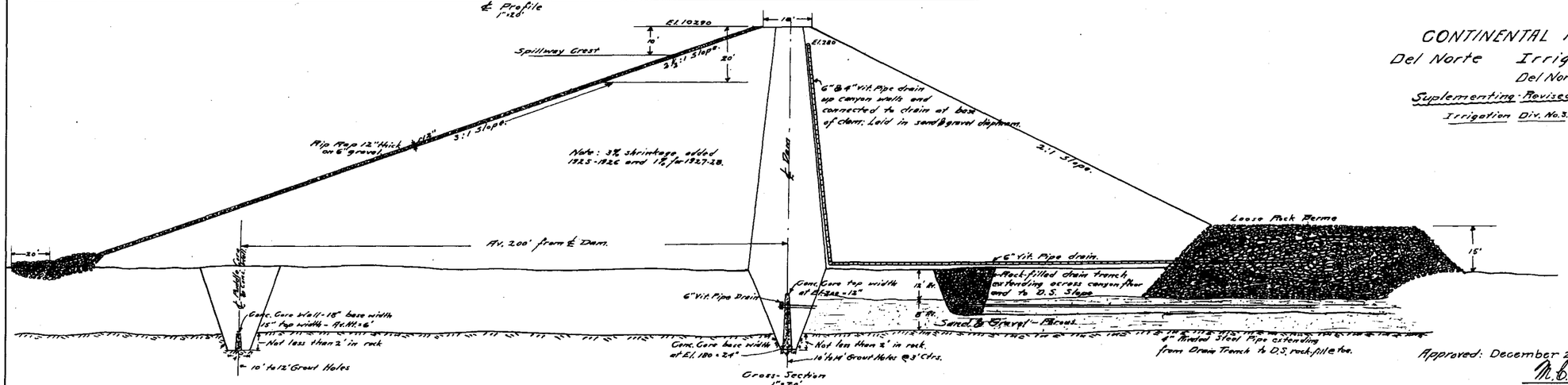
Carl A. Gould being duly sworn on his oath, deposes and says that he is the engineer of the Del Norte Irrigation District, Continental Reservoir Dam; that the construction of the dam and this map thereof were made by him and that such construction is accurately represented upon this map; that he has read the statements thereon and that the same are true of his own knowledge.

Carl A. Gould
Engineer.

Subscribed and sworn to before me this 20th day of December A.D. 1928.
My commission expires August 24, 1932.
Emma J. Roxlow
Notary Public.



℄ Profile
1"=20'

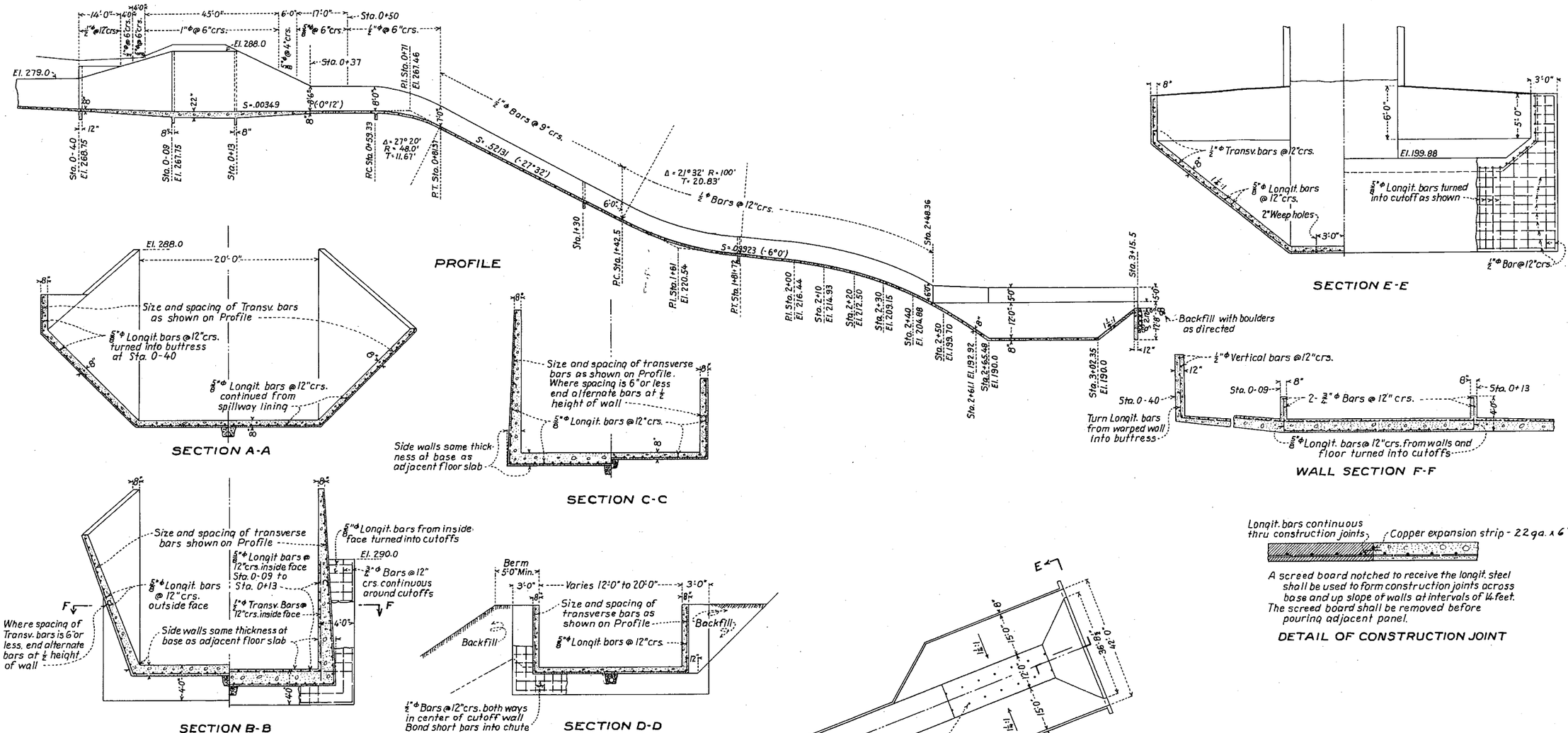


Cross-Section
1"=20'

CONTINENTAL RESERVOIR DAM
Del Norte Irrigation District
Del Norte, Colo.
Suplementing Revised Sheets 1 to 5 inclusive As Built
Irrigation Div. No. 3. Water District No. 20

Approved: December 21st A.D. 1928:
M. C. Hinderlider
State Engineer.
By _____
Deputy.

C-179



STATE OF COLORADO } SS
COUNTY OF DENVER }

Burton Lowther, being first duly sworn upon oath, deposes and says: That he is the Engineer of the Del Norte Irrigation District, owner of the Continental Reservoir; that the proposed Spillway and Stilling Pool, improvements to the said existing Continental Reservoir, as shown on these drawings, Sheets No. 1 and No. 2, were prepared under his direction and to the best of his knowledge and belief represents what it purports to show.

Burton Lowther
Engineer

Subscribed and sworn to before me this 23rd day of May A.D. 1932.

My commission expires May 25, 1933.
Edward K. Goodman
Notary Public.

ESTIMATED QUANTITIES

Concrete (Reinforced.)	473 Cu. Yds.
Reinforcement Steel	47,500 Lbs.
6" Tile Drain	420 Lin. ft.

Approved on the 30th day of August A.D. 1932
M. C. Hinderlider
STATE ENGINEER

Adopted and accepted by Del Norte Irrigation District
By Louis Eichenwald
President.

NOTES

Reinforcement bars shall be placed so that the centers of bars in the outer layer will be 2" from the face of the concrete unless otherwise shown.
Lap all bars 40 diameters at splices. Stagger splices.
Thickness of slabs to vary uniformly between dimensions shown.
Excavation for chute shall be performed and waste banks placed so that backfill will be a minimum.

DEL NORTE IRRIGATION DISTRICT - COLO.

CONTINENTAL RESERVOIR

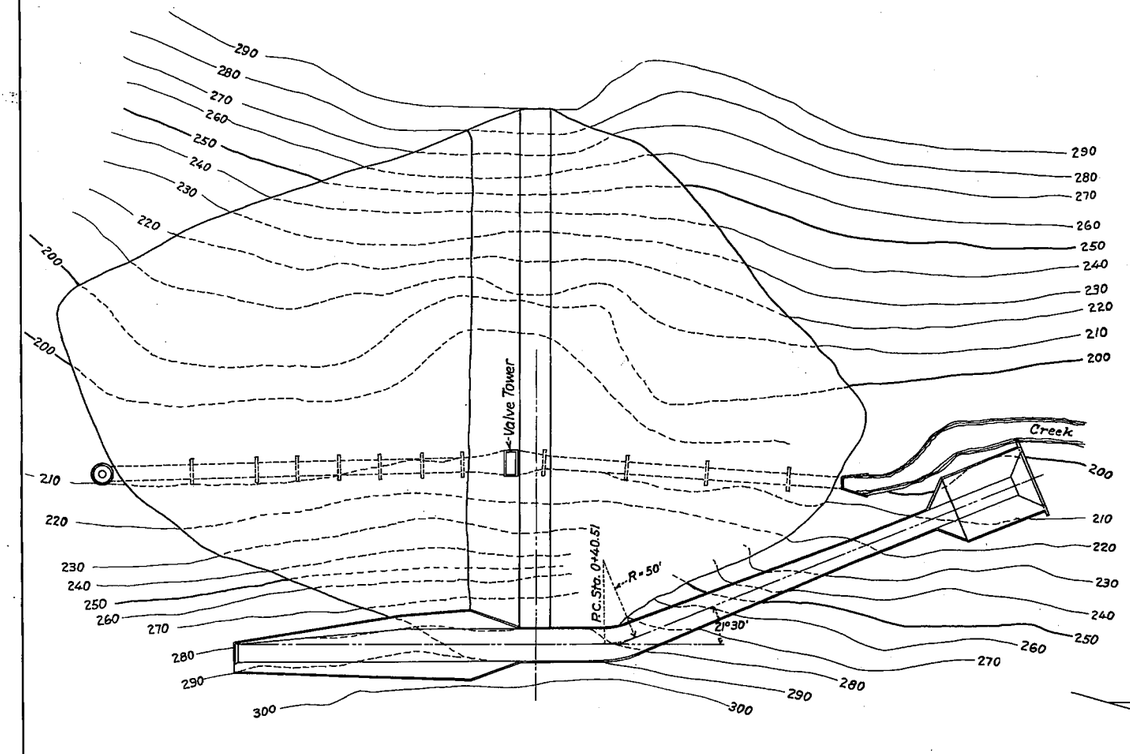
SIDE CHANNEL SPILLWAY CHUTE AND STILLING POOL

CHUTE AND POOL DETAILS
IRRIGATION DIVISION 3. WATER DISTRICT 20.
Burton Lowther, Denver, Colo. Consulting Engr. August, 1932.

C-259

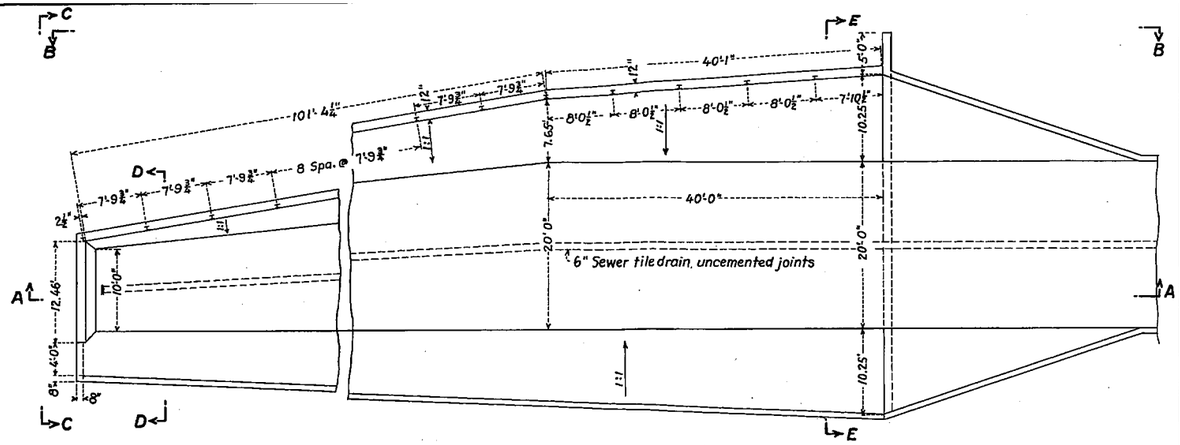
SHEET 2 OF 2 SHEETS

093345

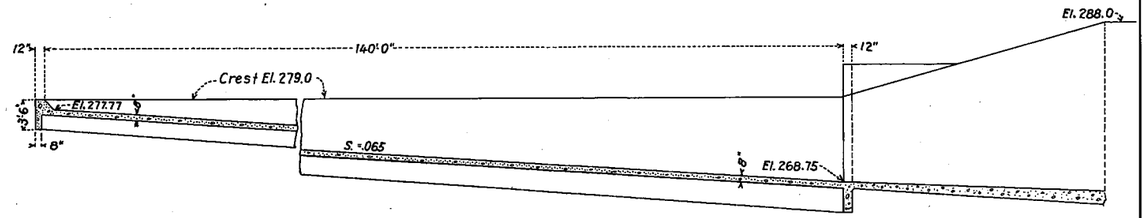


GENERAL PLAN OF SPILLWAY

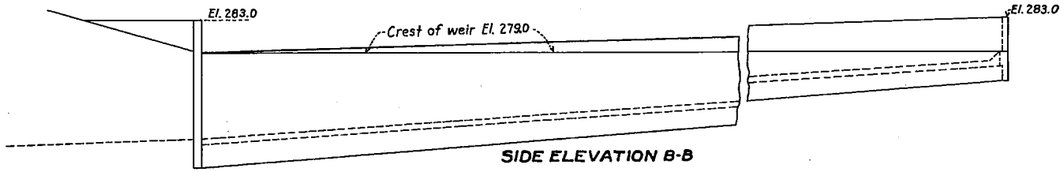
0 20 40 60 80 100
Scale of Feet



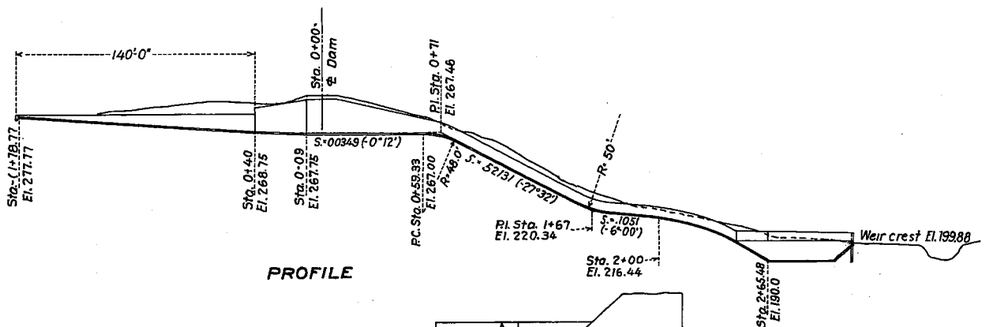
PLAN OF SIDE CHANNEL SPILLWAY



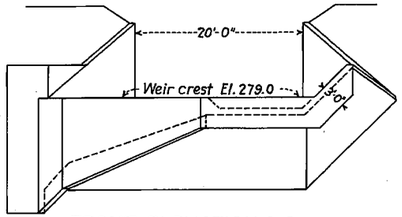
LONGITUDINAL SECTION A-A



SIDE ELEVATION B-B

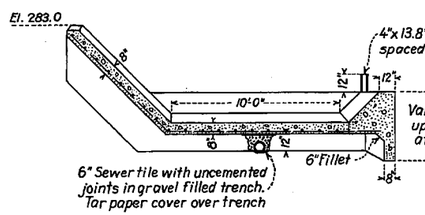


PROFILE



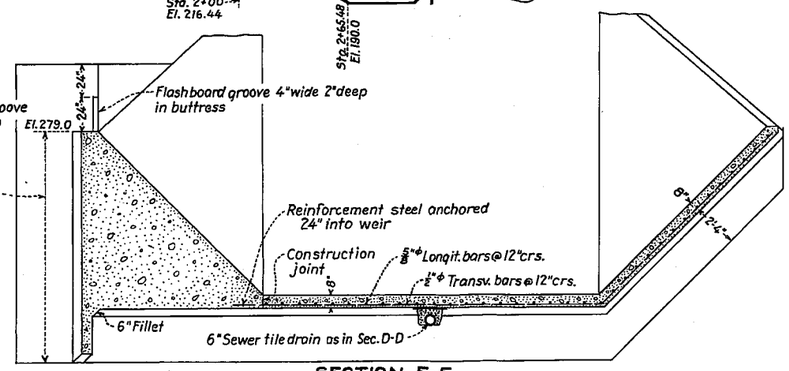
FRONT ELEVATION C-C

0 5 10 15
Scale of Feet



SECTION D-D

1 0 5 10
Scale of Feet



SECTION E-E

Longit. bars continuous thru construction joints
Copper expansion strip - 22 ga. x 6" wide.

A screed board notched to receive the longit. steel shall be used to form construction joints across base and up slope of walls at intervals of 20 feet. The screed board shall be removed before pouring adjacent panel.

DETAIL OF CONSTRUCTION JOINT

NOTES

Reinforcement bars shall be placed so that the centers of bars in the outer layer will be 2" from the face of the concrete unless otherwise shown.
Lap all bars 40 diameters at splices. Stagger splices.
The vertical face of the weir shall be backfilled as directed by the engineer.
For details of Chute and Stilling Pool see Sheet 2

ESTIMATED QUANTITIES

Concrete (in Weir Section)	172 Cu. Yds.
Concrete (Spillway channel lining)	90 Cu. Yds.
Reinforcement Steel	4450 Lbs.
Structural Steel	497 Lbs.

Approved on the 20th day of August A.D. 1932.
M. C. Hinderlider
STATE ENGINEER

C-259

DEL NORTE IRRIGATION DISTRICT - COLO.
CONTINENTAL RESERVOIR
SIDE CHANNEL SPILLWAY CHUTE AND STILLING POOL
SPILLWAY DETAILS

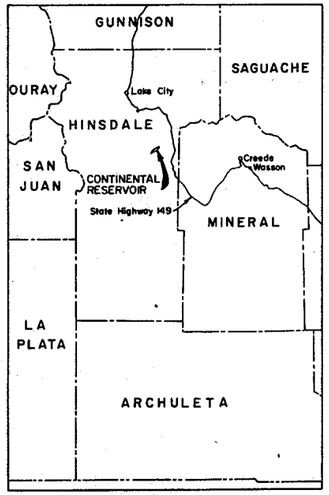
IRRIGATION DIVISION 3. Burton Lowther, Denver, Colo.
WATER DISTRICT 20. Consulting Engr. August, 1932.

SHEET 1 OF 2 SHEETS

CONSTRUCTION DRAWINGS
FOR THE

CONTINENTAL DAM REHABILITATION

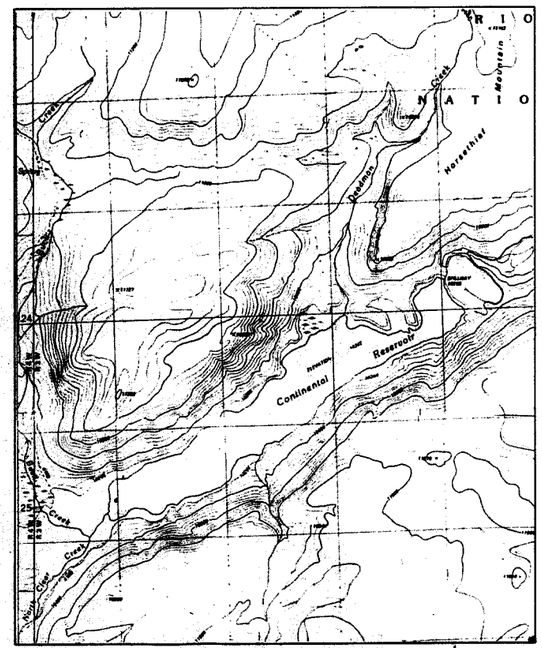
LOCATED NEAR
LAKE CITY, COLORADO
IN
HINSDALE COUNTY, COLORADO
SEC. 21, T42N, R3W OF THE NEW MEXICO P.M.
WATER DIVISION No. 3 - WATER DISTRICT No. 20



COUNTY VICINITY MAP

12.5 0 12.5 25 37.5
SCALE: 1 INCH = 12 MILES

N



DAM LOCATION MAP

2000 0 2000 4000 6000
SCALE: 1"=2,000'

N

DRAWING INDEX

Drawing No.	Sheet No.	Title
116-CO-01	1	Title Sheet
116-CO-02	2	General Site Plan
116-CO-03	3	Dam and Outlet Conduit Plan View
116-CO-04	4	Dam and Abutment Sections
116-CO-05	5	Gravel Drain Profiles & Trench Sections
116-CO-06	6	Bore Hole Logs And Liner Details
116-CO-07	7	Gate Shaft and Conduit Repairs

I hereby certify that these plans for the CONTINENTAL DAM REHABILITATION were prepared under my direct supervision for the owners thereof.

Michael L. Jacobs

MICHAEL L. JACOBS
COLORADO P.E. #23736

I, Barry Nelson, owner, whose address is P.O. Box 288 Monte Vista, Colorado 81144, do hereby accept and approve these plans for the CONTINENTAL DAM REHABILITATION.

Barry B. Nelson — 7-10-1990
Date

Approved on the 29th day of June, 1990

Jeris A. Danielson
State Engineer

H.A. Simpson
Deputy

STATE ENGINEER OF COLORADO

Plans reviewed by: Frank Kugel
Design Review Unit

June 22, 1990
Date

Approval Recommended by:
Supervisor
Dam Safety Branch

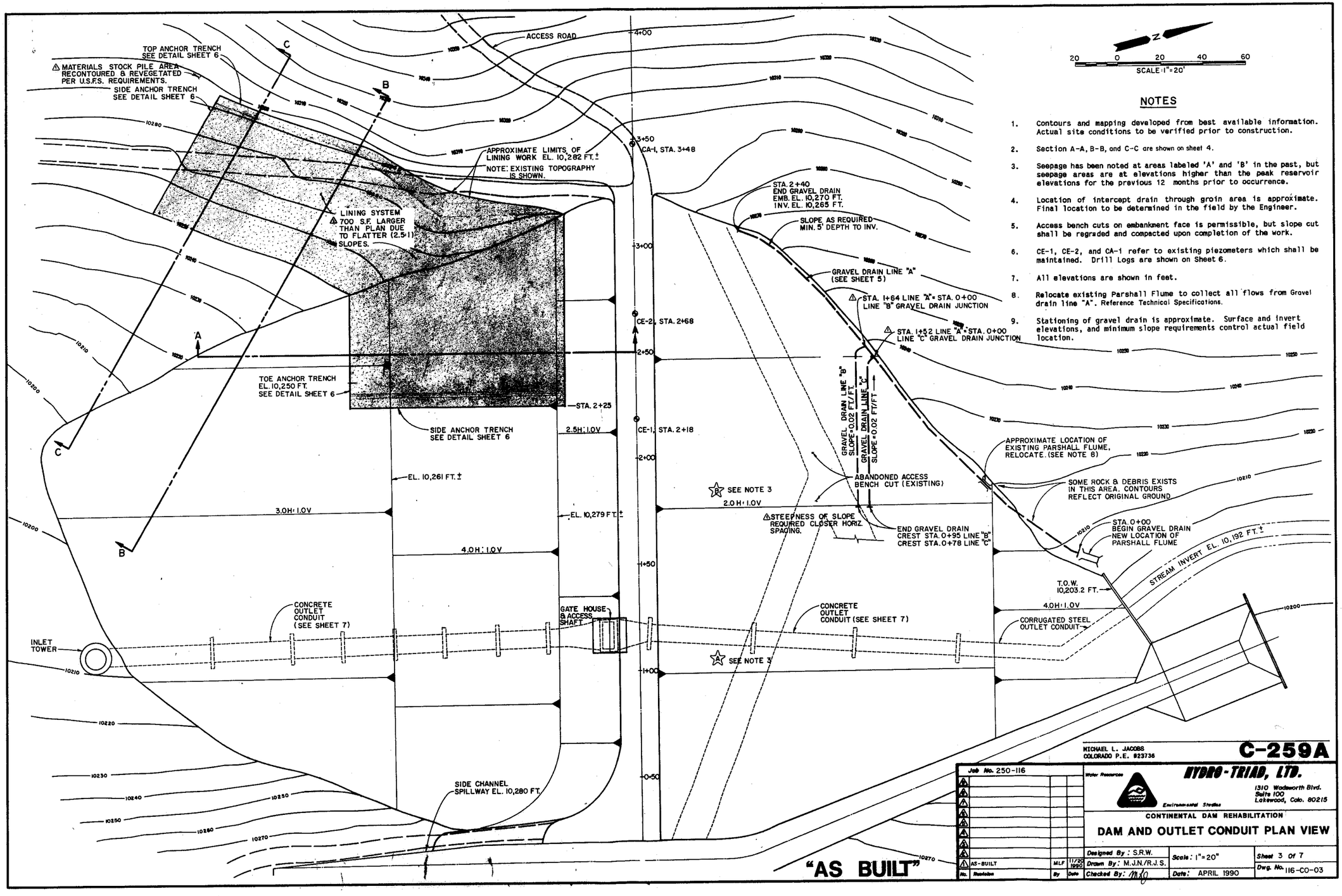
6/29, 1990
Date

These plans represent the AS-CONSTRUCTED conditions of CONTINENTAL dam to the best of our knowledge and judgement, based in part on information furnished by others as of the 20th day of NOVEMBER, 1990.

MICHAEL L. JACOBS (Engineer's printed name)
Michael L. Jacobs (Signature)

Accepted for filing
4/22/91

"AS BUILT" C-259A



NOTES

1. Contours and mapping developed from best available information. Actual site conditions to be verified prior to construction.
2. Section A-A, B-B, and C-C are shown on sheet 4.
3. Seepage has been noted at areas labeled 'A' and 'B' in the past, but seepage areas are at elevations higher than the peak reservoir elevations for the previous 12 months prior to occurrence.
4. Location of intercept drain through groin area is approximate. Final location to be determined in the field by the Engineer.
5. Access bench cuts on embankment face is permissible, but slope cut shall be regraded and compacted upon completion of the work.
6. CE-1, CE-2, and CA-1 refer to existing piezometers which shall be maintained. Drill Logs are shown on Sheet 6.
7. All elevations are shown in feet.
8. Relocate existing Parshall Flume to collect all flows from Gravel drain line "A". Reference Technical Specifications.
9. Stationing of gravel drain is approximate. Surface and invert elevations, and minimum slope requirements control actual field location.

"AS BUILT"

MICHAEL L. JACOBS
COLORADO P.E. #23736

C-259A

Job No. 250-116			
⚠ AS-BUILT	MLF	11/20/1990	
No. Revision	By	Date	

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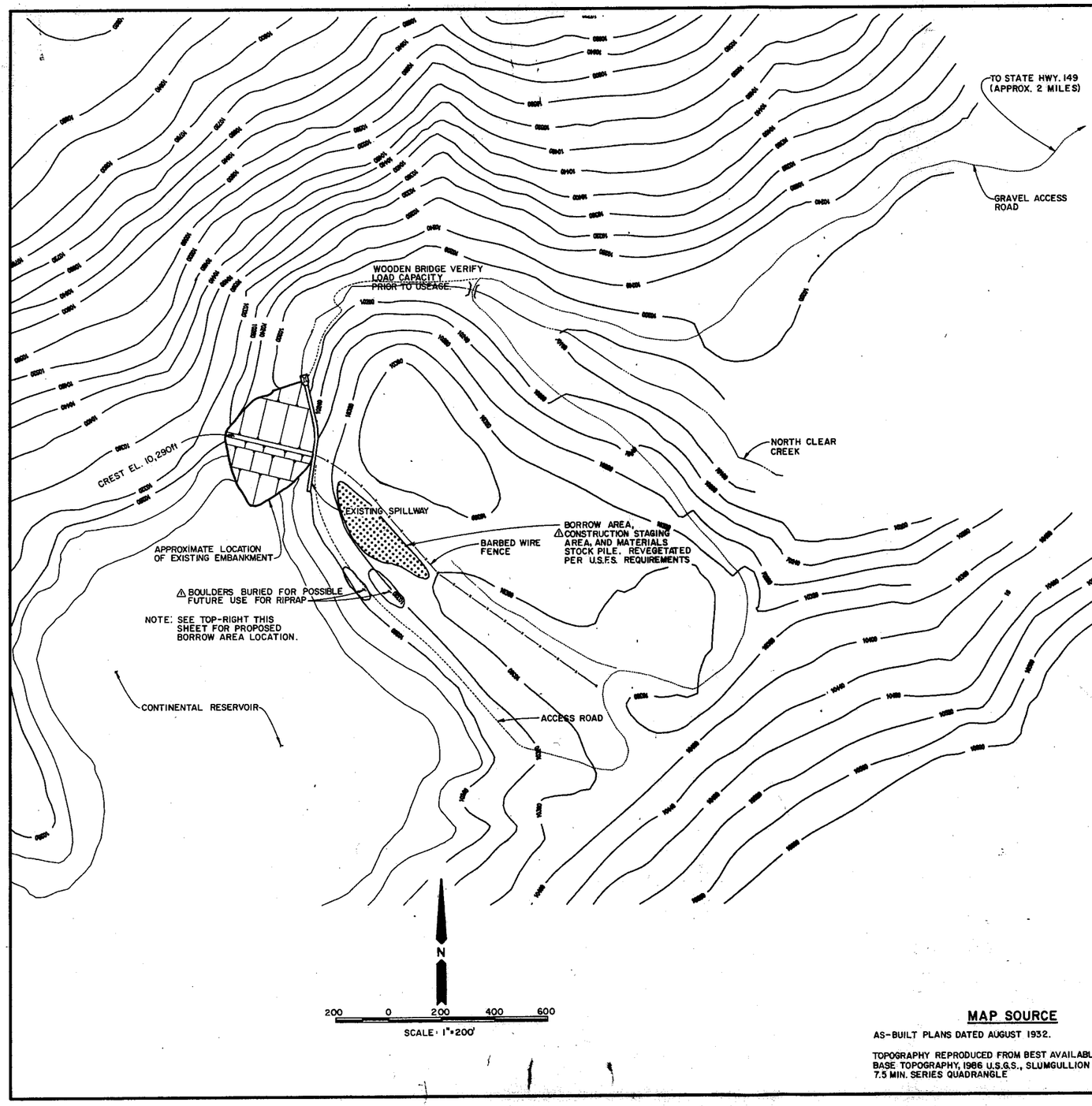
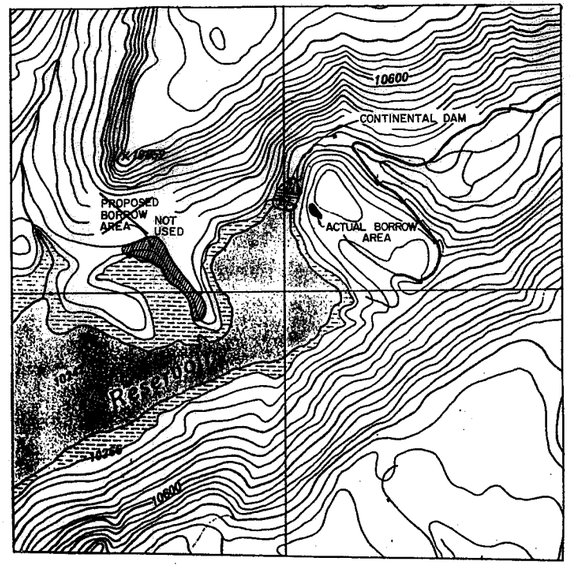
Water Resources
Environmental Studies
1310 Wadsworth Blvd.
Suite 100
Lakewood, Colo. 80215

CONTINENTAL DAM REHABILITATION

DAM AND OUTLET CONDUIT PLAN VIEW

Designed By: S.R.W.
Drawn By: M.J.N./R.J.S.
Checked By: MLJ
Scale: 1"=20"
Date: APRIL 1990
Sheet 3 Of 7
Dwg. No. 116-CO-03





⚠BORROW AREA LOCATION MAP

SCALE: 1"=800'

⚠LIST OF ABBREVIATIONS

FT.	=	FEET (FOOT)
INV.	=	INVERT
DIA.	=	DIAMETER
MIN.	=	MINIMUM
STA.	=	STATION
U.S.F.S.	=	UNITED STATES FOREST SERVICE
U.S.G.S.	=	UNITED STATES GEOLOGICAL SURVEY

MAP SOURCE

AS-BUILT PLANS DATED AUGUST 1932.

TOPOGRAPHY REPRODUCED FROM BEST AVAILABLE DATA:
BASE TOPOGRAPHY, 1986 U.S.G.S., SLUMGULLION PASS, CO.
7.5 MIN. SERIES QUADRANGLE

"AS BUILT"

MICHAEL L. JACOBS
COLORADO P.E. #23736

C-250

Job No. 250-116

No.	Revision	By	Date
⚠	AS BUILT	MLF	11/28/1990

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Suite 100
Lakewood, Colo. 80215

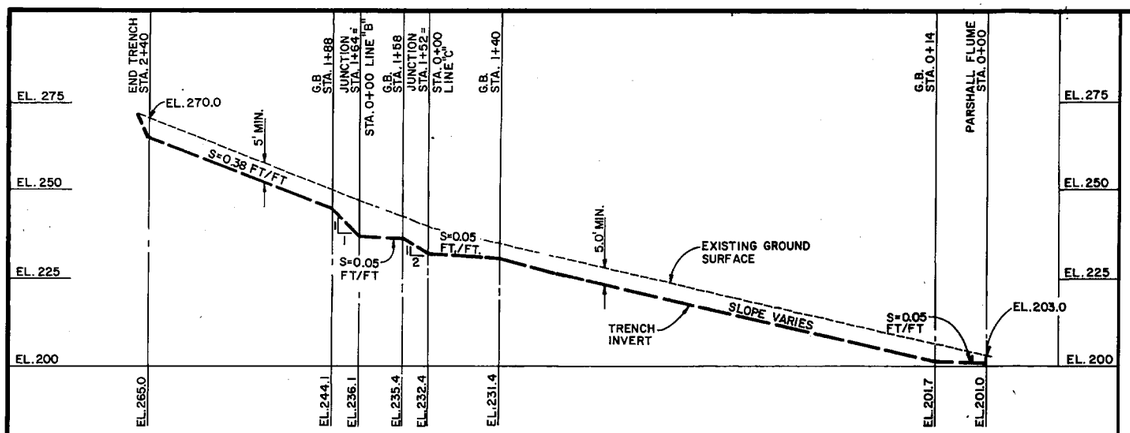
CONTINENTAL DAM REHABILITATION

GENERAL SITE PLAN

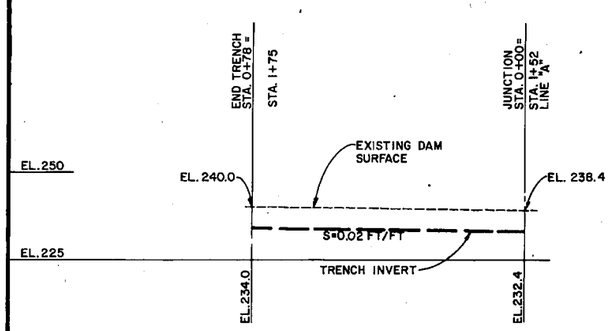
Designed By: S.R.W.
Drawn By: MJN
Checked By: MJ

Scale: 1"= 200'
Date: APRIL 1990

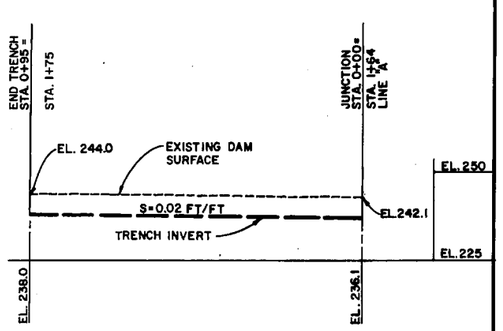
Sheet 2 Of 7
Dwg. No. 116-C0-02



⚠ ABUTMENT/GROIN – LINE "A"



DAM FACE – LINE "C"



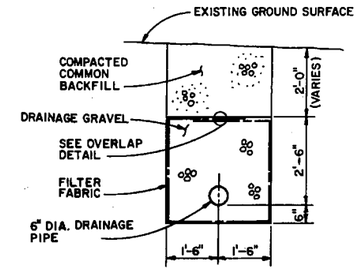
DAM FACE – LINE "B"

⚠ GRAVEL DRAIN PROFILES

SCALE
H. – 1"=20'
V. – 1"=20'

NOTES

1. MAINTAIN 5% MINIMUM SLOPE ON LINE "A"
2. MAINTAIN 5 FT. MINIMUM DEPTH & 2 FT. MINIMUM COMPACTED BACKFILL
3. STATIONING MAY VARY DEPENDING ON FIELD LAYOUT AND TOPOGRAPHY
4. SLOPE IS LABELED IN FEET OF VERTICAL DROP PER FOOT OF HORIZONTAL DISTANCE
5. ALL STATIONING REFLECTS HORIZONTAL NOT SLOPE DISTANCE
6. ADD 10,000 FEET TO ALL ELEVATIONS

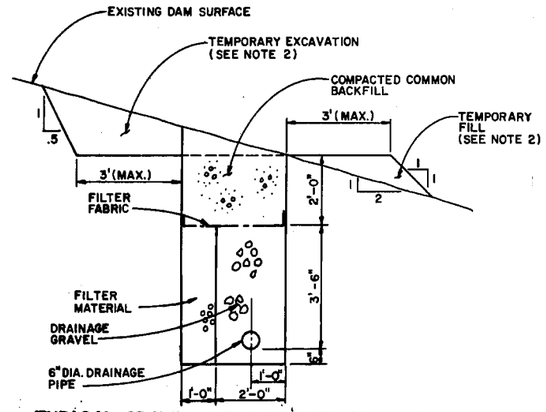


TYPICAL GRAVEL DRAIN TRENCH SECTION ABUTMENT/GROIN (LINE "A")

SCALE:
1/2"=1'-0"

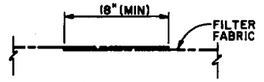
NOTES

1. Maximum length of open trench at any one time shall be 20 feet.
2. Temporary excavation for contractor convenience. Area to be regraded and compacted immediately upon completion of the work.
3. Extreme care shall be taken to avoid sloughing of the embankment slope. Sloughing, if any, shall be repaired immediately.
4. Paylines for drainage trenches are as shown. Over excavation to facilitate construction may be necessary to reduce sloughing of the slopes.



TYPICAL GRAVEL DRAIN TRENCH SECTION DAM FACE (LINES "B" AND "C")

SCALE:
1/2"=1'-0"



FILTER FABRIC OVERLAP DETAIL

SCALE:
1"=1'-0"

"AS BUILT"

MICHAEL L. JACOBS
COLORADO P.E. 23736

No.	Revision	By	Date
Job No.			
⚠	AS BUILT	MLF	11/30/1990

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Water Resources Environmental Studies
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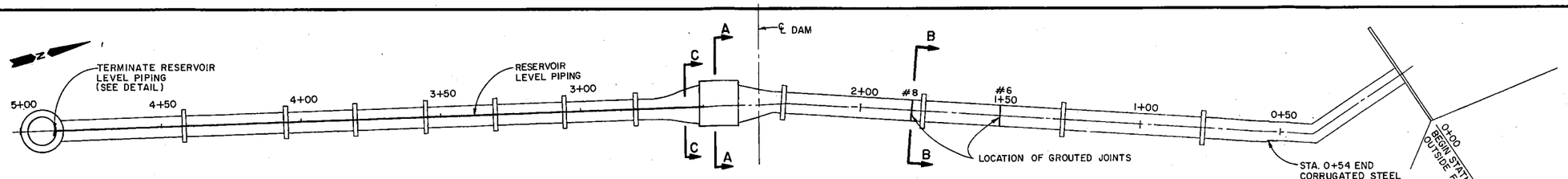
Suite 100
Lakewood, Colo. 80215

CONTINENTAL DAM REHABILITATION

GRAVEL DRAIN PROFILES & TRENCH SECTIONS

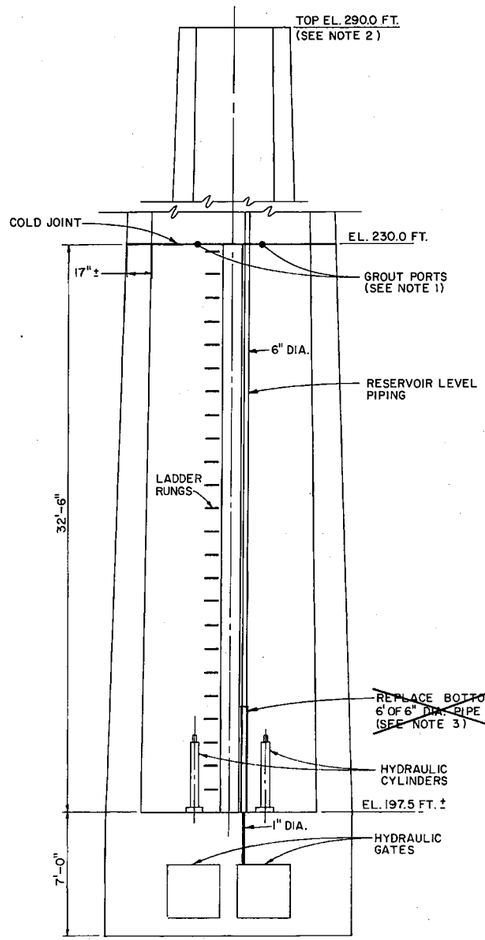
Designed By: S.R.W
Drawn By: R.J.S.
Checked By: MLJ
Scale: AS SHOWN
Date: APRIL 1990
Sheet 5 Of 7
Dwg. No. 116-CO-05

C-259A



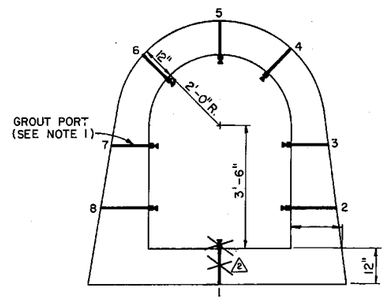
⚠OUTLET CONDUIT

SCALE: 1"=20'



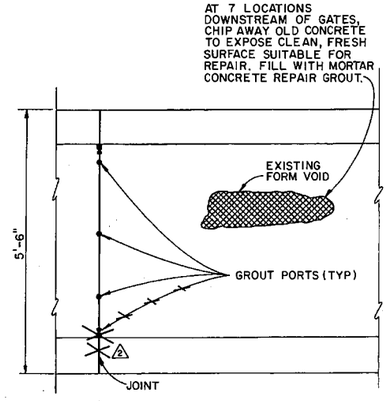
⚠GATE SHAFT REHABILIATION DETAIL SECTION A-A

SCALE: 1/4"=1'-0"



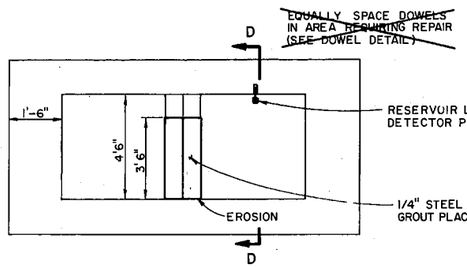
⚠GROUT PORT LOCATION, OUTLET CONDUIT SECTION B-B

SCALE: 1/2"=1'-0"



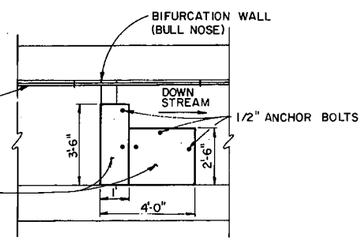
⚠OUTLET CONDUIT REPAIR DETAILS (TYPICAL CROSS-SECTION)

SCALE: 1/2"=1'-0"



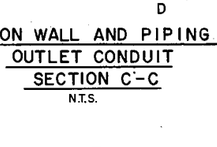
⚠BIFURCATION WALL AND PIPING DETAIL OUTLET CONDUIT SECTION C'-C

N.T.S.

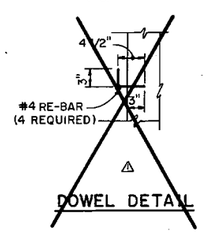


⚠BIFURCATION WALL REPAIR DETAIL SECTION D-D

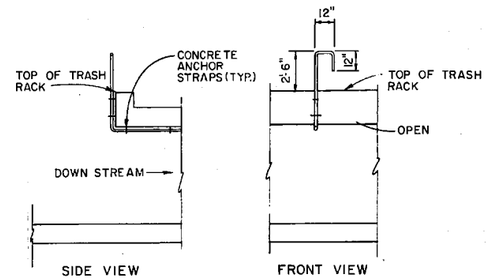
N.T.S.



CLEVIS & ANCHOR DETAIL RESERVOIR LEVEL DETECTOR



DOWEL DETAIL



⚠RESERVOIR LEVEL DETECTOR INTAKE DETAIL

N.T.S.

NOTES

1. ACTUAL QUANTITY AND LOCATION OF GROUT PORTS TO BE DETERMINED IN THE FIELD BY THE ENGINEER. (SEE APPENDIX C OF REPORT FOR GROUT QUANTITIES AT EACH PORT LOCATION. (PORT LOCATIONS #1 WERE OMITTED DUE TO EXISTING SATISFACTORY CONDITIONS.)
2. ADD 10,000 FEET TO ALL ELEVATIONS.
3. TOP ELEVATION OF STANDPIPE MUST BE MAINTAINED AT EXACT ELEVATION AS PRIOR TO CONSTRUCTION.

"AS BUILT"

MICHAEL L. JACOBS
COLORADO P.E. #23736

No.	Revision	By	Date
2			
3			
4			
5			
6			
7			
8	REMOVED GROUT PORT NO. 1	MLF	12/90
1	AS BUILT	MLF	11/20/1990

Job No. 250-116

HYDRO-TRIAD, LTD.
Water Resources Environmental Studies
1310 Wadsworth Blvd. Suite 100 Lakewood, Colo. 80215

CONTINENTAL DAM REHABILITATION

GATE SHAFT AND CONDUIT REPAIRS

Designed By: S.R.W.
Drawn By: R.J.S.
Checked By: MLJ
Scale: AS SHOWN
Date: APRIL 1990
Sheet 7 Of 7
Dwg. No. 116-CO-07

C-259A

Appendix B

Appendix B
Infiltration Calculations

URS CALCULATION COVER SHEET

Project Name:	*Continental*	**Project Number:**	*22241248*
Project Location:	*Mineral County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Brad Rastal

Calculation to be checked: *Infiltration Rates – Green and Ampt - 100yr Storm Revision 1*

Calculation Originator: *Chad Martin / Revised by Joseph Machala 3/30/11*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☒ All items have been found to be correct. Checker has no comments.

_____ 3/11/11

Checker Signature **Date**

or

B. ☐ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

_____ _____

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

References:

1. State of Colorado (SEO). 2008. "Hydrologic Basin Response, Parameter Estimation Guidelines." State of Colorado, Office of the State Engineer, Dam Safety Branch. Prepared by Tierra Grande International, Inc. Revised May 2008.
2. Calculation packet titled "Unit Hydrographs for Continental Reservoir Basin" by Chad Martin on 6/3/10
3. United States Department of Agriculture (USDA). Geospatial Data Gateway. <http://datagateway.nrcs.usda.gov/>. 2010.

GIS File:

N:\Projects\22241248_Santa_Maria_Contine\Sub_00\7.0_CAD_GIS
Continental_Soil

Spreadsheet File:

N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental\
Infiltration_ContinentalJWM_REV.xls

Analysis:

1. Estimate soil texture for each sub-basin based on NRCS Detailed Soil Map Database. Using estimated XKSAT values from Table 10 (SEO 2008) attached below, estimate the area weighted XKSAT for each sub-basin

Steps 1 & 2: Watershed delineation:

The watershed was delineated as described in the Reference 2 (unit hydrographs calculation packet). The watershed is slightly greater than 50 square miles (50.12 sq. mi.).

A detailed soil survey map was obtained from the USDA Data Gateway website (USDA, 2010). Only the first 6 inches of soil was analyzed as suggested on page 51 of the SEO, 2008 guidelines. For soil polygons with more than one soil type in the first 6 inches, the smallest XKSAT was adopted being the limiting infiltration value during a extreme storm event. The figure below shows that the watershed is primarily composed of cobbly loams, silt loams, gravely loams, and a range of decomposed plant material. These areas contain approximately 93% of the watershed. The remaining 7% the watershed composition contains standing water from the reservoir and rock outcroppings, which were considered impervious.

