DOE–EM/GJ1547

Environmental Management - Grand Junction Office

MOAB UTAH

UMTRA Project

Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings At the Crescent Junction, Utah, Disposal Site

Attachment 1: Draft RAP Disposal Cell Design Specifications

February 2008

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE-AT30-07CC00014 and No. DE-AC01-02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

Remedial Action Plan and Site Design
for Stabilization of Moab Title I Uranium Mill Tailings
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Calculation Cross-Reference Guide

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Appendix D	MOA-02-05-2007-3-16-01	Settlement, Cracking, and Liquefaction Analysis
Appendix E	MOA-02-09-2005-2-08-01	Site Drainage – Hydrology Parameters
Appendix F	MOA-02-06-2006-5-08-00	Crescent Junction Site Hydrology Report
Appendix G	MOA-02-04-2007-5-25-02	Diversion Channel Design, North Side Disposal Cell
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Appendix B	MOA-02-04-2007-1-01-01	Surficial and Bedrock Geology of the Crescent Junction Disposal Site
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Attachment 1

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U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-5-19-01 **Discipline:** Engineering Design **No. of Sheets:** 6
Doc No.: X0173800

Location: Attachment 1, Appendix A

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Freeze/Thaw Layer Design

Sources of Data:

Climate Data:

Western Regional Climate Center
Desert Research Institute
University of Nevada, Reno, Nevada
Climate Data from Thompson, Utah
National Climate Data Center COOP Station # 428705
Latitude: 38°58'
Longitude: 109°43'
Elevation: 5150' AMS

Soil Data:

Drilling at Crescent Junction: Field Test Documentation

"Geotechnical Properties of Native Materials" calculation set, RAP Attachment 5, Appendix E.

Sources of Formulae and References:

See "Sources of Formulae and References" on page 3.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-02-05-2006-5-19-00**

Author: Roslyn Ste 6/6/07
Name Date

Checked by: Gary Leidy 5/30/07
Name Date

Greg Smith 5/31/07
Name Date

D Metzler May 31, 07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

REVIEWED: Frank B. Genoe 5-30-07
Name Date

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Problem Statement:

An important design parameter for the final cover of the Moab uranium mill tailings repository is the maximum depth to which frost can be expected to penetrate into the cover. When surficial soils freeze, the coupled processes of freeze-induced expansion and desiccation result in reduced soil density and the development of cracks and fissures in the cover soils. These occurrences lead to increases in hydraulic conductivity and gas permeability, which manifest as detrimental increases in the infiltration of meteoric water into the cover, and also to increased flux of soil gases (e.g. radon) from the cover. As it is a design imperative to reduce both the water infiltration into and the radon flux out of the repository, the upper surface of the radon barrier must be situated sufficiently below the effective ground surface that it is protected from seasonal freeze/thaw effects. The objective of this calculation set is to identify the design maximum frost penetration (design frost depth) at the repository site assuming a recurrence interval of 200 years for design of the freeze/thaw protective layer.

Method of Solution:

- Obtain climate data for the site.
- Obtain material properties for the in-situ borrow materials from the “Geotechnical Properties of Native Materials” calculation set (Attachment 5, Vol. I, Appendix E) for the Crescent Junction Site.
- Use the method described in Smith and Rager (2002) to predict the maximum depth of frost penetration for the Crescent Junction Disposal Site.

Assumptions:

- No climate data is available for the Crescent Junction Disposal Site. Climate data from Thompson Springs, Utah, was available for 36 of 61 years from 1933 to 1994. Thompson Springs is located approximately 5 miles due east of the proposed disposal cell site. The elevation at the weather station (5,150 feet [ft]) is approximately 112 ft higher than the estimated highest top-of-cover elevation (5,038 ft) at the Crescent Junction Site. It is assumed that the climate at the Crescent Junction Disposal Site is the same as that of nearby Thompson Springs, Utah.
- Literature sources are reliable and representative sources of the physical phenomena.
- Regardless of the final cover configuration selected, the loosely compacted cover materials will act as either the protective layer over a typical compacted soil radon barrier or as the upper zone of a monolithic cover. The effects of rock mulch or other surface treatment were conservatively neglected. Frost penetration decreases with both increasing soil bulk density and increasing water content, due to the insulating effect of ice that forms as water freezes. Although the loosely placed cover materials will initially have higher bulk density and water content than the in-situ borrow materials, the cover soil density and moisture conditions will eventually return to their in-situ state due to prolonged exposure to freezing and thawing cycles. Consequently, soil conditions for the frost prediction model were assumed to approximate those of the in-situ borrow soils, as indicated below.

Borrow Material Condition	Dry Density (pcf*)	Water Content (gravimetric) %
Loosely placed cover (85% ASTM D 1557 max dry density @ 2% below optimum water content)	103.5	9.7
Average in-situ conditions	91.3	6.3
Conditions modeled	91.3	6.3

*Pounds per cubic feet

Calculation:

- Step 1. Determine Freeze-Index Parameters
  Climate data consisting of 36 years of maximum and minimum daily air temperatures were used to compute the air-freeze index (degree-days), duration of freeze, and mean annual temperature for each year. Plotted data are included as Appendix A.
- Step 2. Determine Surface Temperature Correction Data

  The daily temperature data used to determine the freeze-index parameters are typically measured 1.5 meters (m) above ground surface. However, measured ground temperatures can be greater than air temperatures due to the effects of snow cover, net solar radiation, thermal conduction from warmer soils below the surface, and convective heat transfer (Smith and Rager 2002). The ratio of the surface-freeze index to the air-freeze index is related through a factor, N. Because of the complexity and uncertainty between the freeze indices, a conservative estimate for N is recommended for practitioners (U.S. Army and U.S. Air Force 1998). The surface correction factor, N, was conservatively assumed to be 1.0 for analysis of the Crescent Junction Disposal Site. In addition, values for N of 0.8 and 0.9 are used as more realistic estimates for depth of frost penetration assuming a vegetative cover and a rock cover, respectively.
- Step 3. Determine Soil Thermal Properties

  Soil thermal properties—thermal conductivity, heat capacity, and latent heat of fusion—are products of empirical relationships between the dry unit weight (pounds per cubic feet [pcf]) and gravimetric moisture content (%). These relationships are reproduced in Aitken and Berg (1968) originally published by Aldrich and Paynter (1953) and Kersten (1949).
- Step 4. Determine Annual Frost Depths

  Annual frost depths were determined for each of the subject years using the Modified Berggren Formula (MBF) as discussed in Smith and Rager (2002). The MBF was converted to PC software by the U. S. Army Corps of Engineers in 1997. Computer output for each year analyzed are presented as Appendix B, including design air freezing index, design surface freezing index, mean annual temperature, length of freezing season, and total frost penetration.
- Step 5. Determine Extreme Frost Depth

  Extreme-value frost depths for the 200-year recurrence interval are determined by extrapolating beyond the record of observed data using the cumulative probability distribution of the Gumbel function (Smith and Rager 2002). Frost depths are plotted in relation to the standard variate and recurrence interval, and linear regression is used to extrapolate and interpolate freezing depths. Graphical results of the extreme-frost-depth analysis are included in Appendix C, and indicate a maximum frost penetration of 44 inches (104 centimeters [cm]) for a recurrence interval of 200 years with a surface factor of 1.0. Frost-depth predictions are also made with surface factors of 0.9, predicted depth of 41.5 inches; and with a surface factor of 0.8, a frost-penetration depth of 38.5 inches is determined.

Discussion:

Placing a 44-inch-thick frost-protection layer over the radon barrier layer is the maximum thickness of soil required to prevent freeze-thaw degradation of the barrier layer (N=1.0). Less thicknesses of 41.5 inches (N=0.9), down to 38.5 inches (N=0.8) are also predicted dependent on the ratio between the air temperature and surface temperature. Verification of the 41.5-inch predicted frost depth at proposed Crescent Junction Disposal Site compares well to other uranium mill tailings disposal cells in the general region as shown in the table below.

Site	Design Dry Density (pcf)	Design Water Content (%)	Predicted Frost Depth (inches)
Monticello, UT	90	17	45
Cheney (Grand Junction, CO)[1]	104	12	38
Estes Gulch (Rifle, CO)[1]	106	9	69
Green River, UT	No frost protection layer included in the design		

[1] Three layers in protective cover: 12-inch coarse material (rock riprap), 6-inch coarse material (sand bedding), and fine material with these properties reported.

Green River, Utah, is the closest constructed disposal cell to the proposed Crescent Junction Site. No information was found to document that a frost-penetration analysis had been performed here. The cover at the Green River Site consists of a 12-inch-thick riprap layer underlain by a 6-inch-thick sand drainage layer. Discussions with designers of the disposal cell reveal that an analysis was performed and without a protective layer, the depth of frost penetration does extend into the radon barrier, but not completely through the layer. No performance data was discovered.

Given similar density and moisture conditions, the depth of frost penetration into coarse-grained soils, such as a sand layer, is slightly greater than for a fine-grained soil layer. Thus, inclusion of a sand drainage layer below a protective layer of soil would slightly increase the magnitude of frost penetration, if the sand were used to replace the fine-grained soil. However, the magnitude of the difference in thicknesses is not expected to be significant.

Conclusions and Recommendations:

- Based on results of the freeze/thaw analysis, a maximum frost penetration of 41.5 inches (1.05 m) should be assumed for design of the Moab uranium tailings cover at the Crescent Junction Disposal Site, using a rock cover, and 38.5 inches (0.98 m) if a vegetated cover is used.
- The design depth of frost protections depends on the type of cover chosen in the final design.

Computer Source:

MBF (Modified Berggren Formula). Coded for personal computer use by U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory in 1997.

Sources of Formulae and References:

Aitken, G.W., and R. L. Berg, 1968. *Digital Solution of Modified Berggren Equation to Calculate Depths of Freeze and Thaw in multilayered Systems*, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, Special Report 122.

Aldrich, H.P., and H.M. Paynter, 1953. *Analytical Studies of Freezing and Thawing of Soils, First Interim Report*, U.S. Army Corps of Engineers, New England Division, Arctic Construction and Frost Effects Laboratory Technical Report 42.

Kersten, M.S., 1949. *Laboratory Research for the Determination of the Thermal Properties of Soils, Final Report,* U.S. Army Corps of Engineers, New England Division, Arctic Construction and Frost Effects Laboratory Technical Report 23.

NAVFAC (Naval Facilities Engineering Command), 1986. *Soil Mechanics Design Manual 7.01,* Alexandria, Virginia, pp. 7.1–42.

Smith, G.E. and R.E. Rager, 2002. “Protective Layer Design in Landfill Covers Based on Frost Penetration,” American Society of Civil Engineers, *Journal of Geotechnical/Geoenvironmental Engineering,* 128(9), pp. 794–799.

U.S. Army and U.S. Air Force, 1988. *Arctic and Subarctic Construction Calculation Methods for Determination of Depths of Freeze and Thaw in Soils, First Intern Report,* Army Technical Manual 5-852-6, Air Force Regulation 88-19, Vol. 6.

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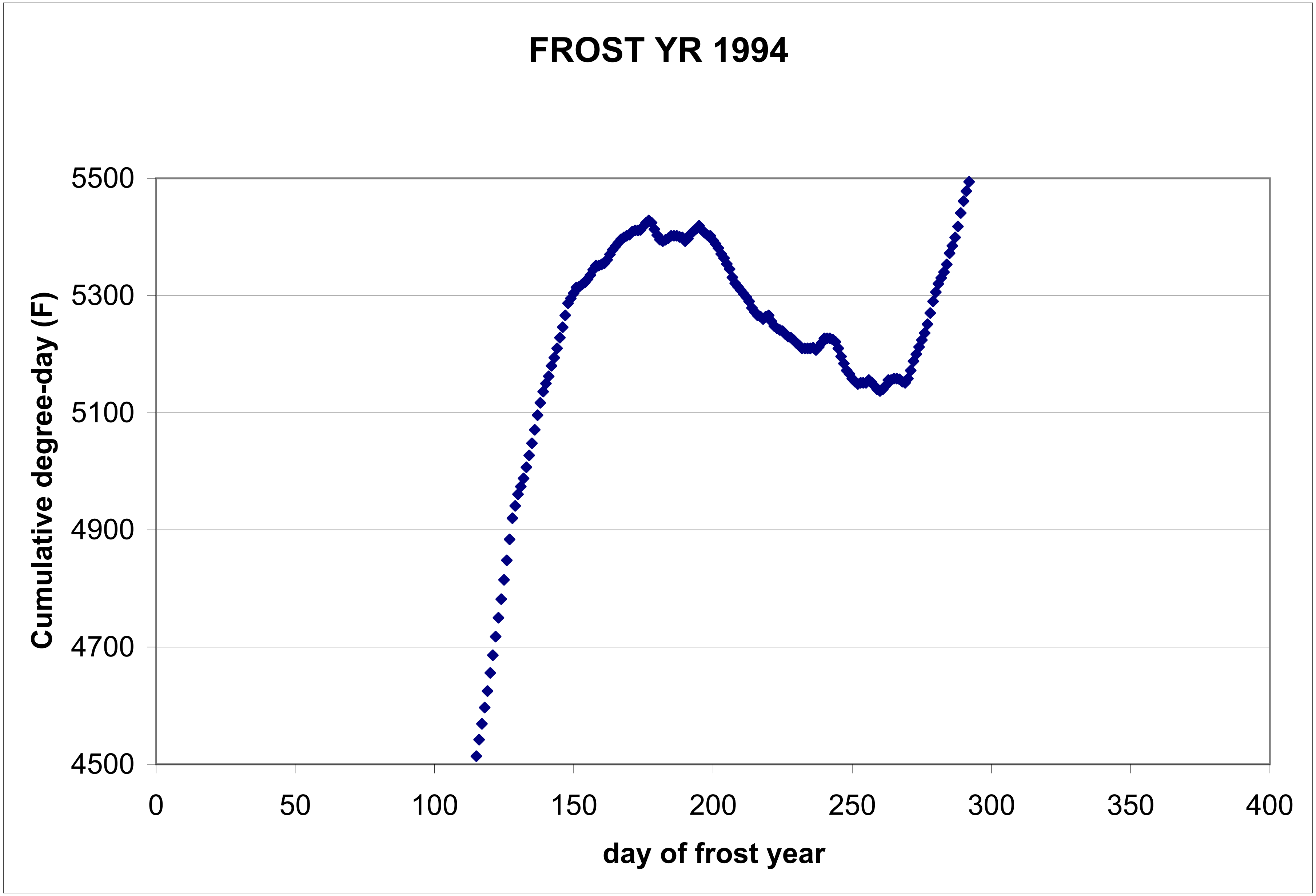
APPENDIX A

PLOTTED FREEZE-INDEX DATA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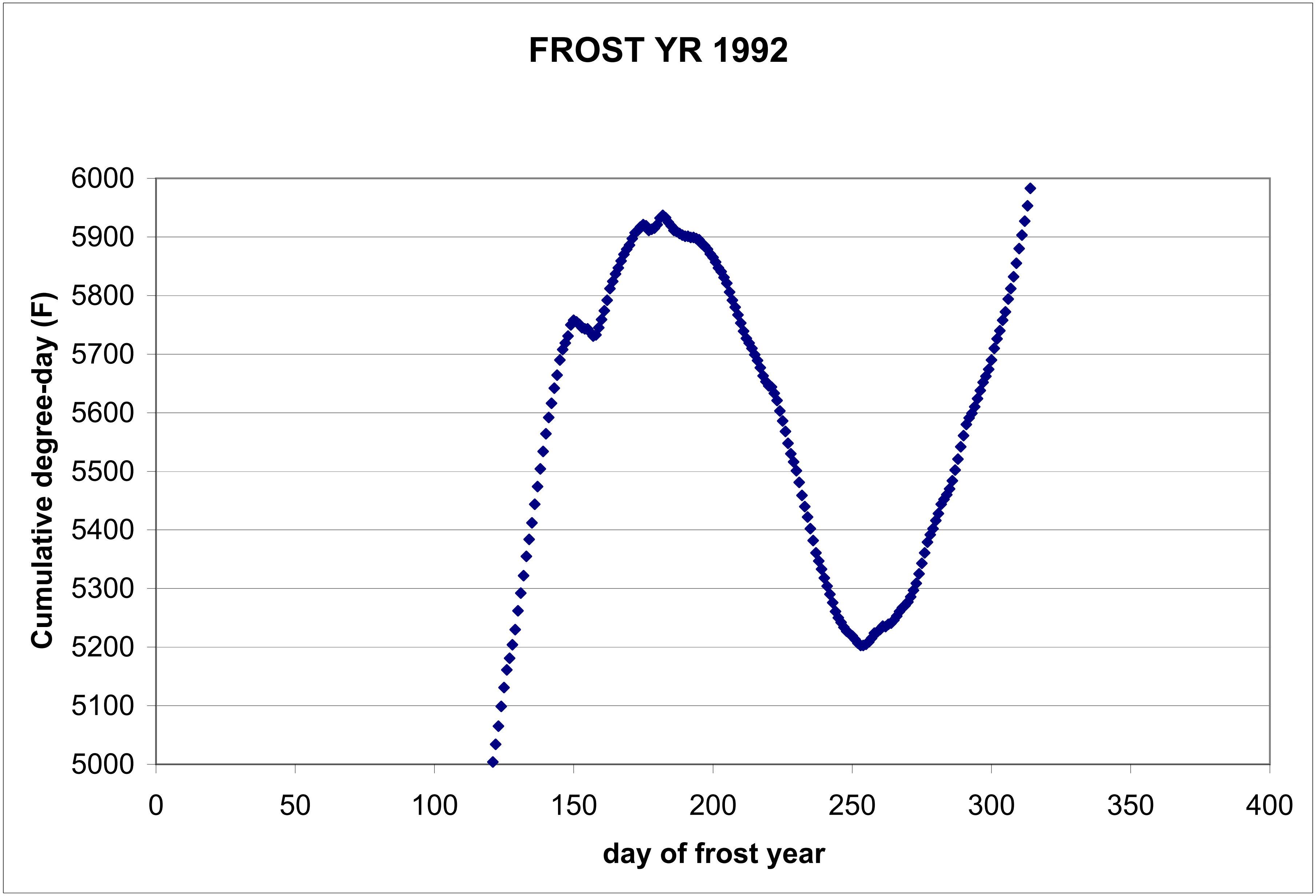
day of frost year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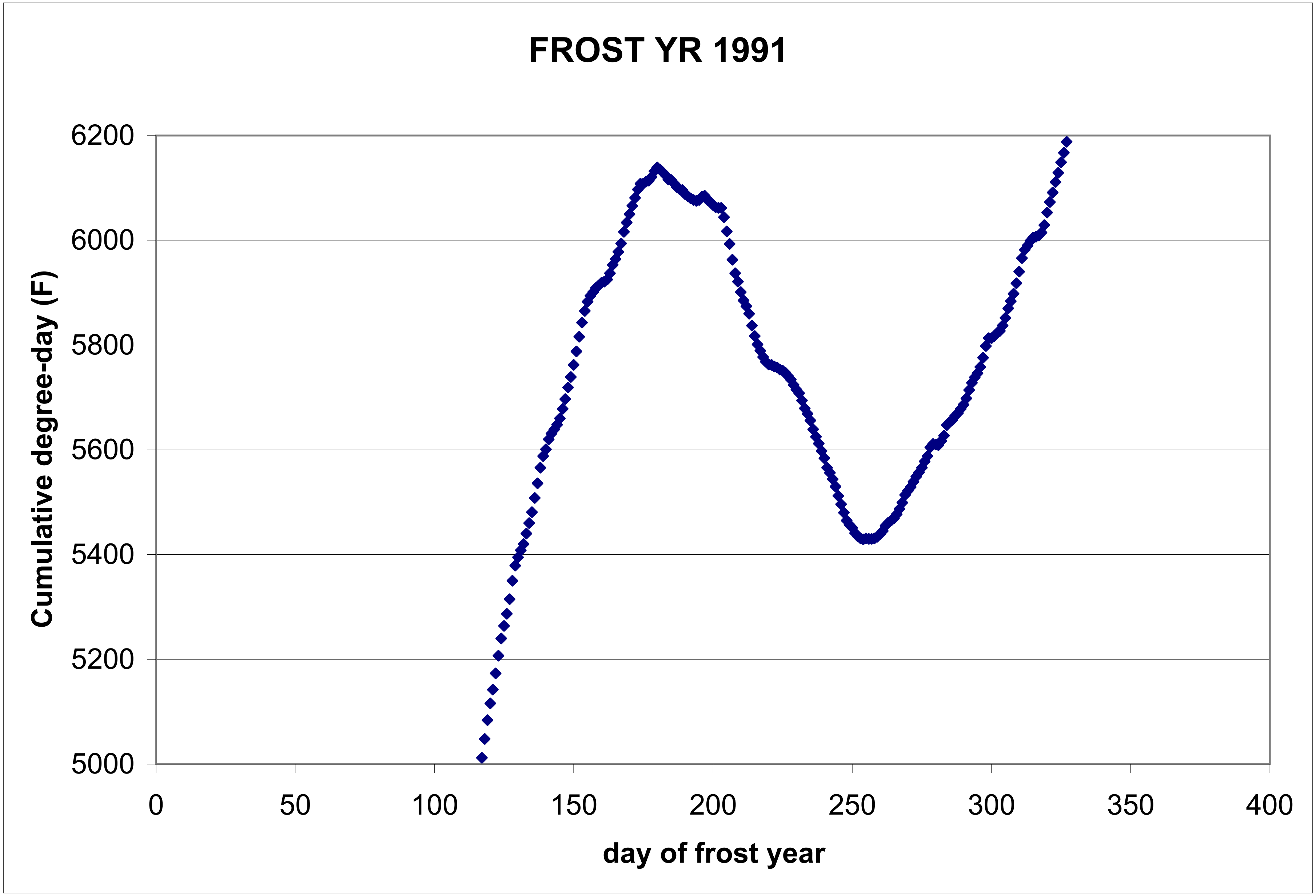
day of frost year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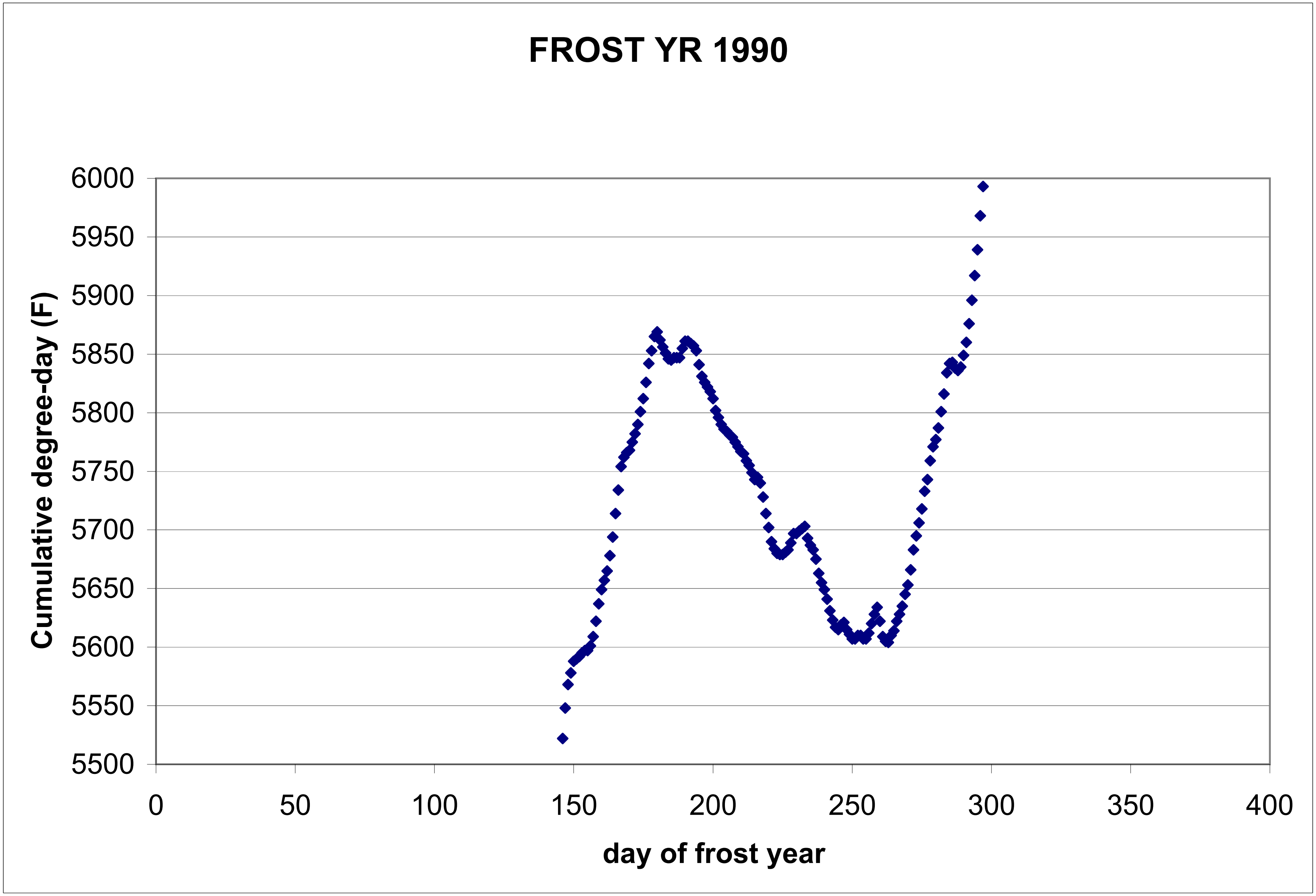
day of frost year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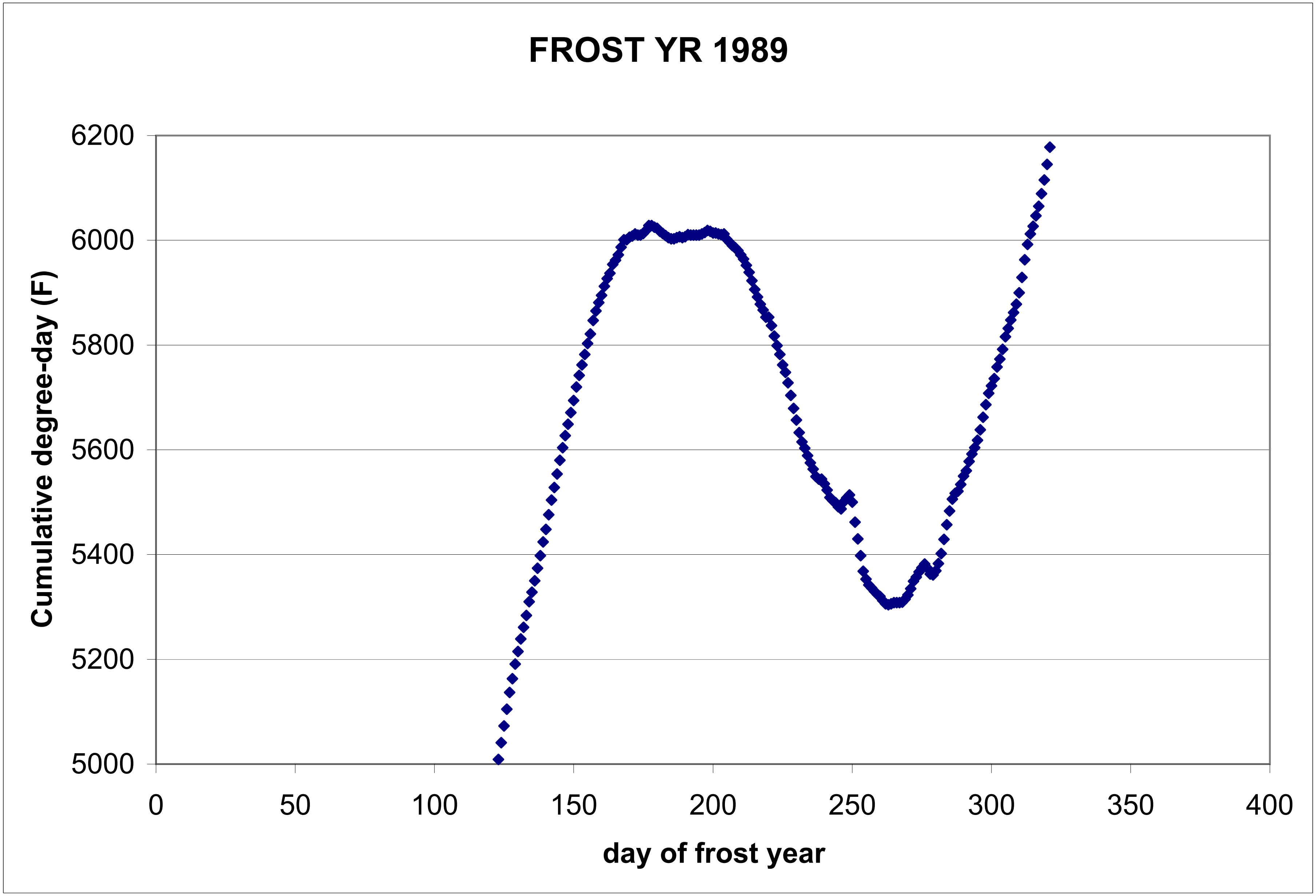
day of frost year



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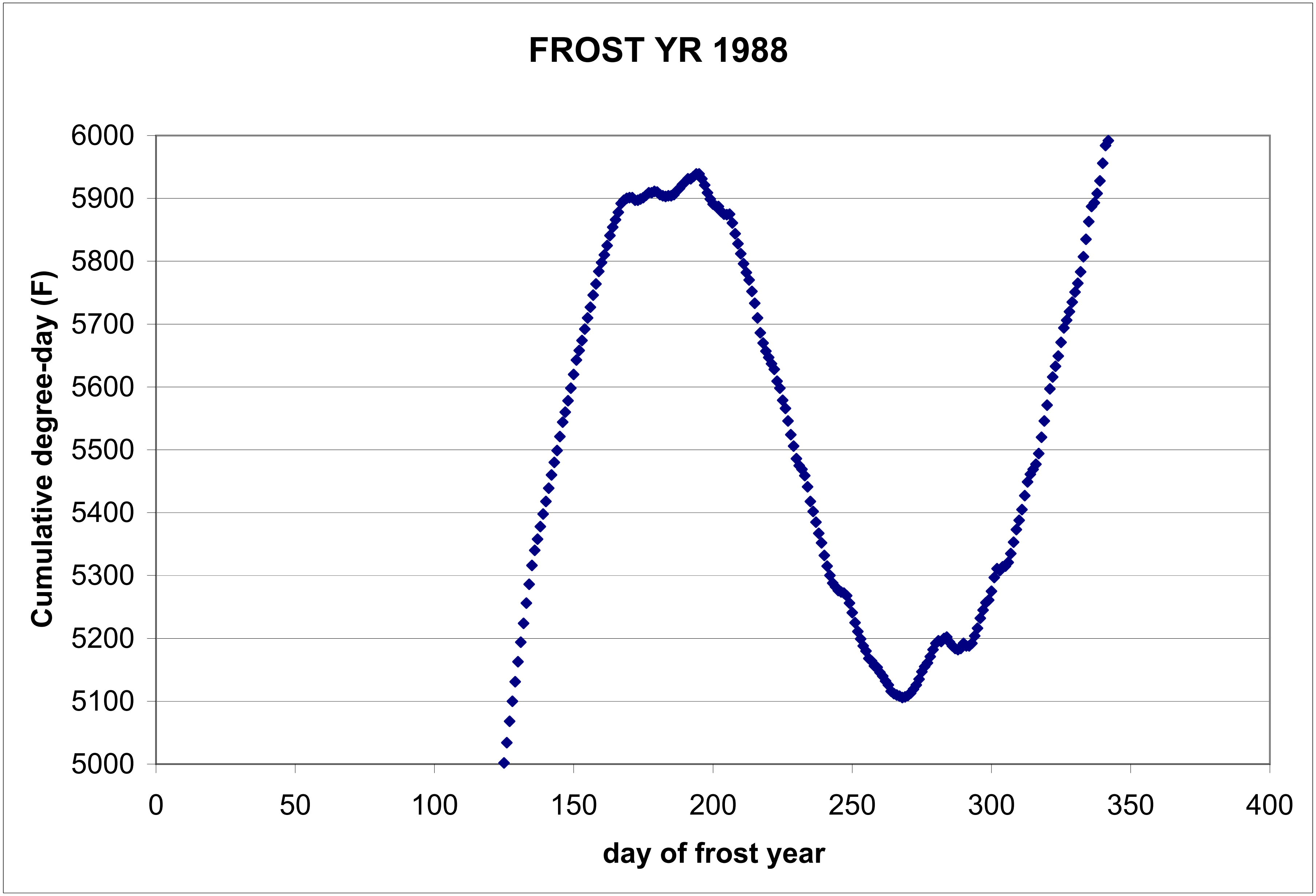
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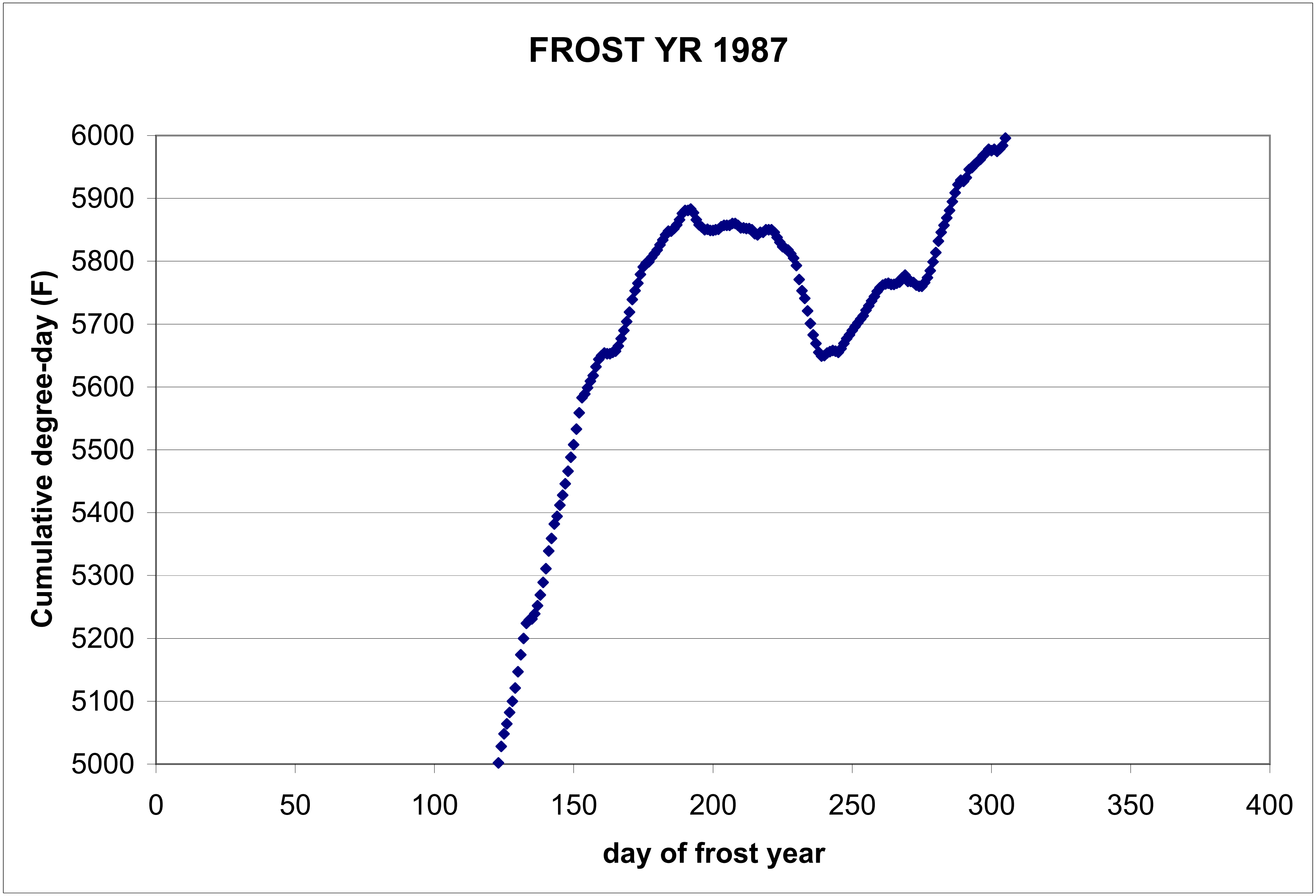
day of frost year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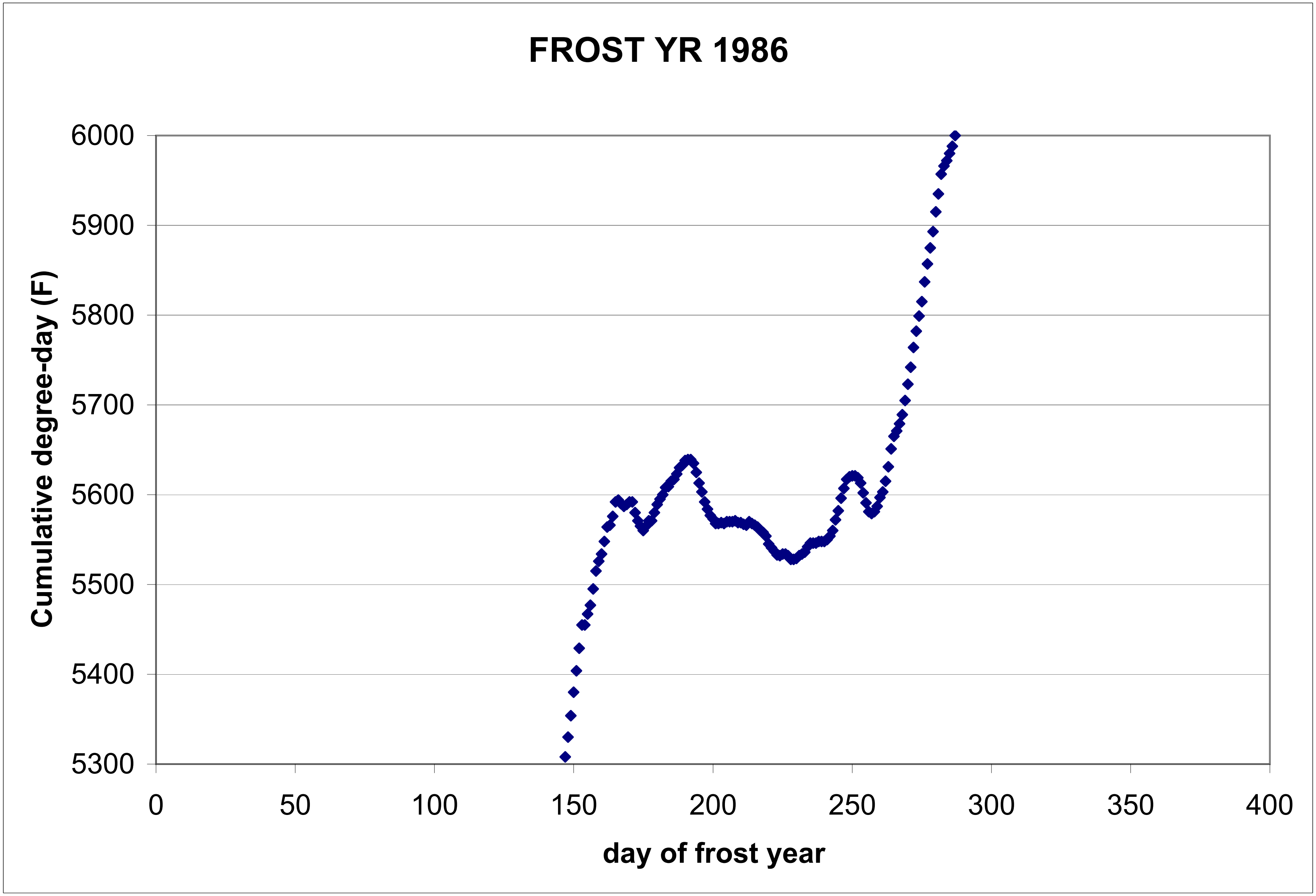
day of frost year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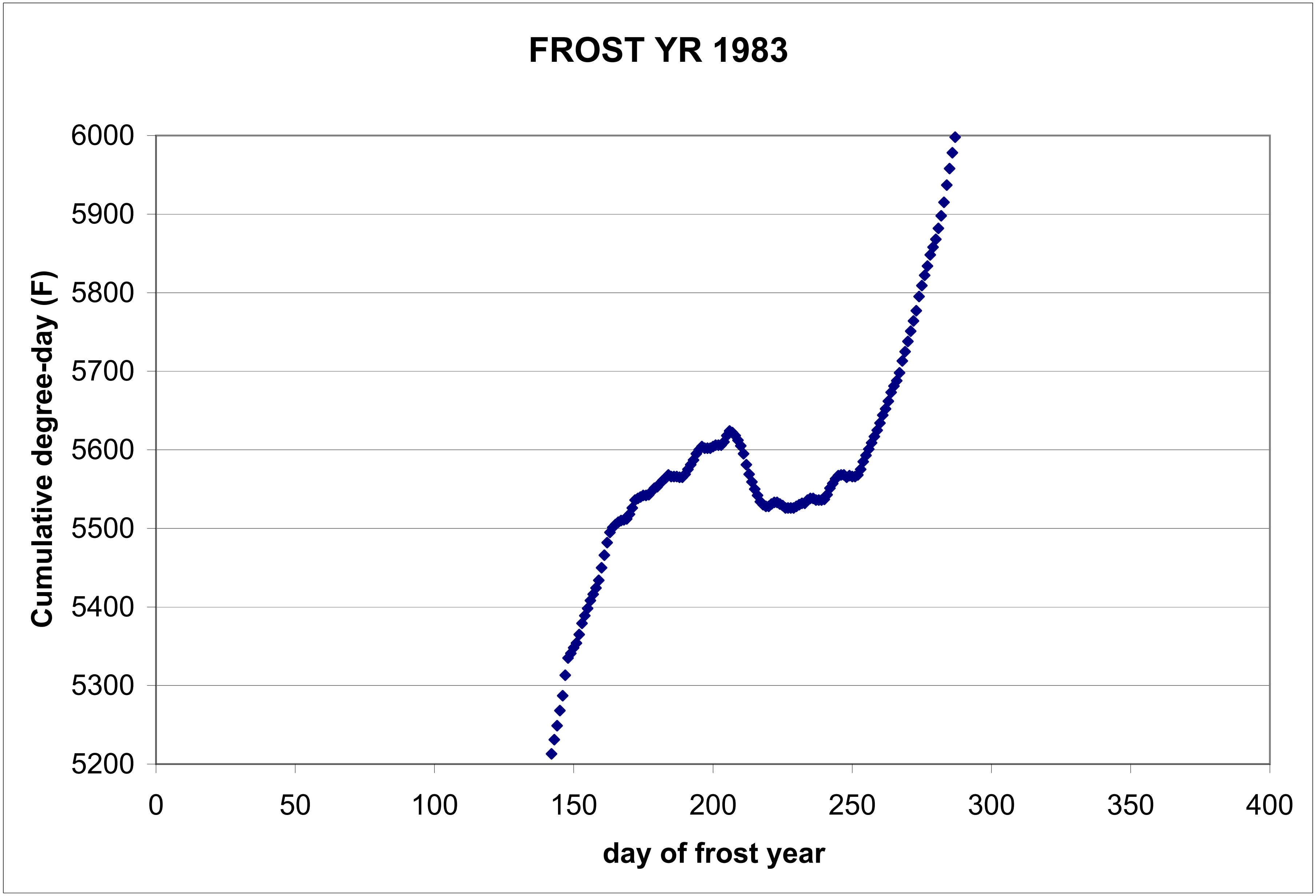
day of frost year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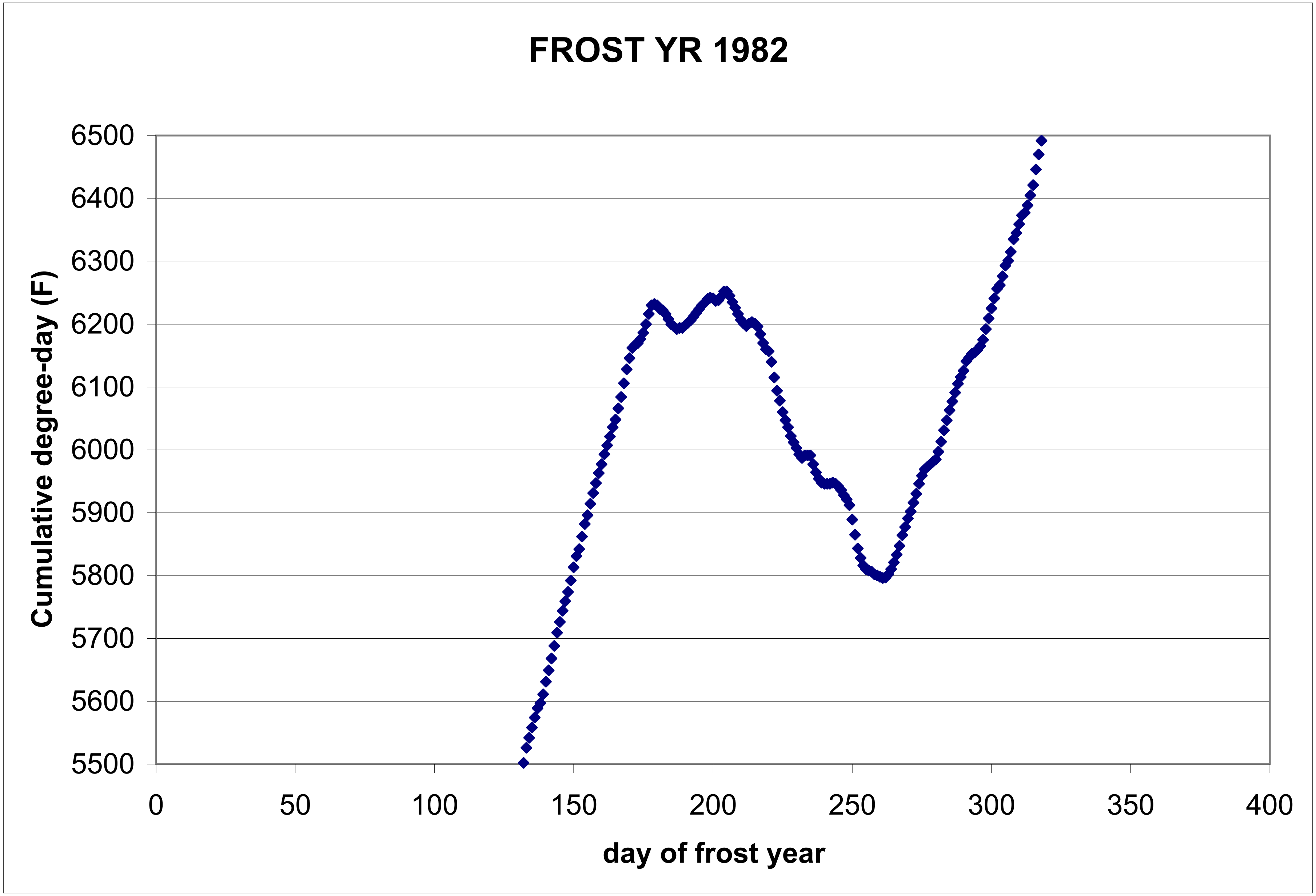
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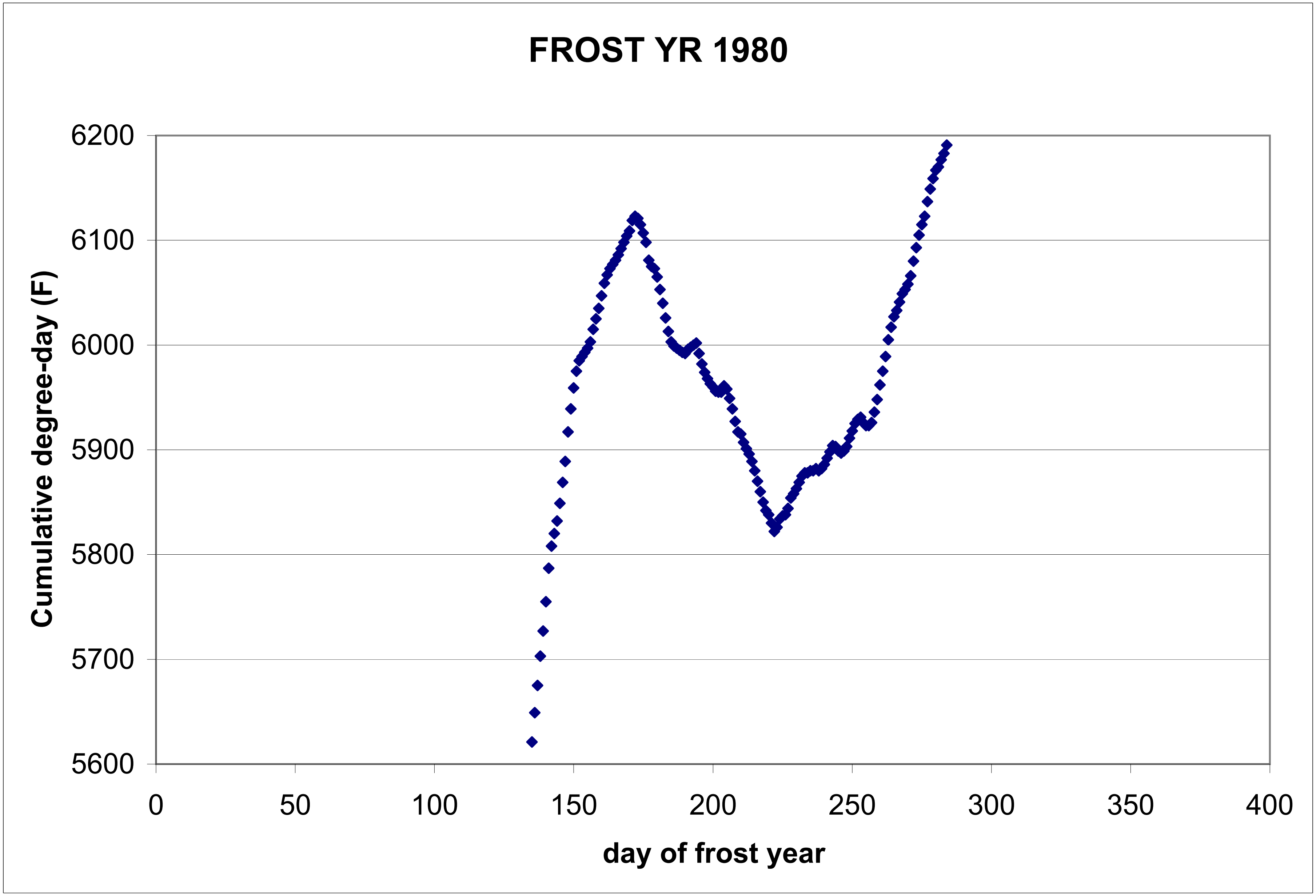

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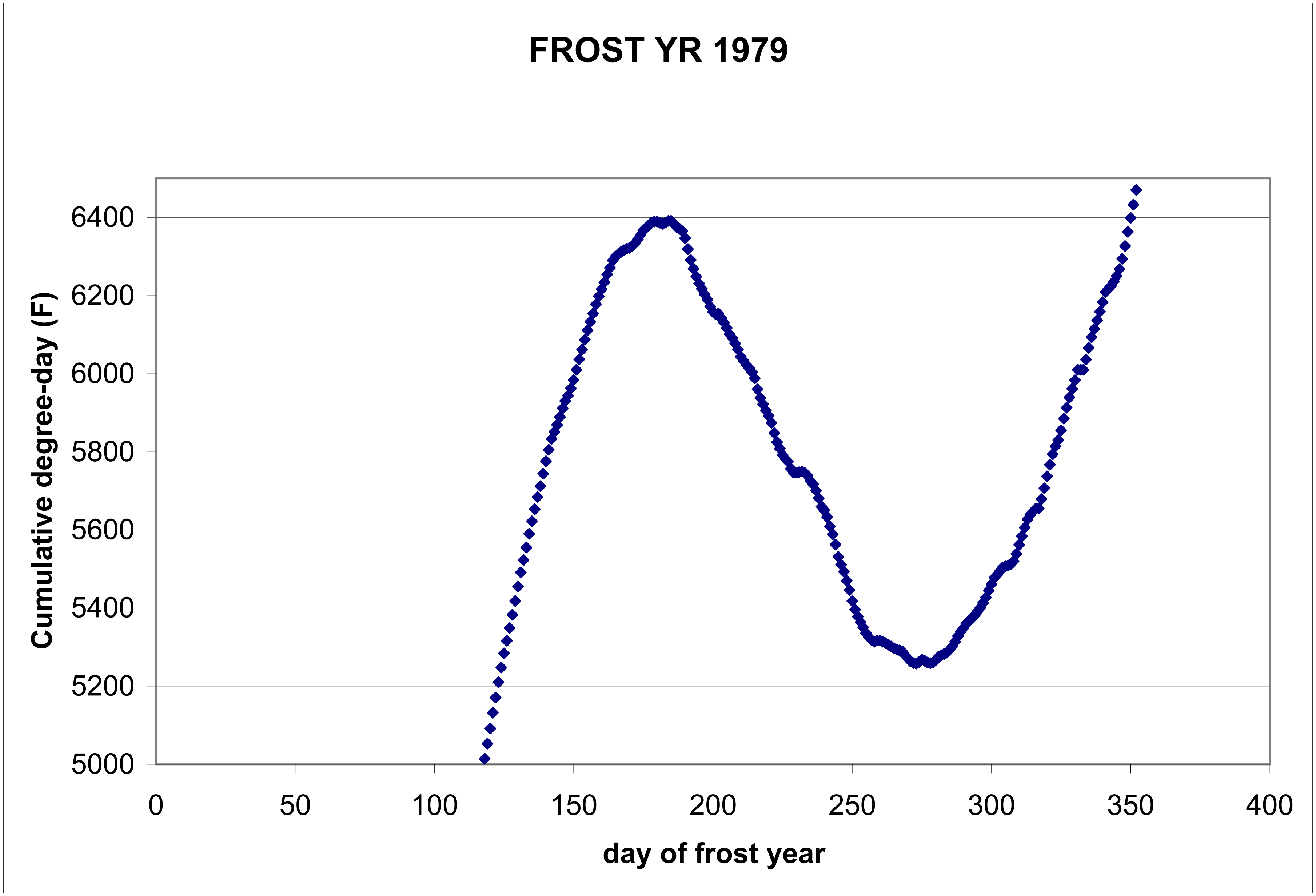
day of frost year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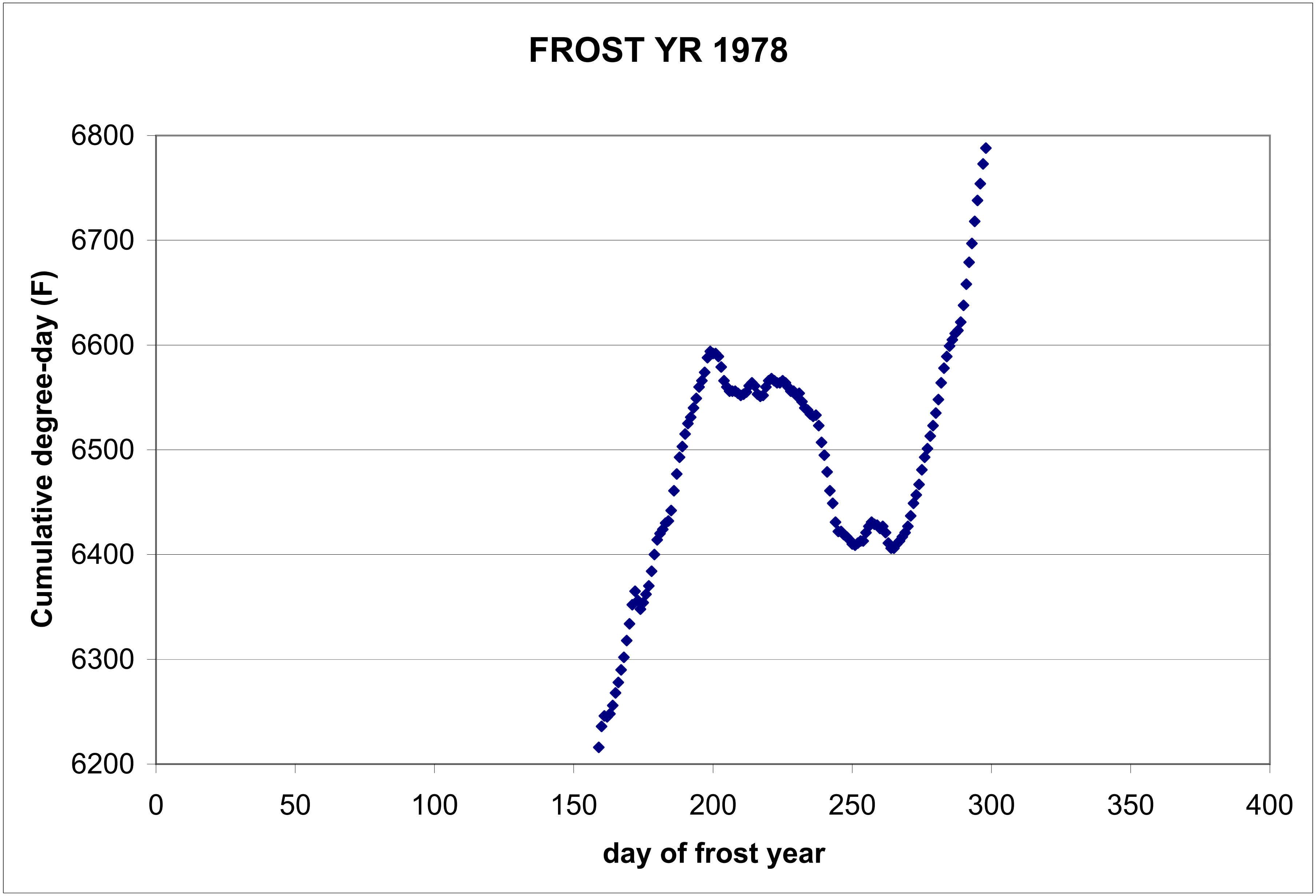
day of frost year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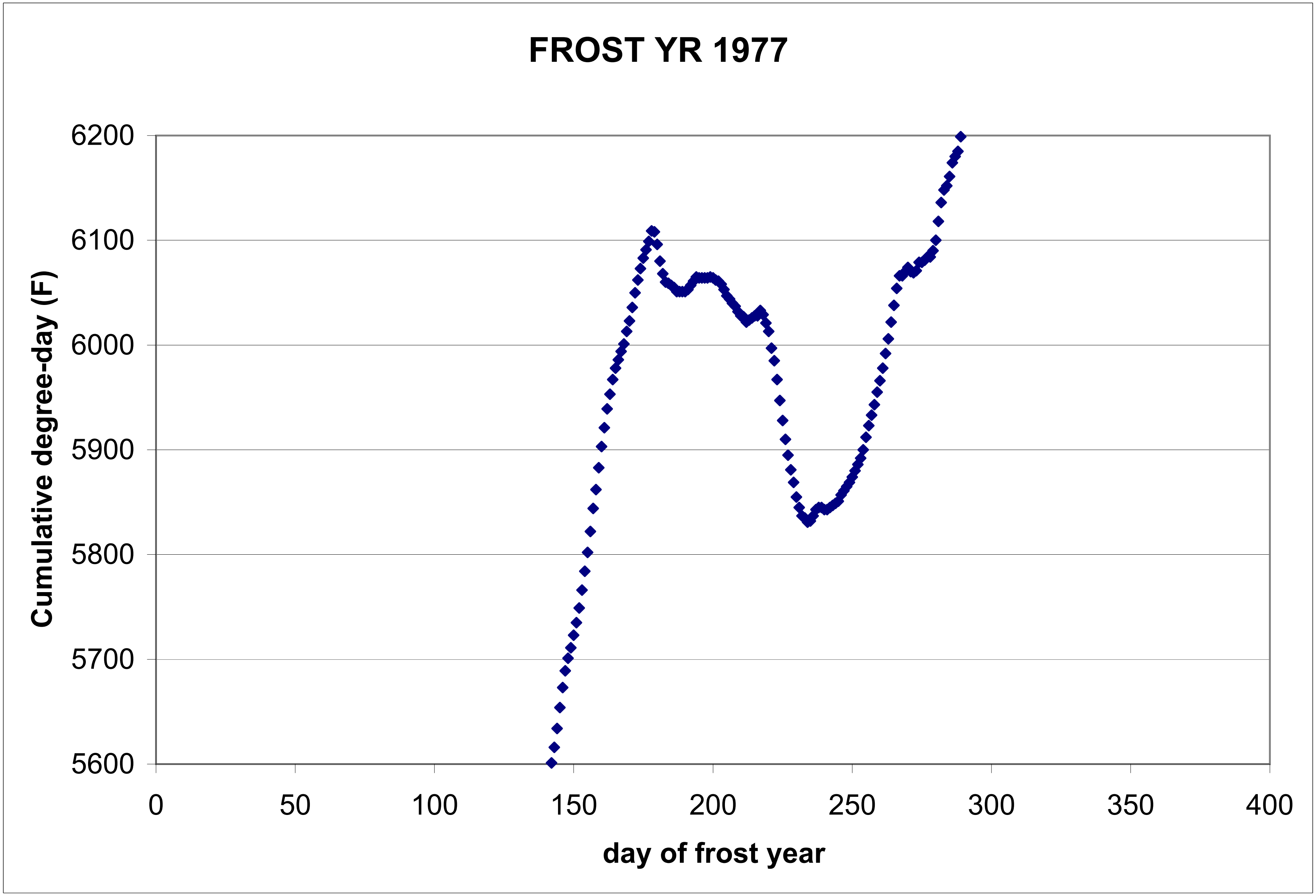
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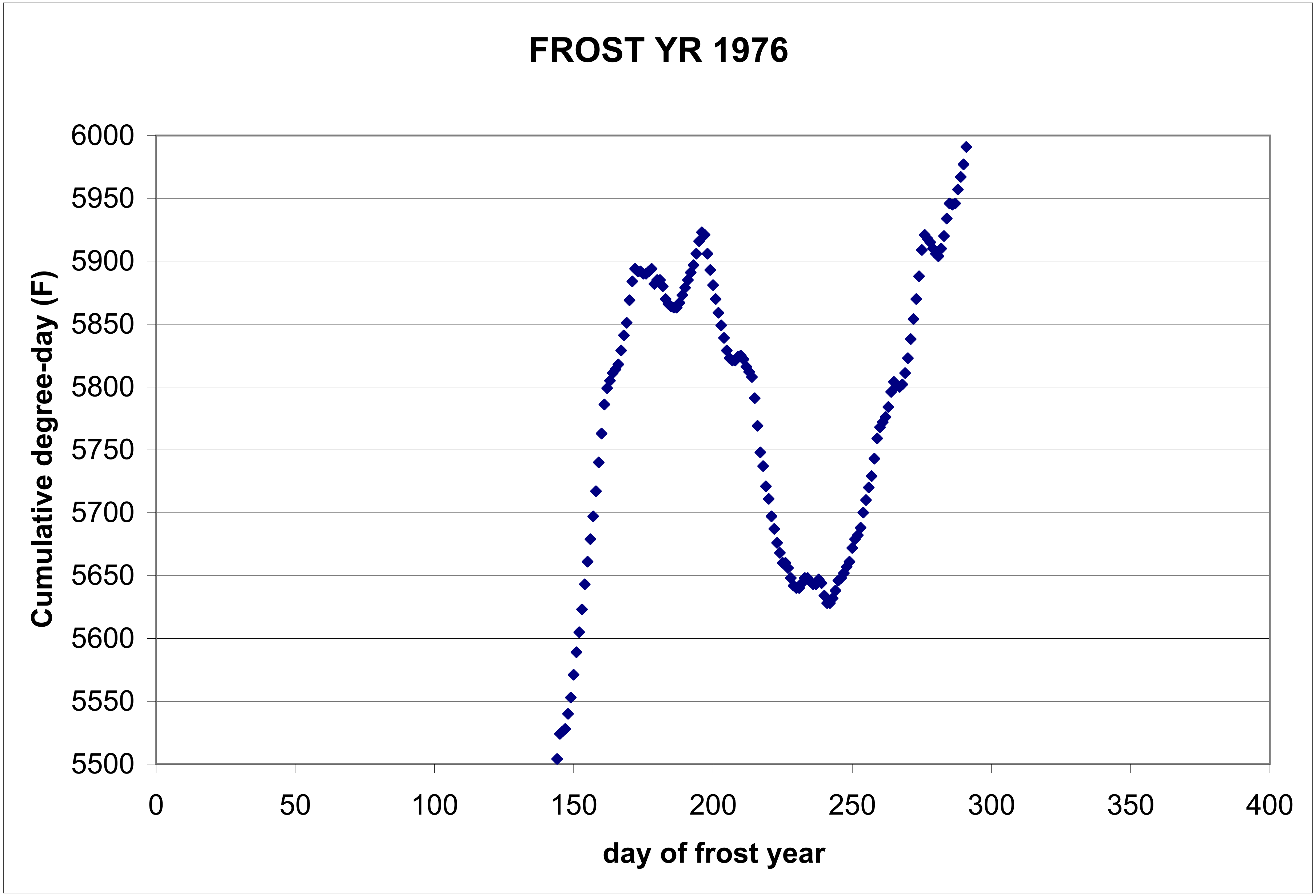
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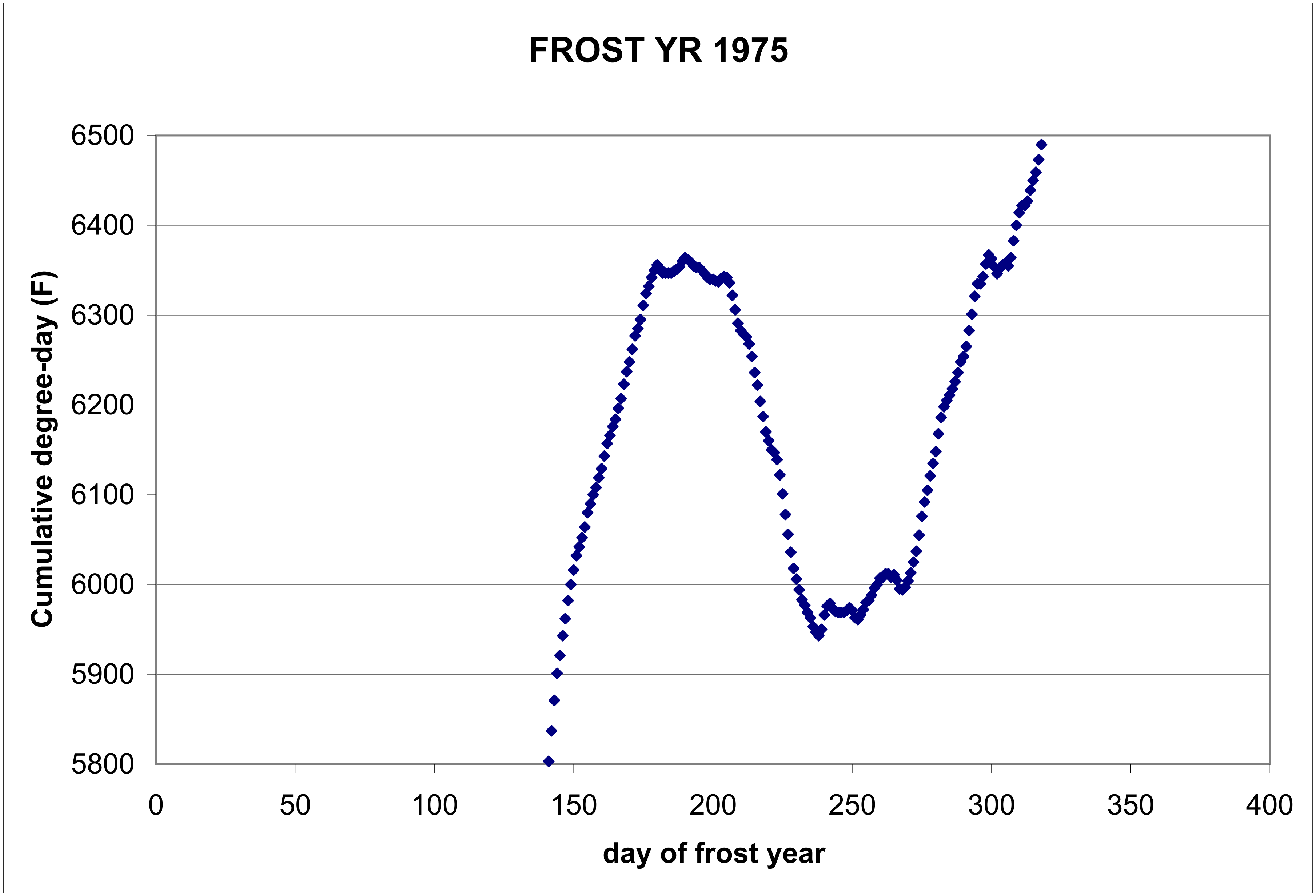
day of frost year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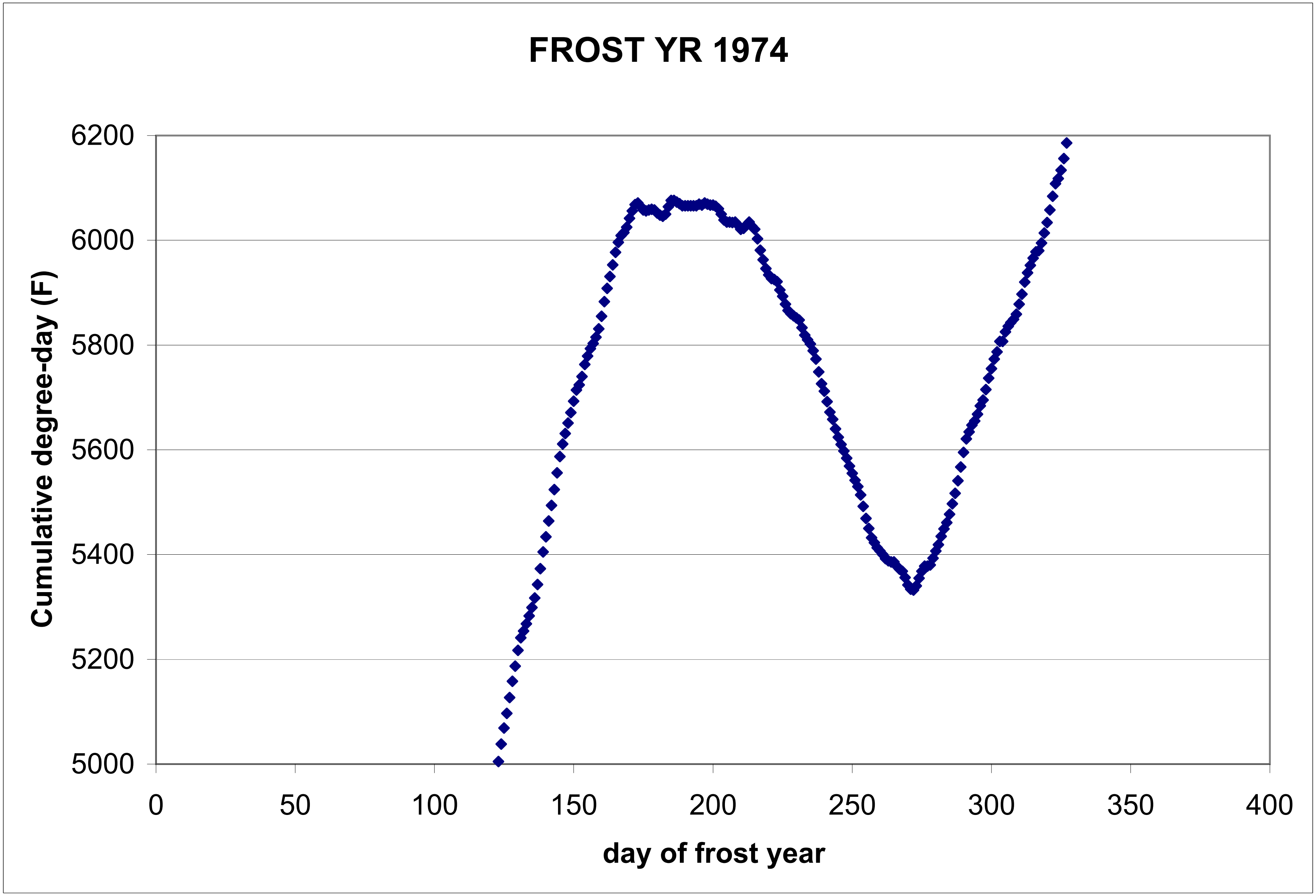
day of frost year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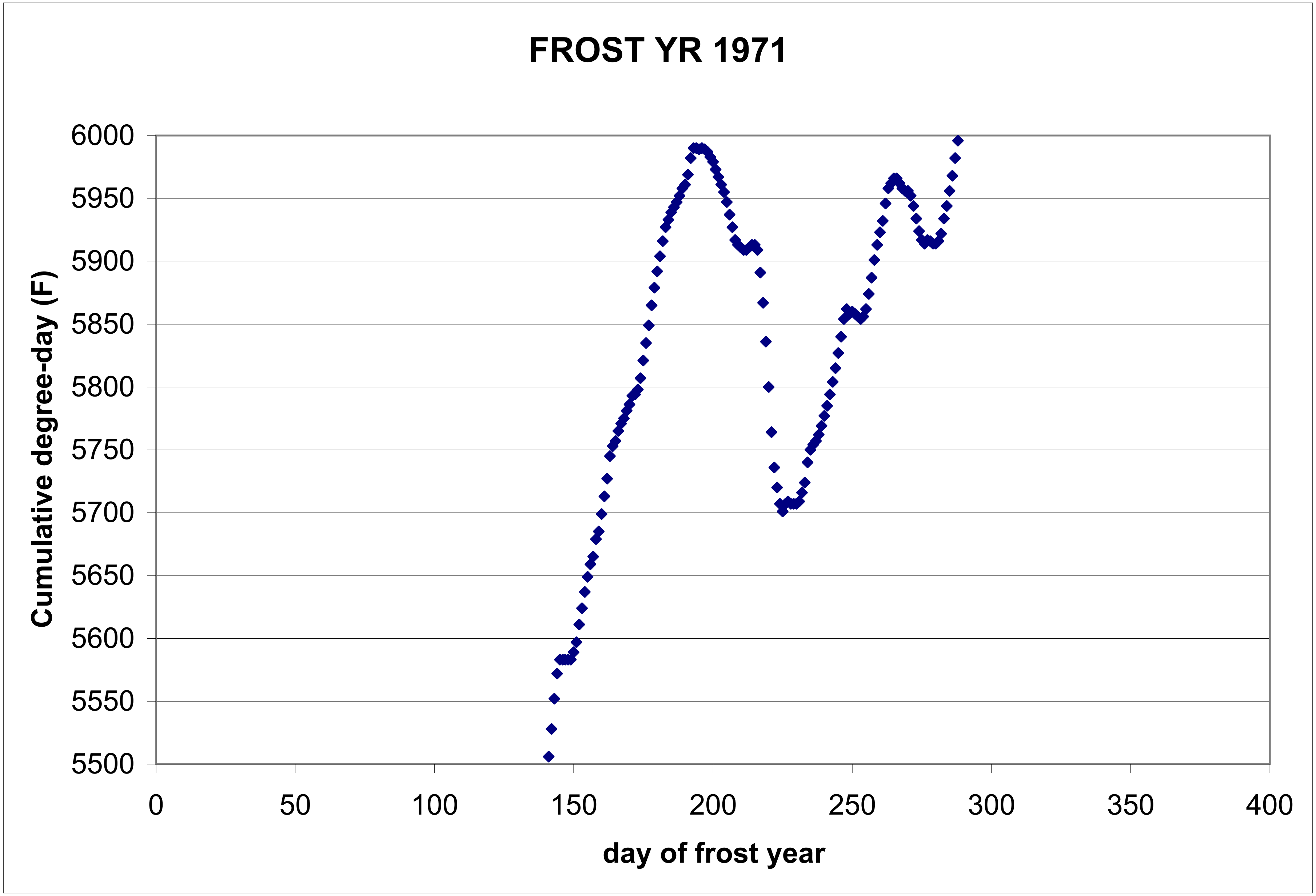
day of frost year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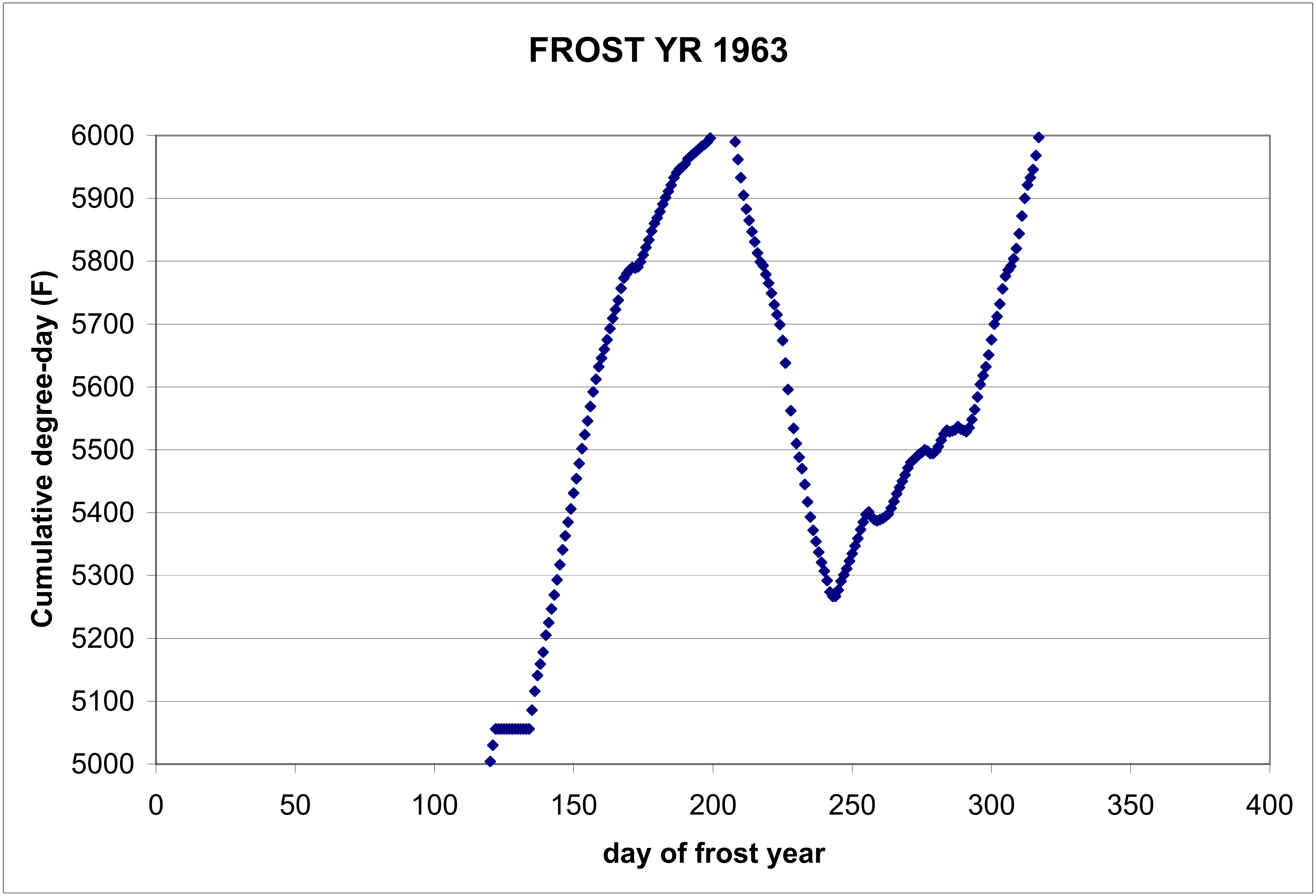
day of frost year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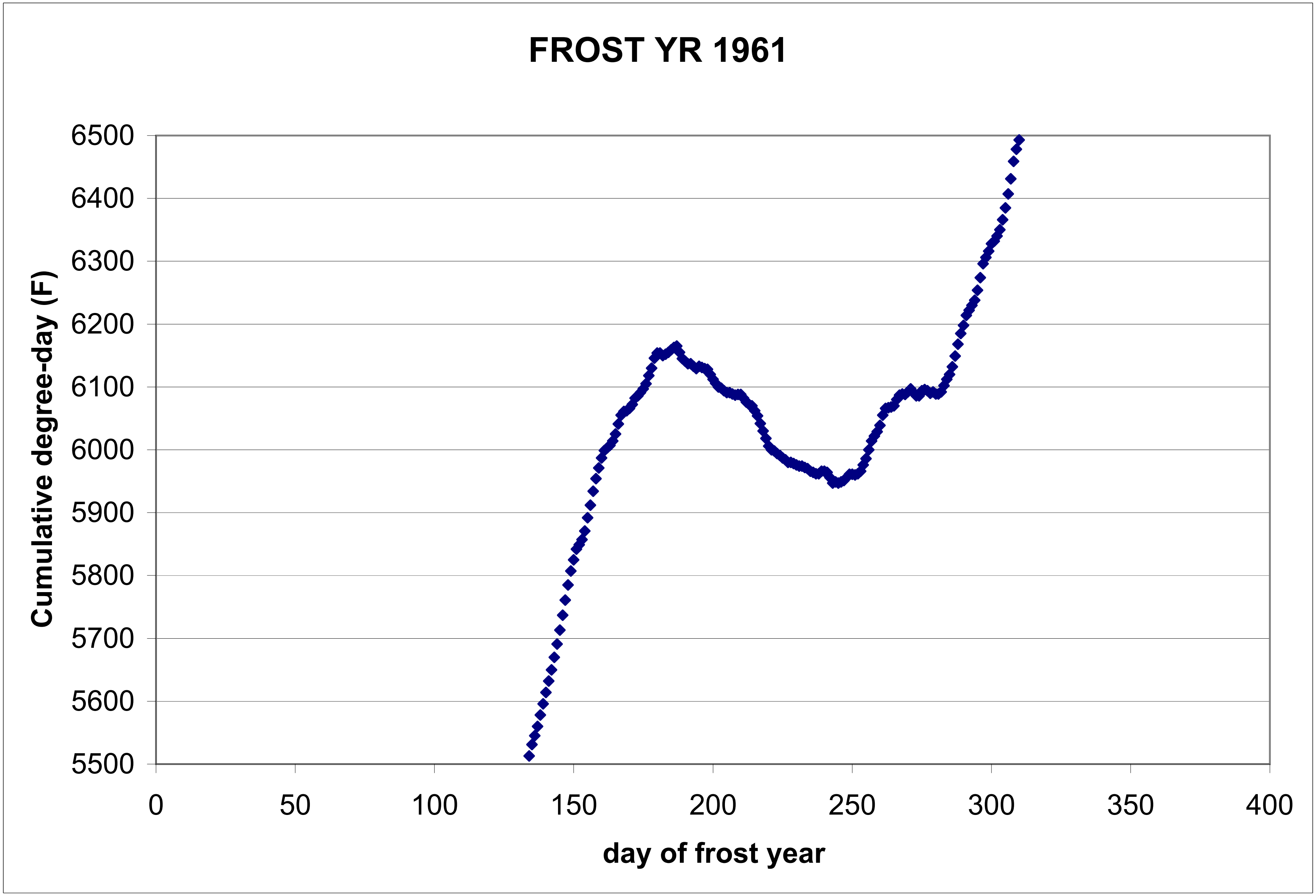
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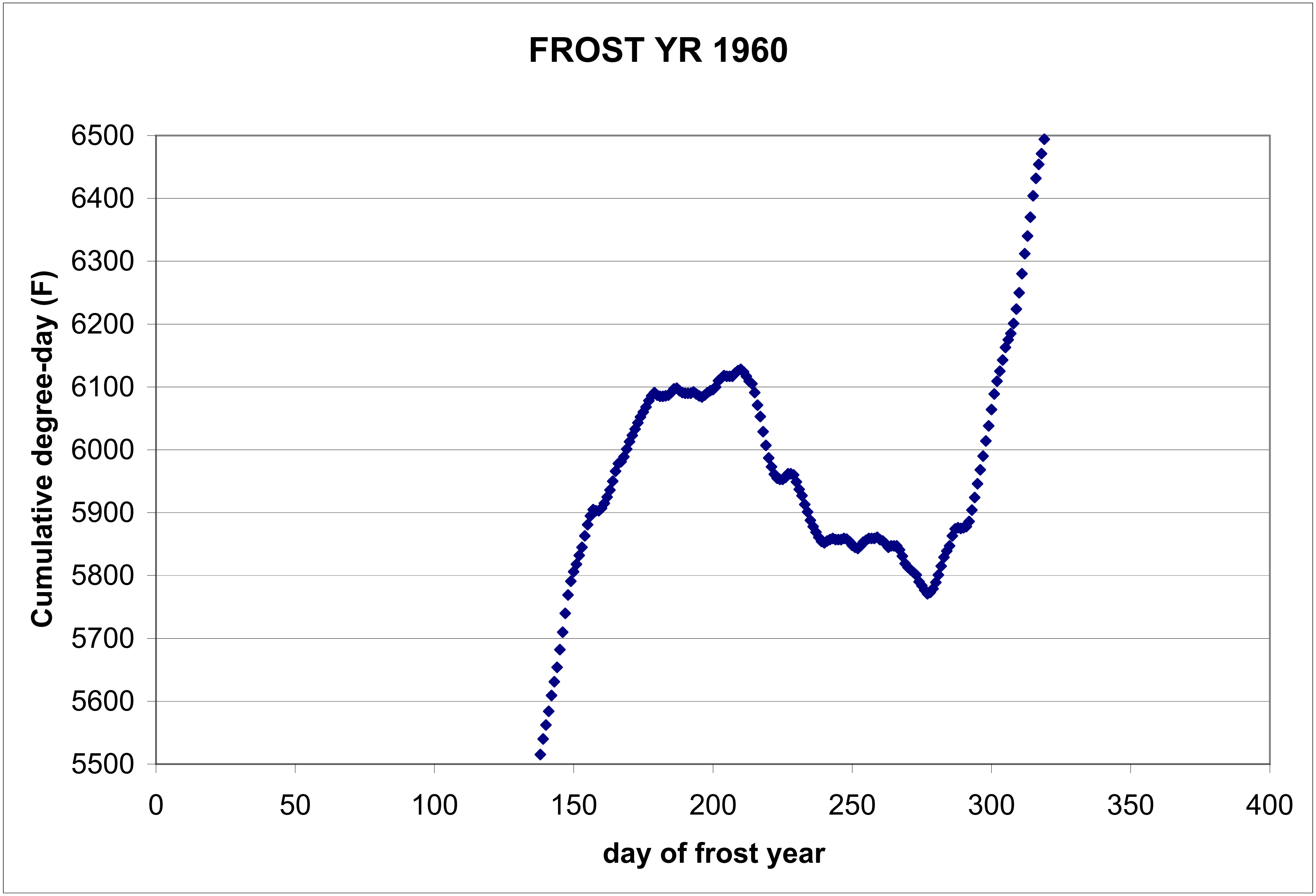
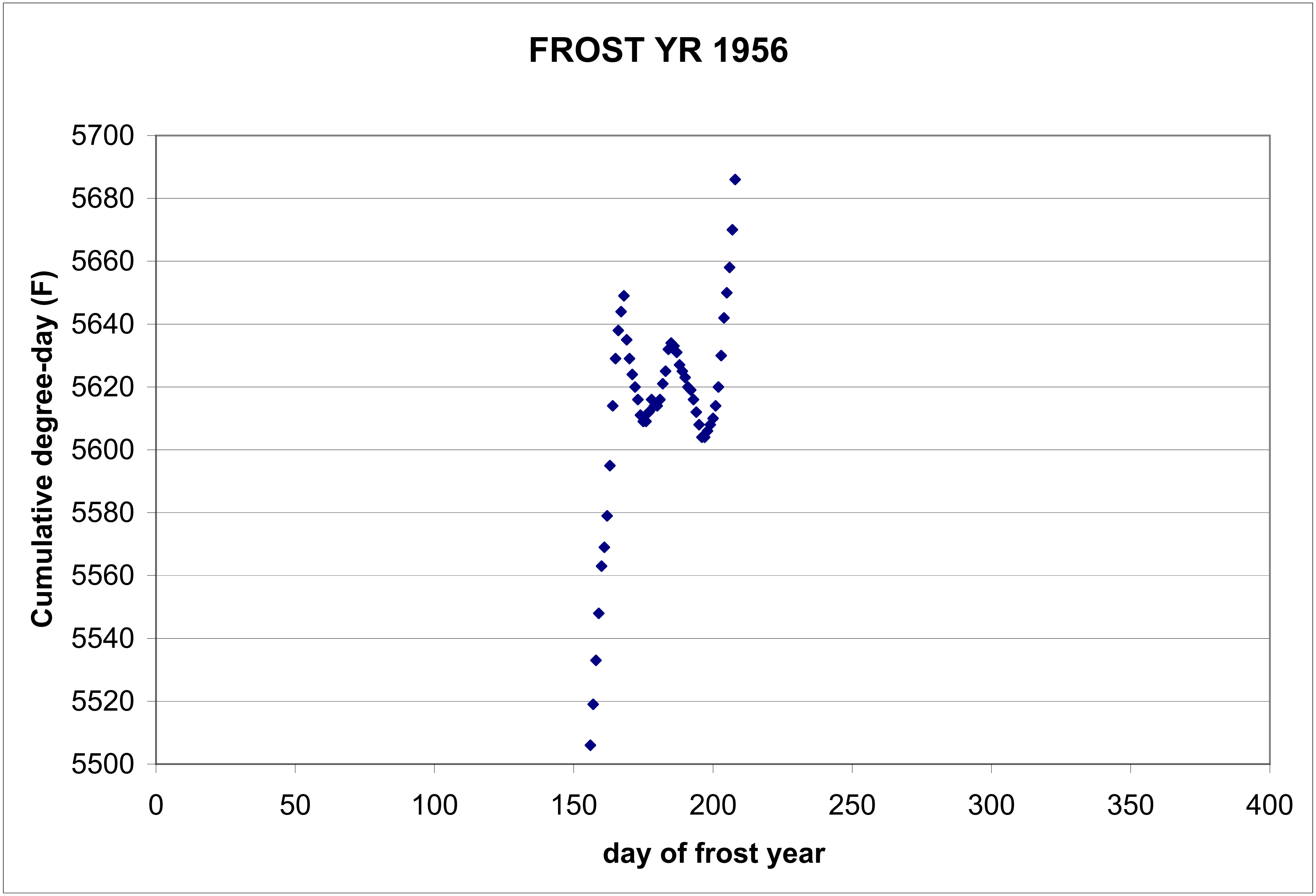
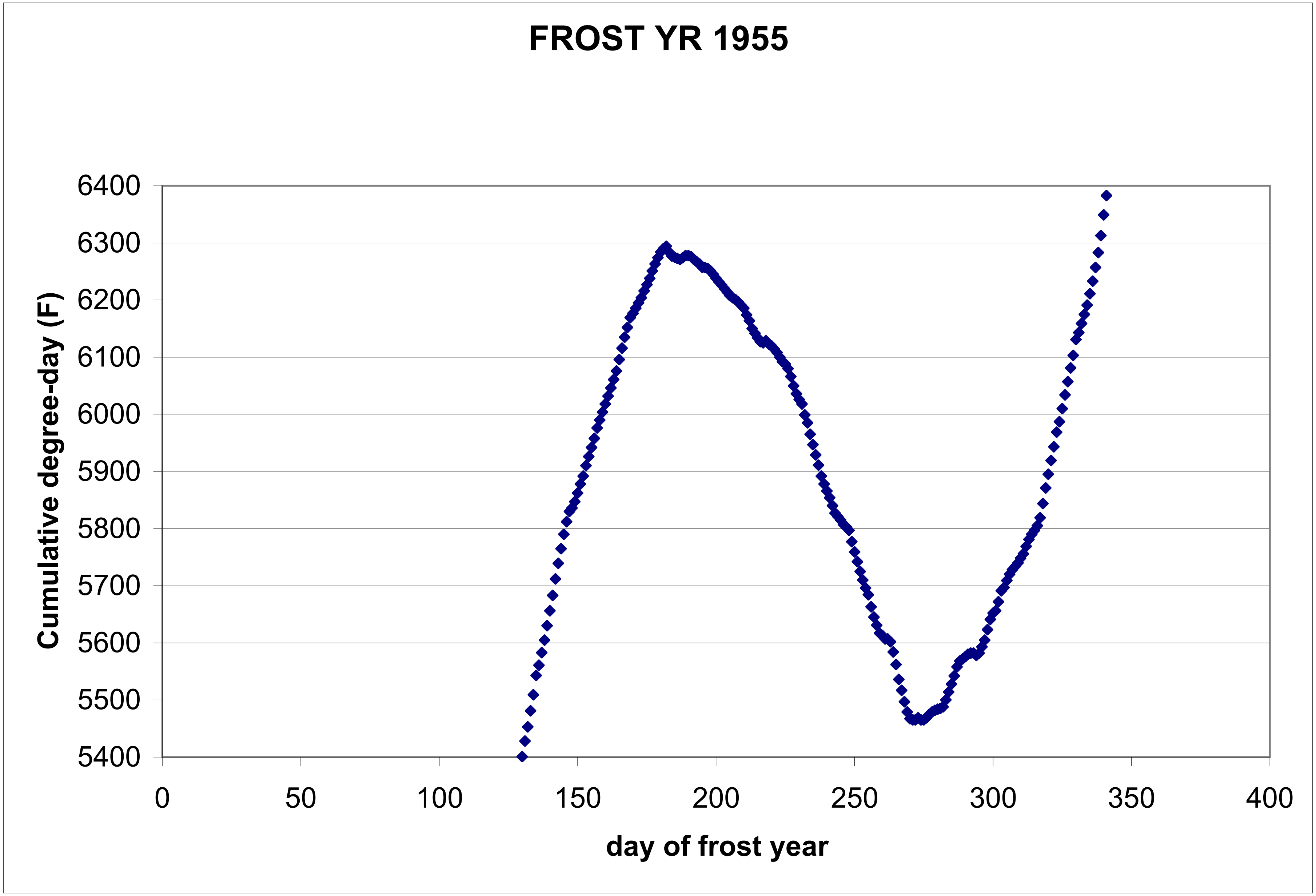
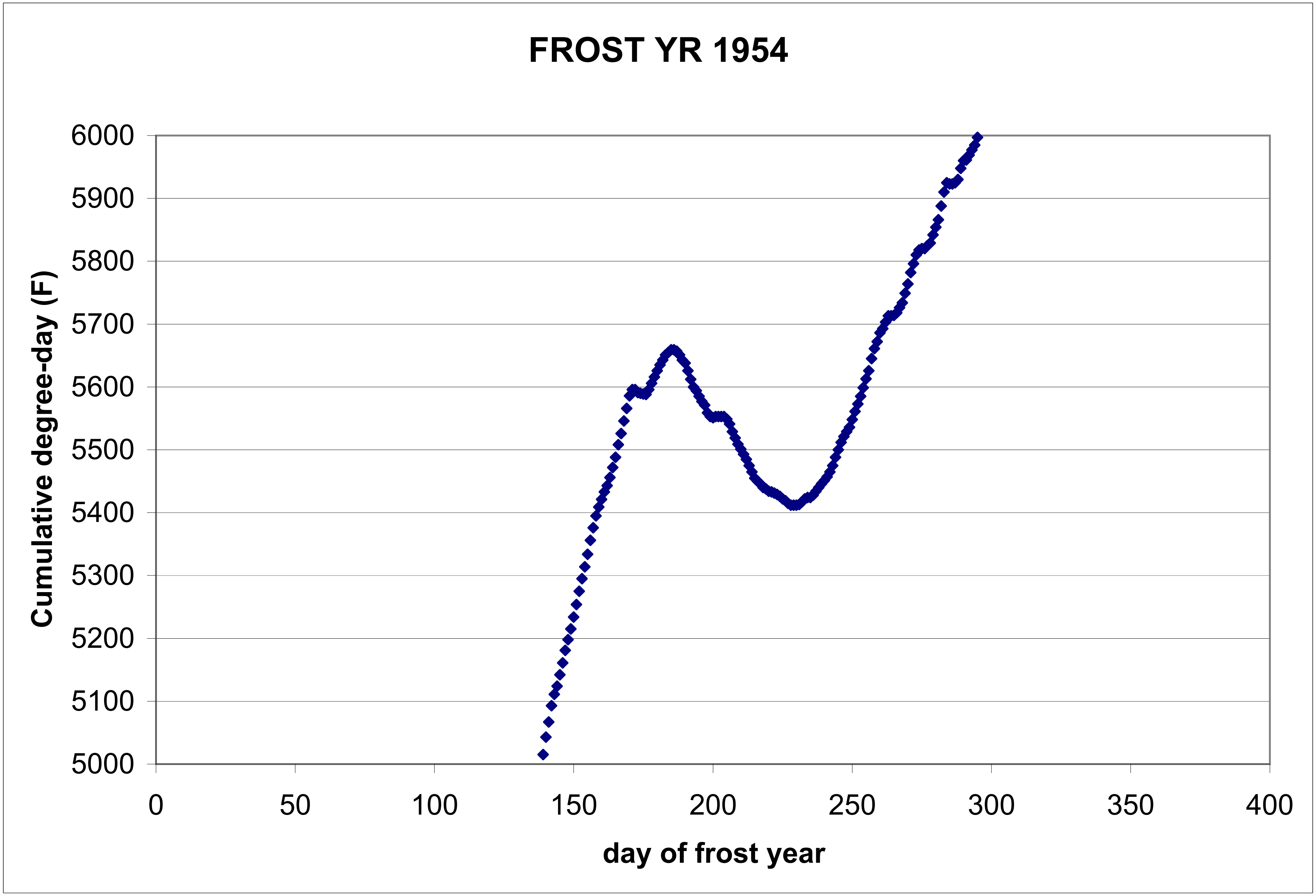
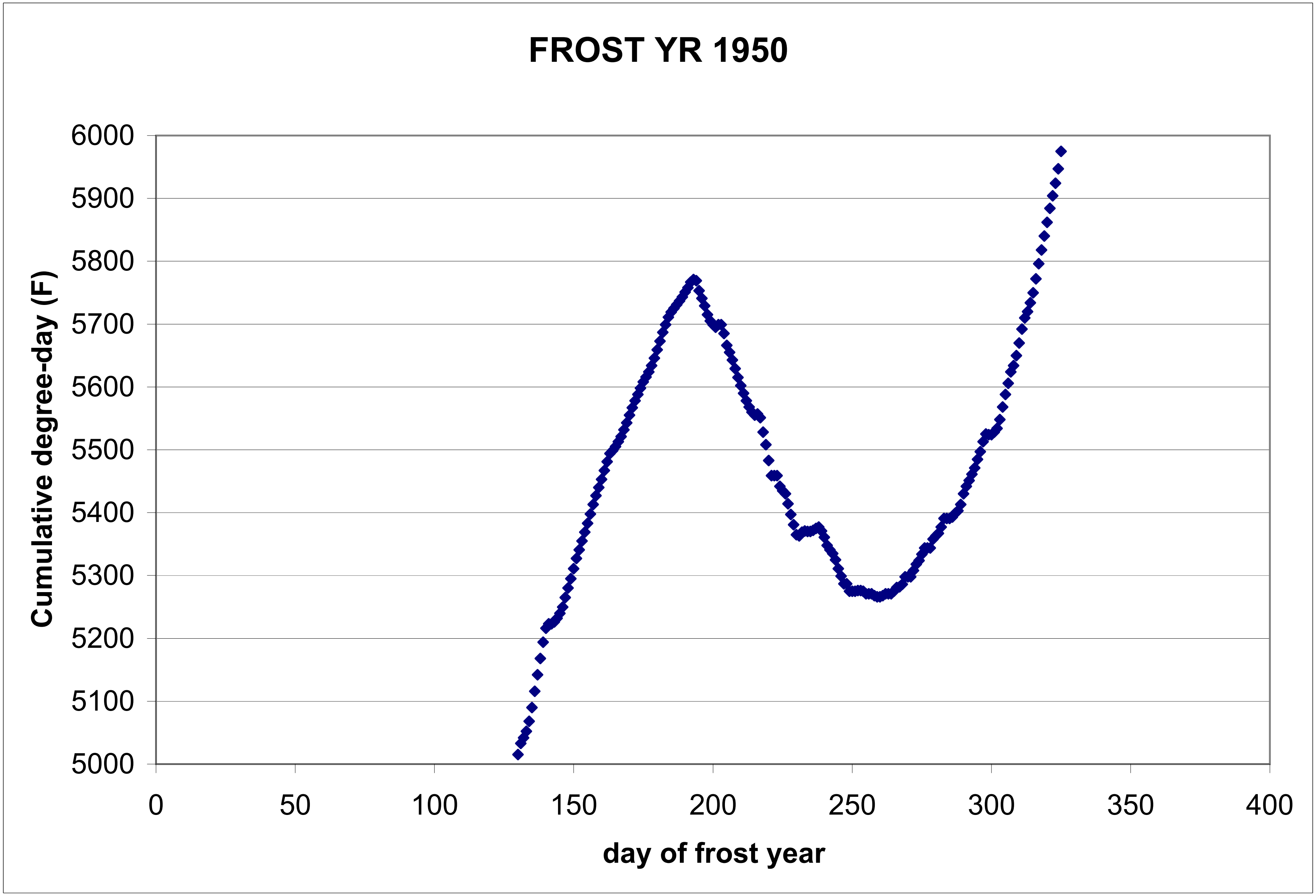
5700
5600
5500
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1960
Cumulative degree-day (F)
6500
6400
6300
6200
6100
6000
5900
5800
5700
5600
5500
0
50
100
150
200
250
300
350
400
day of frost year

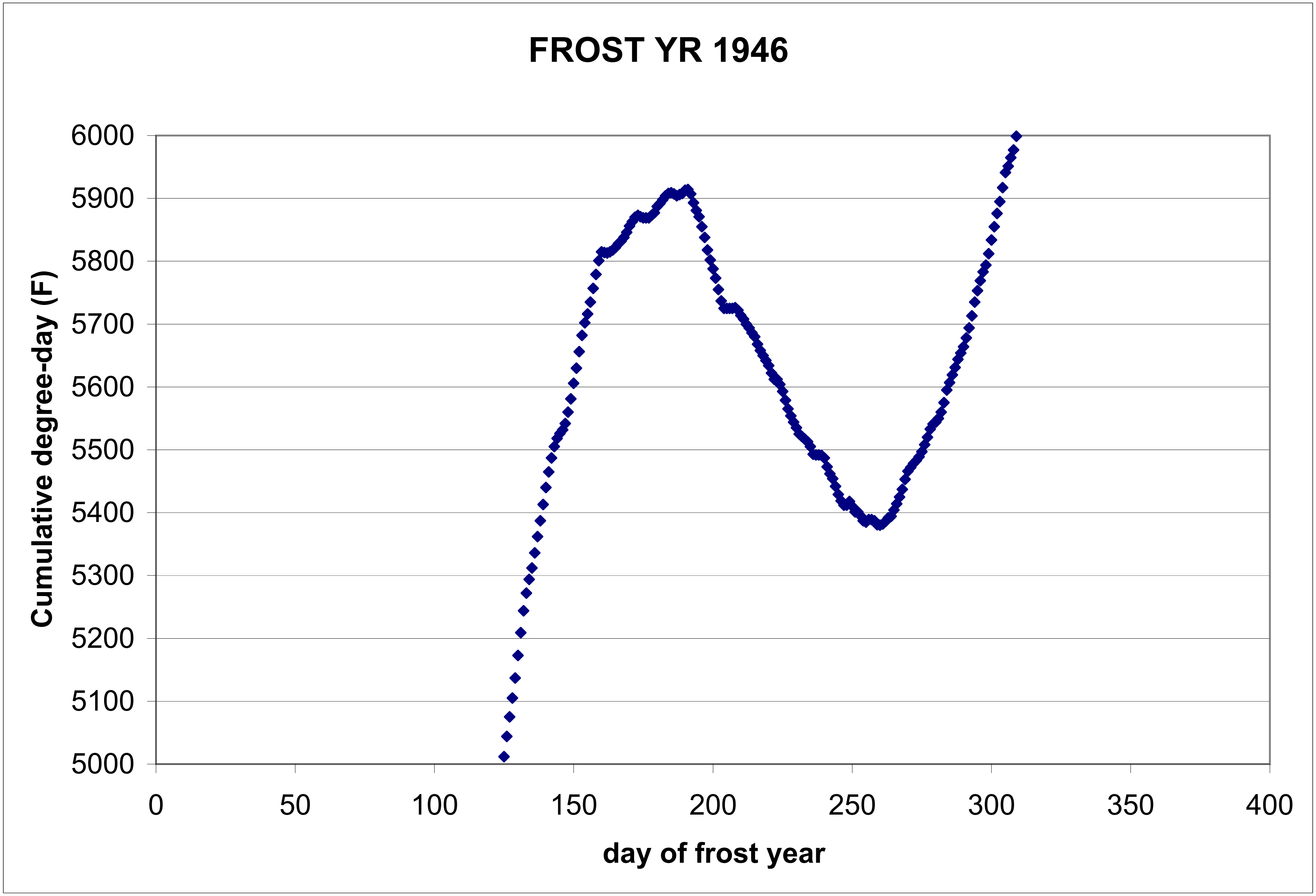

FROST YR 1956
Cumulative degree-day (F)
5700
5680
5660
5640
5620
5600
5580
5560
5540
5520
5500
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1955
Cumulative degree-day (F)
6400
6300
6200
6100
6000
5900
5800
5700
5600
5500
5400
0
50
100
150
200
250
300
350
400
day of frost year