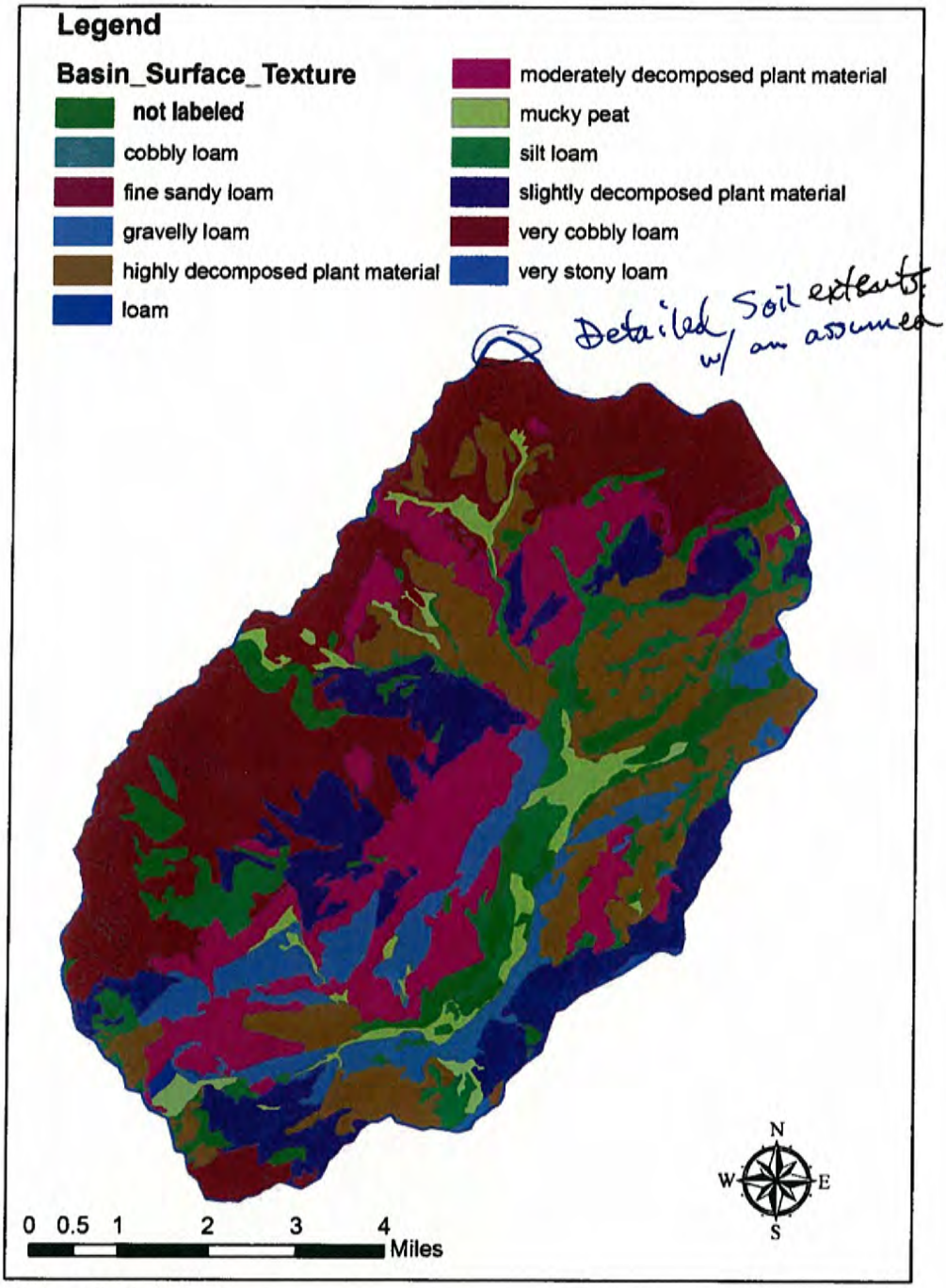


Figure 1: Detailed soil texture map.

Table 1 below shows the suggested XKSAT values suggested by SEO, 2008 with some of the assumed values in this analysis. **Table 2** shows the weighted XKSAT by area composition calculations used in determined a weighted XKSAT value for the entire watershed. The resulting XKSAT value for the watershed was found to be 0.18 in/hr. Note that any cobbley, stoney, or gravely prefix was omitted and the next soil descriptions were adopted in the analysis shown in **Table 2**.

Table 1: Hydraulic Conductivity based on bare ground soil texture (based on Table 10, SEO 2008)

Soil Texture	XKSAT (in/hr)	Source
loamy sand and sand	1.2	SEO, 2008
sandy loam	0.4	SEO, 2008
loam	0.25	SEO, 2008
silty loam	0.15	SEO, 2008
silt	0.1	SEO, 2008
sandy clay loam	0.06	SEO, 2008
clay loam	0.04	SEO, 2008
silty clay loam	0.04	SEO, 2008
sandy clay loam	0.02	SEO, 2008
silty clay loam	0.02	SEO, 2008
clay	0.01	SEO, 2008
rock outcroppings	0	Assumed
water	0	Assumed
cobbly loam	0.25	Assumed
gravelly sandy loam	0.4	Assumed
peat	12	Assumed
decomposed plants	6	Assumed

Table 2: Weighted XKSAT calculations.

ID	SduSoil_M_2	USDA Texture	Adopted XKSAT (in/hr)*	Depth Percentage of Top 6"	Minimum KSAT in Top 6" (in/hr)	Area (mi^2)	Percent Total Area	Contributing Area XKSAT (in/hr)
1	107	Loam	0.25	100.0%	0.25	0.07	0.1%	0.000
2	116	Fine Sandy Loam	0.4	100.0%	0.40	0.01	0.0%	0.000
3	124	Silt Loam	0.15	100.0%	0.15	3.18	6.4%	0.010
4	125	Moderately decomposed plant material	6	33.0%	0.15	7.73	15.5%	0.023
		Stoney Silt Loam	0.15	67.0%				
5	127	Very Stony Loam	0.25	67.0%	0.25	0.04	0.1%	0.000
		Very Gravelly Sandy Loam	1.2	33.0%				
6	128	Silt Loam	0.15	100.0%	0.15	2.14	4.3%	0.006
7	129	Very cobbly Loam	0.25	50.0%	0.15	2.56	5.1%	0.008
		Very cobbly Loam, Very Cobbly Silt Loam	0.15	50.0%				

8	137	Moderately decomposed plant material	6	33.0%	0.25	0.85	1.7%	0.004
		Cobbly Loam	0.25	67.0%				
9	140	Highly Decomposed Plant Material	6	50.0%	0.15	7.81	15.6%	0.023
		Cobbly Silt Loam	0.15	50.0%				
10	142	Highly Decomposed Plant Material	6	50.0%	0.15	0.46	0.9%	0.001
		Cobbly Silt Loam	0.15	50.0%				
11	153	Very cobbly Loam	0.25	100.0%	0.25	0.57	1.1%	0.003
12	154	Very cobbly Loam	0.25	100.0%	0.25	9.62	19.2%	0.048
13	155	Moderately decomposed plant material	6	33.0%	0.25	0.03	0.1%	0.000
		Cobbly Loam	0.25	67.0%				
14	157	Gravelly Loam	0.25	100.0%	0.25	1.08	2.2%	0.005
15	160	Gravelly Loam	0.25	100.0%	0.25	1.79	3.6%	0.009
16	161	Gravelly Loam	0.25	100.0%	0.25	1.20	2.4%	0.006
17	162	Rock Outcrop	0	100.0%	0.00	3.02	6.0%	0.000
18	165	Slightly Decomposed Plant Material	6	33.0%	0.25	7.08	14.2%	0.035
		Cobbly Loam	0.25	67.0%				
19	174	Cobbly Loam	0.25	83.0%	0.04	0.03	0.1%	0.000
		Cobbly Clay Loam	0.04	17.0%				
20	W	Water	0	100.0%	0.00	0.73	1.5%	0.000
					Area Weighted XKSAT			**0.18**

Steps 3, 4, and 5: Estimate IA and RTIMP

IA is surface retention loss and RTIMP is watershed impervious area. Since the watershed was not divided into sub-areas, composite values of IA and RTIMP were not calculated.

The watershed is a natural area (primarily undeveloped), so Table 8 in SEO (2008) was used to estimate IA. Based upon aerial photos, the percent of vegetative cover is 40%-80%. Based upon rough estimates from USGS quad maps, the average basin slope is greater than 10%. Therefore, the surface retention loss is 0.3 inches.

Table 8

IA as a function of vegetation cover and average land slope for natural areas
(to be used with the Green and Ampt infiltration equation for estimating rainfall losses)

Surface Retention Loss (IA), inches

Average Slope (1)	% Vegetation Cover			
	0-10% (2)	10-40% (3)	40-80% (4)	80-100% (5)
0-1%	0.4	0.6	0.8	1.0
1-5%	0.3	0.4	0.6	0.8
5-10%	0.2	0.3	0.4	0.6
>10%	0.1	0.2	0.3	0.4

Note: Not to be used in rainfall-runoff modeling with rainfalls more frequent than 100-year.

The watershed is undeveloped so a small percentage of impervious area exists. It was estimated that the impervious area and RTIMP is 6.5% from the standing water in the reservoir and rock outcroppings.

Steps 6 and 7: Estimate bare ground XKSAT

The bare ground XKSAT was estimated using Table 10 of SEO (2008) and assumed values. Based on a weighted average of all soil polygons, the XKSAT was estimated to be 0.18 in/hr.

Step 8: Estimate PSIF and DTHETA

PSIF is the wetting front capillary suction and DTHETA is the volumetric soil moisture deficit at the start of rainfall. PSIF was estimated using Figure 4 from SEO (2008) with a XKSAT of 0.18 in/hr (see the attached figure). PSIF was estimated to be 5 in. SEO (2008) states that if the soil is effectively saturated at the start of rainfall then DTHETA equals 0.0 and if the soil is dry at the start of rainfall then DTHETA is equivalent to the effective porosity. To be conservative for this analysis, it was assumed that snowmelt would fully saturate the soil, making DTHETA equal to 0.0.

Step 9: Estimate adjusted XKSAT

XKSAT is the bare ground hydraulic conductivity and can be adjusted based upon vegetative cover using Figure 8. This adjustment results is a higher hydraulic conductivity because vegetation increases the infiltration rate over bare soil. The vegetative cover was assumed to be 40% to 80%. To be conservative, a vegetative cover of 40% was used on Figure 8, resulting in a ratio of hydraulic conductivity to XKSAT of 1.33. Therefore, the adjusted hydraulic conductivity (KSAT) is 0.33 in/hr.

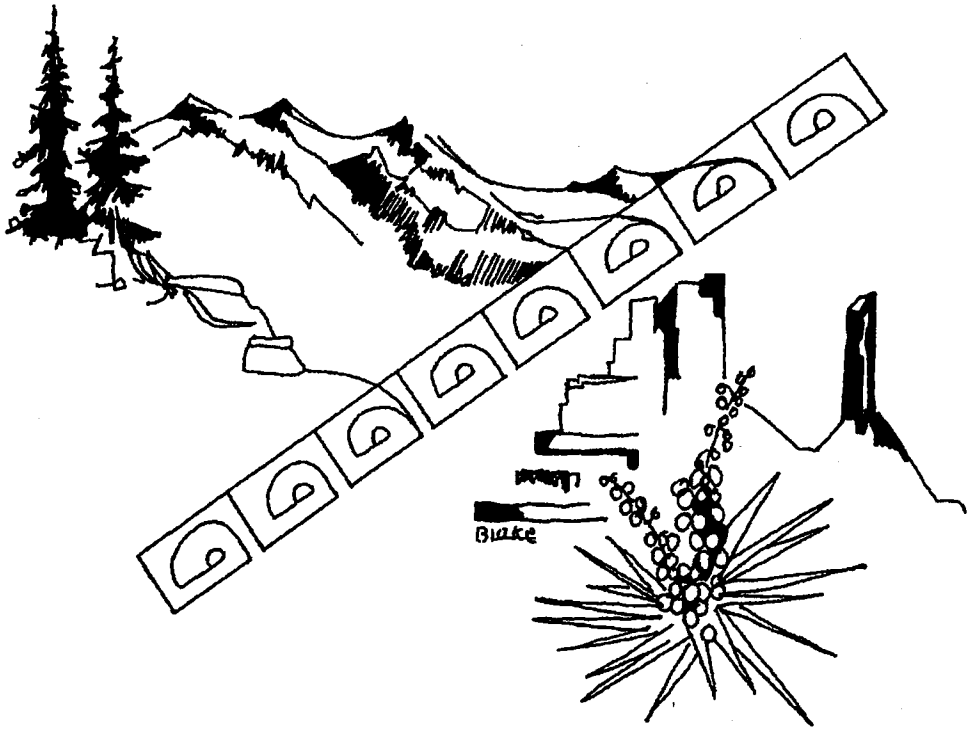
Step 10: Summarize the results

Green & Ampt Parameter	Source	Value
Initial Loss (IA)	Table 8	0.30 in
Bare Ground XKSAT	Table 1 & 2	0.18 in/hr
KSAT Adjustment for XKSAT	Figure 8	1.33 x 0.18 in/hr = 0.24 in/hr
PSIF	Figure 4	5 in
DTHETA	Figure 4	0.0
RTIMP	GIS	6.5%

State of Colorado
Office of the State Engineer
Dam Safety Branch

HYDROLOGIC BASIN RESPONSE

PARAMETER ESTIMATION GUIDELINES



Tierra Grande International, Inc
George V. Sabol, PhD, PE

Revised May 2008

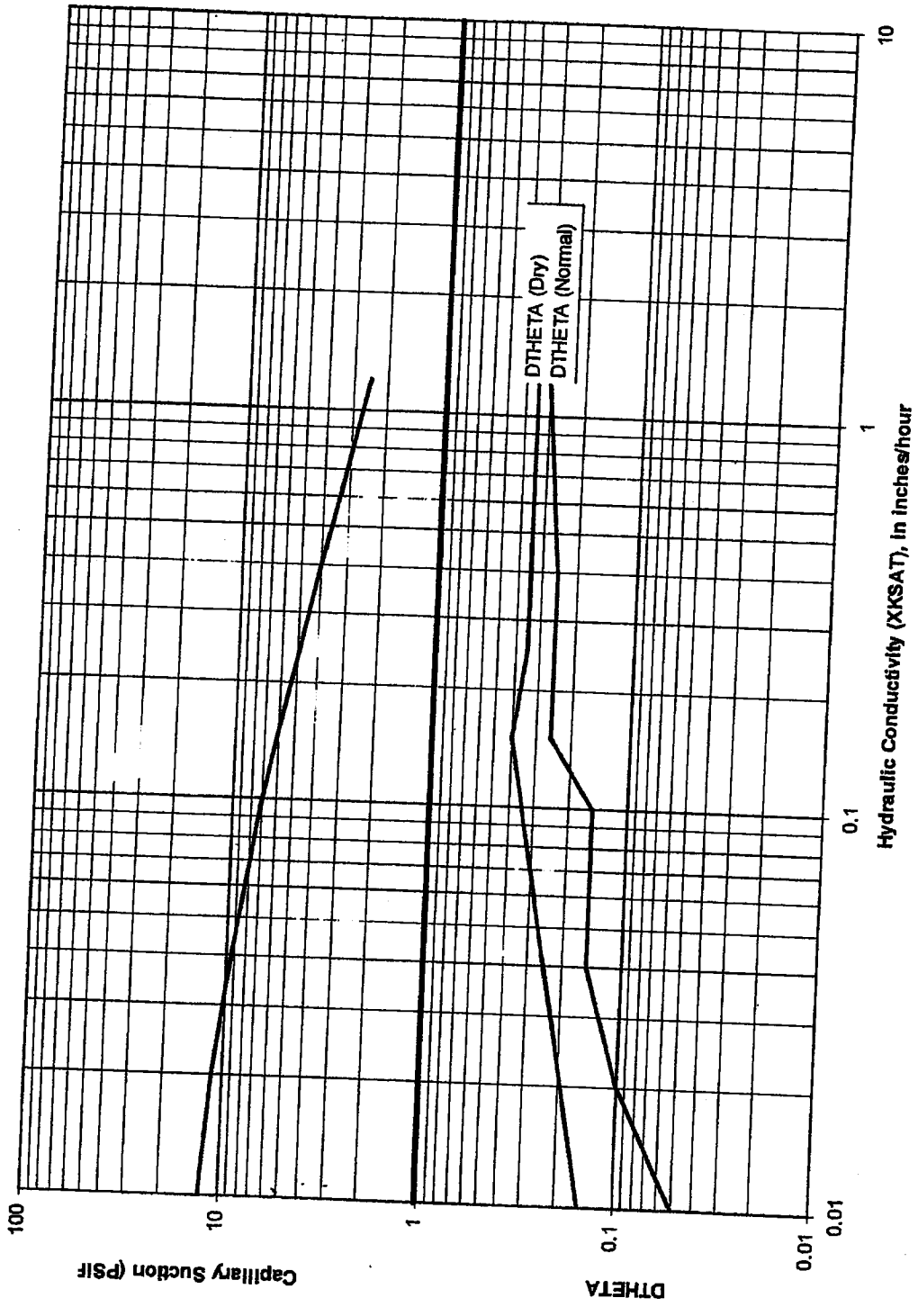
Table 8

IA as a function of vegetation cover and average land slope for natural areas
(to be used with the Green and Ampt infiltration equation for estimating rainfall losses)

Average Slope (1)	Surface Retention Loss (IA), inches: % Vegetation Cover			
	0-10% (2)	10-40% (3)	40-80% (4)	80-100% (5)
0-1%	0.4	0.6	0.8	1.0
1-5%	0.3	0.4	0.6	0.8
5-10%	0.2	0.3	0.4	0.6
>10%	0.1	0.2	0.3	0.4

Note: Not to be used in rainfall-runoff modeling with rainfalls more frequent than 100-year.

Figure 4
Composite values of PSIF and DTHETA as a function of XKSAT
(To be used for Area-Weighted Averaging of Green and Ampt Parameters



Analyzed 1st 6"

T/Canal/GDS/Co Soils/Soils

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

[Absence of an entry indicates that the data were not estimated. This report shows only the major soils in each map unit]

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
107: Booneville	0-10	Loam	ML	A-6, A-7-6	0	0-3	86-94	83-91	72-86	51-63	36-50	11-17
	10-18	Loam	ML	A-6, A-7-6	0	0-12	93-94	91	79-86	58-65	36-50	11-17
	18-26	Very cobbly loam	CL, SC	A-6, A-7-6	0	37-43	72-83	67-78	57-71	42-53	34-45	15-19
	26-37	Very cobbly clay loam	CL, GC	A-6, A-7-6	0	40-46	69-81	64-76	56-71	42-54	38-48	19-23
	37-60	Cobbly sandy clay loam	SC	A-6	0	18-26	75-85	70-80	59-73	37-47	31-39	15-19
Clayburn	0-12	Loam	CL	A-6	0	0	80-100	80-100	69-93	51-71	31-42	13-18
	12-18	Clay loam	CL	A-6, A-7-6	0	0-12	94	91	82-84	63-66	38-45	19-21
	18-31	Clay loam	CL	A-6, A-7-6	0	0-12	94	91	81-88	63-69	37-47	19-24
	31-60	Very cobbly loam	CL, GC	A-6	5-10	40-46	65-78	62-75	53-69	41-54	29-38	13-18
116: Cabin	0-4	Fine sandy loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0	93-100	93-100	79-93	46-56	26-35	5-12
	4-12	Fine sandy loam	SC, SC-SM	A-4, A-6	0	0	93-100	93-100	78-91	41-50	26-35	5-12
	12-18	Gravelly sandy clay loam	SC	A-2-6, A-2-7	0	7-14	71-79	70-78	56-68	29-35	31-42	13-18
	18-23	Very cobbly sandy clay loam	SC	A-2-6, A-6	0	35-47	78-80	77-80	64-71	32-38	30-40	13-18
	23-60	Extremely gravelly loamy sand	GW-GM	A-1-a	0	25-35	25-40	20-30	10-25	5-10	0	NP

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
116:												
Silas	0-5	Silt loam	CL	A-6	0	0	100	100	94-98	86-90	33-42	14-18
	5-12	Silt loam	CL	A-6	0	0	100	100	93-97	85-89	33-42	14-18
	12-16	Silty clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	79-100	71-94	38-47	19-23
	16-23	Silty clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	78-100	71-93	38-47	19-23
	23-27	Silty clay loam	CL	A-6, A-7-6	0	0	92-100	91-100	89-100	80-92	38-47	19-23
	27-33	Silt loam	CL	A-6	0	0	84-100	83-100	77-96	67-85	33-40	15-18
	33-47	Clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	74-97	63-82	37-44	19-23
	47-60	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	8-16	38-45	35-43	25-34	15-20	0-30	NP-10
124:												
Cryaquolls	0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
Cryoborolls	0-4	Loam	ML	A-6, A-7-6	0	0-3	82-100	81-100	71-92	53-69	37-48	12-17
	4-11	Loam	CL	A-6	0	0-3	82-91	81-90	70-82	52-61	33-42	14-18
	11-19	Very gravelly clay loam	GC	A-6, A-7-6	0	0-15	50-60	45-55	40-50	36-45	38-49	19-24
	19-27	Very cobbly clay loam	GC	A-6, A-7-6	0	24-31	56-65	55-64	47-59	36-45	37-47	19-24
	27-60	Very cobbly sandy clay loam	GC	A-2-6	0	30-40	52-61	50-60	42-55	26-35	31-41	15-21

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
125:												
Cryoboralfs	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	2-6	Stony silt loam	CL	A-6, A-7-6	25-30	0	100	100	93-97	82-86	34-44	15-18
	6-9	Stony clay loam	CL	A-6, A-7-6	24-37	0	100	100	90-93	70-73	38-45	19-21
	9-18	Very stony silty clay loam	CL	A-7-6	51-53	0	94-100	93-100	88-100	78-91	40-49	21-26
	18-62	Very stony clay	CH, CL	A-7-6	55-60	0	84-100	83-100	77-97	62-79	47-53	29-32
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
127:												
Cryochrepts	0-4	Very stony loam	GC	A-6	17-25	17-25	67-71	66-70	57-63	40-45	30-37	13-17
	4-10	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	8-15	15-25	47-54	44-52	32-42	20-28	0-31	NP-10
	10-17	Extremely cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	15-25	33-40	32-42	30-40	22-32	14-21	0-31	NP-10
	17-28	Extremely stony sandy loam	GC-GM, GM, GW-GC	A-1-a, A-2-4	33-40	46-52	26-36	23-33	16-26	9-16	0-30	NP-10
	28-38	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
128:												
Cryohemists	0-38	Mucky peat	PT	A-8	0	0	100	100	—	—	—	—
	38-60	Gravelly loam, loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0-5	70-100	65-95	60-90	45-80	24-41	7-17

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
128:												
Cryaquolls	0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
129:												
Cryumbrepts	0-3	Very cobbly loam	GM	A-2-4, A-2-6, A-4	0-15	15-30	55-75	50-70	45-60	30-40	29-45	5-15
	3-12	Very cobbly loam, very cobbly silt loam	GC, GC-GM	A-2-4, A-2-6, A-4	0-15	15-35	55-75	50-70	45-60	30-40	20-33	6-13
	12-16	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rubble land	—	—	—	—	—	—	—	—	—	—	—	—
137:												
Endlich	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	2-9	Cobbly loam	CL, SC, SC-SM	A-4	0-1	18-22	78-86	77-85	64-78	45-56	21-31	6-12
	9-22	Very cobbly sandy loam	GC-GM, GM, SC-SM, SM	A-2-4, A-4	8-15	30-35	67-76	66-75	51-64	32-43	0-31	NP-10
	22-38	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	8-15	65-75	33-52	31-50	23-42	12-24	0-30	NP-10
	38-48	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
137: Hechtman	0-1	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	1-3	Gravelly loam	SC, SC-SM	A-4	0	0-8	76-77	75-76	61-68	38-45	25-35	6-12
	3-11	Very gravelly sandy loam	GC-GM, GM	A-2-4	0	8-15	57-59	55-57	39-45	26-31	0-32	NP-10
	11-16	Extremely gravelly sandy loam	GM, GP-GC	A-1-a, A-2-4	0	8-15	26-33	23-31	17-26	9-14	0-31	NP-10
	16-26	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
140: Frisco	0-3	Highly decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	3-15	Cobbly silt loam	CL, CL-ML	A-4	0	25-30	80-90	79-89	72-89	58-74	21-31	6-12
	15-20	Cobbly fine sandy loam	SC, SC-SM	A-4	0	25-30	80-90	79-89	68-84	40-50	20-31	6-12
	20-48	Very cobbly loam	SC, SC-SM	A-4	0	37-43	69-79	67-79	54-69	36-47	20-30	6-12
	48-63	Very gravelly fine sandy loam	GC, GC-GM	A-2-4	0	8-16	49-57	47-55	39-50	22-30	20-30	6-12
Agneston	0-3	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	3-11	Cobbly loam	CL	A-6	0	19-23	81-89	76-84	66-79	51-60	28-37	12-17
	11-22	Very cobbly clay loam	CL, GC	A-6, A-7-6	0	32-37	69-79	64-74	57-69	44-54	37-43	19-22
	22-31	Very gravelly clay loam	GC	A-6, A-7-6	0	15-20	58-70	53-65	47-61	37-48	36-43	19-22
	31-41	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
142:												
Frisco	0-3	Highly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	3-15	Cobbly silt loam	CL, CL-ML	A-4	0	25-30	80-90	79-89	72-89	58-74	21-31	6-12
	15-20	Cobbly fine sandy loam	SC, SC-SM	A-4	0	25-30	80-90	79-89	68-84	40-50	20-31	6-12
	20-48	Very cobbly loam	SC, SC-SM	A-4	0	37-43	69-79	67-79	54-69	36-47	20-30	6-12
	48-63	Very gravelly fine sandy loam	GC, GC-GM	A-2-4	0	8-16	49-57	47-55	39-50	22-30	20-30	6-12
Scout	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	2-13	Cobbly sandy loam	SC-SM, SM	A-2-4, A-4	0	25-29	71-81	70-80	52-66	31-42	0-31	NP-10
	13-26	Very cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	33-40	59-69	57-68	43-56	22-31	0-31	NP-10
	26-36	Very cobbly fine sandy loam	GC-GM, GM	A-2-4	0-9	33-40	57-61	55-60	50-59	23-30	0-31	NP-10
	36-62	Very cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	0-9	33-40	57-61	55-60	40-47	18-24	0-30	NP-10
153:												
Mirror	0-10	Very cobbly loam	CL, CL-ML	A-4	9-15	32-37	76-78	75-77	65-73	51-56	27-35	6-12
	10-21	Very cobbly loam	GC, GC-GM	A-2-4, A-4	9-14	37-44	54-65	53-64	44-59	31-43	22-35	6-12
	21-35	Very cobbly loam	GC, GC-GM	A-4	9-14	45-50	61-74	60-73	51-67	36-47	21-33	6-12
	35-45	Unweathered bedrock	---	---	---	---	---	---	---	---	---	---

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
153: Brees	50% 0-3	Gravelly silt loam	ML	A-4, A-6	0-9	0-9	74-76	73-75	64-72	51-59	29-46	5-12
	50% 3-8	Very gravelly loam	GC, GC-GM	A-4, A-6	17-25	17-25	61-71	59-70	49-63	36-45	25-35	6-12
	8-12	Very gravelly sandy loam	GC-GM, GM	A-2-4	17-25	17-25	61-71	59-70	43-56	26-35	0-34	NP-10
	12-26	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	26-30	18-25	43-52	41-50	28-38	15-22	0-34	NP-10
	26-32	Very stony sandy loam	SC-SM, SM	A-2-4	32-38	17-25	65-77	64-76	45-59	25-35	0-33	NP-10
	32-60	Very stony sandy loam	GC-GM, GM	A-1-b, A-2-4	30-35	17-25	53-65	51-64	38-52	19-29	0-31	NP-10
154:												
Mirror	100% 0-10	Very cobbly loam	CL, CL-ML	A-4	9-15	32-37	76-78	75-77	65-73	51-56	27-35	6-12
	10-21	Very cobbly loam	GC, GC-GM	A-2-4, A-4	9-14	37-44	54-65	53-64	44-59	31-43	22-35	6-12
	21-35	Very cobbly loam	GC, GC-GM	A-4	9-14	45-50	61-74	60-73	51-67	36-47	21-33	6-12
	35-45	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Teewinot	100% 0-7	Very stony sandy loam	SC-SM, SM	A-2-4	32-38	25-32	72-75	70-74	52-60	26-33	0-34	NP-10
	7-18	Extremely cobbly sandy loam	GM, GW-GC, GW-GM	A-1-a, A-2-4	8-15	44-50	30-41	27-38	20-31	10-16	0-33	NP-10
	18-28	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
157:												
Quander 100%	0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
160:												
Quander 100%	0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
Bushvalley 67%	0-4	Very cobbly coarse sandy loam	GC, SC	A-2-4, A-2-6	0-9	30-35	61-71	59-70	39-49	27-35	29-38	9-13
33%	4-13	Very cobbly clay loam	GC	A-2-7, A-7-6	8-13	30-37	51-60	49-59	42-54	31-41	38-49	19-24
	13-23	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
161:												
Quander	100% 0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
Cryaquolls	100% 0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
Cryohemists	100% 0-38	Mucky peat	PT	A-8	0	0	100	100	—	—	—	—
	38-60	Gravelly loam, loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0-5	70-100	65-95	60-90	45-80	24-41	7-17
162:												
Rock outcrop	100% 0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rubble land	—	—	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
165: Seitz	0-2	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	2-7	Cobbly loam	CL	A-6	0	15-30	83-93	80-90	65-75	51-54	29-42	12-18
	7-11	Cobbly loam	CL	A-6	0	15-30	83-93	80-90	65-75	51-54	29-42	12-18
	11-19	Very cobbly clay	CH	A-7-6	0	50-55	85-100	84-100	77-95	59-74	51-56	29-32
	19-28	Very cobbly clay loam	CL	A-7-6	0	42-50	75-87	74-87	66-81	51-62	45-50	25-28
	28-42	Very cobbly clay loam	GC	A-7-6	0	30-42	58-73	55-70	50-65	40-50	44-50	25-28
	42-62	Cobbly clay loam	CL, GC	A-6, A-7-6	0	15-25	71-80	70-80	61-75	45-56	37-45	19-24
174: Youga	0-5	Cobbly loam	CL	A-6, A-7-6	0	15-25	83-93	80-90	75-85	55-60	33-44	13-18
	5-10	Cobbly clay loam	CL	A-6, A-7-6	0	15-25	83-93	80-90	75-85	65-70	39-49	19-23
	10-23	Cobbly clay loam	CL	A-7-6	0	15-25	83-93	80-90	75-85	65-70	40-48	21-24
	23-28	Cobbly sandy loam	SC-SM, SM	A-4	0	15-25	83-93	80-90	65-70	36-40	0-30	NP-10
	28-60	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	0-10	41-54	38-50	32-40	18-23	0-30	NP-10
Gateview	0-4	Cobbly loam	CL, CL-ML	A-4	0	17-25	81-90	80-90	69-84	51-63	25-34	6-10
	4-13	Cobbly loam	SC, SC-SM	A-4	0	17-25	72-82	71-81	60-73	42-53	25-34	6-10
	13-16	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	0	40-46	30-38	27-36	20-29	13-19	0-33	NP-10
	16-24	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	0	40-46	30-38	27-36	20-29	12-18	0-33	NP-10
	24-60	Extremely cobbly sandy loam	GM, GP-GM	A-1-a, A-2-4	0	46-52	26-36	23-33	18-27	11-17	0-31	NP-10

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
W:												
Water 1086	—	—	—	—	—	—	—	—	—	—	—	—

URS CALCULATION COVER SHEET

Project Name:	*Continental*	**Project Number:**	*22241248*
Project Location:	*Mineral County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Dan Greaves

Calculation to be checked: *Infiltration Rates – Initial and Constant for PMP Storms Revision 1*

Calculation Originator: *Chad Martin / Revised by Joseph Machala 3/31/11*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☐ All items have been found to be correct. Checker has no comments.

_____ _____

Checker Signature **Date**

or

B. ☒ Checker's comments have been provided on:

☐ Calculation
☐ Comment and Disposition Form (Form 3-5 (MM))
☒ Other this calc pack

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☒ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

David Greaves 3/31/2011

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

References:

1. State of Colorado (SEO). 2008. "Hydrologic Basin Response, Parameter Estimation Guidelines." State of Colorado, Office of the State Engineer, Dam Safety Branch. Prepared by Tierra Grande International, Inc. Revised May 2008.
2. Calculation packet titled "Unit Hydrographs for Continental Reservoir Basin" by Chad Martin on 6/3/10
3. United States Department of Agriculture (USDA). Geospatial Data Gateway. <http://datagateway.nrcs.usda.gov/>. 2010.

Excel Worksheet:

N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental\ Infiltration_ContinentalJWM_REV.xls

GIS File:

N:\Projects\22241248_Santa_Maria_Contine\Sub_00\7.0_CAD_GIS Continental_Soil

Analysis:

1. Estimate initial and uniform loss rates for the Continental Dam drainage basin.

Steps 1 & 2: Watershed delineation:

The watershed was delineated as described in the Reference 2 (unit hydrographs calculation packet). The watershed is slightly greater than 50 square miles (50.12 sq. mi.).

A detailed soil survey map was obtained from the USDA Data Gateway website (USDA, 2010). Only the first 18 inches of soil was analyzed as suggested on page 51 of the SEO, 2008 guidelines. For soil polygons with more than one soil type in the first 18 inches, the smallest XKSAT was adopted being the limiting infiltration value during a extreme storm event. The figure below shows that the watershed is primarily composed of cobbly loams, silt loams, gravely loams, and a range of decomposed plant material. These areas contain approximately 93% of the watershed. The remaining approximate 7% the watershed composition contains standing water from the reservoir and rock outcroppings, which were considered impervious.

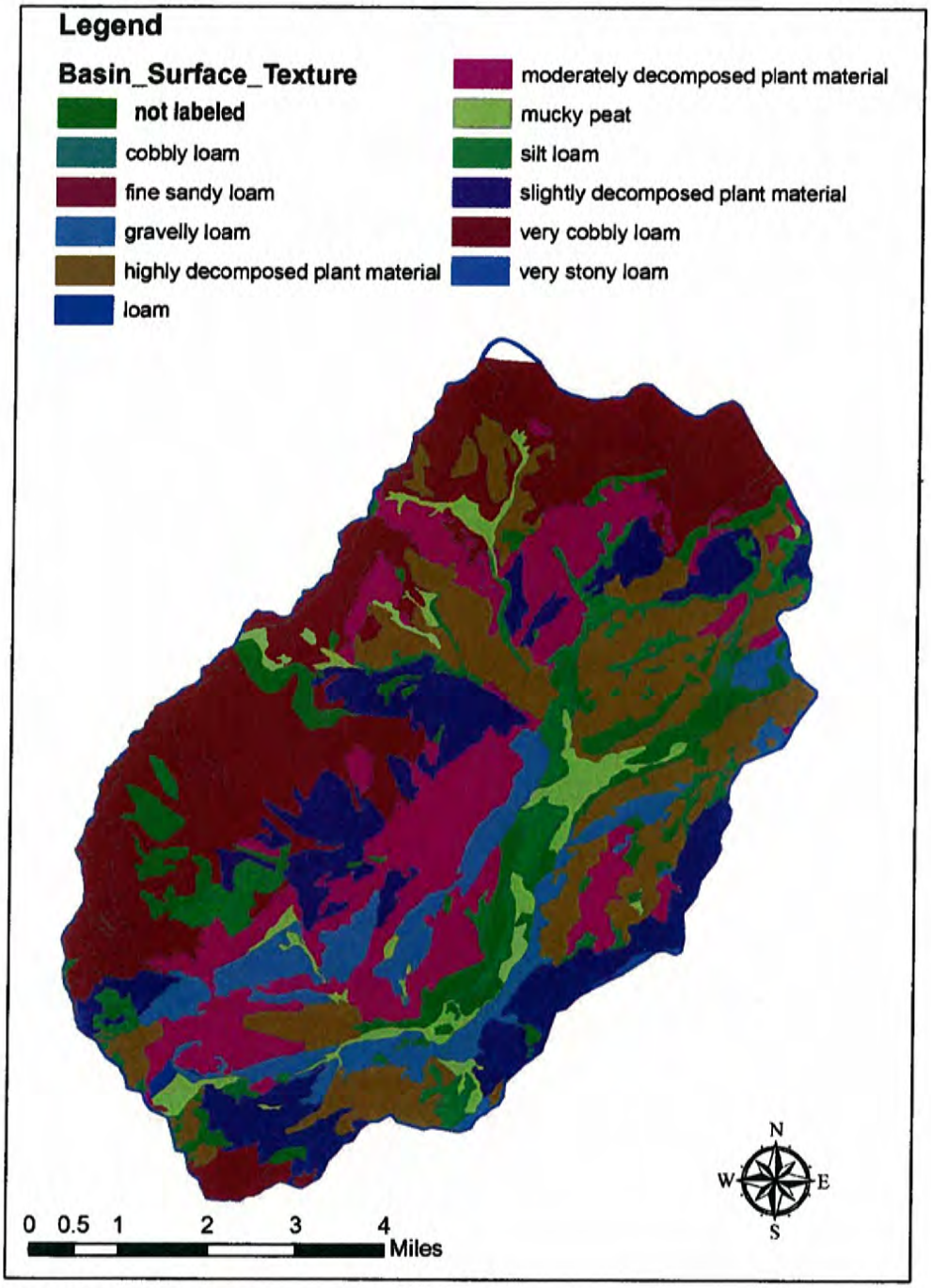


Figure 1: Detailed soil texture map.

Table 1 below shows the suggested XKSAT values suggested by SEO, 2008 with some of the assumed values in this analysis. **Table 2** shows the weighted XKSAT by area composition calculations used in determined a weighted XKSAT value for the entire watershed. The resulting XKSAT value for the watershed was found to be 0.13 in/hr. Note that any cobbley, stoney, or gravelly prefix was omitted and the next soil descriptions were adopted in the analysis shown in **Table 2**.

0.10

Table 1: Hydraulic Conductivity based on bare ground soil texture (based on Table 10, SEO 2008)

Soil Texture	XKSAT (in/hr)	Source
loamy sand and sand	1.2	SEO, 2008
sandy loam	0.4	SEO, 2008
loam	0.25	SEO, 2008
silty loam	0.15	SEO, 2008
silt	0.1	SEO, 2008
sandy clay loam	0.06	SEO, 2008
clay loam	0.04	SEO, 2008
silty clay loam	0.04	SEO, 2008
sandy clay loam	0.02	SEO, 2008
silty clay loam	0.02	SEO, 2008
clay	0.01	SEO, 2008
rock outcroppings	0	Assumed
water	0	Assumed
cobbly loam	0.25	Assumed
gravelly sandy loam	0.4	Assumed
peat	12	Assumed
decomposed plants	6	Assumed

Table 2: Weighted XKSAT calculations.

ID	SduSoil_M_2	USDA Texture	Adopted XKSAT (in/hr)*	Minimum KSAT in Top 18" (in/hr)	Area (mi^2)	Percent Total Area	Contributing Area XKSAT (in/hr)
1	107	Loam	0.25	0.25	0.07	0.1%	0.00
2	116	Fine Sandy Loam	0.4	0.40	0.01	0.0%	0.00
3	124	Silt Loam	0.15	0.04	3.18	6.4%	0.00
		Silty Clay Loam	0.04				
4	125	Moderately decomposed plant material	6	0.04	7.73	15.5%	0.01
		Stoney Silt Loam	0.15				
		Stoney Clay Loam	0.04				
5	127	Very Stony Loam	0.25	0.25	0.04	0.1%	0.00
		Very Gravelly Sandy Loam	1.2				
6	128	Silt Loam	0.15	0.04	2.14	4.3%	0.00
		Silty Clay Loam	0.04				

Steps 4: Adjust XKSAT to estimate CNSTL for vegetation using Figure 8 (SEO, 2008)

XKSAT is the bare ground hydraulic conductivity and can be adjusted based upon vegetative cover using Figure 8. This adjustment results is a higher hydraulic conductivity because vegetation increases the infiltration rate over bare soil. The vegetative cover was assumed to be 40% to 80%. To be conservative, a vegetative cover of 40% was used on Figure 8, resulting in a ratio of hydraulic conductivity to XKSAT of 1.33. Therefore, the adjusted hydraulic conductivity (KSAT) is 0.133 in/hr.

Steps 4: Estimate the surface retention loss (IA) for each sub-basin

Assumed approximately 40 to 80% vegetation cover for all drainage basins. The average basin slope, as calculated using GIS, is greater than 10% for the majority of all sub-basins. **Therefore, a IA value of 0.3 inches for the entire basin (Table 8, SEO, 2008).**

Table 8

IA as a function of vegetation cover and average land slope for natural areas
(to be used with the Green and Ampt infiltration equation for estimating rainfall losses)

Surface Retention Loss (IA), inches

Average Slope (1)	% Vegetation Cover			
	0-10% (2)	10-40% (3)	40-80% (4)	80-100% (5)
0-1%	0.4	0.6	0.8	1.0
1-5%	0.3	0.4	0.6	0.8
5-10%	0.2	0.3	0.4	0.6
>10%	0.1	0.2	0.3	0.4

Note: Not to be used in rainfall-runoff modeling with rainfalls more frequent than 100-year.

Step 5: Based on Table 12 (SEO, 2008), estimate the initial loss plus uniform loss for each sub-basin

1. Majority of the land within the drainage basin is "Dry" mountainous area; however due to the potential of snow melt, "Normal" conditions were assumed.
2. Based on Table 12 (SEO, 2008), **The Initial Infiltration (II) was estimated to be 0.3 inches.**
3. Estimated the Initial Loss (STRL) as the sum of the IA and II values (0.3" + 0.3" = 0.6")

Table 12
Initial Loss Plus Uniform Loss Rate Parameter Values for Bare Ground

Uniform Loss Rate, inches/hour	Initial Infiltration, inches II[1]		
(1)	Dry (2)	Normal (3)	Saturated (4)
0.30 – 1.20	0.6	0.5	0
0.15 – 0.30	0.5	0.3	0
0.05 – 0.15	0.5	0.3	0
0.00 – 0.05	0.4	0.2	0

Note:

1. Selection of II:
   Dry = Non-irrigated lands, such as mountain, hillslope and rangeland.
   Normal = Irrigated lawn, turf, and permanent pasture.
   Saturated = Irrigated agricultural land, or land that can be assumed to have high soil moisture content due to snowmelt.

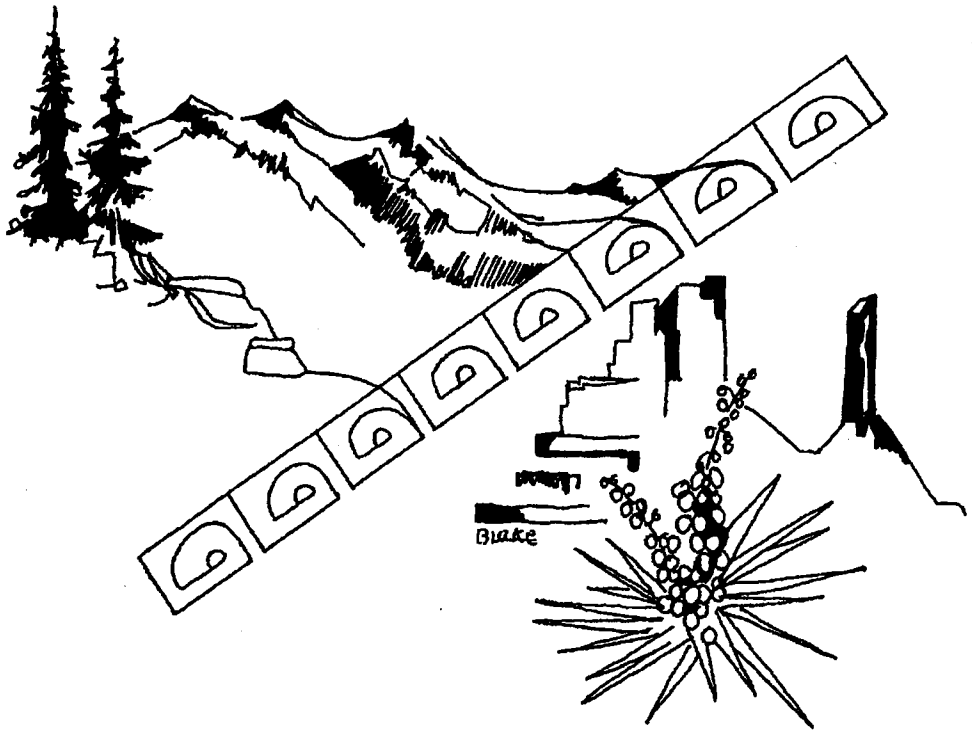
Summary of Results

Sub-basin	Area (mi2)	Uniform Loss Rate (in/hr)	Initial Losses (inches)
Continental Watershed	50	0.13 ✓	0.6 ✓

State of Colorado
Office of the State Engineer
Dam Safety Branch

HYDROLOGIC BASIN RESPONSE

PARAMETER ESTIMATION GUIDELINES



Tierra Grande International, Inc
George V. Sabol, PhD, PE

Revised May 2008

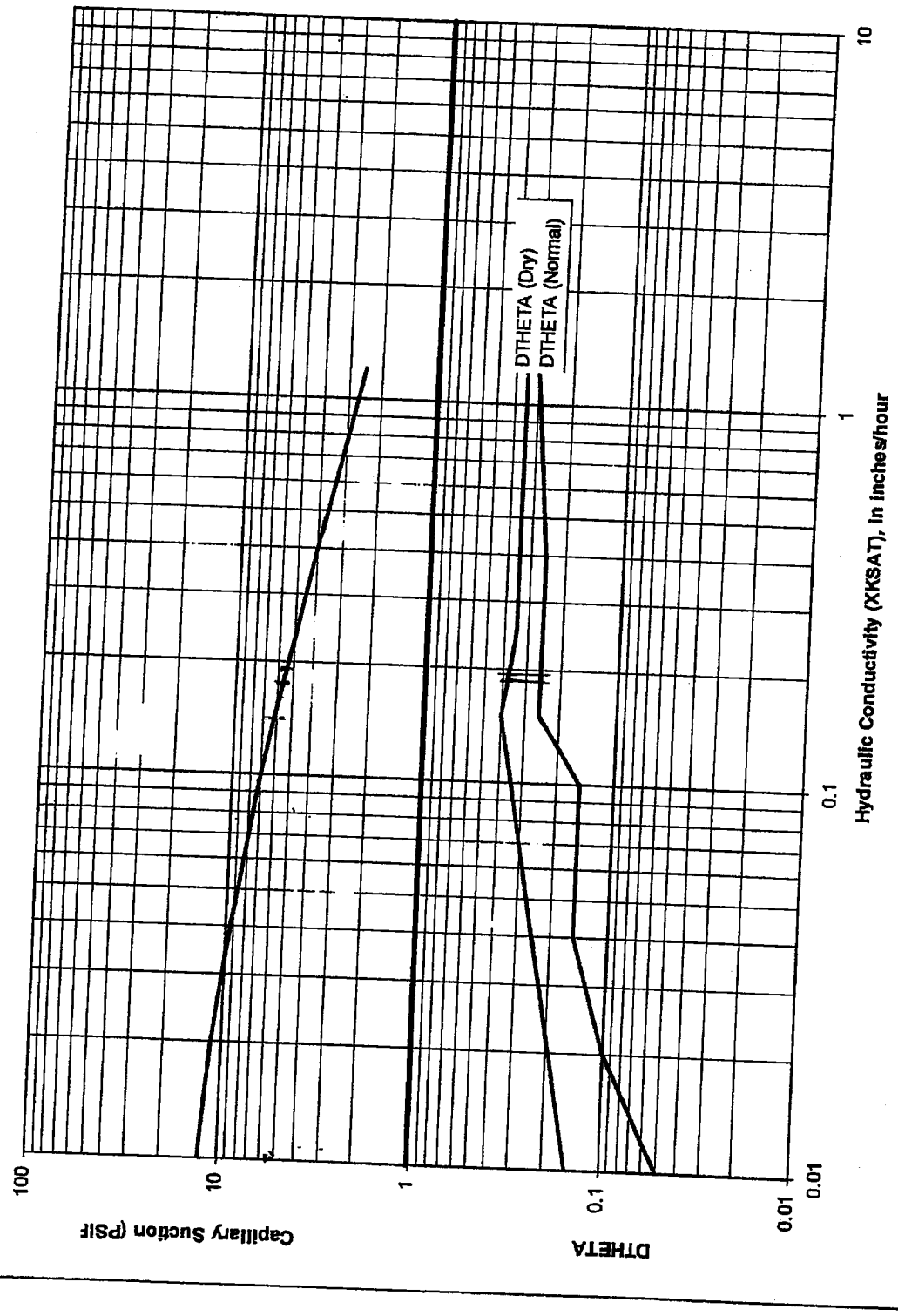
Table 8

IA as a function of vegetation cover and average land slope for natural areas
(to be used with the Green and Ampt infiltration equation for estimating rainfall losses)

Average Slope (1)	Surface Retention Loss (IA), inches: % Vegetation Cover			
	0-10% (2)	10-40% (3)	40-80% (4)	80-100% (5)
0-1%	0.4	0.6	0.8	1.0
1-5%	0.3	0.4	0.6	0.8
5-10%	0.2	0.3	0.4	0.6
>10%	0.1	0.2	0.3	0.4

Note: Not to be used in rainfall-runoff modeling with rainfalls more frequent than 100-year.

Figure 4
Composite values of PSIF and DTHETA as a function of XKSAT
(To be used for Area-Weighted Averaging of Green and Ampt Parameters



Analyzed 1st 6"

T/Canal/GDS/Cobbles/Soils

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

[Absence of an entry indicates that the data were not estimated. This report shows only the major soils in each map unit]

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
107 Booneville	100% 0-10	Loam	ML	A-6, A-7-6	0	0-3	86-94	83-91	72-86	51-63	36-50	11-17
	10-18	Loam	ML	A-6, A-7-6	0	0-12	93-94	91	79-86	58-65	36-50	11-17
	18-26	Very cobbly loam	CL, SC	A-6, A-7-6	0	37-43	72-83	67-78	57-71	42-53	34-45	15-19
	26-37	Very cobbly clay loam	CL, GC	A-6, A-7-6	0	40-46	69-81	64-76	56-71	42-54	38-48	19-23
	37-60	Cobbly sandy clay loam	SC	A-6	0	18-26	75-85	70-80	59-73	37-47	31-39	15-19
Clayburn	100% 0-12	Loam	CL	A-6	0	0	80-100	80-100	69-93	51-71	31-42	13-18
	12-18	Clay loam	CL	A-6, A-7-6	0	0-12	94	91	82-84	63-66	38-45	19-21
	18-31	Clay loam	CL	A-6, A-7-6	0	0-12	94	91	81-88	63-69	37-47	19-24
	31-60	Very cobbly loam	CL, GC	A-6	5-10	40-46	65-78	62-75	53-69	41-54	29-38	13-18
116 Cabin	67% 0-4	Fine sandy loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0	93-100	93-100	79-93	46-56	26-35	5-12
	33% 4-12	Fine sandy loam	SC, SC-SM	A-4, A-6	0	0	93-100	93-100	78-91	41-50	26-35	5-12
	12-18	Gravelly sandy clay loam	SC	A-2-6, A-2-7	0	7-14	71-79	70-78	56-68	29-35	31-42	13-18
	18-23	Very cobbly sandy clay loam	SC	A-2-6, A-6	0	35-47	78-80	77-80	64-71	32-38	30-40	13-18
	23-60	Extremely gravelly loamy sand	GW-GM	A-1-a	0	25-35	25-40	20-30	10-25	5-10	0	NP

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
116:												
Silas	0-5	Silt loam	CL	A-6	0	0	100	100	94-98	86-90	33-42	14-18
	5-12	Silt loam	CL	A-6	0	0	100	100	93-97	85-89	33-42	14-18
	12-16	Silty clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	79-100	71-94	38-47	19-23
	16-23	Silty clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	78-100	71-93	38-47	19-23
	23-27	Silty clay loam	CL	A-6, A-7-6	0	0	92-100	91-100	89-100	80-92	38-47	19-23
	27-33	Silt loam	CL	A-6	0	0	84-100	83-100	77-96	67-85	33-40	15-18
	33-47	Clay loam	CL	A-6, A-7-6	0	0	81-100	80-100	74-97	63-82	37-44	19-23
	47-60	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	8-16	38-45	35-43	25-34	15-20	0-30	NP-10
124:												
Cryaquolls	0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
Cryoborolls	0-4	Loam	ML	A-6, A-7-6	0	0-3	82-100	81-100	71-92	53-69	37-48	12-17
	4-11	Loam	CL	A-6	0	0-3	82-91	81-90	70-82	52-61	33-42	14-18
	11-19	Very gravelly clay loam	GC	A-6, A-7-6	0	0-15	50-60	45-55	40-50	36-45	38-49	19-24
	19-27	Very cobbly clay loam	GC	A-6, A-7-6	0	24-31	56-65	55-64	47-59	36-45	37-47	19-24
	27-60	Very cobbly sandy clay loam	GC	A-2-6	0	30-40	52-61	50-60	42-55	26-35	31-41	15-21

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
125:												
Cryoboralfs	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	2-6	Stony silt loam	CL	A-6, A-7-6	25-30	0	100	100	93-97	82-86	34-44	15-18
	6-9	Stony clay loam	CL	A-6, A-7-6	24-37	0	100	100	90-93	70-73	38-45	19-21
	9-18	Very stony silty clay loam	CL	A-7-6	51-53	0	94-100	93-100	88-100	78-91	40-49	21-26
	18-62	Very stony clay	CH, CL	A-7-6	55-60	0	84-100	83-100	77-97	62-79	47-53	29-32
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
127:												
Cryochrepts	0-4	Very stony loam	GC	A-6	17-25	17-25	67-71	66-70	57-63	40-45	30-37	13-17
	4-10	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	8-15	15-25	47-54	44-52	32-42	20-28	0-31	NP-10
	10-17	Extremely cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	15-25	33-40	32-42	30-40	22-32	14-21	0-31	NP-10
	17-28	Extremely stony sandy loam	GC-GM, GM, GW-GC	A-1-a, A-2-4	33-40	46-52	26-36	23-33	16-26	9-16	0-30	NP-10
	28-38	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
128:												
Cryohemists	0-38	Mucky peat	PT	A-8	0	0	100	100	—	—	—	—
	38-60	Gravelly loam, loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0-5	70-100	65-95	60-90	45-80	24-41	7-17

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
128:												
Cryaquolls	0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
129:												
Cryumbrepts	0-3	Very cobbly loam	GM	A-2-4, A-2-6, A-4	0-15	15-30	55-75	50-70	45-60	30-40	29-45	5-15
	3-12	Very cobbly loam, very cobbly silt loam	GC, GC-GM	A-2-4, A-2-6, A-4	0-15	15-35	55-75	50-70	45-60	30-40	20-33	6-13
	12-16	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rock outcrop	0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rubble land	—	—	—	—	—	—	—	—	—	—	—	—
137:												
Endlich	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	2-9	Cobbly loam	CL, SC, SC-SM	A-4	0-1	18-22	78-86	77-85	64-78	45-56	21-31	6-12
	9-22	Very cobbly sandy loam	GC-GM, GM, SC-SM, SM	A-2-4, A-4	8-15	30-35	67-76	66-75	51-64	32-43	0-31	NP-10
	22-38	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	8-15	65-75	33-52	31-50	23-42	12-24	0-30	NP-10
	38-48	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
137: Hechtman	0-1	Moderately decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	1-3	Gravelly loam	SC, SC-SM	A-4	0	0-8	76-77	75-76	61-68	38-45	25-35	6-12
	3-11	Very gravelly sandy loam	GC-GM, GM	A-2-4	0	8-15	57-59	55-57	39-45	26-31	0-32	NP-10
	11-16	Extremely gravelly sandy loam	GM, GP-GC	A-1-a, A-2-4	0	8-15	26-33	23-31	17-26	9-14	0-31	NP-10
	16-26	Unweathered bedrock	---	---	---	---	---	---	---	---	---	---
140: Frisco	0-3	Highly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	3-15	Cobbly silt loam	CL, CL-ML	A-4	0	25-30	80-90	79-89	72-89	58-74	21-31	6-12
	15-20	Cobbly fine sandy loam	SC, SC-SM	A-4	0	25-30	80-90	79-89	68-84	40-50	20-31	6-12
	20-48	Very cobbly loam	SC, SC-SM	A-4	0	37-43	69-79	67-79	54-69	36-47	20-30	6-12
	48-63	Very gravelly fine sandy loam	GC, GC-GM	A-2-4	0	8-16	49-57	47-55	39-50	22-30	20-30	6-12
Agneston	0-3	Moderately decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	3-11	Cobbly loam	CL	A-6	0	19-23	81-89	76-84	66-79	51-60	28-37	12-17
	11-22	Very cobbly clay loam	CL, GC	A-6, A-7-6	0	32-37	69-79	64-74	57-69	44-54	37-43	19-22
	22-31	Very gravelly clay loam	GC	A-6, A-7-6	0	15-20	58-70	53-65	47-61	37-48	36-43	19-22
	31-41	Unweathered bedrock	---	---	---	---	---	---	---	---	---	---

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
142:												
Frisco	0-3	Highly decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	3-15	Cobbly silt loam	CL, CL-ML	A-4	0	25-30	80-90	79-89	72-89	58-74	21-31	6-12
	15-20	Cobbly fine sandy loam	SC, SC-SM	A-4	0	25-30	80-90	79-89	68-84	40-50	20-31	6-12
	20-48	Very cobbly loam	SC, SC-SM	A-4	0	37-43	69-79	67-79	54-69	36-47	20-30	6-12
	48-63	Very gravelly fine sandy loam	GC, GC-GM	A-2-4	0	8-16	49-57	47-55	39-50	22-30	20-30	6-12
Scout	0-2	Moderately decomposed plant material	PT	A-8	0	0	100	100	—	—	—	—
	2-13	Cobbly sandy loam	SC-SM, SM	A-2-4, A-4	0	25-29	71-81	70-80	52-66	31-42	0-31	NP-10
	13-26	Very cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	33-40	59-69	57-68	43-56	22-31	0-31	NP-10
	26-36	Very cobbly fine sandy loam	GC-GM, GM	A-2-4	0-9	33-40	57-61	55-60	50-59	23-30	0-31	NP-10
	36-62	Very cobbly sandy loam	GC-GM, GM	A-1-b, A-2-4	0-9	33-40	57-61	55-60	40-47	18-24	0-30	NP-10
153:												
Mirror	0-10	Very cobbly loam	CL, CL-ML	A-4	9-15	32-37	76-78	75-77	65-73	51-56	27-35	6-12
	10-21	Very cobbly loam	GC, GC-GM	A-2-4, A-4	9-14	37-44	54-65	53-64	44-59	31-43	22-35	6-12
	21-35	Very cobbly loam	GC, GC-GM	A-4	9-14	45-50	61-74	60-73	51-67	36-47	21-33	6-12
	35-45	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
153:												
Brisbin	50% 0-3	Gravelly silt loam	ML	A-4, A-6	0-9	0-9	74-76	73-75	64-72	51-59	29-46	5-12
	50% 3-8	Very gravelly loam	GC, GC-GM	A-4, A-6	17-25	17-25	61-71	59-70	49-63	36-45	25-35	6-12
	8-12	Very gravelly sandy loam	GC-GM, GM	A-2-4	17-25	17-25	61-71	59-70	43-56	26-35	0-34	NP-10
	12-26	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	26-30	18-25	43-52	41-50	28-38	15-22	0-34	NP-10
	26-32	Very stony sandy loam	SC-SM, SM	A-2-4	32-38	17-25	65-77	64-76	45-59	25-35	0-33	NP-10
	32-60	Very stony sandy loam	GC-GM, GM	A-1-b, A-2-4	30-35	17-25	53-65	51-64	38-52	19-29	0-31	NP-10
154:												
Mirror	100% 0-10	Very cobbly loam	CL, CL-ML	A-4	9-15	32-37	76-78	75-77	65-73	51-56	27-35	6-12
	10-21	Very cobbly loam	GC, GC-GM	A-2-4, A-4	9-14	37-44	54-65	53-64	44-59	31-43	22-35	6-12
	21-35	Very cobbly loam	GC, GC-GM	A-4	9-14	45-50	61-74	60-73	51-67	36-47	21-33	6-12
	35-45	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Teewinot	100% 0-7	Very stony sandy loam	SC-SM, SM	A-2-4	32-38	25-32	72-75	70-74	52-60	26-33	0-34	NP-10
	7-18	Extremely cobbly sandy loam	GM, GW-GC, GW-GM	A-1-a, A-2-4	8-15	44-50	30-41	27-38	20-31	10-16	0-33	NP-10
	18-28	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
157:												
Quander	0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
160:												
Quander	0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
Bushvalley	0-4	Very cobbly coarse sandy loam	GC, SC	A-2-4, A-2-6	0-9	30-35	61-71	59-70	39-49	27-35	29-38	9-13
	4-13	Very cobbly clay loam	GC	A-2-7, A-7-6	8-13	30-37	51-60	49-59	42-54	31-41	38-49	19-24
	13-23	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
161:												
Quander	100% 0-6	Gravelly loam	CL, SC	A-6, A-7-6	0-2	8-15	72-80	71-79	60-70	43-55	33-45	13-18
	6-10	Gravelly clay loam	GC	A-6, A-7-6	0	8-17	60-66	59-65	52-61	39-46	39-49	18-22
	10-20	Very cobbly clay loam	GC	A-6, A-7-6	0	40-46	66-77	64-76	56-70	41-50	38-47	20-24
	20-36	Very cobbly sandy clay loam	GC	A-2-6	0-9	25-30	52-61	50-60	42-54	26-35	31-39	15-19
	36-60	Very cobbly sandy loam	GC, GC-GM	A-2-4, A-2-6	0-4	25-30	43-54	41-52	30-42	19-27	22-31	7-12
Cryaquolls	100% 0-6	Silt loam	ML	A-6, A-7-6	0	0	77-90	76-89	71-89	65-82	36-50	12-18
	6-17	Silty clay loam	CL	A-7-6	0	0	79-91	78-90	76-90	69-83	39-50	19-22
	17-60	Very gravelly silt loam	GC	A-2-6, A-6	0	0	40-49	37-47	34-45	30-40	32-42	13-18
Cryohemists	100% 0-38	Mucky peat	PT	A-8	0	0	100	100	—	—	—	—
	38-60	Gravelly loam, loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0-5	70-100	65-95	60-90	45-80	24-41	7-17
162:												
Rock outcrop	100% 0-60	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—
Rubble land	—	—	—	—	—	—	—	—	—	—	—	—

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
165: Seitz	0-2	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	2-7	Cobbly loam	CL	A-6	0	15-30	83-93	80-90	65-75	51-54	29-42	12-18
	7-11	Cobbly loam	CL	A-6	0	15-30	83-93	80-90	65-75	51-54	29-42	12-18
	11-19	Very cobbly clay	CH	A-7-6	0	50-55	85-100	84-100	77-95	59-74	51-56	29-32
	19-28	Very cobbly clay loam	CL	A-7-6	0	42-50	75-87	74-87	66-81	51-62	45-50	25-28
	28-42	Very cobbly clay loam	GC	A-7-6	0	30-42	58-73	55-70	50-65	40-50	44-50	25-28
	42-62	Cobbly clay loam	CL, GC	A-6, A-7-6	0	15-25	71-80	70-80	61-75	45-56	37-45	19-24
174: Youga	0-5	Cobbly loam	CL	A-6, A-7-6	0	15-25	83-93	80-90	75-85	55-60	33-44	13-18
	5-10	Cobbly clay loam	CL	A-6, A-7-6	0	15-25	83-93	80-90	75-85	65-70	39-49	19-23
	10-23	Cobbly clay loam	CL	A-7-6	0	15-25	83-93	80-90	75-85	65-70	40-48	21-24
	23-28	Cobbly sandy loam	SC-SM, SM	A-4	0	15-25	83-93	80-90	65-70	36-40	0-30	NP-10
	28-60	Very gravelly sandy loam	GC-GM, GM	A-1-b, A-2-4	0	0-10	41-54	38-50	32-40	18-23	0-30	NP-10
Gateview	0-4	Cobbly loam	CL, CL-ML	A-4	0	17-25	81-90	80-90	69-84	51-63	25-34	6-10
	4-13	Cobbly loam	SC, SC-SM	A-4	0	17-25	72-82	71-81	60-73	42-53	25-34	6-10
	13-16	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	0	40-46	30-38	27-36	20-29	13-19	0-33	NP-10
	16-24	Extremely cobbly sandy loam	GC-GM, GM	A-1-a, A-2-4	0	40-46	30-38	27-36	20-29	12-18	0-33	NP-10
	24-60	Extremely cobbly sandy loam	GM, GP-GM	A-1-a, A-2-4	0	46-52	26-36	23-33	18-27	11-17	0-31	NP-10

Engineering Properties

Rio Grande NF Area, Colorado, West Part, Parts of Archuleta, Conejos, Hinsdale, Mineral, Rio Grande, Saguache, and San Juan Counties

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
W:												
Water 1086	—	—	—	—	—	—	—	—	—	—	—	—

Appendix C

Appendix C
Precipitation Calculations

URS CALCULATION COVER SHEET

Project Name:	*Continental dam*	**Project Number:**	*22241248*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	ED TOMS	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Chad Martin

Calculation to be checked: *Probable Maximum Precipitation (PMP) – HMR-55A*

Calculation Originator: *Drew Luebke*

Checker's comments required by:

Submitted by: _____ 6/9/10

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☒ All items have been found to be correct. Checker has no comments.

_____ 6/3/2010

Checker Signature **Date**

or

B. ☐ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

_____ _____

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ 6/9/10

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose:

Determine the probable maximum precipitation (PMP) for the general and local storm events in the Continental Dam watershed using HMR 55A.

References:

NOAA, USACE, and USBR. *Hydrometeorological Report No. 55A*. Silver Spring, MD. June 1988.

NOAA, U.S. Department of Commerce, National Weather Service, *NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Silver Spring, MD. 2004, revised 2006.*

General Storm Estimate:

The steps taken to calculate the general storm PMP, as described in HMR 55A, are in the table below. Each step will be discussed individually.

Step	Description							
1	CATCHMENT AREA	50.12						
2	DURATION (HR)	0	1	6	24	72		
	PMP (in.)	0	4.5	8.1	17	22		
3	SUBREGION AND SUBDIVISION							
	100% Sheltered Orthographic (D)	1.00						
4	AREAL REDUCTION FACTORS							
	DURATION		1	6	24	72		
	100% Sheltered Orthographic (D)		82.0%	89.0%	91.0%	92.0%		
	WEIGHTED PERCENTAGE							
	100% Sheltered Orthographic (D)		82.0%	89.0%	91.0%	92.0%		
5	AVERAGE PMP ESTIMATES	0	3.69	7.21	15.47	20.24		
6	DEPTH DURATION CURVE							
7	PMP ESTIMATES FOR INTERMEDIATE DURATIONS							
	DURATION (HR)	1	6	12	18	24	30	36
	PMP (in.)	3.7	7.2	11.0	13.9	15.5	16.5	17.1
	DURATION (HR)	42	48	54	60	66	72	
	PMP (in.)	17.8	18.2	18.7	19.2	19.8	20.2	
8	INCREMENTAL PMP ESTIMATES							

Duration (hr)	Incr. Precip (in)	Cum. Precip (in)
0	0	0
1	**3.7**	**3.7**
6	**3.5**	**7.2**
12	3.8	11.0
18	2.9	13.9
24	**1.6**	**15.5**
30	1.0	16.5
36	0.6	17.1
42	0.7	17.8
48	0.4	18.2
54	0.5	18.7
60	0.5	19.2
66	0.6	19.8
72	**0.4**	**20.2**

Step #1: The basin catchment area is 50.12 square miles, calculated using Geographic Information System (GIS) software. USGS quadrangle maps (1:24,000 scale) were used to perform the delineation.

Step #2: Unadjusted PMP values were obtained from HMR 55A plates Ib, IIb, IIIb, and IVb (attached) for durations of 1, 6, 24, and 72 hours, respectively. The location of Continental Dam is shown on each plate.

Step #3: The subregions and subdivisions of the watershed were determined using HMR 55a Plate Vb. It was estimated that 100% lies within the Sheltered Orthographic subdivision (subregion "D"). A depiction of the orthographic boundary is presented below. Note that the boundary was manually drawn into GIS using Plate Vb in HMR-55A as a reference; therefore, the actual boundary line may vary.

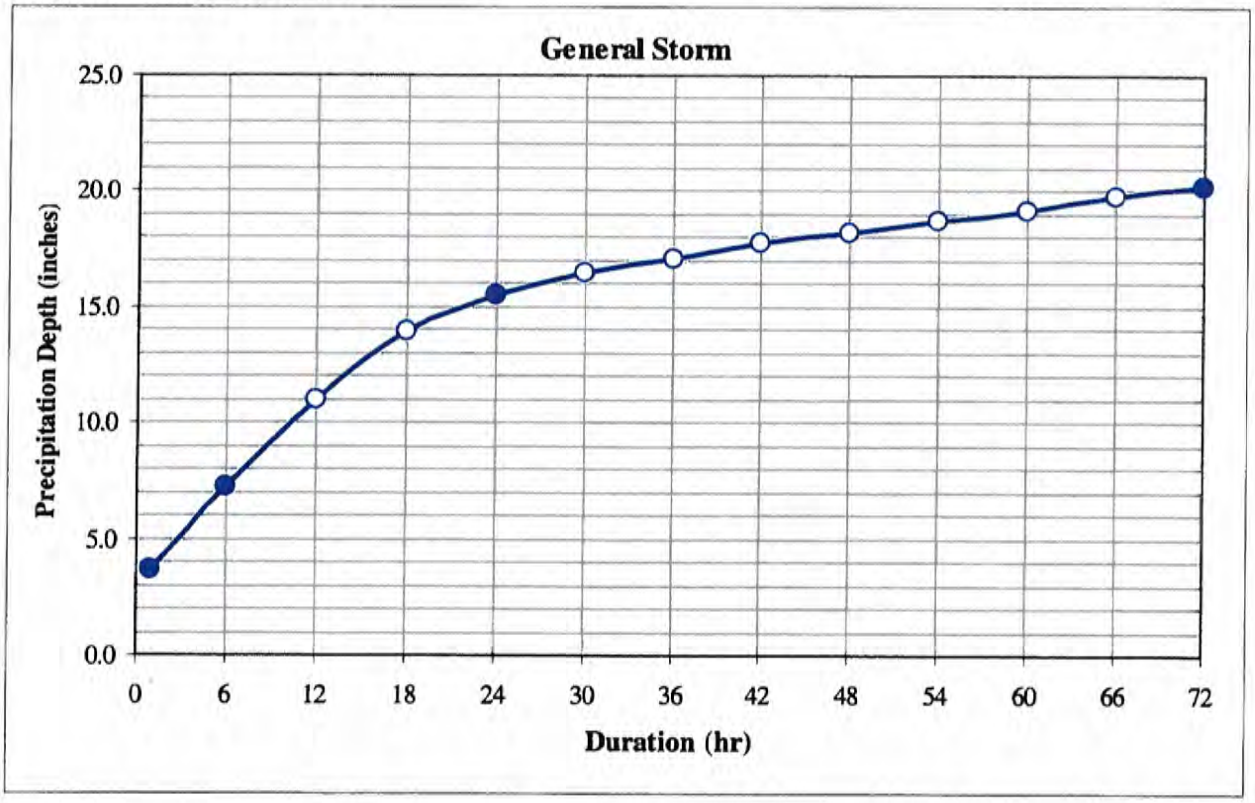
Step #4: The areal reduction factors were estimated using Figure 11.23 (attached) for a watershed area of 50.12 mi^2.

Step #5: The weighted average reduction factors were multiplied by the PMP amounts (from Step #2) at each duration to obtain average PMP estimates.

Step #6: A depth duration curve (shown on the following page) was created based upon the average PMP estimates from Step #5. This plot is shown below with duration in hours on the x-axis and cumulative precipitation in inches on the y-axis.

Step #7: PMP values were interpolated using the depth duration curve to estimate precipitation amounts every 6 hours. The values indicated with a hollow marker symbol (shown on the following page) were obtained from the interpolation process.

The final HMR 55A general storm PMP curve is shown on the following page with duration in hours on the x-axis and precipitation in inches on the y-axis.



Duration (hr)	Incr. Precip (in)	Cum. Precip (in)
0	0	0
1	**3.7**	**3.7**
6	**3.5**	**7.2**
12	3.8	11.0
18	2.9	13.9
24	**1.6**	**15.5**
30	1.0	16.5
36	0.6	17.1
42	0.7	17.8
48	0.4	18.2
54	0.5	18.7
60	0.5	19.2
66	0.6	19.8
72	**0.4**	**20.2**

The 5- and 15-min depths were estimated using Colorado's "Dam Safety Project Review Guide" (1994)

Duration	5 min.	15 min.
Ratio	38% of 15-min	45% of 1-hr
Rainfall Depth	.63	1.67

Local Storm Estimate:

The steps taken to calculate the local storm PMP are in the table below. Each step will be discussed individually.

Steps	Description	Quantities
1	INDEX ESTIMATE AT 5000ft ELEV. REFER TO PLATE VI b.	9.7 inches
2	ADJUSTMENT FOR MEAN ELEVEATION OF DRAINAGE REFER TO FIGURE 4.11 (p.80) REFER TO FIGURE 14.3 (p.219)	76.7 degrees F 56.0% AT ELEV. OF 11,400 ft.
3	INDEX PMP ESTIMATE AT MEAN ELVEVATION OF DRAINAGE	5.4 inches
4	DEPTH DURATION CURVE REFER TO TABLE 12.4 (p.200)	DURATION / PERCENT OF 1HR / PMP EST. 0.25 / 0.68 / 3.7 0.5 / 0.86 / 4.7 0.75 / 0.94 / 5.1 1 / 1 / 5.4 2 / 1.16 / 6.3 3 / 1.23 / 6.7 4 / 1.28 / 7.0 5 / 1.32 / 7.2 6 / 1.35 / 7.3
5	AREAL REDUCTION FACTOR REFER TO FIGURE 12.12 (p.203)	DURATION / REDUCTION FACTOR 0.25 / 47.0% 0.5 / 53.0% 0.75 / 57.0% 1 / 60.5% 2 / 65.0% 3 / 67.0% 4 / 69.5% 5 / 71.0% 6 / 72.0%

Step #1: The index precipitation depth estimate for the basin was obtained using Plate VIb (attached).

Step #2: Adjustments for the mean elevation of the basin (~~10,272~~ 11,400 feet) were determined using HMR 55A graphs. The mean elevation was estimated using GIS by calculating the average elevation of watershed USGS 10m DEM data. Figure 4.12 was used to determine the maximum dew point for August (August gives the largest dew point). The mean basin elevation and the dew point, obtained from Figure 4.11, were used on Figure 14.3 to determine the elevation adjustment percentage. These figures are attached.

Step #3: The elevation adjustment percentage (from Step #2) was then multiplied by the index estimate precipitation (from Step #1) to obtained an index estimate at the mean elevation of the drainage. This product is equal to 5.4 inches.

Step #4: A depth duration curve was then calculated. The precipitation percentages for each listed duration in Table 12.4 was multiplied by the index estimate at the mean elevation of drainage (5.4 inches) to develop the depth duration curve.

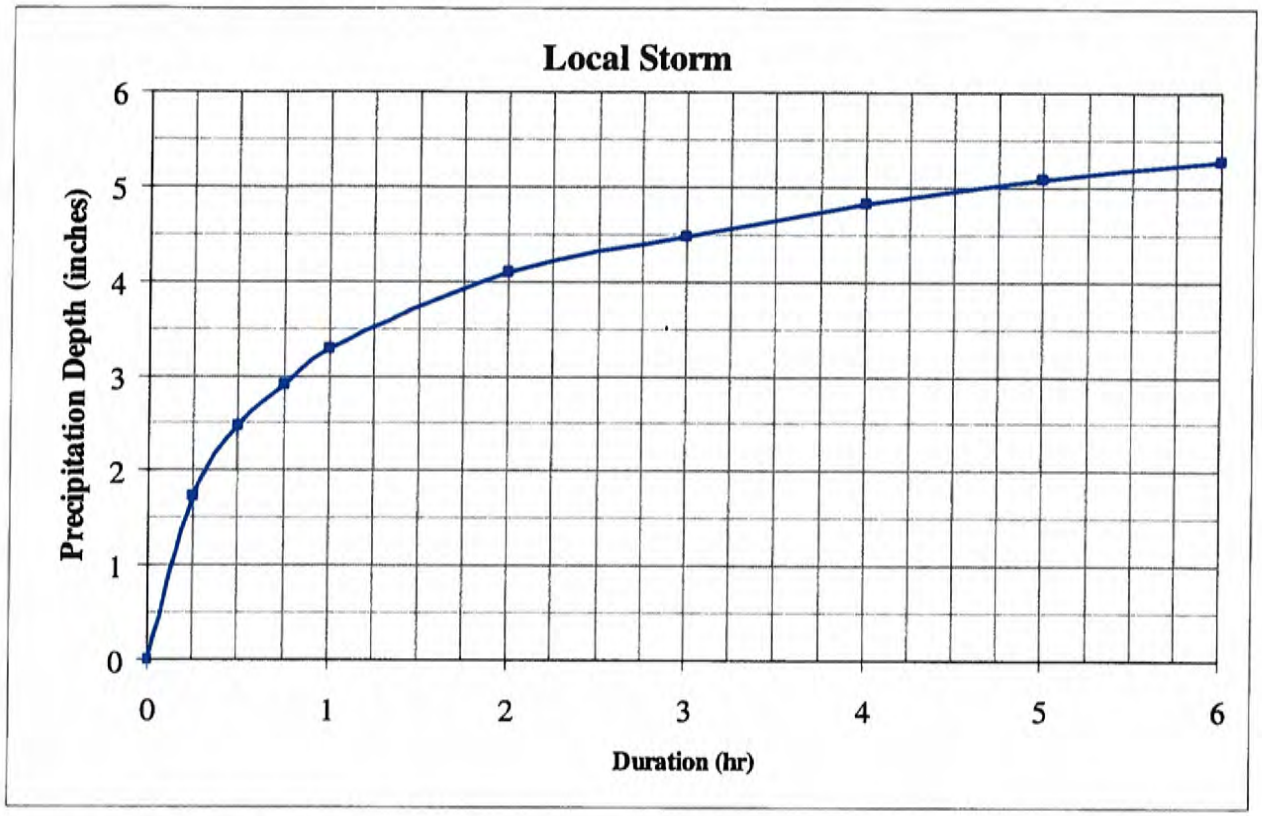
Table 12.4.--Percent of 1-hr local-storm PMP for selected durations for 6-/1-hr ratio of 1.35 (HMR No. 49)

Duration (hr)	Percent of 1 hr
1/4	.68
1/2	.86
3/4	.94
1	1.00
2	1.16
3	1.23
4	1.28
5	1.32
6	1.35

Step #5: Areal reduction factors for each duration of the local storm were estimated using Figure 12.12 (attached) based upon the watershed area.

Step #6: The Areal reduction factors (from Step #5) were multiplied by the depth duration amounts for each duration (from Step #4) to estimate the final PMP values. A summary table of the final local storm PMP estimates is shown in the table below and presented in the graph below.

Duration (hr)	Cum PMP (in)
0	0
0.25	1.7
0.50	2.5
0.75	2.9
1	3.3
2	4.1
3	4.5
4	4.8
5	5.1
6	5.3



The 5- and 15-min depths were estimated using Colorado's "Dam Safety Project Review Guide" (1994)

Duration	5 min.
Ratio	45% of 15-min
Rainfall Depth	0.77 ✓

DAM SAFETY
PROJECT REVIEW GUIDE
[WEB PAGE VERSION]

September 23, 1994
(Third Revision June/1/2000)
(SUPERSEDES "Project Review Guide," Revised May 16, 1996)

This Guide is Subject to Change.
Prior to beginning a new project, call the office of the State Engineer for status of updates.

303-866-3581

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

Atlas No. 2; "Precipitation-Frequency Atlas of the Western United States, Vol III - Colorado" (NOAA-2) is generally used in lieu of site specific statistical studies.

e. The State Engineer uses the U. S. Army Corps of Engineers computer model HEC-1 for evaluating the Inflow Design Flood. The synthetic storm data that is entered into the HEC-1 computer program is determined from the "Depth-Duration Values" table as shown below. The data is entered on the "PH Record" or Hypothetical Storm Record.

FIGURE II-3
PRECIPITATION DEPTH-DURATION VALUES FOR HEC-1 "PH" RECORD

Source	Storm	5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr	48 hr
HMR-55A	GS	A	A	x	I	I	x	I	x	I
HMR-55A	LS	B	x	x	x	x	x	N	N	N
HMR-49	GS	*	*	C	C	C	x	x	x	x
HMR-49	LS	B	x	x	x	x	x	N	N	N
HMR-51/52	GS	x	x	x	I	I	I	x	x	x
NOAA-2	ALL	x	x	x	x	x	x	x	x	N

NOTES: For FIGURE II-3 "Precipitation Depth-Durations Values for HEC-1 "PH" Record.

By using the matrix in the above table and the index below a smooth depth-duration curve may be developed for the storm of interest.

GS: General Storm
LS: Local Storm
x : Precipitation value for this duration can be determined directly from the source publication.
N : Duration of storm not applicable to this series
I : Precipitation value is readily interpolated from a plotted depth-duration curve
A : Precipitation values for these durations computed by : 15 min = 45% of 1 hr; 5 min = 38% of 15 min
B : Precipitation value for this duration is computed by : 5 min = 45% of 15 min
C : Precipitation values for these durations computed by : 1 hr = 25% 6 hr; 2 hr = 48% 6 hr; 3 hr = 66% 6 hr.
* : No current recommendation; HMR-49 Local Storm is more critical for short duration precipitation.

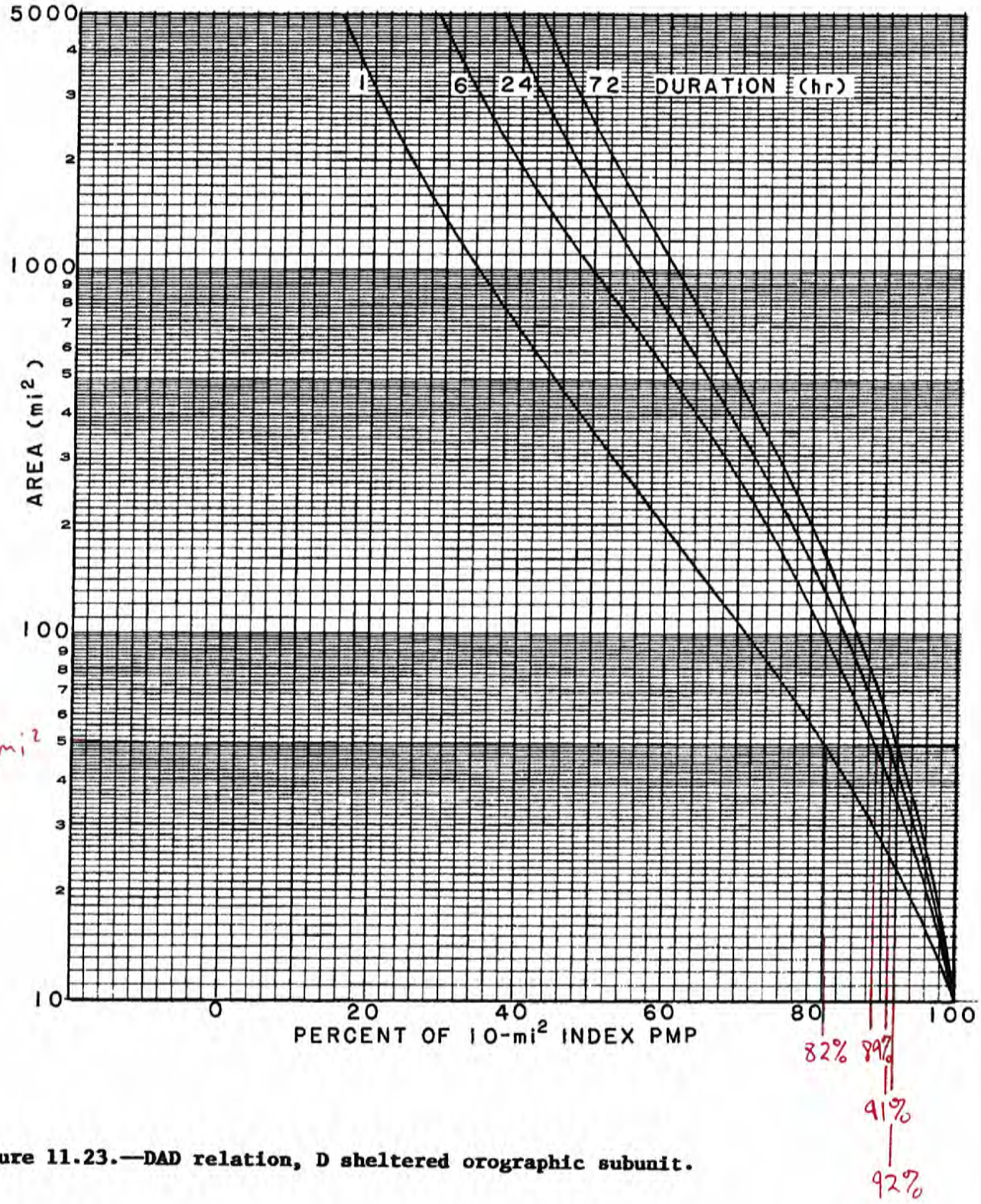


Figure 11.23.—DAD relation, D sheltered orographic subunit.

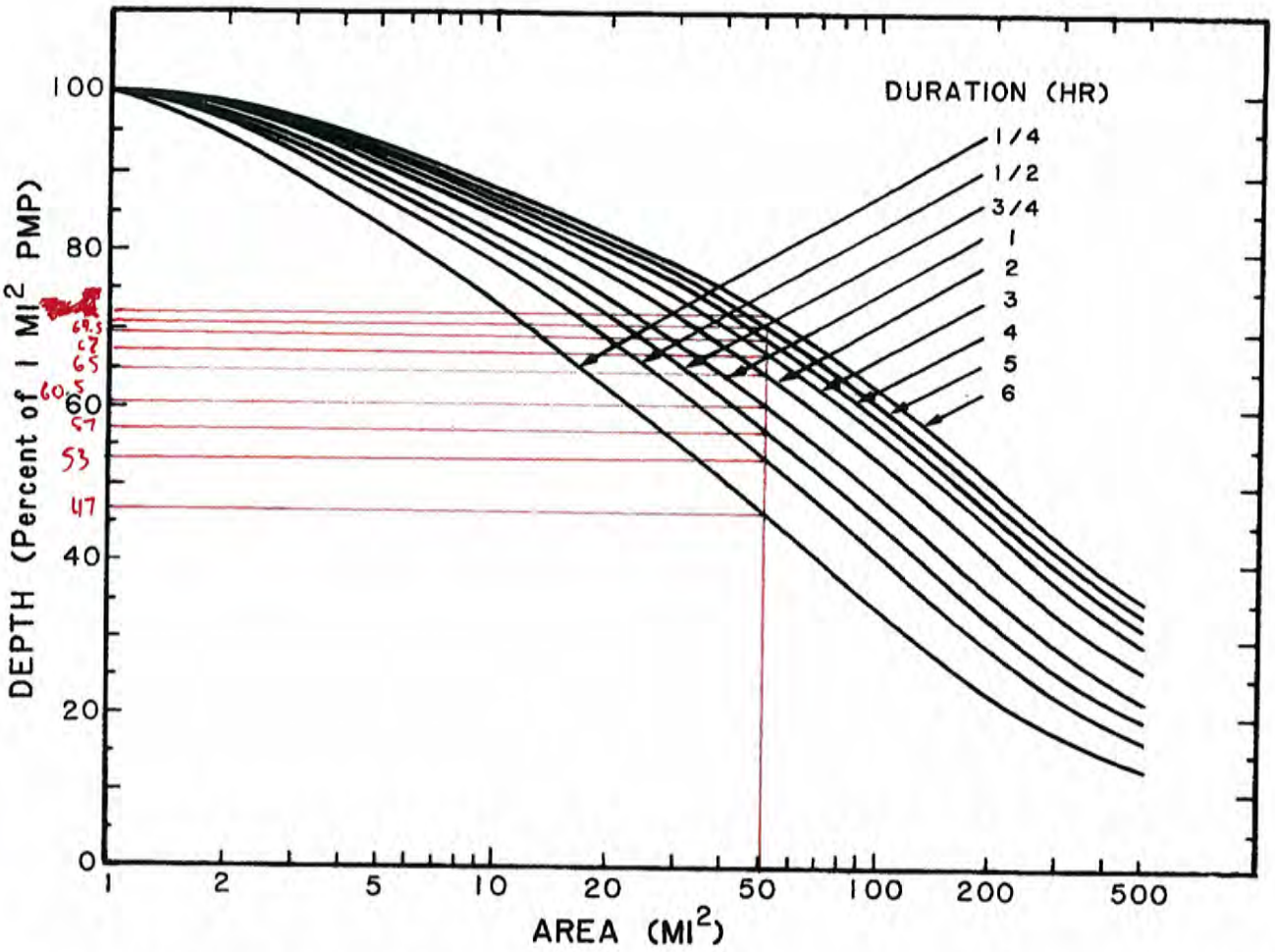


Figure 12.12.--Depth-area relations adopted for local-storm PMP in the CD-103 region (Hansen et al. 1977).

the storm in figure 12.9 that was constructed from a written account of the storm. The sequence of the hourly incremental rainfall for the storm shows that the storm decreased each succeeding hour after the first hour. However, meaningful conclusions cannot be drawn from this one example.

To supplement the lack of available data in the CD-103 region, data from HMR No. 49 was utilized. These data are presented in table 12.5 and include time distribution measurements from 6-hr storms, as utilized by the U.S. Weather Bureau (1947) and by the U.S. Army Corps of Engineers (1965). The choice of which of the two to apply is left to the user, as one sequence may be more critical than the other in a specific case.

There were no data available for the extreme local storms in the CD-103 region from which to determine the sequence of 15-min increments in the 1-hr storm. The 15-min incremental sequence taken from HMR No. 49 is, therefore, recommended. This incremental sequence appears in table 12.6. It is the result of percentages of total rainfall for thunderstorm rainfall determined by the U.S. Weather Bureau (1947).

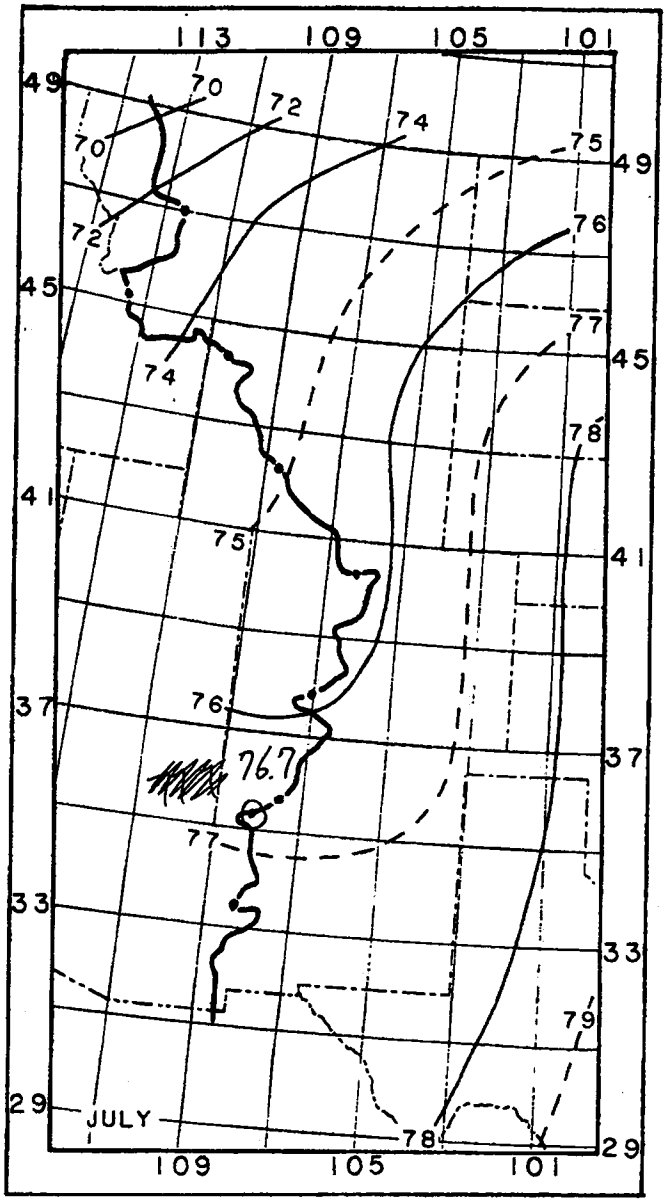


Figure 4.11.--Maximum persisting 12-hr 1000-mb dew points (°F) for July.

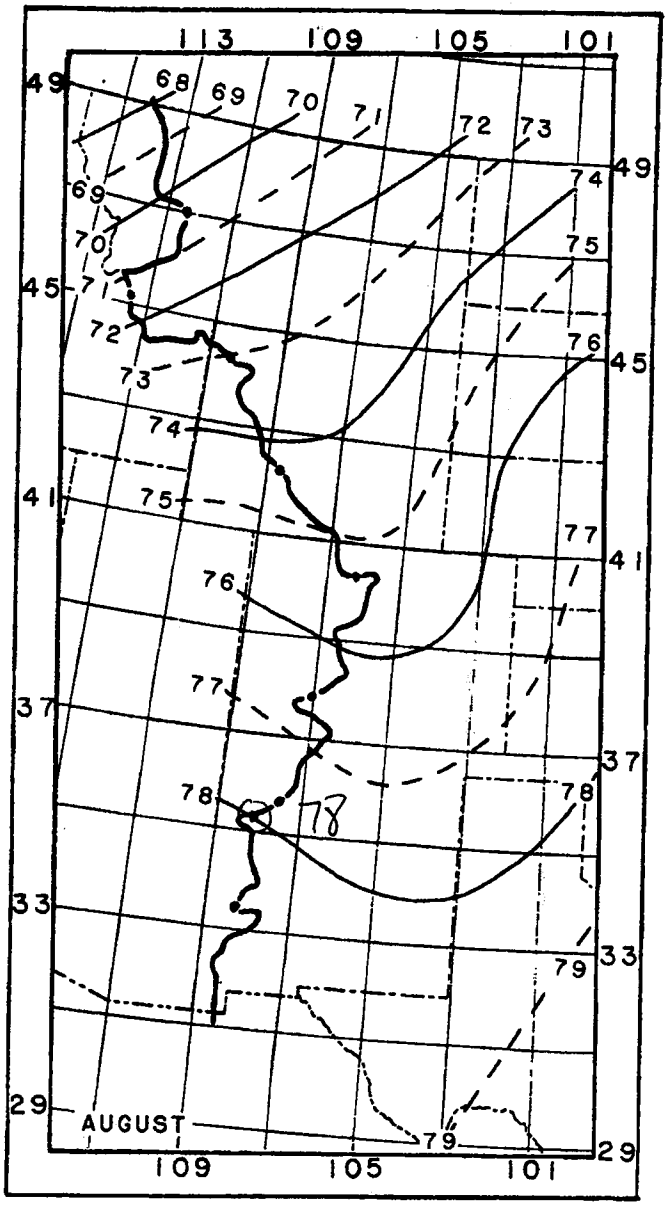


Figure 4.12.--Maximum persisting 12-hr 1000-mb dew points (°F) for August.