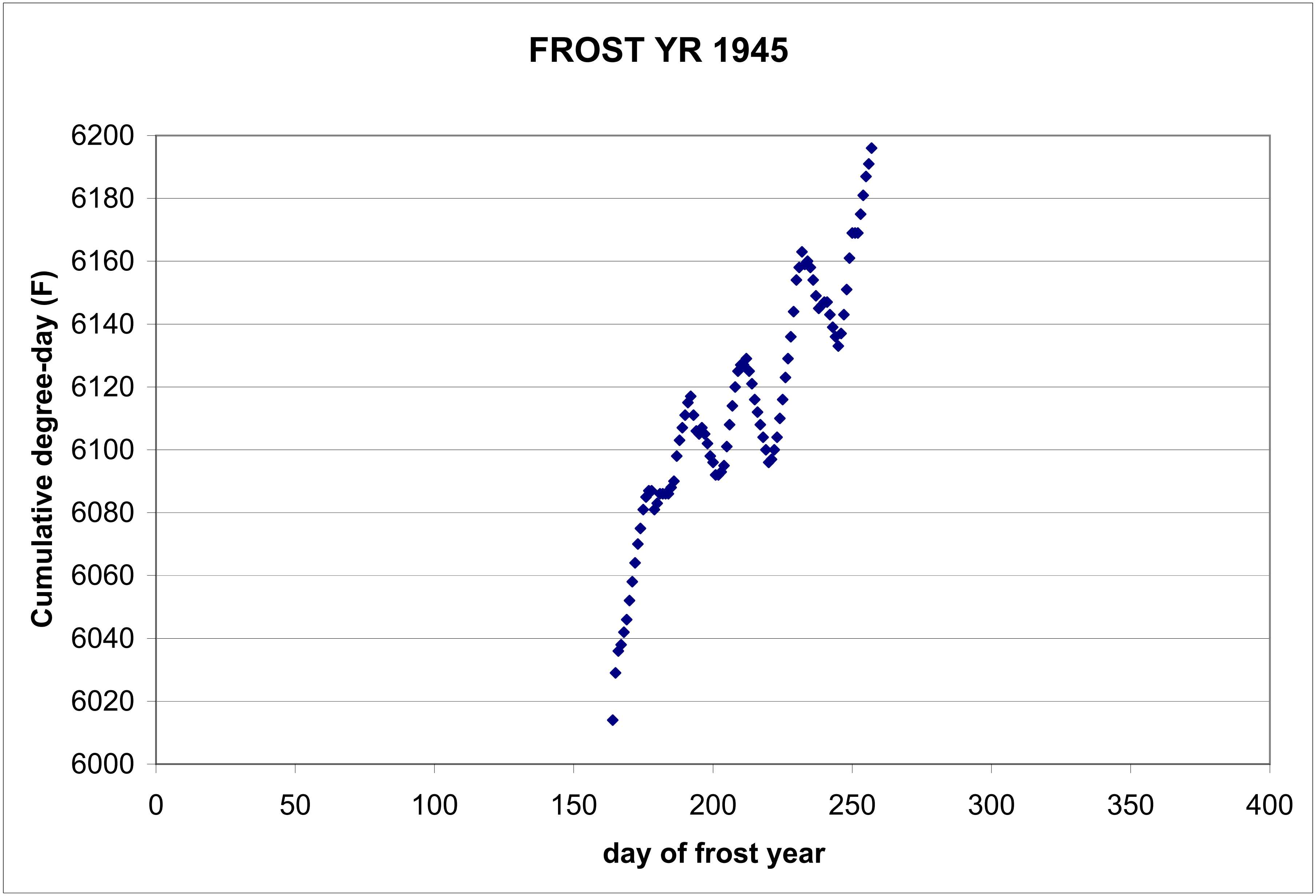

FROST YR 1954
Cumulative degree-day (F)
6000
5900
5800
5700
5600
5500
5400
5300
5200
5100
5000
0
50
100
150
200
250
300
350
400
day of frost year

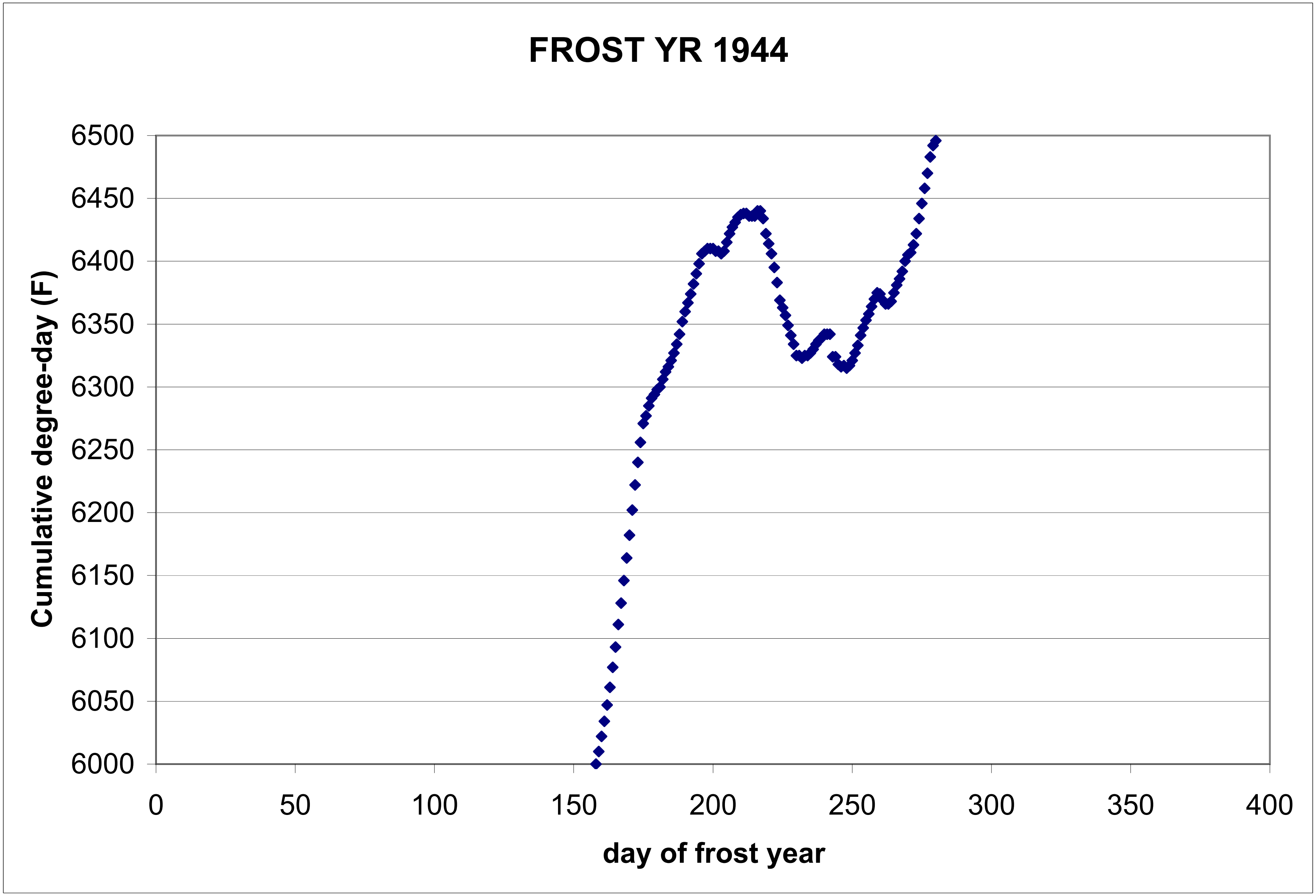


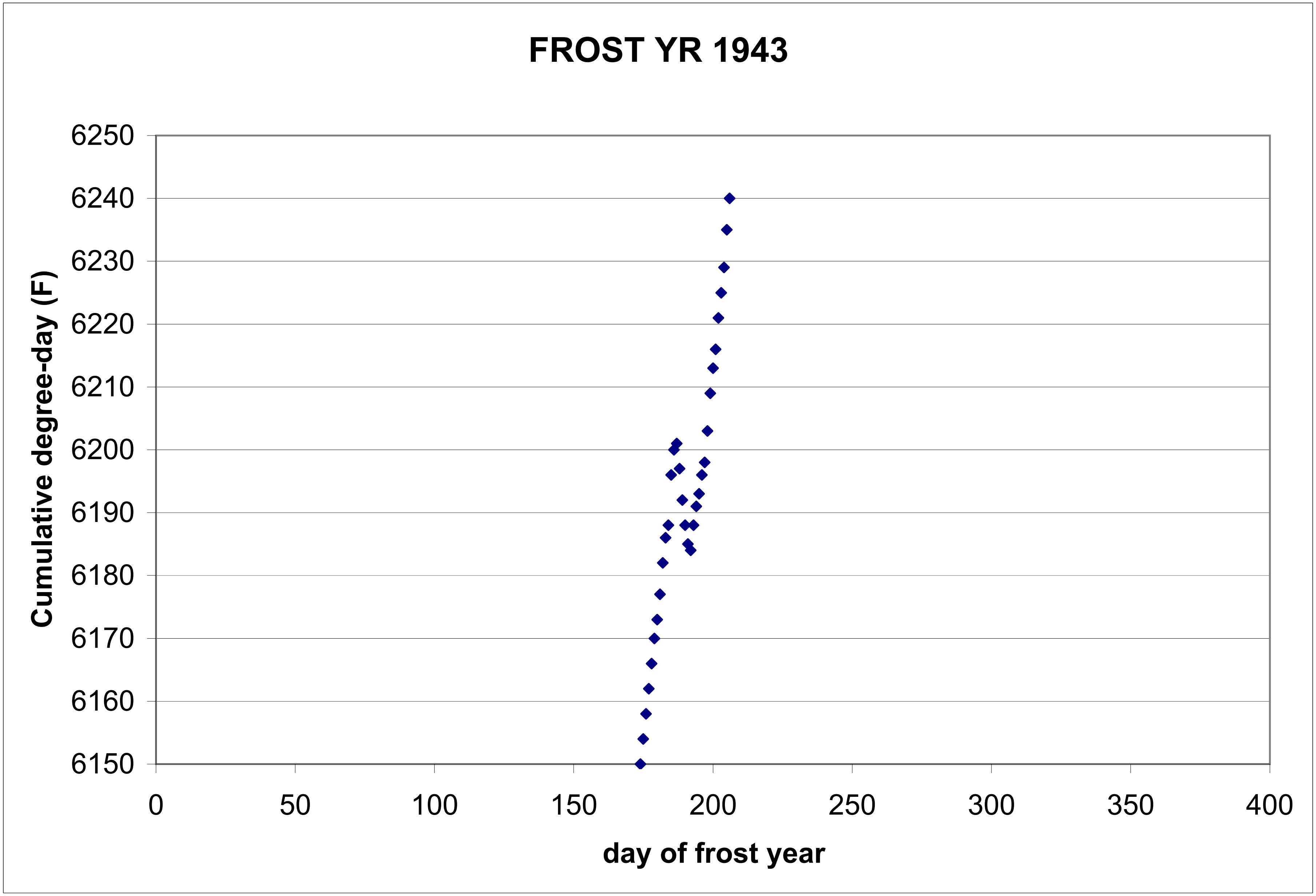
FROST YR 1950

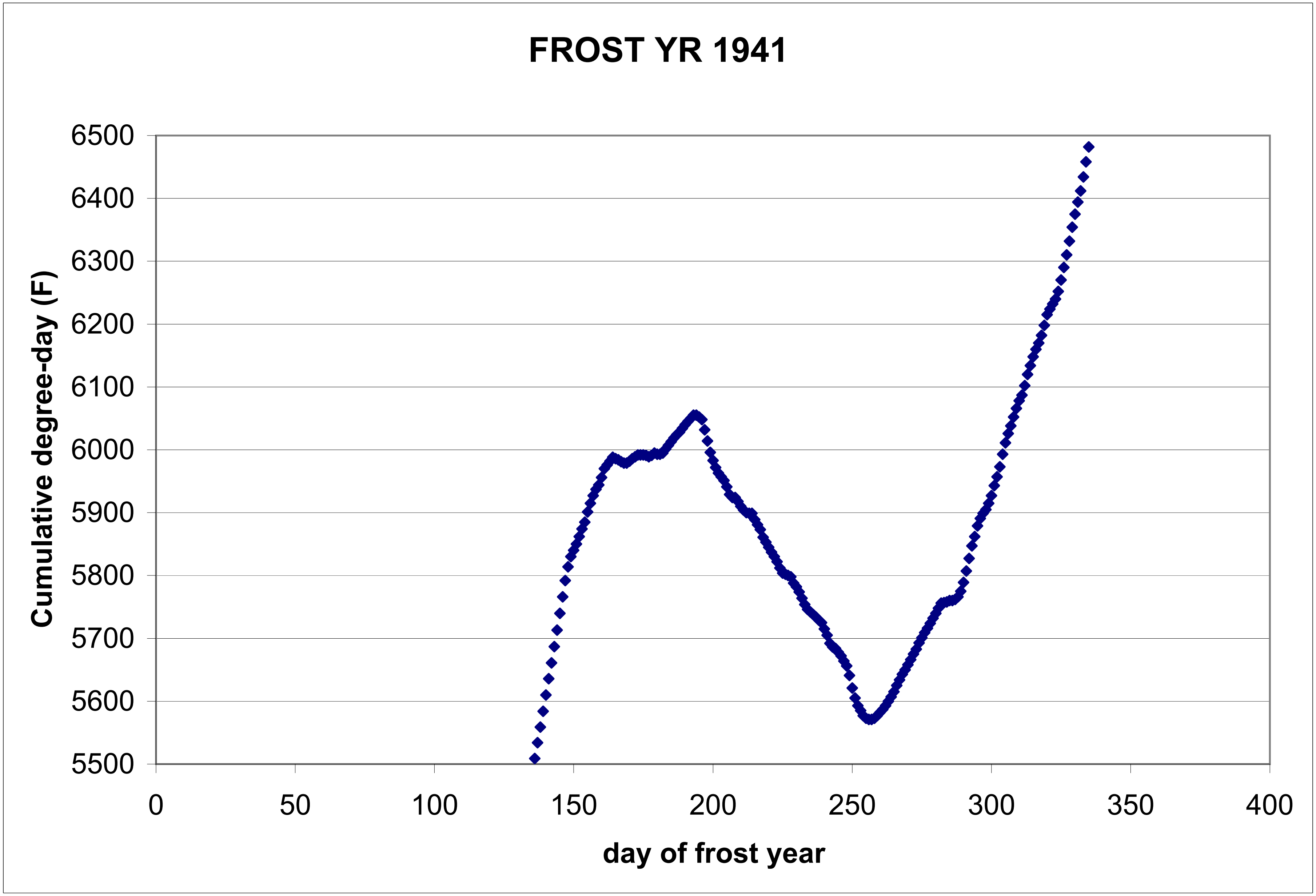


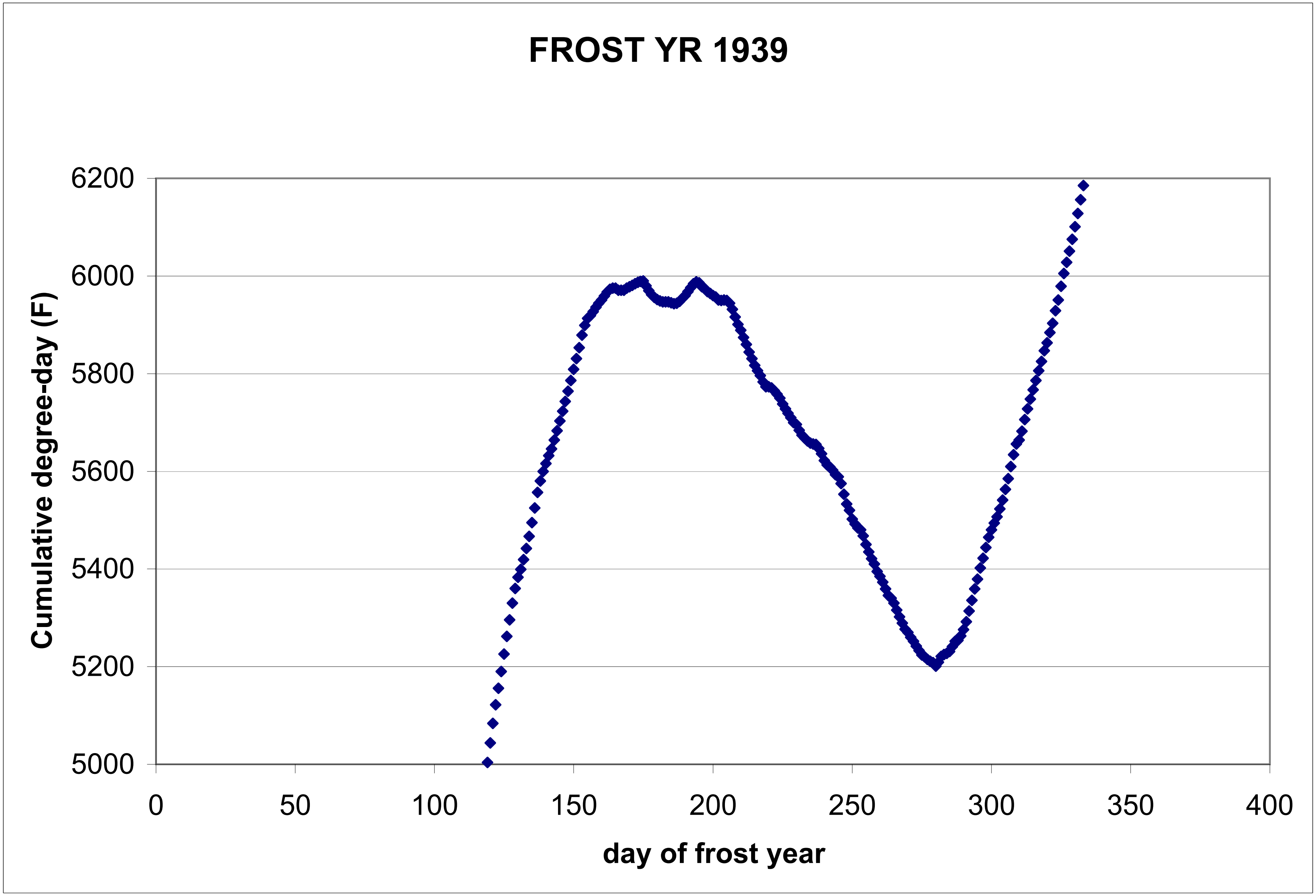
FROST YR 1946
Cumulative degree-day (F)
6000
5900
5800
5700
5600
5500
5400
5300
5200
5100
5000
0
50
100
150
200
250
300
350
400
day of frost year

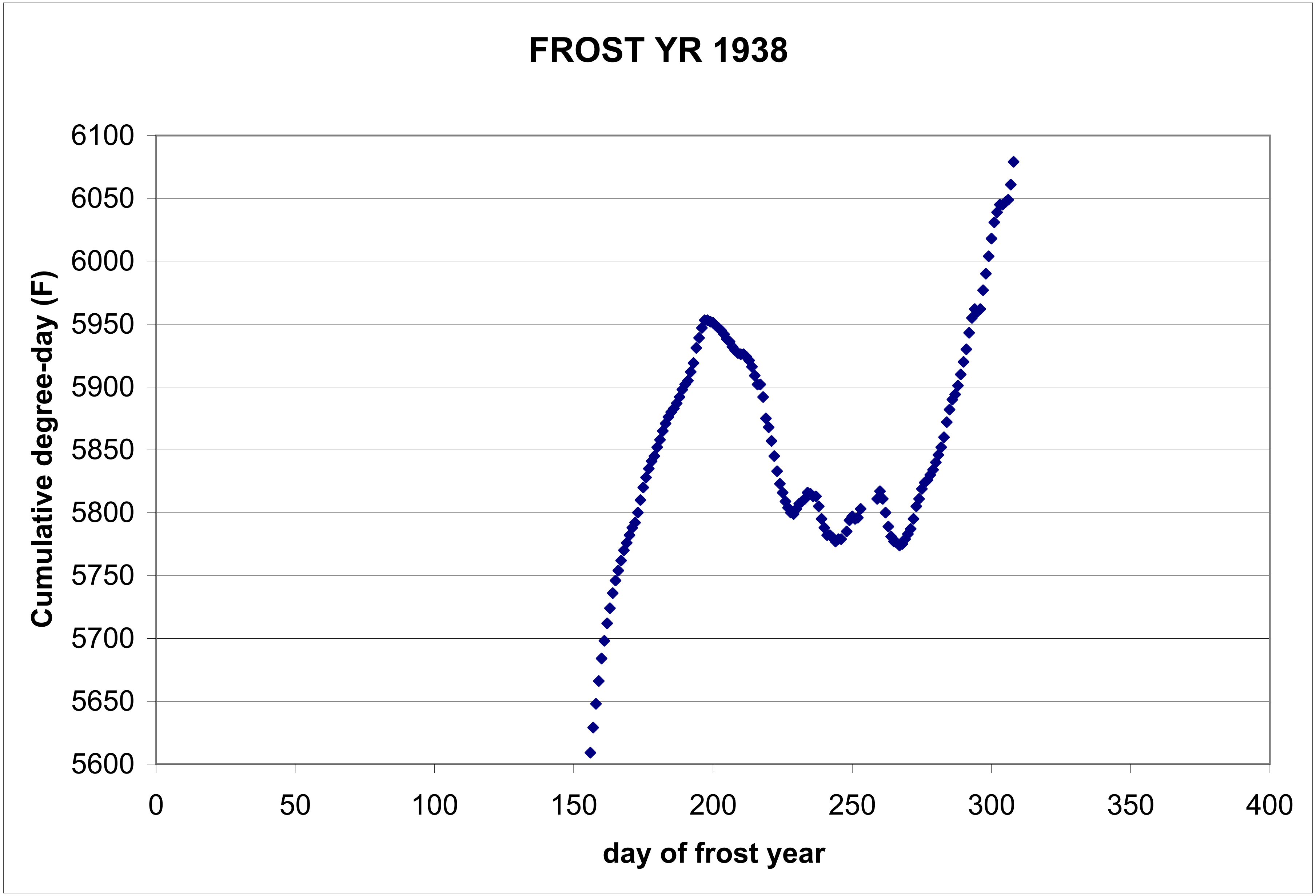

FROST YR 1945
Cumulative degree-day (F)
6200
6180
6160
6140
6120
6100
6080
6060
6040
6020
6000
0
50
100
150
200
250
300
350
400
day of frost year

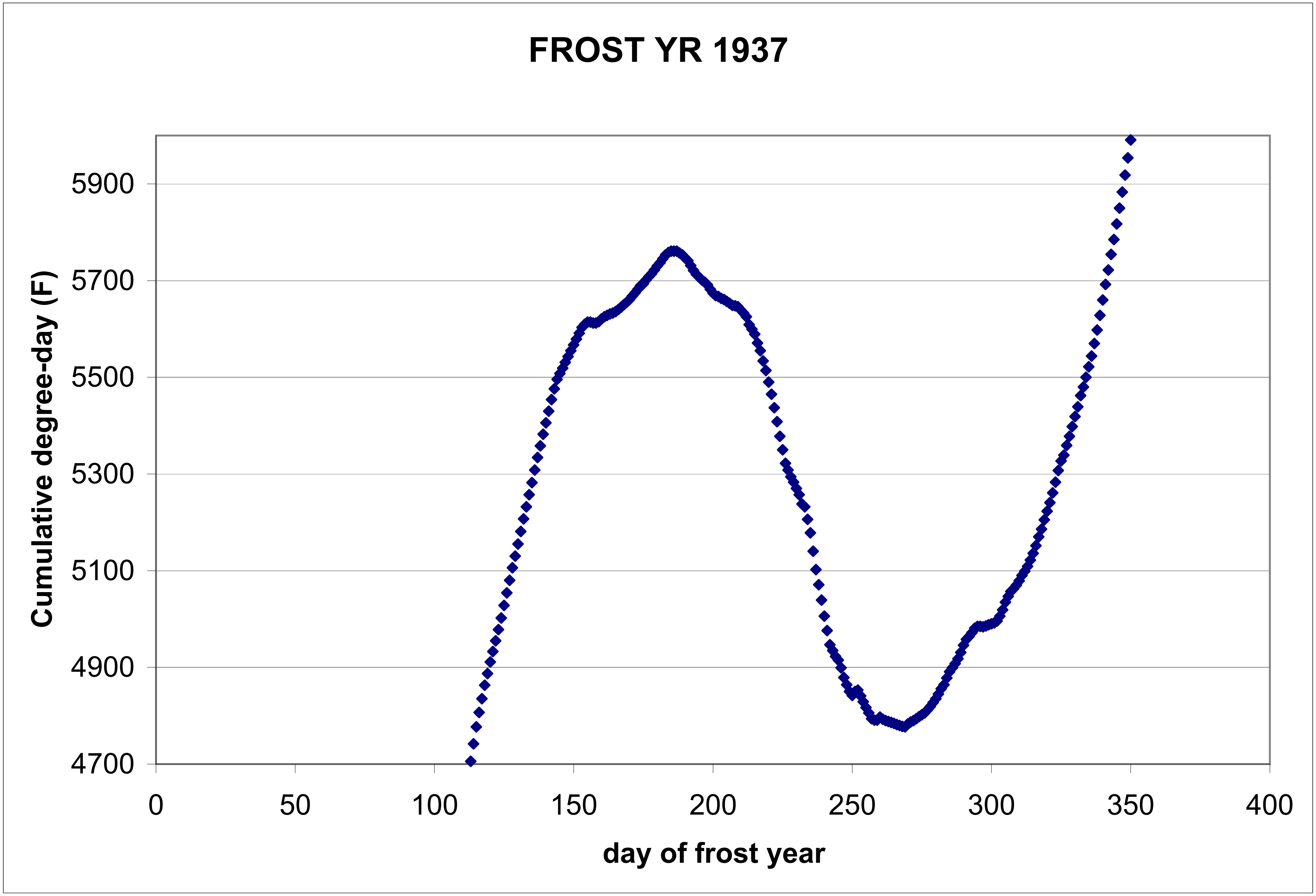

FROST YR 1944
Cumulative degree-day (F)
6500
6450
6400
6350
6300
6250
6200
6150
6100
6050
6000
0
50
100
150
200
250
300
350
400
day of frost year

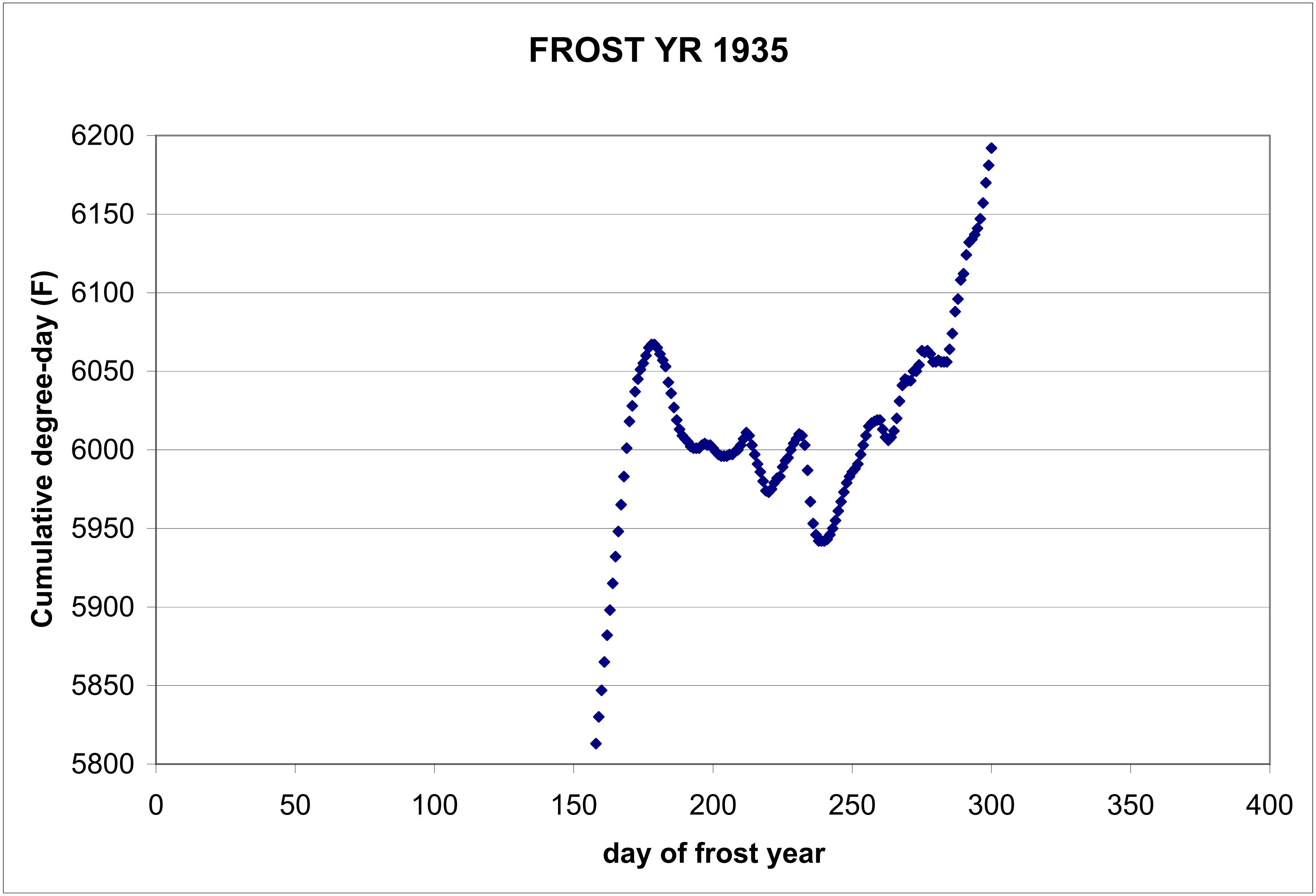

FROST YR 1943
Cumulative degree-day (F)
6250
6240
6230
6220
6210
6200
6190
6180
6170
6160
6150
0
50
100
150
200
250
300
350
400
day of frost year

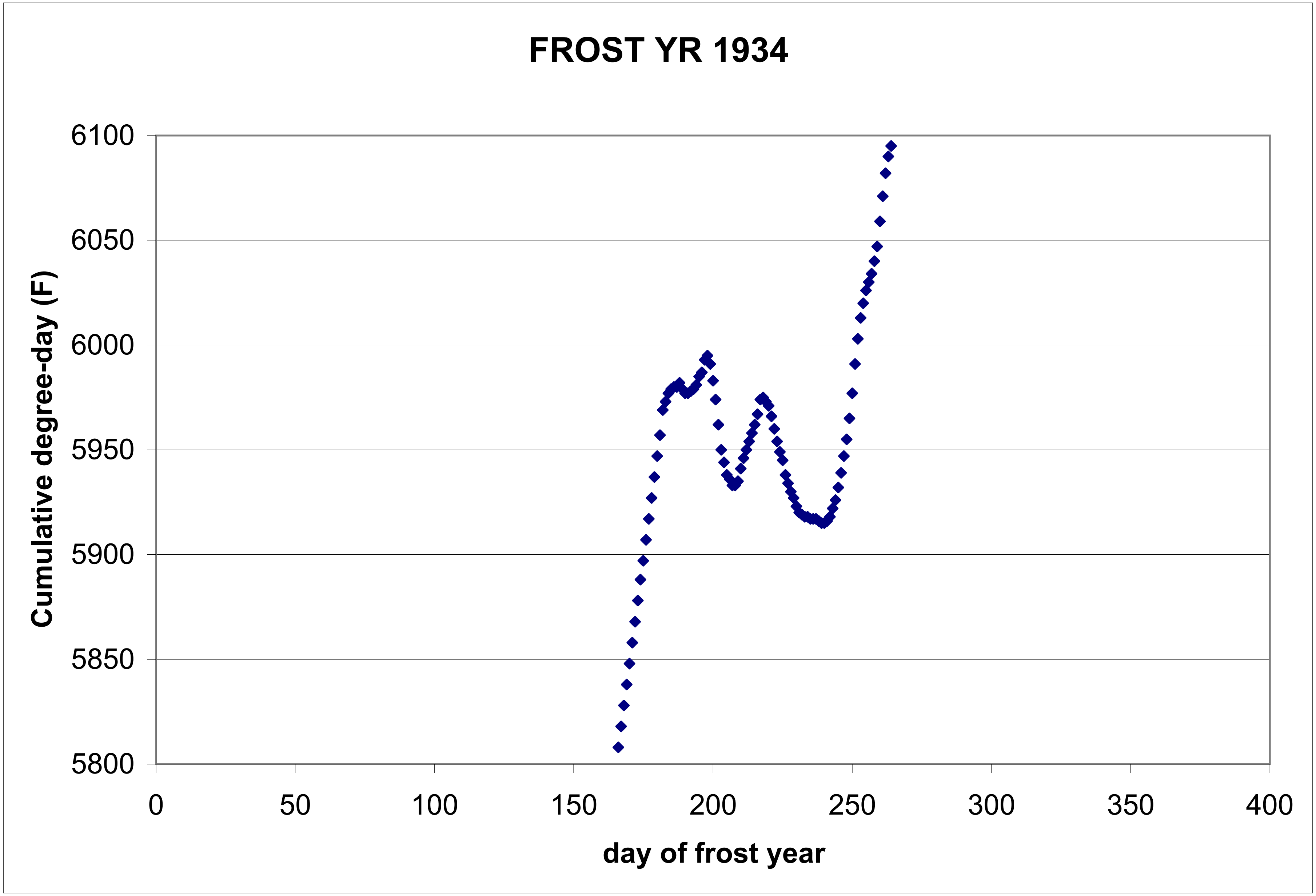

FROST YR 1941
Cumulative degree-day (F)
6500
6400
6300
6200
6100
6000
5900
5800
5700
5600
5500
0
50
100
150
200
250
300
350
400
day of frost year

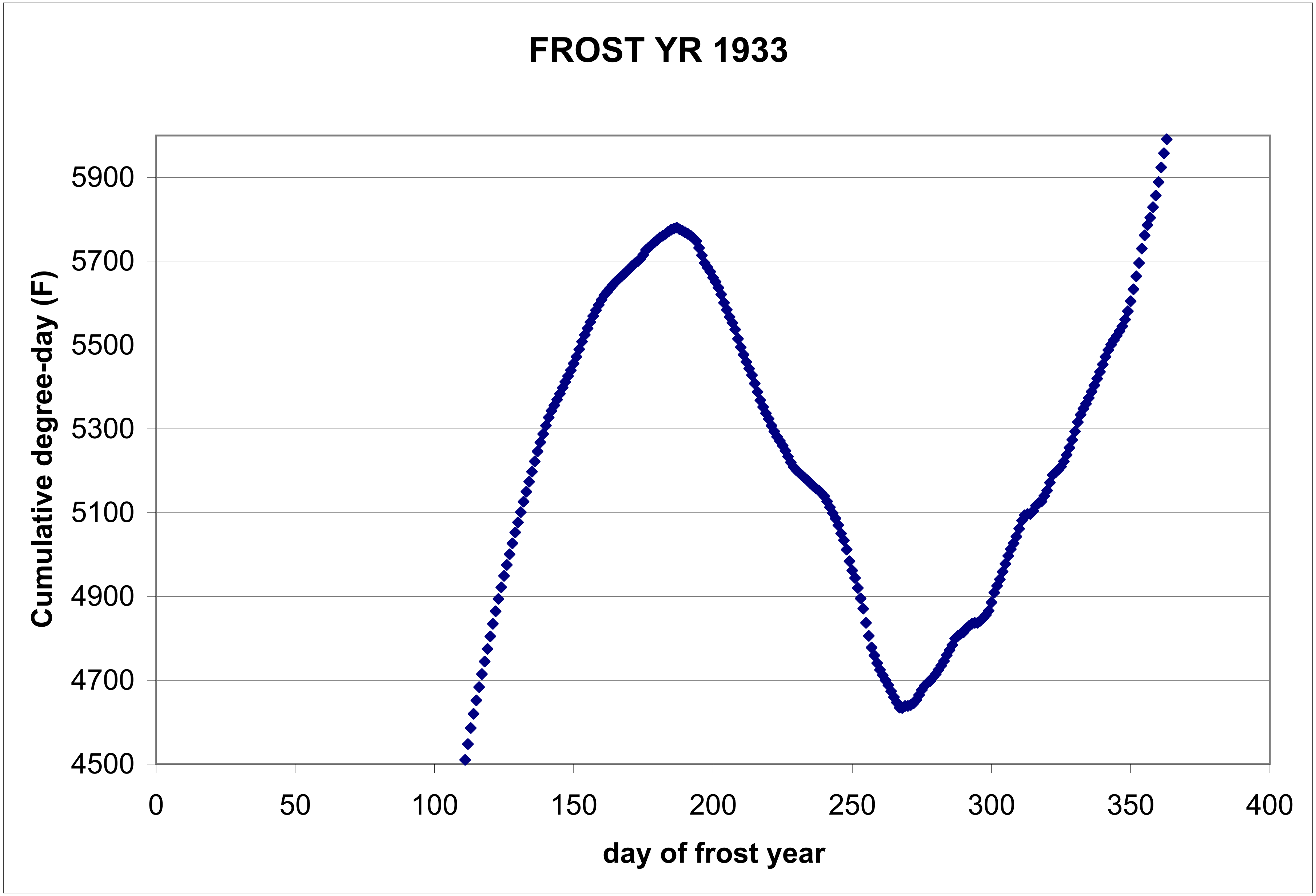

FROST YR 1939
Cumulative degree-day (F)
6200
6000
5800
5600
5400
5200
5000
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1938
Cumulative degree-day (F)
6100
6050
6000
5950
5900
5850
5800
5750
5700
5650
5600
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1937
Cumulative degree-day (F)
5900
5700
5500
5300
5100
4900
4700
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1935
Cumulative degree-day (F)
6200
6150
6100
6050
6000
5950
5900
5850
5800
0
50
100
150
200
250
300
350
400
day of frost year

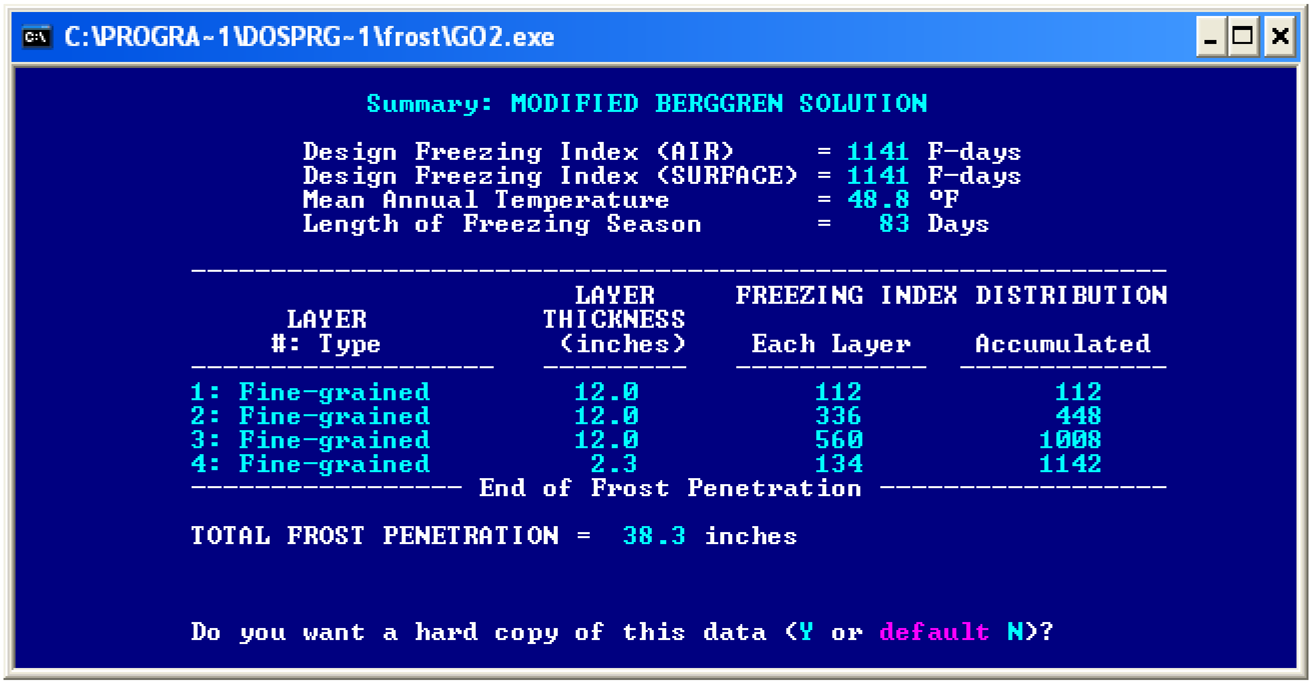

FROST YR 1934
Cumulative degree-day (F)
6100
6050
6000
5950
5900
5850
5800
0
50
100
150
200
250
300
350
400
day of frost year


FROST YR 1933
Cumulative degree-day (F)
5900
5700
5500
5300
5100
4900
4700
4500
0
50
100
150
200
250
300
350
400
day of frost year

APPENDIX B

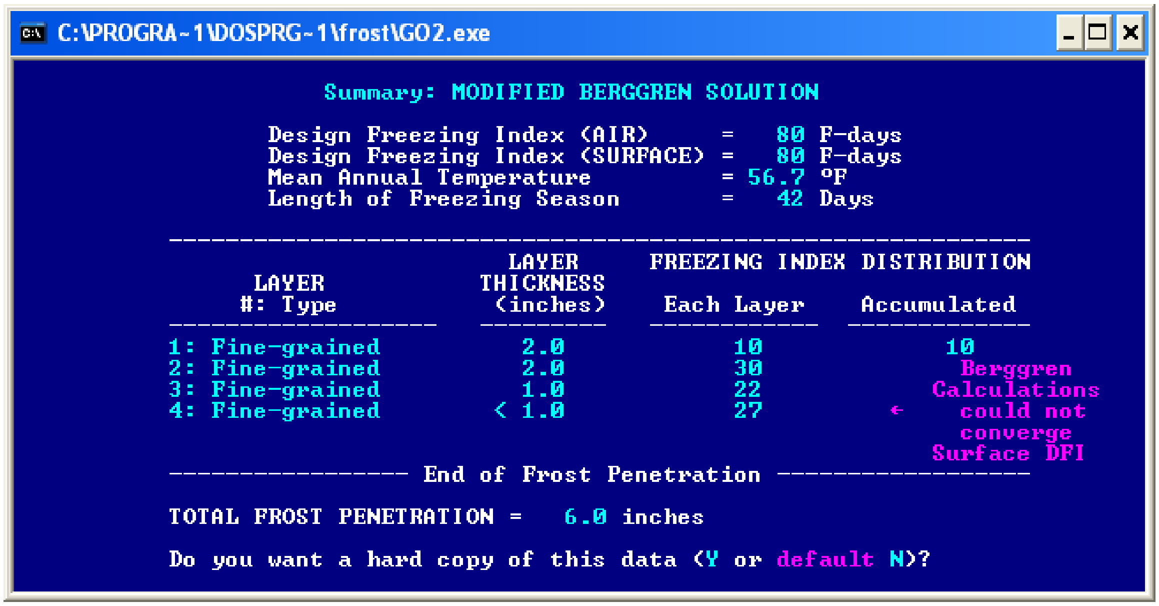
MBF COMPUTER OUTPUT

1933



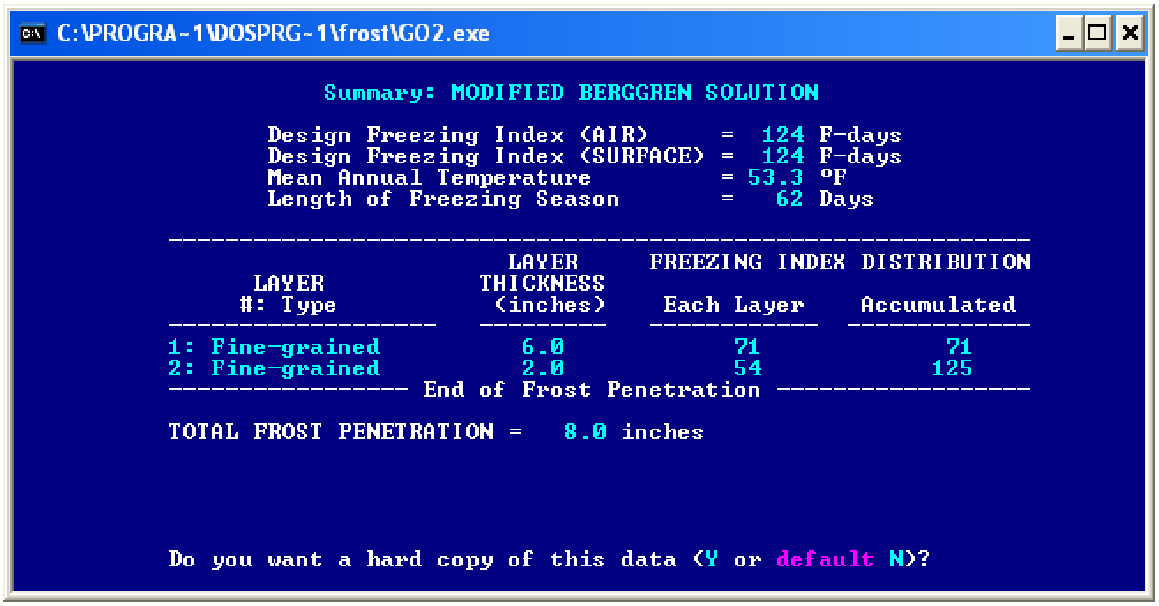
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)     = 1141 F-days
             Design Freezing Index (SURFACE) = 1141 F-days
             Mean Annual Temperature         = 48.8 ºF
             Length of Freezing Season       =   83 Days

      -------------------------------------------------------------
                                 LAYER     FREEZING INDEX DISTRIBUTION
            LAYER              THICKNESS
           #: Type              (inches)    Each Layer    Accumulated
      -------------------      ---------   ------------  -------------
      1: Fine-grained            12.0          112            112
      2: Fine-grained            12.0          336            448
      3: Fine-grained            12.0          560           1008
      4: Fine-grained             2.3          134           1142
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =  38.3 inches


      Do you want a hard copy of this data (Y or default N)?
```

1934



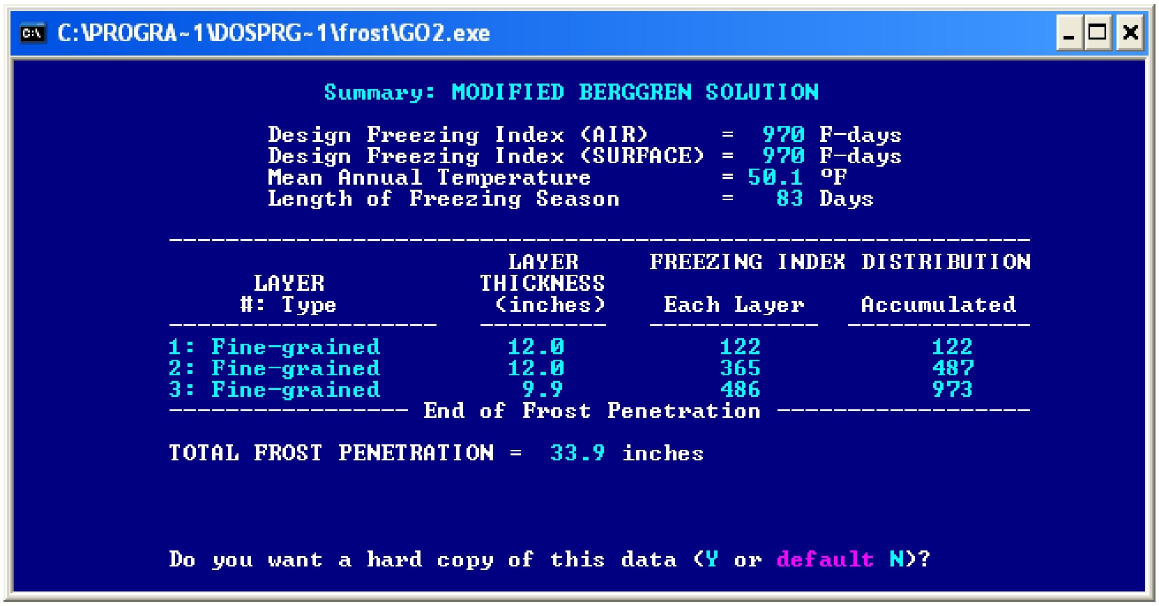
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)     =   80 F-days
             Design Freezing Index (SURFACE) =   80 F-days
             Mean Annual Temperature         = 56.7 ºF
             Length of Freezing Season       =   42 Days

      -------------------------------------------------------------
                                 LAYER     FREEZING INDEX DISTRIBUTION
            LAYER              THICKNESS
           #: Type              (inches)    Each Layer    Accumulated
      -------------------      ---------   ------------  -------------
      1: Fine-grained             2.0          10             10
      2: Fine-grained             2.0          30              Berggren
      3: Fine-grained             1.0          22            Calculations
      4: Fine-grained           < 1.0          27         ←    could not
                                                               converge
                                                             Surface DFI
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =   6.0 inches

      Do you want a hard copy of this data (Y or default N)?
```

1935



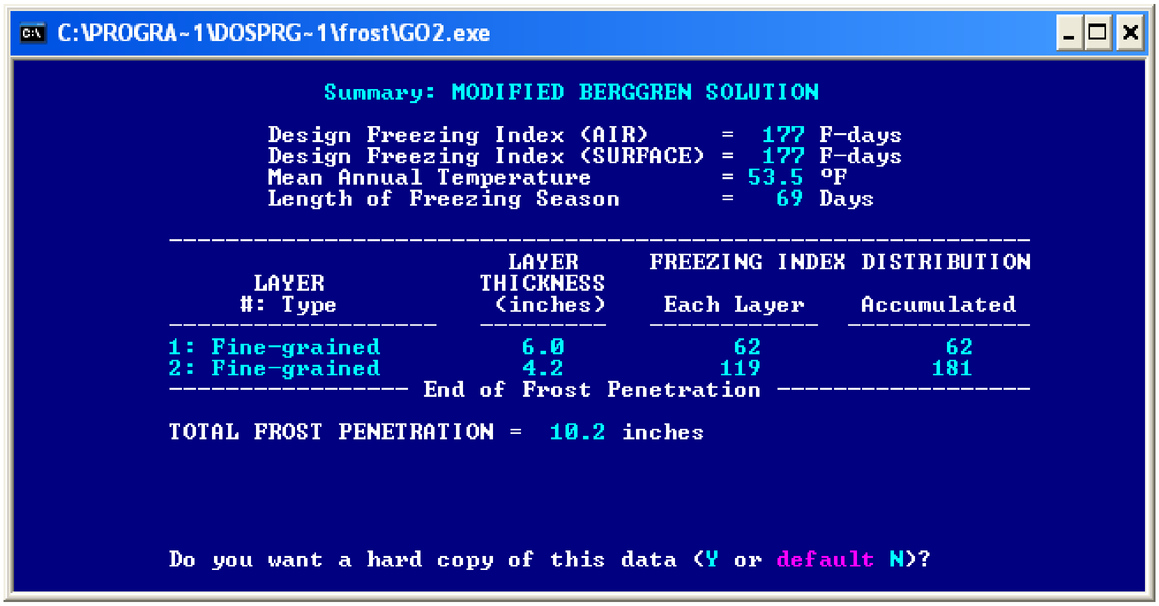
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      =  124 F-days
             Design Freezing Index (SURFACE) =  124 F-days
             Mean Annual Temperature         = 53.3 ºF
             Length of Freezing Season       =   62 Days

      -------------------------------------------------------------
                             LAYER     FREEZING INDEX DISTRIBUTION
            LAYER          THICKNESS
           #: Type          (inches)    Each Layer    Accumulated
      -------------------  ---------   ------------  -------------
      1: Fine-grained          6.0          71             71
      2: Fine-grained          2.0          54            125
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =    8.0 inches