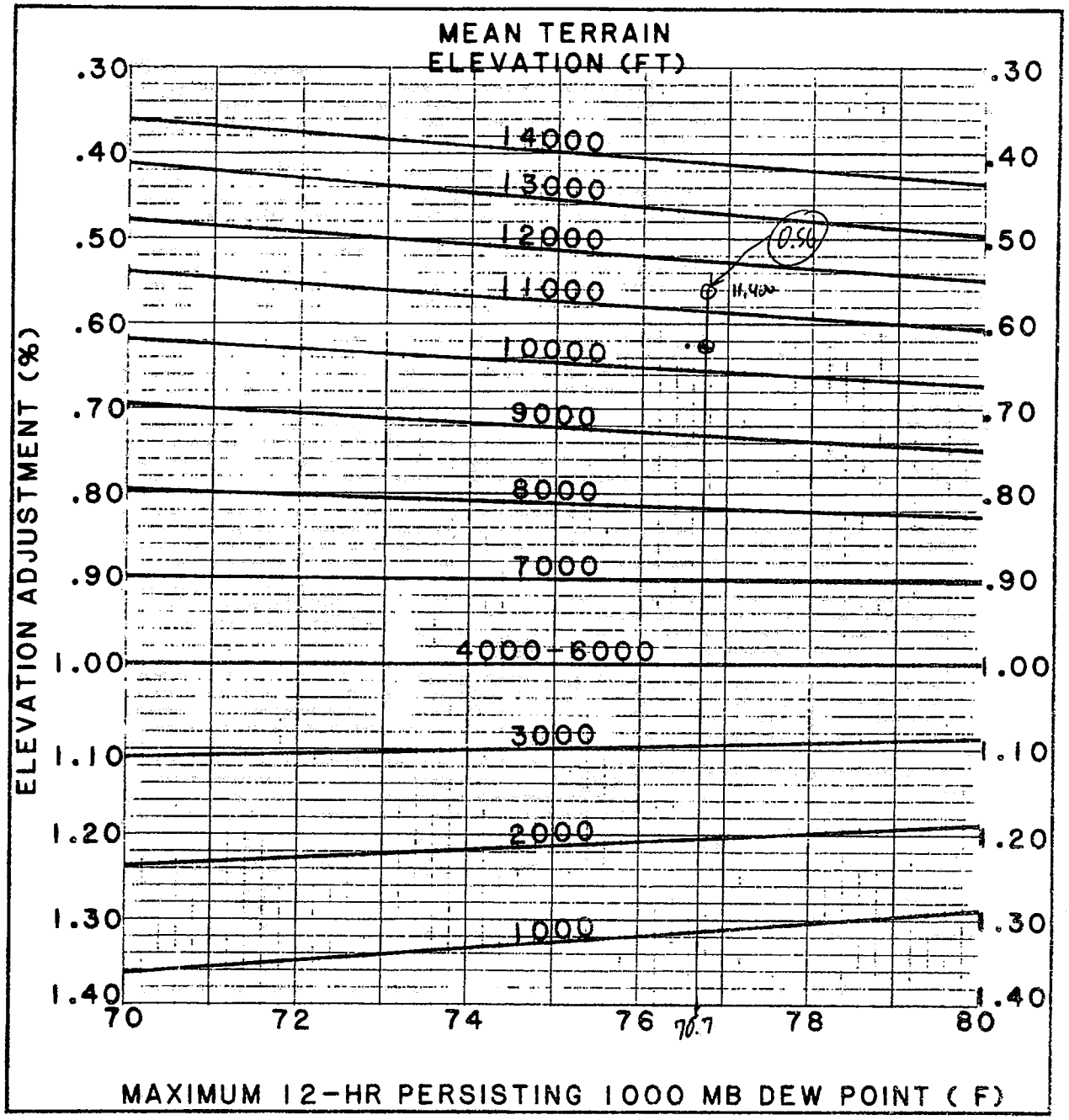
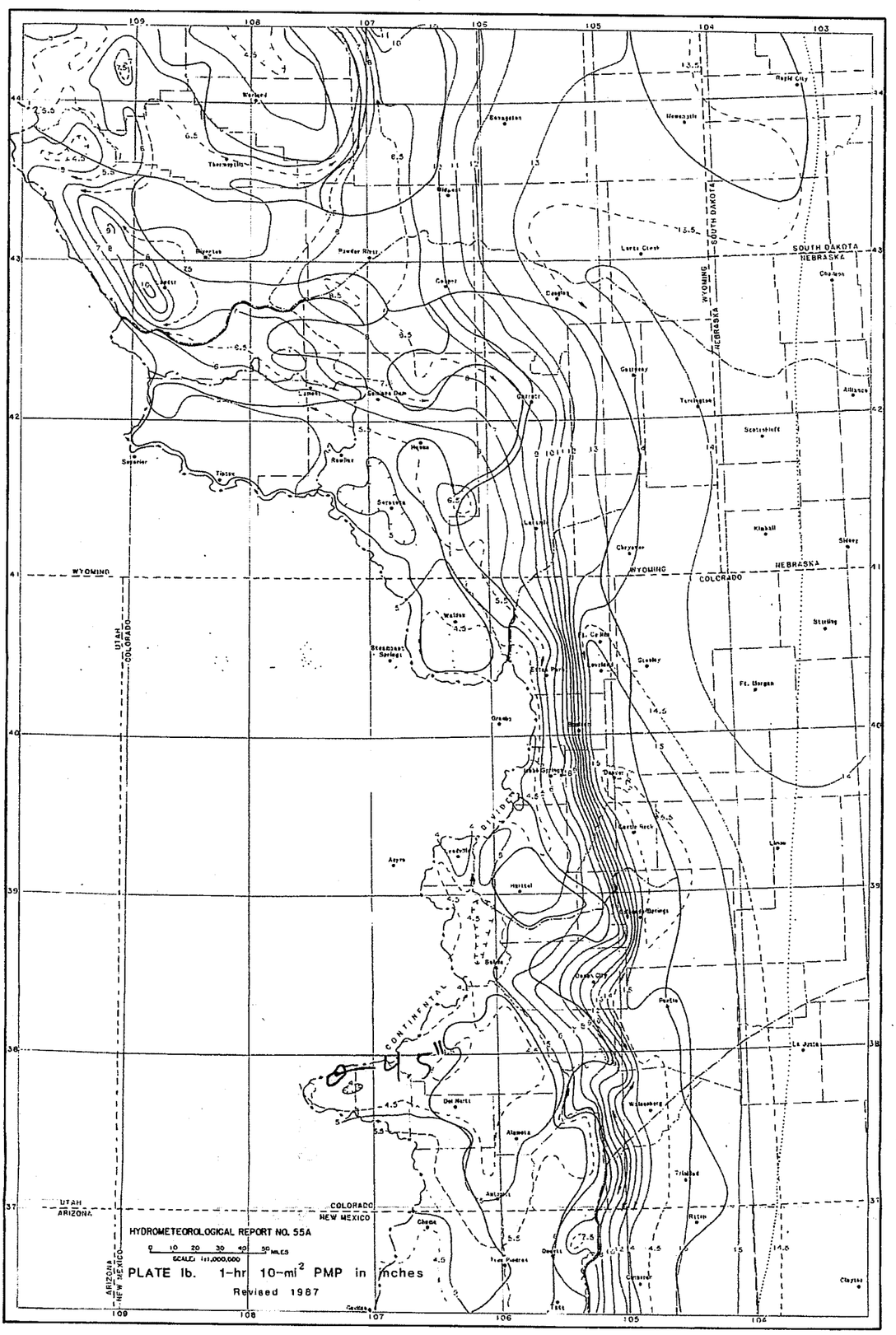
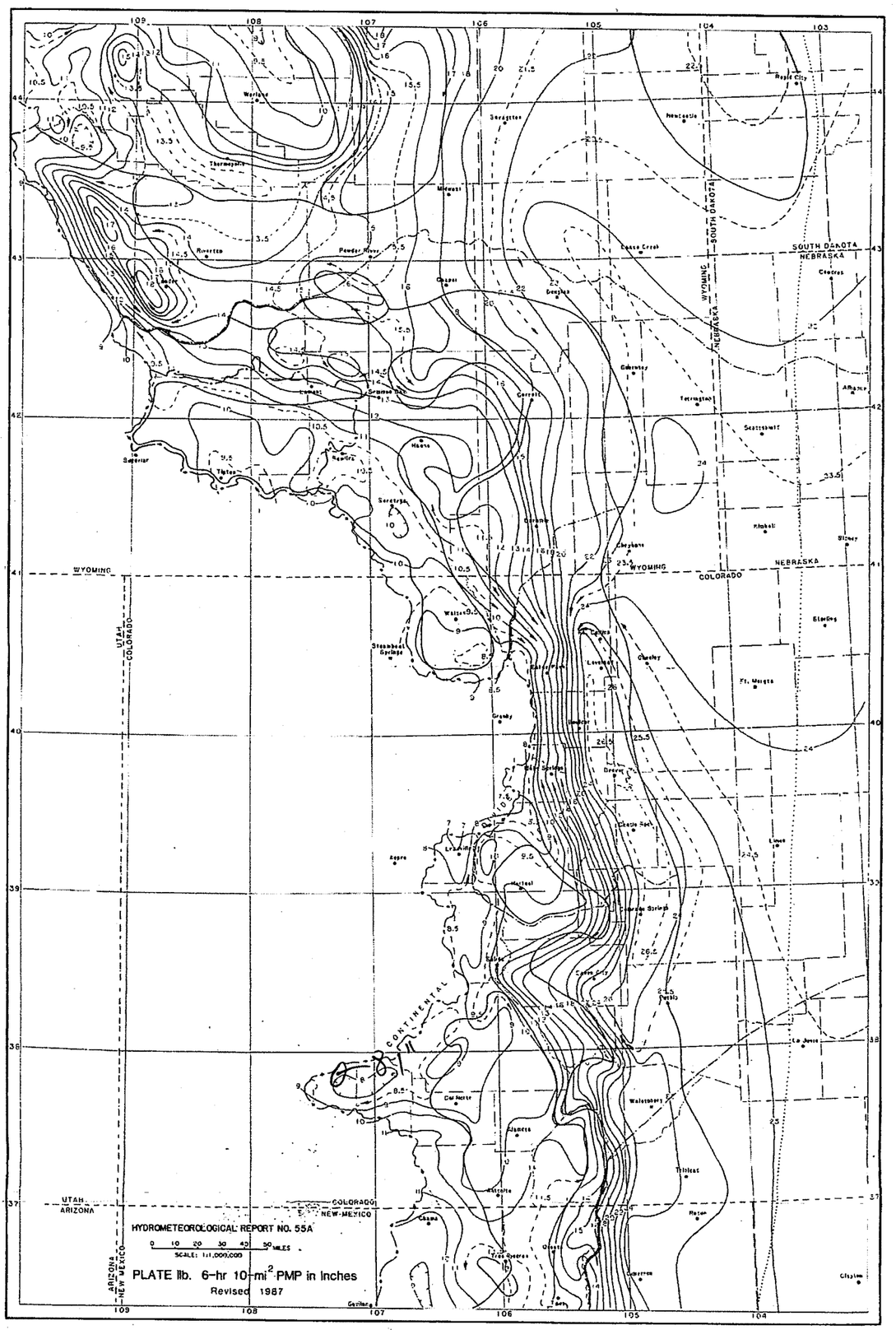
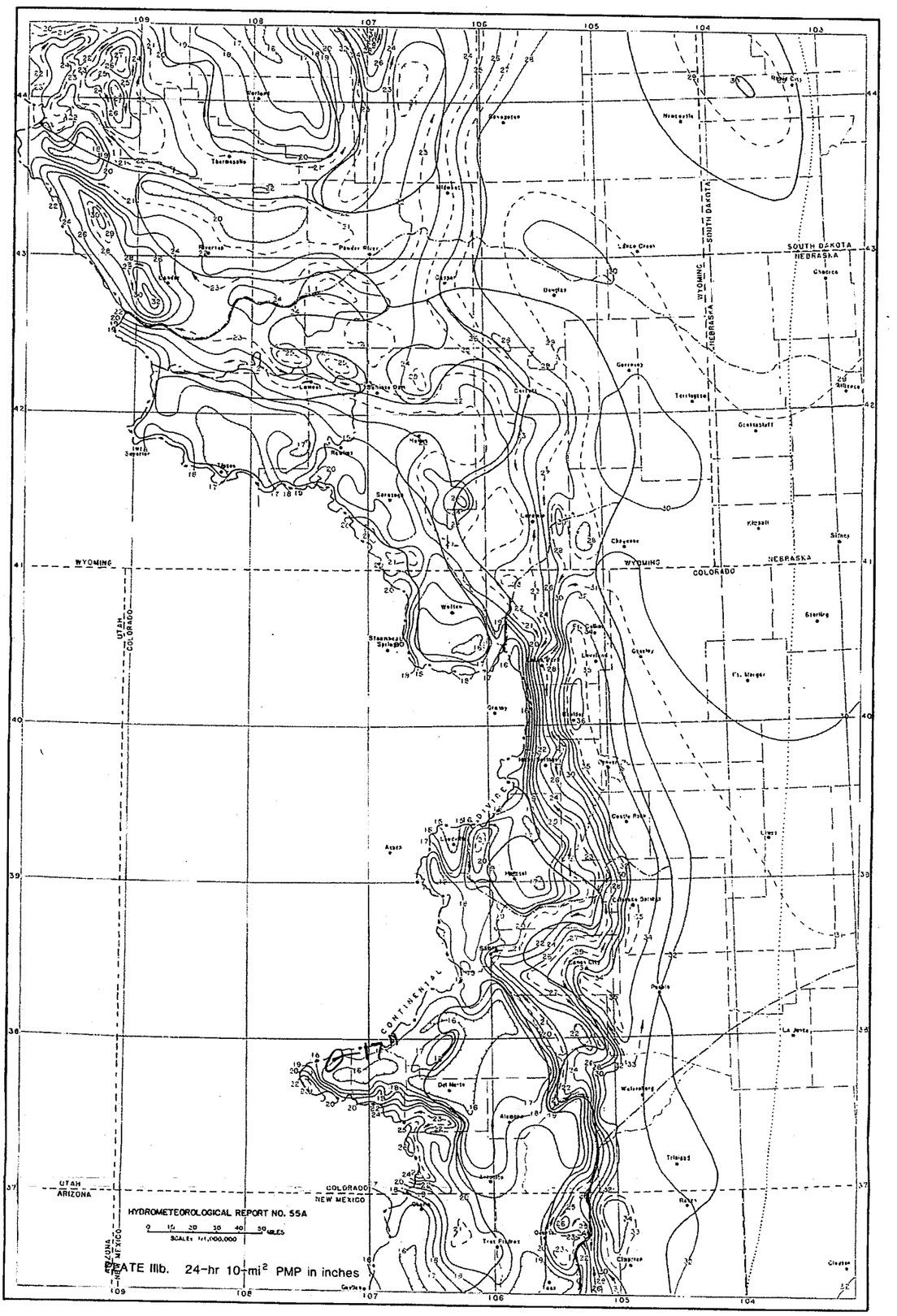


Figure 14.3.--Adjustment for elevation for local-storm PMP based on procedures developed in the report and maximum persisting 12-hr 1000-mb dew point (F).


WYOMING
COLORADO
NEBRASKA
SOUTH DAKOTA
UTAH
ARIZONA
NEW MEXICO
CONTINENTAL DIVIDE
HYDROMETEOROLOGICAL REPORT NO. 55A
0 10 20 30 40 50 MILES
SCALE: 1:1,000,000
PLATE Ib. 1-hr 10-mi² PMP in inches
Revised 1987


HYDROMETEOROLOGICAL REPORT NO. 55A
0 10 20 30 40 50 MILES
SCALE: 1:1,000,000
PLATE IIb. 6-hr 10-mi² PMP in Inches
Revised 1987
WYOMING
COLORADO
NEBRASKA
SOUTH DAKOTA
UTAH
ARIZONA
NEW MEXICO
CONTINENTAL


HYDROMETEOROLOGICAL REPORT NO. 55A
0 10 20 30 40 50 MILES
SCALE 1:1,000,000
STATE IIIb. 24-hr 10-mi² PMP in inches
WYOMING
COLORADO
NEBRASKA
SOUTH DAKOTA
UTAH
ARIZONA
NEW MEXICO
CONTINENTAL DIVIDE

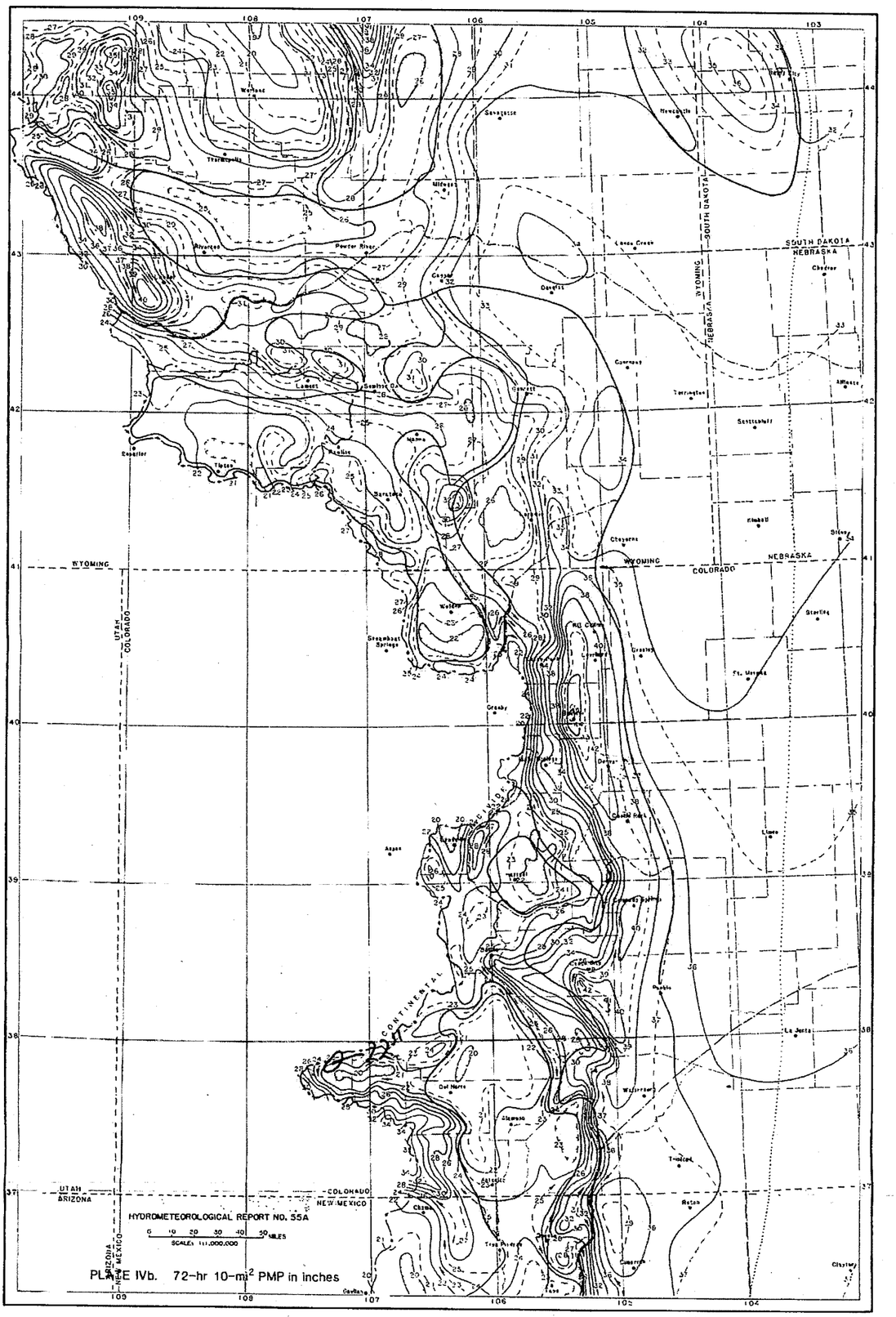
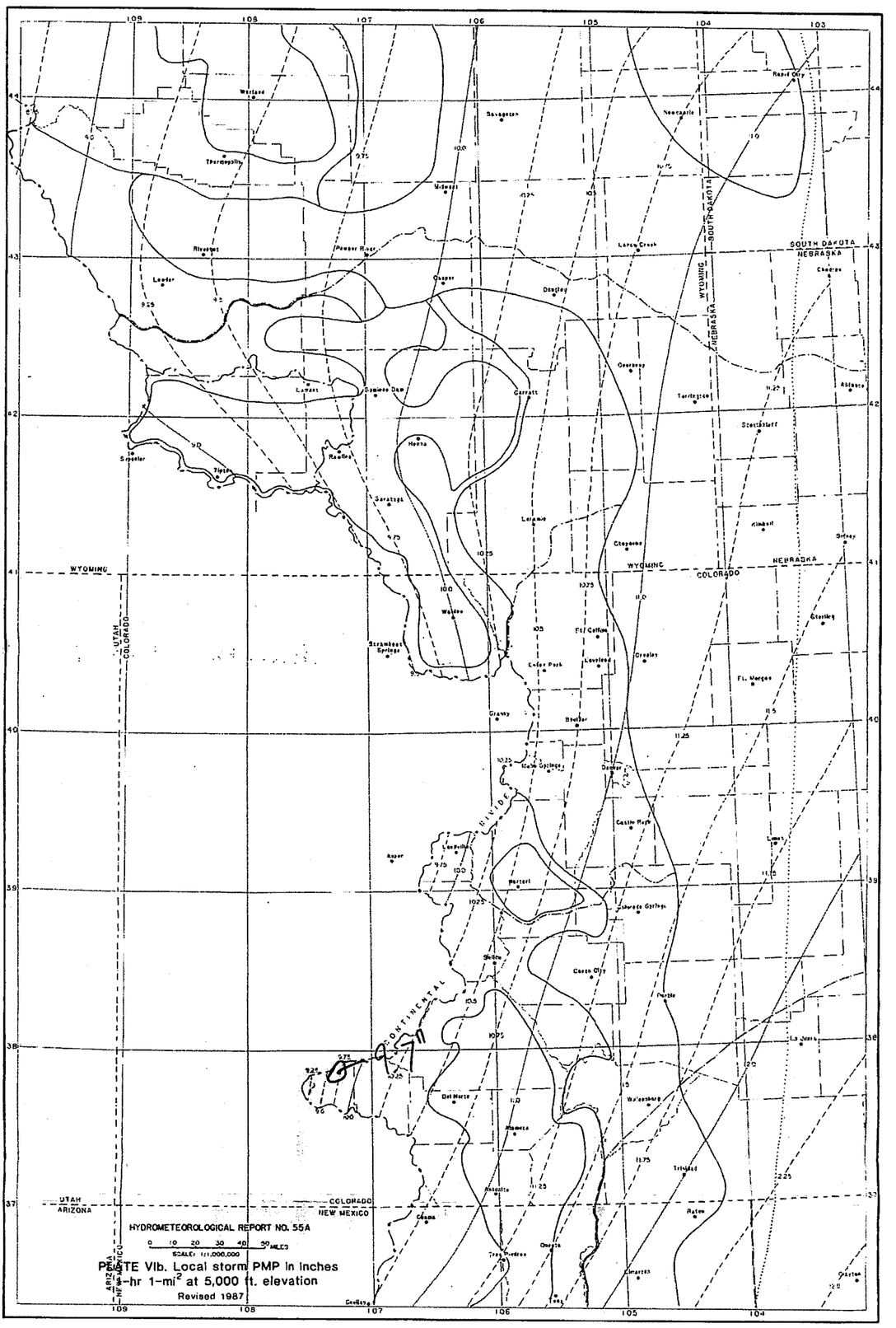


PLATE IVb. 72-hr 10-mi^2 PMP in inches

PLATE Vb. Regional limits for terrain classifications (heavy solid lines)


HYDROMETEOROLOGICAL REPORT NO. 55A
SCALE: 1:1,000,000
PLATE VIb. Local storm PMP in inches
1-hr 1-mi² at 5,000 ft. elevation
Revised 1987
WYOMING
COLORADO
NEBRASKA
SOUTH DAKOTA
UTAH
ARIZONA
NEW MEXICO
CONTINENTAL DIVIDE

URS CONTINENTAL E

CALCULATION COVER SHEET

Project Name:	Santa Maria	**Project Number:**	22241248
Project Location:	Mineral County, CO	**Client Name:**	Santa Maria Reservoir Co.
PM Name:	Ed Toms	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: CHAD MARTIN

Calculation to be checked: *EPAT – Continental*

Calculation Originator: *Jared Walter*

Checker's comments required by:

Submitted by: _____ 6/9/10

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☒ All items have been found to be correct. Checker has no comments.

_____ 6/8/2010

Checker Signature **Date**

or

B. ☐ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

_____ _____

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

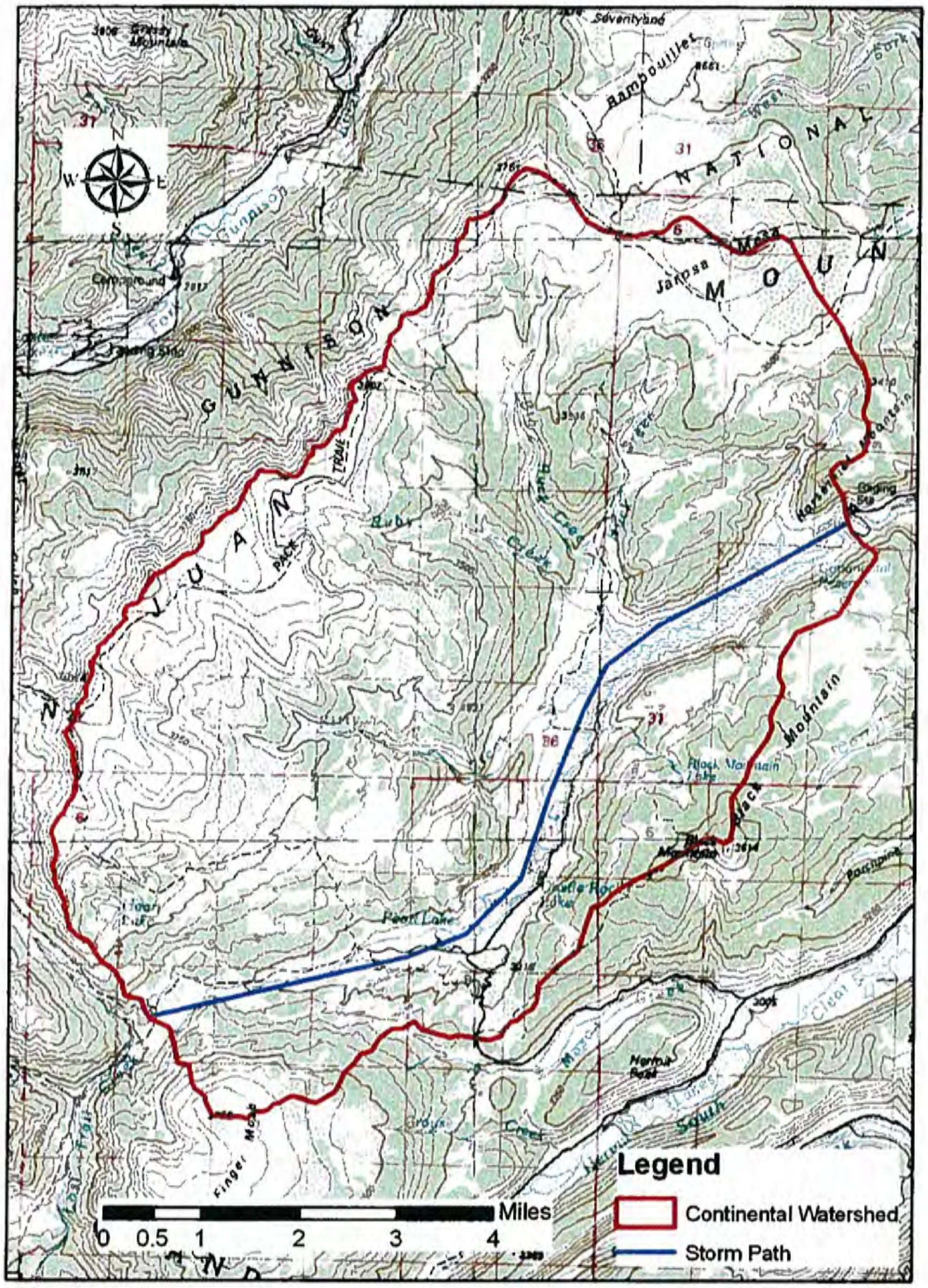
☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ 6/9/10

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder


Legend
Continental Watershed
Storm Path
Miles
0 0.5 1 2 3 4

EPAT Basin Analysis Results

Report Generated on 11/4/2009 at 2:20:15 PM

Project Name: Continental

General Storm Results: Palisade Lake

Original Event Historic Data

Storm ID:	23	**Storm Source:**	HMR
State:	CO	**Start Date:**	6/26/1927
Originator:	CSU Report	**End Date:**	6/29/1927
Low Level Wind:	190	**Elevation:**	9836
Cloud Level Wind:	190	**Col. Cen. X,Y:**	2457747.48136,870396.186761
Duration:	84		
Max Precipitation:	5.90" 84 hrs, Palisade Lakes		
Narrative:	Widespread heavy high elevation rain over SW CO		

EPAT Event Transposed and Maximized

EPAT Report Ranking:	1
Ideal Run #	4
Peak Rainfall (inches):	7.02
Total Rain Volume (acre feet):	18421.38

EPAT Event Basin Average Rainfall

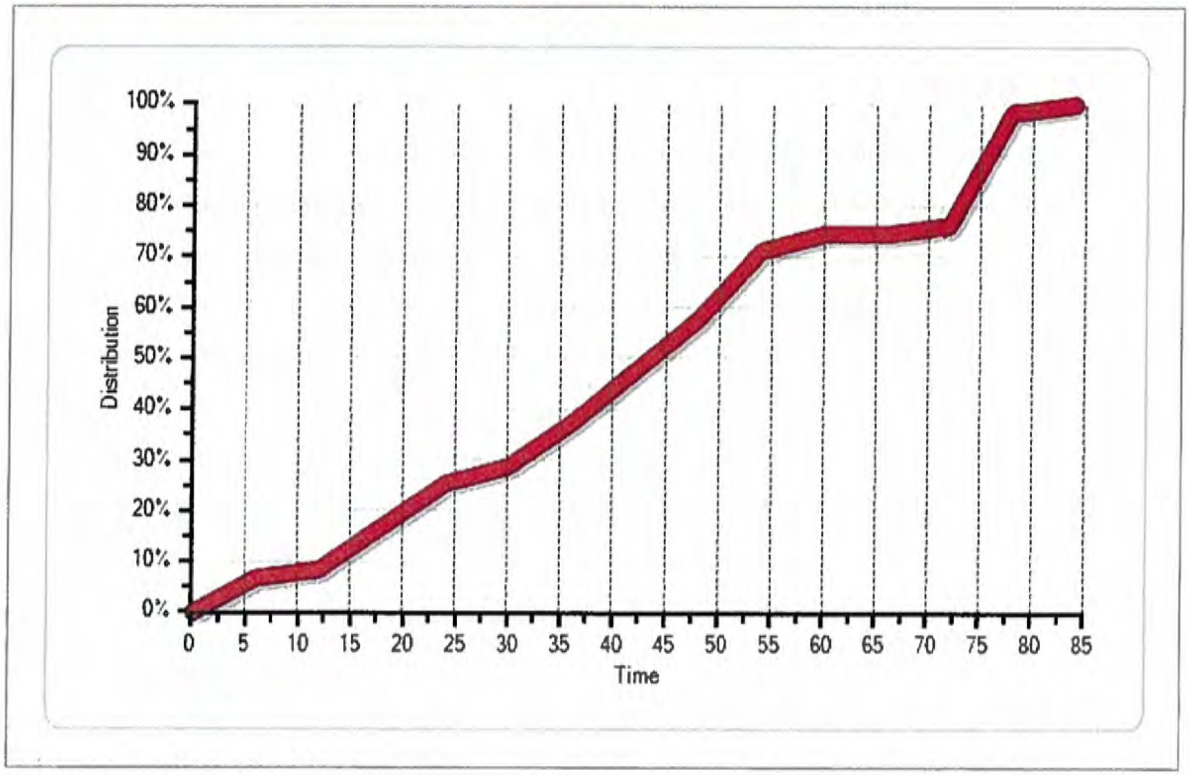
** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	6.89	50.14	18,424.78

Project Name: Continental

General Storm Results: Palisade Lake

EPAT Event Observed Temporal



(Time in Hours | Distribution %)

0	0.00%	1	1.13%	2	2.26%
3	3.39%	4	4.52%	5	5.65%
6	6.78%	7	7.06%	8	7.34%
9	7.63%	10	7.91%	11	8.19%
12	8.47%	13	9.89%	14	11.30%
15	12.71%	16	14.12%	17	15.54%
18	16.95%	19	18.36%	20	19.77%
21	21.19%	22	22.60%	23	24.01%
24	25.42%	25	25.99%	26	26.55%
27	27.12%	28	27.68%	29	28.25%
30	28.81%	31	30.23%	32	31.64%
33	33.05%	34	34.46%	35	35.88%
36	37.29%	37	38.98%	38	40.68%
39	42.37%	40	44.07%	41	45.76%
42	47.46%	43	49.15%	44	50.85%
45	52.54%	46	54.24%	47	55.93%

General Storm Results: Palisade Lake

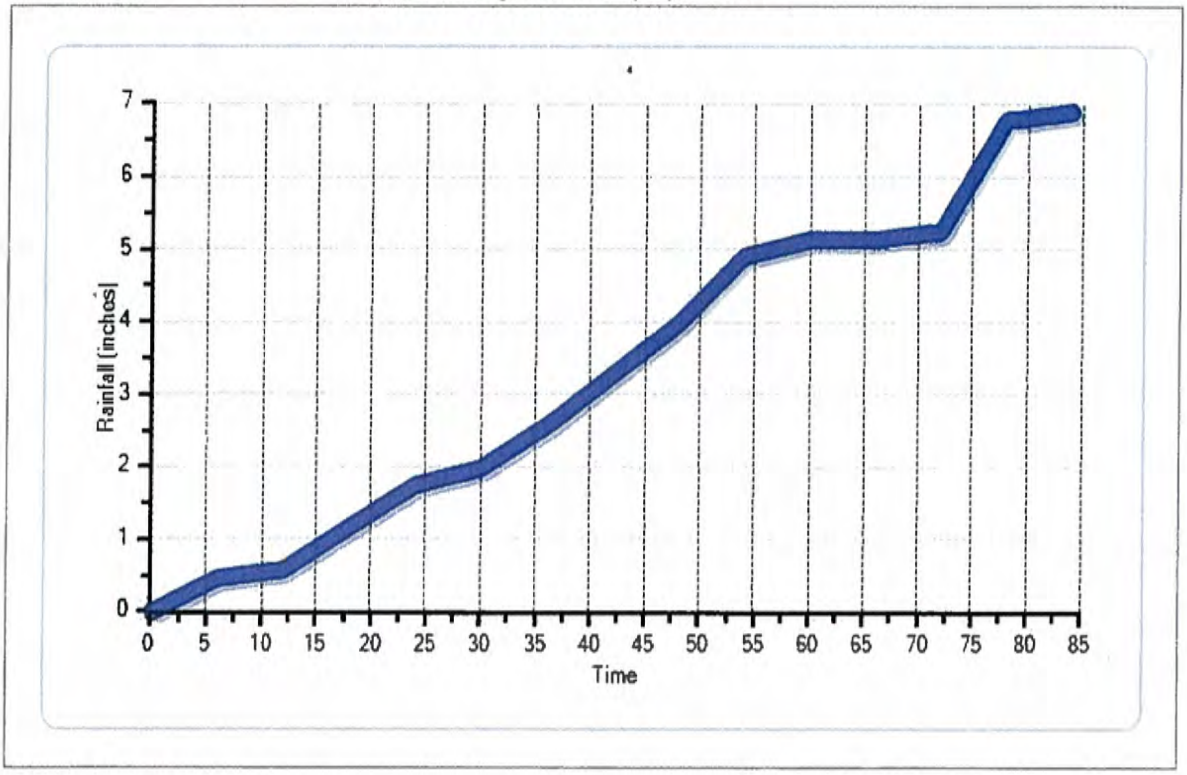
48	57.63%	49	59.89%	50	62.15%
51	64.41%	52	66.67%	53	68.93%
54	71.19%	55	71.75%	56	72.32%
57	72.88%	58	73.45%	59	74.01%
60	74.58%	61	74.58%	62	74.58%
63	74.58%	64	74.58%	65	74.58%
66	74.58%	67	74.86%	68	75.14%
69	75.42%	70	75.71%	71	75.99%
72	76.27%	73	79.94%	74	83.62%
75	87.29%	76	90.96%	77	94.63%
78	98.31%	79	98.59%	80	98.87%
81	99.15%	82	99.44%	83	99.72%
84	100.00%				

Project Name: Continental

General Storm Results: Palisade Lake

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 6.89



(Time in Hours | Rainfall in inches)

0	0.00	1	0.08	2	0.16
3	0.23	4	0.31	5	0.39
6	0.47	7	0.49	8	0.51
9	0.53	10	0.54	11	0.56
12	0.58	13	0.68	14	0.78
15	0.88	16	0.97	17	1.07
18	1.17	19	1.27	20	1.36
21	1.46	22	1.56	23	1.65
24	1.75	25	1.79	26	1.83
27	1.87	28	1.91	29	1.95
30	1.99	31	2.08	32	2.18
33	2.28	34	2.37	35	2.47

Project Name: Continental

General Storm Results: Palisade Lake

36	2.57	37	2.69	38	2.80
39	2.92	40	3.04	41	3.15
42	3.27	43	3.39	44	3.50
45	3.62	46	3.74	47	3.85
48	3.97	49	4.13	50	4.28
51	4.44	52	4.59	53	4.75
54	4.90	55	4.94	56	4.98
57	5.02	58	5.06	59	5.10
60	5.14	61	5.14	62	5.14
63	5.14	64	5.14	65	5.14
66	5.14	67	5.16	68	5.18
69	5.20	70	5.22	71	5.24
72	5.26	73	5.51	74	5.76
75	6.01	76	6.27	77	6.52
78	6.77	79	6.79	80	6.81
81	6.83	82	6.85	83	6.87
84	6.89				

Project Name: Continental

General Storm Results: SW CO / Wolf Creek

Original Event Historic Data

Storm ID:	28	**Storm Source:**	HMR
State:	CO	**Start Date:**	8/27/1993
Originator:	CSU Report	**End Date:**	8/30/1993
Low Level Wind:	215	**Elevation:**	10704
Cloud Level Wind:	215	**Col. Cen. X,Y:**	2647755.32161,863616.274583
Duration:	72		
Max Precipitation:	2.70" on 29th - Upper San Juan (5.60" storm total), 2.70" on 29th-Wolf Creek Summit (5.50" storm total), snotel sites		
Narrative:	Wolf Creek Pass 1E - 5.42" - 3 day total, steady rains across southwestern CO		

EPAT Event Transposed and Maximized

EPAT Report Ranking:	2
Ideal Run #	5
Peak Rainfall (inches):	6.81
Total Rain Volume (acre feet):	17863.64

EPAT Event Basin Average Rainfall

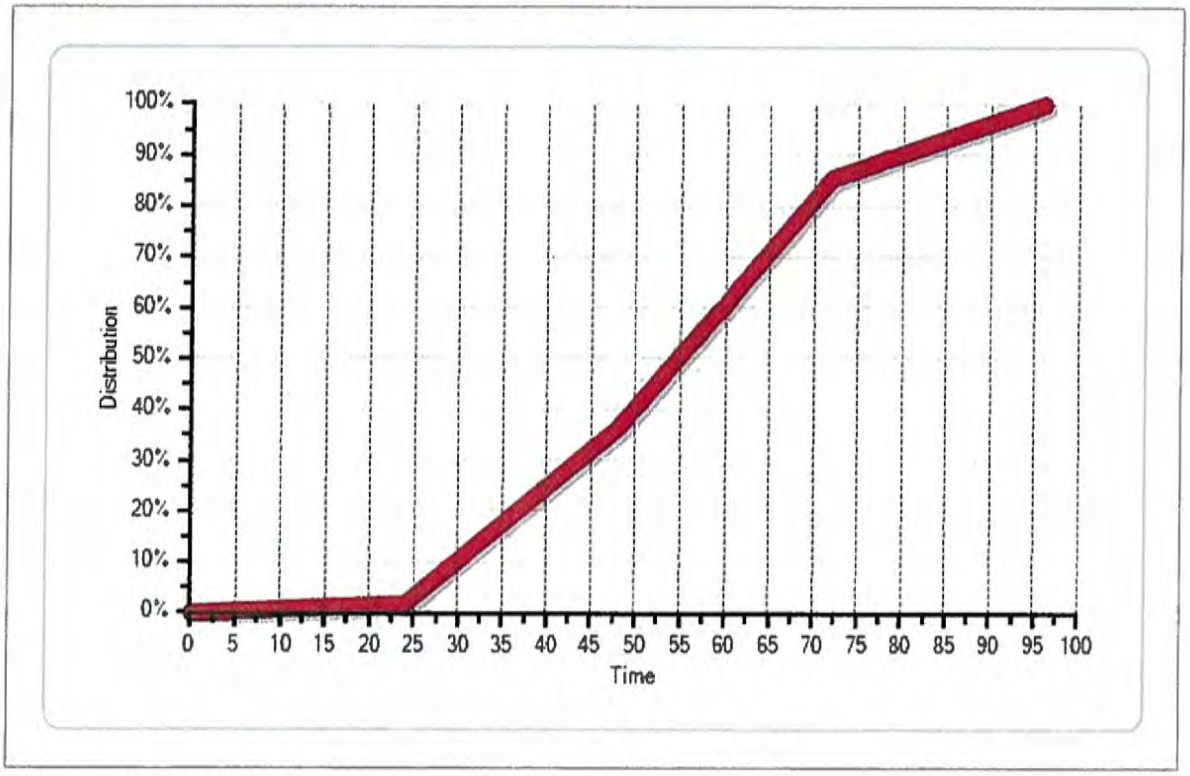
** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	6.68	50.14	17,863.21

Project Name: Continental

General Storm Results: SW CO / Wolf Creek

EPAT Event Observed Temporal



(Time in Hours | Distribution %)

0	0.00%	1	0.08%	2	0.15%
3	0.23%	4	0.30%	5	0.38%
6	0.45%	7	0.53%	8	0.60%
9	0.68%	10	0.75%	11	0.83%
12	0.90%	13	0.98%	14	1.05%
15	1.13%	16	1.20%	17	1.28%
18	1.35%	19	1.43%	20	1.50%
21	1.58%	22	1.65%	23	1.73%
24	1.80%	25	3.24%	26	4.68%
27	6.13%	28	7.57%	29	9.01%
30	10.45%	31	11.89%	32	13.33%
33	14.78%	34	16.22%	35	17.66%
36	19.10%	37	20.54%	38	21.98%
39	23.43%	40	24.87%	41	26.31%
42	27.75%	43	29.19%	44	30.63%
45	32.08%	46	33.52%	47	34.96%

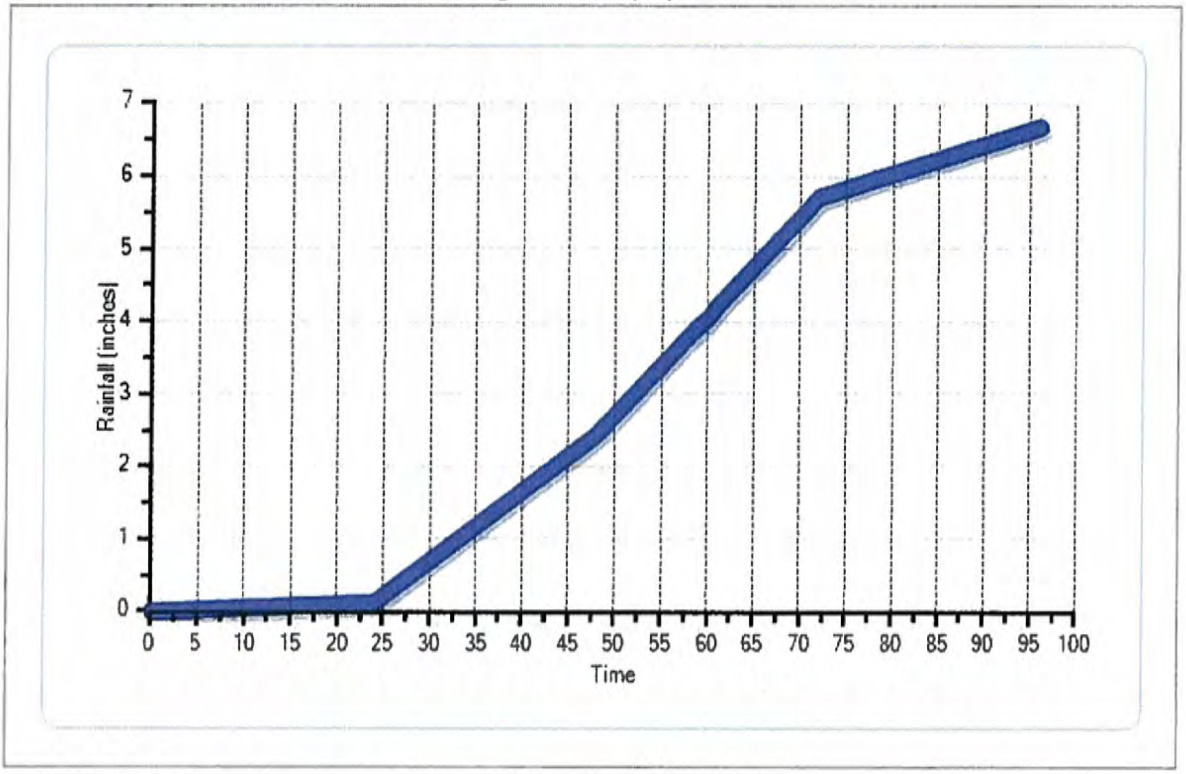
48	36.40%	49	38.45%	50	40.49%
51	42.54%	52	44.58%	53	46.63%
54	48.68%	55	50.72%	56	52.77%
57	54.81%	58	56.86%	59	58.90%
60	60.50%	61	63.00%	62	65.04%
63	67.09%	64	69.13%	65	71.18%
66	73.23%	67	75.27%	68	77.32%
69	79.36%	70	81.41%	71	83.45%
72	85.50%	73	86.10%	74	86.71%
75	87.31%	76	87.92%	77	88.52%
78	89.30%	79	89.73%	80	90.33%
81	90.94%	82	91.54%	83	92.15%
84	92.75%	85	93.35%	86	93.96%
87	94.56%	88	95.17%	89	95.77%
90	96.38%	91	96.98%	92	97.58%
93	98.19%	94	98.79%	95	99.40%
96	100.00%				

Project Name: Continental

General Storm Results: SW CO / Wolf Creek

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 6.68



(Time in Hours | Rainfall in inches)

0	0.00	1	0.01	2	0.01
3	0.02	4	0.02	5	0.03
6	0.03	7	0.04	8	0.04
9	0.05	10	0.05	11	0.06
12	0.06	13	0.07	14	0.07
15	0.08	16	0.08	17	0.09
18	0.09	19	0.10	20	0.10
21	0.11	22	0.11	23	0.12
24	0.12	25	0.22	26	0.31
27	0.41	28	0.51	29	0.60
30	0.70	31	0.79	32	0.89
33	0.99	34	1.08	35	1.18

Project Name: Continental

General Storm Results: SW CO / Wolf Creek

36	1.28	37	1.37	38	1.47
39	1.57	40	1.66	41	1.76
42	1.85	43	1.95	44	2.05
45	2.14	46	2.24	47	2.34
48	2.43	49	2.57	50	2.70
51	2.84	52	2.98	53	3.11
54	3.25	55	3.39	56	3.53
57	3.66	58	3.80	59	3.93
60	4.04	61	4.21	62	4.34
63	4.48	64	4.62	65	4.75
66	4.89	67	5.03	68	5.16
69	5.30	70	5.44	71	5.57
72	5.71	73	5.75	74	5.79
75	5.83	76	5.87	77	5.91
78	5.97	79	5.99	80	6.03
81	6.07	82	6.11	83	6.16
84	6.20	85	6.24	86	6.28
87	6.32	88	6.36	89	6.40
90	6.44	91	6.48	92	6.52
93	6.56	94	6.60	95	6.64
96	6.68				

Project Name: Continental

General Storm Results: San Juans/Gladstone/Silverton

Original Event Historic Data

Storm ID:	22	**Storm Source:**	HMR
State:	CO	**Start Date:**	10/4/1911
Originator:	Bureau of	**End Date:**	10/6/1911
Low Level Wind:	240	**Elevation:**	11954
Cloud Level Wind:	240	**Col. Cen. X,Y:**	2406051.53139,974914.098881
Duration:	33		
Max Precipitation:	8.05" 24 hrs, Gladstone, CO. Storm real but max precip. values is suspect.		
Narrative:	Large flood Durango and Animas River, many 3-4" totals		

EPAT Event Transposed and Maximized

EPAT Report Ranking:	3
Ideal Run #	7
Peak Rainfall (inches):	5.29
Total Rain Volume (acre feet):	13202.83

EPAT Event Basin Average Rainfall

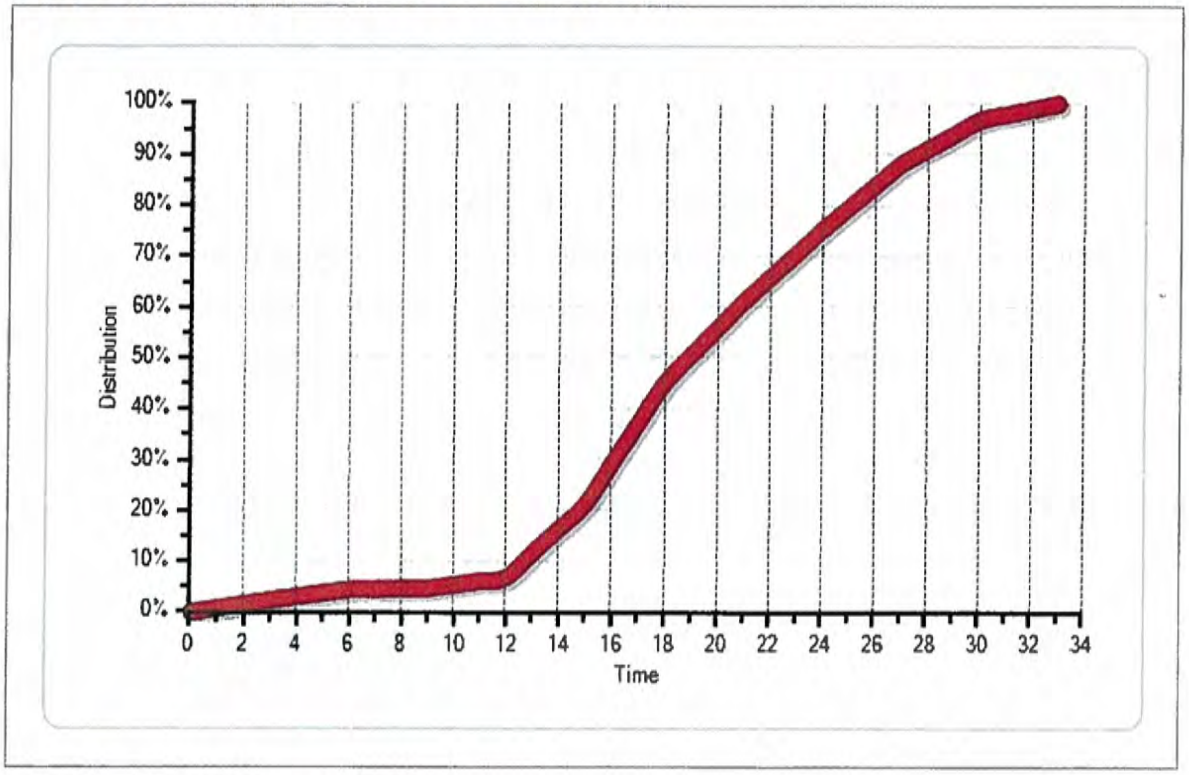
** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	4.94	50.14	13,210.22

Project Name: Continental

General Storm Results: San Juans/Gladstone/Silverton

EPAT Event Observed Temporal

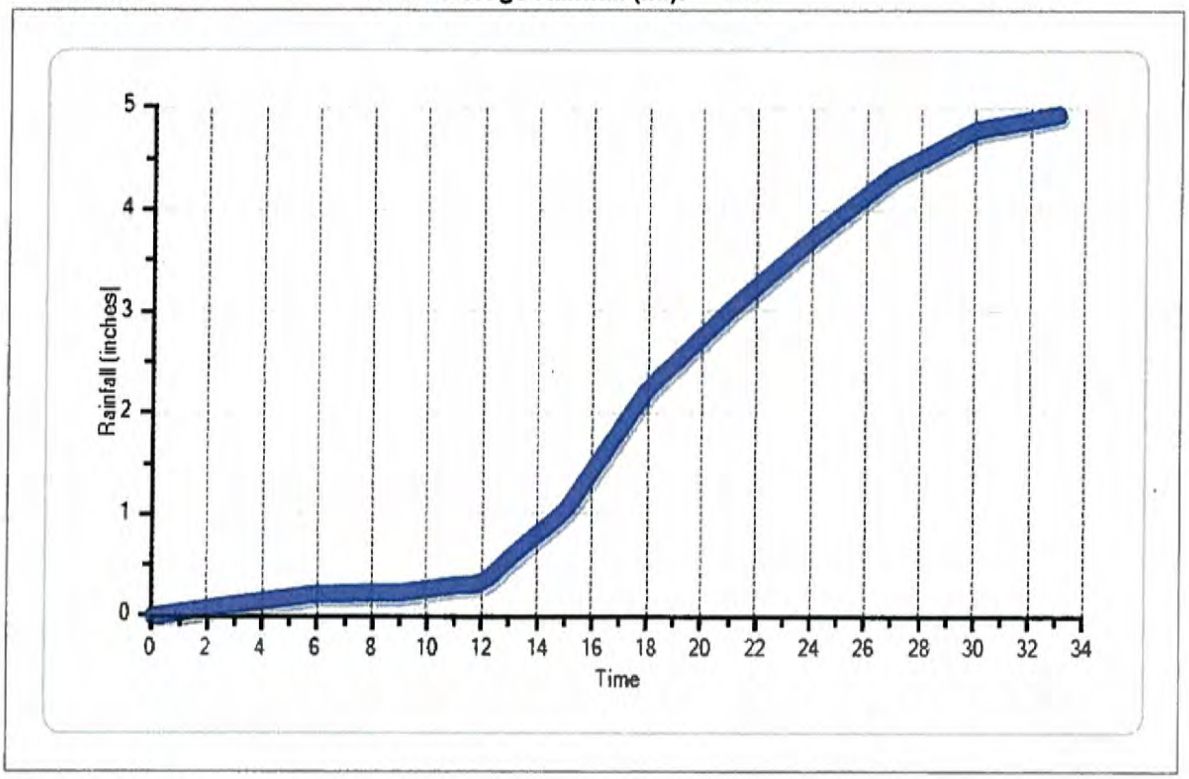


(Time in Hours | Distribution %)

0	0.00%	1	0.78%	2	1.57%
3	2.35%	4	3.06%	5	3.76%
6	4.47%	7	4.55%	8	4.63%
9	4.71%	10	5.41%	11	6.12%
12	6.82%	13	11.61%	14	16.39%
15	21.18%	16	29.18%	17	37.18%
18	45.18%	19	50.51%	20	55.84%
21	61.18%	22	65.88%	23	70.59%
24	75.29%	25	79.61%	26	83.92%
27	88.24%	28	91.14%	29	94.04%
30	96.94%	31	97.96%	32	98.98%
33	100.00%				

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 4.94



(Time in Hours | Rainfall in inches)

0	0.00	1	0.04	2	0.08
3	0.12	4	0.15	5	0.19
6	0.22	7	0.22	8	0.23
9	0.23	10	0.27	11	0.30
12	0.34	13	0.57	14	0.81
15	1.05	16	1.44	17	1.84
18	2.23	19	2.50	20	2.76
21	3.02	22	3.25	23	3.49
24	3.72	25	3.93	26	4.15
27	4.36	28	4.50	29	4.65
30	4.79	31	4.84	32	4.89
33	4.94				

Project Name: Continental

General Storm Results: SW CO / Durango

Original Event Historic Data

Storm ID:	27	**Storm Source:**	HMR
State:	CO	**Start Date:**	10/19/1972
Originator:	CSU Report	**End Date:**	10/20/1972
Low Level Wind:	180	**Elevation:**	8458
Cloud Level Wind:	180	**Col. Cen. X,Y:**	2308966.51031,846333.840291
Duration:	120		
Max Precipitation:	5.00" 48 hrs, Durango, CO		
Narrative:	Heavy rains, flooding		

EPAT Event Transposed and Maximized

EPAT Report Ranking:	4
Ideal Run #	5
Peak Rainfall (inches):	4.9
Total Rain Volume (acre feet):	13103.45

EPAT Event Basin Average Rainfall

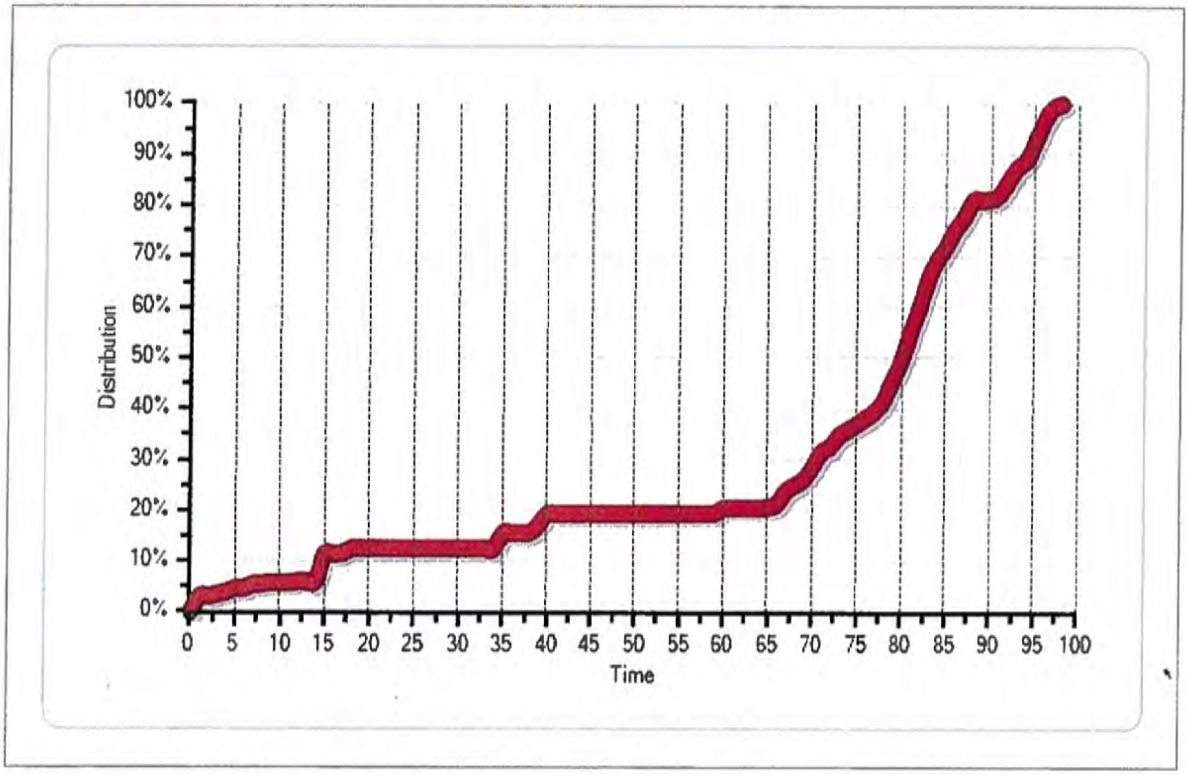
** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	4.90	50.14	13,103.25

Project Name: Continental

General Storm Results: SW CO / Durango

EPAT Event Observed Temporal



(Time in Hours | Distribution %)

0	0.00%	1	3.14%	2	3.14%
3	3.59%	4	4.04%	5	4.71%
6	4.71%	7	5.61%	8	5.61%
9	5.83%	10	5.83%	11	5.83%
12	6.05%	13	6.05%	14	6.05%
15	11.43%	16	11.43%	17	11.66%
18	12.56%	19	12.56%	20	12.56%
21	12.56%	22	12.56%	23	12.56%
24	12.56%	25	12.56%	26	12.56%
27	12.56%	28	12.56%	29	12.56%
30	12.56%	31	12.56%	32	12.56%
33	12.56%	34	12.56%	35	15.70%
36	15.70%	37	15.70%	38	15.70%
39	17.26%	40	19.51%	41	19.51%
42	19.51%	43	19.51%	44	19.51%
45	19.51%	46	19.51%	47	19.51%

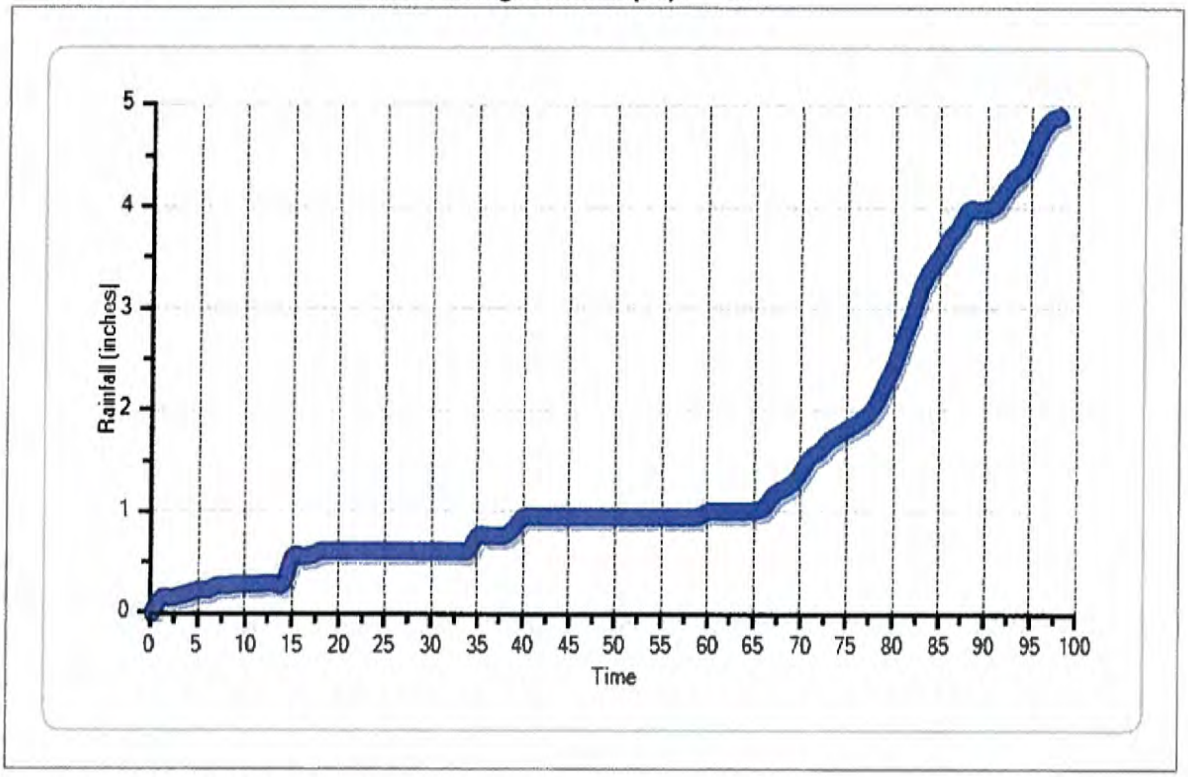
48	19.51%	49	19.51%	50	19.51%
51	19.51%	52	19.51%	53	19.51%
54	19.51%	55	19.51%	56	19.51%
57	19.51%	58	19.51%	59	19.51%
60	20.63%	61	20.63%	62	20.63%
63	20.63%	64	20.63%	65	20.85%
66	21.30%	67	23.99%	68	25.11%
69	26.23%	70	28.70%	71	31.61%
72	32.74%	73	34.98%	74	36.10%
75	37.22%	76	38.34%	77	39.69%
78	41.93%	79	45.96%	80	49.78%
81	55.38%	82	60.09%	83	65.92%
84	69.51%	85	72.20%	86	75.56%
87	77.80%	88	81.17%	89	81.17%
90	81.39%	91	82.29%	92	85.20%
93	87.67%	94	89.01%	95	92.83%
96	96.86%	97	99.33%	98	100.00%

Project Name: Continental

General Storm Results: SW CO / Durango

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 4.90



(Time in Hours | Rainfall in inches)

0	0.00	1	0.15	2	0.15
3	0.18	4	0.20	5	0.23
6	0.23	7	0.27	8	0.27
9	0.29	10	0.29	11	0.29
12	0.30	13	0.30	14	0.30
15	0.56	16	0.56	17	0.57
18	0.62	19	0.62	20	0.62
21	0.62	22	0.62	23	0.62
24	0.62	25	0.62	26	0.62
27	0.62	28	0.62	29	0.62
30	0.62	31	0.62	32	0.62
33	0.62	34	0.62	35	0.77

36	0.77	37	0.77	38	0.77
39	0.85	40	0.96	41	0.96
42	0.96	43	0.96	44	0.96
45	0.96	46	0.96	47	0.96
48	0.96	49	0.96	50	0.96
51	0.96	52	0.96	53	0.96
54	0.96	55	0.96	56	0.96
57	0.96	58	0.96	59	0.96
60	1.01	61	1.01	62	1.01
63	1.01	64	1.01	65	1.02
66	1.04	67	1.18	68	1.23
69	1.29	70	1.41	71	1.55
72	1.60	73	1.71	74	1.77
75	1.82	76	1.88	77	1.94
78	2.05	79	2.25	80	2.44
81	2.71	82	2.94	83	3.23
84	3.41	85	3.54	86	3.70
87	3.81	88	3.98	89	3.98
90	3.99	91	4.03	92	4.17
93	4.30	94	4.36	95	4.55
96	4.75	97	4.87	98	4.90

Project Name: Continental

Local Storm Results: Saguache

Original Event Historic Data

Storm ID:	29	**Storm Source:**	EPAT
State:	CO	**Start Date:**	7/25/1999
Originator:	Henz	**End Date:**	
Low Level Wind:	140	**Elevation:**	8884
Cloud Level Wind:	220	**Col. Cen. X,Y:**	2749047.24371,1136751.50964
Duration:	2		

Max Precipitation: Peak radar-derived estimate of 5.22" were made through detailed reconstruction efforts.

Narrative: Strong local, stationary storm developed over the Saguache Creek basin during the mid-afternoon hours. Unofficial reports of 7" in 3 hours were made by an unknown camper. Peak radar-derived estimate of 5.22" were made through detailed reconstruction efforts. Large mudslide near the Eisenhower Tunnel the same day

EPAT Event Transposed and Maximized

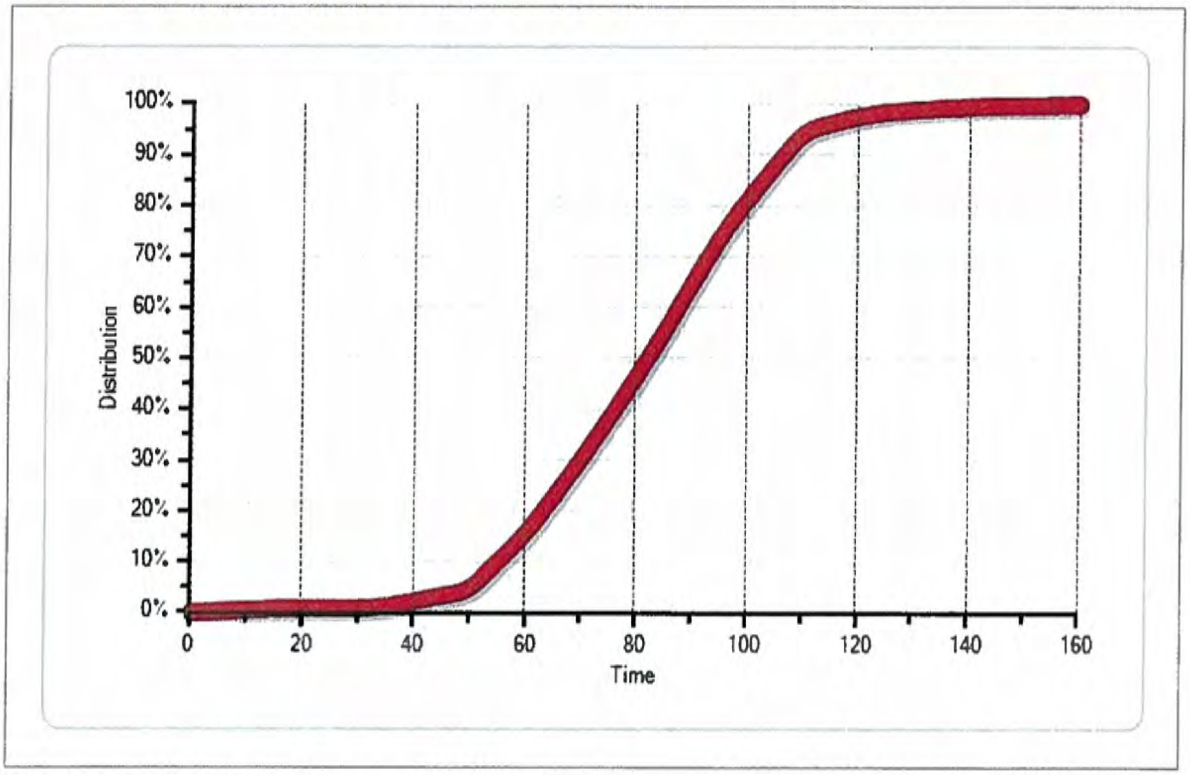
EPAT Report Ranking:	1
Ideal Run #	5
Peak Rainfall (inches):	4.6
Total Rain Volume (acre feet):	7710.26

EPAT Event Basin Average Rainfall

** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	2.88	50.14	7,701.50

EPAT Event Observed Temporal

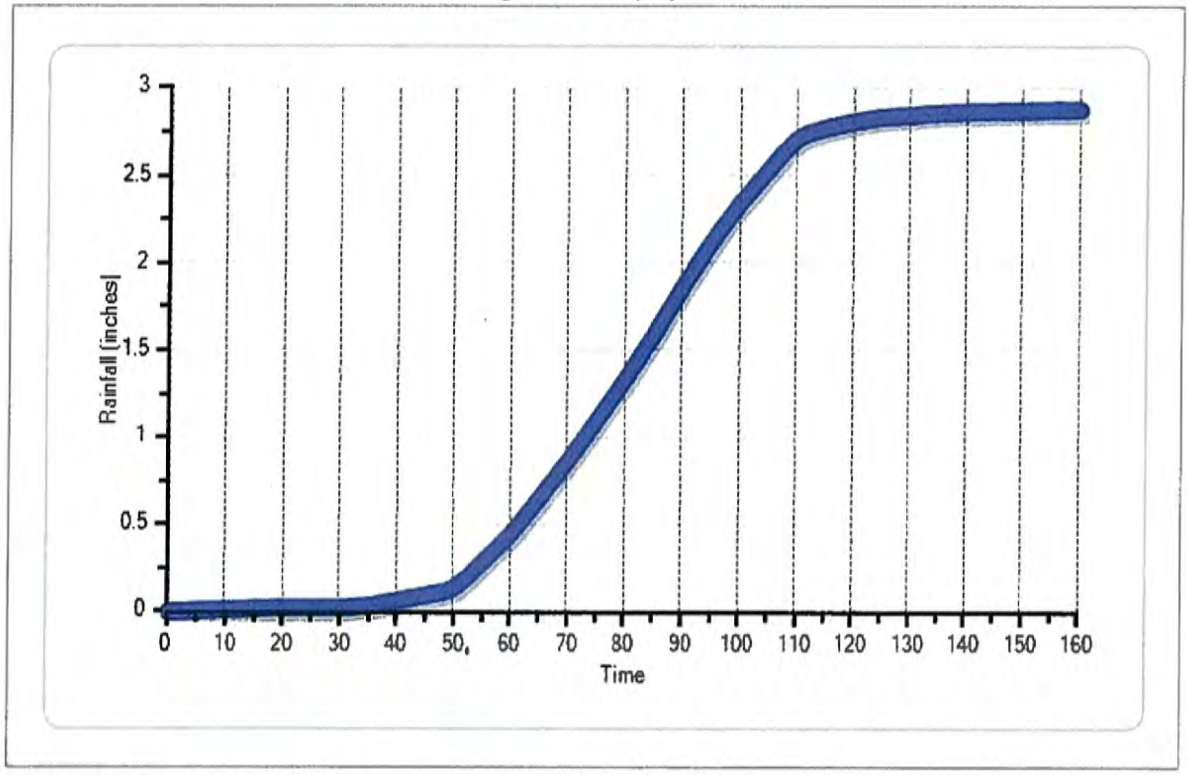


(Time in Minutes | Distribution %)

0	0.00%	5	0.30%	10	0.50%
15	0.70%	20	0.80%	25	0.80%
30	0.80%	35	1.20%	40	2.20%
45	3.30%	50	4.80%	55	9.90%
60	15.50%	65	22.60%	70	30.00%
75	38.00%	80	46.20%	85	55.10%
90	64.60%	95	73.70%	100	81.40%
105	88.20%	110	94.20%	115	96.30%
120	97.60%	125	98.50%	130	98.90%
135	99.30%	140	99.50%	145	99.70%
150	99.80%	155	99.90%	160	100.00%

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 2.88



(Time in Minutes | Rainfall in inches)

0	0.00	5	0.01	10	0.01
15	0.02	20	0.02	25	0.02
30	0.02	35	0.03	40	0.06
45	0.10	50	0.14	55	0.29
60	0.45	65	0.65	70	0.86
75	1.09	80	1.33	85	1.59
90	1.86	95	2.12	100	2.34
105	2.54	110	2.71	115	2.77
120	2.81	125	2.84	130	2.85
135	2.86	140	2.87	145	2.87
150	2.87	155	2.88	160	2.88

Project Name: Continental

Local Storm Results: Placerville

Original Event Historic Data

Storm ID:	1	**Storm Source:**	RADAR
State:	CO	**Start Date:**	8/8/2001
Originator:	NWS	**End Date:**	
Low Level Wind:	210	**Elevation:**	9896
Cloud Level Wind:	25	**Col. Cen. X,Y:**	2290182.11559,1068253.80748
Duration:	1.5		
Max Precipitation:	Up to 5"/2hrs Coop observer in Storm Data, 4.3"(NWS radar)		
Narrative:	Slow moving thunderstorms over eastern San Miguel County dropped up to 5 inches of rain in a 2 hour period between Telluride and Placerville. The heavy rains triggered numerous mud and rock slides throughout the eastern portion of the county. Several vehicles were swept from highway 145/62 as up to 6 feet of mud		

EPAT Event Transposed and Maximized

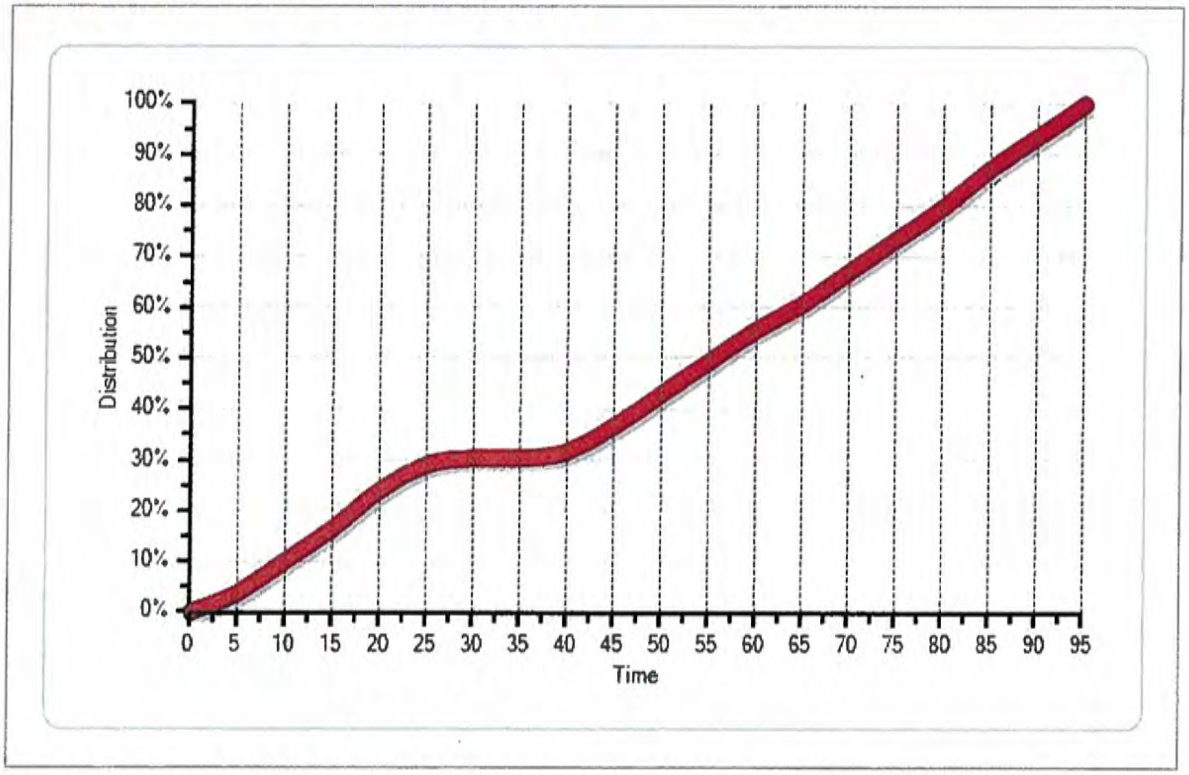
EPAT Report Ranking:	2
Ideal Run #	6
Peak Rainfall (inches):	5.96
Total Rain Volume (acre feet):	7535.51

EPAT Event Basin Average Rainfall

** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	2.82	50.14	7,541.06

EPAT Event Observed Temporal

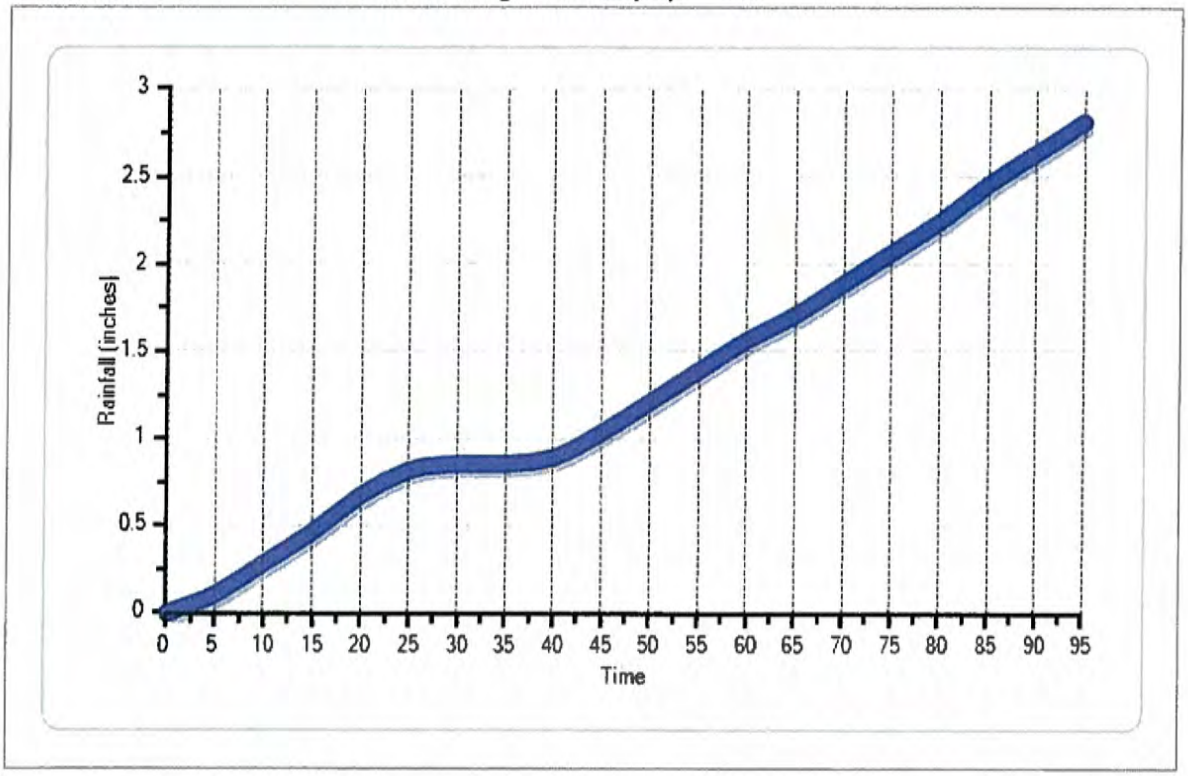


(Time in Minutes | Distribution %)

0	0.00%	5	3.80%	10	10.13%
15	16.46%	20	24.05%	25	29.11%
30	30.38%	35	30.38%	40	31.65%
45	36.71%	50	43.04%	55	49.37%
60	55.70%	65	60.76%	70	67.09%
75	73.42%	80	79.75%	85	87.34%
90	93.67%	95	100.00%		

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 2.82



(Time in Minutes | Rainfall in inches)

0	0.00	5	0.11	10	0.29
15	0.46	20	0.68	25	0.82
30	0.86	35	0.86	40	0.89
45	1.04	50	1.21	55	1.39
60	1.57	65	1.71	70	1.89
75	2.07	80	2.25	85	2.46
90	2.64	95	2.82		

Project Name: Continental

Local Storm Results: Dallas Creek - West Side of Divide

Original Event Historic Data

Storm ID:	4	**Storm Source:**	RADAR
State:	CO	**Start Date:**	7/31/1999
Originator:	NWS	**End Date:**	
Low Level Wind:	360	**Elevation:**	9212
Cloud Level Wind:	225	**Col. Cen. X,Y:**	2313725.77099,1102555.94809
Duration:	2		
Max Precipitation:	3.50"-4.75"/5hrs est. by radar, 3.88" at Pleasant Valley Met station		
Narrative:	Heavy rains resulted in widespread flash flooding, mudslides, and turned Leopard Creek into a raging torrent which overflowed its banks and washed across State Highway 62, undercutting the roadbed. Eyewitnesses reported trash cans, canoes, trees, and other debris floating down the swollen San Miguel River which parallels		

EPAT Event Transposed and Maximized

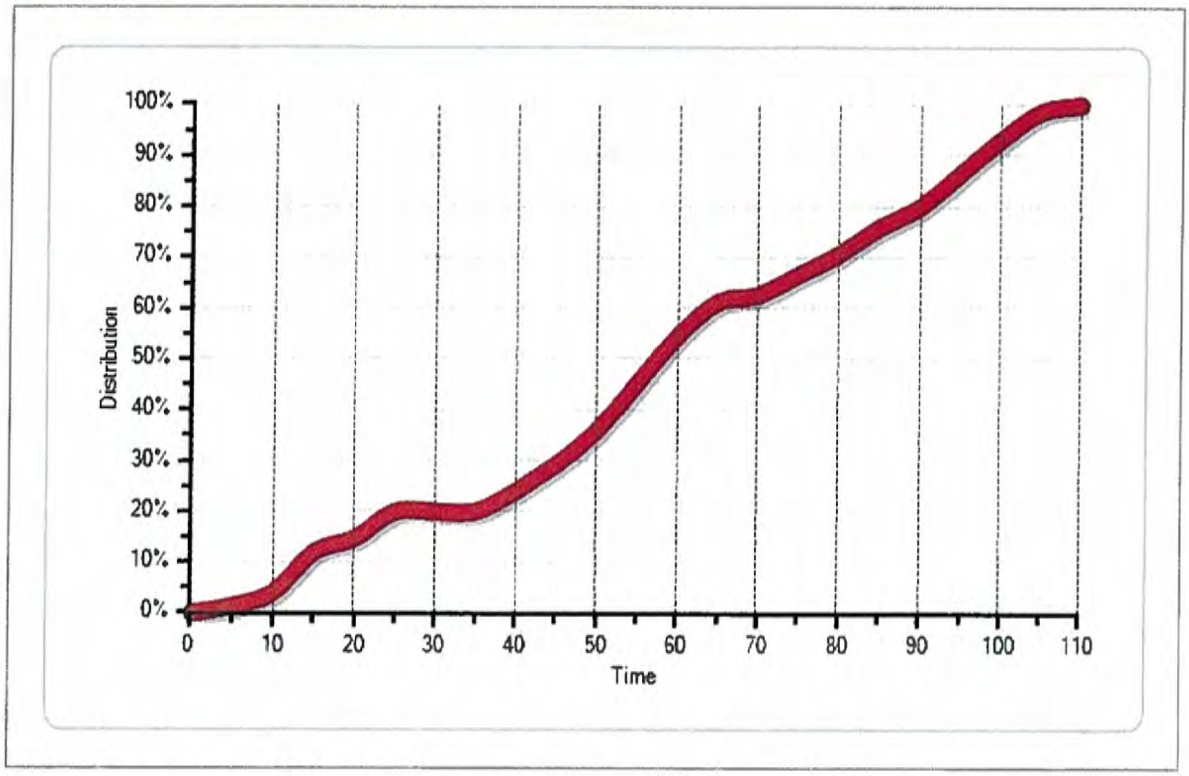
EPAT Report Ranking:	3
Ideal Run #	5
Peak Rainfall (inches):	4.7
Total Rain Volume (acre feet):	7170.61

EPAT Event Basin Average Rainfall

** Volume results may differ from summary results by 0.01 percent due to rounding. Results are well within error range of observation.*

Basin	Rainfall (in.)	Area (sq. mi.)	Volume (acre-ft.)
0	2.68	50.14	7,166.68

EPAT Event Observed Temporal

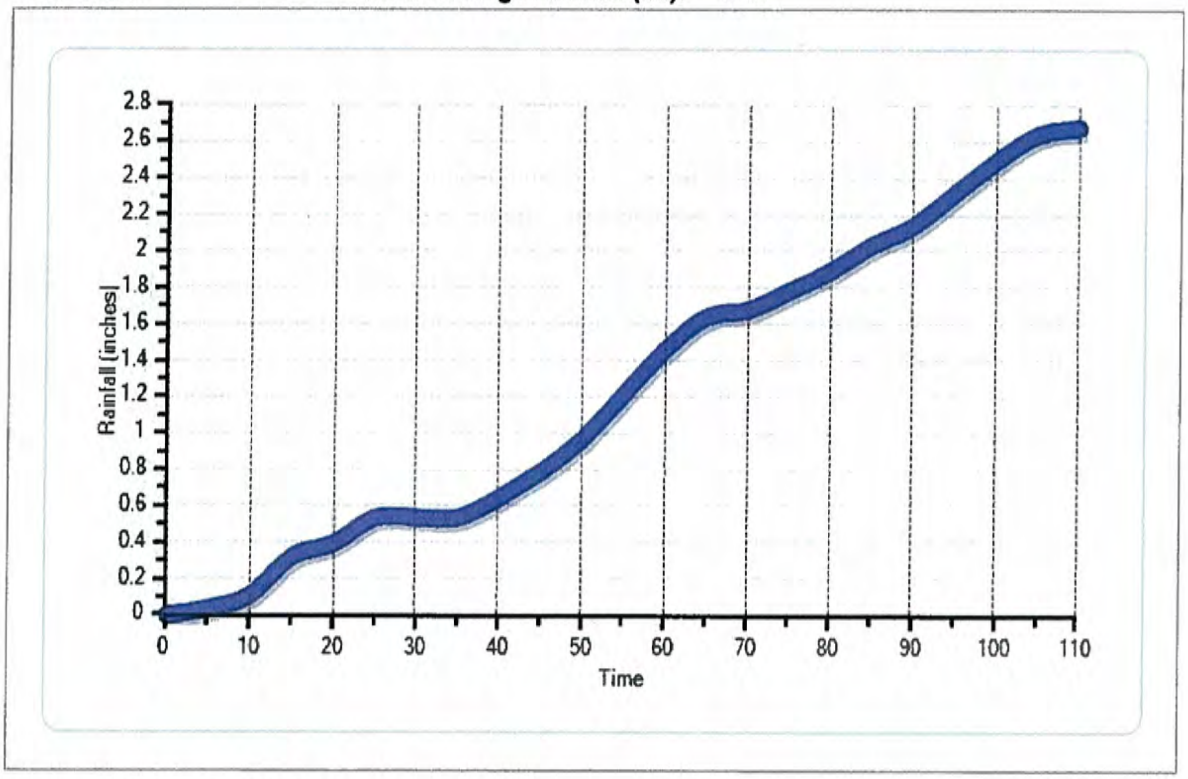


(Time in Minutes | Distribution %)

0	0.00%	5	1.33%	10	4.00%
15	12.00%	20	14.67%	25	20.00%
30	20.00%	35	20.00%	40	24.00%
45	29.33%	50	36.00%	55	45.33%
60	54.67%	65	61.33%	70	62.67%
75	66.67%	80	70.67%	85	76.00%
90	80.00%	95	86.67%	100	93.33%
105	98.67%	110	100.00%		

EPAT Event Temporal Basin Average

Basin: 0 **Total Average Rainfall (in.):** 2.68



(Time in Minutes | Rainfall in inches)

0	0.00	5	0.04	10	0.11
15	0.32	20	0.39	25	0.54
30	0.54	35	0.54	40	0.64
45	0.79	50	0.96	55	1.21
60	1.47	65	1.64	70	1.68
75	1.79	80	1.89	85	2.04
90	2.14	95	2.32	100	2.50
105	2.64	110	2.68		

*DISCLAIMER: The user should read the entire EPAT project report and should be aware of all the elements of this tool, including the strengths and weaknesses, and the individual responsibilities of the user to input basin information properly. The EPATS tool, presented herein, and in the technical report, is useful as one step in evaluating the probable maximum flood that could impact the basin and associated dam structures. Therefore nothing contained herein may be construed as a guarantee of the EPATS tool or its operation, or create any liability on the part of any party or tis directors, officers, employees or agents for any damage that may be alleged to result from the operation, or failure to operate, of the system or any of its component parts. This constitutes notice to any and all person or parties that HDR Engineering Inc., or any officer, agent or employee thereof, shall not be liable for any injuries or damages of what ever kind that may result from reliance on the terms and conditions of the EPATS tool.

URS CALCULATION COVER SHEET

Project Name:	*Continental & Santa Maria Dam*	**Project Number:**	*22241248.00001*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: MIKE PHILLIPS

Calculation to be checked: 100 Year Precipitation Depth for Continental Dam

Calculation Originator: *Chad Martin*

Checker's comments required by:

Submitted by: _____ 6/9/10

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☑ All items have been found to be correct. Checker has no comments.

_____ 8 JUNE 2010

Checker Signature **Date**

or

B. ☐ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

_____ _____

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ 6/9/10

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose:
Estimate the 100-year precipitation for Continental Reservoir using NOAA Atlas 2.

References:

National Oceanic and Atmospheric Administration (NOAA). *Precipitation-Frequency Atlas of the Western United States, Volume III – Colorado.* United States Department of Commerce, National Weather Service. Silver Springs, Md. 1973.

National Oceanic and Atmospheric Administration (NOAA). *NOAA Atlas 2 Precipitation Frequency Estimates in GIS Compatible Formats, Precipitation Frequency Estimates at a Point.* . Hydrometeorological Design Studies Center. <http://www.nws.noaa.gov/ohd/hdsc/noaaatlas2.htm>. June 7, 2010

iTouchMaps.com. *Latitude and Longitude of a Point.* Copyright 2007-2010. <http://www.itouchmap.com/latlong.html> June 7, 2010.

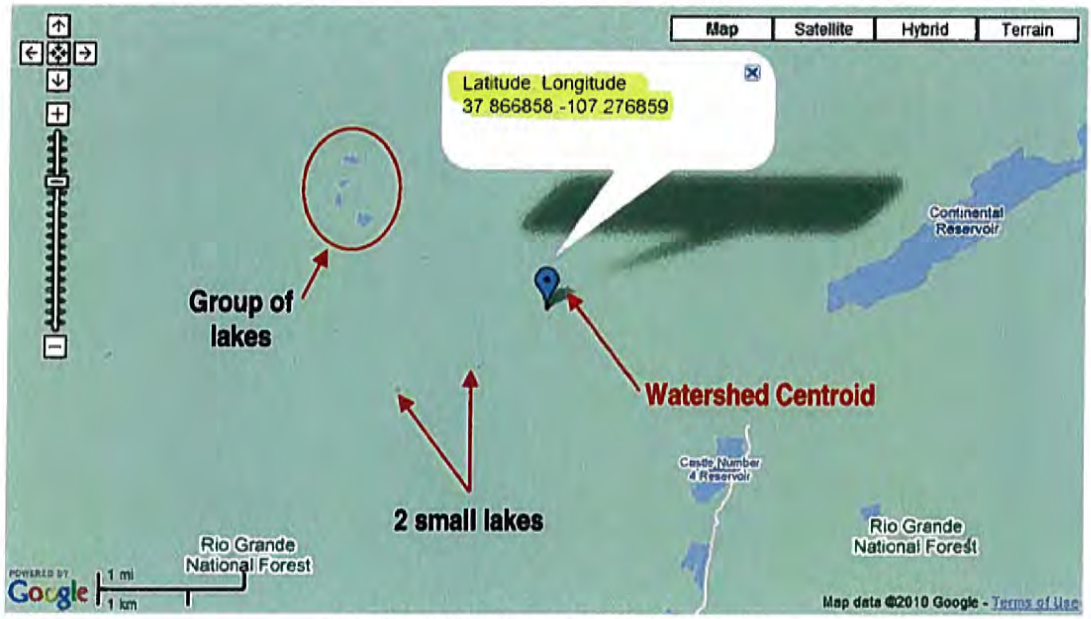
Procedure:
Step 1: Determine the location of the watershed centroid
Step 2: Estimate the 6- and 24-hour precipitation depths for the 100-year storm using NOAA Atlas 2
Step 3: Estimate the 1-hour precipitation depth using Table 11
Step 4: Estimate the percent of point precipitation (areal reduction)
Step 5: Estimate the 2- and 3-hour precipitation depths using Equations 5 and 6, respectively
Step 6: Estimate the 12-hour precipitation depth using Figure 17
Step 7: Estimate the 5- and 15-minutes precipitation depths using Table 12
Step 8: Summary of Results

Step 1: Determine the location of the watershed centroid
The longitude and latitude of the watershed centroid was estimated using iTouchMap.com, as shown in the figure below. The approximate longitude and latitude of the watershed centroid is:

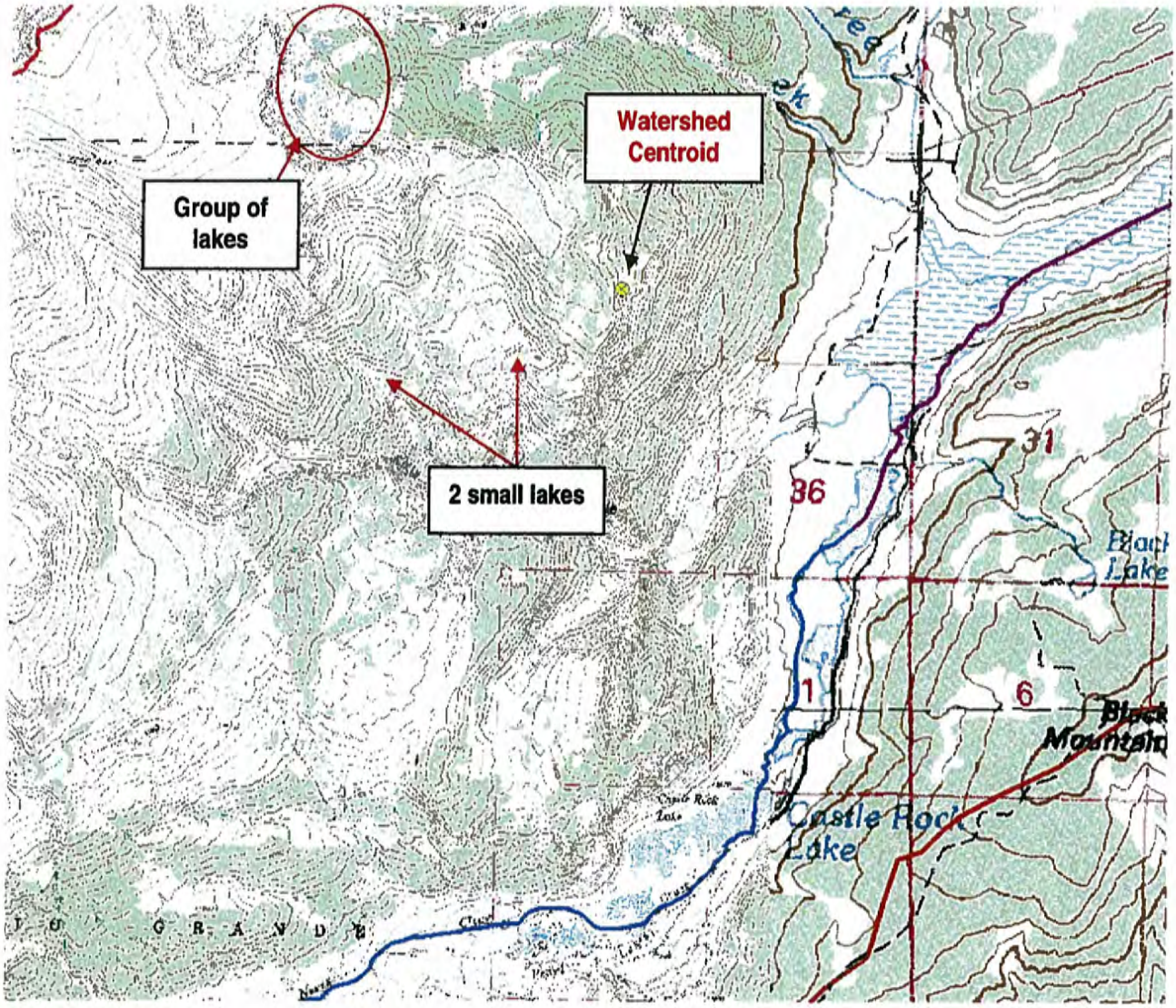
- Longitude = 37.866858
- Latitude = -107.276859

Refer to the maps below for the watershed centroid location.

Latitude and Longitude of a Point



http://www.itouchmap.com/latlong.html



Step 2: Estimate the 6- and 24-hour precipitation depths for the 100-year storm using NOAA Atlas 2

The 6- and 24-hour, 100-year precipitation depths were estimated using the NOAA Atlas 2 website (NOAA, 2010). The results were confirmed with hard copies of NOAA Atlas 2 maps (attached). The longitude and latitude were entered on the NOAA website and the following results were given. The hard copies confirm that these results are reasonable (see attached sheets).

- 6-hour, 100-year = 2.41"
- 24-hour, 100-year = 3.31"

Precipitation Frequency Data Output

NOAA Atlas 2
Colorado 37.866858°N 107.276859°W
Site-specific Estimates

Map	Precipitation (inches)	Precipitation Intensity (in/hr)
2-year 6-hour	0.97	0.16
2-year 24-hour	1.65	0.07
100-year 6-hour	2.41	0.40
100-year 24-hour	3.31	0.14

Hydrometeorological Design Studies Center - NOAA/National Weather Service
1325 East-West Highway - Silver Spring, MD 20910 - (301) 713-1669
Mon Jun 7 22:05:47 2010

Step 3: Estimate the 1-hour precipitation depth using Table 11

Using Figure 19 (attached), it was determined that the watershed lies within Region 2. The equation for the 1-hour 100-year precipitation depth for Region 2 was obtained from Table 11 (attached). It appears below:

$$P_{1hr} = 0.494 + 0.755\left(X_3 \frac{X_3}{X_4}\right)$$

Where: X_3 = 100-yr 6-hr value from precipitation frequency maps = 2.41 in
X_4 = 100-yr 24-hr value from precipitation frequency maps = 3.31 in

$$P_{1hr} = 0.494 + 0.755\left(2.41\left(\frac{2.41}{3.31}\right)\right) = 1.82in$$

Step 4: Estimate the percent of point precipitation (areal reduction)

The percent of point precipitation was estimated using Figure 14 for the 1-, 6-, and 24-hour precipitation depths. The ratios and reduced depths are presented in the table below:

Duration	Percentage	Precipitation Depth
1-hr	80%	0.80 x 1.82" = 1.46"
6-hr	89.5%	0.895 x 2.41" = 2.16"
24-hr	95%	0.95 x 3.31" = 3.14"

Step 5: Estimate the 2- and 3-hour precipitation depths using Equations 5 and 6, respectively

The 2- and 3-hour precipitation depths were estimated using Equations 5 and 6 for Region 2 (attached), as shown below:

$$P_{2hr} = 0.341(P_{6hr}) + 0.659(P_{1hr})$$
$$P_{3hr} = 0.569(P_{6hr}) + 0.431(P_{1hr})$$

Where: P_{1hr} = 1.46 in
P_{6hr} = 2.16 in

$$P_{2hr} = 0.341(2.16) + 0.659(1.46) = 1.70in$$
$$P_{3hr} = 0.569(2.16) + 0.431(1.46) = 1.86in$$

Step 6: Estimate the 12-hour precipitation depth using Figure 17

The 12-hour precipitation depth was estimated using the 6- and 24-hour depths on Figure 17 (attached). The precipitation depth was estimated to be 2.65 in.