      Do you want a hard copy of this data (Y or default N)?
```

1937



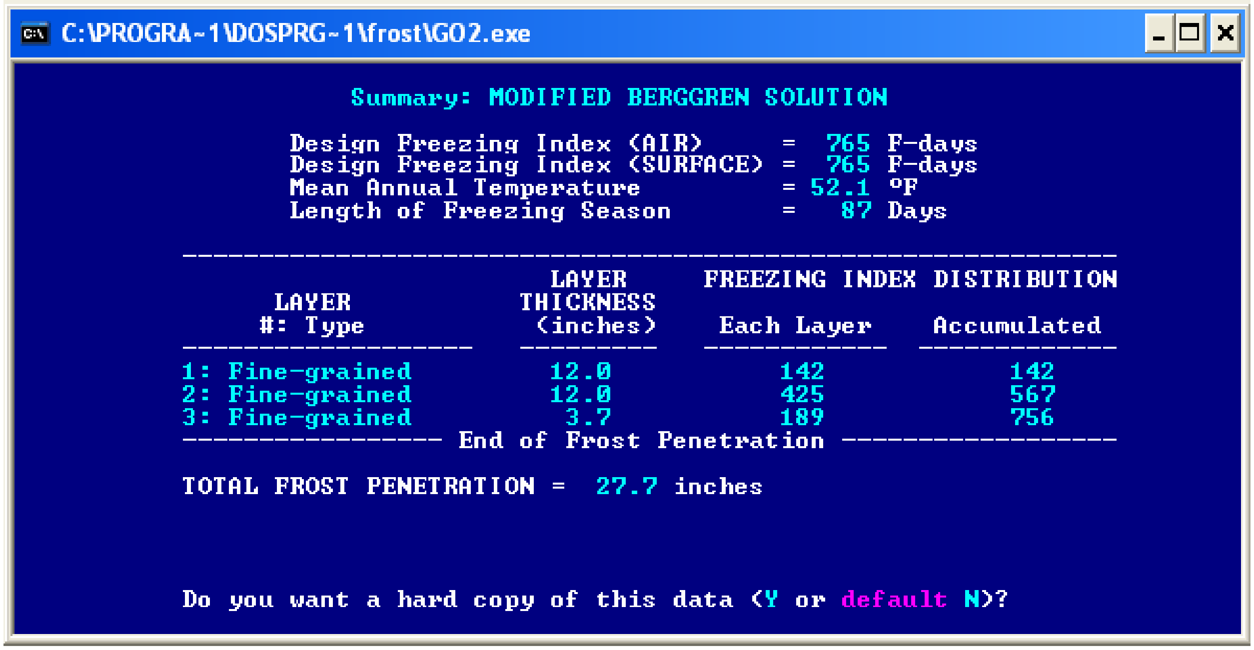
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      =  970 F-days
             Design Freezing Index (SURFACE) =  970 F-days
             Mean Annual Temperature         = 50.1 ºF
             Length of Freezing Season       =   83 Days

      -------------------------------------------------------------
                             LAYER     FREEZING INDEX DISTRIBUTION
            LAYER          THICKNESS
           #: Type          (inches)    Each Layer    Accumulated
      -------------------  ---------   ------------  -------------
      1: Fine-grained         12.0         122            122
      2: Fine-grained         12.0         365            487
      3: Fine-grained          9.9         486            973
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =   33.9 inches



      Do you want a hard copy of this data (Y or default N)?
```

1938



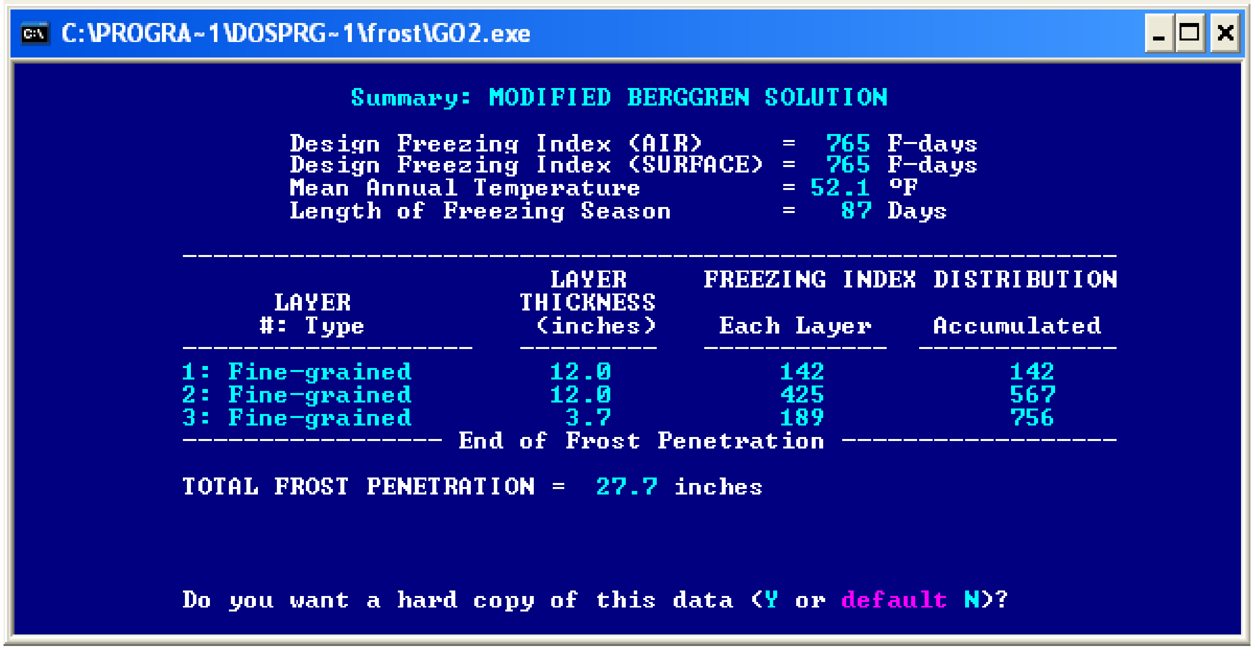
```
                  Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)      =  177 F-days
              Design Freezing Index (SURFACE) =  177 F-days
              Mean Annual Temperature          = 53.5 °F
              Length of Freezing Season        =   69 Days

     -------------------------------------------------------------
                               LAYER     FREEZING INDEX DISTRIBUTION
           LAYER             THICKNESS
          #: Type             (inches)     Each Layer    Accumulated
     -------------------    ---------    ------------  -------------
     1: Fine-grained           6.0           62              62
     2: Fine-grained           4.2          119             181
     ----------------- End of Frost Penetration ------------------

     TOTAL FROST PENETRATION =  10.2 inches



     Do you want a hard copy of this data (Y or default N)?
```

1939



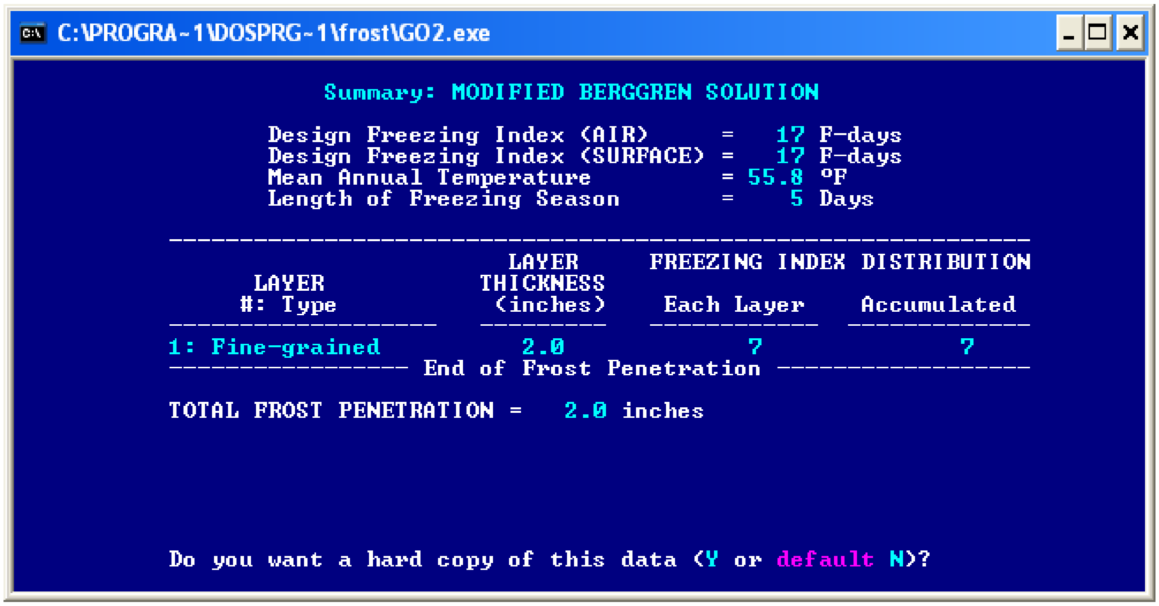
```
                Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      =  765 F-days
            Design Freezing Index (SURFACE) =  765 F-days
            Mean Annual Temperature          = 52.1 °F
            Length of Freezing Season        =   87 Days

     -------------------------------------------------------------
                               LAYER     FREEZING INDEX DISTRIBUTION
           LAYER             THICKNESS
          #: Type             (inches)     Each Layer     Accumulated
     -------------------   ---------   ------------   -------------
     1: Fine-grained          12.0          142              142
     2: Fine-grained          12.0          425              567
     3: Fine-grained           3.7          189              756
     ----------------- End of Frost Penetration ------------------

     TOTAL FROST PENETRATION =  27.7 inches



     Do you want a hard copy of this data (Y or default N)?
```

1941



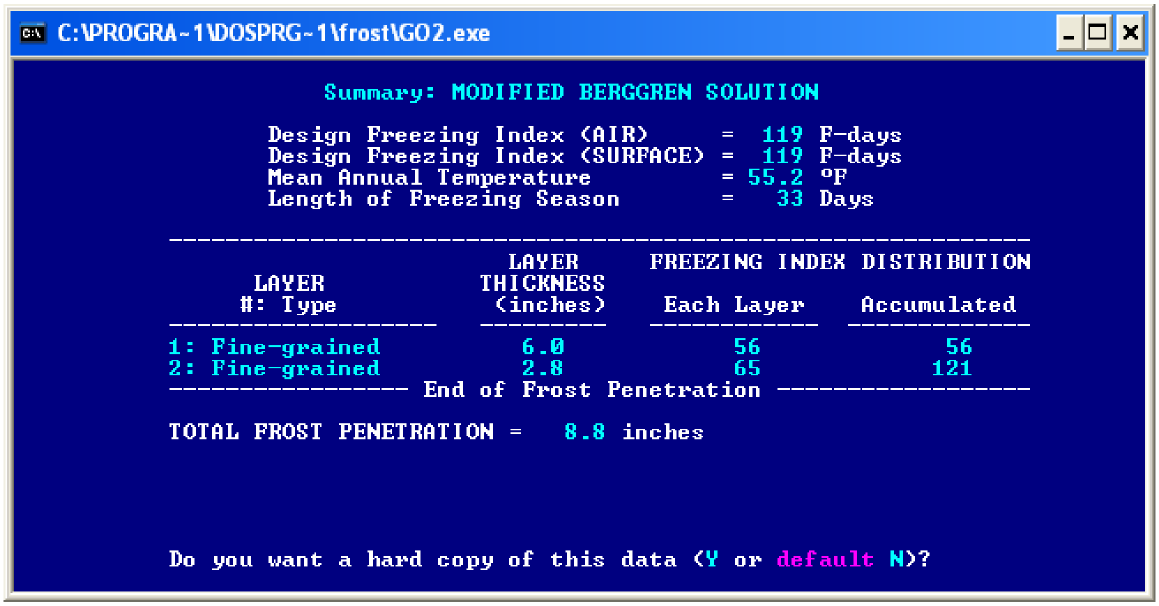
```
                Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      =  765 F-days
            Design Freezing Index (SURFACE) =  765 F-days
            Mean Annual Temperature          = 52.1 °F
            Length of Freezing Season        =   87 Days

     -------------------------------------------------------------
                               LAYER     FREEZING INDEX DISTRIBUTION
           LAYER             THICKNESS
          #: Type             (inches)     Each Layer     Accumulated
     -------------------   ---------   ------------   -------------
     1: Fine-grained          12.0          142              142
     2: Fine-grained          12.0          425              567
     3: Fine-grained           3.7          189              756
     ----------------- End of Frost Penetration ------------------

     TOTAL FROST PENETRATION =  27.7 inches



     Do you want a hard copy of this data (Y or default N)?
```

1943



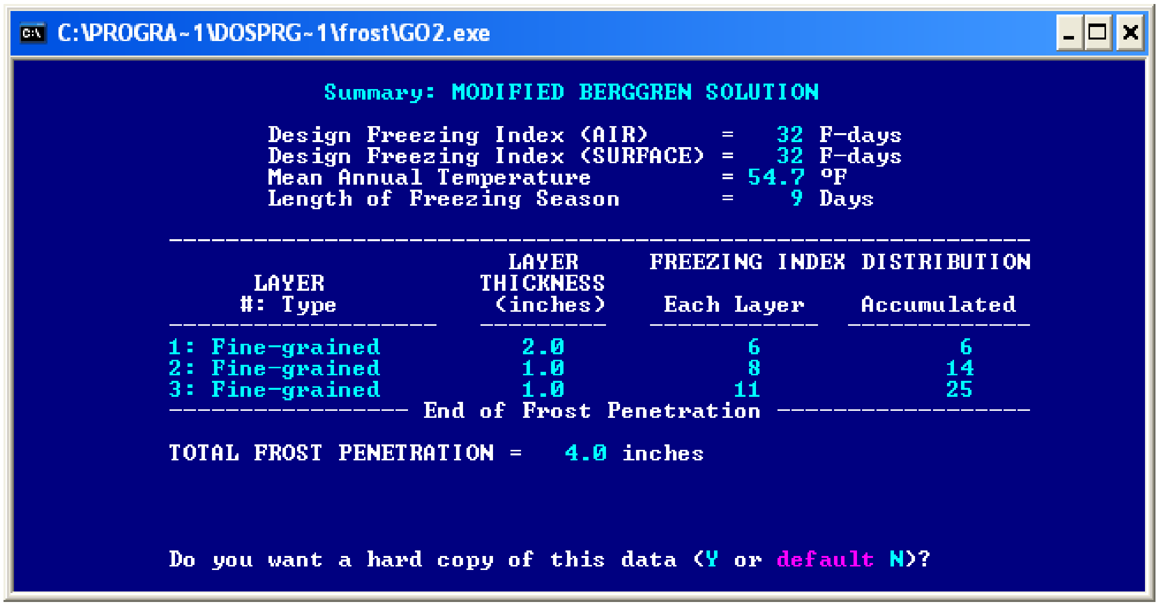
```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =   17 F-days
                Design Freezing Index (SURFACE) =   17 F-days
                Mean Annual Temperature          = 55.8 ºF
                Length of Freezing Season        =    5 Days

           -------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER           THICKNESS
                #: Type           (inches)    Each Layer    Accumulated
           -------------------   ---------   ------------  -------------
           1: Fine-grained          2.0            7              7
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =    2.0 inches




           Do you want a hard copy of this data (Y or default N)?
```

1944



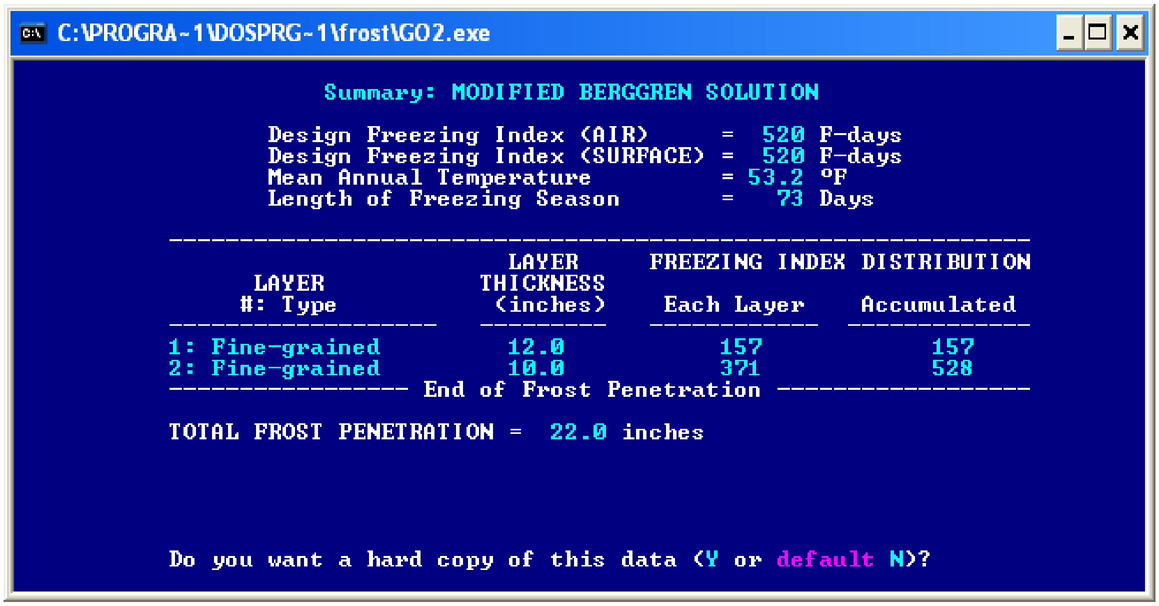
```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =  119 F-days
                Design Freezing Index (SURFACE) =  119 F-days
                Mean Annual Temperature          = 55.2 ºF
                Length of Freezing Season        =   33 Days

           -------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER           THICKNESS
                #: Type           (inches)    Each Layer    Accumulated
           -------------------   ---------   ------------  -------------
           1: Fine-grained          6.0           56             56
           2: Fine-grained          2.8           65            121
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =    8.8 inches




           Do you want a hard copy of this data (Y or default N)?
```

1945



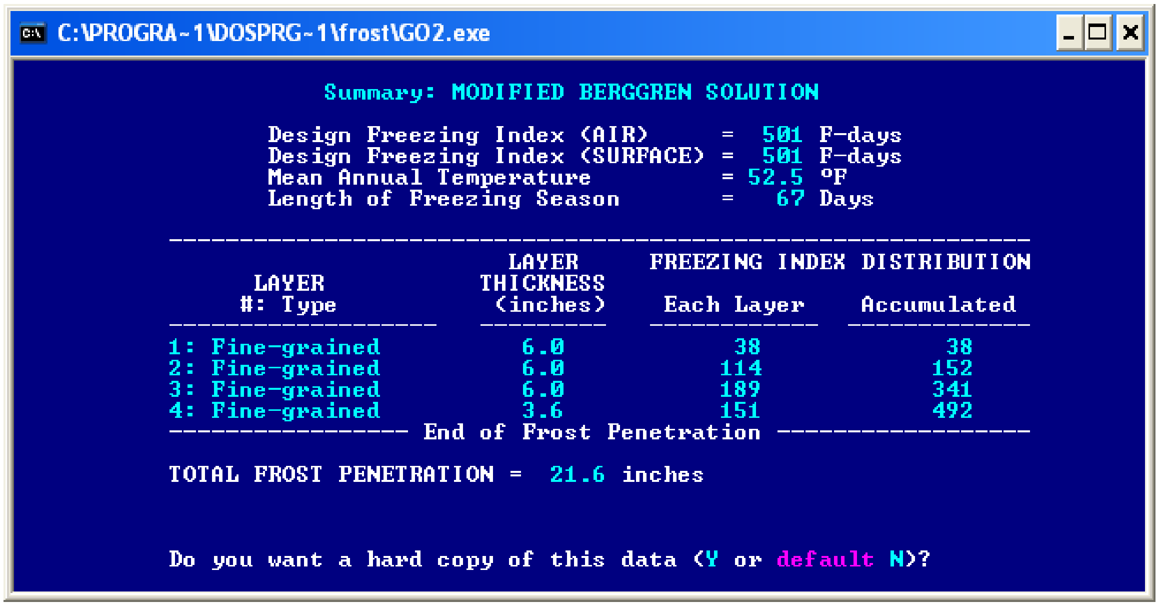
```
                  Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      =   32 F-days
             Design Freezing Index (SURFACE) =   32 F-days
             Mean Annual Temperature          = 54.7 °F
             Length of Freezing Season        =    9 Days

      -------------------------------------------------------------
                                LAYER      FREEZING INDEX DISTRIBUTION
            LAYER             THICKNESS
           #: Type             (inches)      Each Layer    Accumulated
      -------------------      ---------    ------------  -------------
      1: Fine-grained             2.0            6              6
      2: Fine-grained             1.0            8             14
      3: Fine-grained             1.0           11             25
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =    4.0 inches



      Do you want a hard copy of this data (Y or default N)?
```

1946



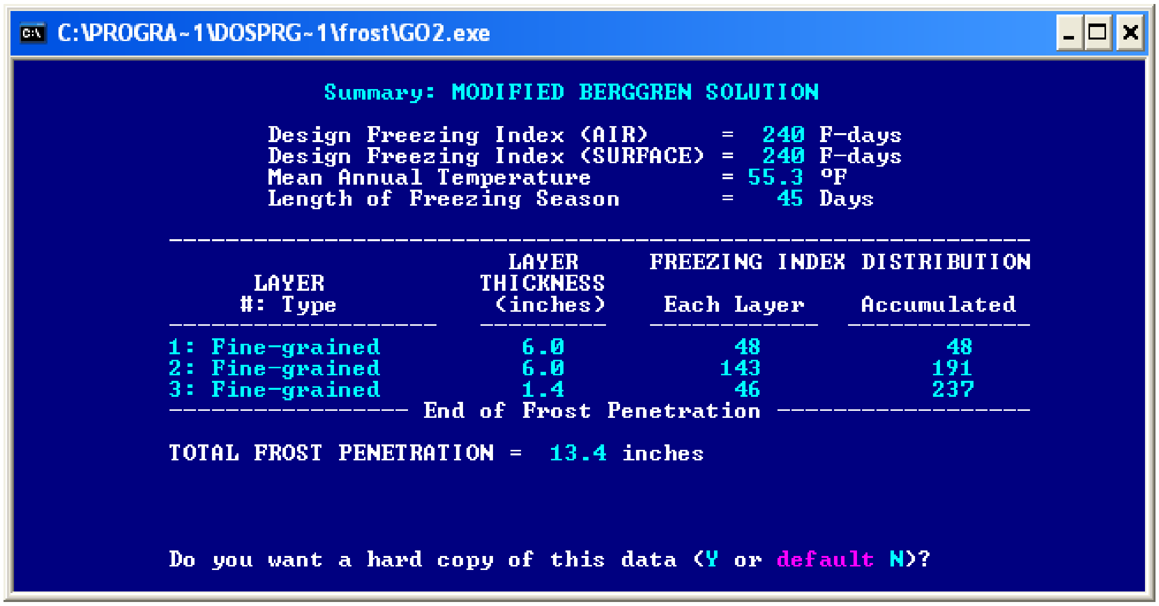
```
                  Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      =  520 F-days
             Design Freezing Index (SURFACE) =  520 F-days
             Mean Annual Temperature          = 53.2 °F
             Length of Freezing Season        =   73 Days

      -------------------------------------------------------------
                                LAYER      FREEZING INDEX DISTRIBUTION
            LAYER             THICKNESS
           #: Type             (inches)      Each Layer    Accumulated
      -------------------      ---------    ------------  -------------
      1: Fine-grained            12.0          157            157
      2: Fine-grained            10.0          371            528
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =   22.0 inches



      Do you want a hard copy of this data (Y or default N)?
```

1950



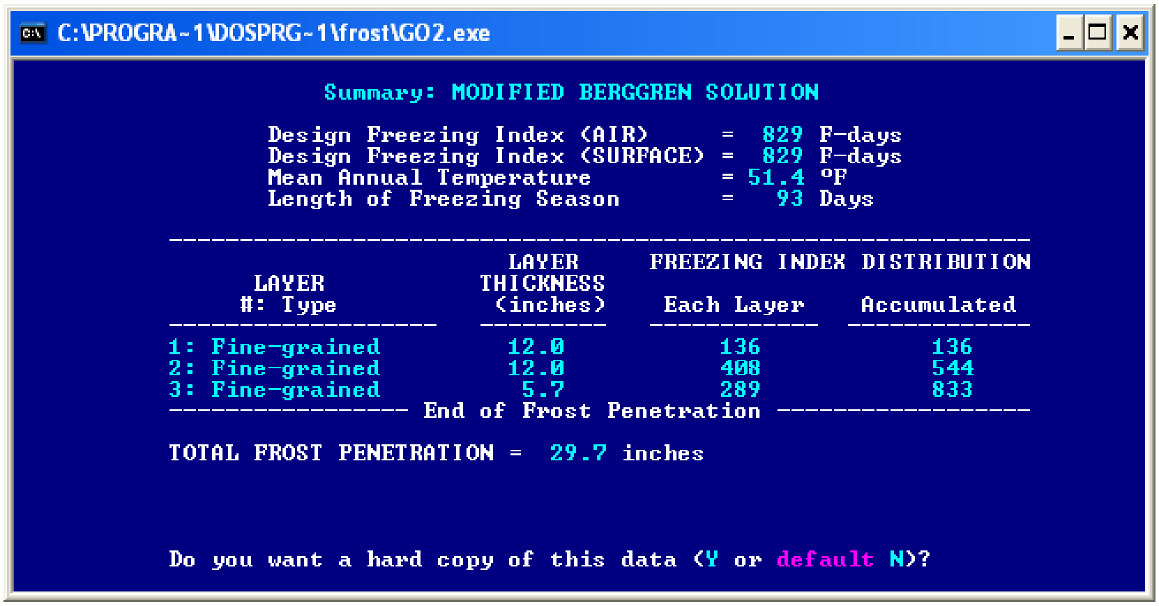
```
                  Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)      =  501 F-days
              Design Freezing Index (SURFACE) =  501 F-days
              Mean Annual Temperature          = 52.5 ºF
              Length of Freezing Season        =   67 Days

 -------------------------------------------------------------
                             LAYER      FREEZING INDEX DISTRIBUTION
       LAYER               THICKNESS
      #: Type               (inches)    Each Layer    Accumulated
 -------------------       ---------   ------------  -------------
 1: Fine-grained              6.0           38             38
 2: Fine-grained              6.0          114            152
 3: Fine-grained              6.0          189            341
 4: Fine-grained              3.6          151            492
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  21.6 inches


 Do you want a hard copy of this data (Y or default N)?
```

1954



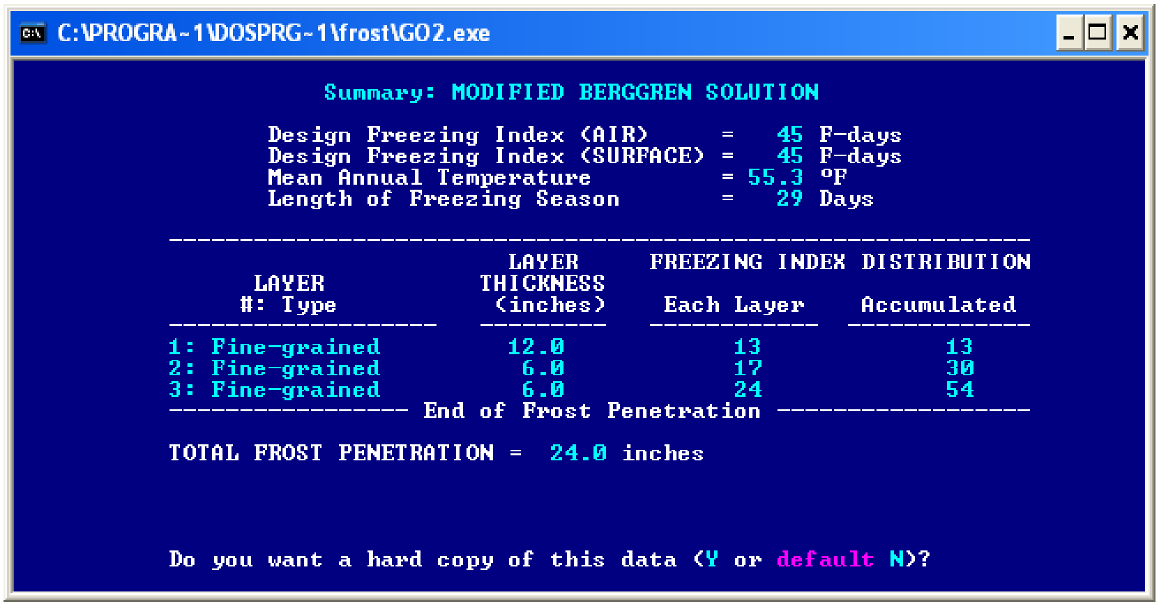
```
                  Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)      =  240 F-days
              Design Freezing Index (SURFACE) =  240 F-days
              Mean Annual Temperature          = 55.3 ºF
              Length of Freezing Season        =   45 Days

 -------------------------------------------------------------
                             LAYER      FREEZING INDEX DISTRIBUTION
       LAYER               THICKNESS
      #: Type               (inches)    Each Layer    Accumulated
 -------------------       ---------   ------------  -------------
 1: Fine-grained              6.0           48             48
 2: Fine-grained              6.0          143            191
 3: Fine-grained              1.4           46            237
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  13.4 inches



 Do you want a hard copy of this data (Y or default N)?
```

1955



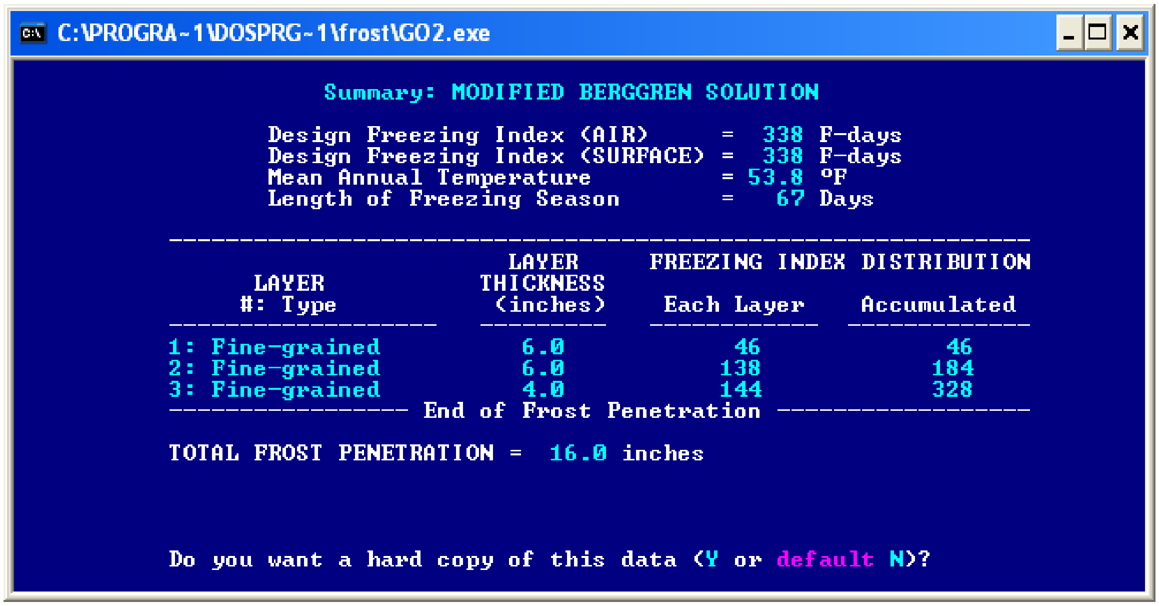
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)       =  829 F-days
       Design Freezing Index (SURFACE) =  829 F-days
       Mean Annual Temperature         = 51.4 °F
       Length of Freezing Season       =   93 Days

--------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer     Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0          136            136
2: Fine-grained         12.0          408            544
3: Fine-grained          5.7          289            833
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  29.7 inches



Do you want a hard copy of this data (Y or default N)?
```

1956



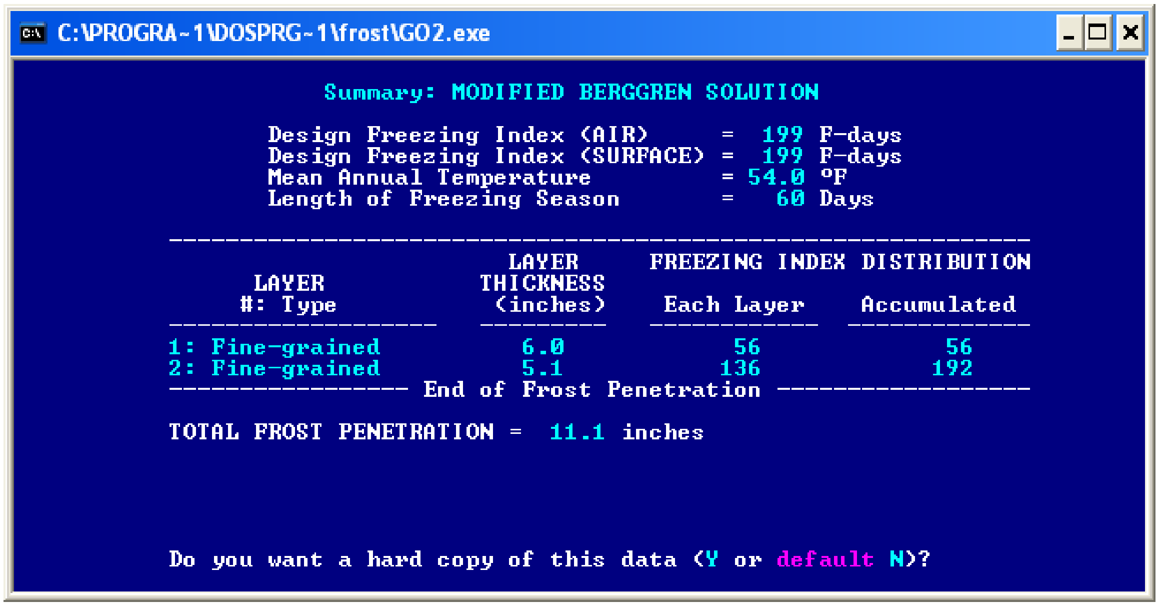
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)       =   45 F-days
       Design Freezing Index (SURFACE) =   45 F-days
       Mean Annual Temperature         = 55.3 °F
       Length of Freezing Season       =   29 Days

--------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer     Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           13             13
2: Fine-grained          6.0           17             30
3: Fine-grained          6.0           24             54
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  24.0 inches



Do you want a hard copy of this data (Y or default N)?
```

1960



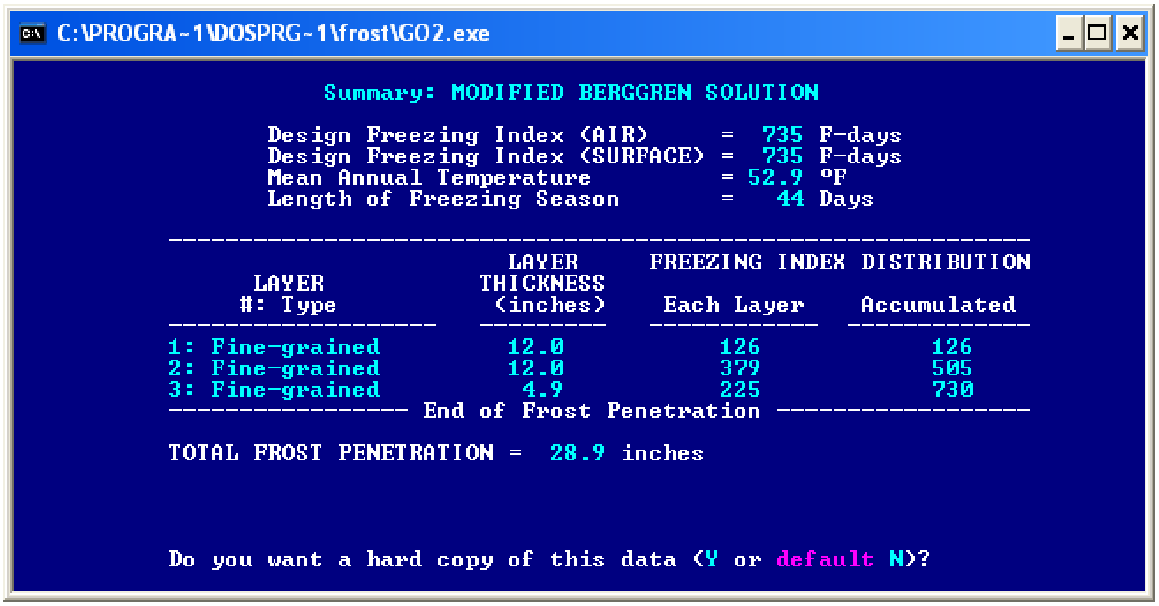
```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)     =  338 F-days
                Design Freezing Index (SURFACE) =  338 F-days
                Mean Annual Temperature         = 53.8 ºF
                Length of Freezing Season       =   67 Days

           -------------------------------------------------------------
                                      LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER              THICKNESS
                #: Type              (inches)    Each Layer    Accumulated
           -------------------     ---------   ------------  ------------
           1: Fine-grained            6.0          46             46
           2: Fine-grained            6.0         138            184
           3: Fine-grained            4.0         144            328
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  16.0 inches



           Do you want a hard copy of this data (Y or default N)?
```

1961



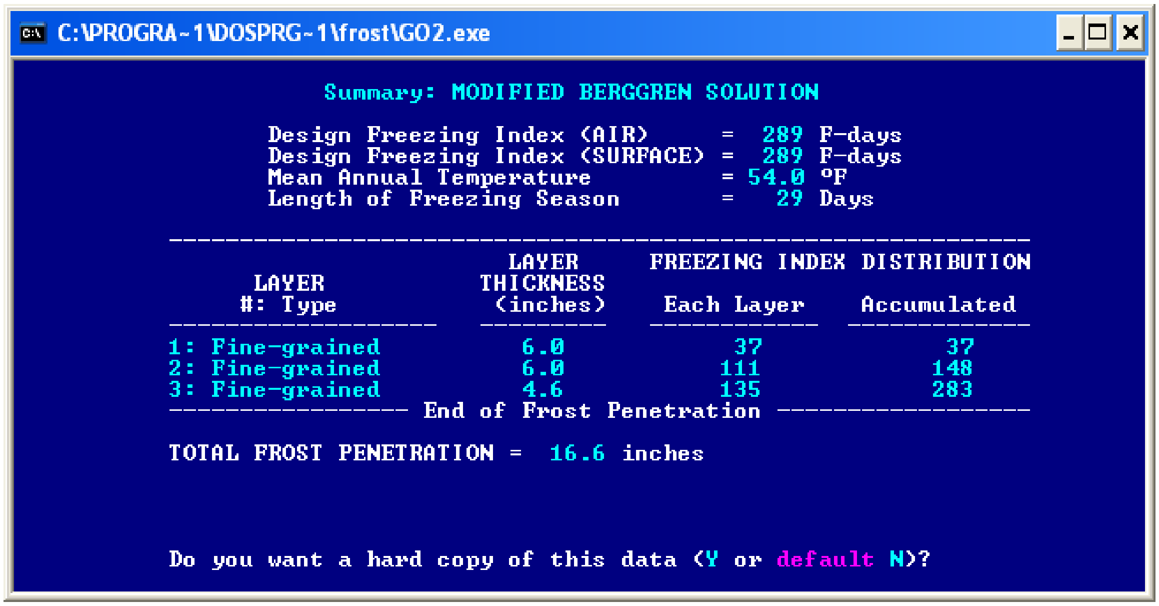
```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)     =  199 F-days
                Design Freezing Index (SURFACE) =  199 F-days
                Mean Annual Temperature         = 54.0 ºF
                Length of Freezing Season       =   60 Days

           -------------------------------------------------------------
                                      LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER              THICKNESS
                #: Type              (inches)    Each Layer    Accumulated
           -------------------     ---------   ------------  ------------
           1: Fine-grained            6.0          56             56
           2: Fine-grained            5.1         136            192
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  11.1 inches




           Do you want a hard copy of this data (Y or default N)?
```

1963



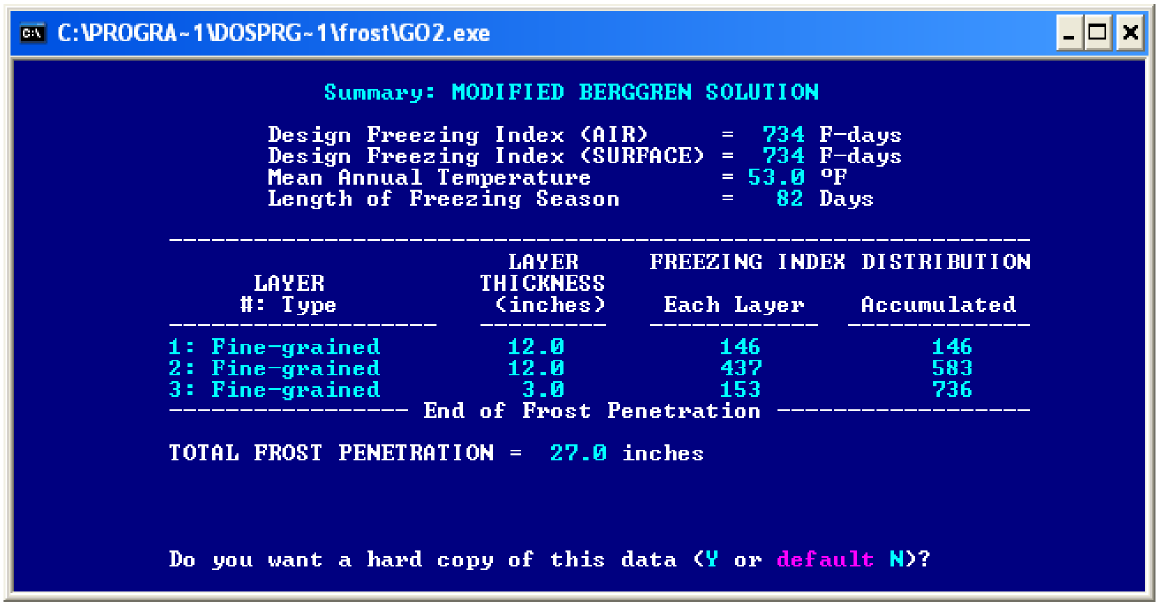
```
                  Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)     =  735 F-days
              Design Freezing Index (SURFACE) =  735 F-days
              Mean Annual Temperature         = 52.9 ºF
              Length of Freezing Season       =   44 Days

       -------------------------------------------------------------
                              LAYER    FREEZING INDEX DISTRIBUTION
             LAYER          THICKNESS
            #: Type          (inches)    Each Layer    Accumulated
       -------------------   ---------   ------------  -------------
       1: Fine-grained         12.0         126            126
       2: Fine-grained         12.0         379            505
       3: Fine-grained          4.9         225            730
       ----------------- End of Frost Penetration ------------------

       TOTAL FROST PENETRATION =  28.9 inches



       Do you want a hard copy of this data (Y or default N)?
```

1971



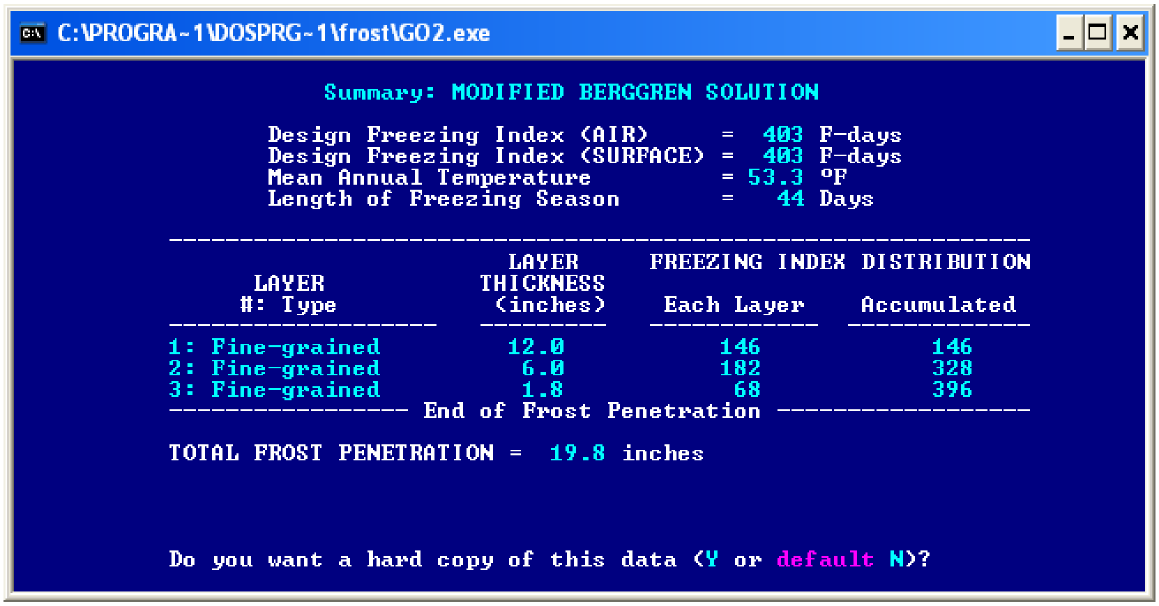
```
                  Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)     =  289 F-days
              Design Freezing Index (SURFACE) =  289 F-days
              Mean Annual Temperature         = 54.0 ºF
              Length of Freezing Season       =   29 Days

       -------------------------------------------------------------
                              LAYER    FREEZING INDEX DISTRIBUTION
             LAYER          THICKNESS
            #: Type          (inches)    Each Layer    Accumulated
       -------------------   ---------   ------------  -------------
       1: Fine-grained          6.0          37             37
       2: Fine-grained          6.0         111            148
       3: Fine-grained          4.6         135            283
       ----------------- End of Frost Penetration ------------------

       TOTAL FROST PENETRATION =  16.6 inches



       Do you want a hard copy of this data (Y or default N)?
```

1974



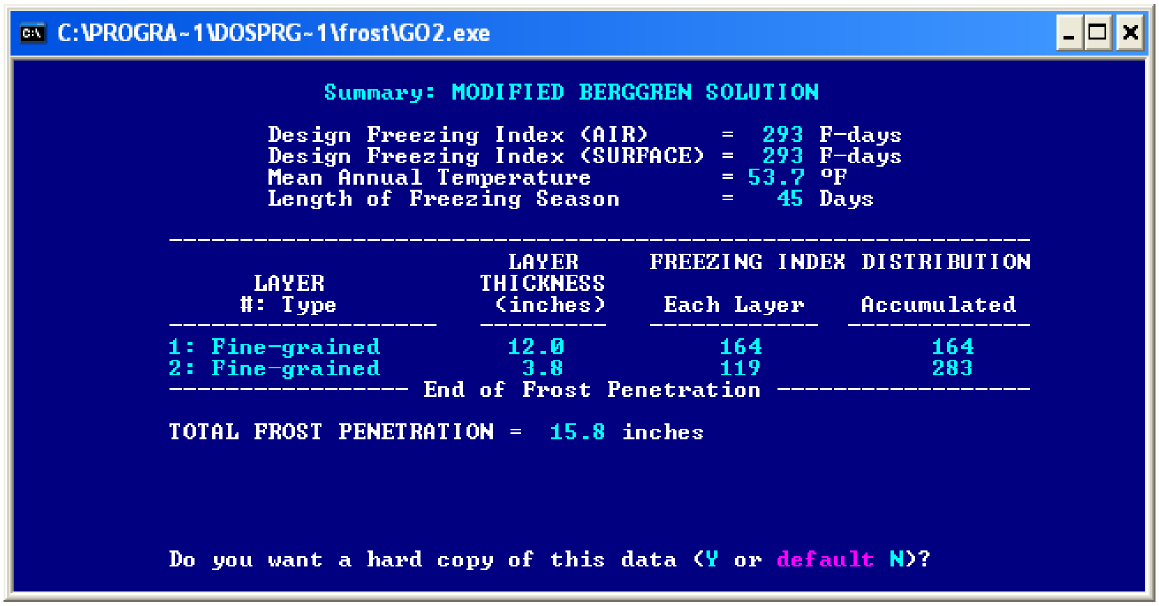
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =   734 F-days
       Design Freezing Index (SURFACE) =   734 F-days
       Mean Annual Temperature         = 53.0 °F
       Length of Freezing Season       =    82 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           146            146
2: Fine-grained         12.0           437            583
3: Fine-grained          3.0           153            736
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  27.0 inches



Do you want a hard copy of this data (Y or default N)?
```

1975



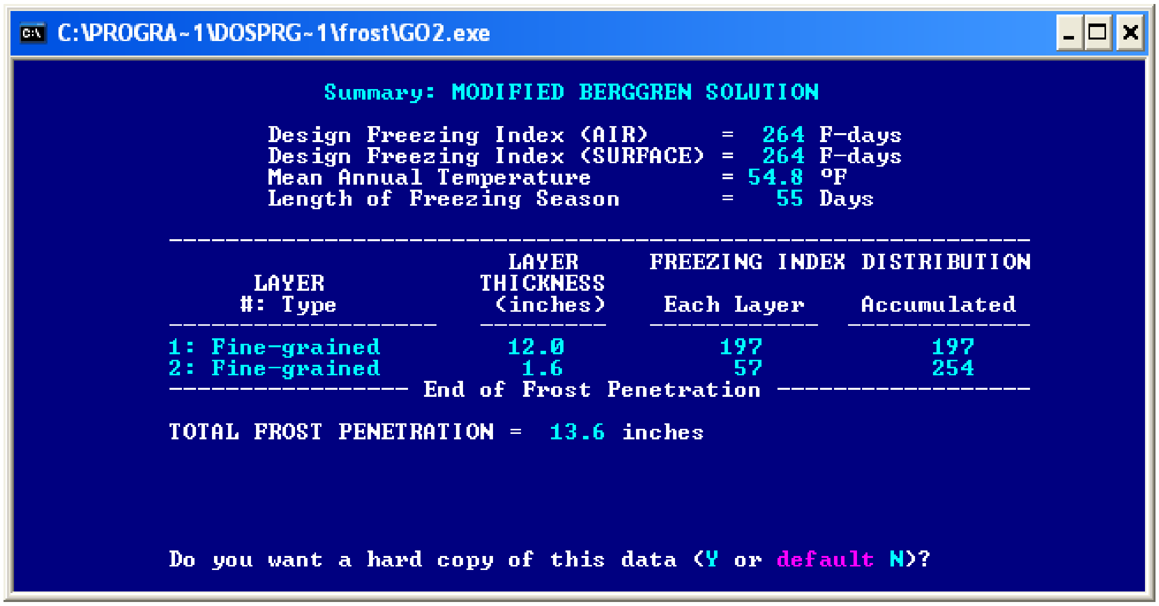
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =   403 F-days
       Design Freezing Index (SURFACE) =   403 F-days
       Mean Annual Temperature         = 53.3 °F
       Length of Freezing Season       =    44 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           146            146
2: Fine-grained          6.0           182            328
3: Fine-grained          1.8            68            396
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  19.8 inches



Do you want a hard copy of this data (Y or default N)?
```

1976



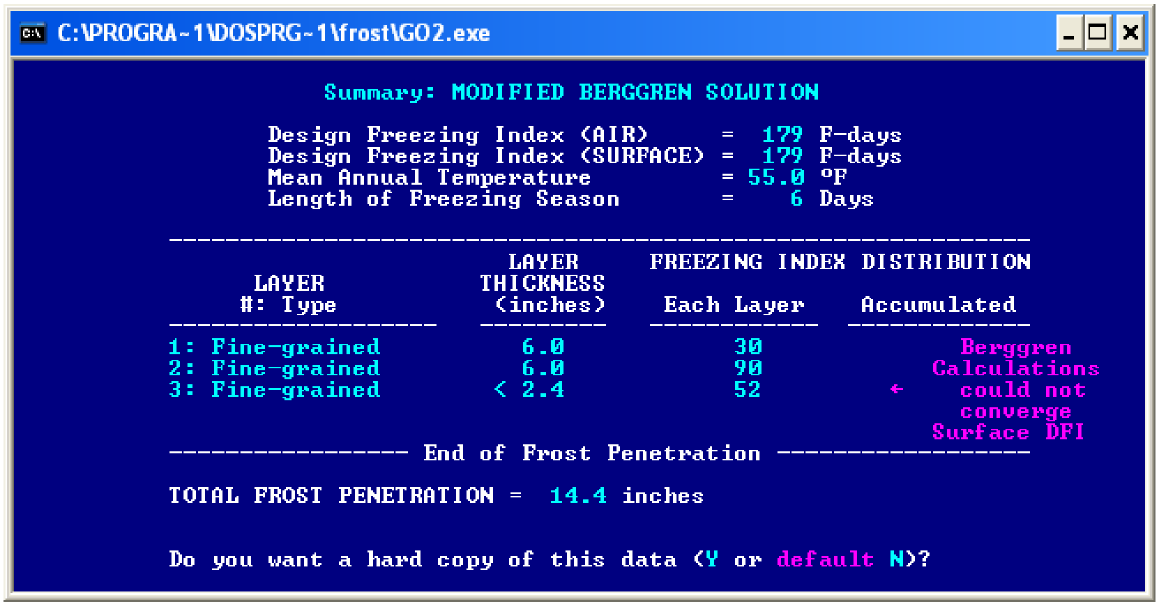
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =  293 F-days
       Design Freezing Index (SURFACE) =  293 F-days
       Mean Annual Temperature         = 53.7 ºF
       Length of Freezing Season       =   45 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           164            164
2: Fine-grained          3.8           119            283
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  15.8 inches




Do you want a hard copy of this data (Y or default N)?
```

1977



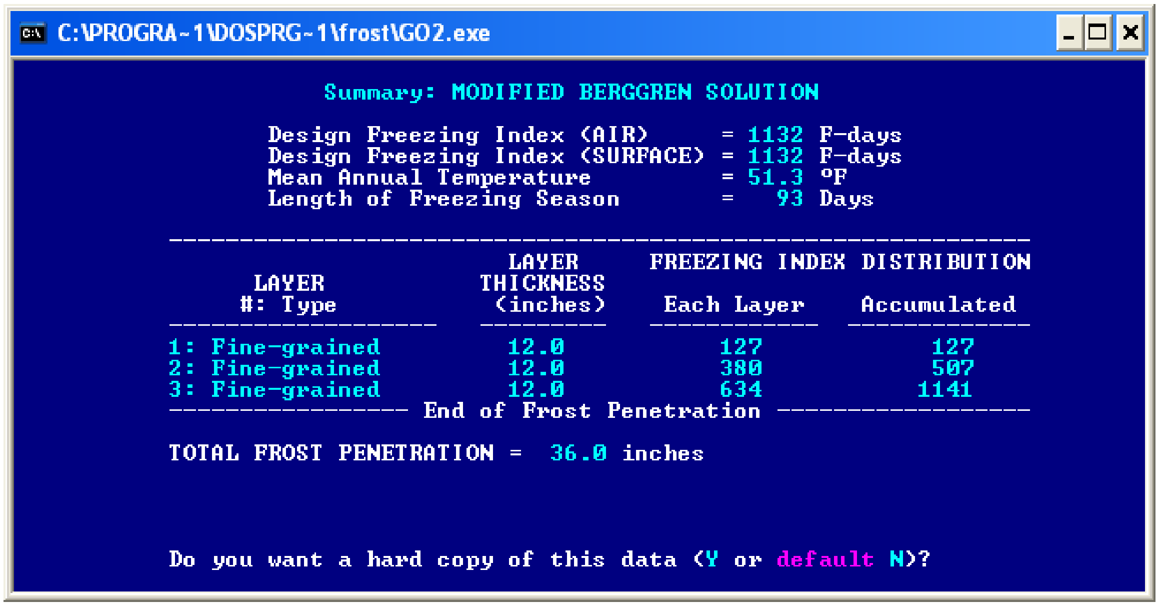
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =  264 F-days
       Design Freezing Index (SURFACE) =  264 F-days
       Mean Annual Temperature         = 54.8 ºF
       Length of Freezing Season       =   55 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           197            197
2: Fine-grained          1.6            57            254
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  13.6 inches




Do you want a hard copy of this data (Y or default N)?
```

1978



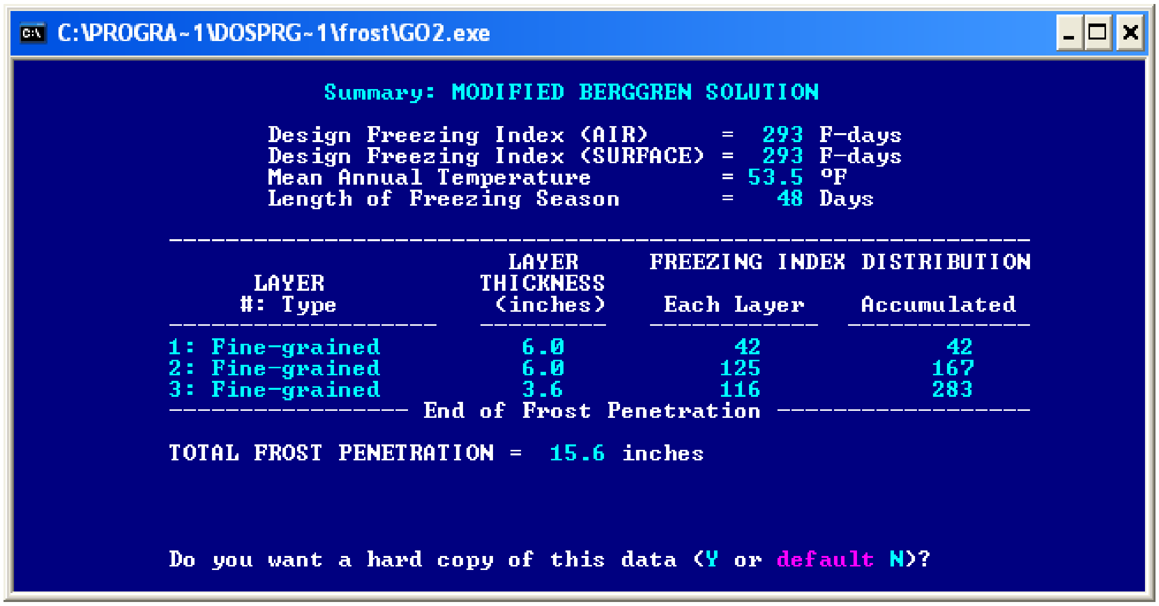
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      =  179 F-days
             Design Freezing Index (SURFACE)  =  179 F-days
             Mean Annual Temperature          = 55.0 °F
             Length of Freezing Season        =    6 Days

      -------------------------------------------------------------
                                LAYER     FREEZING INDEX DISTRIBUTION
            LAYER             THICKNESS
           #: Type            (inches)     Each Layer    Accumulated
      -------------------     ---------   ------------  -------------
      1: Fine-grained            6.0           30                 Berggren
      2: Fine-grained            6.0           90               Calculations
      3: Fine-grained          < 2.4           52          ←      could not
                                                                  converge
                                                                Surface DFI
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =  14.4 inches

      Do you want a hard copy of this data (Y or default N)?
```

1979



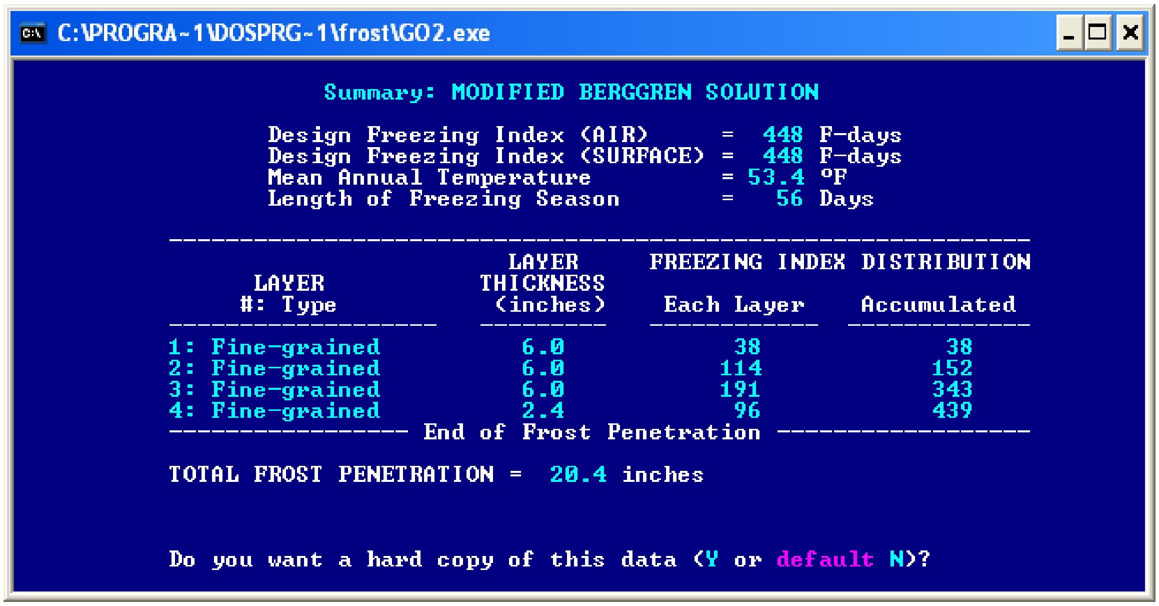
```
                 Summary: MODIFIED BERGGREN SOLUTION

             Design Freezing Index (AIR)      = 1132 F-days
             Design Freezing Index (SURFACE)  = 1132 F-days
             Mean Annual Temperature          = 51.3 °F
             Length of Freezing Season        =   93 Days

      -------------------------------------------------------------
                                LAYER     FREEZING INDEX DISTRIBUTION
            LAYER             THICKNESS
           #: Type            (inches)     Each Layer    Accumulated
      -------------------     ---------   ------------  -------------
      1: Fine-grained           12.0          127            127
      2: Fine-grained           12.0          380            507
      3: Fine-grained           12.0          634           1141
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =  36.0 inches



      Do you want a hard copy of this data (Y or default N)?
```

1980



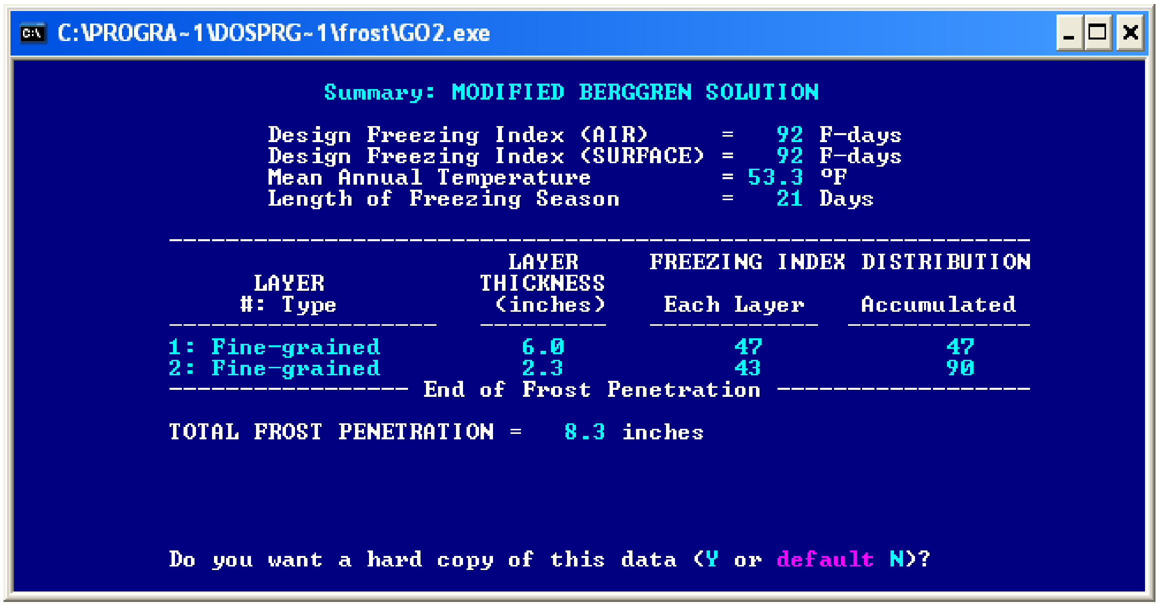
```
                 Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =  293 F-days
                Design Freezing Index (SURFACE)  =  293 F-days
                Mean Annual Temperature          = 53.5 °F
                Length of Freezing Season        =   48 Days

     -------------------------------------------------------------
                              LAYER     FREEZING INDEX DISTRIBUTION
           LAYER            THICKNESS
          #: Type            (inches)    Each Layer    Accumulated
     -------------------   ---------   ------------  -------------
     1: Fine-grained          6.0          42             42
     2: Fine-grained          6.0         125            167
     3: Fine-grained          3.6         116            283
     ----------------- End of Frost Penetration ------------------

     TOTAL FROST PENETRATION =  15.6 inches


     Do you want a hard copy of this data (Y or default N)?
```

1982



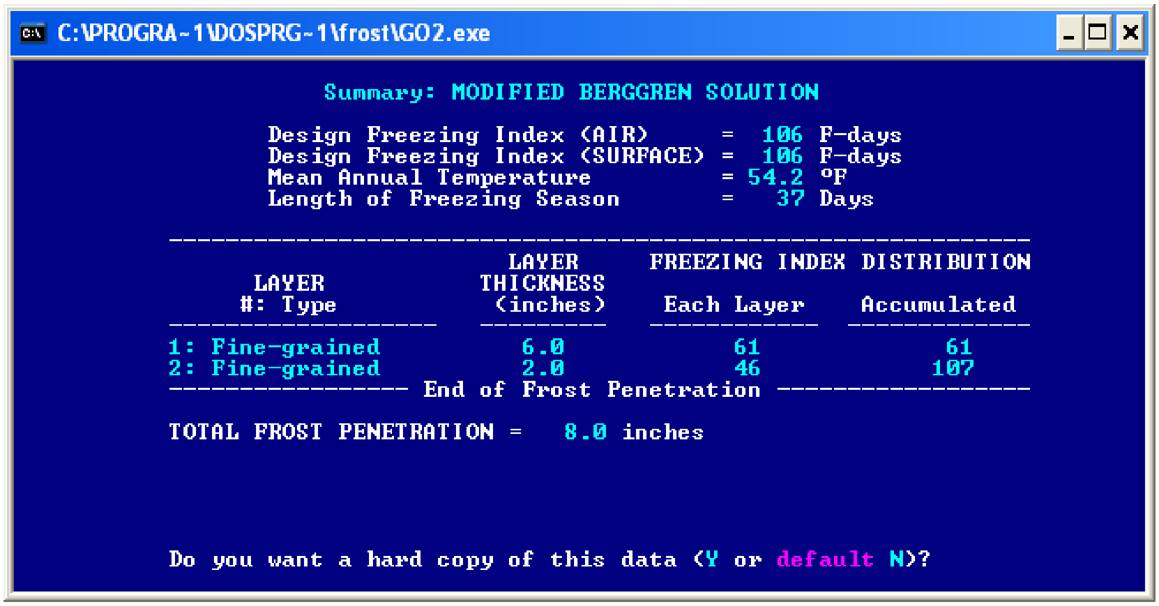
```
                 Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =  448 F-days
                Design Freezing Index (SURFACE)  =  448 F-days
                Mean Annual Temperature          = 53.4 °F
                Length of Freezing Season        =   56 Days

     -------------------------------------------------------------
                              LAYER     FREEZING INDEX DISTRIBUTION
           LAYER            THICKNESS
          #: Type            (inches)    Each Layer    Accumulated
     -------------------   ---------   ------------  -------------
     1: Fine-grained          6.0          38             38
     2: Fine-grained          6.0         114            152
     3: Fine-grained          6.0         191            343
     4: Fine-grained          2.4          96            439
     ----------------- End of Frost Penetration ------------------

     TOTAL FROST PENETRATION =  20.4 inches


     Do you want a hard copy of this data (Y or default N)?
```

1983



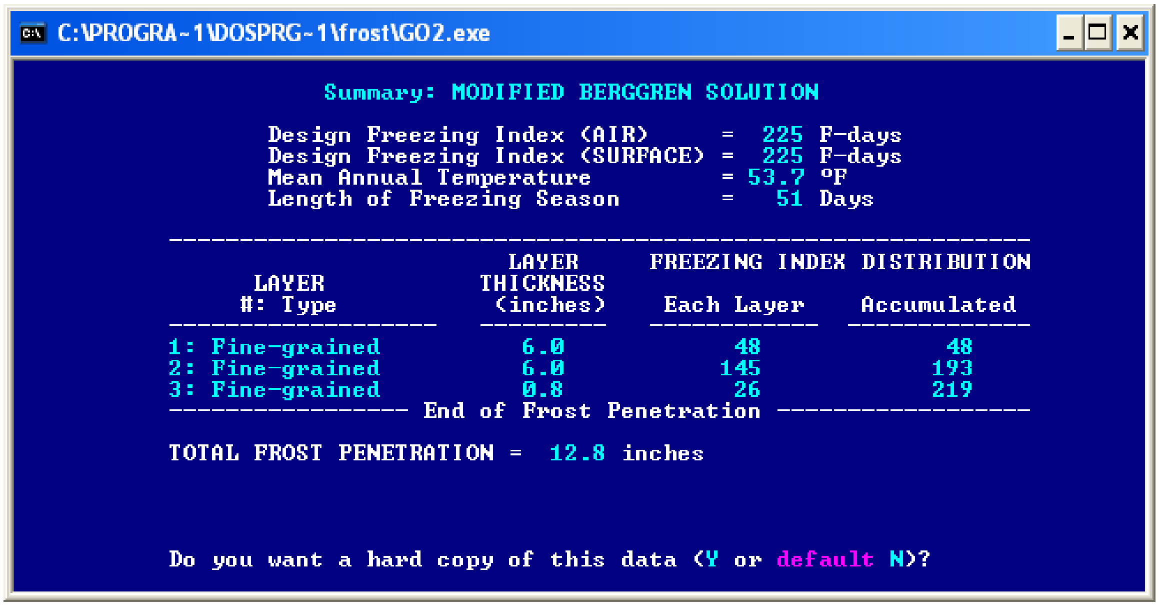
```
                      Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =   92 F-days
                Design Freezing Index (SURFACE)  =   92 F-days
                Mean Annual Temperature          = 53.3 °F
                Length of Freezing Season        =   21 Days

         -------------------------------------------------------------
                                     LAYER     FREEZING INDEX DISTRIBUTION
               LAYER               THICKNESS
              #: Type               (inches)    Each Layer    Accumulated
         -------------------       ---------  ------------  -------------
         1: Fine-grained              6.0          47             47
         2: Fine-grained              2.3          43             90
         ----------------- End of Frost Penetration ------------------

         TOTAL FROST PENETRATION =    8.3 inches



         Do you want a hard copy of this data (Y or default N)?
```

1986



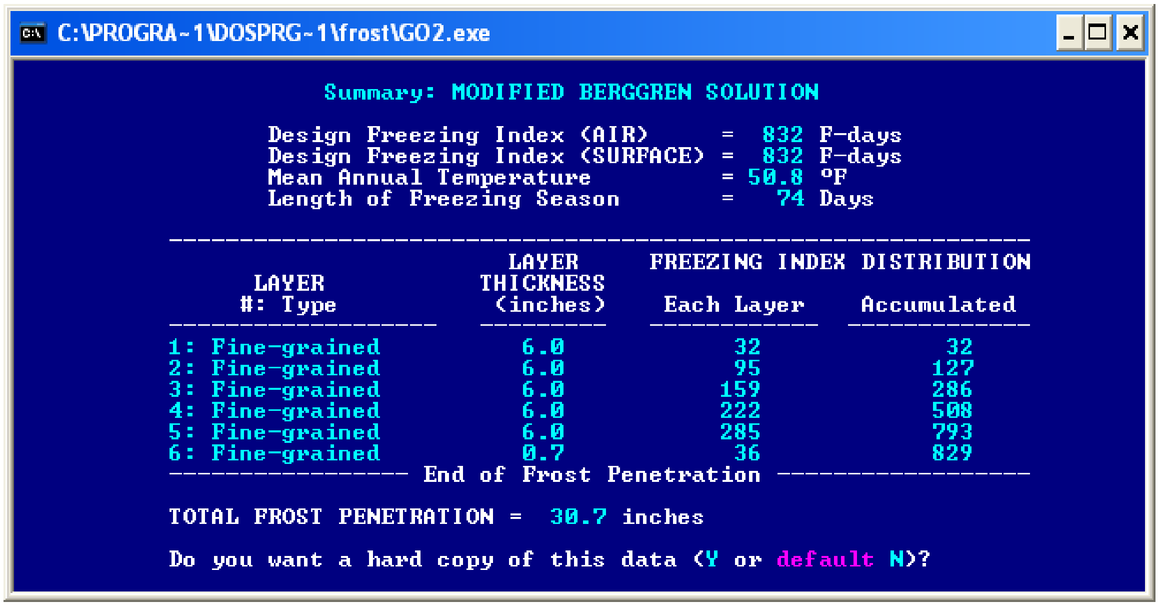
```
                      Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      =  106 F-days
                Design Freezing Index (SURFACE)  =  106 F-days
                Mean Annual Temperature          = 54.2 °F
                Length of Freezing Season        =   37 Days

         -------------------------------------------------------------
                                     LAYER     FREEZING INDEX DISTRIBUTION
               LAYER               THICKNESS
              #: Type               (inches)    Each Layer    Accumulated
         -------------------       ---------  ------------  -------------
         1: Fine-grained              6.0          61             61
         2: Fine-grained              2.0          46            107
         ----------------- End of Frost Penetration ------------------

         TOTAL FROST PENETRATION =    8.0 inches



         Do you want a hard copy of this data (Y or default N)?
```

1987



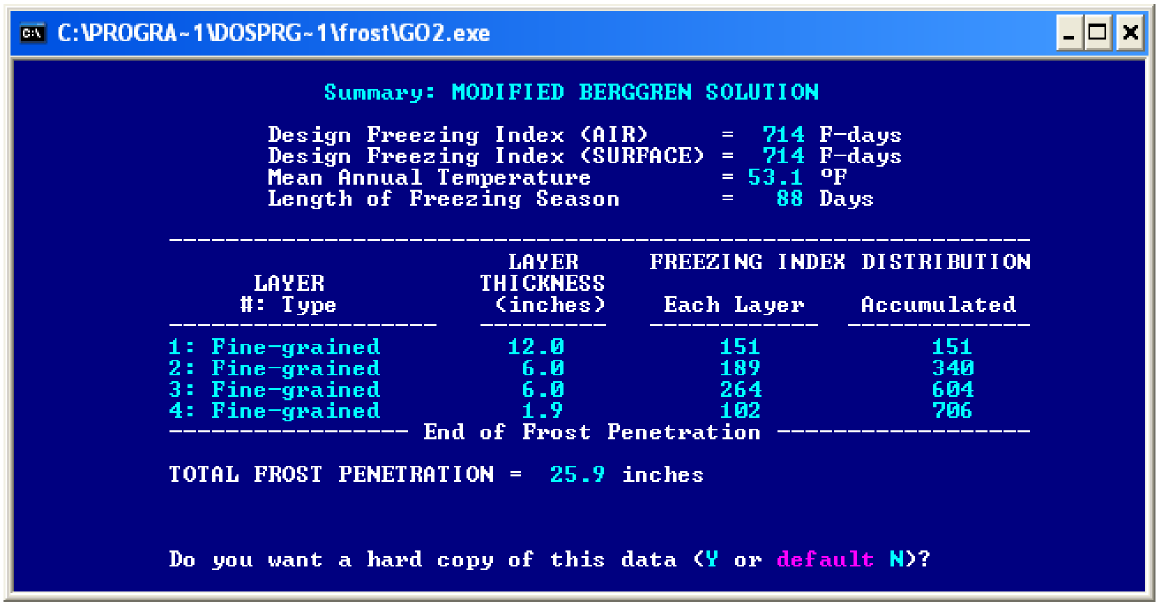
```
                 Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      =  225 F-days
            Design Freezing Index (SURFACE)  =  225 F-days
            Mean Annual Temperature          = 53.7 ºF
            Length of Freezing Season        =   51 Days

 -------------------------------------------------------------
                           LAYER      FREEZING INDEX DISTRIBUTION
       LAYER             THICKNESS
      #: Type            (inches)     Each Layer     Accumulated
 -------------------     ---------    ------------   -------------
 1: Fine-grained            6.0           48               48
 2: Fine-grained            6.0          145              193
 3: Fine-grained            0.8           26              219
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  12.8 inches


 Do you want a hard copy of this data (Y or default N)?
```

1988



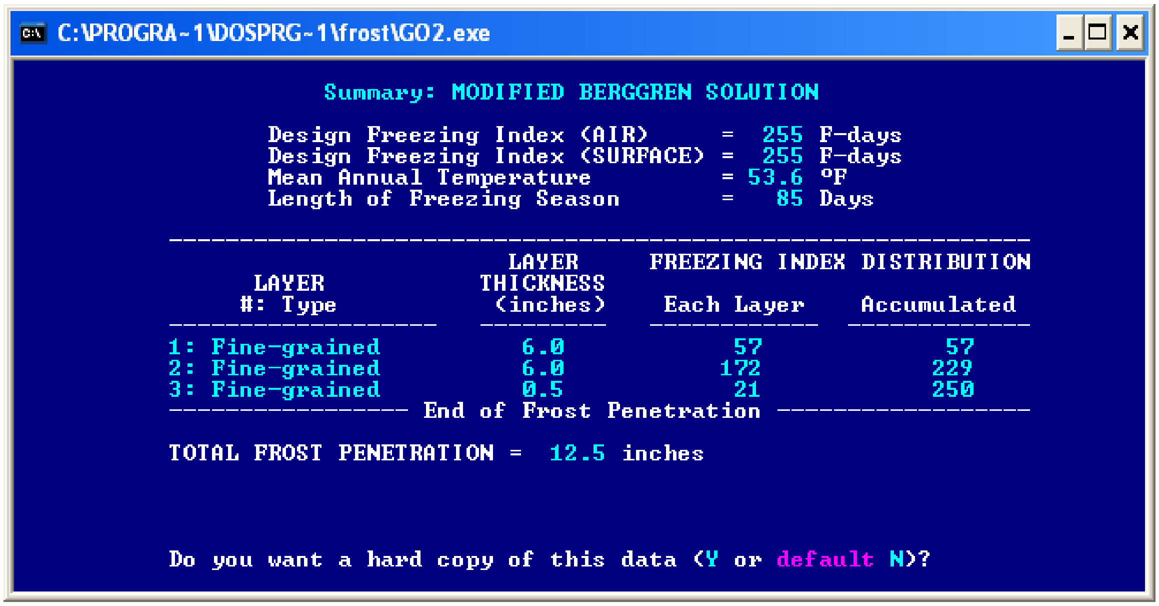
```
                 Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      =  832 F-days
            Design Freezing Index (SURFACE)  =  832 F-days
            Mean Annual Temperature          = 50.8 ºF
            Length of Freezing Season        =   74 Days

 -------------------------------------------------------------
                           LAYER      FREEZING INDEX DISTRIBUTION
       LAYER             THICKNESS
      #: Type            (inches)     Each Layer     Accumulated
 -------------------     ---------    ------------   -------------
 1: Fine-grained            6.0           32               32
 2: Fine-grained            6.0           95              127
 3: Fine-grained            6.0          159              286
 4: Fine-grained            6.0          222              508
 5: Fine-grained            6.0          285              793
 6: Fine-grained            0.7           36              829
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  30.7 inches

 Do you want a hard copy of this data (Y or default N)?
```

1989



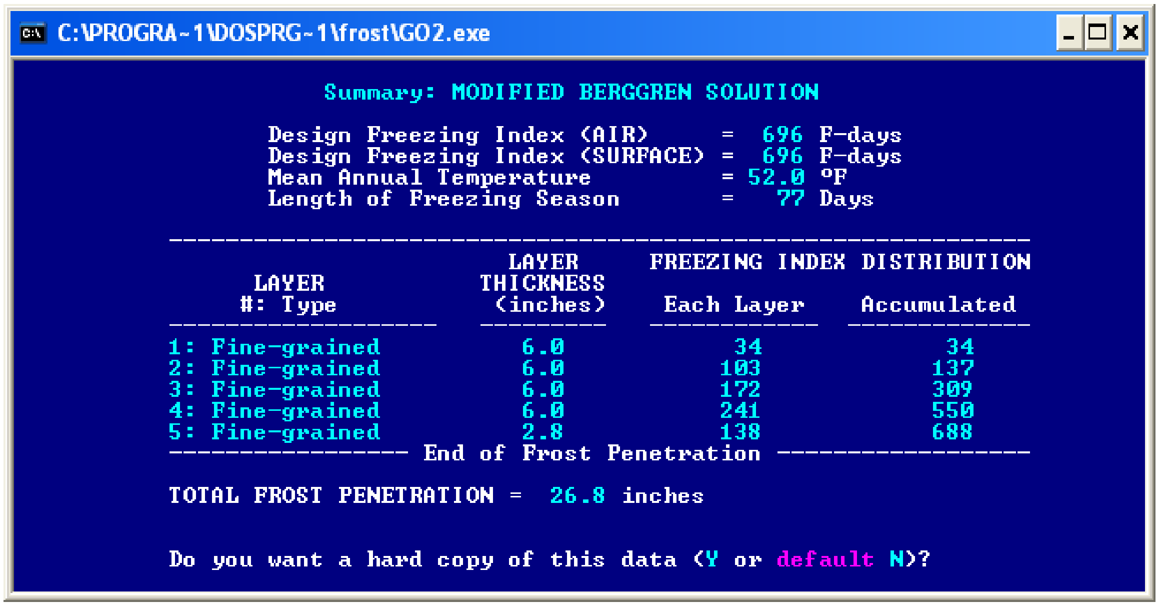
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =  714 F-days
       Design Freezing Index (SURFACE) =  714 F-days
       Mean Annual Temperature         = 53.1 ºF
       Length of Freezing Season       =   88 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0          151            151
2: Fine-grained          6.0          189            340
3: Fine-grained          6.0          264            604
4: Fine-grained          1.9          102            706
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  25.9 inches


Do you want a hard copy of this data (Y or default N)?
```

1990



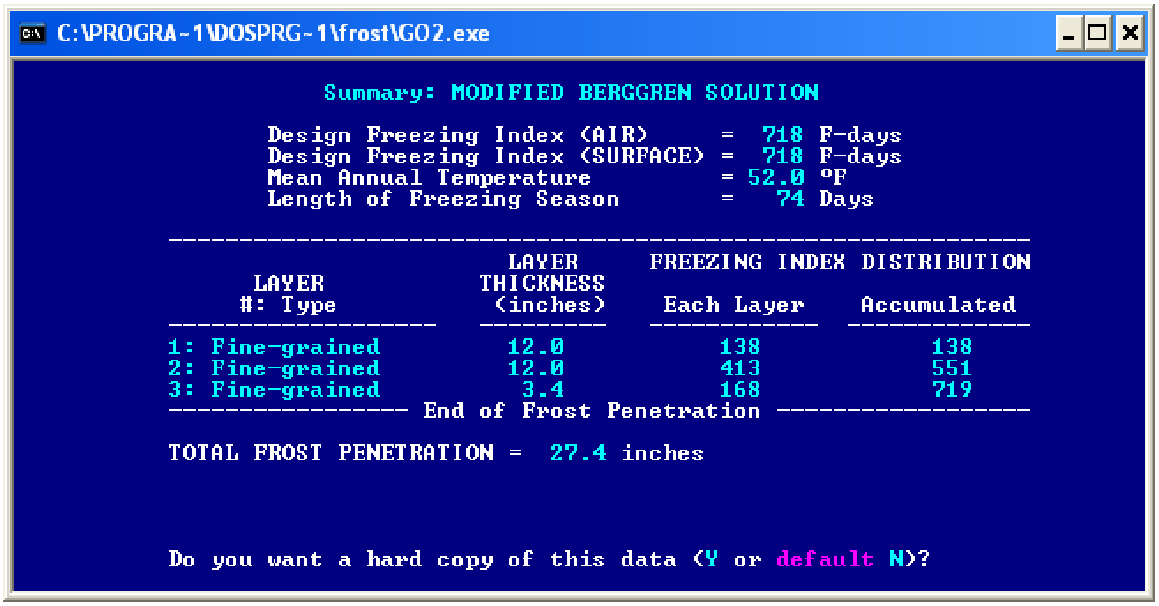
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)     =  255 F-days
       Design Freezing Index (SURFACE) =  255 F-days
       Mean Annual Temperature         = 53.6 ºF
       Length of Freezing Season       =   85 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer    Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained          6.0           57             57
2: Fine-grained          6.0          172            229
3: Fine-grained          0.5           21            250
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =  12.5 inches



Do you want a hard copy of this data (Y or default N)?
```

1991



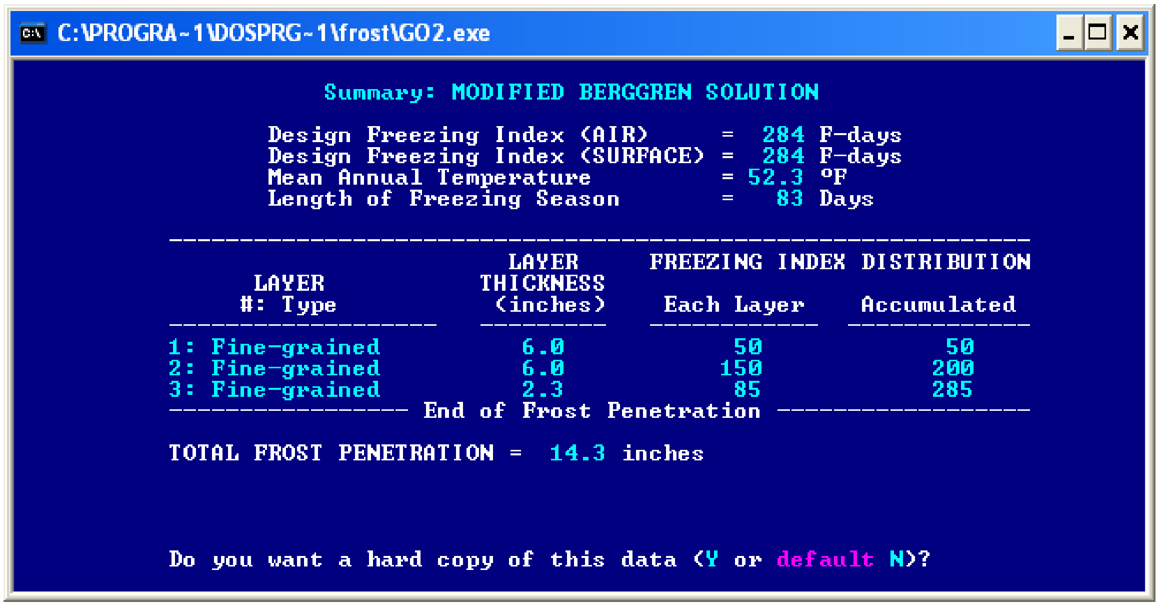
```
                 Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)      =  696 F-days
              Design Freezing Index (SURFACE) =  696 F-days
              Mean Annual Temperature          = 52.0 ºF
              Length of Freezing Season        =   77 Days

      --------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
            LAYER                THICKNESS
           #: Type                (inches)     Each Layer    Accumulated
      -------------------       ---------    ------------  -------------
      1: Fine-grained               6.0            34             34
      2: Fine-grained               6.0           103            137
      3: Fine-grained               6.0           172            309
      4: Fine-grained               6.0           241            550
      5: Fine-grained               2.8           138            688
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =  26.8 inches


      Do you want a hard copy of this data (Y or default N)?
```

1992

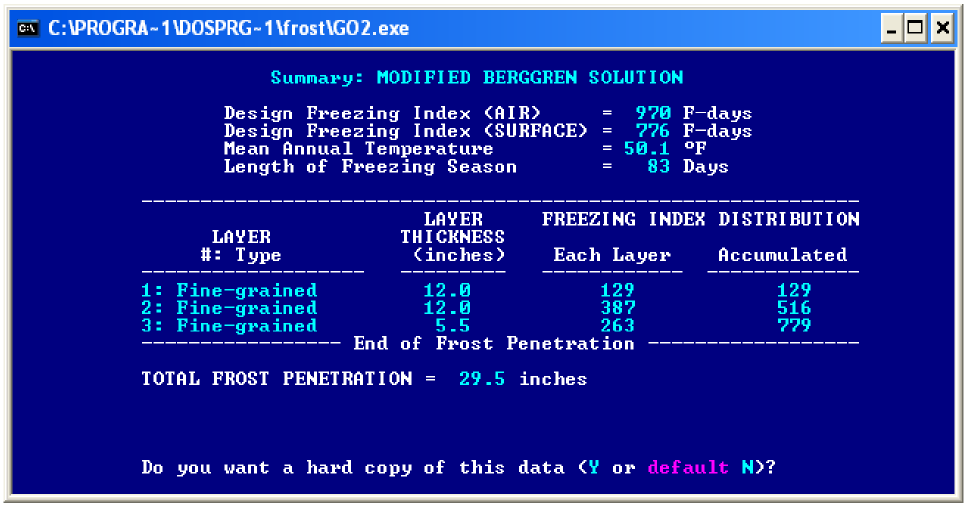


```
                 Summary: MODIFIED BERGGREN SOLUTION

              Design Freezing Index (AIR)      =  718 F-days
              Design Freezing Index (SURFACE) =  718 F-days
              Mean Annual Temperature          = 52.0 ºF
              Length of Freezing Season        =   74 Days

      --------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
            LAYER                THICKNESS
           #: Type                (inches)     Each Layer    Accumulated
      -------------------       ---------    ------------  -------------
      1: Fine-grained              12.0           138            138
      2: Fine-grained              12.0           413            551
      3: Fine-grained               3.4           168            719
      ----------------- End of Frost Penetration ------------------

      TOTAL FROST PENETRATION =  27.4 inches



      Do you want a hard copy of this data (Y or default N)?
```

1994

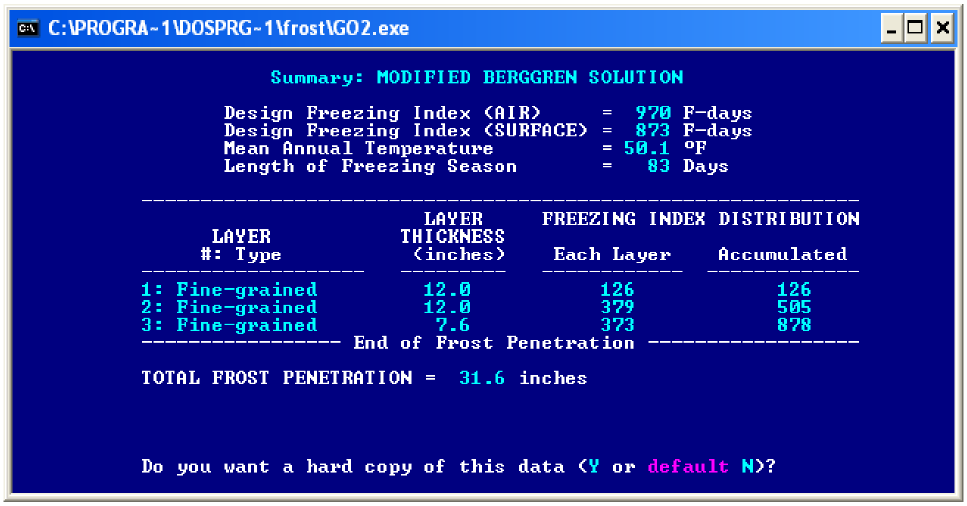


```
                      Summary: MODIFIED BERGGREN SOLUTION

                  Design Freezing Index (AIR)      =  284 F-days
                  Design Freezing Index (SURFACE) =  284 F-days
                  Mean Annual Temperature          = 52.3 ºF
                  Length of Freezing Season        =   83 Days

           -------------------------------------------------------------
                                     LAYER      FREEZING INDEX DISTRIBUTION
                 LAYER             THICKNESS
                #: Type            (inches)      Each Layer     Accumulated
           -------------------    ---------     ------------   -------------
           1: Fine-grained           6.0             50              50
           2: Fine-grained           6.0            150             200
           3: Fine-grained           2.3             85             285
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  14.3 inches



           Do you want a hard copy of this data (Y or default N)?
```



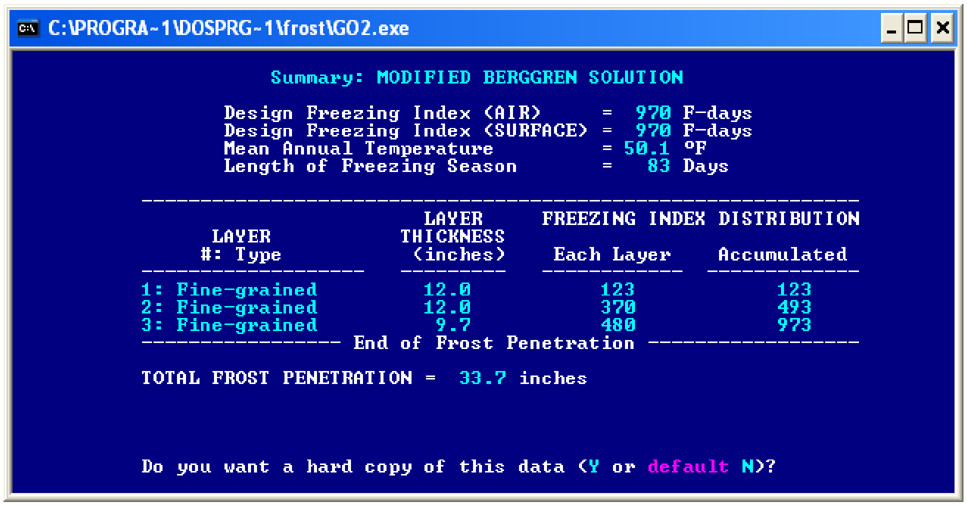
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)      =  970 F-days
       Design Freezing Index (SURFACE)  =  776 F-days
       Mean Annual Temperature          = 50.1 °F
       Length of Freezing Season        =   83 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer     Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           129            129
2: Fine-grained         12.0           387            516
3: Fine-grained          5.5           263            779
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =   29.5 inches


Do you want a hard copy of this data (Y or default N)?
```

1937, N=0.8



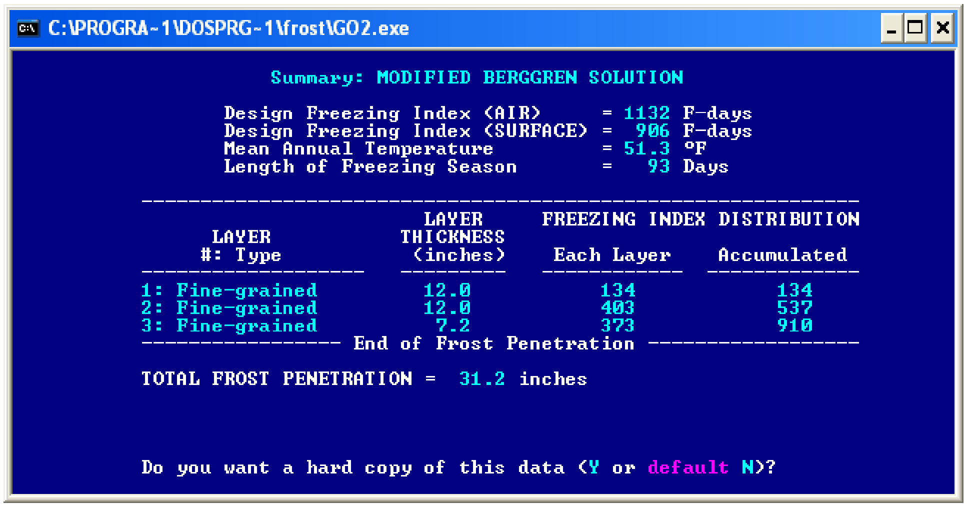
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)      =  970 F-days
       Design Freezing Index (SURFACE)  =  873 F-days
       Mean Annual Temperature          = 50.1 °F
       Length of Freezing Season        =   83 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer     Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           126            126
2: Fine-grained         12.0           379            505
3: Fine-grained          7.6           373            878
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =   31.6 inches


Do you want a hard copy of this data (Y or default N)?
```

1937, N=0.9



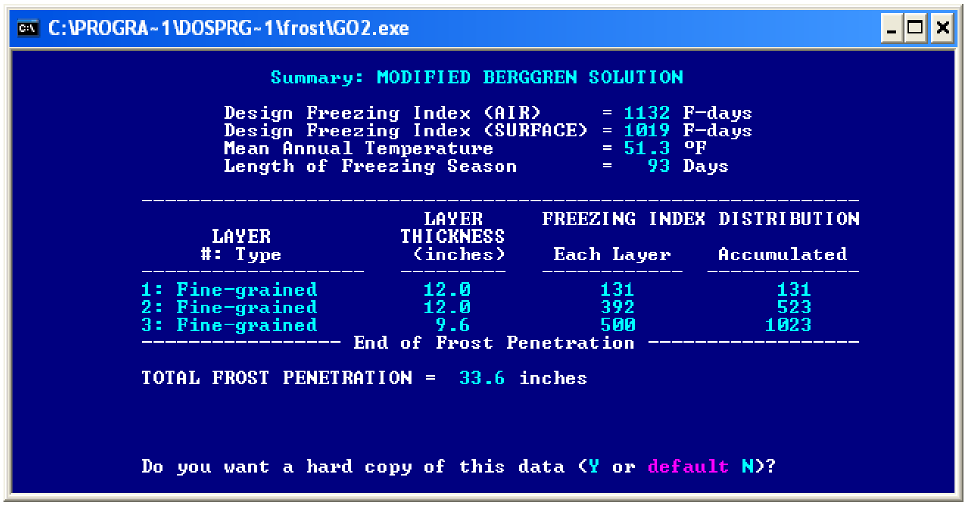
```
           Summary: MODIFIED BERGGREN SOLUTION

       Design Freezing Index (AIR)      =  970 F-days
       Design Freezing Index (SURFACE)  =  970 F-days
       Mean Annual Temperature          = 50.1 °F
       Length of Freezing Season        =   83 Days

-------------------------------------------------------------
                        LAYER     FREEZING INDEX DISTRIBUTION
      LAYER           THICKNESS
     #: Type           (inches)    Each Layer     Accumulated
-------------------   ---------   ------------  -------------
1: Fine-grained         12.0           123            123
2: Fine-grained         12.0           370            493
3: Fine-grained          9.7           480            973
----------------- End of Frost Penetration ------------------

TOTAL FROST PENETRATION =   33.7 inches


Do you want a hard copy of this data (Y or default N)?
```

1937, N=1.0



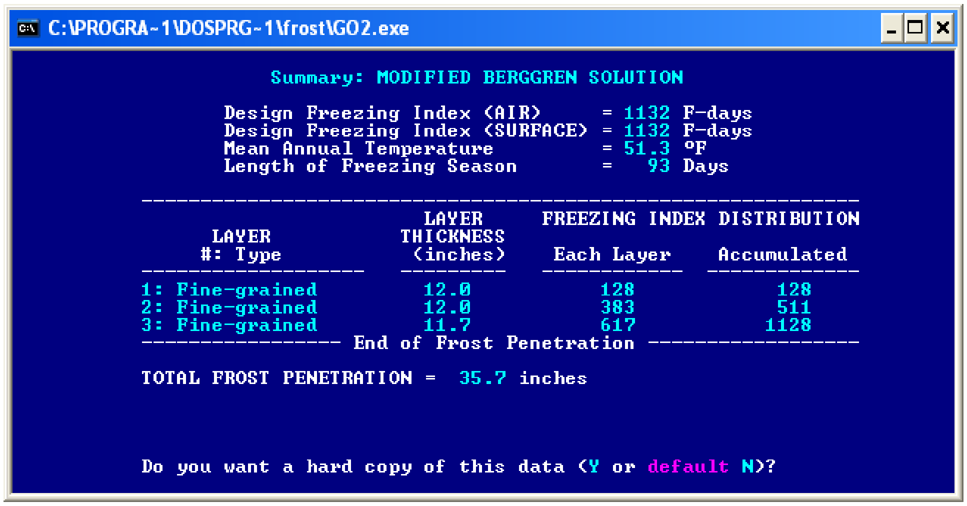
```
                    Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      = 1132 F-days
            Design Freezing Index (SURFACE)  =  906 F-days
            Mean Annual Temperature          = 51.3 ºF
            Length of Freezing Season        =   93 Days

 -------------------------------------------------------------
                   LAYER      FREEZING INDEX DISTRIBUTION
      LAYER      THICKNESS
     #: Type      (inches)    Each Layer    Accumulated
 ------------------- --------  ------------ -------------
 1: Fine-grained       12.0       134            134
 2: Fine-grained       12.0       403            537
 3: Fine-grained        7.2       373            910
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  31.2 inches



 Do you want a hard copy of this data (Y or default N)?
```

1979, N=0.8



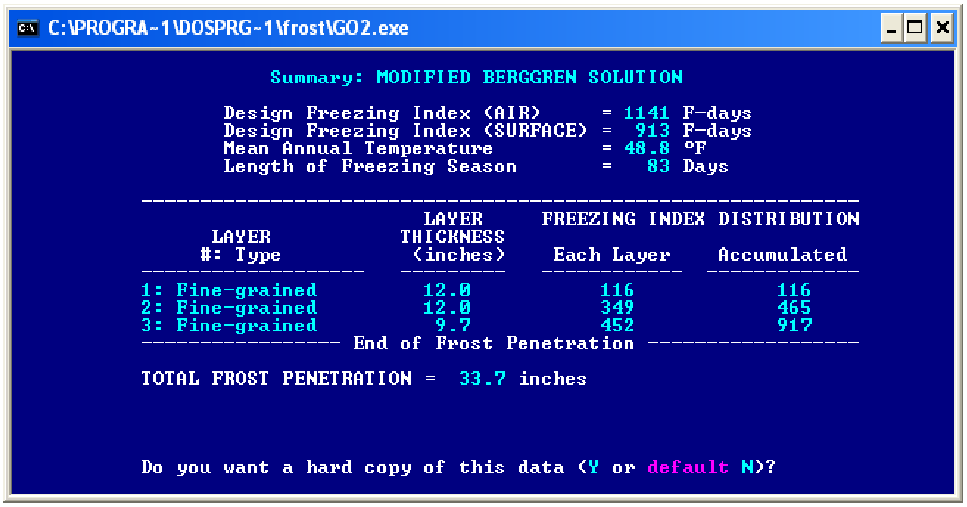
```
                    Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      = 1132 F-days
            Design Freezing Index (SURFACE)  = 1019 F-days
            Mean Annual Temperature          = 51.3 ºF
            Length of Freezing Season        =   93 Days

 -------------------------------------------------------------
                   LAYER      FREEZING INDEX DISTRIBUTION
      LAYER      THICKNESS
     #: Type      (inches)    Each Layer    Accumulated
 ------------------- --------  ------------ -------------
 1: Fine-grained       12.0       131            131
 2: Fine-grained       12.0       392            523
 3: Fine-grained        9.6       500           1023
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  33.6 inches



 Do you want a hard copy of this data (Y or default N)?
```

1979, N=0.9



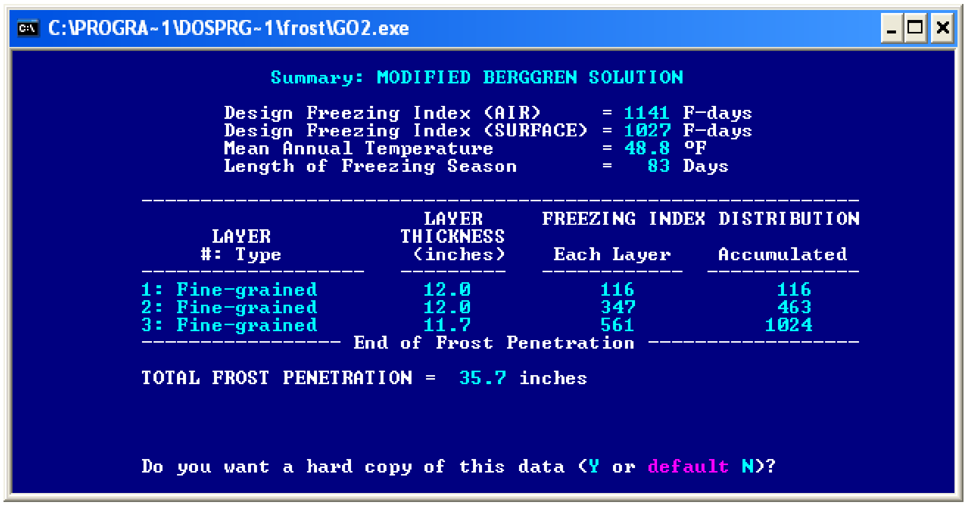
```
                    Summary: MODIFIED BERGGREN SOLUTION

            Design Freezing Index (AIR)      = 1132 F-days
            Design Freezing Index (SURFACE)  = 1132 F-days
            Mean Annual Temperature          = 51.3 ºF
            Length of Freezing Season        =   93 Days

 -------------------------------------------------------------
                   LAYER      FREEZING INDEX DISTRIBUTION
      LAYER      THICKNESS
     #: Type      (inches)    Each Layer    Accumulated
 ------------------- --------  ------------ -------------
 1: Fine-grained       12.0       128            128
 2: Fine-grained       12.0       383            511
 3: Fine-grained       11.7       617           1128
 ----------------- End of Frost Penetration ------------------