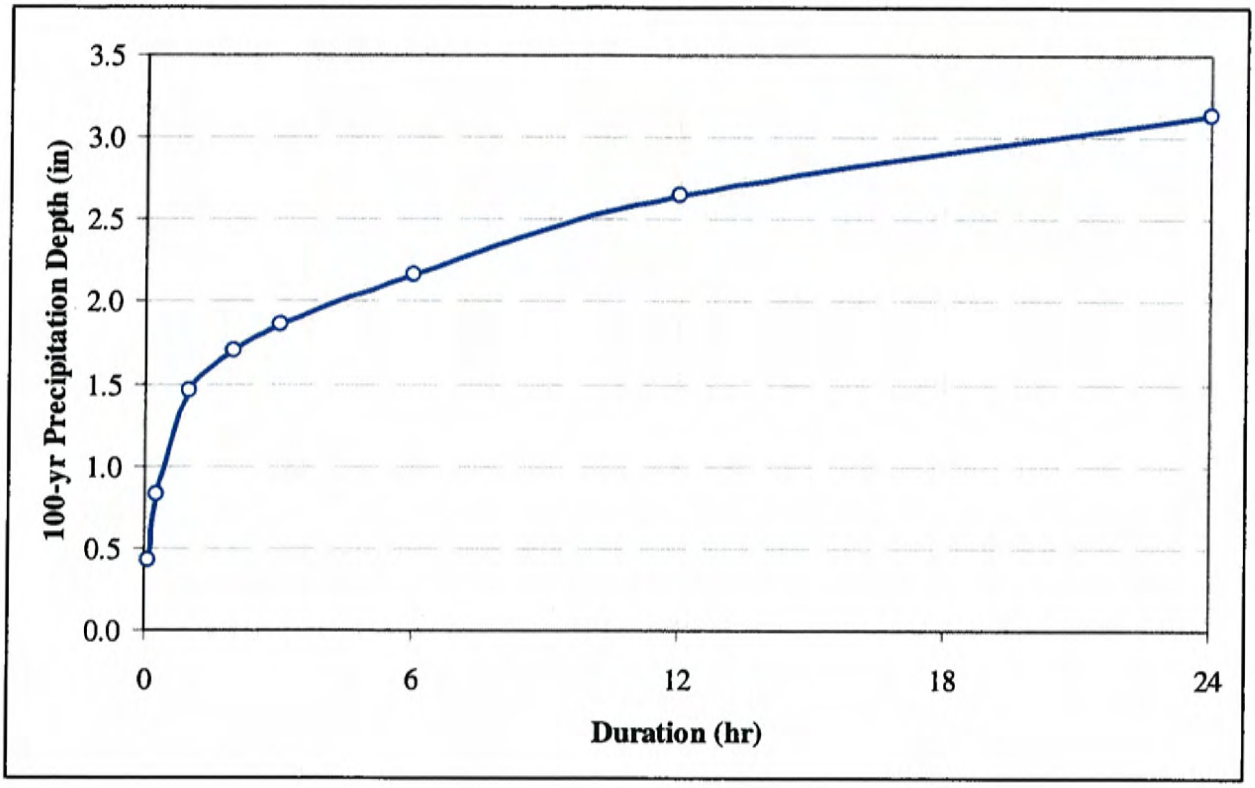
Step 7: Estimate the 5- and 15-minutes precipitation depths using Table 12 of NOAA Atlas 2

Table 12 of NOAA Atlas 2 is attached. The 5- and 15-minute precipitation depths are calculated as ratios of the 1-hour depth. The results are presented in the table below:

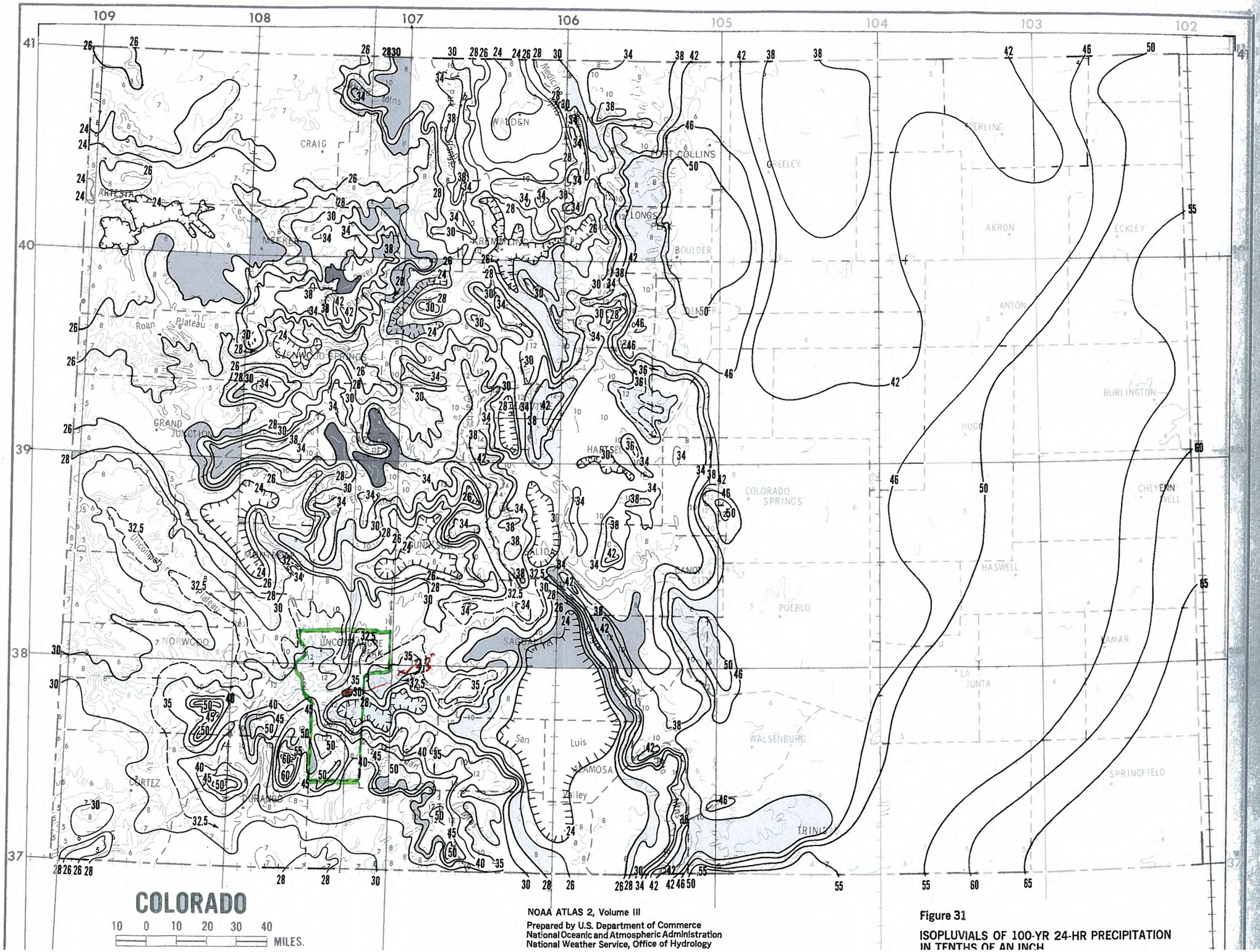
Duration	Ratio of the 1-hour depth	Precipitation Depth
5-minute	0.29	0.29 x 1.46" = 0.42"
15-minute	0.57	0.57 x 1.46" = 0.83"

Step 8: Summary of Results

Duration	Depth (in)
5-min	0.42
15-min	0.83
1-hr	1.46
2-hr	1.70
3-hr	1.86
6-hr	2.16
12-hr	2.65
24-hr	3.14


3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
100-yr Precipitation Depth (in)
0
6
12
18
24
Duration (hr)


Chaffee
Montrose
Gunnison
COUNTY BOUNDARY
Ouray
CONTINENTAL WATERSHED
AREA = 50.12 mi²
Saguache
San Miguel
Hinsdale
Dolores
San Juan
Mineral
Rio Grande
Alamosa
La Plata
Archuleta
Conejos
San Juan
Rio Arriba

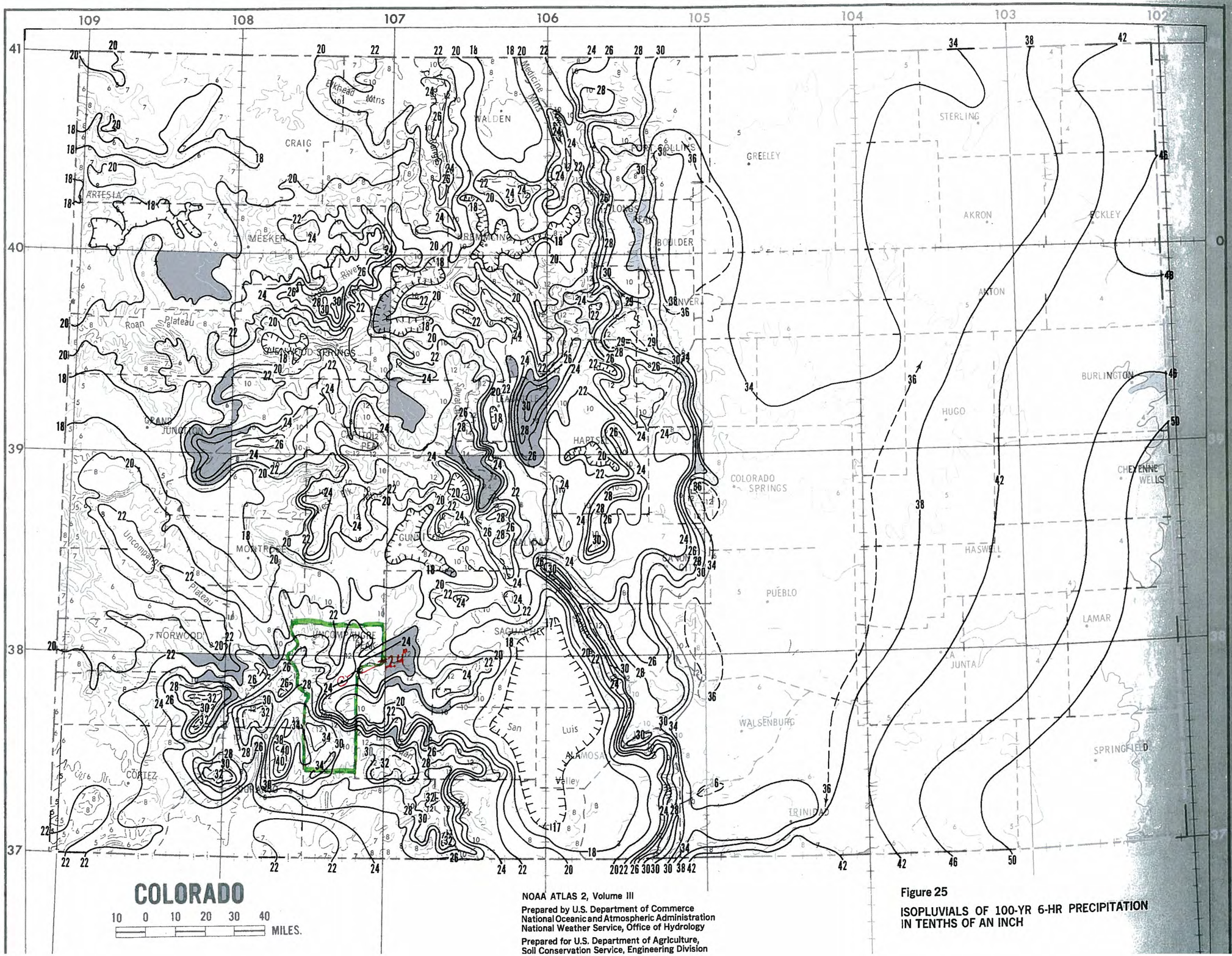


NOAA ATLAS 2, Volume III

Prepared by U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology

Figure 31

ISOPLUVIALS OF 100-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH



NOAA ATLAS 2, Volume III

Prepared by U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology

Prepared for U.S. Department of Agriculture,
Soil Conservation Service, Engineering Division

Figure 25

ISOPLUVIALS OF 100-YR 6-HR PRECIPITATION IN TENTHS OF AN INCH

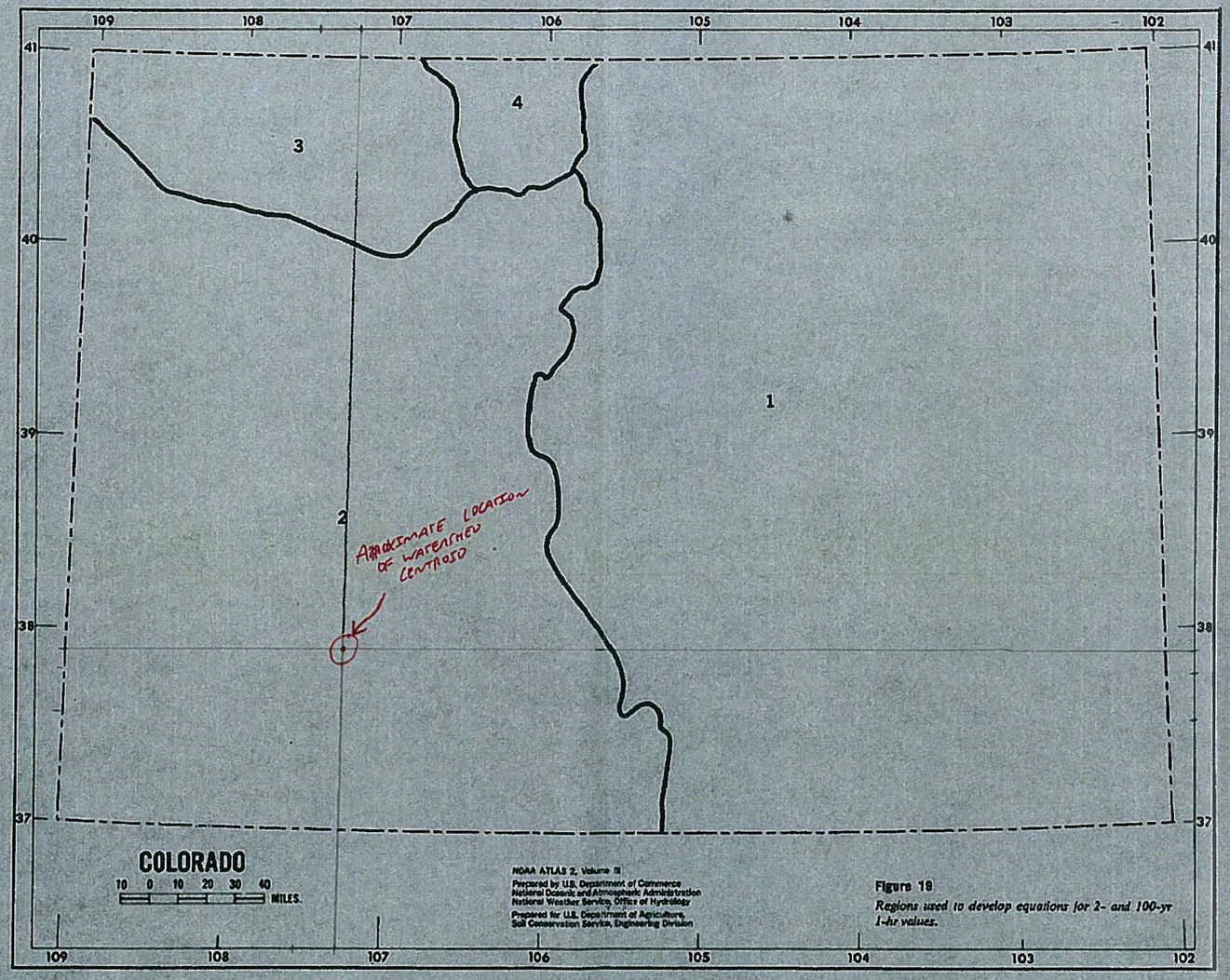


Figure 18

Regions used to develop equations for 2- and 100-yr 1-hr values.

Colorado

Discussion of Maps

Figures 20 through 43 present precipitation-frequency maps for Colorado for 6- and 24-hr durations. Figures 20 through 31 are for annual (or all-season) values for the 2-, 5-, 10-, 25-, 50, and 100-yr return periods. Figures 32 through 43 are for the May through October season and are for probabilities of 0.50, 0.20, 0.10, 0.04, 0.02, and 0.01. The isopluvial maps represent the 360- and 1,440-min durations for the partial-duration series. Data were tabulated for clock and observation-day intervals for the annual series and were adjusted by the empirical factors given in the ANALYSIS section.

Isoline interval. The isoline interval selected was designed to provide a reasonably complete description of the isopluvial pattern in various regions of the state. The isoline interval over most of the state on maps for the 24-hr duration is 0.2 in. for precipitation-frequency values below 3.0 in., 0.4 in. between 3.0 in. and 5.0 in., and 0.5 in. at values greater than 5.0 in. However, in southwestern Colorado along the San Juan Mountains, the annual maps use an isoline interval of 0.2 in. below precipitation-frequency values of 2.0 in., and 0.5 in. for values over 2.0 in. On the maps for the 6-hr duration, the interval is 0.1 in. for precipitation-frequency values under 1.2 in. at the 2-yr and 0.50 and 0.20 probability level (on maps for the May through October season). At longer return periods (or lower probabilities), the upper limit of the 0.1-in. isoline interval increases in order to maintain the isopluvial gradient and degree of detail. On all maps for the 6-hr duration, the isoline interval changes from 0.2 in. below 3.0 in. to 0.4 in. over 3.0-in. precipitation-frequency values. Dashed intermediate lines have been placed between widely separated isolines and in regions where a linear interpolation between the normal isopluvial interval would lead to erroneous interpolation. "Lows" that close within the boundaries of a particular map have been hatched on the low-valued side of the isoline.

Importance of snow in precipitation-frequency values. The annual maps in this Atlas represent frequency values of precipitation regardless of type. For many hydrologic purposes, precipitation falling as rain must be treated in a different manner from that falling as snow. The contribution of snow amounts to precipitation-frequency values in Colorado and the Rocky Mountain States (roughly Montana, Wyoming, Colorado, New Mexico, and Utah) was investigated. In this area, there were about 50 stations per state having 10 to 15 yrs of observation of snowfall as part of the precipitation observing program. For each such station, two data series were formed as discussed under Interpretation of Results, Importance of Snow in Estimating Frequency Values.

A ratio was formed of the 2-yr 24-hr value for the series containing maximum annual events without regard to the type of precipitation and the 2-yr 24-hr value for the series with snow occurrences eliminated. A plot of this ratio vs. latitude (fig. 15) shows that the ratio tends to be at a maximum in the latitude of Colorado and Utah. Over all of Colorado, the all-precipitation series tends to average about 10 percent higher than the series with snow eliminated. However, examination of the data shows that in the relatively flat areas east of a smoothed 6,000-ft contour the differences between the two series are minor. With data from this area eliminated, the difference between the two series averages about 15 percent, with some individual differences as large as 40 to 50 percent. About half the stations have differences greater than 10 percent. These differences indicate that frequency values computed from an annual series of rainfall amounts only would be different from those composed of all-precipitation values, and two separate sets of precipitation-frequency maps were needed.

Snowfall observations are made at only about 15 percent of the precipitation stations used in this study. For this reason, a rainfall-frequency study could not be made by direct methods. Since most snowfall occurs during the colder half of the year, a series containing only values for the May to October season was compared with the series that was based on rainfall only. The two series were in good agreement, except for a slight bias toward higher values for the May to October season. This bias results from some large amounts in late October and early May occurring as snow and thus excluded from the rainfall-only series. The average difference is only about 4 percent, with no consistent preference toward higher elevations or particular geographic regions.

Two sets of maps were prepared for Colorado. The first set consists of annual maps based on precipitation data from all months of the year without regard to the type of precipitation; rain, rain and snow mixed, all snow, hail, etc. The second series takes precipitation values from the months May to October. No attempt was made in this second series to differentiate between types of precipitation occurring within these months, but the investigations mentioned in the preceding paragraph indicate that these maps will approximate the values that would be obtained by using a data series made up of precipitation events that are exclusively rain. Since data for only part of the year were used, these maps have been labeled with the appropriate probabilities rather than with a return period in years (figs. 32–43).

Table 11. *Equations for estimating 1-hr values in Colorado with statistical parameters for each equation*

Region of applicability*	Equation	Corr. coeff.	No. of stations	Mean of computed stn. values (inches)	Standard error of estimate (inches)
South Platte, Republican, Arkansas, and Cimarron River Basins (1)	$Y_2 = 0.218 + 0.709[(X_1)(X_1/X_5)]$ $Y_{100} = 1.897 + 0.439[(X_3)(X_3/X_4)]$ $- 0.008Z$	.94 .84	75 75	1.01 2.68	0.074 .317
San Juan, Upper Rio Grande, Upper Colorado, and Gunnison River Basins and Green River Basin below confluence with the Yampa River (2)	$Y_2 = -0.011 + 0.942[(X_1)(X_1/X_5)]$ $Y_{100} = 0.494 + 0.755[(X_3)(X_3/X_4)]$	.95 .90	85 85	0.72 1.96	.085 .290
Yampa and Green River Basins above confluence of Green and Yampa Rivers (3)	$Y_2 = 0.019 + 0.711[(X_2)(X_1/X_5)]$ $+ 0.001Z$ $Y_{100} = 0.338 + 0.670[(X_3)(X_3/X_4)]$ $+ 0.001Z$	.82 .80	98 79	0.40 1.04	.031 .141
North Platte (4)	$Y_2 = 0.028 + 0.890[(X_1)(X_1/X_5)]$ $Y_{100} = 0.671 + 0.757[(X_3)(X_3/X_4)]$ $- 0.003Z$	.93 .91	90 88	0.60 1.71	.062 .236

* Numbers in parentheses refer to geographic regions shown in figure 19. See text for more complete description.

List of variables
Y_2 = 2-yr 1-hr estimated value
Y_{100} = 100-yr 1-hr estimated value
X_1 = 2-yr 6-hr value from precipitation-frequency maps
X_2 = 2-yr 24-hr value from precipitation-frequency maps
X_3 = 100-yr 6-hr value from precipitation-frequency maps
X_4 = 100-yr 24-hr value from precipitation-frequency maps
Z = point elevation in hundreds of feet

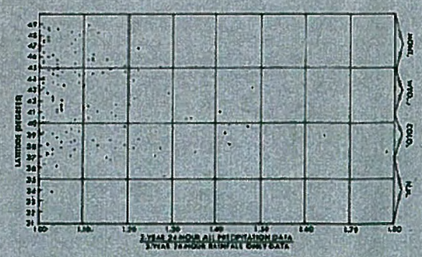


Figure 15. *Ratio of 2-yr 24-hr value for all data to 2-yr 24-hr value for rainfall only vs. latitude.*

Table 12. *Adjustment factors to obtain n-min estimates from 1-hr values*

Duration (min)	5	10	15	30
Ratio to 1-hr	0.29	0.45	0.57	0.79

(Adopted from *U.S. Weather Bureau Technical Paper* No. 40, 1961.)

Procedures for Estimating Values for Durations Other Than 6 and 24 Hrs

The isopluvial maps in this Atlas are for 6- and 24-hr durations. For many hydrologic purposes, values for other durations are necessary. Such values can be estimated using the 6- and 24-hr maps and the empirical methods outlined in the following sections. The procedures detailed below for obtaining 1-, 2-, and 3-hr estimates were developed specifically for this Atlas. The procedures for obtaining estimates for less than 1-hr duration and for 12-hr duration were adopted from *Weather Bureau Technical Paper* No. 40 (U.S. Weather Bureau 1961) only after investigation demonstrated their applicability to data from the area covered by this Atlas.

Procedures for estimating 1-hr (60-min) precipitation-frequency values. Multiple-regression screening techniques were used to develop equations for estimating 1-hr duration values. Factors considered in the screening process were restricted to those that could be determined easily from the maps of this Atlas or from generally available topographic maps.

The 11 western states were separated into several geographic regions. The regions were chosen on the basis of meteorological and climatological homogeneity and are generally combinations of river basins separated by prominent divides. Four of these geographic regions are partially within Colorado. For convenience and use as an overlay on the precipitation-frequency maps, these regions are outlined on figure 19. The first Colorado region is part of the region that lies to the east of the Continental Divide and the crest of the Sangre de Cristo and Sacramento Mountains and is south of the divide separating the drainage basins of the North and South Platte Rivers. It consists of that portion of Colorado drained by the South Platte, Republican, Arkansas, and Cimarron Rivers (Region 1, fig. 19). The second region consists of the area drained by the San Juan, Upper Rio Grande, Upper Colorado, and Gunnison Rivers and by the Green River below its confluence with the Yampa River (Region 2, fig. 19). This is part of a larger region that extends from southwestern Colorado, westward to the Wasatch Mountains of Utah, and southward through Arizona and the western half of New Mexico. The third region is the mountainous portion of the area between the Continental Divide and the crest of the Cascade Range. The portion that lies within Colorado is the northwestern portion of the State that is drained by the Yampa River and the Green River above its confluence with the Yampa (Region 3, fig. 19). A small portion of Colorado drained by the North Platte is Region 4, figure 19. The larger region of which this is a part includes that portion of Wyoming and Montana east of the Continental Divide. Equations to provide estimates for the 1-hr duration for 2- and 100-yr return periods are shown in table 11. Also listed are the statistical parameters associated with each equation. In these equations, the variable $[(X_1)(X_1/X_5)]$ or

Interpretation of Results

Season of Occurrence

The maps in this Atlas are based upon data for the entire year. In certain sections of the West, precipitation is highly seasonal. Thus, rainy season precipitation-frequency values approach the annual values. In sections where the greatest annual *n*-hour precipitation amount may be observed in any season, seasonal precipitation-frequency maps would differ from those presented in this Atlas. In no case could the seasonal value be greater than the annual value. However, the seasonal values would be a certain percent of the annual values, with the percent varying according to the frequency of large storms during the season under investigation. Generalizations about the seasonal distribution of large storms can be obtained from ESSA, *U.S. Weather Bureau Technical Paper* No. 57 (Environmental Science Services Administration, Weather Bureau, 1966). Currently, there is no convenient manner of applying this knowledge to the maps of this Atlas, other than subjectively.

Within Vs. Among Storms

Data for the various duration maps and diagrams in this Atlas were determined independently; that is, there was no requirement that the maximum 6- or 1-hr amount for a particular year be included within the maximum 24-hr amount for that year. The maps, therefore, represent an "among" storm distribution. In regions where winter-type storms predominate, the 6-hr value for a particular return period would more closely approximate the 6-hr value within the 24-hr storm for the same return period than would generally be the case in regions where convective storms predominate. In a study for the United States east of the Mississippi River, Miller (1971) showed that the ratio between the 2-yr 1-hr value computed from the maximum 1-hr amount within the 24-hr maximum and the 2-yr 1-hr value computed using maximum 1-hr amounts varied between 0.52 and 0.91. Studies have not been undertaken of this relation in the West, but a wide range in such ratios and similar ratios for the 6-hr duration could be expected.

Point Probabilities

The maps in this Atlas are derived from and depict point probabilities; the data points are independent of each other. Precipitation over a region is variable, even in large general area storms; neighboring stations do not necessarily experience maximum annual amounts from the same storm. Thus, the individual points on these maps express individual probabilities. That a point within a particular watershed may receive an amount equal to or greater than its 50- or 100-yr value on a particular day does not affect probabilities for any other point within that watershed. A second point within the watershed may experience an amount equal to or greater than its 50- or 100-yr value within the same storm or on the next day, within the next week or at any other time.

Areal Analysis

A value read from an isopluvial map in this Atlas is the value for that point and the amount for that particular duration which will be equaled or exceeded, on the average, once during the period indicated on the individual map. In hydrologic design, engineers are more concerned with the average depth of precipitation over an area than with the depth at a particular point. Depth-area curves were developed to meet this need. The depth-area curve is an attempt to relate the average of all point values for a given duration and frequency within a basin to the average depth over the basin for the same duration and frequency.

Generally, there are two types of depth-area relations. The first is the storm-centered relation; that is, the maximum precipitation occurring when the storm is centered on the area affected (fig. 13). The second type is the geographically fixed-area relation where the area is fixed and the storm is either centered over it or is displaced so only a portion of the storm affects the area (fig. 13). We can say that storm-centered rainfall data represent profiles of discrete storms, whereas the fixed-area data are statistical averages in which the maximum point values frequently come from different storms. At times, the maximum areal value for the network is from a storm that does not produce maximum point amounts. Each type of depth-area relation is useful, but each must be applied to appropriate data. Generally, the storm-centered relations are used for preparing estimates of probable maximum precipitation, while the geographically fixed relations are used for studies of precipitation-frequency values for basins.

Dense networks of precipitation gages are required to furnish basic data used in developing depth-area relations for fixed areas. The criteria used in selecting dense networks for the determination of areal precipitation-frequencies by the National Weather Service have been:

1. A network should be composed entirely of recording gages. The use of nonrecording gages may greatly increase the number and density of stations within a network, but it involves the construction of mass curves and introduces additional subjectivity. Nonrecording gages are read at various hours, usually early morning, late afternoon, or midnight. Because of conflicting activities, a cooperative observer may not always be able to read his precipitation gage at the exact hour specified. In these cases, the exact time of the observation may not be available, so it is hard to relate the reported amounts to those of surrounding stations with the precision required for development of depth-area relations.
2. A minimum length of record should be established to ensure a reasonable estimate of the 2-yr areal precipitation.
3. Gage locations and exposures should remain consistent during the period of record analyzed.
4. Gages should be located so that there is at least one gage located within each 100 square-mile area.

The average depth-area curves in this Atlas (fig. 14) are for fixed areas and were developed from dense networks meeting the above criteria. The curves were first prepared for an earlier study (U.S. Weather Bureau 1957–60) and have since been rechecked against longer record data; no changes were needed. Application of these curves must be consistent with the manner in which they were developed. The following steps are used:

1. Estimate point values from a grid of many points over the basin of interest for the duration and return period required.
2. Compute an average of the point values obtained in step 1.
3. Use figure 14 to obtain an areal reduction factor required for the precipitation duration and size of area under consideration.
4. Multiply the average value obtained in step 2 by the ratio obtained in step 3. The value obtained in this step provides the areal value for the basin of interest for the duration and return period under consideration.

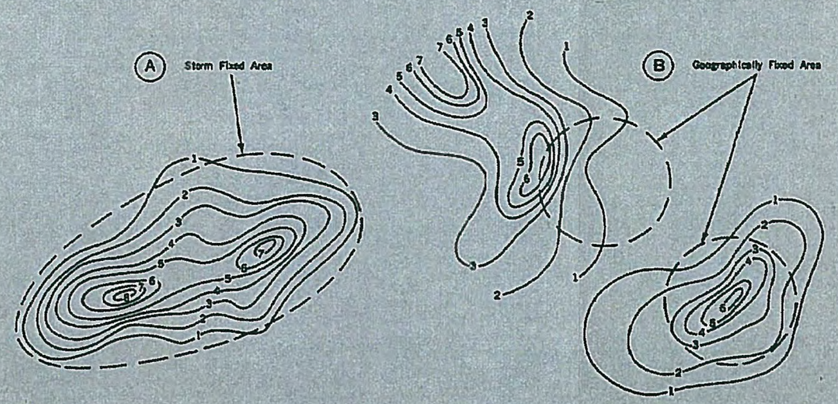


Figure 13. *Examples of (A) isohyetal pattern centered over basin as would be the case for storm-centered depth-area curves and (B) two possible occurrences of isohyetal patterns over a geographically fixed area as would be the case in development of curves for a geographically fixed area.*

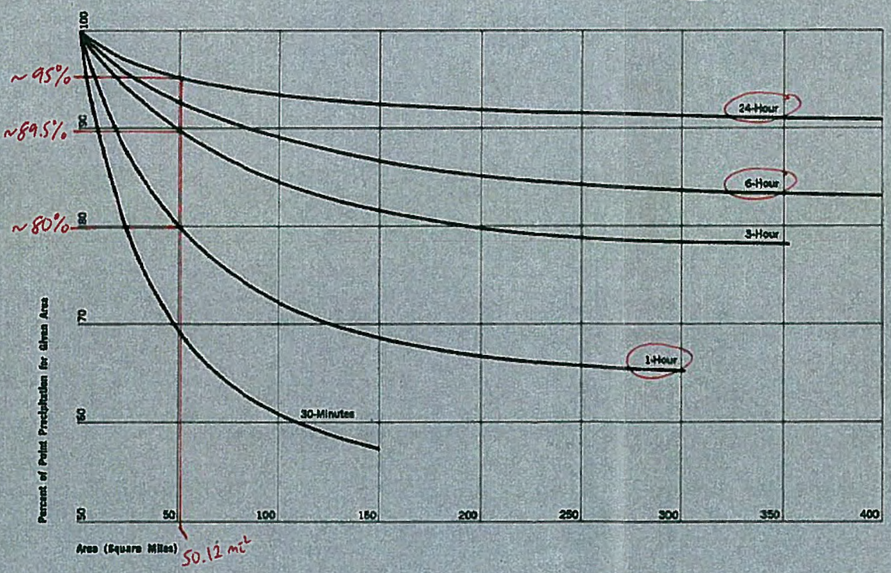


Figure 14. *Depth-Area curves.*

$[(X_4)(X_6/X_4)]$ can be regarded as the 6-hr value times the slope of the line connecting the 6- and 24-hr values for the appropriate return period.

As with any separation into regions, the boundary can only be regarded as the sharpest portion of a zone of transition between regions. These equations have been tested for boundary discontinuities by computing values using equations from both sides of the boundary. Differences were found to be mostly under 15 percent. However, it is suggested that when computing estimates along or within a few miles of a regional boundary computations be made using equations applicable to each region and that the average of such computations be adopted.

Estimates of 1-hr precipitation-frequency values for return periods between 2 and 100 yrs. The 1-hr values for the 2- and 100-yr return periods can be plotted on the nomogram of figure 6 to obtain values for return periods greater than 2 yrs or less than 100 yrs. Draw a straight line connecting the 2- and 100-yr values and read the desired return-period value from the nomogram.

Estimates for 2- and 3-hr (120- and 180-min) precipitation-frequency values. To obtain estimates of precipitation-frequency values for 2 or 3 hrs, plot the 1- and 6-hr values from the Atlas on the appropriate nomogram of figure 16. Draw a straight line connecting the 1- and 6-hr values, and read the 2- and 3-hr values from the nomogram. This nomogram is independent of return period. It was developed using data from the same regions used to develop the 1-hr equations.

The mathematical solution from the data used to develop figure 16 gives the following equations for estimating the 2- and 3-hr values:

For Region 1, figure 19	2-hr = 0.342 (6-hr) + 0.658 (1-hr)	(3)
	3-hr = 0.597 (6-hr) + 0.403 (1-hr)	(4)
For Region 2, figure 19	2-hr = 0.341 (6-hr) + 0.659 (1-hr)	(5)
	3-hr = 0.569 (6-hr) + 0.431 (1-hr)	(6)
For Regions 3 and 4, figure 19	2-hr = 0.250 (6-hr) + 0.750 (1-hr)	(7)
	3-hr = 0.467 (6-hr) + 0.533 (1-hr)	(8)

Estimates for 12-hr (720-min) precipitation-frequency values. To obtain estimates for the 12-hr duration, plot values from the 6- and 24-hr maps on figure 17. Read the 12-hr estimates at the intersection of the line connecting these points with the 12-hr duration line of the nomogram.

Estimates for less than 1 hr. To obtain estimates for durations of less than 1 hr, apply the values in table 12 to the 1-hr value for the return period of interest.

Illustration of Use of Precipitation-Frequency Maps, Diagrams, and Equations

To illustrate the use of these maps, values were read from figures 20 to 31 for the point at 39°00′ N. and 106°00′ W. These values are shown in boldface type in table 13. The values read from the maps should be plotted on the return-period diagram of figure 6 because (1) not all points are as easy to locate on a series of maps as are latitude-longitude intersections, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. This has been done for the 24-hr values in table 13 (fig. 18a) and a line of best fit has been drawn subjectively. On this nomogram, the line fits the data rather well. Had any points deviated noticeably from the line, the value would have been reread from the line and the new value substituted in table 13 and adopted in preference to the original readings.

The 2- and 100-yr 1-hr values for the point were computed from the equations applicable to Region 1, figure 19 (table 11), since the point is east of the Continental Divide. The 2-yr 1-hr value is estimated at 0.71 in. (2-yr 6- and 24-hr values from table 13); the estimated 100-yr 1-hr value is 1.86 in. (100-yr 6- and 24-hr values from table 13 and elevation of 9,500 ft). By plotting these 1-hr values on figure 6 and connecting them with a straight line, one can obtain estimates for return periods of 5, 10, 25, and 50 yrs.

The 2- and 3-hr values can be estimated by using the nomogram of figure 16 or equations (3) and (4). The 1- and 6-hr values for the desired return period are obtained as above. Plot these points on the nomogram of figure 16 and connect them with a straight line. Read the estimates for 2 or 3 hrs at the intersections of the connecting line and the 2- and 3-hr vertical lines. An example is shown in figure 18b for the 2-yr return period. The 2-yr 2-hr (0.83 in.) and 2-yr 3-hr (0.91 in.) values are in italics on table 13.

	1-hr	2-hr	3-hr	6-hr	24-hr
2-yr	*0.71*	*0.83*	*0.91*	1.05	1.58
5-yr				1.38	1.99
10-yr				1.59	2.27
25-yr				1.90	2.65
50-yr				2.19	2.95
100-yr	*1.86*			2.39	3.35

Table 13. *Precipitation data for depth-frequency atlas computation point 106°00′ W., 39°00′ N.*

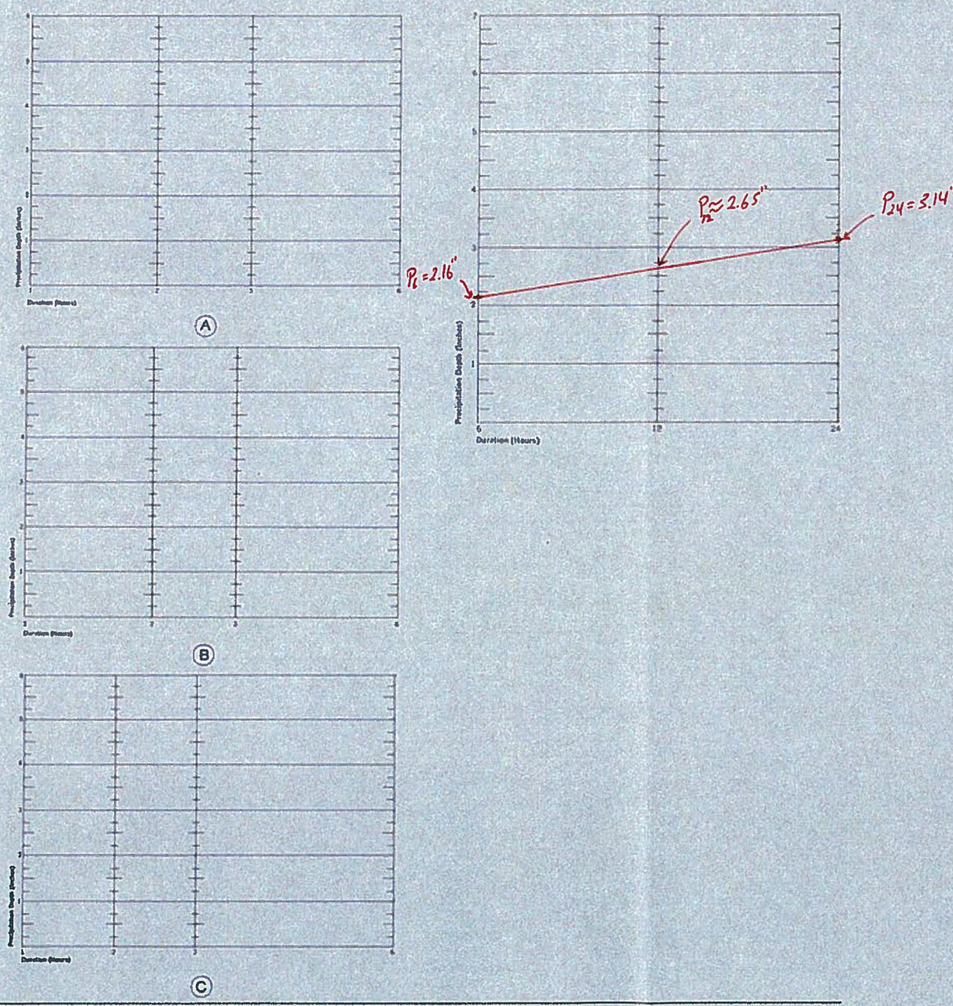


Figure 16. *Precipitation depth-duration diagram (1- to 6-hr).*
a. South Platte, Republican, Arkansas, and Cimarron River Basins (Region 1, fig. 19).
b. San Juan, Upper Rio Grande, Upper Colorado, and Gunnison River Basins and Green River Basin below its confluence with the Yampa River (Region 2, fig. 19).
c. Yampa and Green River Basins above confluence of Green and Yampa Rivers (Region 3, fig. 19) and North Platte Drainage (Region 4, fig. 19).

Figure 17. *Precipitation depth-duration diagram (6- to 24-hr).*

Appendix D

Appendix D
Unit Hydrograph Calculations

URS CALCULATION COVER SHEET

Project Name:	Continental & Santa Maria Dam	**Project Number:**	22241248.00001
Project Location:	Hindsdale County, CO	**Client Name:**	Santa Maria Reservoir Co.
PM Name:	Ed Toms	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: MIKE PHILLIPS

Calculation to be checked: *Unit hydrographs for Continental Reservoir Basin (7 pages including cover sheet).*

Calculation Originator: *Chad Martin*

Checker's comments required by: 6/3/2010

Submitted by: _____ 6/9/10

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☒ All items have been found to be correct. Checker has no comments.

_____ 9 JUNE 2010

Checker Signature **Date**

or

B. ☐ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☐ Verification of correct incorporation of resolved comments into final document is complete.

_____ _____

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ 6/9/10

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose:
Generate unit hydrographs for the Continental Reservoir watershed using the Rocky Mountain General Storm and Thunderstorm unit hydrographs.

References:

Cudworth, A.G., *Flood Hydrology Manual.* United States Department of Commerce Bureau of Reclamation. Denver, Colorado. 1989

United States Department of the Agriculture (USDA). Geospatial Data Gateway. <http://datagateway.nrcs.usda.gov/> November 2009.

State of Colorado (SEO). 2008. "Hydrologic Basin Response, Parameter Estimation Guidelines." State of Colorado, Office of the State Engineer, Dam Safety Branch. Prepared by Tierra Grande International, Inc. Revised May 2008.

Files:

Folder:
N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\Hydrology\Continental

Continental_Basin_UH_General.xls
Continental_Basin_UH_Local.xls
Continental_Basin_UH_100yr.xls

Analysis:

USBR's *Flood Hydrology Manual* (Cudworth, 1989) was used to formulate unit hydrographs for the watershed. The "Rocky Mountains" unit hydrograph was chosen to be the most appropriate unit hydrograph type. Both the "General Storm" and "Thunderstorm" options were estimated. Geographic Information Systems (GIS) software was used to determine the parameters dependent on basin topography including the drainage basin area (*A*), main watercourse length (*L*), basin slope (*S*), and distance to basin centroid (L_{ca}). Also see the attached map indicating the GIS information used to estimate basin parameters. See the memorandum date November 6. 2009 from Jared Walter to Greg Glunz concerning estimation of the lag coefficient, **Kn**.

A summary of hydrologic parameters used to develop the unit hydrographs is presented below. For the 100-year storm, SEO (2008) recommends using the local thunderstorm unit hydrograph with a K_n between 0.20-0.30. Average K_n values suggested by SEO (2008) were used for all storms.

Storm Type	Basin Area (mi^2)	Main Watercourse Flow Length, **L** (mi)	Distance to Centroid, L_{ca} (mi)	Main Watercourse Slope, **S** (ft/mi)	Lag Coefficient, **Kn**
General Storm	50.12	12.46	4.14	206.98	0.225
Thunderstorm					0.065
100-yr					0.250

The lag time was estimated using the lag time equation presented in Cudworth (1989).

$$L_g = 26K_n\left(\frac{LL_{ca}}{S^{0.5}}\right)^{0.33}$$

Sub-basin	Lag Time (hrs)
General Storm	8.92
Thunderstorm	2.58
100-year	9.91

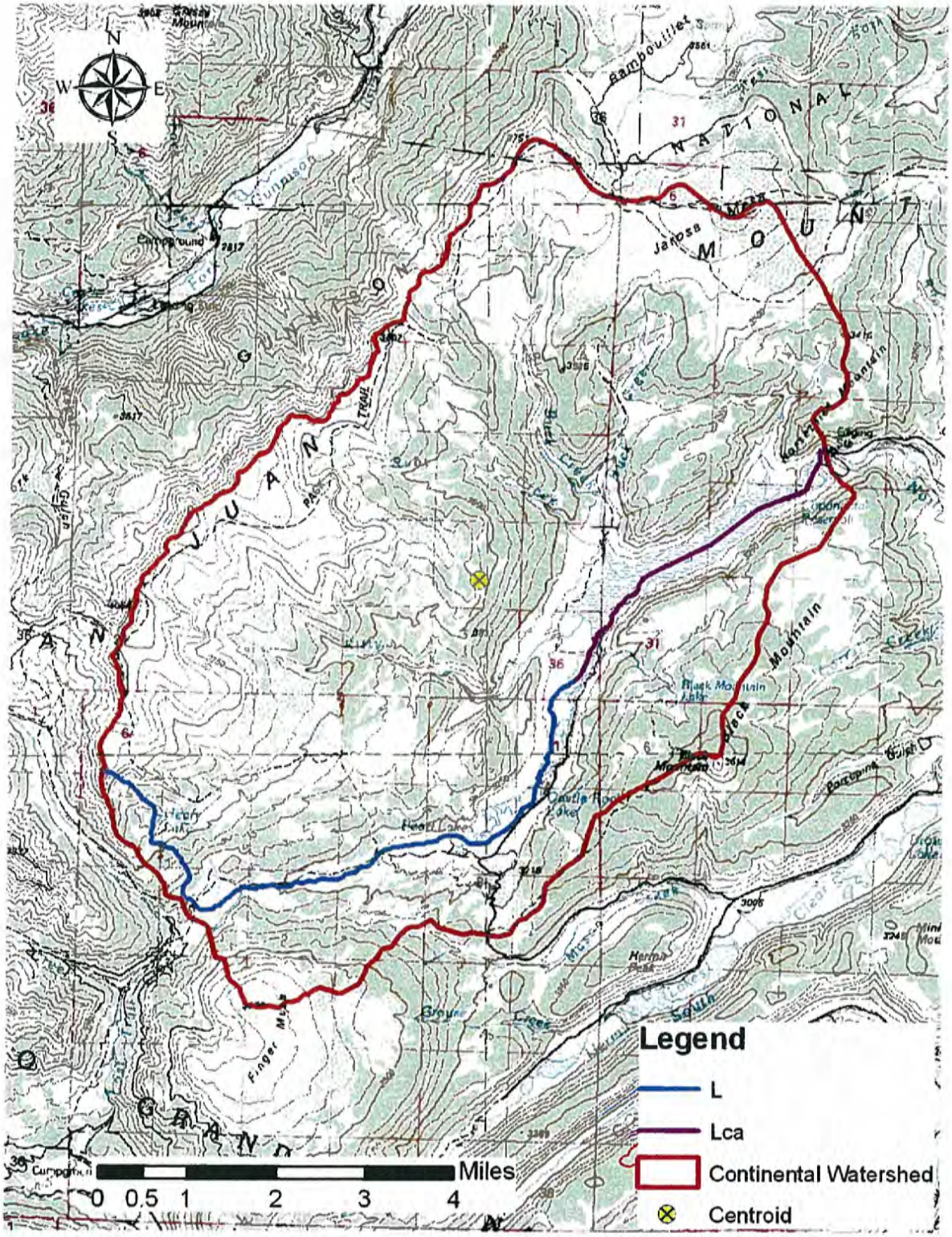
Unit hydrographs were developed based upon Cudworth (1989). An Excel spreadsheet was used to generate the unit hydrograph. Required inputs for the spreadsheet included drainage area, basin slope, length of watercourse, distance to centroid, and the average weighted Manning's n value.

Attributes of Continental Watershed

FID	Shape	Id	sq_Miles	X	Y
0	Polygon	0	50.12	2487413.563	1441454.71466825

Attributes of Main_Chnnl_Length

FID	Shape *	Id	Length_mi	Type
0	Polyline	0	12.46	L
1	Polyline	0	4.14	Lca


N
W
E
S
Legend
L
Lca
Continental Watershed
Centroid
Miles
0 0.5 1 2 3 4

ROCKY MOUNTAIN (GENERAL STORM) UNIT HYDROGRAPH 03-Jun-10

Continental Reservoir

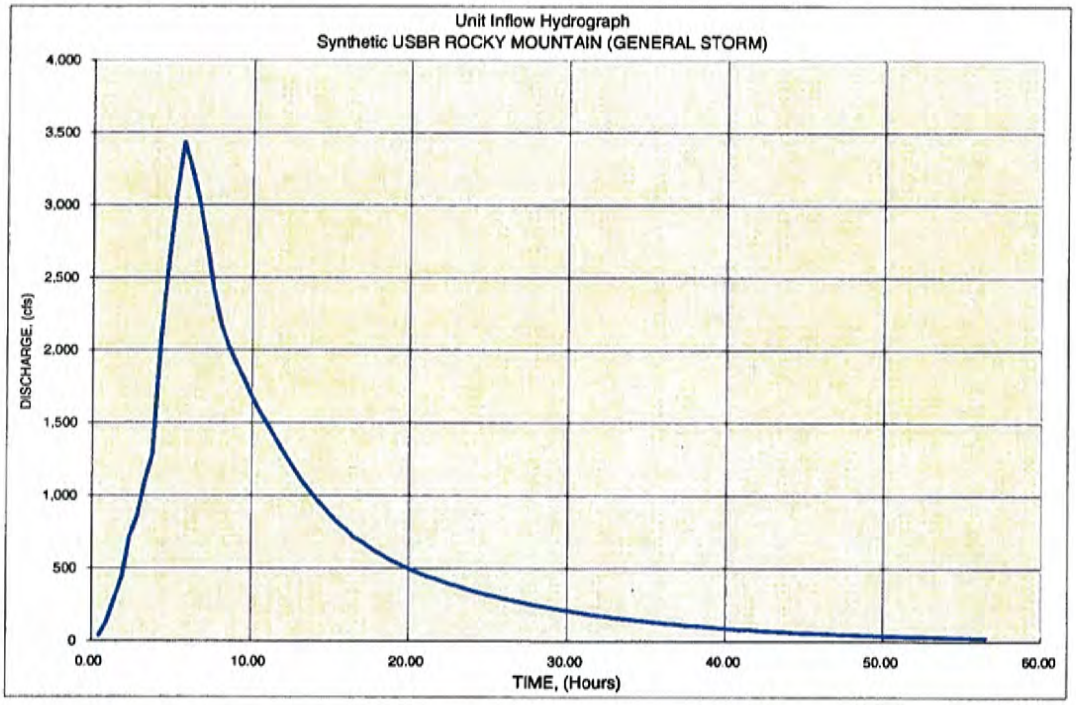
DAMID: 200356 JAW

Drainage Area =	50.12 sq. miles	Lg+D/2 =	9.42 Hours
Basin Slope =	206.98 ft./mile	Basin Factor =	3.59
L =	12.46 mi., Length of Watercourse	V' =	1347.73 cfs/Day
Lca =	4.14 mi., Distance to Centroid	Qs =	143.1 * q, cfs
Kn =	0.225 -, Ave. Weighted Manning's n		

PARAMETERS:

Calculated:	Lag Time, Lg =	8.92 Hours	Unit Duration, D =	97.26 minutes
			Calculated Timestep =	28.25 minutes

Data to be used Unit Duration, D =	60 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
In Analysis Selected Timestep =	30 minutes, integer value evenly divisible into 60



Rocky Mountain General Storm Unit Hydrograph

ROCKY MOUNTAIN (THUNDERSTORM) UNIT HYDROGRAPH 03-Jun-10

Continental Reservoir

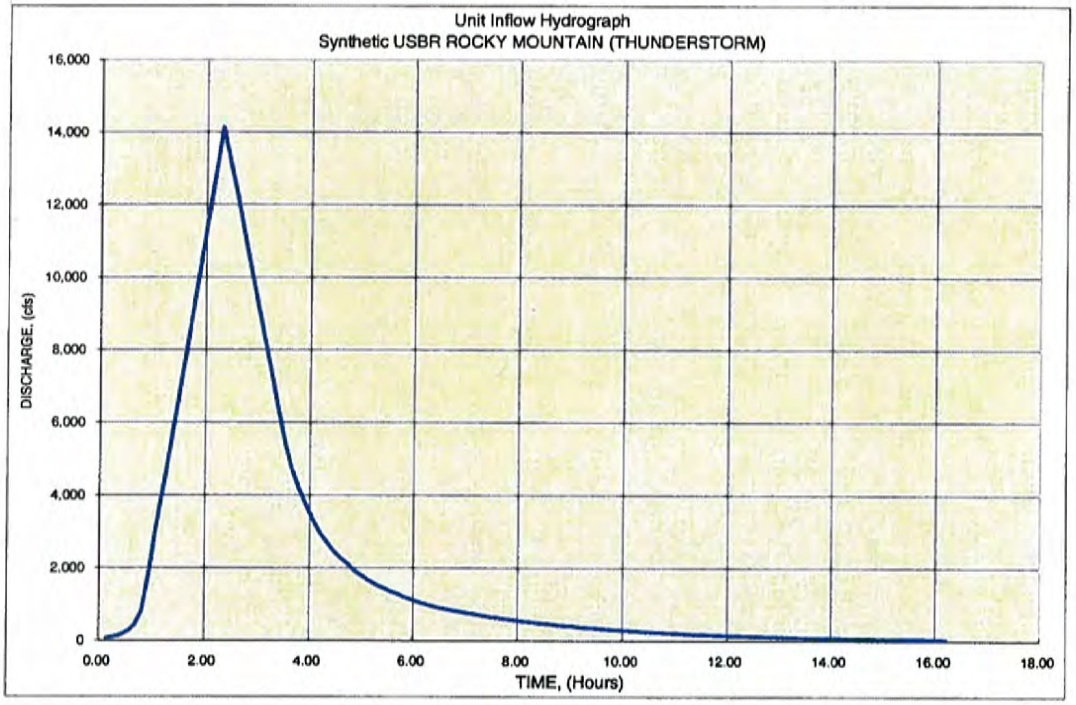
DAMID: 200356 JAW

Drainage Area =	50.12 sq. miles	Lg+D/2 =	2.70	Hours
Basin Slope =	206.98 ft./mile	Basin Factor =	3.59	
L =	12.46 mi., Length of Watercourse	V' =	1347.73	cfs/Day
Lca =	4.14 mi., Distance to Centroid	Qs =	499.0	* q, cfs
Kn =	0.065 -, Ave. Weighted Manning's n			

PARAMETERS:

Calculated:	Lag Time, Lg =	2.58 Hours	Unit Duration, D =	28.10 minutes
			Calculated Timestep =	8.10 minutes

Data to be used in Analysis	Unit Duration, D =	15 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
	Selected Timestep =	5 minutes, integer value evenly divisible into 60



Rocky Mountain Thunderstorm Unit Hydrograph

ROCKY MOUNTAIN (THUNDERSTORM) UNIT HYDROGRAPH 07-Jun-10

Continental Reservoir - 100yr

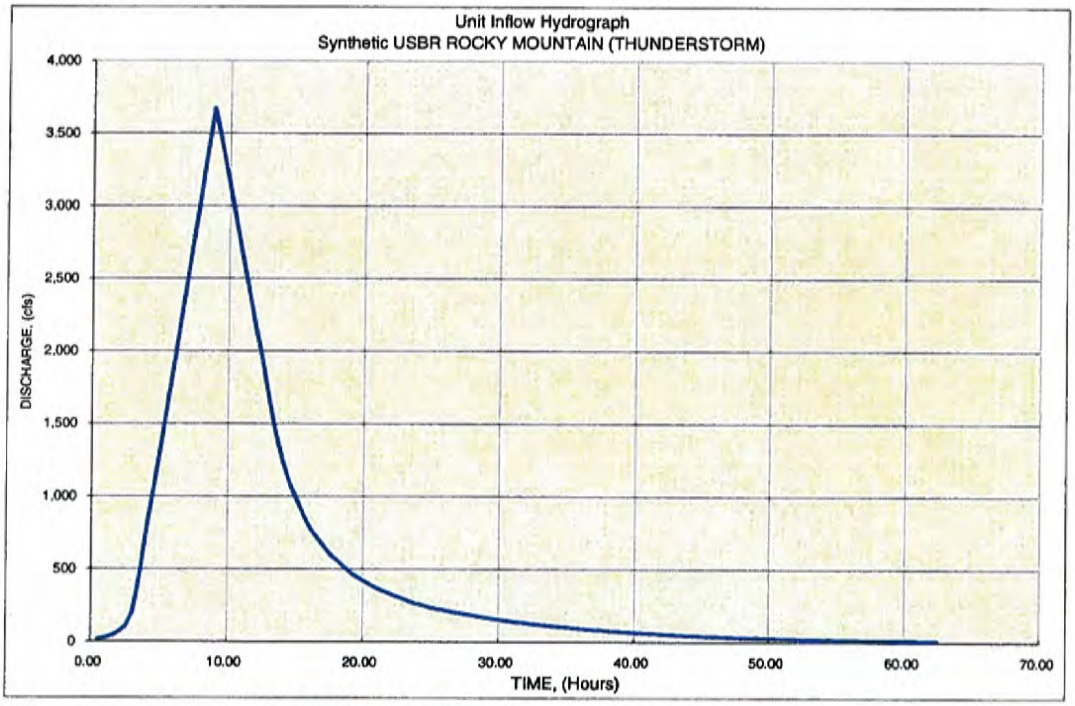
DAMID: 200356 CAM

Drainage Area =	50.12 sq. miles	Lg+D/2 =	10.41	Hours
Basin Slope =	206.98 ft./mile	Basin Factor =	3.59	
L =	12.46 mi., Length of Watercourse	V' =	1347.73	cfs/Day
Lca =	4.14 mi., Distance to Centroid	Qs =	129.5	* q, cfs
Kn =	0.25 -, Ave. Weighted Manning's n			

PARAMETERS:

Calculated:	Lag Time, Lg =	9.91 Hours	Unit Duration, D =	108.07 minutes
			Calculated Timestep =	31.22 minutes

Data to be used	Unit Duration, D =	60 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
In Analysis	Selected Timestep =	30 minutes, integer value evenly divisible into 60

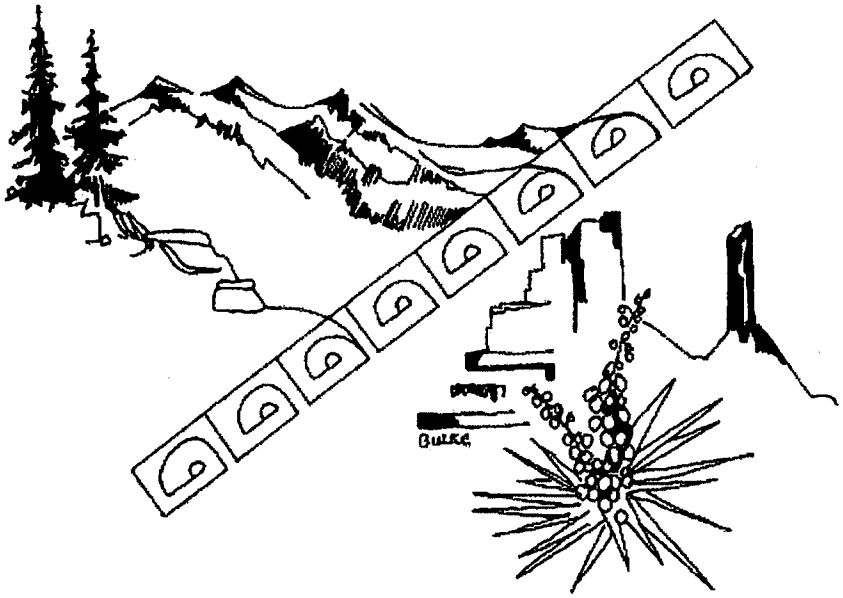


Rocky Mountain 100-year Unit Hydrograph

State of Colorado
Office of the State Engineer
Dam Safety Branch

HYDROLOGIC BASIN RESPONSE

PARAMETER ESTIMATION GUIDELINES



Tierra Grande International, Inc
George V. Sabol, PhD, PE

Revised May 2008

TABLE 7

Summary of Unit Hydrographs and Kn Values for Colorado Watersheds

Watershed Type	Recommended Unit Hydrograph	K_n for Dimensionless Unit Hydrograph			
		Range	100-yr[1]	PMF Thunderstorm	PMF General Storm
(1)	(2)	(3)	(4)	(5)	(6)
Mountains (PMP thunderstorm)	Dimensionless Rocky Mountain Thunderstorm	0.05-0.08	NA	0.05-0.08	NA
Mountains (PMP general storm)	Dimensionless Rocky Mountain General Storm	0.15-0.30	NA	NA	0.15-0.30
Mountains (100-year)	Dimensionless Rocky Mountain Thunderstorm	0.20-0.30	0.20-0.30	NA	NA
Rangelands of western Colorado	Dimensionless Colorado Plateau	0.04-0.07	0.05-0.07	0.04-0.06	0.05-0.07
Valleys ("Parks") within mountains	Dimensionless Great Plains	0.03-0.07	0.04-0.07	0.03-0.06	0.04-0.07
Western Colorado, arid Plateau	Dimensionless Colorado Plateau	0.04-0.07	0.05-0.07	0.04-0.06	0.05-0.07
Plains of Front Range	Dimensionless Great Plains	0.03-0.07	0.04-0.07	0.03-0.06	0.04-0.07
Agricultural Fields	Clark Unit Hydrograph	NA	NA	NA	NA
Urban	Clark Unit Hydrograph	NA	NA	NA	NA

Notes:
[1] – It is assumed that for the 100-year storm the 24-hour hypothetical rainfall distribution is used. That rainfall distribution simulates high intensity thunderstorm rainfall within a long-term general storm.