 TOTAL FROST PENETRATION =  35.7 inches



 Do you want a hard copy of this data (Y or default N)?
```

1979, N=1.0



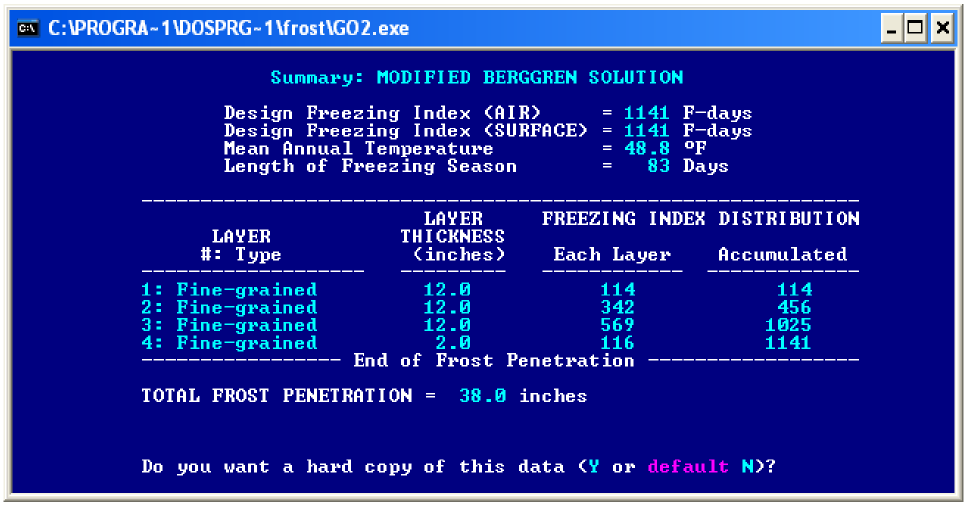
```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      = 1141 F-days
                Design Freezing Index (SURFACE)  =  913 F-days
                Mean Annual Temperature          = 48.8 ºF
                Length of Freezing Season        =   83 Days

           -------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER           THICKNESS
                #: Type           (inches)    Each Layer    Accumulated
           -------------------  ---------   ------------  -------------
           1: Fine-grained         12.0          116            116
           2: Fine-grained         12.0          349            465
           3: Fine-grained          9.7          452            917
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  33.7 inches



           Do you want a hard copy of this data (Y or default N)?
```

1933, N=0.8



```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      = 1141 F-days
                Design Freezing Index (SURFACE)  = 1027 F-days
                Mean Annual Temperature          = 48.8 ºF
                Length of Freezing Season        =   83 Days

           -------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER           THICKNESS
                #: Type           (inches)    Each Layer    Accumulated
           -------------------  ---------   ------------  -------------
           1: Fine-grained         12.0          116            116
           2: Fine-grained         12.0          347            463
           3: Fine-grained         11.7          561           1024
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  35.7 inches



           Do you want a hard copy of this data (Y or default N)?
```

1933, N=0.9

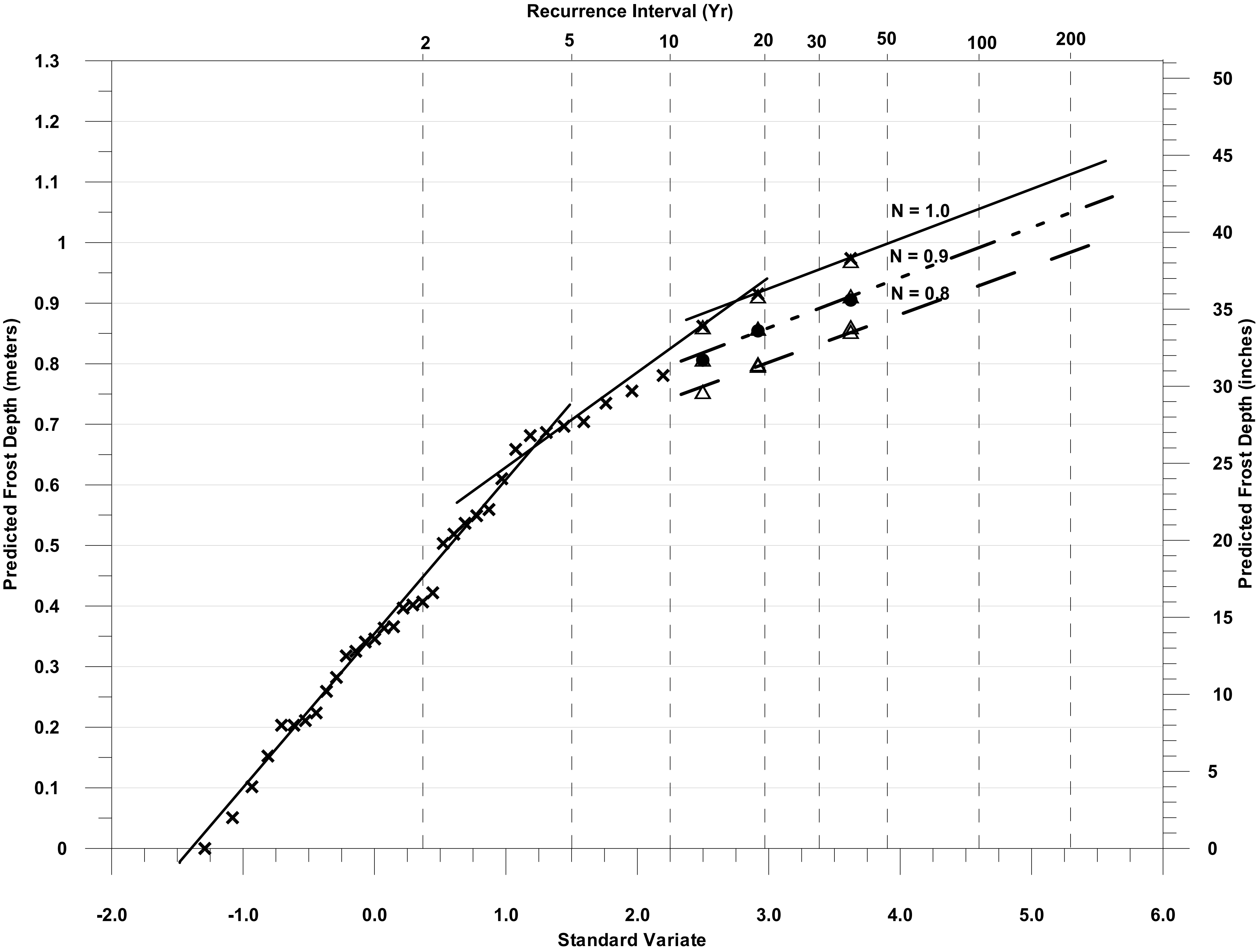


```
                    Summary: MODIFIED BERGGREN SOLUTION

                Design Freezing Index (AIR)      = 1141 F-days
                Design Freezing Index (SURFACE)  = 1141 F-days
                Mean Annual Temperature          = 48.8 ºF
                Length of Freezing Season        =   83 Days

           -------------------------------------------------------------
                                   LAYER     FREEZING INDEX DISTRIBUTION
                 LAYER           THICKNESS
                #: Type           (inches)    Each Layer    Accumulated
           -------------------  ---------   ------------  -------------
           1: Fine-grained         12.0          114            114
           2: Fine-grained         12.0          342            456
           3: Fine-grained         12.0          569           1025
           4: Fine-grained          2.0          116           1141
           ----------------- End of Frost Penetration ------------------

           TOTAL FROST PENETRATION =  38.0 inches


           Do you want a hard copy of this data (Y or default N)?
```

1933, N=1.0

Appendix C

Results of Extreme Frost Depth Analysis



Recurrence Interval (Yr)
2
5
10
20
30
50
100
200
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Predicted Frost Depth (meters)
50
45
40
35
30
25
20
15
10
5
0
Predicted Frost Depth (inches)
N = 1.0
N = 0.9
N = 0.8
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Standard Variate

End of current text

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-5-13-01 **Discipline:** Geology **No. of Sheets:** 16
Doc No.: X0175600

Location: Attachment 1, Appendix B

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Radon Barrier Design Remedial Action Plan

Sources of Data:

RAP calculations as referenced in text.

Sources of Formulae and References:

See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-02-05-2006-3-13-00**

Author: Roslyn Stern 6/6/07
Name Date

Checked by: 5/30/07
Name Date

Andy Smith 5/31/07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Name Date

May 31, 07
Name Date

No text for this page

Problem Statement:

- Part 40 of the United States *Code of Federal Regulations*, section 192.02 (40 CFR 192.02) requires that control of radioactive materials and their listed constituents shall be designed to provide reasonable assurance that release of radon-222 from residual radioactive material (RRM) to the atmosphere will not exceed an average of 20 picocuries per square meter per second (pCi/m^2/sec), averaged over the entire cover top slope.
- The cover of the Crescent Junction Disposal Cell must be sufficient to provide isolation of tailings and control of radon emanation for the period of up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years.
- This calculation establishes the dimensions and input parameters for design of the Crescent Junction Disposal Cell radon barrier that will provide the requisite reasonable assurance of performance.

Method of Solution:

- Site-specific data for the RRM, which includes tailings, contaminated soils, mill debris, and other contaminated materials, and for the native cover materials were developed through thorough field investigations and laboratory testing programs (Golder 2006a, Remedial Action Plan calculations referenced herein). These site-specific data are presented in summary tables in Appendix B.
- Two conceptual design configurations were evaluated: one using a compacted-clay radon barrier (Uranium Mill Tailings Remedial Action [UMTRA] checklist cover), and one using a monolithic soil cover (alternative cover).
- The Nuclear Regulatory Commission (NRC) computer code RADON (NRC 1989a) was used to calculate the optimum radon-barrier thickness, given the specific input parameters for each model run.

Assumptions:

- Tailings activity will be relatively homogeneous as placed; no layers of different radium-226 activity were modeled. This is conservative, as placement of contaminated soils of lower activity may be placed in the upper portions of the pile. It is anticipated that the cover design will be re-evaluated during construction using actual as-placed source material activities and properties to ensure the cover is optimized for as-built conditions.
- Bottom-boundary radon flux is equal to zero, as per the Technical Approach Document (TAD) (DOE 1989).
- Ambient air radon concentrations were assumed to equal the conservative default value of zero, no local ambient air radon concentration data were available. Should these data become available prior to construction, these measured values should be considered in evaluation of the final cover design.
- The cell side slopes will be constructed of dikes made from clean fill to thicknesses far in excess of the cover and with properties comparable to the cover material; therefore, radon flux through the side slopes was not modeled.
- Following UMTRA precedence, materials above the radon barrier (e.g., frost protection layers, riprap, or rock mulch erosion-protection layers) were not modeled. These overlying materials provide additional radon attenuation. This conservative assumption enhances the reasonable assurance that the barrier as designed will provide the requisite protection and long-term performance.
- A clean-fill interim cover with a minimum thickness of 1 foot (ft) will be placed over the tailings as a best management practice.
- Physical properties of the cover materials are adequately represented by the characterization data.
- RADON model (NRC 1989a) default values for radon-emanation coefficient (0.35) are assumed conservative and appropriate.

- Capillary breaks, drainage layers/ biointrusion layers were assumed to have insignificant impact on radon attenuation, given their large pore size and low long-term moisture content. Therefore, these layers have conservatively been omitted from the RADON model runs.

Calculation:

- The mean value (x_{mean}) of any parameter is calculated by the equation:

$$x_{mean} = \sum x_i / n$$

where: x_i = the i^{th} value, and
n = the total number of values.

- The standard deviation (s) of a set of values is calculated by the equation:

$$s = \mathrm{sqrt}((\sum(x_i - x_{mean})^2 / [n-1]))$$

where: sqrt = the square root of the value.

- Porosity (η) of a sample is calculated from the equation:

$$(\eta = (1 - [\text{dry bulk density} \div (\text{specific gravity} \times \text{unit weight of water})])$$

where the unit weight of water is 62.4 pounds per cubic foot (pcf), or 1 gram per cubic centimeter (g/cc).

- Radon (^{222}Rn) Diffusion coefficients were calculated using equation 9 from Rogers and Nielson (1991) as follows:

$$D=Da*p*\exp(-6Sp-6S14p)$$

where: D = the calculated ^{222}Rn diffusion coefficient
Da = the ^{222}Rn diffusion coefficient in air (1.10×10^{-5} m^2/s)
p = the porosity of the individual material (also represented by the symbol η, as above)
S = the degree of material saturation, represented the following equation:

$$\text{Saturation (S)} = \text{Long-term water content}/((\text{unit weight of water/material dry density}) - (1 - \text{material specific gravity}))$$

- The density of a sample in g/cc is converted to pcf by multiplying the unit weight of water (62.4 pcf).
- The Rawls & Brakensiek equation referenced in the NRC Regulatory Guide 3.64 (NRC 1989b) can be used to estimate the 15 bar moisture content as a reasonable lower bound of long-term moisture content. The equation is:

$$\text{15 bar moisture content} = 0.026 + 0.005z + 0.0158y$$

where: z = percent clay in the soil
y = percent organic matter in the soil

For example, the calculated 15 bar moisture content of the alluvial site materials, which have a mean clay content of 18.63 percent and a mean organic matter content of 0.28 percent is:

$$\text{15 bar moisture content} = 0.026 + 0.005(18.23) + 0.0158(0.28)$$
$$\text{15 bar moisture content} = 0.075\text{, or 7.5 percent}$$

The individual RADON model (NRC 1989a) output files, which include the input parameter values for each model layer, are included in Appendix A. Appendix B provides additional calculations and data supporting development of the input parameters.

Discussion:

Two general cover configurations were considered: a “typical” UMTRA-style cover consisting of a compacted, native-clay radon barrier (see Figure 1), and an alternative cover design using a monolithic cover of loosely compacted native materials (see Figure 2). It has been assumed as a best management practice that a 1-ft-thick interim cover of clean native materials will be placed on the RRM to control wind transport of fine material and to provide for a relatively clean and uniform work surface on which the radon barrier will be constructed.

The radon barrier layers have been optimized by the RADON model to limit the radon flux to 20 pCi/m^2/sec under long-term moisture content conditions. As with previous UMTRA Title I cover designs, the attenuation of radon by the drainage layer or frost protection layers are not considered in these analyses, though these layers will further reduce the radon flux rate at the Disposal Cell surface. An additional model run was performed for the UMTRA cover to illustrate the calculated radon barrier thickness required, should the attenuation of radon by the frost protection layer be considered.

Clean fill embankments made of native materials will be used around the perimeter of the new disposal cell constructed with 5H:1V exterior side slopes and a minimum 30-ft-wide crest. Consequently, the tailings side slope thicknesses will be far in excess of the cover requirements.

Several model sensitivity runs were performed for the UMTRA cover design to illustrate the sensitivity of the calculated radon barrier thickness to the thickness of the interim cover and to the long-term tailings moisture content. Model sensitivity runs were also performed for the alternative cover to illustrate the sensitivity of the calculated radon barrier thickness to the long-term tailings moisture content.

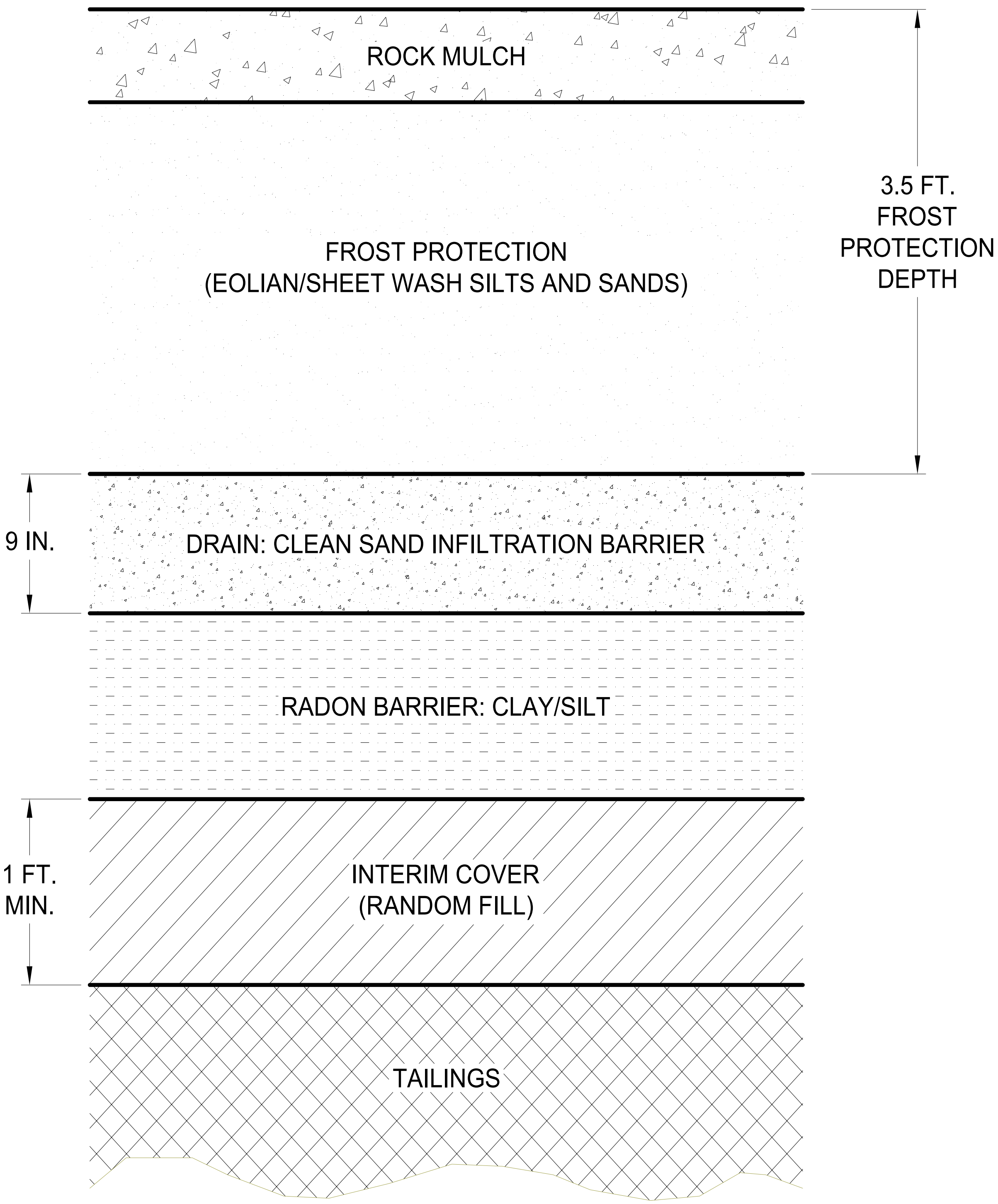


Figure 1. UMTRA Checklist Top Cover

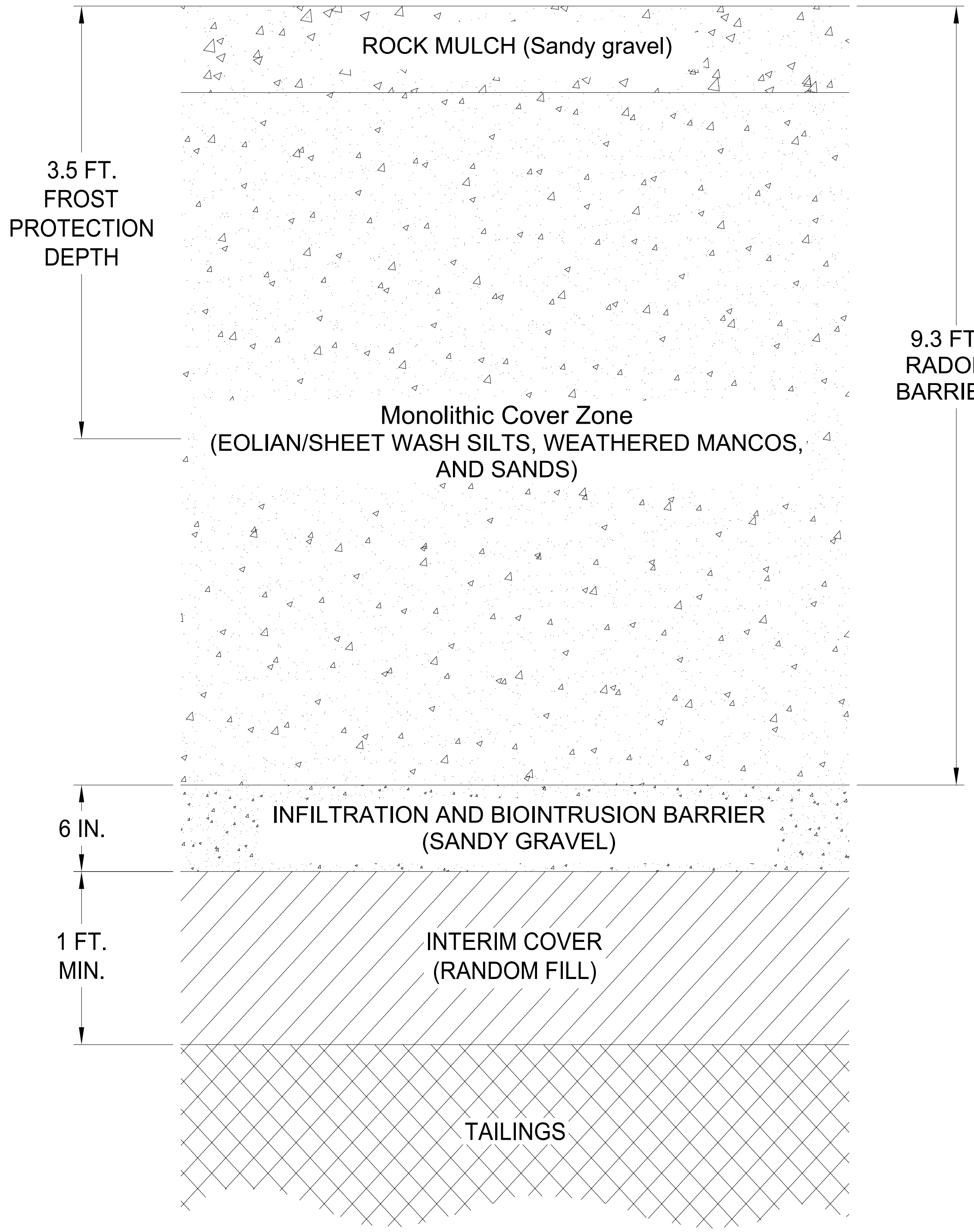


Figure 2. Alternative Top Cover

UMTRA-Style Cover

The current conceptual design of the UMTRA cover system consists of 1 ft of interim cover on the tailings surface below the compacted-clay radon barrier consisting of clean, native materials placed as a best management practice to control wind transport of fine material and to provide for a relatively clean, uniform work surface upon which to construct the radon barrier. The model is used to optimize the layer thickness of the compacted-clay radon barrier. Several model runs were performed to assess model sensitivity to certain variables as described below.

- Model run UMTRA 1a uses mean input values for the UMTRA style cover with a 1-ft-thick interim cover.
- Model runs UMTRA 1b through UMTRA 1d are sensitivity runs to illustrate the effect of the interim cover thickness on the calculated radon barrier thickness to meet the 20 pCi/m^2/s flux requirement.
  - Model run UMTRA 1b is the same as run UMTRA 1a but with a 3-ft-thick interim cover.
  - Model run UMTRA 1c is the same as run UMTRA 1a but with a 5-ft-thick interim cover.
  - Model run UMTRA 1d is the same as run UMTRA 1a but with a 7-ft-thick interim cover.
- Model run UMTRA 2a is a sensitivity run illustrating the calculated radon barrier thickness required should the attenuation of radon by the freeze/thaw protection layer be considered.
- Model runs UMTRA 3a and UMTRA 3b are sensitivity runs illustrating the effect of tailings moisture content on the calculated radon barrier thickness.
  - Model run UMTRA 3a is the same as UMTRA 1a but with the tailings moisture content set to 10 percent.
  - Model run UMTRA 3a is the same as UMTRA 1a but with the tailings moisture content set to 20 percent.

Alternative Cover

The alternative cover system design consists of 1 ft of interim cover, a 6-inch-thick capillary break layer and a monolithic radon-barrier layer. However, because the capillary barrier is very coarse grained and will have very low long-term moisture content, experience has shown that its influence on radon attenuation is minimal. Therefore, it has conservatively been omitted from the model runs.

The alternative cover uses a monolithic soil layer placed at a density similar to existing native soils conditions and is modeled under conservative long-term soil moisture conditions. Therefore, a frost protection layer is not needed to protect it from changes due to seasonal freeze/thaw cycles.

This monolithic soil layer will also be covered by a rock mulch designed to resist wind and surface water runoff erosional forces under the Probable Maximum Flow (PMF) event, ensuring that the layer endures as an integral unit for the design life of the disposal cell. Several model runs were performed to assess model sensitivity to certain variables as described below.

- Model run Alt 1a uses mean input values for the alternative cover.
- Model runs Alt 1b and Alt 1c are sensitivity runs illustrating the effect of tailings moisture content on the calculated radon barrier thickness.
  - Model run Alt 1b is the same as Alt 1a but with the tailings moisture content set to 10 percent.
  - Model run Alt 1b is the same as Alt 1a but with the tailings moisture content set to 20 percent.

Description of Model and Input Values

Radon emanation calculations from a multilayered cover system were made with the RADON model, a one-dimensional model that calculates radon flux from decay of a radium-226 (Ra-226) source (such as the tailings). The key input parameters to the model include:

- Layer thickness.
- Porosity.
- Mass density.
- Ra-226 activity concentration.
- Emanation coefficient.
- Weight percent moisture.
- Coefficient of radon diffusion.

Only those material layers including the radon barrier and below are modeled. This ensures that the radon barrier alone can meet the long-term average radon flux requirement of 20 $pCi/m^2/s$, without the additional attenuation provided by overlying layers such as freeze/thaw protection layers or rock mulch layers. The input parameters and values used in the model are outlined below. Table 1 summarizes the individual input parameters used for all of the models run and their bases and the results of the model runs. Figure 1 and Figure 2 illustrate the UMTRA checklist cover and the alternative cover design configurations. Appendix A presents the RADON model output files. Appendix B presents all raw data used in developing the model input parameters.

Layer Thickness

The layers and material sequences for the UMTRA cover and the alternative cover are illustrated in Figure 1 and Figure 2, respectively, and represent the geometries of the tailings and of each cover-layer component. Therefore, radon flux through the side slopes was not modeled. For all model runs, a tailings thickness of 500 centimeters (cm) is used; the model output is insensitive to source term thicknesses greater than 500 cm.

The UMTRA cover design evaluated for radon flux consists of an a 1-ft-thick interim cover constructed of clean native alluvium and a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale. The overlying sand drainage/biointrusion layer, frost protection layer and rock mulch erosion protection layer are not considered in the base-line modeling consistent with the historic UMTRA design approach. However, an additional model run was performed for the UMTRA cover to illustrate the calculated radon barrier thickness required should the attenuation of radon by the 3.5-ft-thick frost protection layer be considered.

The alternative cover design evaluated for radon flux consists of the same interim cover as used for the UMTRA cover. A monolithic radon barrier consisting of the same materials as the interim cover placed at the same densities overlies the interim cover. The sand drainage layer is not considered in the modeling as it has a high porosity, low long-term moisture content and would not significantly add to the attenuation characteristics of the cover.

Table 1. Crescent Junction Disposal Cell Radon Barrier Design, RADON Model Runs Summary

Model Run	**Layer Type**	**Layer Thickness (cm)**	**Layer Thickness (ft)**	**Porosity**	**Density (g/cc)**	**Ra-226 Activity (pCi/g)**	**Gravimetric Moisture Content (%)**	**Moisture Saturation Fraction (%)**	**Calculated Diffusion Coefficient (m^2/s)**	**Notes**
(Appendix B data reference)		Prescribed	Prescribed	Table 2	Table 2	Table 3	Table 4	Table 5	Table 5	
Alt 1a	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	Alt. cover, baseline model run, mean input parameters
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**284.4**	**9.3**	0.38	1.66	1.9	9	39.4%	1.629E-02	
Alt 1b	Tailings	500	16.4	0.44	1.57	707	10	35.6%	1.873E-02	Alt. Cover, sensitivity Run, baseline model w/ Tailings Moisture content = 10%
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**288.5**	**9.5**	0.38	1.66	1.9	9	39.4%	1.629E-02	
Alt 1c	Tailings	500	16.4	0.44	1.57	707	20	71.2%	3.541E-03	Alt. Cover, sensitivity Run, baseline model w/ Tailings Moisture content = 20%
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**261**	**8.6**	0.38	1.66	1.9	9	39.4%	1.629E-02	
UMTRA 1a	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	UMTRA Cover, baseline model run, mean input parameters Interim Cover = 1-ft thick
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**119.8**	**3.9**	0.33	1.77	2.3	12	64.4%	4.636E-03	
UMTRA 1b	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	UMTRA Cover, sensitivity run, baseline model w/ Interim Cover = 3-ft thick
	Interim Cover	91.5	3.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**86.4**	**2.8**	0.33	1.77	2.3	12	64.4%	4.636E-03	
UMTRA 1c	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	UMTRA Cover, sensitivity run, baseline model w/ Interim Cover = 5-ft thick
	Interim Cover	152.5	5.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**55.1**	**1.8**	0.33	1.77	2.3	12	64.4%	4.636E-03	

Table 1 (continued). Crescent Junction Disposal Cell Radon Barrier Design, RADON Model Runs Summary

Model Run	**Layer Type**	**Layer Thickness (cm)**	**Layer Thickness (ft)**	**Porosity**	**Density (g/cc)**	**Ra-226 Activity (pCi/g)**	**Gravimetric Moisture Content (%)**	**Moisture Saturation Fraction (%)**	**Calculated Diffusion Coefficient (m^2/s)**	**Notes**
(Appendix B data reference)		Prescribed	Prescribed	Table 2	Table 2	Table 3	Table 4	Table 5	Table 5	
UMTRA 1d	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	UMTRA Cover, sensitivity run, baseline model w/ Interim Cover = 5 ft. thick
	Interim Cover	213.5	7.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**27.9**	**0.9**	0.33	1.77	2.3	12	64.4%	4.636E-03	
UMTRA 2a	Tailings	500	16.4	0.44	1.57	707	15	53.4%	1.044E-02	UMTRA Cover, sensitivity run, baseline model w/ freeze/thaw layer Radon barrier optimized to make radon flux at the surface of the freeze/thaw layer = 20 pCi/m^2/sec
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**81.72**	**2.7**	0.33	1.77	2.3	12	64.4%	4.636E-03	
	Freeze/ Thaw Layer	106.8	3.5	0.38	1.66	1.9	9	39.4%	1.629E-02	
UMTRA 3a	Tailings	500	16.4	0.44	1.57	707	10	35.6%	1.873E-02	UMTRA Cover, sensitivity Run, baseline model w/ Tailings Moisture content = 10%
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**119.1**	**3.9**	0.33	1.77	2.3	12	64.4%	4.636E-03	
UMTRA 3b	Tailings	500	16.4	0.44	1.57	707	20	71.2%	3.541E-03	UMTRA Cover, sensitivity Run, baseline model w/ Tailings Moisture content = 20%
	Interim Cover	30.5	1.0	0.38	1.66	1.9	9	39.4%	1.629E-02	
	Radon Barrier	**111.7**	**3.7**	0.33	1.77	2.3	12	64.4%	4.636E-03	

Porosity (n)

The porosity of the layer materials have been calculated based on the dry density and the specific gravity of the specific materials according to the equation identified in the previous section.

The porosity of the tailings was modeled as 0.44, given a mean specific gravity of 2.8 for the tailings based on the data in the “Geotechnical Laboratory Testing Results for the Moab Processing Site” calculation (RAP Attachment 5, Vol. I, Appendix J), and a designed placement density of 1.57 g/cc (98 pcf).

The porosity of the interim cover and the monolithic layer of the alternative cover, to be developed from the alluvial silty sands and sheetwash deposits overlying the in-situ weathered Mancos Shale, was modeled as 0.38, given a mean specific gravity of 2.65—based on nine samples presented in the “Geotechnical Properties of Native Materials” calculation (RAP Attachment 5, Vol. I, Appendix E) and Appendix B—and a designed placement density of 1.66 g/cc (103 pcf). These two layers will be constructed of the same on-site materials from the Crescent Junction Site and will be placed in the same conditions. The porosity of the frost protection layer was modeled assuming the same conditions as the interim cover material.

The porosity of the compacted Mancos Shale was modeled as 0.33, given a mean specific gravity for the Mancos Shale of 2.65—based on the data in the “Geotechnical Properties of Native Materials” calculation (RAP Attachment 5, Vol. I, Appendix E) and Appendix B—and a designed placement density of 1.77 g/cc (111 pcf).

Mass Density

The dry density of the tailings as placed has been modeled as 1.57 g/cc (98 pcf), which is 90 percent of the mean standard Proctor maximum dry density of transition tailings materials as reported in the Draft Tech Memo by Golder Associates (2006b).

The density of the interim cover materials and the alternative cover monolithic layer, as placed, has been modeled as 1.66 g/cc (103 pcf), which is 85 percent of the mean modified Proctor dry density value (121.8 pcf) for these materials as developed in the “Geotechnical Properties of Native Materials” calculation (RAP Attachment 5, Vol. I, Appendix E). The density of the frost protection layer has been modeled as the same as the interim cover materials. Because these materials will be installed using more energy and in a different manner than the native in-situ alluvial materials, it is anticipated that the frost protection layer will have long-term density more representative of the as-placed conditions than the native in-situ material conditions.

The density of the compacted clay materials and the UMTRA-style cover, as placed, has been modeled as 1.77 g/cc (111 pcf), which is 90 percent of the mean modified Proctor dry density value (123 pcf) for these materials, as developed in the “Geotechnical Properties of Native Materials” calculation (RAP Attachment 5, Vol. I, Appendix E).

Radium Activity Concentration

The Ra-226 activity concentration values used in the model for each specific material are outlined below.

Tailings

Radium-226 concentrations for the tailings pile materials were assessed based on 94 samples of tailings sands, slimes, transitional tailings and other contaminated materials. Radium-226 analyses were performed by gamma spectroscopy from these locations. The estimated volumes of tailings material are provided in the “Volume Calculation for the Moab Tailings Pile,” calculation (RAP Attachment 1, Appendix I). The average Ra-226 activity for the contaminated materials is 707 picocuries per gram (pCi/g), with values ranging from 2 to 2,195 pCi/g, as developed in the “Average Radium-226 Concentrations for the Moab Tailings Pile,” calculation (RAP Attachment 1, Appendix K) (see also Appendix B of this calculation).

The current conceptual plan for tailings removal and placement would entail a significant amount of blending of lower-activity beach sands and higher-activity slimes. Therefore, no layering of the tailings source term has been modeled, and a single activity value has been used. However, it is highly likely that lower-activity contaminated sub-pile soils and contaminated soils from the mill site and cleanup of peripheral and vicinity properties will be placed above the higher activity tailings, which would serve to further reduce Ra-226 activity at the base of the cover. The tailings source term activity, as well as the actual cover materials properties site, should be reevaluated once delivered to ensure that the cover design is optimized for the actual as-built conditions of the cell contents.

Interim Cover and Alternative Cover Monolithic Layer

The Ra-226 activity of the alluvial materials to be used for the interim cover, alternative cover, and the clean-fill perimeter dikes is based on five samples of native materials collected from the Crescent Junction Site as developed in the “Geotechnical Properties of Native Materials” calculation (RAP Attachment 5, Vol. I, Appendix E) (see also Appendix B of this calculation). Samples were collected from alluvial materials and weathered Mancos Shale with depths ranging from 4 to 22 ft below the surface. The Ra-226 activity of the alluvial material ranged from 1.4 to 2.3 pCi/g, with a mean value of 1.9 pCi/g.

Compacted Clay Layer

The Ra-226 activity value for the compacted clay layer is based on two samples of Mancos Shale collected from the Crescent Junction Site that will be used to construct the compacted-clay radon barrier and clean-fill perimeter dikes (see Appendix B). Samples were collected from weathered Mancos Shale samples with depths of approximately 20 to 22 ft below the surface. The Ra-226 activity of the weathered Mancos Shale ranged from 1.6 to 3.0 pCi/g, with a mean value of 2.3 pCi/g.

Radon Emanation Coefficient

A radon-emanation coefficient of 0.35 was used for all of the tailings, random fill, and cover materials. This is the conservative default value used in the RADON model.

Long-Term Weight Percent Moisture

The mean weight percent moisture of the tailings has been modeled as 15 percent, which is in the typical range for tailings and is below that value used for the modeling of the Grand Junction UMTRA Site (18 percent). Sensitivity analyses for the influence of long-term tailings moisture content were used to evaluate the influence of this parameter on predicted radon barrier thicknesses. Values of 10 percent moisture content and 20 percent moisture content were modeled. The results of the sensitivity analyses are discussed in the “Conclusion and Recommendations” section.

The mean long-term gravimetric moisture content of the interim cover and the alternative cover monolithic layer is modeled as 9 percent. This value is based on the mean of 20 measured 15 bar tests as determined by ASTM Method D3152 and presented in the “Supplemental Geotechnical Properties of Native Materials” calculation (Attachment 5, Vol. I, Appendix K). This mean measured value was evaluated for reasonableness using the Rawls and Brakensiek equation as presented in the NRC Regulatory Guide 3.64 (NRC 1989b). The Rawls and Brakensiek equation is a simplified empirical relationship based on the correlation of measured 15-bar moisture contents to the percent clay and organic matter in a range of soils. However, this relationship is not considered as reliable as the site-specific test data, and is considered as confirmatory information only. The calculated value, using the mean percent clay of eight alluvial samples and the percent organic matter of six alluvial samples, is 7.5 percent, which agrees well with the measured value of site-specific soils, or 9 percent. These data and calculations are summarized in Appendix B.

The mean long-term moisture content of the compacted clay derived from the on-site weathered Mancos Shale is modeled as 12 percent. This value is based on the mean of 12 measured 15 bar moisture content (12.1 percent) as determined by ASTM Method D3152 and presented in “Supplemental Geotechnical Properties of Native Materials” calculation (Attachment 5, Vol. I, Appendix K). This mean measured value was also evaluated for reasonableness using the Rawls and Brakensiek equation as presented in the NRC Regulatory Guide 3.64 (NRC 1989b). The calculated value is 12.4 percent, which agrees well with the measured value of site-specific soils, or 9 percent. These data and calculations are summarized in Appendix B.

In-situ moisture content for weathered Mancos was not included in the calculation of the mean, as in-situ moisture contents are not representative of remolded weathered Mancos. Long-term moisture content of the remolded weathered Mancos are better represented by the calculated and measured 15 bar moisture content test values due to the significantly different fabric the material will have as placed in the cell cover.

Radon-Diffusion Coefficient

The radon-diffusion coefficient used in the RADON model can either be calculated within the model (based on an empirical relationship with degree of saturation and porosity) or input directly into the model using values measured from laboratory testing. However, the radon diffusion equations in the 1989 version of RADON are not consistent with the later equations based on a much larger set of data correlating radon diffusion with soil cover materials. Therefore, this evaluation calculated the layer specific radon diffusion coefficients based on equation 9 from Rogers and Nielson (1991) as described in the “Calculation” section, above. The applied diffusion coefficients are presented in Table 1. These calculations are presented in Appendix B.

Radon in Ambient Air

The ambient air radon concentrations above the radon-barrier layer are assumed to be zero (0) in absence of site-specific data.

Conclusion and Recommendations:

- Based on the model runs developed in this evaluation, both design approaches are capable of meeting the requisite reasonable assurance of providing long-term control of radon flux to the specific average of 20 pCi/m^2/sec.
- As shown in Table 1, the compacted-clay radon barrier of the UMTRA checklist-type cover under the modeled conditions can vary from 0.9 to 3.9 ft, depending on the thickness of the interim cover. Model runs UMTRA 1a through UMTRA 1d varied the thickness of the interim cover from 1 ft to 7 ft in 2-ft increments. Figure 3 illustrates the relationship between interim cover thickness and calculated compacted clay radon barrier thickness. These data are also summarized in Appendix B.
- The compacted-clay radon barrier of the UMTRA checklist-type cover is relatively insensitive to the long-term moisture content of the tailings. Model run UMTRA 3a used a long-term tailings moisture contents of 10 percent and resulted in essentially no change in calculated cover thickness, indicating that potential drying of the contaminated materials below the anticipated baseline moisture content of 15 percent would not result in radon flux in excess of the standard. In addition, Model run UMTRA 3a used a long-term tailings moisture content of 20 percent and resulted in 8 percent decrease in the calculated radon barrier thickness.
- The alternative cover radon barrier thickness is calculated to be 9.3 ft, assuming a 1-ft-thick interim cover. The interim cover materials and the alternative cover materials are essentially the same and are to be placed to essentially the same conditions. Therefore, the relationship between interim cover thickness and calculated alternative cover radon barrier thickness is of little value, and no sensitivity runs to evaluate this relationship were performed.
- Like the UMTRA checklist cover, the alternative cover radon barrier is also relatively insensitive to the long-term moisture content of the tailings. Model run Alt 1b used a long-term tailings moisture contents of 10 percent and resulted in an approximate 1 percent increase in calculated cover thickness, indicating that potential drying of the contaminated materials below the anticipated baseline moisture content of 15 percent would not significantly result in radon flux in excess of the standard. In addition, Model run Alt 1c used a long-term tailings moisture content of 20 percent and resulted in 7 percent decrease in the calculated radon barrier thickness.

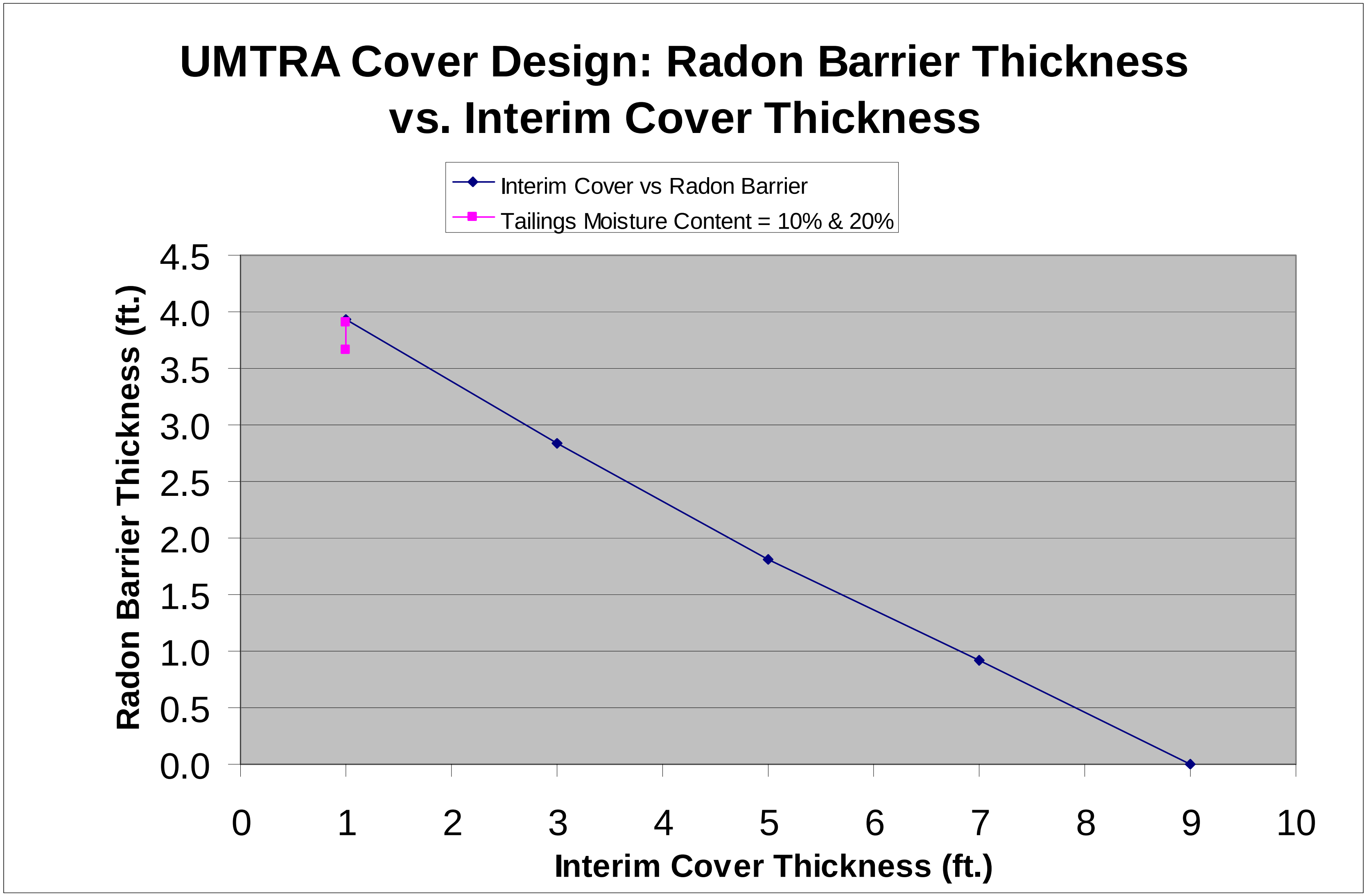


Figure 3. UMTRA Cover Design: Radon Barrier Thickness vs. Interim Cover Thickness

- Because the geometry and material properties (e.g., activity, grain size distribution, etc.) of contaminated materials placed in the cell may differ from that considered herein, it is recommended that three actions occur during construction and prior to placement of the radon barrier:
  - Additional testing of Ra-226 activity for the contaminated materials placed in the upper 10 ft of the cell.
  - Additional testing of long-term moisture content of materials stockpiled for construction of the radon barrier.
  - The radon barrier be re-optimized if any of the design assumptions differ from those considered herein.

Computer Source:

See NRC 1989a, below.

References:

DOE (U.S. Department of Energy), 1989. *Technical Approach Document, Revision II*, UMTRA-DOE/AL 050425.0002, U.S. Department of Energy, Uranium Mill Tailings Remedial Action Project, December.

Golder Associates, 2006a. Bench Scale Testing Program on Uranium Mill Tailings, April.

Golder Associates, 2006b. Draft Tech Memo, April 3.

NRC (Nuclear Regulatory Commission), 1989a. *Staff Technical Position, Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites*, February 24.

NRC (Nuclear Regulatory Commission), 1989b. *Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers,* Regulatory Guide 3.64.

Rogers, V.C., and K.K. Nielson, 1991. "Correlations for Predicting Air Permeabilities and ^{222}Rn Diffusion Coefficients of Soils," *Health Physics*, 61(2), pp. 235–230.

Rogers, V.C., K.K. Nielson, and D.R. Kalkwarf, 1984. *Radon Attenuation Handbook for Uranium Mill Tailings Cover Design,* NUREG/CR-3533, prepared for U.S. Nuclear Regulatory Commission (NRC), April.

Appendix A

RADON Model Output Files

```
          -----*****! RADON !****-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000
U.S. Nuclear Regulatory Commission Office of Research

     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Alt 1a

DESCRIPTION: alternative cover, mean input values, 1-ft thick interim cover


       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          868     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    2.276D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             15      %
MOISTURE SATURATION FRACTION        .535
MEASURED DIFFUSION COEFFICIENT       .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.95     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.261D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01637    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.95     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.261D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01637    cm^2 s^-1





       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00    3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 2.276D-03 5.352D-01 1.570
 2  3.050D+01 1.637D-02 3.800D-01 6.261D-06 3.932D-01 1.660
 3  1.000D+01 1.637D-02 3.800D-01 6.261D-06 3.932D-01 1.660


BARE SOURCE FLUX FROM LAYER 1: 7.056D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  3.943D+02  4.786D+05
        2   3.050D+01  2.793D+02  3.984D+05
        3   3.038D+02  1.998D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Alt 1b

DESCRIPTION: alternative cover, Sensitivity run, mean input values, Tailings
             moisture content = 10%

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             10      %
MOISTURE SATURATION FRACTION        .357
MEASURED DIFFUSION COEFFICIENT       .01873    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1




       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
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LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.873D-02 4.400D-01 1.854D-03 3.568D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660


BARE SOURCE FLUX FROM LAYER 1: 7.666D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  3.358D+02  4.981D+05
        2   3.050D+01  2.377D+02  3.400D+05
        3   2.885D+02  1.998D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: Alt 1c

DESCRIPTION: alternative cover, Sensitivity run, mean input values, Tailings
             moisture content = 20%

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             20      %
MOISTURE SATURATION FRACTION        .714
MEASURED DIFFUSION COEFFICIENT       .003541   cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9       %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1





       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 3.541D-03 4.400D-01 1.854D-03 7.136D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660


BARE SOURCE FLUX FROM LAYER 1: 3.350D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  2.461D+02  2.342D+05
        2   3.050D+01  1.743D+02  2.494D+05
        3   2.610D+02  1.998D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 1a

DESCRIPTION: UMTRA Cover, mean input parameters, 1-ft thick interim cover


       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT           20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE              15      %
MOISTURE SATURATION FRACTION         .535
MEASURED DIFFUSION COEFFICIENT        .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE              9      %
MOISTURE SATURATION FRACTION         .393
MEASURED DIFFUSION COEFFICIENT        .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .33
MEASURED MASS DENSITY           1.77     g cm^-3
MEASURED RADIUM ACTIVITY          2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             12      %
MOISTURE SATURATION FRACTION        .644
MEASURED DIFFUSION COEFFICIENT       .004636   cm^2 s^-1




       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
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LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 1.854D-03 5.352D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 5.748D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  2.496D+02  4.998D+05
        2   3.050D+01  1.197D+02  4.967D+05
        3   1.198D+02  1.999D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 1b

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, 3 feet
thick              interim cover

       CONSTANTS

RADON DECAY CONSTANT           .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             15      %
MOISTURE SATURATION FRACTION        .535
MEASURED DIFFUSION COEFFICIENT       .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 91.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                   10      cm
POROSITY                   .33
MEASURED MASS DENSITY            1.77     g cm^-3
MEASURED RADIUM ACTIVITY           2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE               12      %
MOISTURE SATURATION FRACTION         .644
MEASURED DIFFUSION COEFFICIENT        .004636   cm^2 s^-1






       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 1.854D-03 5.352D-01 1.570
 2  9.150D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 5.748D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  3.037D+02  4.168D+05
        2   9.150D+01  6.024D+01  2.422D+05
        3   8.643D+01  2.001D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 1c

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, 5 feet
thick              interim cover


       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             15      %
MOISTURE SATURATION FRACTION        .535
MEASURED DIFFUSION COEFFICIENT       .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 152.5    cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .33
MEASURED MASS DENSITY           1.77     g cm^-3
MEASURED RADIUM ACTIVITY          2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             12      %
MOISTURE SATURATION FRACTION        .644
MEASURED DIFFUSION COEFFICIENT       .004636   cm^2 s^-1





       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 1.854D-03 5.352D-01 1.570
 2  1.525D+02 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 5.748D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  3.169D+02  3.965D+05
        2   1.525D+02  3.339D+01  1.171D+05
        3   5.511D+01  2.002D+01  0.000D+00
```

```
          -----*****! RADON !*****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 1d

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, 7 feet
thick              interim cover

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             15      %
MOISTURE SATURATION FRACTION        .535
MEASURED DIFFUSION COEFFICIENT       .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 213.5    cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9       %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                   10      cm
POROSITY                    .33
MEASURED MASS DENSITY             1.77     g cm^-3
MEASURED RADIUM ACTIVITY           2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE               12      %
MOISTURE SATURATION FRACTION        .644
MEASURED DIFFUSION COEFFICIENT       .004636   cm^2 s^-1






       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 1.854D-03 5.352D-01 1.570
 2  2.135D+02 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 5.748D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  3.201D+02  3.916D+05
        2   2.135D+02  2.276D+01  5.130D+04
        3   2.790D+01  2.001D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 2a

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, frost
             protection layer contributes to radon attenuation

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        4
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             15      %
MOISTURE SATURATION FRACTION        .535
MEASURED DIFFUSION COEFFICIENT       .01044    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9       %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                  10      cm
POROSITY                   .33
MEASURED MASS DENSITY            1.77     g cm^-3
MEASURED RADIUM ACTIVITY          2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE              12      %
MOISTURE SATURATION FRACTION        .644
MEASURED DIFFUSION COEFFICIENT       .004636   cm^2 s^-1


LAYER 4    Frost Protection


THICKNESS                  106.8    cm
POROSITY                   .38
MEASURED MASS DENSITY            1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE              9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1




       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 4  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX      D      P      Q      XMS   RHO
 1  5.000D+02 1.044D-02 4.400D-01 1.854D-03 5.352D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770
 4  1.068D+02 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
```

```
BARE SOURCE FLUX FROM LAYER 1: 5.748D+02 pCi m^-2 s^-1


       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  2.509D+02  4.978D+05
        2   3.050D+01  1.217D+02  4.936D+05
        3   8.172D+01  3.348D+01  3.043D+04
        4   1.068D+02  2.000D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 3a

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, tailings
             moisture content = 10%

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION          .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             10      %
MOISTURE SATURATION FRACTION        .357
MEASURED DIFFUSION COEFFICIENT       .01873    cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                   10      cm
POROSITY                   .33
MEASURED MASS DENSITY             1.77     g cm^-3
MEASURED RADIUM ACTIVITY           2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE               12      %
MOISTURE SATURATION FRACTION         .644
MEASURED DIFFUSION COEFFICIENT        .004636   cm^2 s^-1




       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D      P      Q      XMS   RHO
 1  5.000D+02 1.873D-02 4.400D-01 1.854D-03 3.568D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 7.666D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  2.462D+02  6.007D+05
        2   3.050D+01  1.181D+02  4.899D+05
        3   1.191D+02  1.999D+01  0.000D+00
```

```
          -----*****! RADON !****-----

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     RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS             ARE
CALCULATED FOR MULTIPLE LAYERS

OUTPUT FILE: UMTRA 3b

DESCRIPTION: UMTRA Cover, Sensitivity run, mean input parameters, tailings
             moisture content = 20%

       CONSTANTS

RADON DECAY CONSTANT            .0000021   s^-1
RADON WATER/AIR PARTITION COEFFICIENT   .26
DEFAULT SPECIFIC GRAVITY OF COVER & TAILINGS       2.65


       GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS        3
DEFAULT RADON FLUX LIMIT          20      pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED      3
DEFAULT SURFACE RADON CONCENTRATION    0      pCi l^-1
SURFACE FLUX PRECISION           .001     pCi m^-2 s^-1


       LAYER INPUT PARAMETERS

LAYER 1    Tailings


THICKNESS                 500     cm
POROSITY                  .44
MEASURED MASS DENSITY           1.57     g cm^-3
MEASURED RADIUM ACTIVITY          707     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    1.854D-03  pCi cm^-3 s^-1
WEIGHT % MOISTURE             20      %
MOISTURE SATURATION FRACTION        .714
MEASURED DIFFUSION COEFFICIENT       .003541   cm^2 s^-1


LAYER 2    Interim Cover


THICKNESS                 30.5     cm
POROSITY                  .38
MEASURED MASS DENSITY           1.66     g cm^-3
MEASURED RADIUM ACTIVITY          1.9     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    6.100D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             9      %
MOISTURE SATURATION FRACTION        .393
MEASURED DIFFUSION COEFFICIENT       .01629    cm^2 s^-1
```

```
LAYER 3    Radon Barrier


THICKNESS                 10      cm
POROSITY                  .33
MEASURED MASS DENSITY           1.77     g cm^-3
MEASURED RADIUM ACTIVITY          2.3     pCi/g^-1
DEFAULT LAYER EMANATION COEFFICIENT    .35
CALCULATED SOURCE TERM CONCENTRATION    9.067D-06  pCi cm^-3 s^-1
WEIGHT % MOISTURE             12      %
MOISTURE SATURATION FRACTION        .644
MEASURED DIFFUSION COEFFICIENT       .004636   cm^2 s^-1




       DATA SENT TO THE FILE `RNDATA' ON DRIVE A:

 N    F01    CN1    ICOST   CRITJ    ACC
 3  -1.000D+00 0.000D+00   3   2.000D+01 1.000D-03

LAYER   DX     D     P     Q     XMS   RHO
 1  5.000D+02 3.541D-03 4.400D-01 1.854D-03 7.136D-01 1.570
 2  3.050D+01 1.629D-02 3.800D-01 6.100D-06 3.932D-01 1.660
 3  1.000D+01 4.636D-03 3.300D-01 9.067D-06 6.436D-01 1.770


BARE SOURCE FLUX FROM LAYER 1: 3.350D+02 pCi m^-2 s^-1



       RESULTS OF THE RADON DIFFUSION CALCULATIONS


       LAYER  THICKNESS  EXIT FLUX  EXIT CONC.
             (cm)  (pCi m^-2 s^-1) (pCi l^-1)