Appendix E

Stage-Storage-Discharge Calculations

URS CALCULATION COVER SHEET

Project Name:	*Continental Dam*	**Project Number:**	*22241248.00001*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: *Dan Greaves*

Calculation to be checked: *Elevation-Storage-Discharge Calculations for the Continental Dam Reservoir*

Calculation Originator: *Jared Walter/ Revised by Joseph Machala 3/31/2011*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☐ All items have been found to be correct. Checker has no comments.

_____ _____

Checker Signature **Date**

or

B. ☒ Checker's comments have been provided on:

- ☐ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☒ Other ~~Note~~ calc pack

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☒ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☒ Verification of correct incorporation of resolved comments into final document is complete.

Dan Greaves 4/1/2011

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose

Develop an elevation-storage-discharge relationship for Continental Reservoir using data obtained from the Colorado Division of Water Resources.

Files

Filename: El_Strg_Dschrg_ContinentalJWM_REV.xls
Folder: N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental

References

1) **Filename:** DWR_DCD_0000675[1].pdf
   Title: Continental Reservoir Dam Del Norte Irrigation District
   Date: February 2nd 1925 – September 10th 1925
   Sheets: 5
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2) **Filename:** SEO Comments Continental 3-25-2011.pdf
   Title: Review of the Continetal Reservoir Flood Hydrology Report
   Date: March 11, 2011
   Sheets: 3
   Folder: N:\Projects\22241248_Santa_Maria_Contine\Sub_00\3.0_Corresp

Background

URS submitted a preliminary copy of the Continental Reservoir Flood Hydrology Report to the State of Colorado Office of the State Engineer (SEO) dated August 2, 2010. Mr. Matthew Gavin, Dam Safety Engineer (District 3), reviewed the report and suggested adopting the attached spillway rating curve developed by the USACE in 1978 in their Phase 1 Report for Continental Dam. He suggested that URS approach did not address the backwater effects resulting from the constriction in the side-channel below the spillway crest and the rating curve from the USACE, 1978 report did. URS has reviewed this spillway discharge curve and adopted it for the Continental Reservoir Flood Hydrology Report. The original stage-storage curve and approach was not altered.

Analysis

The stage-storage relationship was converted to elevations using the assumptions gathered from review of Reference 1):

Table 1
Assumptions Used to Convert Stage to Elevation

Stage	Elev.*	Location
0.0	10203.3[1)]	Invert of Low Level outlet Works
76.7	10280.0[2)]	Spillway Crest
86.7	10290.0[2)]	Dam Crest

[1)] Sheet 4 of Reference 1)
[2)] Sheet 3 of Reference 1)
* Unspecified Vertical Datum

It was assumed that the relative elevations indicated in Table 1 were correct and could be correlated to the stage-storage relationship. The maximum stage of the stage-storage relationship, received from Mr. Gavin on 11/15/2010, was 81.8 ft leaving a data gap in the upper 4.9 ft below the dam crest. It was assumed that a linear extrapolation would suffice for the elevation-storage relationship for this upper portion of the reservoir.

Table 2 shows the adopted elevation-storage-discharge relationship including the USACE 1978 spillway discharge rating curve and overtopping dam flow. The elevations were approximately 1 foot below the report values used in the development of the spillway stage-storage curve. All flows were shifted 1 foot higher to account for the spillway elevation of 10,280 ft. Figure 1 shows the graphical stage-storage relationship with linear extrapolated storage past elevation 10,285 used in the original Hydrology Report. Figure 1 shows the graphical elevation-discharge relationship adopted from the USACE, 1978 Phase 1 Report. Storages above elevation 10,285 ft were linear extrapolated based on the previous two points on the curve. All low level outlet works were considered negligible during these extreme precipitation events.

It was assumed that the dam embankment would overtop during the General or Local HRM storms. Elevations-discharge relationships above the dam crest (10,290 ft) were treated as broad crested weir and added to the extrapolated spillway flows. A dam crest length of 310 feet and assumed weir coefficient of 2.65 were used to calculate increase stage-storage-discharge curve extents an additional 4 feet above the dam crest. Table 3 shows the total stage-storage-discharge relationship, including flow over the dam crest.

FIGURE 1
Continental Reservoir Elevation-Storage

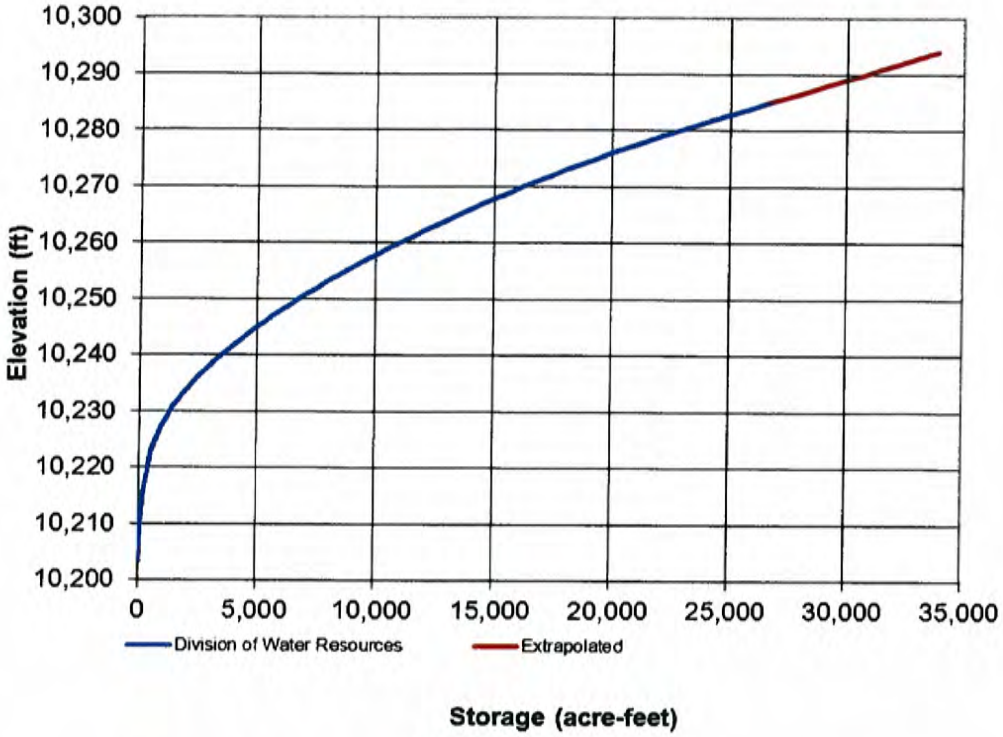

FIGURE 2
Adopted Continental Reservoir Elevation-Discharge

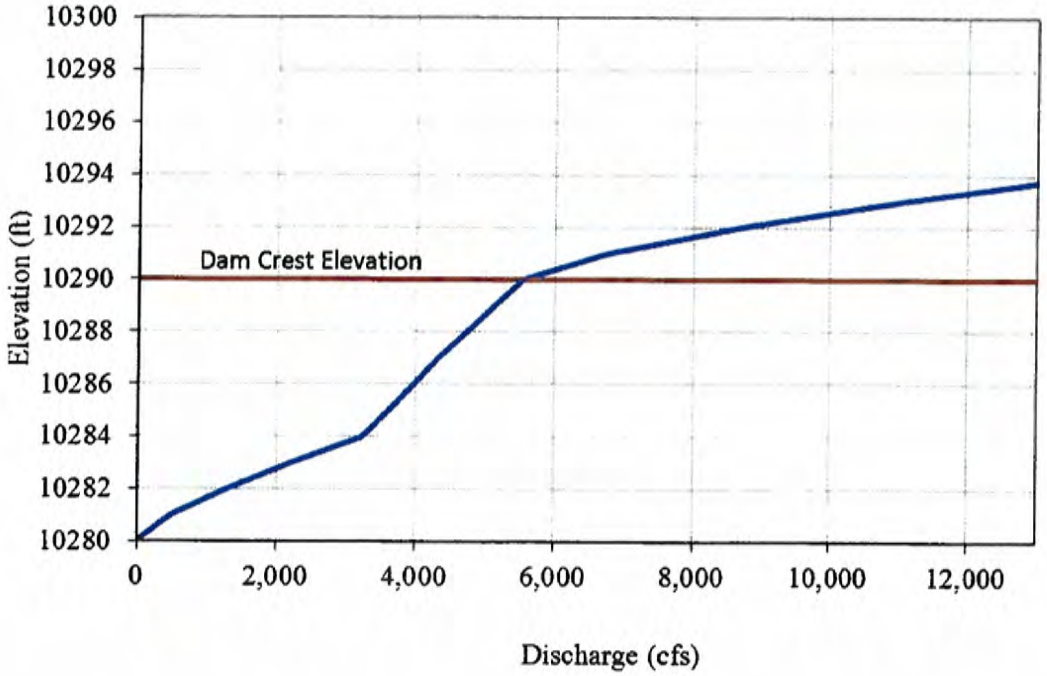

Table 2
Continental Reservoir
Elevation-Stage-Storage-Discharge

Stage (ft)	Elev. (ft)	Storage (ac-ft)	Spillway Discharge (cfs)	Dam Discharge (cfs)	Stage (ft)	Elev. (ft)	Storage (ac-ft)	Spillway Discharge (cfs)	Dam Discharge (cfs)
0.0	10,203.3	-	0	0	45.7	10,249	6,382	0	0
0.7	10,204	1.8	0	0	46.7	10,250	6,754	0	0
1.7	10,205	6.0	0	0	47.7	10,251	7,135	0	0
2.7	10,206	12.2	0	0	48.7	10,252	7,526	0	0
3.7	10,207	20.4	0	0	49.7	10,253	7,926	0	0
4.7	10,208	30.8	0	0	50.7	10,254	8,337	0	0
5.7	10,209	43.4	0	0	51.7	10,255	8,757	0	0
6.7	10,210	58.4	0	0	52.7	10,256	9,187	0	0
7.7	10,211	75.8	0	0	53.7	10,257	9,626	0	0
8.7	10,212	95.5	0	0	54.7	10,258	10,076	0	0
9.7	10,213	118.0	0	0	55.7	10,259	10,535	0	0
10.7	10,214	143.0	0	0	56.7	10,260	11,003	0	0
11.7	10,215	170.0	0	0	57.7	10,261	11,482	0	0
12.7	10,216	200.0	0	0	58.7	10,262	11,969	0	0
13.7	10,217	234.0	0	0	59.7	10,263	12,466	0	0
14.7	10,218	271.0	0	0	60.7	10,264	12,972	0	0
15.7	10,219	313	0	0	61.7	10,265	13,489	0	0
16.7	10,220	359	0	0	62.7	10,266	14,016	0	0
17.7	10,221	410	0	0	63.7	10,267	14,554	0	0
18.7	10,222	468	0	0	64.7	10,268	15,104	0	0
19.7	10,223	532	0	0	65.7	10,269	15,667	0	0
20.7	10,224	605	0	0	66.7	10,270	16,242	0	0
21.7	10,225	687	0	0	67.7	10,271	16,831	0	0
22.7	10,226	779	0	0	68.7	10,272	17,434	0	0
23.7	10,227	885	0	0	69.7	10,273	18,051	0	0
24.7	10,228	1,006	0	0	70.7	10,274	18,683	0	0
25.7	10,229	1,142	0	0	71.7	10,275	19,332	0	0
26.7	10,230	1,292	0	0	72.7	10,276	19,997	0	0
27.7	10,231	1,454	0	0	73.7	10,277	20,679	0	0
28.7	10,232	1,628	0	0	74.7	10,278	21,378	0	0
29.7	10,233	1,813	0	0	75.7	10,279	22,095	0	0
30.7	10,234	2,011	0	0	76.7	10,280	22,825	0	0
31.7	10,235	2,222	0	0	77.7	10,281	23,571	500	0
32.7	10,236	2,446	0	0	78.7	10,282	24,331	1,270	0
33.7	10,237	2,683	0	0	79.7	10,283	25,106	2,180	0
34.7	10,238	2,932	0	0	80.7	10,284	25,895	3,250	0
35.7	10,239	3,194	0	0	81.7	10,285	26,697	3,620	0
36.7	10,240	3,466	0	0	82.7	10,286	27,499	3,980	0
37.7	10,241	3,750	0	0	83.7	10,287	28,301	4,350	0
38.7	10,242	4,045	0	0	84.7	10,288	29,103	4,740	0
39.7	10,243	4,350	0	0	85.7	10,289	29,905	5,140	0
40.7	10,244	4,665	0	0	86.7	10,290	30,707	5,550	0
41.7	10,245	4,990	0	0	87.7	10,291	31,509	5,960	822
42.7	10,246	5,324	0	0	88.7	10,292	32,311	6,370	2,324
43.7	10,247	5,667	0	0	89.7	10,293	33,113	*6,780*	4,269
44.7	10,248	6,020	0	0	90.7	10,294	33,915	*7,190*	6,572

Notes:

- Low Level Outlet Works Invert Elevation = 10,203.3 ft
- Spillway Crest Elevation = 10,280.0 ft
- Dam Crest Elevation = 10,290.0 ft
- Extrapolated Values indicated in *Red Italics*
- The Vertical Datum associated with the Elevations is unknown.

Table 3
Continental Reservoir Total
Elevation-Stage-Storage-Discharge

Stage (ft)	Elev. (ft)	Storage (ac-ft)	Total Discharge (cfs)	Stage (ft)	Elev. (ft)	Storage (ac-ft)	Total Discharge (cfs)
0.0	10,203.3	-	0	45.7	10,249	6,382	0
0.7	10,204	1.8	0	46.7	10,250	6,754	0
1.7	10,205	6.0	0	47.7	10,251	7,135	0
2.7	10,206	12.2	0	48.7	10,252	7,526	0
3.7	10,207	20.4	0	49.7	10,253	7,926	0
4.7	10,208	30.8	0	50.7	10,254	8,337	0
5.7	10,209	43.4	0	51.7	10,255	8,757	0
6.7	10,210	58.4	0	52.7	10,256	9,187	0
7.7	10,211	75.8	0	53.7	10,257	9,626	0
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9.7	10,213	118.0	0	55.7	10,259	10,535	0
10.7	10,214	143.0	0	56.7	10,260	11,003	0
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14.7	10,218	271.0	0	60.7	10,264	12,972	0
15.7	10,219	313	0	61.7	10,265	13,489	0
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19.7	10,223	532	0	65.7	10,269	15,667	0
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21.7	10,225	687	0	67.7	10,271	16,831	0
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24.7	10,228	1,006	0	70.7	10,274	18,683	0
25.7	10,229	1,142	0	71.7	10,275	19,332	0
26.7	10,230	1,292	0	72.7	10,276	19,997	0
27.7	10,231	1,454	0	73.7	10,277	20,679	0
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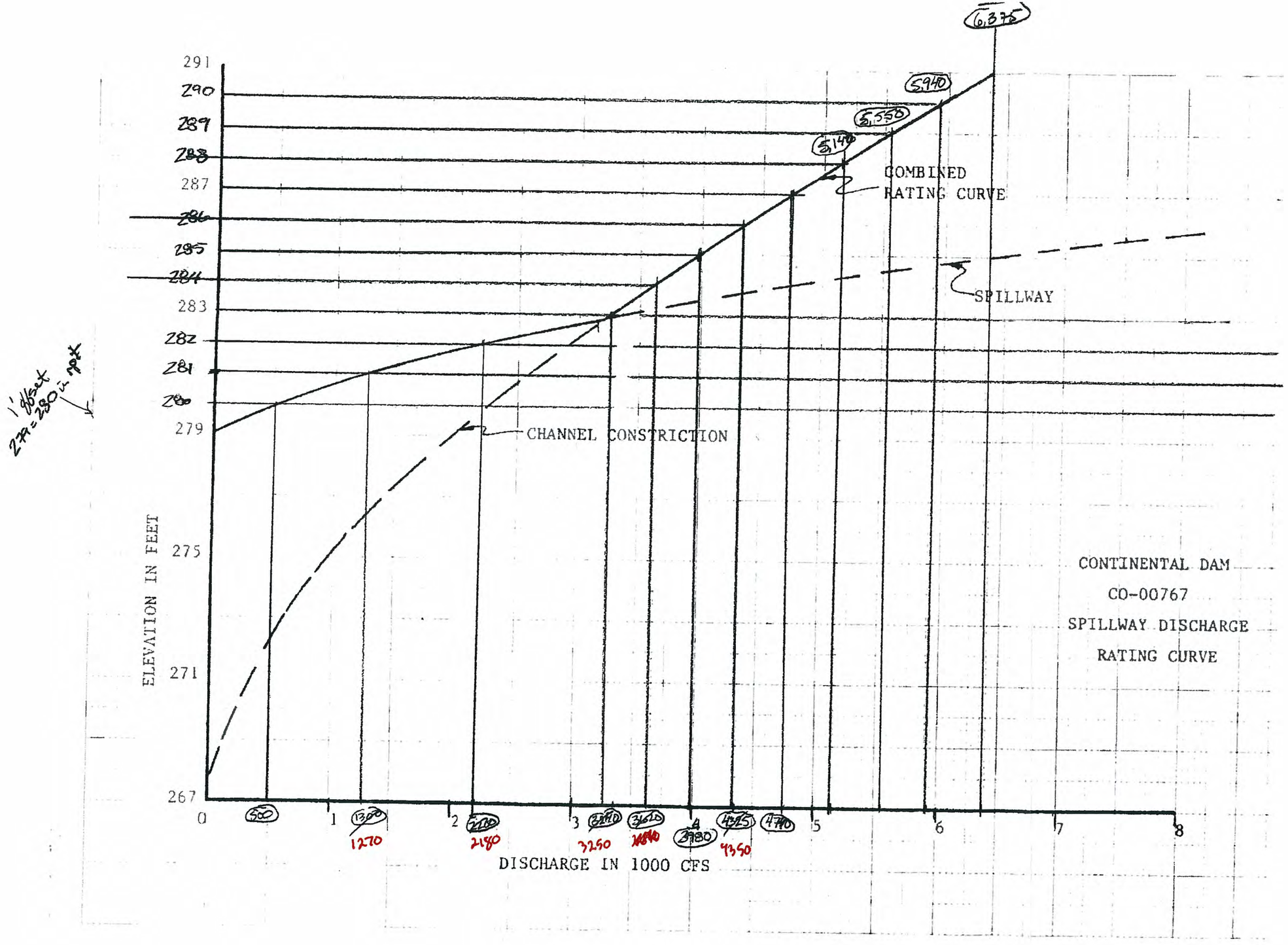
31.7	10,235	2,222	0	77.7	10,281	23,571	500
32.7	10,236	2,446	0	78.7	10,282	24,331	1,270
33.7	10,237	2,683	0	79.7	10,283	25,106	2,180
34.7	10,238	2,932	0	80.7	10,284	25,895	3,250
35.7	10,239	3,194	0	81.7	10,285	26,697	3,620
36.7	10,240	3,466	0	82.7	10,286	27,499	3,980
37.7	10,241	3,750	0	83.7	10,287	28,301	4,350
38.7	10,242	4,045	0	84.7	10,288	29,103	4,740
39.7	10,243	4,350	0	85.7	10,289	29,905	5,140
40.7	10,244	4,665	0	86.7	10,290	30,707	5,550
41.7	10,245	4,990	0	87.7	10,291	31,509	6,782
42.7	10,246	5,324	0	88.7	10,292	32,311	8,694
43.7	10,247	5,667	0	89.7	10,293	33,113	*11,049*
44.7	10,248	6,020	0	90.7	10,294	33,915	*13,762*

Notes:

- Low Level Outlet Works Invert Elevation = 10,203.3 ft
- Spillway Crest Elevation = 10,280.0 ft
- Dam Crest Elevation = 10,290.0 ft
- Extrapolated Values indicated in *Red Italics*

The Vertical Datum associated with the Elevations is unknown


291
290
289
288
287
286
285
284
283
282
281
280
279
275
271
267
ELEVATION IN FEET
0
1
2
3
4
5
6
7
8
DISCHARGE IN 1000 CFS
6,375
5,940
5,550
5,140
COMBINED
RATING CURVE
SPILLWAY
CHANNEL CONSTRICTION
500
1300
1270
2180
2180
3250
3610
3780
4325
4350
4740
1 foot at 279 = 280 ft
CONTINENTAL DAM
CO-00767
SPILLWAY DISCHARGE
RATING CURVE

Appendix F

Appendix F

HEC-HMS Model Screen Captures

URS CALCULATION COVER SHEET

Project Name:	*Continental & Santa Maria Dam*	**Project Number:**	*22241248.00001*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Dan Greaves

Calculation to be checked: HEC-HMS Model for 100-year Storm – Continental Dam

Calculation Originator: *Chad Martin / Revised by Joseph Machala 4/1/2011*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☐ All items have been found to be correct. Checker has no comments.

_____ _____

Checker Signature **Date**

or

B. ☒ Checker's comments have been provided on:

- ☒ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☑ Verification of correct incorporation of resolved comments into final document is complete.

Dan Greaves 4/4/2011

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose:
Route the 100 Year storm through Continental Dam.

Files/Folders:

HEC-HMS Model:
Filename: Cntntl_Res
Folder: N:\Projects\22241248....\10.0_Calculations_Analysis_Data\H&H\Continental\HMS\Cntntl_Res

HEC-HMS Results:
Filename: HEC_HMS_100yr-Output
Folder: N:\Projects\22241248....\10.0_Calculations_Analysis_Data\H&H\Continental

References:

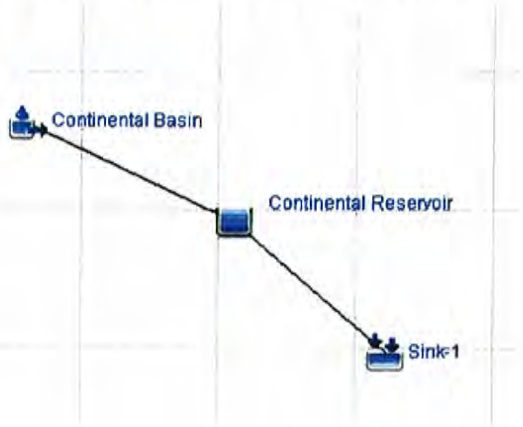
1. Calculation packet titled "100 Year Precipitation Depth for Continental Dam" by Chad Martin on 6/7/10
2. Calculation packet titled "Infiltration Rates – Green and Ampt – 100yr StormREV" revised by Joseph Machala on 3/31//10
3. Calculation packet titled "Unit Hydrographs for Continental Reservoir Basin" by Chad Martin on 6/3/10
4. Calculation packet titled "Elevation-Storage-Discharge Relationship for Continental Reservoir" revised by Joseph Machala on 4/1/11
5. State of Colorado "Rules and Regulations for Dam Safety and Dam Construction" 2-CCR 402-1 dated January 1, 2007
6. State of Colorado (SEO). 2008. "Hydrologic Basin Response, Parameter Estimation Guidelines." State of Colorado, Office of the State Engineer, Dam Safety Branch. Prepared by Tierra Grande International, Inc. Revised May 2008.

General Approach:
The HEC-HMS model has been set up primarily using References 1 through 4. Pertinent dam and reservoir information has been input using Reference 4 and assuming the initial reservoir water level to be at the normal pool or elevation 10,280. Pertinent watershed data like area, infiltration rate and imperviousness have been input to the model from Reference 2. Unit hydrograph data has been entered from Reference 3.

The meteorological model was developed using References 1 and 4. One meteorological model was examined:

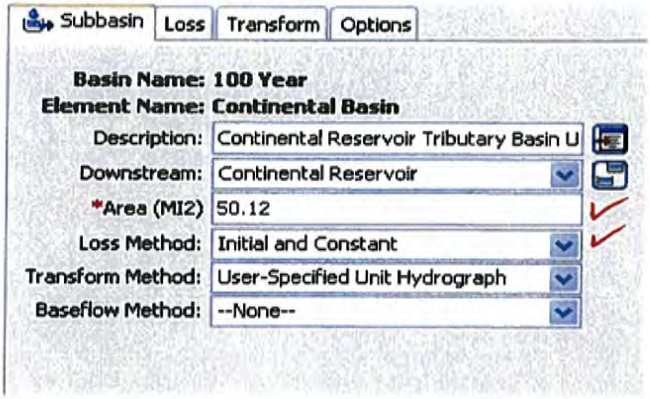
1. 24-hour 100-year, P = 3.14 inches

Analysis:
HEC-HMS (version 3.4) was used for hydrologic modeling and reservoir routing.



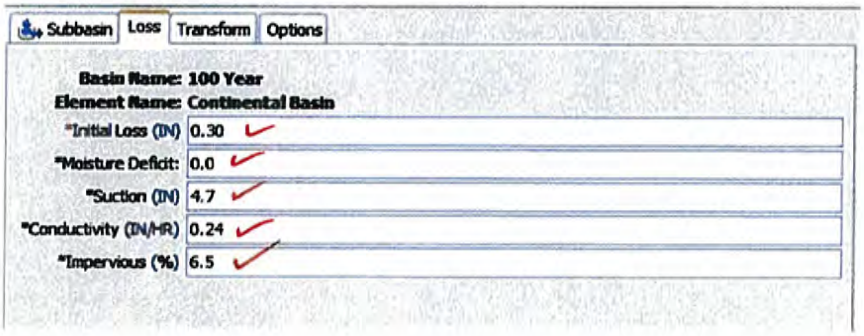
Watershed:

The watershed area was assigned a value of 50.12 square miles. The loss method and transform methods are discussed below.



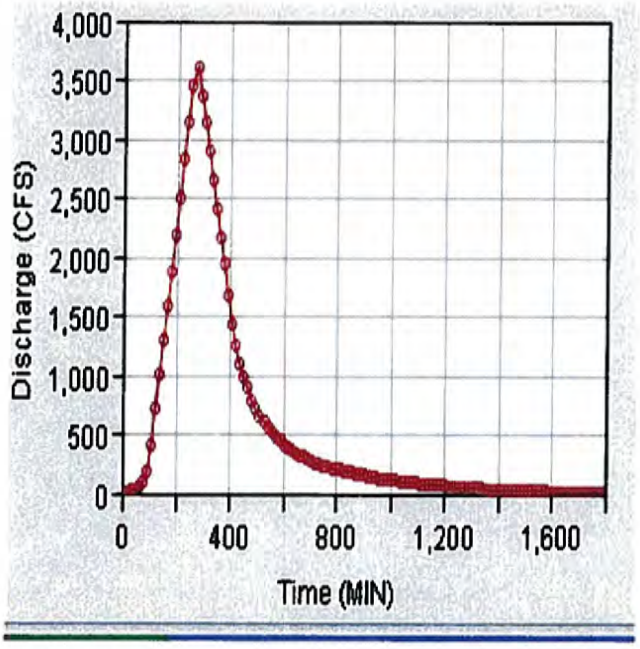
Infiltration Rates:

The State of Colorado's "Hydrology Basin Response Parameter Estimation Guideline" (SEO, 2008) suggests using Green and Ampt infiltration methodology for the 100-year storm event. Estimated parameters for Green and Ampt methodology are presented in Reference 2 and shown in the screen shot below.



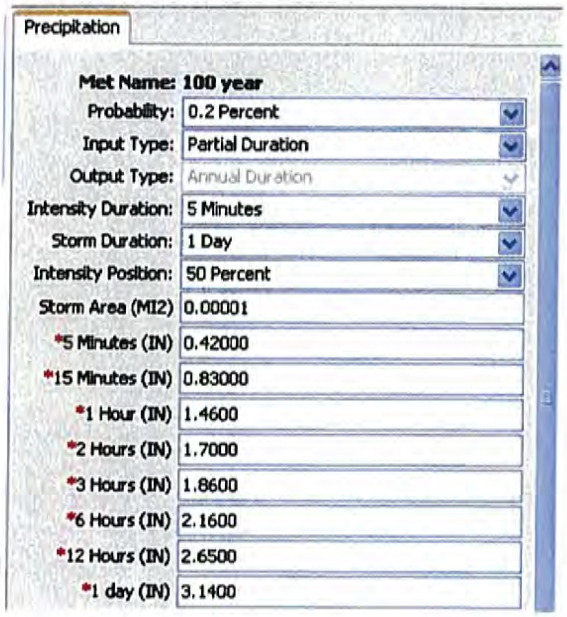
Transform Method:

A synthetic unit hydrograph developed for the 100-yr thunderstorm from United States Bureau of Reclamation methodology was used for the Transform Method in HEC-HMS. The unit hydrograph development is documented in the calculation packet listed in the References section.



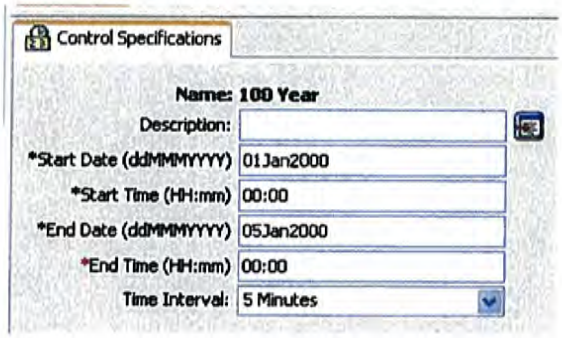
Meteorological Model:

The 100 Year storm was modeled as a frequency storm. The depth-duration curve was developed from NOAA Atlas 2, Volume III. Refer to the calculation packet listed in the Reference section. The storm area was set to a small value because an areal reduction was already taken in the NOAA Atlas 2 calculations. A balance storm was modeled (50% intensity position). Other storm distributions were analyzed (25%, 67%, 75%, etc.) and gave the same results as the balanced storm.



Computational Methodology:

The smallest timestep for the frequency storm is 5-minutes, so a computational timestep of 5-minutes was selected to ensure that the peak runoff rate would be captured. The model was run for 4 days.



Results:

A summary of the reservoir routing results is shown below. Screen captures were included in the following pages.

For the 24-hr 100-year Storm, the peak inflow is 4,509 cfs, the peak outflow is, 907 cfs, and the peak water surface elevation is 10,281.4 ft (8.6 feet below the dam crest elevation of 10,290 ft)

Model Scenario	Total Precip. (in)	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Reservoir Surface Elev. (feet)	Dam Overtopping Depth (feet)
100-year storm – 24hr	3.14	4,509	907	10,281.5	--

Summary Results for Reservoir "Continental Reservoir"

Project: Cntntl_Res
Simulation Run: 100 Year Reservoir: Continental Reservoir

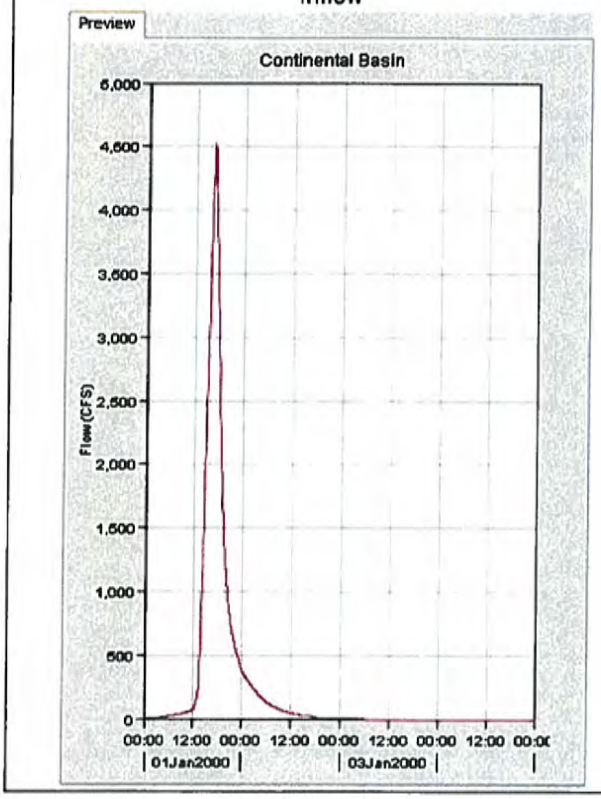
Start of Run:	01Jan2000, 00:00	Basin Model:	100 Year
End of Run:	05Jan2000, 00:00	Meteorologic Model:	100 year
Compute Time:	04Apr2011, 09:23:52	Control Specifications:	100 Year

Volume Units: (•) IN ( ) AC-FT

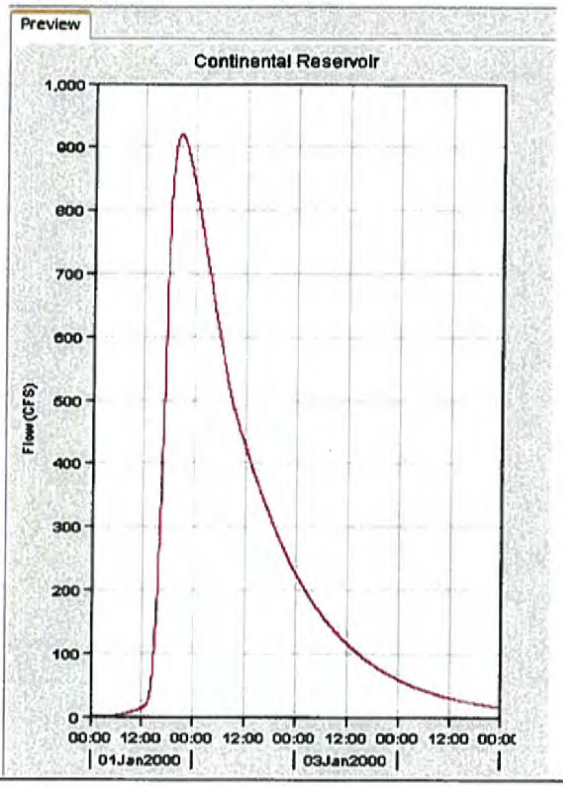
Computed Results

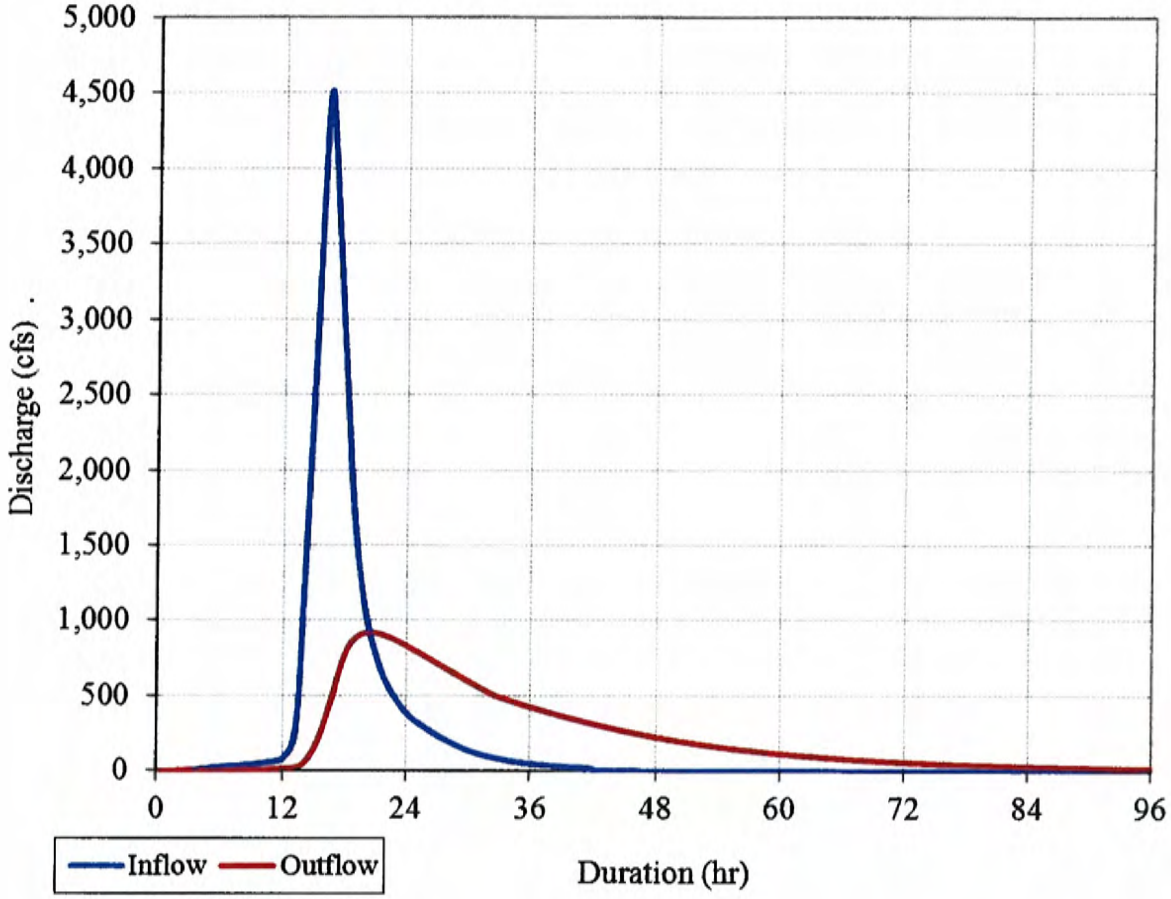
Peak Inflow :	4509.0 (CFS)	Date/Time of Peak Inflow :	01Jan2000, 16:25
Peak Outflow :	906.6 (CFS)	Date/Time of Peak Outflow :	01Jan2000, 20:25
Total Inflow :	0.67 (IN)	Peak Storage :	23972.3 (AC-FT)
Total Outflow :	0.66 (IN)	Peak Elevation :	10281.5 (FT)

Inflow



Outflow




5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Discharge (cfs)
0
12
24
36
48
60
72
84
96
Duration (hr)
Inflow
Outflow

URS CALCULATION COVER SHEET

Project Name:	*Continental & Santa Maria Dam*	**Project Number:**	*22241248.00001*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Dan Greaves

Calculation to be checked: *HEC-HMS model runs of 7 EPAT storms for Continenral Reservoir*

Calculation Originator: *Chad Martin / Revised by Joseph Machala 4/1/2011*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☐ All items have been found to be correct. Checker has no comments.

_____ _____

Checker Signature **Date**

or

B. ☒ Checker's comments have been provided on:

- ☒ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☑ Verification of correct incorporation of resolved comments into final document is complete.

Dan Greaves 4/4/2011

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose

Model rainfall runoff and reservoir routing of seven (7) precipitation events developed using EPAT (**E**xtreme **P**recipitation **A**nalysis **T**ool) through the Continental Reservoir located in Hindsdale County, CO.

Files

HEC-HMS v. 3.4 model files:

Filename: Cntntl_Res
Folder: N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental\HMS\Cntntl_Res

References

1) **Filename:** CalcPacket - Continental - Infiltration - Initial and Constant - PMPREV.doc
Folder:
N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\CalcPacket\Continental

2) **Filename:** CalcPacket - Continental - Infiltration
Folder:
N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\CalcPacket\Continental

3) **Filename:** EPAT_ContinentalDam_results.pdf
Description: Extreme Precipitation Analysis Tool (EPAT) output report generated on 11/4/2009 at 2:20:15 PM. Includes cumulative storm hyetographs for seven different storms.
Folder: N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental\EPAT

4) **Filename:** CalcPacket_El_Strg_Dschrg_Continental.doc
Folder: N:\Projects\22241248_Santa_Maria_Contine\Sub_00\10.0_Calculations_Analysis_Data\H&H\Continental

Method

HEC-HMS v 3.4 (HMS) was used to model the rainfall runoff from the 50.12 mi^2 basin tributary to Continental Reservoir and subsequent routing through the reservoir. Following is a description of the HMS model components and input parameters and tables. Table 1 summarizes the HMS output and is included after the descriptions. Finally, HMS screenshots are included on the pages following Table 1.

Rainfall Runoff

Rainfall runoff was estimated by compiling two unit hydrographs (refer to Reference 1) to model surface water runoff. Two Basin Models were input in HMS; one entitled "Local Storm" and the other "General Storm." Both basin models were set up with one subbasin element entitled "Continental Basin" representative of the 50.12 mi^2 basin tributary to Continental Reservoir and linked downstream to a reservoir element entitled "Continental Reservoir" linked downstream to a sink. The "User-Specified Unit Hydrograph" having the same name as the Basin Model was specified for each of the subbasin elements associated with each Basin Model. A constant infiltration rate of 0.13 inches per hour was used (refer to Reference 2) and

an initial loss of 0.6 inches. A basin impervious percentage of 6.5 % was input based on the combined water surface area of Continental Reservoir and rock outcroppings stated in Reference 2).

Rainfall

Cumulative storm hyetographs were input into HMS (refer to Reference 3). A total of 7 different storms were modeled; 4 General Storms and 3 Local Storms. The hyetographs were each entered as a precipitation gage with the time interval identical to the EPAT output.

Reservoir Routing

Reservoir routing was performed using the "Outflow Curve" method. This method requires an elevation-storage relationship and a storage-discharge relationship (refer to Reference 4 for these relationships). The initial reservoir water surface elevation was assumed to be at the spillway crest, elevation 10,280. Discharge through the low level outlet works was not modeled.

Control Specifications

Seven (7) different model runs were created and each with a name corresponding to the EPAT storm. All model runs were run at 1-minute time intervals.

Results

The results are summarized in Table 1 on the next page. None of the seven model runs resulted in overtopping of Continental Dam. The maximum peak reservoir water surface elevation was 10,285.3 ft for the Saguache local storm event. The peak inflow for this storm was 27,087 cfs with a peak outflow of 3,729 cfs. The general storm events had rainfall intensities that were mainly less than the constant infiltration rate of 0.13 inches per hour, which resulted in little runoff volumes.

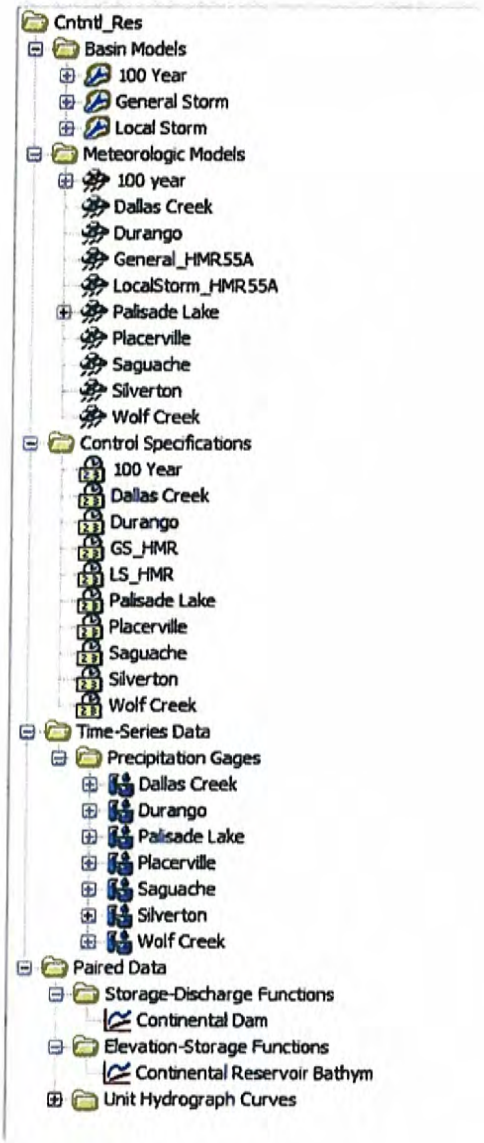
Table 1
Continental Reservoir
HEC-HMS v 3.3 Model Results

Model Run (corresponds to EPAT Storm)	Rainfall					Runoff		Routing	
	Storm Type	Total Rainfall (inches)	Total Loss (inches)	Total Excess (inches)	Duration (hrs)	Inflow Volume (ac-ft)	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Storage Level (ft)
Palisade Lake	General Storm	6.89	5.62	1.27	84	3,049	2,019	949	10,281.6
SW CO / Wolf Creek		6.68	6.08	0.6	72	1,598	492	355	10,280.7
San Juan/Gladstone/Silverton		4.94	2.75	2.19	33	5,836	3,572	2,260	10,283.1
SW CO / Durango		4.90	3.81	1.09	98	2,804	1,775	839	10,281.4
Saguache	Local Storm	2.88	0.72	2.16	2.58	5,626	27,087	3,729	10,285.3
Placerville		2.82	0.91	2.11	1.58	5,512	24,908	3,686	10,285.2
Dallas Creek - West Side of Divide		2.68	0.71	1.97	1.83	5,146	22,920	3,557	10,284.8

Notes:

- Initial reservoir water surface Elev. set to spillway crest - Elev. 10,280 ft.
- Dam Crest Elev. = 10,290 ft.

Model Components

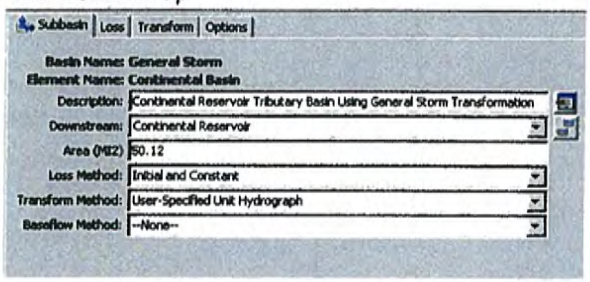


Basin Model

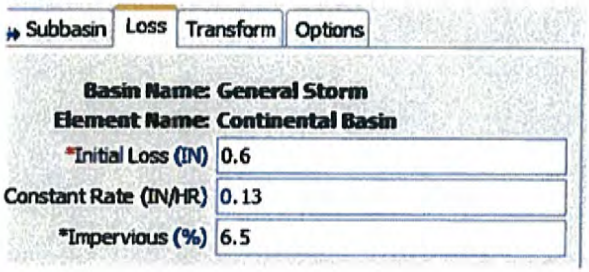
Note: Two basin models were set up with identical elements shown above.

General Storm Basin Model Options

Subbasin Set Up

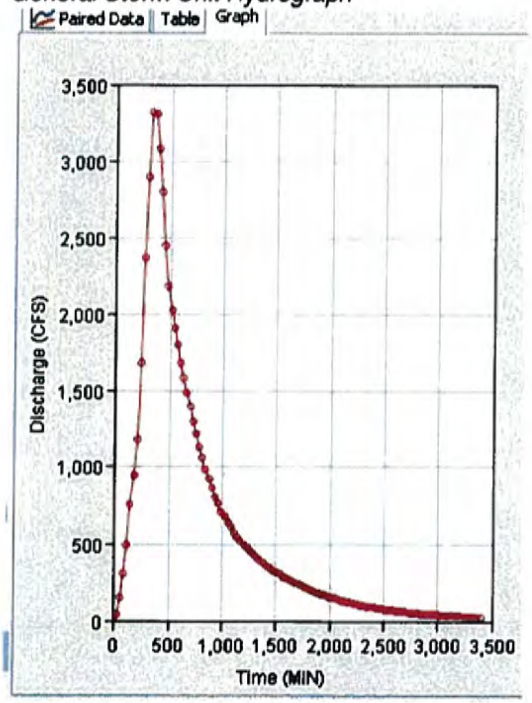


Loss



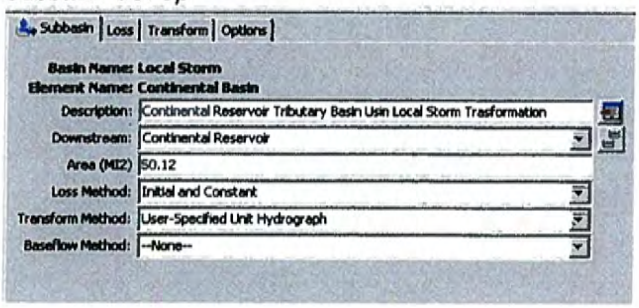
Transform

General Storm Unit Hydrograph

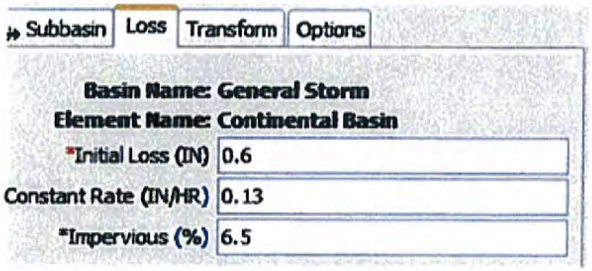


Local Storm Basin Model Options

Subbasin Set Up

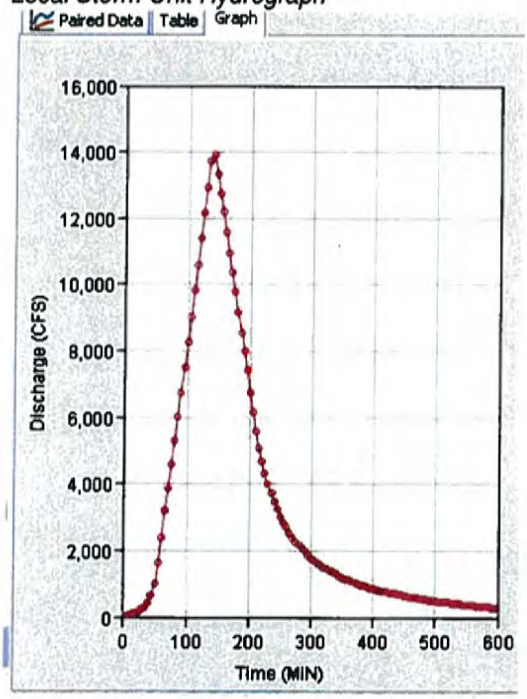


Loss



Transform

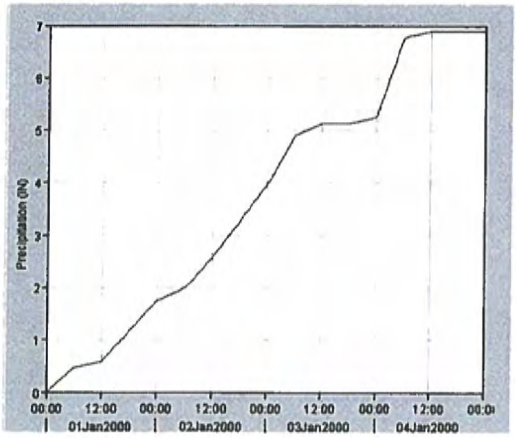
Local Storm Unit Hydrograph



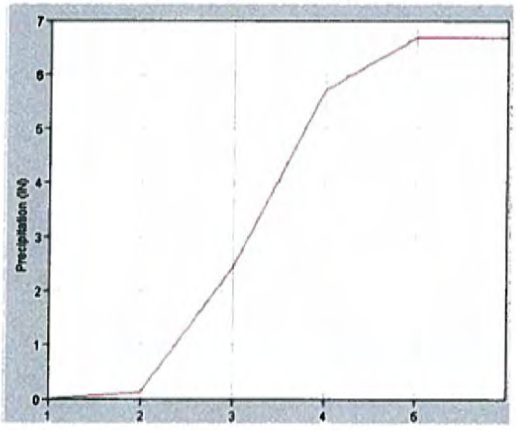
Meteorology

General Storms (4)

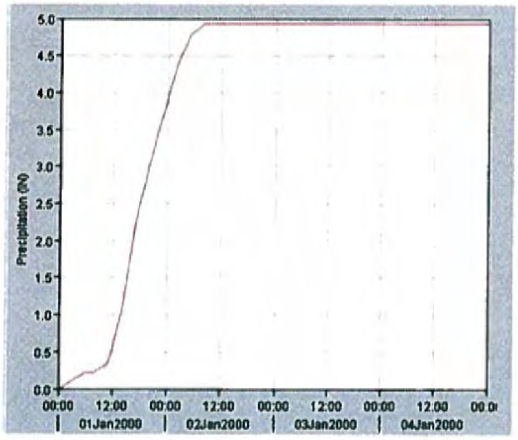
Palisade Lake: 6.89 inches in 84 hrs



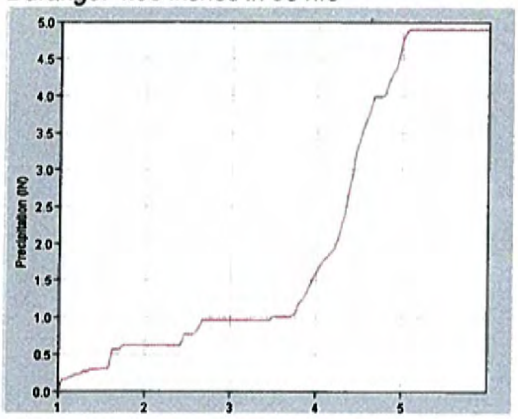
Wolf Creek: 6.68 inches in 96 hrs



Silverton: 4.94 inches in 33 hrs

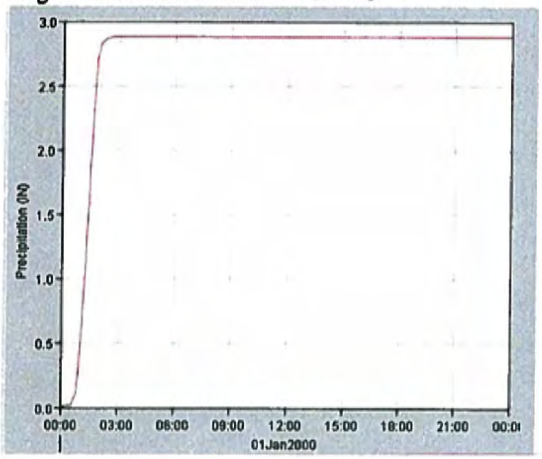


Durango: 4.90 inches in 98 hrs

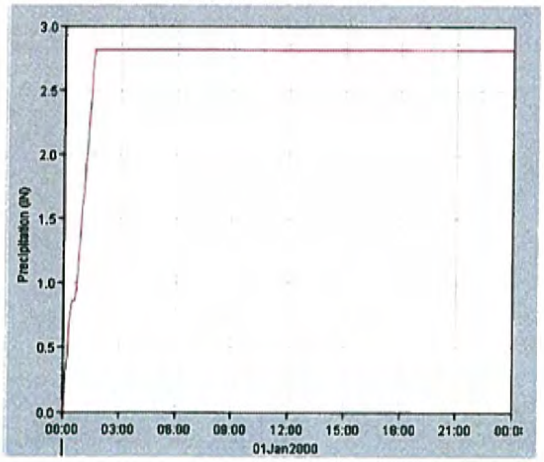


Local Storms (3)

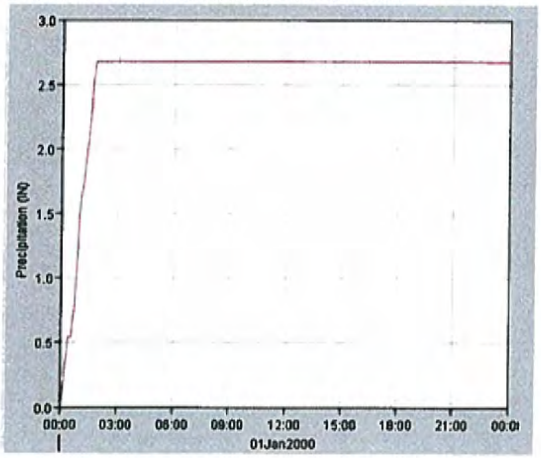
Saguache: 2.88 inches in 2.67 hrs



Placerville: 2.82 inches in 1.58 hrs

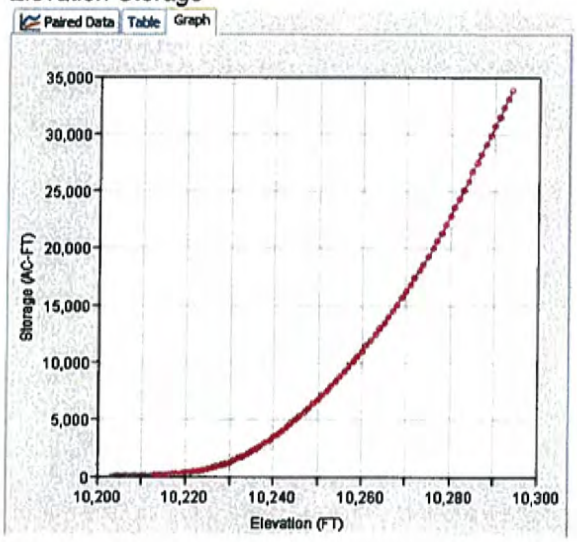


Dallas Creek: 2.68 inches in 1.83 hrs

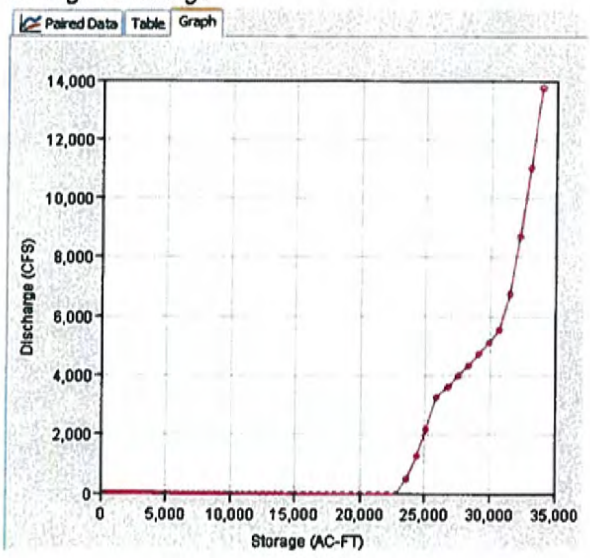


Reservoir Routing

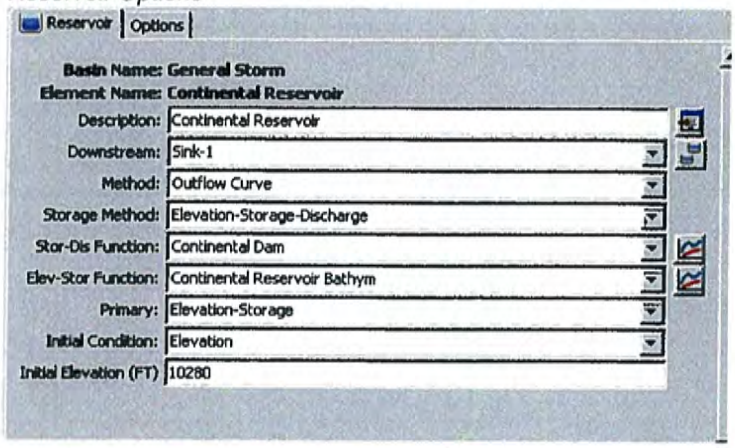
Elevation-Storage



Storage-Discharge

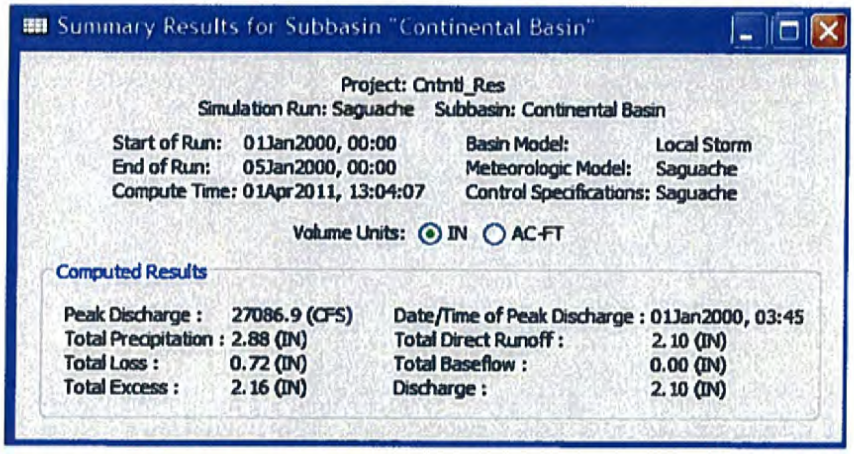


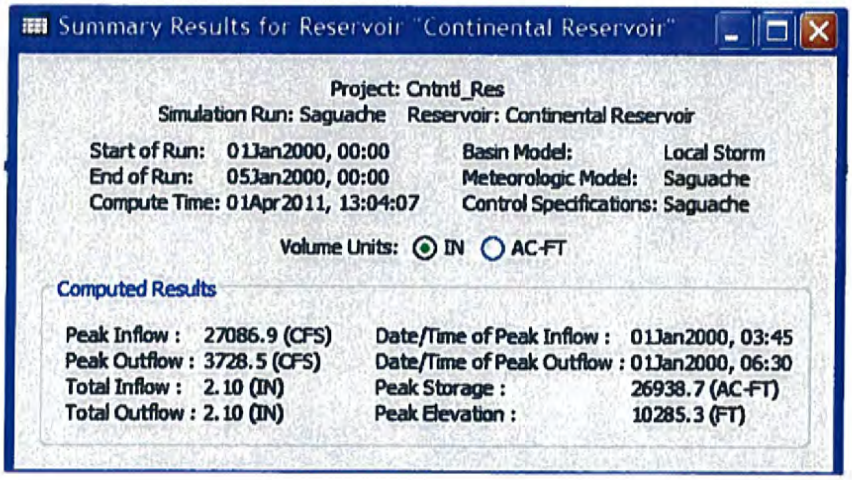
Reservoir Options

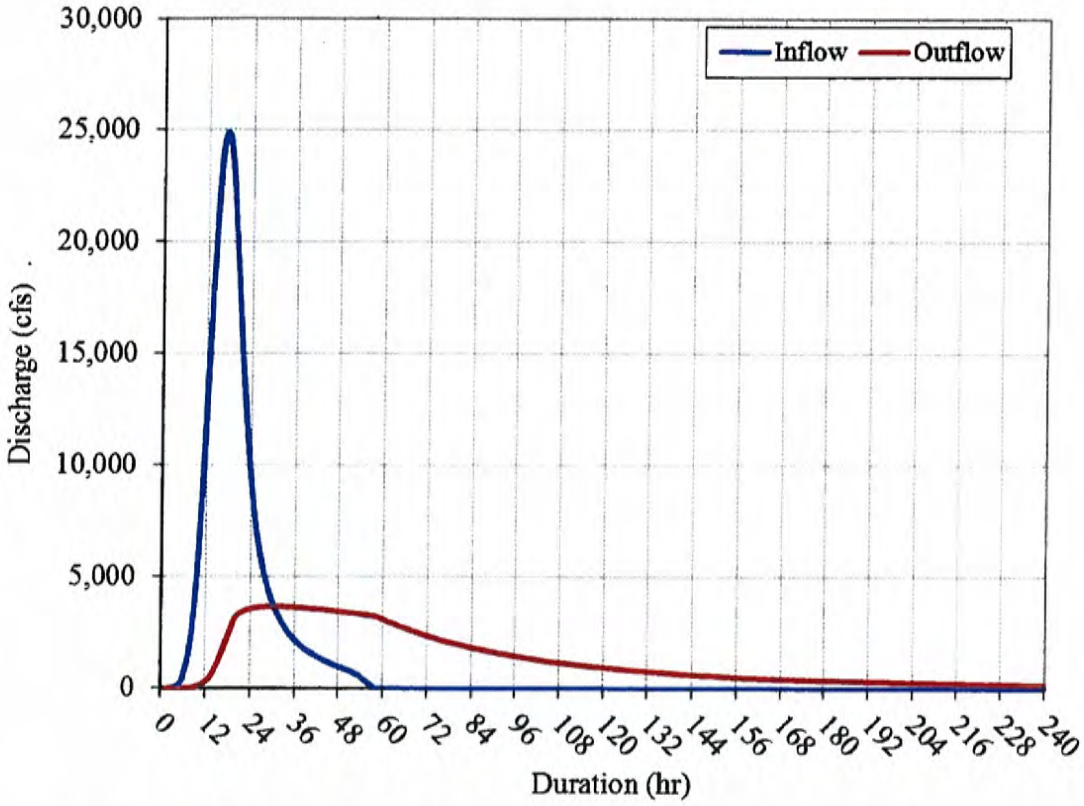


Results

The controlling storm for EPAT is the Saguache local storm. The results are shown below.







The results for the Local, Placerville storm are also presented as requested by OSE, response letter dated March 11, 2011, with it being a close second place.

Summary Results for Subbasin "Continental Basin"

Project: Cntntl_Res
Simulation Run: Placerville Subbasin: Continental Basin

Start of Run:	01Jan2000, 00:00	Basin Model:	Local Storm
End of Run:	05Jan2000, 00:00	Meteorologic Model:	Placerville
Compute Time:	01Apr2011, 13:04:02	Control Specifications:	Placerville

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Discharge :	24908.0 (CFS)	Date/Time of Peak Discharge :	01Jan2000, 03:25
Total Precipitation :	2.82 (IN)	Total Direct Runoff :	2.06 (IN)
Total Loss :	0.71 (IN)	Total Baseflow :	0.00 (IN)
Total Excess :	2.11 (IN)	Discharge :	2.06 (IN)

Summary Results for Reservoir "Continental Reservoir"

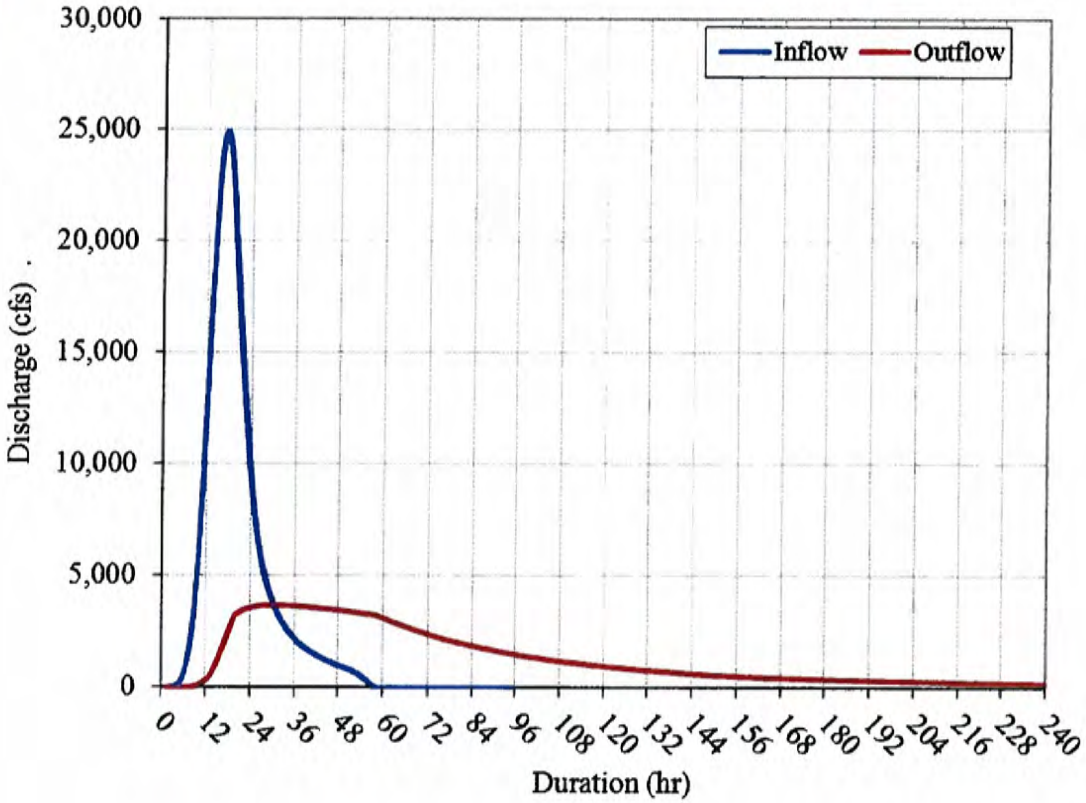
Project: Cntntl_Res
Simulation Run: Placerville Reservoir: Continental Reservoir

Start of Run:	01Jan2000, 00:00	Basin Model:	Local Storm
End of Run:	05Jan2000, 00:00	Meteorologic Model:	Placerville
Compute Time:	01Apr2011, 13:04:02	Control Specifications:	Placerville

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Inflow :	24908.0 (CFS)	Date/Time of Peak Inflow :	01Jan2000, 03:25
Peak Outflow :	3686.0 (CFS)	Date/Time of Peak Outflow :	01Jan2000, 06:06
Total Inflow :	2.06 (IN)	Peak Storage :	26844.0 (AC-FT)
Total Outflow :	2.05 (IN)	Peak Elevation :	10285.2 (FT)



URS CALCULATION COVER SHEET

Project Name:	*Continental & Santa Maria Dam*	**Project Number:**	*22241248.00001*
Project Location:	*Hindsdale County, CO*	**Client Name:**	*Santa Maria Reservoir Co.*
PM Name:	*Ed Toms*	**PIC Name:**	

Identifying Information

This section is to be completed by the Project Manager.

Assigned Checker: Dan Greaves

Calculation to be checked: HEC-HMS Model for HMR-55a storms

Calculation Originator: *Chad Martin / Revised by Joseph Machala 4/1/2011*

Checker's comments required by:

Submitted by: _____ _____

Project Manager Signature **Date**

Checker Report

This Section is to be completed by the Checker.

Check box A **or** B:

A. ☐ All items have been found to be correct. Checker has no comments.

_____ _____

Checker Signature **Date**

or

B. ☒ Checker's comments have been provided on:

- ☒ Calculation
- ☐ Comment and Disposition Form (Form 3-5 (MM))
- ☐ Other ____

This section is to be completed after verification of comment incorporation, if box B is checked off above.

Check box C **or** D and E:

C. ☐ Back-check of Checker's comments has been performed by Originator AND all issues have been resolved between Originator and Checker.

or

D. ☐ Unresolved issues have been submitted to the Project Manager, Principal-in-Charge or designee for resolution.

and

E. ☒ Verification of correct incorporation of resolved comments into final document is complete.

Dan Greaves 4/4/2011

Checker Signature **Date**

APPROVAL and DISTRIBUTION

*To be signed after box A **or** E are completed.*

☐ The Calculation Check has been completed. Any significant issues not resolved between the Checker and the Originator have been resolved by the Approver.

_____ _____

Project Manager, Principal-in-Charge or Designee Signature **Date**

Distribution:

Project Central File – Quality folder

Purpose:
Route the local storm and general storm floods through Continental Dam. Determine which flood results in the PMF.

Files/Folders:

HEC-HMS Model:
Filename: Cntntl_Res
Folder: N:\Projects\22241248....\10.0_Calculations_Analysis_Data\H&H\Continental\HMS\Cntntl_Res

HEC-HMS Results:
Filename: HEC_HMS_HMR55a-Output
Folder: N:\Projects\22241248....\10.0_Calculations_Analysis_Data\H&H\Continental

References:

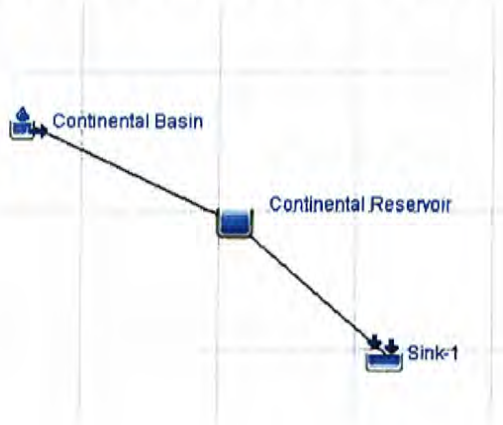
1. Calculation packet titled "*Probable Maximum Precipitation (PMP) – HMR-55A*" Revised by Joseph Machala on 3/31/2011
2. Calculation packet titled "Infiltration Rates" by Revised by Joseph Machala on 3/31/11
3. Calculation packet titled "Unit Hydrographs for Continental Reservoir Basin" by Chad Martin on 6/3/10
4. Calculation packet titled "Elevation-Storage-Discharge Relationship for Continental Reservoir" Revised by Joseph Machala on 3/31/2011
5. State of Colorado "Rules and Regulations for Dam Safety and Dam Construction" 2-CCR 402-1 dated January 1, 2007

General Approach:
The HEC-HMS model has been set up primarily using References 1 through 4. Pertinent dam and reservoir information has been input using Reference 4 and assuming the initial reservoir water level to be at the normal pool or elevation 10,280. Pertinent watershed data like area, infiltration rate and imperviousness have been input to the model from Reference 2. Unit hydrograph data has been entered from Reference 3.

The meteorological models have been developed using References 1 and 4. A total of three meteorological models have been examined including:

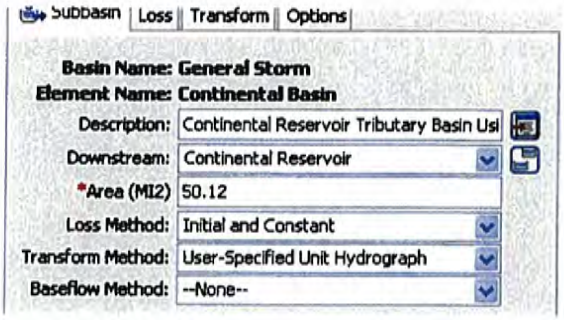
1. 48-hour General Storm, P = 18.2 inches
2. 6-hour Local Storm, P = 5.3 inches

Analysis:
HEC-HMS (version 3.4) was used for hydrologic modeling and reservoir routing.



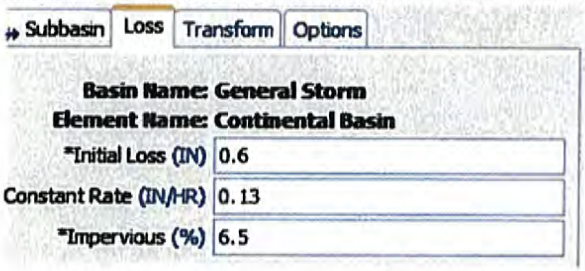
Watershed:

The watershed area was assigned a value of 50.12 square miles. The loss method and transform methods are discussed below.



Infiltration Rates:

As calculated in the Reference 2, and Initial and Constant loss method was selected. An initial infiltration rate of 0.6 inches was assumed with a constant infiltration rate of 0.13 inches/hour and a watershed imperviousness of 6.5%.

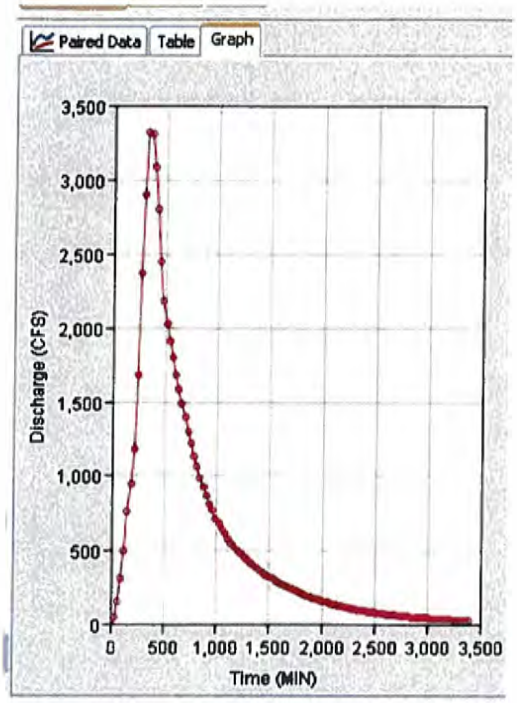


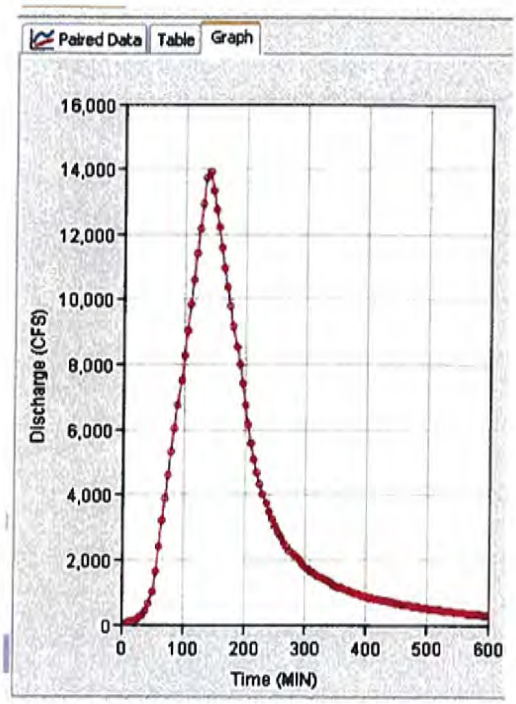
Transform Method:

A synthetic unit hydrograph develop for the Local Storm and for the General Storm from United States Bureau of Reclamation methodology was used for the Transform Method in HEC-HMS. The unit hydrograph development is documented in the calculation packet listed in the References section.

General Storm

Local Storm





Meteorological Model:

The Local Storm and General Storm were modeled as frequency storms. The depth-duration relationships are documented in the calculation packet listed in the References section. The intensity positions were set at 50%, such that a balanced storm would be modeled. The 2- and 3-hour precipitation depths for the General Storm were interpolated from the HMR-55a values. The rainfall intensity beyond the 48-hour duration is 0.083 in/hr (2 inches between the 48- and 72-hour durations), which is less than the constant infiltration rate of 0.13 in/hr. Imperviousness is small, therefore the General Storm was not modeled beyond the 48-hour duration.

General Storm

Precipitation

Met Name:	**General_HMR55A**
Probability:	0.2 Percent
Input Type:	Partial Duration
Output Type:	Annual Duration
Intensity Duration:	5 Minutes
Storm Duration:	2 Days
Intensity Position:	50 Percent
Storm Area (MI2)	0.000001
*5 Minutes (IN)	0.63000
*15 Minutes (IN)	1.6700
*1 Hour (IN)	3.7000
*2 Hours (IN)	4.5000
*3 Hours (IN)	5.4000
*6 Hours (IN)	7.2000
*12 Hours (IN)	11.000
*1 day (IN)	15.500
*2 Days (IN)	18.200
4 Days (IN)	

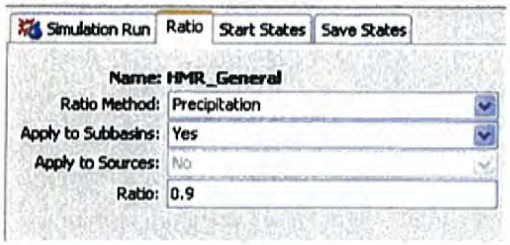
Local Storm

Precipitation

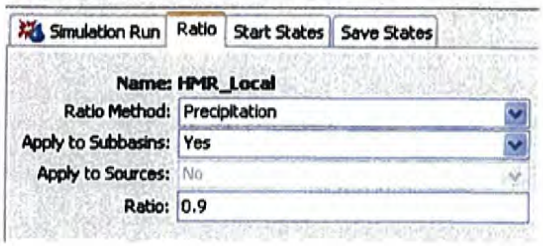
Met Name:	**LocalStorm_HMR55A**
Probability:	0.2 Percent
Input Type:	Partial Duration
Output Type:	Annual Duration
Intensity Duration:	5 Minutes
Storm Duration:	6 Hours
Intensity Position:	50 Percent
Storm Area (MI2)	0.00001
*5 Minutes (IN)	0.77000
*15 Minutes (IN)	1.7000
*1 Hour (IN)	3.3000
*2 Hours (IN)	4.1000
*3 Hours (IN)	4.5000
*6 Hours (IN)	5.3000

As documented in the State of Colorado's "Rules and Regulations for Dam Safety and Dam Construction" (2007) guidelines, which are attached, the HMR precipitation can be reduced to 90% of the HMR values for a large, high hazard dam. Therefore, a precipitation ratio of 0.90 was assigned to the Local and General storms as shown below:

General Storm



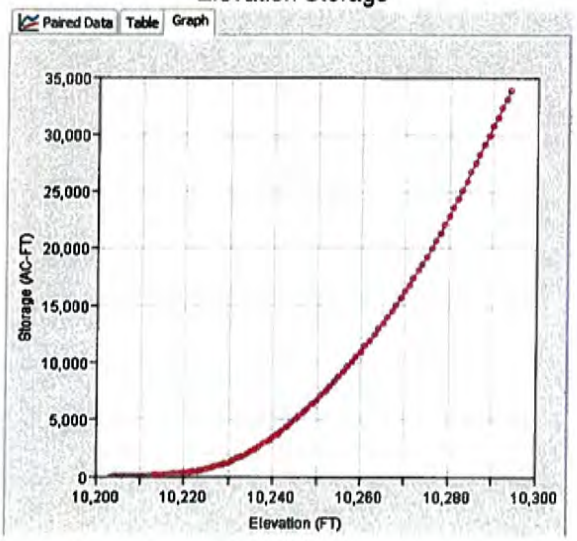
Local Storm



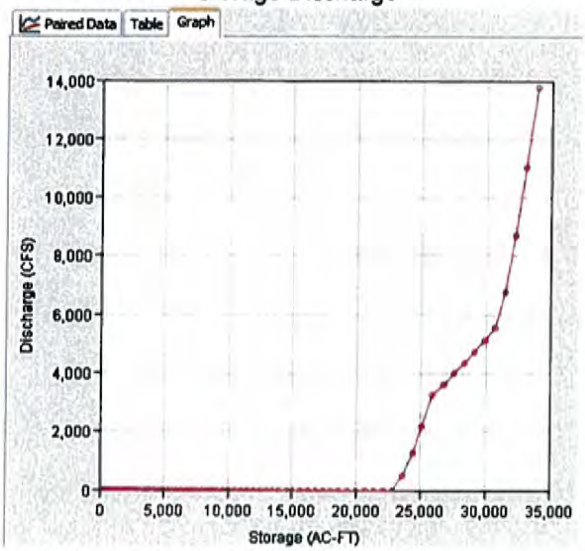
Stage-Storage-Discharge:

Stage-storage and storage-discharge curves were inserted into the model. Discharge rating curve calculations were made by URS and can be found in the calculation packet listed in the References section.

Elevation Storage



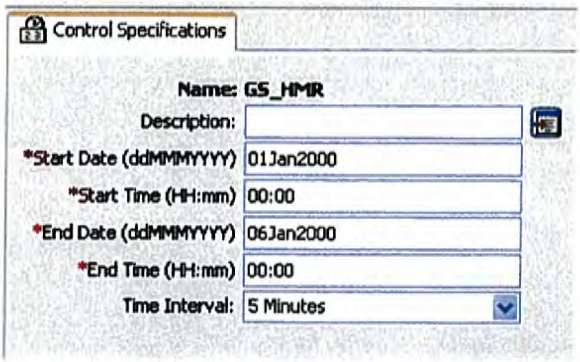
Storage-Discharge



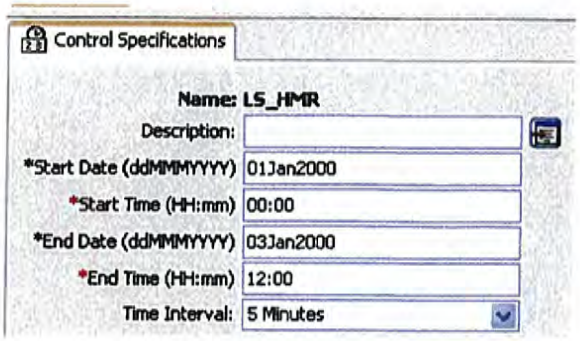
Computational Methodology:

A computational timestep of 5-minutes was selected for both the Local Storm and General Storm. A 5-minute precipitation depth was developed for both storm events, therefore a timestep of 5-minutes was adopted so the peak runoff rate could be captured.

General Storm:



Local Storm:



Results:

A summary of the reservoir routing results is shown below. Screen captures were included in the following pages.

The General Storm results in a larger peak reservoir water surface elevation and peak outflow than the Local Storm. Therefore, the General Storm is considered the controlling storm event using HMR-55a methodology. For the General Storm, the peak inflow is 17,244 cfs, the peak outflow is, 10,300 cfs, and the peak water surface elevation is 10,289.3 ft (0.7 feet below the dam crest elevation of 10,290 ft)

Model Scenario	Total Precip. (in)	Peak Inflow (cfs)	Peak Outflow (cfs)	Maximum Reservoir Surface Elev. (feet)	Dam Overtopping Depth (feet)
General Storm (PMP) – 48hr	16.38*	20,469	12,912	10,293.7	3.7
Local Storm – 6hr	4.77*	41,870	5,256	10,289.3	--

*Note: 0.90 precipitation ratio of the HMR-55a per Reference 5 (attached)

48-hr General Storm

Summary Results for Reservoir "Continental Reservoir"

Project: Cntntl_Res
Simulation Run: HMR_General Reservoir: Continental Reservoir

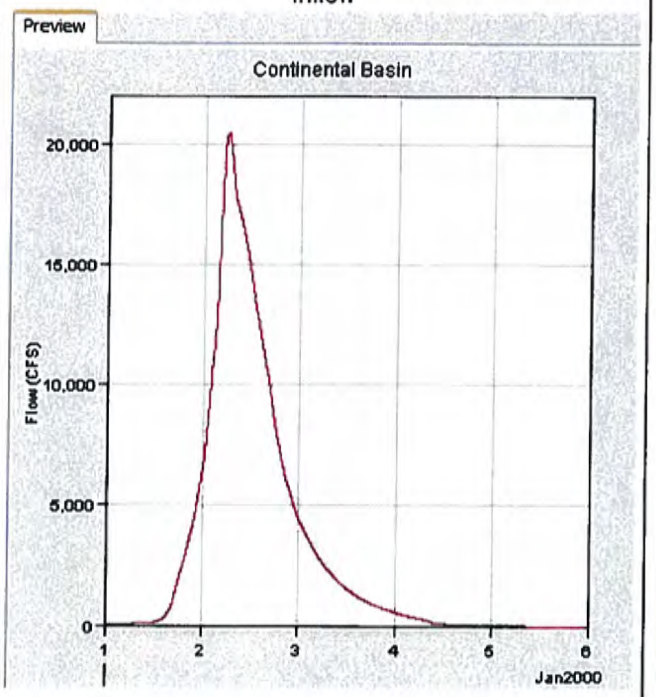
Start of Run:	01Jan2000, 00:00	Basin Model:	General Storm
End of Run:	06Jan2000, 00:00	Meteorologic Model:	General_HMR55A
Compute Time:	01Apr2011, 13:03:45	Control Specifications:	GS_HMR

Volume Units: ○ IN ◉ AC-FT

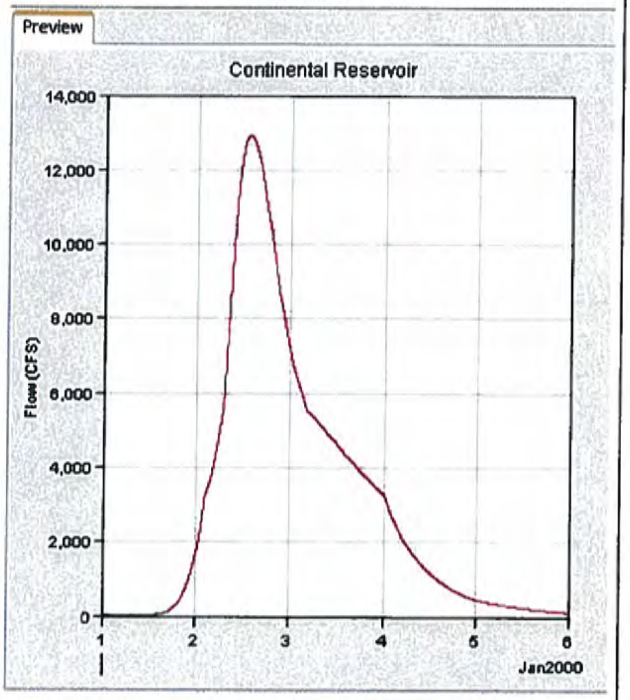
Computed Results

Peak Inflow :	20468.8 (CFS)	Date/Time of Peak Inflow :	02Jan2000, 05:45
Peak Outflow :	12911.7 (CFS)	Date/Time of Peak Outflow :	02Jan2000, 13:15
Total Inflow :	29859.8 (AC-FT)	Peak Storage :	33663.7 (AC-FT)
Total Outflow :	29679.3 (AC-FT)	Peak Elevation :	10293.7 (FT)

Inflow



Outflow



6-hr Local Storm

Summary Results for Reservoir "Continental Reservoir"

Project: Cntntl_Res
Simulation Run: HMR_Local Reservoir: Continental Reservoir

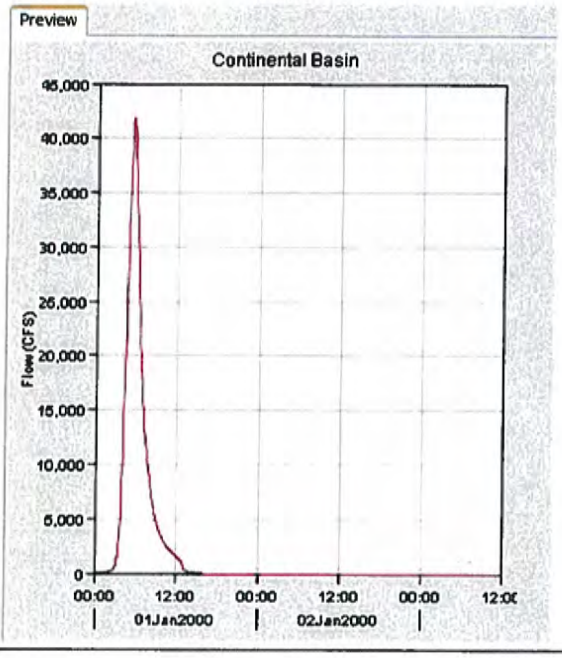
Start of Run:	01Jan2000, 00:00	Basin Model:	Local Storm
End of Run:	03Jan2000, 12:00	Meteorologic Model:	LocalStorm_HMR55A
Compute Time:	01Apr2011, 13:03:50	Control Specifications:	LS_HMR

Volume Units: ○ IN ◉ AC-FT

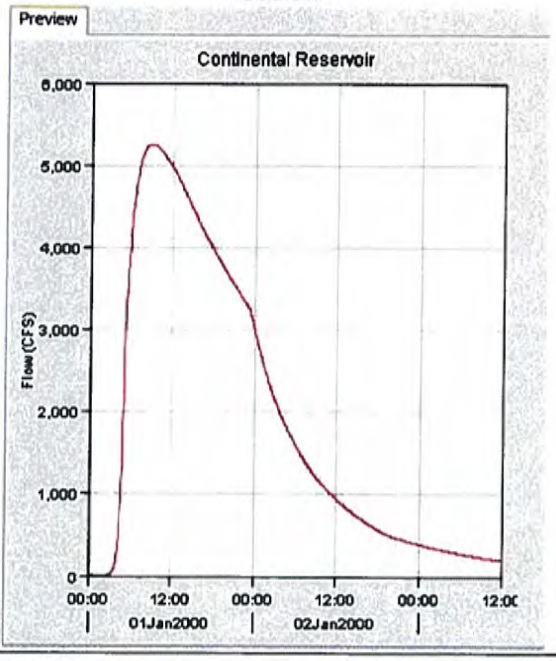
Computed Results

Peak Inflow :	41870.3 (CFS)	Date/Time of Peak Inflow :	01Jan2000, 05:20
Peak Outflow :	5256.4 (CFS)	Date/Time of Peak Outflow :	01Jan2000, 08:50
Total Inflow :	9743.0 (AC-FT)	Peak Storage :	30132.8 (AC-FT)
Total Outflow :	9442.5 (AC-FT)	Peak Elevation :	10289.3 (FT)

Inflow



Outflow



STATE OF COLORADO

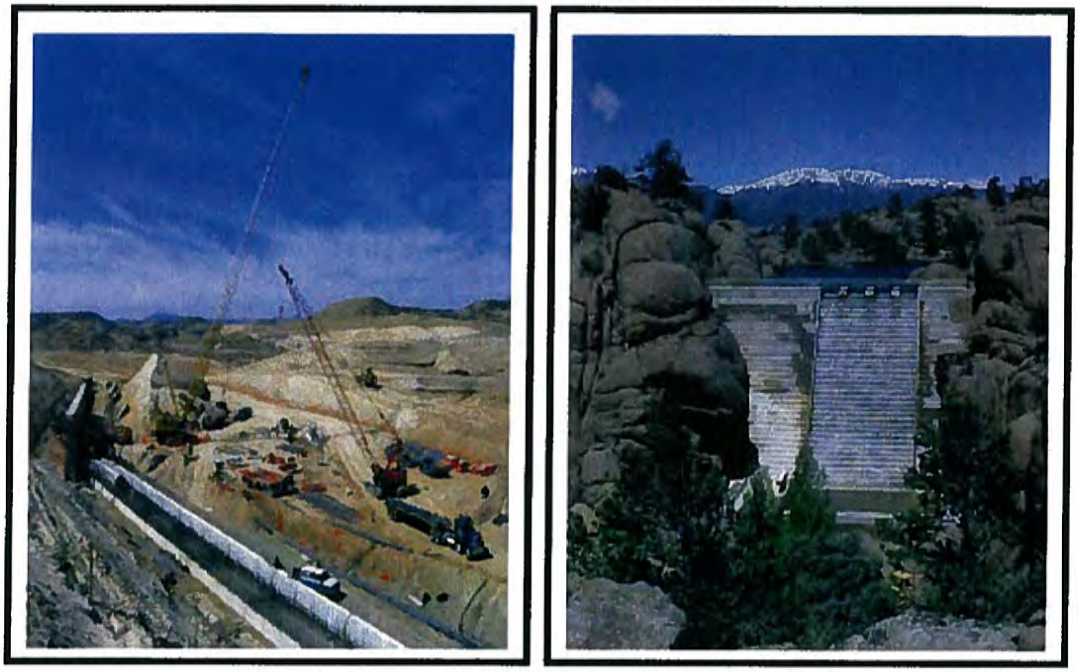
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER RESOURCES

OFFICE OF THE STATE ENGINEER

DAM SAFETY BRANCH

RULES AND REGULATIONS FOR DAM SAFETY AND DAM CONSTRUCTION



EFFECTIVE DATE: JANUARY 1, 2007

2-CCR 402-1

1313 SHERMAN STREET
ROOM 818 CENTENNIAL BUILDING
DENVER, COLORADO
TELEPHONE 303-866-3581
FACSIMILE 303-866-3589
WEBSITE:
http://water.state.co.us

5.9.1.3.3 New Small, Significant Hazard dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by 50 percent of the Extreme Storm Precipitation (ESP), unless an Incremental Damage Analysis (IDA) demonstrates a lesser inflow design flood is applicable.

5.9.1.3.4 New Minor, Significant Hazard plus new Large and Small, Low Hazard dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by a 24-hour, 100-year rainstorm event.

5.9.1.3.5 New Minor, Low Hazard dams and new Large, NPH Dams and enlargements shall have spillways capable of passing the inflow design flood generated by a 24-hour, 50-year rainstorm event.

5.9.1.3.6 New Small and Minor NPH dams and enlargements shall have spillways capable of passing the Inflow Design Flood (IDF) generated by a 24-hour, 25 year rainstorm event.

5.9.1.3.7 The minimum size spillway for all High Hazard, Significant Hazard, and Large and Small, Low Hazard jurisdictional size dams for which an IDA shows a smaller spillway is justifiable under Rule 5.9.7.1 shall be capable of passing the inflow design flood generated by a 24-hour, 100-year rainstorm event. For all other jurisdictional size dams, the minimum size spillway shall be capable of passing the IDF generated by the appropriate rainstorm event presented in the above table.

5.9.1.4 Hydrometeorological Report PMP - The Inflow Design Flood (IDF) requirements for determining the spillway capacity may be developed through the use of the most current Probable Maximum Precipitation (PMP) estimates from the Office of Hydrology, National Weather Service, NOAA Hydrometeorological Report Series. The PMP values are normally determined from the appropriate Hydrometeorological Report (HMR). Currently, HMR 52 and 55A are applicable for drainage basin located to the east of the Continental Divide and HMR 49 for drainage basin west of the Continental Divide. The IDF requirements for determining the spillway capacity using the appropriate HMR are summarized in Table 5.2:

TABLE 5.2

INFLOW DESIGN FLOOD REQUIREMENTS USING HYDROMETEOROLOGICAL REPORTS (HMR)

DAM SIZE	HAZARD CLASSIFICATION			
	High	Significant	Low	NPH
Large	0.90 PMP	0.68 PMP	100 YR	50 YR
Small	0.90 PMP	0.45 PMP	100 YR	25 YR
Minor	0.45 PMP	100 YR	50 YR	25 YR

Appendix G

Appendix G
HEC-HMS Electronic Files