        1   5.000D+02  2.103D+02  3.287D+05
        2   3.050D+01  1.011D+02  4.179D+05
        3   1.117D+02  1.998D+01  0.000D+00
```

Appendix B

Supporting Calculations and Data

Table B–1. Moab Project, Crescent Junction Native Materials Index Test Results Summary

Geotechnical Testing Data from the “Geotechnical Properties of Native Materials” Calculation (RAP Attachment 5, Appendix E)

Sample	**No.**	**Field Description**	**Test Depth (ft)**	**Natural Moisture (%)**	**Dry Density (pcf)**	**Liquid Limit (%)**	**Plasticity Index (%)**	**Passing No. 200 (%)**	**Specific Gravity**	**□$_{max}$ (Modified Proctor) (pcf)**	**□$_{max}$ (Modified Proctor) (g/cc)**	**w_{opt} (Modified Proctor) (%)**	**Sieve**			**Hydrometer**		**% Organic Matter**	**Double Hydro-meter**	**Ra-226 (pCi/g)**
													% Gravel	% Sand	% Fines	% silt	% clay			
BH	031	Clay, sandy, silty L/SC)	12	8.2	96.0	24	4	50												
BH	007	Clay, silty sandy (CL)	7	4.9		23	8	94												
BH	007	Clay, silty sandy (CL)	10.5	4.5	100.0	21	9	62												
BH	045	Clay, silty sandy (CL)	1.5	4.6	84.0	19	7	57												
BH	005	Clay, silty sandy (CL)	2	4.2	91.0	21	4	69												
BH	011	Clay, silty sandy (CL)	2	6.1	83.0	22	9	78												
BH	064	Clay, silty, sandy (CL)	2	12.4	95.0	34	5	74												
BH	068	Clay, silty, sandy (CL)	2	4.2	94.0	21	6	36												
BH	092	Clay, silty, sandy (CL)	2	5.7	87.0	22	9	63												
BH	013	Clay, silty sandy (CL)	2.5	5.8	89.0	24	9	70												
BH	080	Clay, silty, sandy (CL)	3	2.8	95.0	19	5	53												
BH	023	Clay, silty sandy (CL)	3.5	6.0		25	8	72												
BH	043	Clay, silty, sandy (CL)	3.5	6.1	90.0	25	8	53												
BH	051	Clay, silty, sandy (CL)	3.5	3.8	85.0	20	6	57												
BH	066	Clay, silty, sandy (CL)	3.5	4.7	90.0	21	5	53												
BH	100	Clay, silty sandy (CL)	4	8.0		25	5	69												
BH	009	Clay, silty sandy (CL)	4	6.6	83.0	24	9	74												
BH	062	Clay, silty, sandy (CL)	4	7.6	103.0	29	10	69												
BH	094	Clay, silty, sandy (CL)	4	12.2	89.0	31	10	61												
BH	031	Clay, silty, sandy (CL)	5.5	7.0	87.0	25	9	85												
BH	025	Clay, silty, sandy (CL)	6	4.9	89.0	24	9	59												
BH	007	Clay, silty sandy (CL)	6.5	6.5		23	5													
BH	045	Clay, silty, sandy (CL)	6.5	8.6	98.0	32	9	78												
BH	049	Clay, silty, sandy (CL)	6.5	6.0	83.0	20	6	62												
BH	029	Clay, silty, sandy (CL)	7	13.4	77.0	23	6	77												
BH	078	Clay, silty, sandy (CL)	7	5.7	85.0	23	7	70												
BH	080	Clay, silty, sandy (CL)	7	6.0	89.0	24	7	65												
BH	095	Clay, silty, sandy (CL)	7	6.5	85.0	23	7	46												
BH	049	Clay, silty, sandy (CL)	12	5.4	102.0	19	5	80												
BH	082	Clay, silty, sandy (CL)	12	4.7	91.0	21	8	79												
BH	025	Clay, silty sandy (CL)	16.5	7.3	106.0	21	6	66												
BH	027	Clay, silty, sandy (CL)	16.5	8.4	108.0	24	11	87												
BH	094	Clay, silty, sandy (CL)	17	7.1	102.0	20	5	37												
TP	153	Clay, silty, sandy (CL)	3.5	5.7		23	5	72	2.68	120.5	1.93	12.5	0	27	73	60	13			
TP	154	Clay, silty, sandy (CL)	4	7.6		22	4	83		123.0	1.97	12.0	0	16	84	62	22	0.5	79	2.3
TP	151	Clay, silty, sandy (CL)	4.5	5.6		24	5	66		118.5	1.90	13.0	4	30	66					
TP	152	Clay, silty, sandy (CL)	7.5	4.3		26	9	74	2.64	121.0	1.94	13.5	0	25	75	59	16			1.9
TP	154	Clay, silty, sandy (CL)	12	2.7		20	3	63	2.65	122.5	1.96	12.0	0	33	67	40	27	0.2	62	1.6
TP	156	Clay, silty, sandy (CL)	12	2.7		19	2	64	2.64	124.5	1.99	11.0	0	35	65	39	26	0.1	83	2.1
TP	152	Clay, silty, sandy (CL)	15	2.9		21	3	84	2.63	128.0	2.05	10.5	49	22	29	15	14	0.2		1.4

Sample	No.	Field Description	Test Depth (ft)	Natural Moisture (%)	Dry Density (pcf)	Liquid Limit (%)	Plasticity Index (%)	Passing No. 200 (%)	Specific Gravity	$\square_{max}$ (Modified Proctor) (pcf)	$\square_{max}$ (Modified Proctor) (g/cc)	w_{opt} (Modified Proctor) (%)	Sieve			Hydrometer		% Organic Matter	Double Hydro-meter	Ra-226 (pCi/g)
													% Gravel	% Sand	% Fines	% silt	% clay			
TP	156	Clay, silty, sandy (CL)	4-5	7.2			7	69	2.82	120.0	1.92	11.5	1	29	70	54	16		61	
TP liner	156	Eolian	12.25	7.9	88.0	0	0	50												
TP liner	154	Eolian	13	5.7	82.0	20	2	69												
TP	156	Fluvial/eolian	15															0.2		
BH	027	Sand, clayey, silty (SC)	4	5.9		24	3	44												
BH	099	Sand, clayey, silty (C/SM)	2.5	4.8	87.0	18	3	47												
BH	011	Sand, silty gravelly	11.5	2.6		21	4	19												
BH	013	Sandy silt	7	8.3	113.4	0	0	43												
TP	155	Sheetwash	4															0.4		
TP liner	156	Sheetwash	3.5	9.5	89.0	0	0	79												
TP liner	154	Sheetwash	4	9.5	81.0	22	5	81												
TP liner	156	Sheetwash	7.25	6.0	91.0			63										0.3		
TP	153	Silt, sandy, clayey (ML)	8.5	4.4		0	0	67	2.65	118.0	1.89	11.0	1	32	67	52	15			
BH	064	Weathered shale	3.5	10.0	109.0	31	19	86												
BH	043	Weathered shale	6	5.0	93.0	24	16	47												
BH	009	Weathered shale	6.5	6.6	107.2	28	9	84												
BH	066	Weathered shale	7	12.3	112.0	31	10	90												
BH	079	Weathered shale	10.5	4.4		25	10	78												
BH	033	Weathered shale	10.75	6.7	117.0	34	18	82												
BH	005	Weathered shale	11	6.0	118.0	25	10	79												
BH	090	Weathered shale	12	8.2	99.0	22	5	55												
BH	092	Weathered shale	12	7.7	71.0	26	6	71												
BH	026	Weathered shale	15.5	5.7		24	10	71												
BH	011	Weathered shale	16	7.9	119.4	37	20	96												
BH	082	Weathered shale	17	7.1	118.0	34	14	93												
BH	094	Weathered shale	21.5	6.8	112.0	21	4	33												
BH	029	weathered shale	27	6.4	81.0	29	10	81												
TP	154	weathered shale	20	5.5		38	20	95	2.73	120.5	1.93	13.0	0	5	95	55	40		62	1.6
TP	156	Weathered shale	22			25	7	84	2.56	127.5	2.04	11.0	2	14	84	53	31	0.4	86	3.0
TP	152	Weathered shale	23	5.5		33	12	97		121.0	1.94	12.0	0	3	97	55	42			
		Weathered Mancos Shale	**Max**	12.3	119.4	38.0	20.0	97.0	2.73	127.5	2.04	13.0	2.0	14.0	97.0	55.0	42.0	0.4	86.0	3.0
			Min	4.4	71.0	21.0	4.0	33.0	2.56	120.5	1.93	11.0	0.0	3.0	84.0	53.0	31.0	0.4	62.0	1.6
			Mean	**7.0**	**104.7**	**28.6**	**11.8**	**77.8**	**2.65**	**123.0**	**1.97**	**12.0**	**0.7**	**7.3**	**92.0**	**54.3**	**37.7**	**0.4**	**74.0**	**2.3**
			Median	6.7	110.5	28.0	10.0	82.0	2.65	121.0	1.94	12.0	0.0	5.0	95.0	55.0	40.0	0.4	74.0	2.3
			count	16	12	17	17	17	2	3	3	3	3	3	3	3	3	1	2	2
		Alluvium	**Max**	13.4	113.4	34.0	11.0	94.0	2.82	128.0	2.05	13.5	49.0	35.0	84.0	62.0	27.0	0.5	83.0	2.3
		(All Data w/out Weath. Mancos Shale)	**Min**	2.6	77.0	0.0	0.0	19.0	2.63	118.0	1.89	10.5	0.0	16.0	29.0	15.0	13.0	0.1	61.0	1.4
			Mean	**6.3**	**91.3**	**21.1**	**5.8**	**64.8**	**2.67**	**121.8**	**1.95**	**11.9**	**6.1**	**27.7**	**66.2**	**47.6**	**18.6**	**0.3**	**71.3**	**1.9**
			Median	6.0	89.0	22.0	6.0	66.5	2.65	121.0	1.94	12.0	0.0	29.0	67.0	53.0	16.0	0.2	70.5	1.9
			Count	51	36	49	50	50	7	9	9	9	9	9	9	8	8	7	4	5

liner = Brass Liner samples collected in pit side walls

Table B–2. Radon Barrier Design, RAECOM Model Runs, Summary of Key Parameters

Porosity f (G_s)	**No. of Samples**	**Mean Specific Gravity (G_s)**	**No. of Samples**	**Mean Dry Density (g/cc)**	**Porosity**
Alluvium	7	2.67	9	1.66	0.38
Alluvium (in-situ)	7	2.67	36	1.46	0.45
Weathered Mancos	2	2.65	3	1.77	0.33
Tailings	5	2.8	5	1.57	0.44

Long-term Gravimetric Moisture Content (%)	**No. of Samples**	**In Situ**	**Rawls & Brakensiek[3]**	**No. of Samples**	**ASTM D3151 15 bar tests**	**Used**
			Avg		**Avg**	
Alluvium	51	6.3	7.5	20	9.0	91
Weathered Mancos	16	7.0	12.4	12	12.1	122
Tailings	NA	NA	Not Available	Not Available	Not Available	10 ,15, 20

Ra-226 Activity (pCi/g)	**No. of Samples**	**Mean**
Alluvium	5	1.9
Weathered Mancos	2	2.3
Tailings & Contaminated Materials	94	565

Cover Layer	**Calculated Diffusion Coefficient (cm^2/s)**
Tailings (both cover designs)	1.044E-02
Interim Cover (both cover designs)	1.629E-02
Alternative Cover Radon Barrier	1.629E-02
Frost Protection Layer (Alluvium in-situ)	2.869E-02
UMTRA Cover Radon Barrier	4.636E-03

Note:
NA = Not applicable
Mean Dry density as placed for alluvium = 85% of Maximum Dry Density from Modified Proctor Density Tests
Mean Dry density as placed for weathered Mancos = 90% of Maximum Dry Density from Modified Proctor Density Tests
Mean Dry density as placed for tailings = 90% of Maximum Dry Density from Standard Proctor Density Tests
Porosity (n) is calculated form Gs and Dry density by n = 1 - Dry density/(Gs x Unit weight of water)
Unit weight of water is = 1 g/cc
Mean values developed from raw data presented in Table 1

[1] Long-term moisture content of Alluvium based on 20 ASTM D5131 15 Bar moisture tests, calculated value using Rawls & Brakensiek equation (in NRC 1989b) is approximately 1 standard deviation from the mean test value ands is considered confirmatory of the mean value.

[2] In-situ moisture content for weathered Mancos is not included in the calculation of the mean long-term moisture as in-situ moisture contents are not representative of remolded weathered Mancos. Remolded weathered Mancos long-term moisture contents are better represented by the calculated and 15 bar test values due to the significantly different fabric of the material as placed in the cell cover.

[3] Rawls & Brakensiek equation (in NRC 1989b) based on mean values for each material type.

Table B–3. Moab Project, Crescent Junction Disposal Cell Tailings and Other Contaminated Materials Ra-226

No. of Samples	Sample	Depth	Ra-226 Activity (pCi/g)	Material Type	No. of Samples	Sample	Depth	Ra-226 Activity (pCi/g)	Material Type
Transitional Tailings					**Slimes**				
1	BH-701	0-20	400.9	trans	1	PB-2	34-36	782	slime
2	BH-701	20-40	480.8	trans	2	PB-2	54-56	2070	slime
3	BH-703	0-20	457.6	trans	3	437	40.75-41	2194.9	slime
4	BH-703	20-40	610.1	trans	4	438	72.75-73	1891.7	slime
5	BH-705	20-40	616.9	trans	5	439	82-82.25	2157.5	slime
6	BH-709	20-40	546.6	trans	6	AR-10	75-86	588.8	slime
7	BH-713	20-36.5	631.1	trans	7	BH-700	30-60	466.5	slime
8	BH-715	20-40	278.9	trans	8	BH-701	40-60	758.9	slime
9	BH-718	0-20	717.8	trans	9	BH-701	60-80	1215.8	slime
10	BH-718	20-40	917.3	trans	10	BH-703	40-60	1396.3	slime
11	BH-719	0-20	357.4	trans	11	BH-703	65-73	1333	slime
12	PB-1	39-41	335	trans	12	BH-705	40-60	1232.8	slime
13	PB-1	44-46	464	trans	13	BH-709	40-60	1195.3	slime
14	PB-1	49-51	566	trans	14	BH-709	60-65	1205.8	slime
15	PB-1	64-66	418	trans	15	BH-715	0-20	1000.5	slime
16	PB-1	74-76	605	trans	16	BH-715	40-60	1225.9	slime
17	PB-1	76-81	220	trans	17	BH-715	60+	1518.6	slime
18	PB-1	81-83	201	trans	18	BH-718	40-43	1601.7	slime
19	PB-2	9-11	803	trans	19	BH-719	20-40	1117.7	slime
20	PB-2	29-31	192	trans	20	BH-719	40-51.5	1669.7	slime
21	PB-2	39-41	325	trans	21	PB-1	59-61	236	slime
22	PB-2	49-51	816	trans	22	PB-1	69-71	748	slime
23	PB-2	59-61	781	trans	23	PB-1	83-85	1600	slime
24	PB-2	61-66	711	trans	24	PB-1	85-87	2040	slime
25	PB-2	69-71	614	trans	25	PB-1	87-89	1640	slime
26	AR-4S	20-21	530.6	unconsol	26	PB-1	89-91	1690	slime
27	AR-8	21-22	594.8	unconsol	27	PB-2	44-46	1740	slime
28	AR-8	25-35	639.9	unconsol	28	PB-2	71-73	1390	slime
					29	PB-2	73-75	1280	slime
Sands					30	PB-2	75-77	1130	slime
1	Impound 2	imp	12.7	imp	31	PB-2	77-79	1240	slime
2	Impound 3	imp	87.4	imp	32	PB-2	79-81	1550	slime
3	AR-10	3-4	311.8	sand	33	PB-2	84-86	1620	slime
4	AR-10	20-25	98	sand					
5	AR-6	35-40	100.4	sand	**Alluvium**				
6	AR-9	10-11	320.2	sand	1	437	44-44.25	135.5	alluvium
7	AR-9	30-32	87.2	sand	2	438	74-74.25	134.3	alluvium
8	BH-705	0-20	186.2	sand	3	438	75-75.25	92.8	alluvium
9	BH-709	0-20	289.9	sand	4	438	76-76.25	31.3	alluvium
10	PB-1	9-11	215	sand	5	438	78-78.25	118.4	alluvium
11	PB-1	14-16	99.7	sand	6	439	87-87.25	23.9	alluvium
12	PB-1	19-21	202	sand	7	AR-5	0-1	84.3	alluvium
13	PB-1	24-26	148	sand	8	AR-6	0-1	17.3	alluvium
14	PB-1	29-31	153	sand	9	PB-1	94-96	208	alluvium
15	PB-1	34-36	447	sand	10	PB-2	89-91	1.83	alluvium

Table B–3 (continued). Moab Project, Crescent Junction Disposal Cell Tailings and Other Contaminated Materials Ra-226

No. of Samples	Sample	Depth	Ra-226 Activity (pCi/g)	Material Type
16	PB-1	54-56	849	sand
17	PB-2	14-16	269	sand
18	PB-2	19-21	150	sand
19	PB-2	24-26	100	sand
20	AR-2	5.5-10	786.5	silt
21	AR-7	20-25	562.2	silt
22	AR-9	50-55	543.6	silt
23	AR-9	60-62	239.1	silt

	All Data	Sands	Transitional Tailings	Slimes	Off Pile & Sub Pile & Interim Cover Materials (Alluvium)
Max:	2,195	849	917	2,195	208
Min:	2	13	192	236	2
Average:	707	**272**	**530**	**1,349**	**85**
Median:	564	202	556	1,333	89
Std Dev.:	589	224	195	479	66
Count:	94	23	28	33	10
Material Volume (cy)	14,546,054	3,743,474	4,864,651	3,258,910	2,679,019
Volume %:	100%	26%	33%	22%	18%
Weighted Activity (pCi/g)	**565**	70	177	302	16

Table B–4. Moab Project, Crescent Junction Disposal Cell 15 Bar Moisture Content

Sample Description	Soil Type	% Moisture (15 Bar)		
TP-153, 8.5, A	Fluvial/Eolian	6.74	**All Data**	
TP-153, 8.5, A-R	Fluvial/Eolian	6.75	Maximum	14.0
TP-153, 8.5 B	Fluvial/Eolian	6.56	Minimum	6.4
TP-153, 8.5 B-R	Fluvial/Eolian	6.43	Mean	10.1
TP-152, 15, A	Fluvial/Eolian	8.53	Median	10.1
TP-152, 15, A-R	Fluvial/Eolian	8.52	St. Deviation	2.1
TP-152, 15, B	Fluvial/Eolian	8.61	Count	32
TP-152, 15, B-R	Fluvial/Eolian	8.62		
TP-153, 3.5, A	Sheetwash	10.86		
TP-153, 3.5, A-R	Sheetwash	10.6		
TP-153, 3.5 B	Sheetwash	10.49	**Sheetwash/Fluvial/Eolian**	
TP-153, 3.5 B-R	Sheetwash	10.52	Maximum	10.9
TP-152, 7.5 A	Sheetwash	10.08	Minimum	6.4
TP-152, 7.5 A-R	Sheetwash	10.19	Mean	9.0
TP-152, 7.5, B	Sheetwash	9.99	Median	9.0
TP-152, 7.5, B-R	Sheetwash	10.03	St. Deviation	1.4
TP-155, 5, A	Sheetwash	9.56	Count	20
TP-155, 5, A-R	Sheetwash	9.28		
TP-155, 5, B	Sheetwash	8.75		
TP-155, 5, B-R	Sheetwash	8.72		
TP-154, 20, A	Weathered Shale	12.1	**Weathered Shale**	
TP-154, 20, A-R	Weathered Shale	12.33	Maximum	14.0
TP-154, 20, B	Weathered Shale	12.19	Minimum	9.3
TP-154, 20, B-R	Weathered Shale	12.22	Mean	12.1
TP-152, 23, A	Weathered Shale	13.99	Median	12.2
TP-152, 23, A-R	Weathered Shale	13.73	St. Deviation	1.6
TP-152, 23, B	Weathered Shale	13.47	Count	12
TP-152, 23, B-R	Weathered Shale	13.56		
TP-156, 22, A	Weathered Shale	11.16		
TP-156, 22, A-R	Weathered Shale	11.16		
TP-156, 22, B	Weathered Shale	9.28		
TP-156, 22, B-R	Weathered Shale	9.52		

Note: values are gravimetric moisture content on a dry unit weight basis

Table B–5. Moab Project, Crescent Junction Disposal Cell Calculation of Radon Diffusion Coefficients Using Updated Equation (Rogers and Nielson, 1991)

Cover Layer	**Mass Density (g/cm3)**	**Dry Density (pcf)**	**Long-Term Water Content (w)**	**Specific Gravity (G_s)**	**Porosity[1] (p)**	**Calculated Saturation[2] (S)**	**Calculated Diffusion Coefficient[3] (cm^2/s)**
Tailings (both cover designs)	1.57	97.8	0.15	2.8	0.44	53.4%	1.044E-02
(moisture content = 10%)	1.57	97.8	0.10	2.8	0.44	35.6%	1.873E-02
(moisture content = 20%)	1.57	97.8	0.20	2.8	0.44	71.2%	3.541E-03
Interim Cover (both cover designs)	1.66	103.5	0.09	2.67	0.38	39.4%	1.629E-02
Alternative Cover Radon Barrier	1.66	103.5	0.09	2.67	0.38	39.4%	1.629E-02
UMTRA Cover Radon Barrier	1.77	110.7	0.12	2.65	0.33	64.4%	4.636E-03

[1] Porosity (p) = 1 - dry density/(specific gravity x unit weight of water)

[2] Saturation (S) = Long-term water content/((unit weight of water/dry density) - (1 - specific gravity))

[3] D=Da*p*exp(-6Sp-6S14p) Source: Rogers and Nielson, 1991, equation 9

unit weight of water	62.4	pcf
^{222}Rn diffusion coefficient in air (Da)	1.10E-05	m^2/s

Rogers and Nielson, 1991. Correlations for Predicting Air Permeabilities and ^{222}Rn Diffusion Coefficients of Soils, Health Physics, Vol. 61, No. 2, pp. 225-230, August.

Table B–6. Moab Project, Crescent Junction Disposal Cell Calculation of 15 bar Moisture Content

Using Empirical Relationship Rawls & Brakensiek (in NRC 1989b): 15 bar Vol. moisture content = 0.026 + 0.005z + 0.0158y

(where z = % of Clay in the soil and y = % of organic matter in the soil)

Alluvium			
Mean Max. Dry Density as placed =	103.4	lbs/cu. ft.	(1.66 g/cc; 85% of Max Dry Density from Modified Proctor Tests)
Mean % Clay =	18.6		
Mean % Organic Matter =	0.3		
15 bar vol. moisture content = 0.026 + 0.005(18.63) + 0.0158(0.3)			
	Volumetric (%)	**Gravimetric (%)**	
15 bar Vol. Moisture Content =	12.3	7.5	Using mean values
Weathered Mancos			
Mean Max. Dry Density as placed =	110.7	lbs/cu. ft.	(1.77 g/cc; 90% of Max. Dry Density from Modified Proctor Tests)
Mean % Clay =	37.7		
Mean % Organic Matter =	0.4		
15 bar vol. moisture content = 0.026 + 0.005(37.67) + 0.0158(0.4)			
	Volumetric (%)	**Gravimetric (%)**	
15 bar Vol. Moisture Content =	22.1	12.4	Using mean values

Table B–7. Tailings Density

Tailings Maximum Dry Density				
Source: Golder Associates 4/3/06 Draft Tech Memo				
Standard Proctor Maximum Dry Density of Transition Tailings				
Sample Number	**Max Dry Density (pcf)**			
GABT-05	113.3			
GABT-07	107.3			
GABT-08	112.8			
GABT-09	102			
GABT-10	107.8		**90% of Mean**	
	108.6	**Mean**	98	pcf
	5	**Count**	1.57	g/cc

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-05-2007-5-17-02 **Discipline:** Geotechnical **No. of Sheets:** 20
Doc. No.: X0175900

Location: Attachment 1, Appendix C

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Slope Stability of Crescent Junction Disposal Cell

Sources of Data:

Remedial Action Plan (RAP) calculation sets as referenced in text.

Purpose of Revision:

Revision was made to address the Nuclear Regulatory Commission comments GT4 and GT9 (see Appendix A of the Remedial Action Selection Report) to clarify materials to be used in various components of proposed covers, and to analyze the stability of the UMTRA cover.

Sources of Formulae and References:

See list of references at end of calculation set

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-02-05-2006-05-17-01**

Author: Roslyn Stern 5/25/07
Name Date

Checked by: 5/30/07
Name Date

5/31/07
Name Date

MAY 31, 07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Reviewed: 5-29-07
Name Date

No text for this page

Problem Statement:

The purpose of this calculation is to assess the stability of the disposal cell at the Crescent Junction Site. Both the short-term (end-of-construction) and long-term conditions were evaluated under static and seismic conditions.

Method of Solution:

Slope stability analyses were performed using limit equilibrium methods with the aid of the computer program SLOPE/W (Geo-Slope/W 2004). The SLOPE/W program calculates factors of safety by a variety of methods. Spencer's method was used for these analyses because it considers both force equilibrium and moment equilibrium in the factor of safety calculation.

Failure surfaces represented the most likely modes of failure, including circular, non-circular, and infinite slope failure surfaces. Circular failure surface analyses were analyzed by targeting deeper, full-slope failures. Small shallow failures were not considered. In both cases, a number of failure surfaces were analyzed to find the lowest factor of safety.

In addition, the analysis of the infinite slope scenario (slope length much longer than thickness of critical layer) was conducted on the side slopes. This conservative analysis minimizes any stabilization effects of a passive resistive wedge at the base of the slope.

Slope stability analyses were performed to analyze both the UMTRA cover and the proposed alternative cover.

Assumptions:

See "Discussion."

Calculation:

See "Discussion."

Discussion:

Critical Conditions

Slope-stability analyses are typically conducted under scenarios that represent the critical conditions for construction and operation. For the disposal cell, these conditions include: (1) the period immediately after construction, and (2) the long-term period after cell construction.

Key factors during construction are development of excess porewater pressures in foundation, dike, tailings, or cover materials due to equipment or fill placement, or displacement of low-strength fill materials (such as slime tailings) in response to covering fill placement. These factors are not of concern for slope stability during cell construction. The foundation materials (unsaturated weathered Mancos Shale) are not susceptible to development of excess porewater pressures since they are not likely to be saturated. Tailings will be placed and compacted at optimum or slightly (up to 2 percent) wet of optimum water content. This placement procedure will minimize future settlement. Because of this placement method, it is likely that only the bottom portion of the tailings below natural grade will become saturated due to consolidation and draindown during construction. The development of some excess pore pressures at the base of the tailings is not expected to affect long-term stability.

Critical Geometry

The critical cross-section location used in the analysis is shown in Figure 1. The profile at this location is shown in Figure 2. This section was chosen for analysis because it represents a combination of both highest slope face of the disposal cell and down-sloping natural grade.

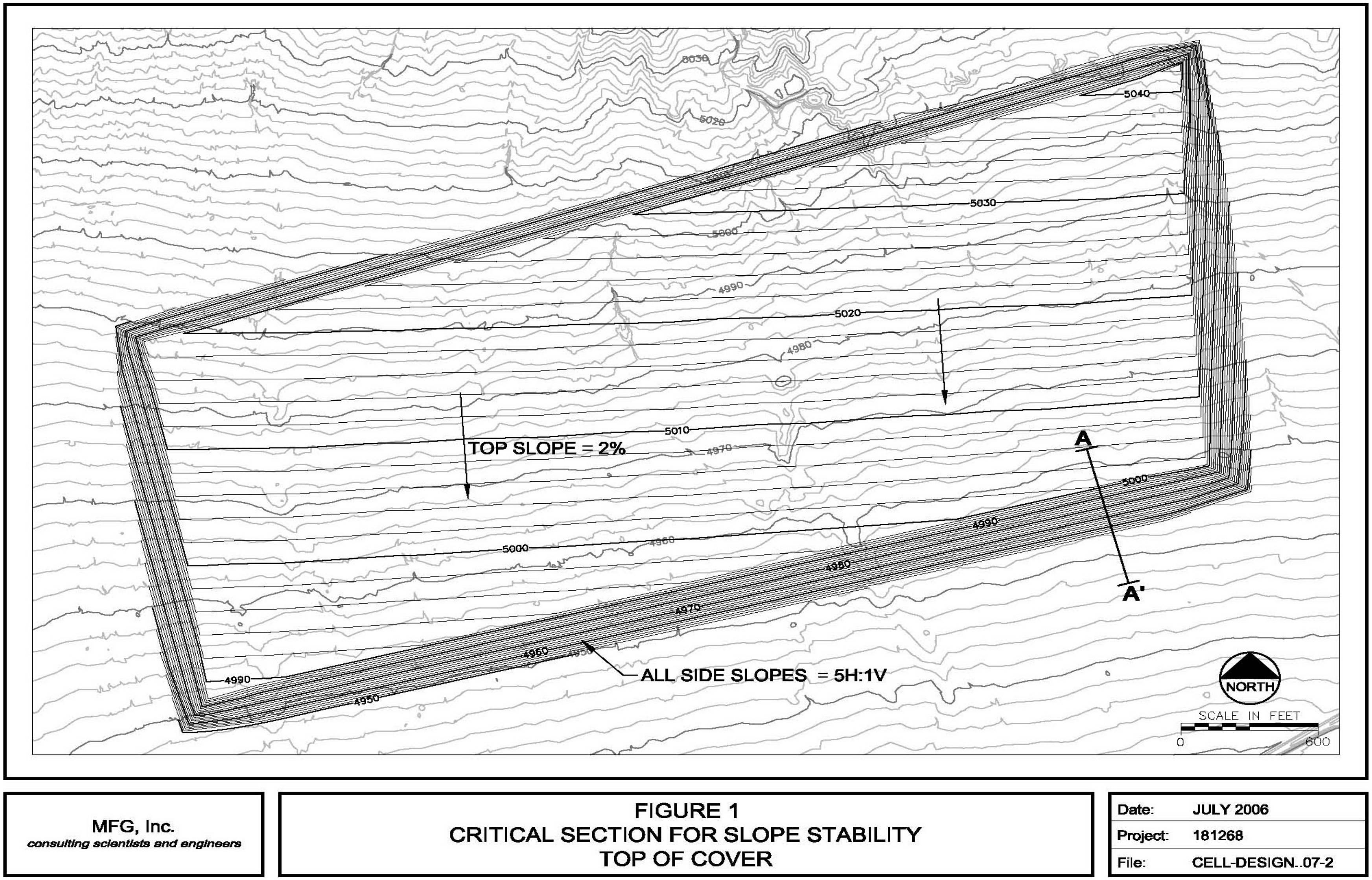


Figure 1.Critical Section for Slope Stability, Top of Tailings

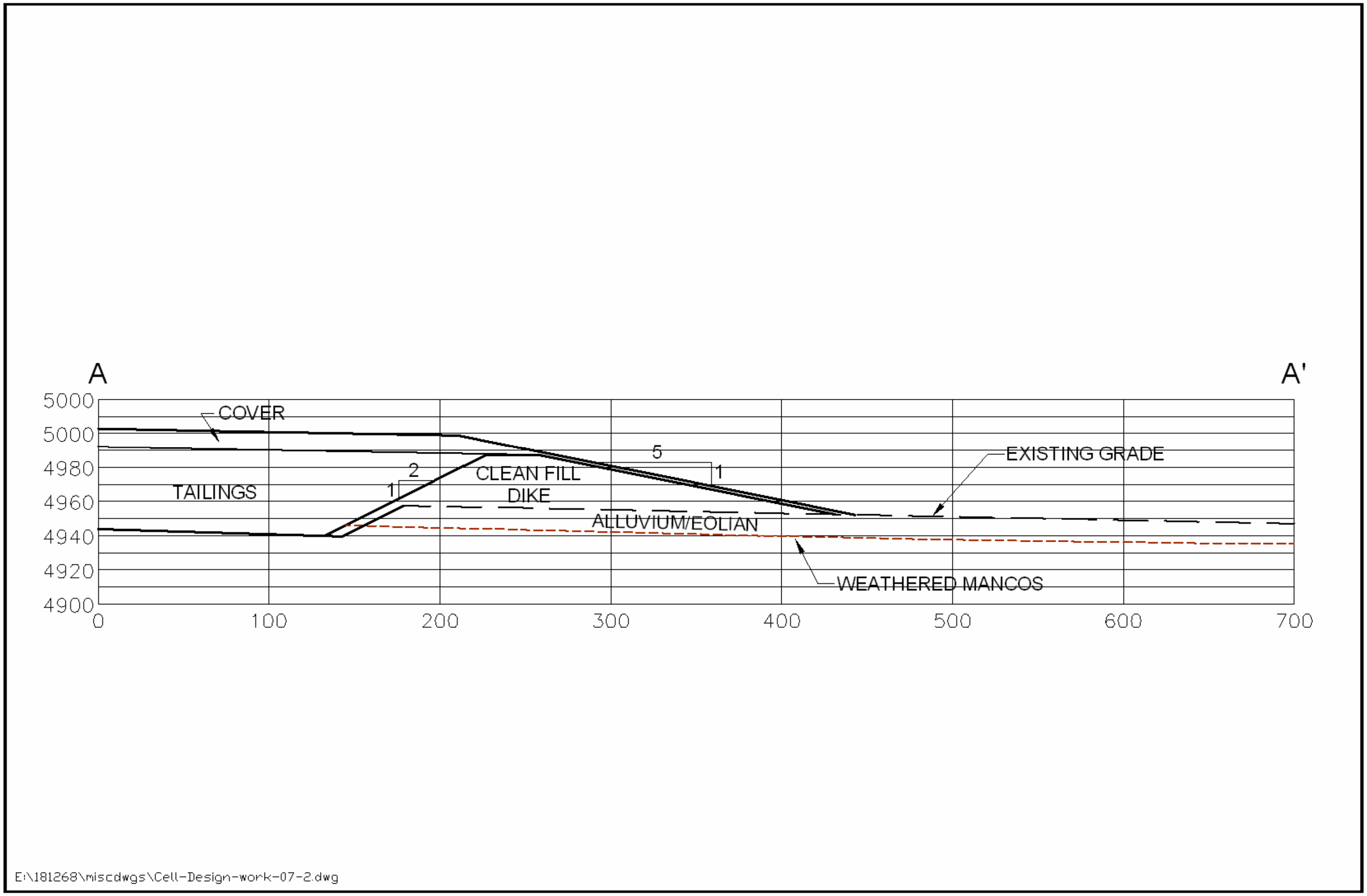


Figure 2. Cross Section A–A'

The cell profile geometry was based on the current cell excavation plan and final cell configuration. This configuration includes excavating existing soils within the footprint of the disposal cell to a depth of approximately 16 ft. Tailings will be compacted, along with the construction of a clean-fill dike, to grades as shown on Figure 1.

The proposed alternative cover consists (from bottom to top) of approximately 6 inches of infiltration and biointrusion barrier (clean sands and gravels), approximately 10 ft of recompacted native alluvial and weathered Mancos shale soils excavated from within the disposal cell footprint, and 6 inches of rock mulch.

The UMTRA cover consists (from bottom to top) of approximately 4 ft of compacted Radon Barrier consisting of recompacted weathered Mancos shale, 6 inches of infiltration/biointrusion material, 3 ft of frost protection consisting of recompacted native alluvial and weathered Mancos Shale soils, and 6 inches of rock mulch. The stability of the UMTRA cover was conservatively analyzed by assuming a 10-ft cover (using the same model geometry as the alternative cover for ease of computation) constructed of the recompacted weathered Mancos shale, which represents the weakest layer of the UMTRA cover system.

Pore Water Conditions

Site investigations (RAP Attachment 5, Vol. I, “Test Pit Logs” [Appendix B], “Borehole Logs” [Appendix D] and “Geotechnical Properties of Native Materials” [Appendix E]) indicate that the foundation soils are dry. The shallowest water encountered in piezometer wells was at a depth of approximately 100 ft (see “Hydrologic Characterization–Vertical Travel Time to Uppermost (Dakota) Aquifer,” RAP Attachment 3, Appendix E); therefore, the foundation materials are not expected to be saturated from naturally occurring ground water during construction.

Due to the placement procedure of the tailings (placed between 2 percent dry and 2 percent wet of optimum water content and compacted to 90 percent of maximum dry density of Standard Proctor), it is unlikely that a phreatic surface will exist above natural grade within the tailings. Permeability testing of the tailings is ongoing; however, preliminary results conducted under low confining pressures (2 psi) indicate the permeability of the tailings is approximately 3.0E-5 cm/sec (see “Supplemental Geotechnical Properties of Tailings Materials from the Moab Processing Site,” RAP Attachment 5, Vol. II, Appendix N). This compares with estimates of the permeability of the tailings based on literature values for sandy silt tailings of 7E-5 centimeters per second (cm/sec) (Geo-Slope/W) and between 1E-5 and 1E-6 cm/sec (Keshian and Rager 1988). Packer tests performed within the weathered Mancos zone indicate the foundation materials immediately underlying the tailings have an average hydraulic conductivity of approximately 1E-4 cm/sec (see “Hydrologic Characterization–Vertical Travel Time to Uppermost (Dakota) Aquifer,” RAP Attachment 3, Appendix E). Because the foundation is more permeable than the tailings, saturation within the tailings is expected to be minimal and confined to the tailings below natural grade. Due to the construction of the clean-fill dike surrounding the tailings, below-grade saturation of tailings will have minimal impact on slope stability. Therefore, potentiometric water surface within the foundation, tailings, cover, or dike material was not considered.

Material Properties

The soil properties used in the stability analyses are summarized in Table 1.

Erosion Protection

The current cell configuration requires rock mulch with a D_{50} of 2.2 inches along the 2 percent top slope of the cell to protect against erosion from action of wind and water. The south side slope requires riprap with a minimum D_{50} of 8.2 inches. This rock will have little impact on the slope stability because it is a relatively thin layer, and the rock will have relatively strong shear strength in relation to other components of the cover. Densities for the rock mulch are assumed from literature values for silty or clayey gravel and sand (Carter and Bentley 1991), and for the riprap, from typical values based on experience. Shear strength values are estimated from Figure 4.8 of NUREG/CR-4620 (Nelson et al. 1986). As the erosion protection will not be subject to excess pore water pressures, shear strength values are modeled as being the same for all three loading cases.

Table 1. Material Properties

Soil Layer	Description	In-Place Dry Density (pcf)	In-Place Moist Density (pcf)	In-Place Saturated Density (pcf)	Short Term		Long Term		Long-Term Seismic	
					Cohesion (psf)	Angle of Internal Friction (degrees)	Cohesion (psf)	Angle of Internal Friction (degrees)	Cohesion (psf)	Angle of Internal Friction (degrees)
Erosion Protection, Top Slope	Angular rock mulch with D_{50} = 2.2 inches	109	123	130	0	37	0	37	0	37
Erosion Protection, Side Slope	Angular riprap with D_{50} = 8.2 inches	135	135	146	0	37	0	37	0	37
Alternative Cover	On-site weathered Mancos shale, alluvial and eolian soils recompacted to 85% maximum dry density from Modified Proctor	103	115	127	0	29	0	29	0	24
UMTRA Cover	On-site weathered Mancos shale recompacted to 90% maximum dry density from Modified Proctor	111	124	132	0	26	0	26	0	21
Clean-fill Dike	On-site weathered Mancos shale, alluvial and eolian soils recompacted to 90% maximum dry density from Modified Proctor	111	124	132	0	19	0	26	0	21
Tailings	Compacted to a minimum of 90% standard Proctor	98	115	125	615	0	0	32	0	27
Sheet wash/eolian soils	In-situ foundational soil outside of tailings footprint	91	97	119	0	26	0	26	0	22
Weathered Mancos Shale	In-situ foundational soil	103	114	127	0	25	0	25	0	21

Alternative Cover

The alternative cover consists of approximately 10 ft of relatively lightly recompacted native alluvial and eolian soils and weathered Mancos shale excavated from the disposal cell footprint. Densities are estimated based on 85 percent of the average of maximum dry densities from Modified Proctor tests performed on these soils (see “Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol I, Appendix E). Shear strength parameters used in the model are an average of triaxial shear strength values that were performed on these materials (see “Supplemental Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol. I, Appendix K). Cohesion is neglected. Because the cover will not be placed or loaded under saturated conditions, short-term shear strength parameters are estimated to be equivalent to long-term drained conditions. Under seismic loading, the shear strength parameters are estimated to be 80 percent of long-term shear strength ($\tan(\phi)_{\text{seismic}} = 0.8 \times \tan(\phi)_{\text{long-term}}$) to account for strain softening during a seismic event. Although conditions do not exist that would cause liquefaction of materials, a reduction of up to 80 percent of peak shear strength under cyclical loading is conservatively considered (Makdisi and Seed 1978) under seismic loading.

UMTRA Cover

The UMTRA cover is conservatively modeled as consisting entirely of recompacted weathered Mancos shale, the weakest component of the cover system. Densities are estimated based on 90 percent of the average of maximum dry densities from Modified Proctor tests performed on the weathered Mancos (see “Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol. I, Appendix E). Shear strength parameters used in the model are an average of the triaxial shear strength values that were performed on the weathered Mancos (see “Supplemental Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol. I, Appendix K). Cohesion is neglected. Short-term and seismic reductions in shear strength are the same as discussed for the alternative cover.

Clean-Fill Dike

A clean-fill dike will be constructed around the perimeter of the disposal cell. The height of the dike will be the same as that of the tailings, and will vary from 10 to 30 ft. The dike will be constructed from recompacted weathered Mancos Shale, alluvial, and eolian soils that are excavated from the disposal cell footprint. Densities are based on 90 percent of the average of maximum dry density from Modified Proctor tests (see “Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol. I, Appendix E). Long-term shear strength parameters used in the model are an average of effective triaxial shear strength of the weathered Mancos Shale (the weakest component of the soils used in construction of the dike) (see “Supplemental Geotechnical Properties of Native Materials,” RAP Attachment 5, Vol. I, Appendix K). Cohesion is neglected. For short-term analyses, the average total shear strength of the weathered Mancos Shale is used, neglecting cohesion. Under seismic loading, the shear strength is estimated to be 80 percent of long-term shear strength to account for strain softening during a seismic event. The strain-softening approach is used to account for some loss in strength under high strain. An undrained shear strength approach is not considered appropriate because the dike is not expected to be saturated.

Tailings

Tailings will be relocated from the current site in Moab. During the relocation process, tailings will be mixed such that fine-grained particles (slimes) will be combined with coarse-grained particles (sands). The resulting material will consist of transitional tailings, or a mixture of sands and slimes. The tailings will be moisture conditioned and compacted in maximum 12-inch loose lifts within the disposal cell. Densities of the tailings are based on 90 percent of the average of maximum dry density from Standard Proctor tests on transitional tailings (Golder 2006). Shear strength testing on the tailings is ongoing. Literature values for hydraulically placed uranium mill tailings indicate that an effective angle of internal friction of 32 degrees is appropriate for preliminary estimates of the strength of sand/slime mixtures (Keshian and Rager 1988). For short-term, the shear strength of the tailings is estimated based on the average of unconfined compressive strength tests performed on undisturbed samples of the tailings sampled from the current site in Moab (see “Geotechnical Laboratory Testing Results for the Moab Processing Site,” RAP Attachment 5, Vol. I, Appendix J). This is considered a conservative approach because the tailings in Moab that were tested for unconfined compressive strength were predominately slimes and have been hydraulically placed. In contrast, the relocated tailing at the Crescent Junction Site will be mixed in such a manner that percent slimes placed will be minimal. The tailings will also be compacted, thereby increasing the density and shear strength above that currently seen at the Moab Site. Because the tailings will be placed at close to optimum moisture content and compacted, they are not expected to be saturated. Under seismic loading, the shear strength parameters are estimated to be 80 percent of long-term shear strength to account for strain softening during a seismic event. The strain-softening approach is used to account for some loss in strength under high strain during cyclical loading.

Alluvial/Eolian Soil and Weathered Mancos Shale

The native soils outside the footprint of the disposal cell are modeled to check against failures that may incorporate foundation materials. The densities of the alluvial/eolian soils and the weathered Mancos Shale are based on average dry densities measured from respective liner samples taken during the field investigation (see "Geotechnical Properties of Native Materials," RAP Attachment 5, Vol. I, Appendix E). Shear strength parameters for the alluvial/eolian soils are modeled as being 90 percent of the recompacted shear strength of the same material to reflect lower shear strength due to less compaction. The in-situ weathered shale has essentially the same dry density as the recompacted samples and is therefore estimated to have similar shear strength parameters.

Seismic Coefficient

As per the "Site and Regional Seismicity – Results of Maximum Credible Earthquake Estimation and Peak Horizontal Acceleration" calculation (RAP Attachment 2, Appendix F), the predicted peak horizontal acceleration (PHA) is estimated to be 0.22 g. In accordance with guidance given in the Technical Approach Document (TAD) (DOE 1989), the seismic coefficient for a pseudostatic analysis is equivalent to 1/2 of PHA (0.11 g) for end-of-construction analyses, and is equivalent to 2/3 of PHA (0.15 g) for the long-term analyses.

Stability Criteria

The required safety factors as given in the TAD are as follows:

Loading Condition	Minimum Factor of Safety
End-of-construction:	
Static	1.3
Pseudostatic (kh=0.11 g)*	1.0
Long-term:	
Static	1.5
Pseudostatic (kh=0.15 g)	1.0

*kh = seismic coefficient

Results from Stability Analyses

Based on the input parameters outlined previously, critical failure surfaces and the associated factor of safety are shown in Figures 3 through 10. The stability results are summarized below:

Loading Condition	Results of Analysis	
	Alternative Cover	UMTRA Cover
End-of-construction:		
Static	1.7	1.7
Pseudostatic (kh=0.11g)	1.1	1.1
Infinite Slope (Static)	1.7	1.7
Infinite Slope (Pseudostatic)	1.1	1.1
Long-term:		
Static	2.4	2.4
Pseudostatic (kh=0.15 g)	1.0	1.0
Infinite Slope (Static)	2.4	2.4
Infinite Slope (Pseudostatic)	1.1	1.1

*kh = seismic coefficient

Name: short-term seismic.gsz

Comments: End-of-Construction

Comments: End-of-ConstructionHorz Seismic Load: 0.11

Material #: 1 Description: Alternative Cover Wt: 115 Cohesion: 0 Phi: 29
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 19
Material #: 3 Description: Tailings Wt: 115 Cohesion: 615
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 26
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 25

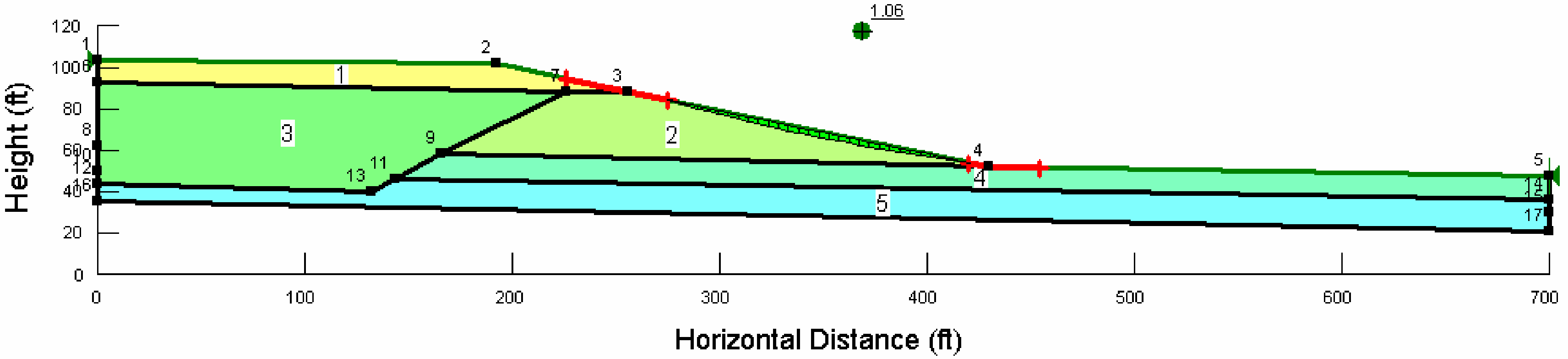


Figure 3. Short-Term Seismic (Alternative Cover)

Name: short-term static.gsz

Comments: End-of-Construction

Comments: End-of-ConstructionHorz Seismic Load: 0

Material #: 1 Description: Alternative Cover Wt: 115 Cohesion: 0 Phi: 29
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 19
Material #: 3 Description: Tailings Wt: 115 Cohesion: 615
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 26
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 25

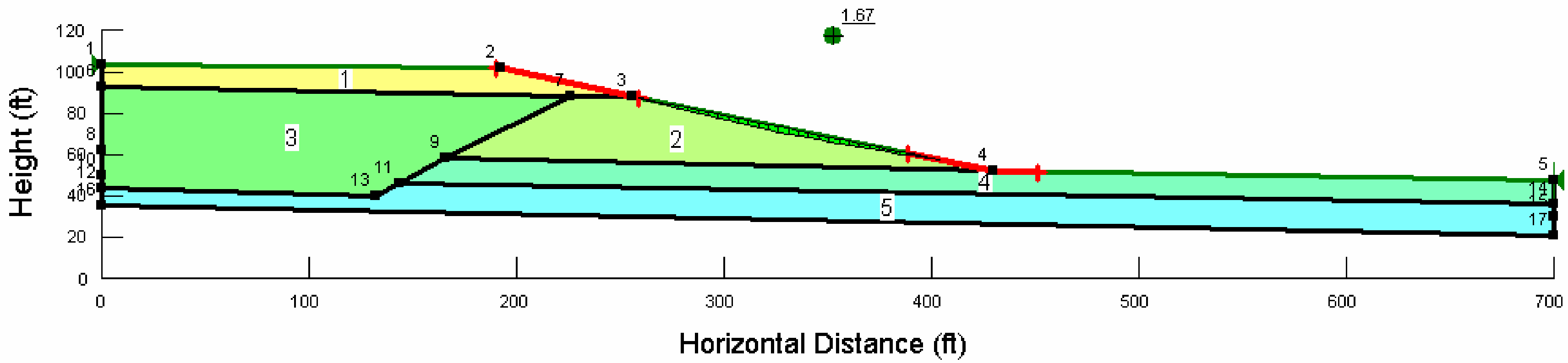


Figure 4. Short-Term Static (Alternative Cover)

Name: long-term seismic.gsz

Comments: Long-term

Comments: Long-termHorz Seismic Load: 0.15

Material #: 1 Description: Alternative Cover Wt: 115 Cohesion: 0 Phi: 24
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 21
Material #: 3 Description: Tailings Wt: 115 Cohesion: 0 Phi: 27
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 22
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 21

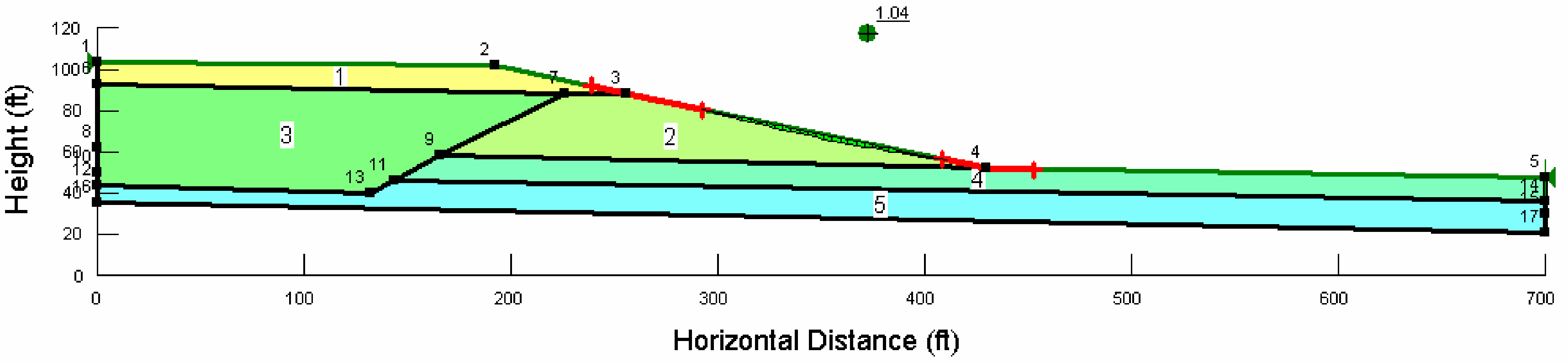


Figure 5. Long-Term Seismic (Alternative Cover)

Name: long-term static.gsz

Comments: Long-term

Comments: Long-termHorz Seismic Load: 0

Material #: 1 Description: Alternative Cover Wt: 115 Cohesion: 0 Phi: 29
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 26
Material #: 3 Description: Tailings Wt: 115 Cohesion: 0 Phi: 32
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 26
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 25

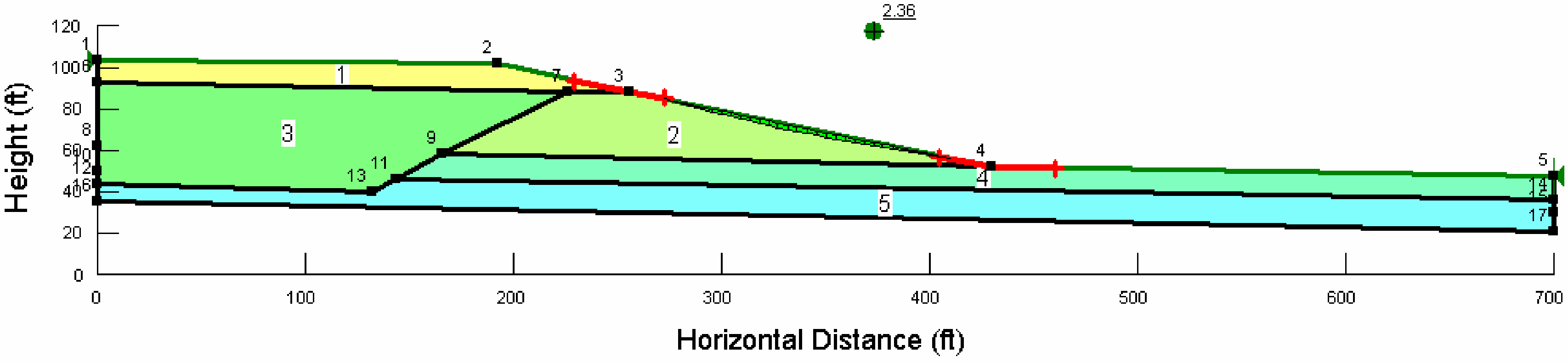
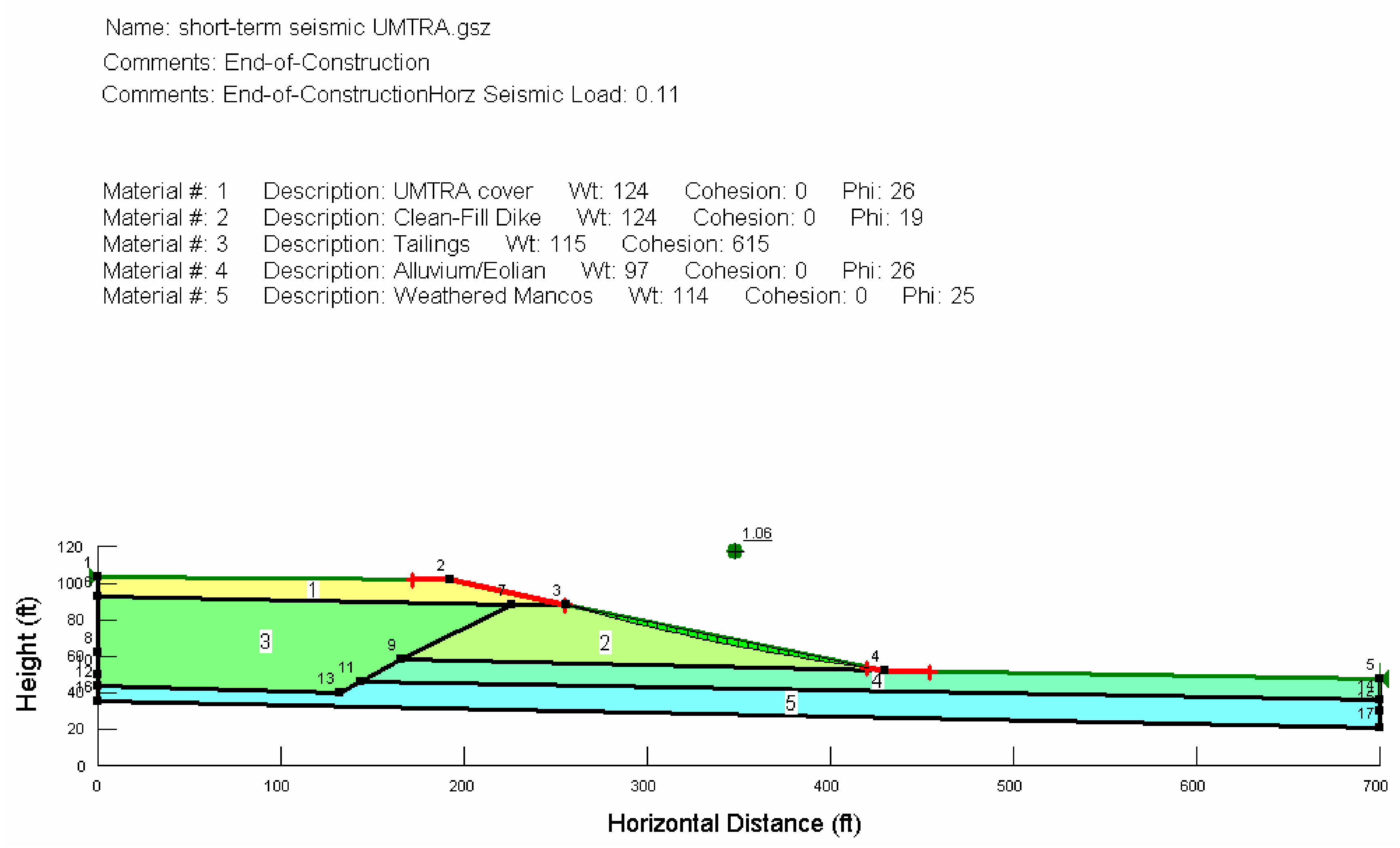


Figure 6. Long-Term Static (Alternative Cover)



Name: short-term seismic UMTRA.gsz
Comments: End-of-Construction
Comments: End-of-ConstructionHorz Seismic Load: 0.11

Material #: 1 Description: UMTRA cover Wt: 124 Cohesion: 0 Phi: 26
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 19
Material #: 3 Description: Tailings Wt: 115 Cohesion: 615
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 26
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 25

Figure 7. Short-Term Seismic (UMTRA Cover)

Name: short-term static UMTRA.gsz
Comments: End-of-Construction
Comments: End-of-ConstructionHorz Seismic Load: 0

Material #: 1	Description: UMTRA Cover	Wt: 124	Cohesion: 0	Phi: 26
Material #: 2	Description: Clean-Fill Dike	Wt: 124	Cohesion: 0	Phi: 19
Material #: 3	Description: Tailings	Wt: 115	Cohesion: 615	
Material #: 4	Description: Alluvium/Eolian	Wt: 97	Cohesion: 0	Phi: 26
Material #: 5	Description: Weathered Mancos	Wt: 114	Cohesion: 0	Phi: 25

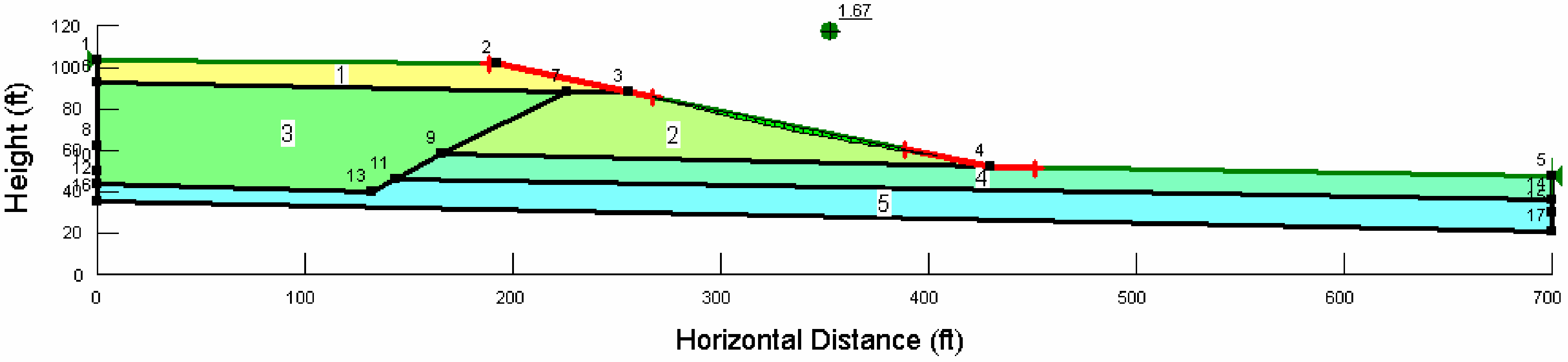


Figure 8. Short-Term Static (UMTRA Cover)

Name: long-term seismic UMTRA.gsz

Comments: Long-term

Comments: Long-termHorz Seismic Load: 0.15

Material #: 1	Description: UMTRA cover	Wt: 124	Cohesion: 0	Phi: 21
Material #: 2	Description: Clean-Fill Dike	Wt: 124	Cohesion: 0	Phi: 21
Material #: 3	Description: Tailings	Wt: 115	Cohesion: 0	Phi: 27
Material #: 4	Description: Alluvium/Eolian	Wt: 97	Cohesion: 0	Phi: 22
Material #: 5	Description: Weathered Mancos	Wt: 114	Cohesion: 0	Phi: 21

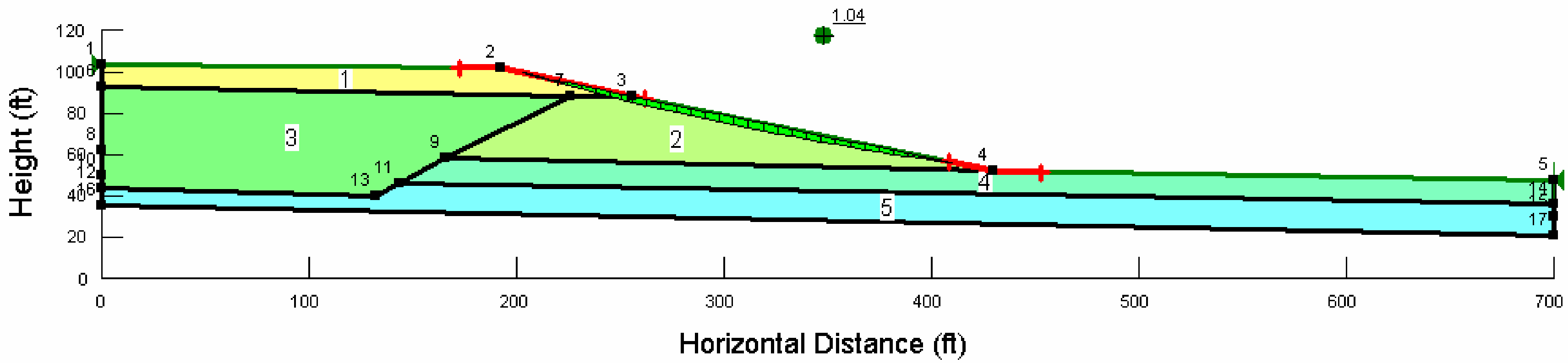


Figure 9. Long-Term Seismic (UMTRA Cover)

Name: long-term static UMTRA.gsz
Comments: Long-term
Comments: Long-termHorz Seismic Load: 0

Material #: 1 Description: UMTRA Cover Wt: 124 Cohesion: 0 Phi: 26
Material #: 2 Description: Clean-Fill Dike Wt: 124 Cohesion: 0 Phi: 26
Material #: 3 Description: Tailings Wt: 115 Cohesion: 0 Phi: 32
Material #: 4 Description: Alluvium/Eolian Wt: 97 Cohesion: 0 Phi: 26
Material #: 5 Description: Weathered Mancos Wt: 114 Cohesion: 0 Phi: 25

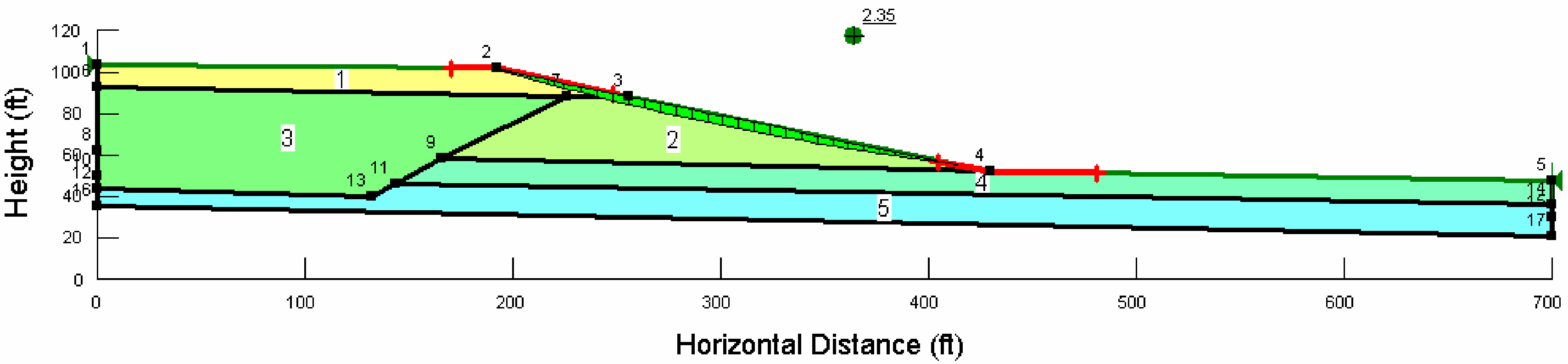


Figure 10. Long-Term Static (UMTRA Cover)

Conclusion and Recommendations:

Based on results of geologic literature review, the Crescent Junction Site appears to be suitable for disposal of the Moab uranium mill tailings and contaminated material. The computed factors of safety for the alternative cover are similar to the UMTRA cover analyses. Critical failure surfaces pass predominately through the perimeter embankment. Therefore, the stability of the disposal cell is relatively insensitive to cover material thickness and to cover material and compacted tailings shear strength. Based on this information, and in conjunction with findings of field investigations, this site is deemed suitable for the intended use.

Computer Source:

Geo-Slope/W International, LTD, 2004. SLOPE/W version 6.19, Calgary, Alberta, Canada.

References:

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Nelson, J.D., S.R. Abt, R.L. Volpe, D. van Zyl, N.E. Hinkle, and W.P. Staub, 1986. *Methodologies for Evaluating Long-Term Stabilization Design of Uranium Mill Tailings Impoundments*, NUREG/CR-4620, U.S. Nuclear Regulatory Commission, June.

NRC (U.S. Nuclear Regulatory Commission), 1993. *Final Standard Review Plan for the Review and Remedial Action of Inactive Mill Tailings Sites under Title 1 of the Uranium Mill Tailings Radiation Control Act*, *Revision I*, U.S. Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards, June.

End of current text

Appendix A

Infinite Slope Analysis

Client:	U.S. Department of Energy	Job No. 181268	Page: 1 of 1
Project:	Disposal Cell	Date: 5/19/06	Date Checked: 5/7/07
Detail:	Slope Stability, Seismic Analyses for Infinite Slope	Computed by: RTS	Checked by: CLS

Problem Statement:

Calculate the Factor of Safety assuming infinite slope failure. Analyze side slope at 5H:1V. Critical surface is at the clean-fill dike around the perimeter of the disposal cell. Average properties of borrow material for Mancos Shale soils are LL = 28 and PI = 11. Assume that under moderate loading conditions (10 to 30 feet of material), soils force failure. Use long-term, static friction angle of 26 degrees (average of effective shear strength results for weathered Mancos Shale), long-term pseudostatic friction angle of 21 degrees (80 percent reduction in strength), and short-term friction angle of 19 degrees (average of total shear strength results for weathered Mancos Shale).

Solution:

Use the following equation

$$FS = \frac{\tan(\phi)}{\tan\left[\beta + \arctan(k_h)\right]}$$

where FS= Factor of Safety

ϕ= friction angle of clean fill dike

β= slope angle of cover=arctan (1/5)

k_h=horizontal seismic coefficient (g)

For static, short-term conditions, k_h=0.0 g and ϕ=19 degrees:

$$FS = \frac{\tan(19)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.0)\right]} = 1.72$$

For pseudostatic, short-term conditions, k_h=0.11 g and ϕ=19 degrees:

$$FS = \frac{\tan(19)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.11)\right]} = 1.09$$

For static, long-term conditions, k_h=0.0 g and ϕ=26 degrees:

$$FS = \frac{\tan(26)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.0)\right]} = 2.44$$

For pseudostatic, long-term conditions, k_h=0.15g and ϕ=21 degrees:

$$FS = \frac{\tan(21)}{\tan\left[\arctan(\frac{1}{5}) + \arctan(0.15)\right]} = 1.06$$

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-05-2007-3-16-01 **Discipline:** Engineering Design **No. of Sheets:** 6
Doc. No.: X0176100

Location: RAP Attachment 1, Appendix D

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site, Disposal Cell Design

Feature: Settlement, Cracking, and Liquefaction Analysis

Sources of Data:

Remedial Action Plan (RAP) calculations as cited in the text.

Purpose of Revision:

Revision to address Nuclear Regulatory Commission comments G15 and GT5 (see Appendix A of the Remedial Action Selection Report) and to include laboratory test results on tailings.

Sources of Formulae and References:

See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** MOA-02-05-2006-3-16-00

Author: Clint Strachan 30 May 07
Name Date

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Problem Statement:

Evaluate (1) the potential for post-construction tailings settlement, (2) the potential for cover cracking, and (3) the potential for liquefaction under seismic loading conditions.

Method of Solution:

See “Discussion.”

Assumptions:

- Tailings will be placed at approximately 98 pounds per cubic foot (pcf), 17 percent to 21 percent gravimetric moisture content (above 90 percent of average Standard Proctor maximum dry density, and within 2 percent of optimum moisture content).
- Tailings will be placed in thin lifts, compacted, and placed to an ultimate thickness of 38 feet (ft).
- Peak horizontal ground acceleration is 0.22 g (see the “Site and Regional Seismicity–Results of Literature Research” calculation in the Remedial Action Plan [RAP], Attachment 2, Appendix E).

Calculation:

See attached sheets.

Discussion:

The calculations outline the analyses of (1) post-construction tailings settlement, (2) the impact of differential tailings settlement on cover performance (specifically cover cracking), and (3) the potential for tailings liquefaction.

Tailings Settlement

Typical settlement analyses are conducted for uranium tailings reclamation planning, because tailings will settle to varying amounts due to the stress changes from reclamation activity. These stress changes can be caused by: (1) the weight of construction equipment; (2) the loading due to the reclamation cover; and (3) lowering of the zone of saturation in the tailings. These changes have a larger effect with reclamation of tailings deposited as a slurry. In this case, the tailings will be placed in the repository as an unsaturated material, spread in lifts, and rolled with conventional construction equipment. Other Title I sites with relocated tailings have been evaluated for post-construction settlement, and areas of concern for differential settlement are transition zones between tailings and embankment materials or subsoils or zones between tailings and contaminated soils (such as described in Larson and Keshian 1988).

Analysis of tailings settlement is based on the anticipated method of placement and cover system loads on the tailings, and Moab tailings test results, as well as published data on uranium tailings characteristics.

Settlement of the tailings was evaluated to check the magnitude of primary and secondary settlement of the tailings due to the loading of subsequent tailings and cover materials. From data in Keshian and Rager (1988) on Title I tailings samples, the compression index (C_c) for remolded, mixed tailings ranged from 0.01 to 0.1, and the secondary compression index (C_α) ranged from 0.003 to 0.01. From consolidation testing on Moab tailings (Shaw E & I, Inc., 2006b), the median C_c value was approximately 0.2, for transition tailings compacted to 90 percent of Standard Proctor density. Primary settlement of the 38-ft-thick zone of tailings is estimated to be approximately 1.2 ft. Due to the construction schedule, settlement of one area of tailings (due to subsequent tailings placement) may be nearly complete by the time cover construction is started, so that this primary settlement may occur primarily during construction. The secondary settlement (over a 1,000-year period) would range from approximately 0.28 to 0.76 ft for C_α values ranging from 0.003 to 0.01 (using the procedure outlined in Larson and Keshian 1988).

Downward migration of pore water in the tailings may create a saturated zone at the bottom of the compacted tailings. This would be a post-construction effect, and gradual dissipation of pore water pressures over the design period would not significantly change the void ratio of these tailings.

The multi-year construction schedule for the disposal cell provides significant time for tailings drying and settlement prior to cover placement. Tailings will be placed in regions of the cell in lifts, compacted, and covered with interim cover. These regions will subsequently be covered with the soil cover system. The relatively thick cover is sufficiently thick to accommodate differential settlement without detrimental effects. This was evaluated by the calculations described below.

Cover Cracking

Cover cracking was evaluated by comparison of allowable strain for the cover materials with maximum calculated strain due to differential settlement in the cover. The area of the cell with the highest anticipated differential settlement (and associated largest horizontal strain) is inside the perimeter embankment.

The allowable strain for the cover materials was calculated using the equation in Caldwell and Reith (1993) based on soil plasticity index:

$$e_f = 0.05 + 0.003\ \mathrm{PI}$$

where e_f = soil tensile strain at failure (in percent)
PI = plasticity index of the cover soil

For the UMTRCA cover, with a weathered Mancos Shale radon barrier with a PI of 10, the maximum allowable strain is approximately 0.08 percent. For the alternative cover with slopewash soils with a plasticity index of 5 or less, the maximum allowable strain is approximately 0.06 percent. These allowable strain values are consistent with the allowable strains presented in Larson and Keshian (1988) and EPA (1991).

The differential settlement of tailings along the perimeter embankment would be zero near the embankment crest to as much as 2.0 ft at the inside edge of the cell excavation (conservatively adding primary and secondary settlement). This amount of differential settlement over the inside embankment slope distance (76 ft) is equivalent to a horizontal tensile strain of approximately 0.03 percent. This calculated strain is lower than the allowable tensile strain for the soil, indicating acceptable cover performance.

Liquefaction

Although the tailings will be placed in the repository in an unsaturated condition, downward migration of porewater or inclusion of meteoric water may create zones in the tailings with saturated conditions. The potential liquefaction of saturated zones of the tailings was checked with standard procedures outlined in Day (1999), based on the classic paper by Seed and Idriss (1971). This involves comparison of the seismic stress ratio due to the design seismic event with the seismic stress ratio that would cause liquefaction of the tailings at a specific depth of analysis. The analysis was performed assuming the entire tailings thickness is saturated. This situation is extremely unlikely, but was used to conservatively analyze the liquefaction potential.

These stress ratios were calculated at the top and bottom of the tailings. The stress ratio due to the design seismic event was calculated from the peak estimated acceleration at the ground surface of 0.22 g. The stress ratio required for liquefaction was based a conservatively estimated relative density of the tailings of 50 percent, based on a tailings compaction at 90 percent of Standard Proctor density (using a correlation in Holtz and Kovacs 1981). For this tailings relative density, fines content values ranging from 17 to 46 percent (representing the minimum and mean measured values), and the two depths of analysis, the stress ratio required to cause liquefaction was higher than the seismic stress ratio from the design earthquake. This indicates that if the tailings were to become saturated, the tailings would not liquefy under peak seismic ground acceleration conditions.

Conclusion and Recommendations:

- The cover for the disposal cell should not undergo significant settlement due to (1) the placement characteristics (density and moisture content of the tailings), and (2) the compaction energies applied by the equipment used to place the material. Due to the multi-year construction schedule and dry site climate, considerable tailings settlement would be expected before the cover is constructed over the cell.
- In the event of differential settlement of tailings, an analysis of cover cracking shows that the maximum calculated tensile stresses in the cover due to differential settlement are less than the allowable stresses in the cover. In addition, the cover thickness (roughly 10 to 14 ft for the UMTRCA and alternative cover designs) would accommodate cracking without affecting the performance of the entire cover system.
- Tailings liquefaction is not likely because of the placement of unsaturated tailings in the cell (as described above), the density that the tailings will achieve with placement in lifts and rolling with construction equipment, and the fines content of the tailings. In the event of zones of tailings becoming saturated, the calculated stress ratio required to cause liquefaction of the tailings is higher than the seismic stress ratio for all of the cases considered, indicating that liquefaction would not occur.

Computer Source:

Not applicable.

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Shaw E & I Inc., 2006a. Geotechnical test results on tailings samples, March 13.

Shaw E & I Inc., 2006b. Geotechnical test results on tailings samples, November 7.

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Appendix A

Liquefaction Analysis

MWH
MONTGOMERY WATSON HARZA

By CLS Date 20 MAR 07 Client Sheet 1 of 3

Chkd. By CLS 6May07 30 May 07 Description TAILINGS LIQUEFACTION ANALYSIS CJ Job No. 181268

ANALYSIS METHOD OUTLINED IN DAY (1999) AND OTHER REFERENCES

1. CALCULATION OF SEISMIC SHEAR STRESS RATIO (caused by peak acceleration)

$$SSR_a = 0.65\, r_d \left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma_{vo}'}\right)$$

where: a_{max} = peak acceleration at the ground surface for Crescent Valley. a_{max}/g = 0.22

σ_{vo} = total vertical stress at depth of analysis

σ_{vo}' = effective vertical stress at depth of analysis

r_d = depth reduction factor = $1 - 0.012\,z$

z = depth (in meters) below ground surface at depth of analysis

ASSUMPTIONS:

tailings thickness = 38 feet
cover thickness = 13 feet
saturated thickness = 38 feet (tailings saturated)

cover unit weight = 103 pcf dry
110.2 pcf at 7% water content

tailings unit weight = 98 pcf dry
124.1 pcf at 26.6% water content (saturated)

tailings fines content = 17% (minimum)
46% (mean)

CALCULATING r_d:

- at top of tailings: $z = 13/3.28 = 3.96$ m

  $r_d = 1 - 0.012 \cdot 3.96 = 0.952$

- at bottom of tailings: $z = 51/3.28 = 15.55$ m

  $r_d = 1 - 0.012 \cdot 15.55 = 0.813$

MWH

By ______ Date ______ Client ______ Sheet 2 of 3

Chkd. By CLS 30 May 07 Description ______ Job No. ______

CALCULATION OF SSR_a (cont'd)

A. At top of tailings :

$$\sigma_{vo} = 13 \cdot 110.2 = 1433 \text{ psf}$$
$$\sigma_{vo}' = 13 \cdot 110.2 = 1433 \text{ psf}$$
$$\sigma_{vo}/\sigma_{vo}' = 1.0$$

B. At bottom of tailings :

$$\sigma_{vo} = 13 \cdot 110.2 + 38 \cdot 124.1 = 1433 + 4716 = 6149 \text{ psf}$$
$$\sigma_{vo}' = \sigma_{vo} - u = 6149 - 38 \cdot 62.4 = 6149 - 2371 = 3778 \text{ psf}$$
$$\sigma_{vo}/\sigma_{vo}' = 1.63$$

At top of tailings: $SSR_a = 0.65\, r_d \left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma_{vo}'}\right)$

$$= 0.65 \cdot 0.952 \cdot 0.22 \cdot 1.0 = 0.136$$

At bottom of tailings: $SSR_a = 0.65 \cdot 0.813 \cdot 0.22 \cdot 1.63 = 0.190$

2. CALCULATION OF STRESS RATIO CAUSING LIQUEFACTION, SSR_l

SSR_l determined from Figure 11.8 of Day (1999), using calculated values of corrected blow count $(N_1)_{60}$ and fines content of tailings.

$(N_1)_{60}$ represents the resistance to liquefaction in terms of a corrected SPT blow count. The corrections are made for 60% rod energy ratio and for overburden pressure, as outlined in National Research Council (1985) and Carter and Bentley (1991).

For tailings compacted to 90% relative compaction, the equivalent relative density is 50% (Holtz and Kovacs, 1981). A relative density of 50% is equivalent to an SPT blow count of 20 blows/foot (Lambe and Whitman, 1969; Carter and Bentley, 1991). This is equivalent to an $(N_1)_{60}$ value of 15 (Carter and Bentley, 1991).

MWH

By______ Date ______ Client ______ Sheet 3 of 3

Chkd. By CLS 30May07 Description ______ Job No. ______

CALCULATING SSR_ℓ (cont'd)

The range of tailings fines content (from the Shaw test data) is 17 to 46 %. The $(N_1)_{60}$ value for compacted tailings is 15 throughout the tailings profile. Using Figure 11.8 of Day (1999) or Figure 4-7 of National Research Council (1985), the SSR_ℓ value for 17% fines is 0.23, and SSR_ℓ for 46% fines is 0.27.

3. COMPARING CALCULATED STRESS RATIO VALUES

Location in profile	% Fines	SSR_a	SSR_ℓ	Comment
Top of tailings	17	0.136	0.23	No liquefaction
	46	0.136	0.27	"
Bottom of tailings	17	0.190	0.23	"
	46	0.190	0.27	"

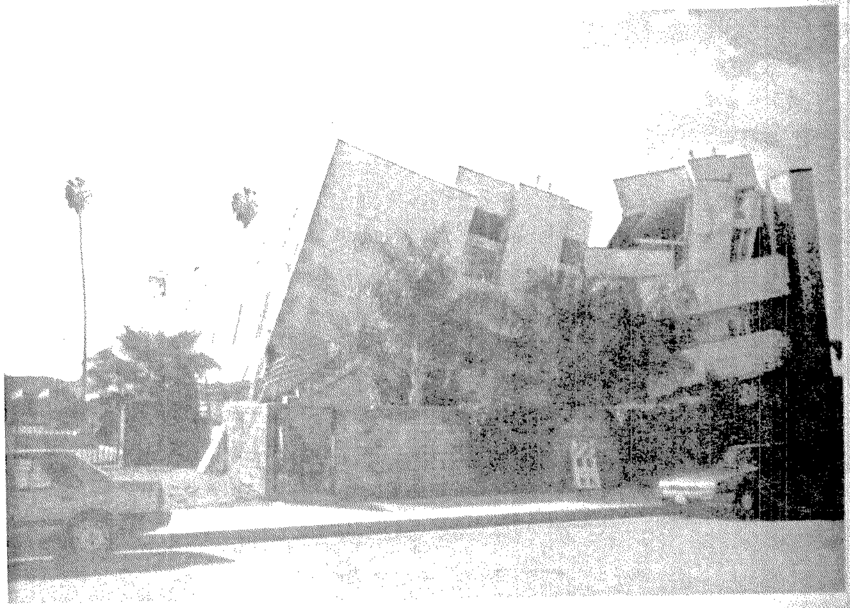

FIGURE 11.1 Building collapse caused by the 1994 Northridge, California, earthquake.

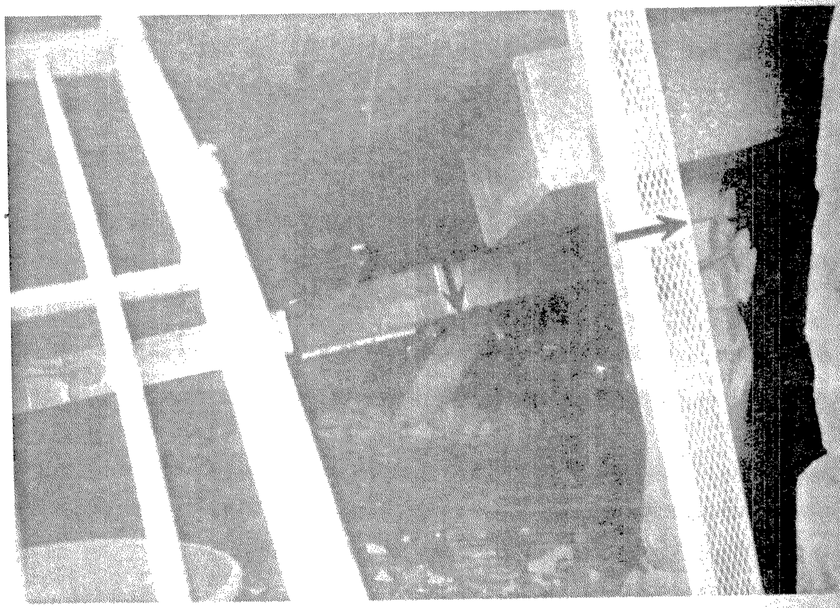

FIGURE 11.2 View inside the collapsed first floor parking garage (arrows point to columns).

FIGURE 11.3 Collapse of brick chimney, 1994 Northridge, California, earthquake.

two primary types of damage have developed: (1) longitudinal cracks at the top of the dam and (2) crest settlement. In the case of the Sheffield Dam, a complete failure did occur, probably due to liquefaction of the very loose and saturated lower portion of the embankment (Sherard et al., 1963).

11.2 *EARTHQUAKES*

A structure can be damaged by many different earthquake effects. Examples previously provided include a lack of shear resistance (Figs. 11.1 and 11.2) and poor construction practices (Fig. 11.3). The purpose of the following sections is to provide a brief summary of the common earthquake effects that need to be considered by the geotechnical engineer.

11.2.1 Fault and Ground Rupture Zone

Surface fault rupture caused by the earthquake is important because it has caused severe damage to buildings, bridges, dams, tunnels, canals, and underground utilities (Lawson et al., 1908; Ambraseys, 1960; Duke, 1960; California Department of Water Resources, 1967; Bonilla, 1970; Steinbrugge, 1970). Fault displacement is defined as the relative movement of the two sides of a fault, measured in a specific direction (Bonilla, 1970). Figure 11.4 shows the displacement of rock strata caused by the Carmel Valley Fault, located at Torry Pines, California.

Examples of very large surface fault rupture are the 11 m (35 ft) of vertical displacement in the Assam earthquake of 1897 (Oldham, 1899) and the 9 m (29 ft) of horizontal

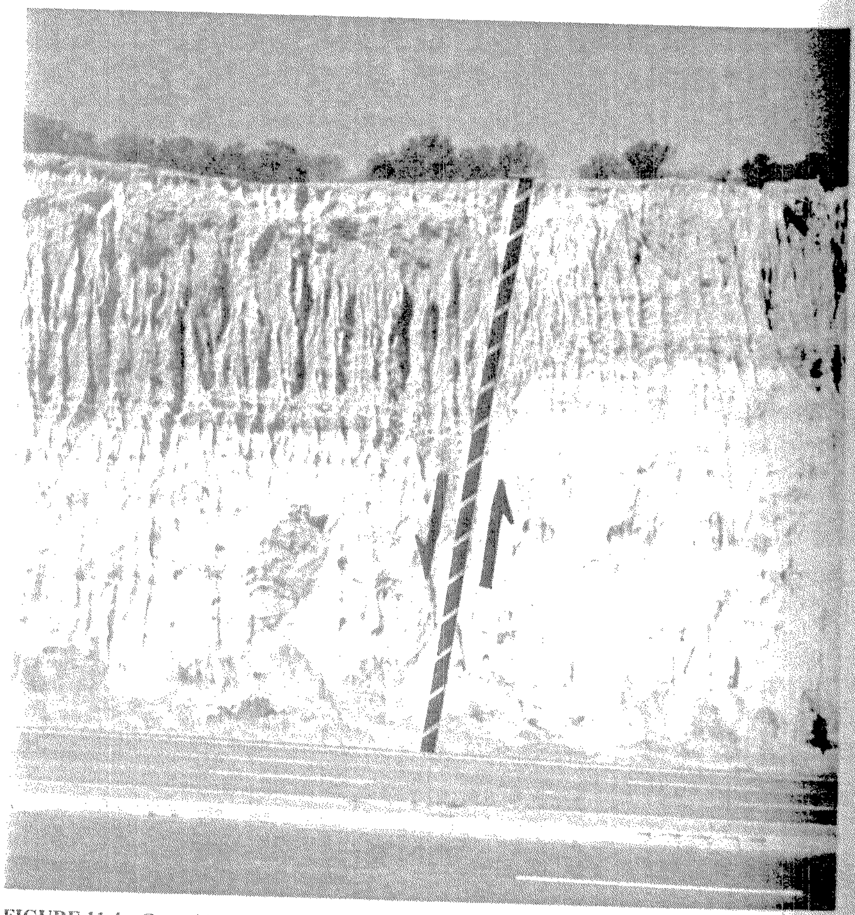

FIGURE 11.4 Carmel Valley Fault, located at Torry Pines, California.

movement during the Gobi-Altai earthquake of 1957 (Florensov and Solonenko, 1965). The length of the fault rupture can be quite significant. For example, the estimated length of surface faulting in the 1964 Alaskan earthquake varied from 600 to 720 km (Savage and Hastie, 1966; Housner, 1970).

A recent (geologically speaking) earthquake caused the fault rupture shown in Fig. 11.5. The fault is located at the base of the Black Mountains, in California. The vertical fault displacement caused by the earthquake is the vertical distance between the two arrows in Fig. 11.5. The fault displacement occurred in an alluvial fan being deposited at the base of the Black Mountains. Most structures would be unable to accommodate the huge vertical displacement shown in Fig. 11.5.

In addition to fault rupture, there can also be ground rupture away from the main trace of the fault. These ground cracks could be caused by many different factors, such as movement of subsidiary faults, auxiliary movement that branches off from the main fault trace, or ground rupture caused by the differential or lateral movement of underlying soil deposits. For example, Fig. 11.6 shows ground rupture during the 1994 Northridge

California, earthquake. The direction of the ground shear movement shown in Fig. 11.6 is toward the northwest. The ground movement sheared both the concrete patio and adjacent pool and knocked the house off its foundation.

Since most structures will be unable to resist the shear movement associated with surface faulting and ground rupture, one design approach is to simply restrict construction in the active fault shear zone. The best individual to determine the location and width of the active fault shear zone is the engineering geologist. Seismic study maps, such as the *State of California Special Studies Zones Maps* (1982), which were developed as part of the Alquist-Priolo Special Studies Zones Act, delineate the approximate location of active fault zones that require special geologic studies. These maps also indicate the approximate locations of historic fault offsets, which are indicated by year of earthquake-associated event, as well as the locations of ongoing fault displacement due to fault creep. There are many other geologic references, such as the cross section shown in Fig. 4.2, that can be used to identify active shear fault zones. Trenches, such as shown in Figs. 4.20 and 4.21, can be excavated across the fault zone to more accurately identify the width of the active fault shear zone. Critical structures, such as essential transportation routes (see Sec. 2.2) that must cross the active shear fault zones, will need special designs to resist the earthquake forces induced by ground rupture.

11.2.2 Liquefaction

The typical subsurface condition that is susceptible to liquefaction is a loose or very loose sand, that has been newly deposited or placed, with a groundwater table near ground surface. During an earthquake, the ground shaking causes the loose sand to contract, resulting in an increase in pore water pressure. Because the seismic shaking occurs so quickly, the

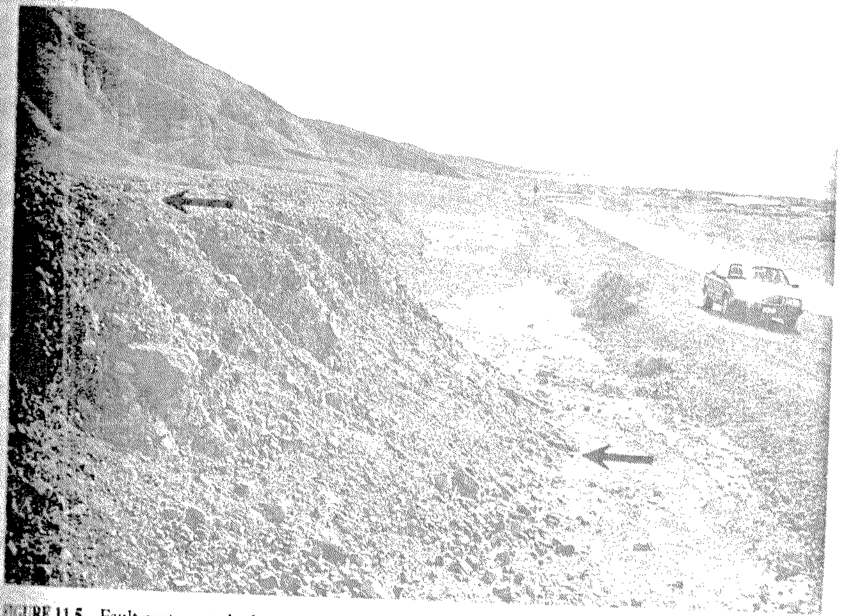

FIGURE 11.5 Fault rupture at the base of the Black Mountains (arrows indicate the amount of vertical displacement caused by the earthquake).

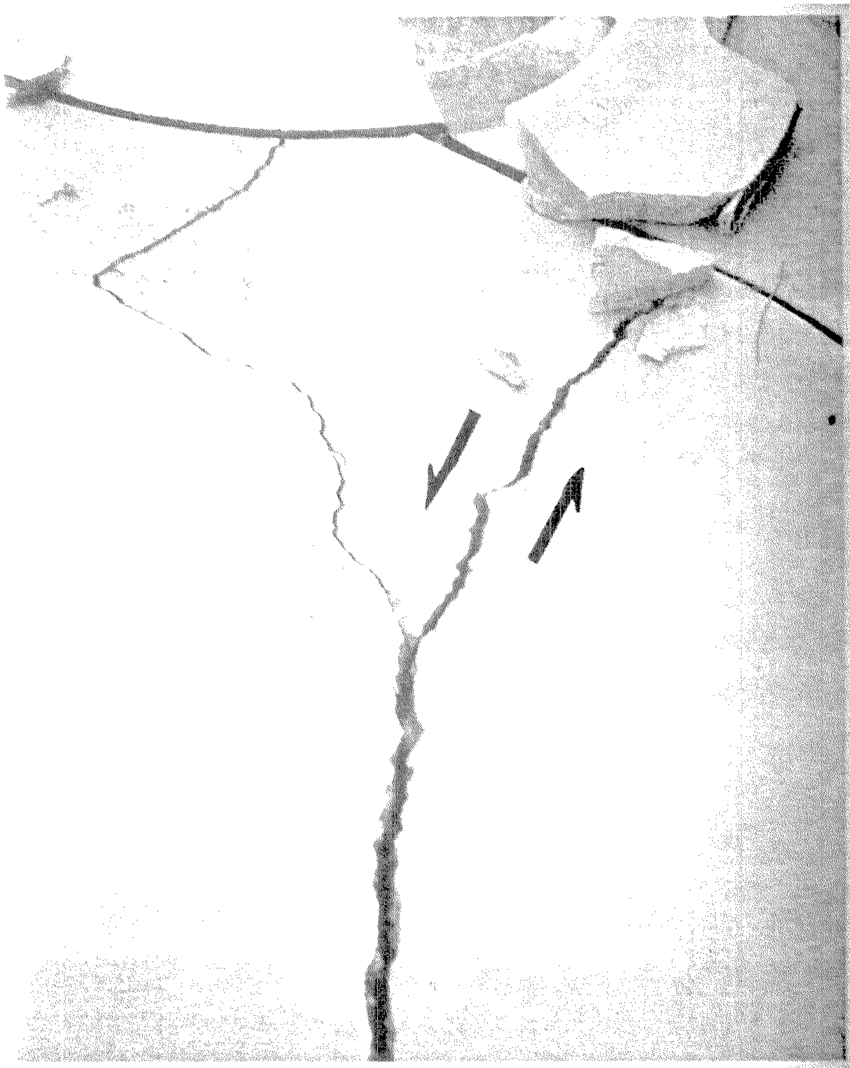

FIGURE 11.6 Ground rupture, 1994 Northridge, California, earthquake.

cohesionless soil is subjected to an undrained loading (total stress analysis). The increase in pore water pressure causes an upward flow of water to the ground surface, where it emerges in the form of mud spouts or sand boils. The development of high pore water pressures due to the ground shaking (i.e., the effective stress becomes zero) and the upward flow of water may turn the sand into a liquefied condition, which has been termed *liquefaction.* Structures on top of the loose sand deposit that has liquefied during an earthquake will sink or fall over, and buried tanks will float to the surface when the loose sand liquefies (Seed, 1970).

Liquefaction can also cause lateral movement of slopes and create flow slides (Ishihara, 1993). Seed (1970) states:

> If liquefaction occurs in or under a sloping soil mass, the entire mass will flow or translate laterally to the unsupported side in a phenomenon termed a flow slide. Such slides also develop in loose, saturated, cohesionless materials during earthquakes and are reported at Chile (1960), Alaska (1964), and Niigata (1964).

An example of lateral movement of liquefied sand is shown in Fig. 11.7 (from Kerwin and Stone, 1997). This damage occurred to a marine facility at Redondo Beach King Harbor during the 1994 Northridge, California, earthquake. The 5.5 m (18 ft) of horizontal displacement was caused by the liquefaction of an offshore sloping fill mass that was constructed as a part of the marine facility.

There can also be liquefaction of seams of loose saturated sands within a slope. This can cause the entire slope to move laterally along the liquefied layer at the base. These types of gross slope failures caused by liquefied seams of soil caused extensive damage during the 1964 Alaskan earthquake (Shannon and Wilson, Inc., 1964; Hansen, 1965). It has been observed that slope movement of this type typically results in little damage to structures located on the main slide mass, but buildings located in the graben area are subjected to large differential settlements and are often completely destroyed (Seed, 1970).

Main Factors for Liquefaction of Cohesionless Soil. There are many factors that govern the liquefaction process. The most important factors are as follows:

1. *Earthquake intensity and duration.* In order to have liquefaction of soil, there must be ground shaking. The character of the ground motion, such as acceleration and frequency content, determines the shear strains that cause the contraction of the soil particles and the development of excess pore water pressures leading to liquefaction. The most common

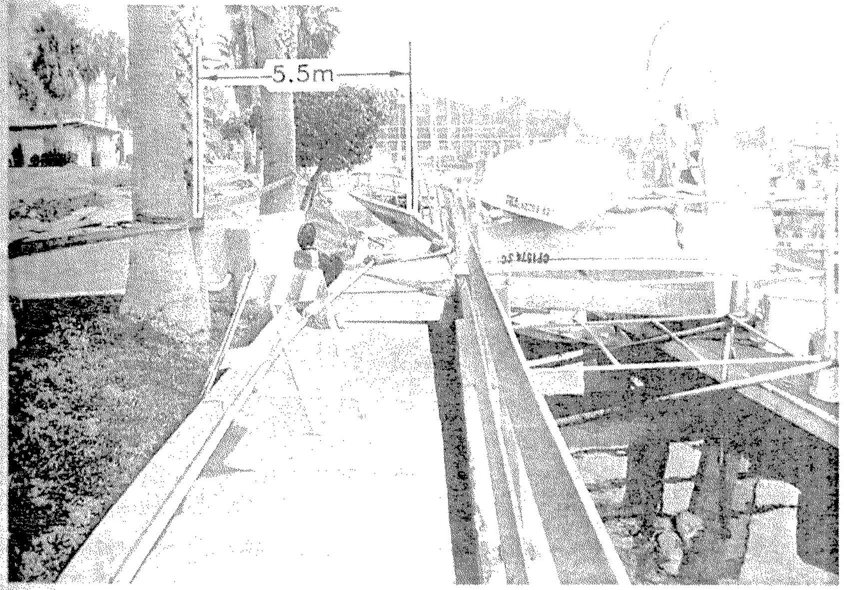

FIGURE 11.7 Damage to marine facility, 1994 Northridge, California, earthquake. (*From Kerwin and Stone, 1997; reprinted with permission from the American Society of Civil Engineers.*)

cause of liquefaction is the seismic energy released during an earthquake. The potential for liquefaction increases as the earthquake intensity and duration increase. Sites located near the epicenter of major earthquakes will be subjected to the largest intensity and duration of ground shaking (i.e., higher number of applications of cyclic shear strain). Besides earthquakes, other conditions can cause liquefaction, such as subsurface blasting.

2. *Groundwater table.* The condition most conducive to liquefaction is a near-surface groundwater table. Unsaturated soil located above the groundwater table will not liquefy.

3. *Soil type.* The soil types susceptible to liquefaction are nonplastic (cohesionless) soils. Seed et al. (1983) state that, on the basis of both laboratory testing and field performance, the great majority of clayey soils will not liquefy during earthquakes.

An approximate listing of cohesionless soils from least to most resistant to liquefaction are clean sands, nonplastic silty sands, nonplastic silt, and gravels. There could be numerous exceptions to this sequence. For example, Ishihara (1985, 1993) describes the case of tailings derived from the mining industry that were essentially composed of ground-up rocks and were classified as rock flour. Ishihara (1985, 1993) states that the rock flour in a water-saturated state did not possess significant cohesion and behaved as if it were a clean sand. These tailings were shown to exhibit as low a resistance to liquefaction as clean sand.

4. *Soil relative density D_r.* Cohesionless soils in a very loose relative density state are susceptible to liquefaction, while the same soil in a very dense relative density state will not liquefy. Very loose nonplastic soils will contract during the seismic shaking which will cause the development of excess pore water pressures. Very dense soils will dilate during seismic shaking and are not susceptible to liquefaction.

5. *Particle size gradation.* Poorly graded nonplastic soils tend to form more unstable particle arrangements and are more susceptible to liquefaction than well-graded soils.

6. *Placement conditions.* Hydraulic fills (fill placed under water) tend to be more susceptible to liquefaction because of the loose and segregated soil structure created by the soil particles falling through water.

7. *Drainage conditions.* If the excess pore water pressure can quickly dissipate, the soil may not liquefy. Thus gravel drains or gravel layers can reduce the liquefaction potential of adjacent soil.

8. *Confining pressures.* The greater the confining pressure, the less susceptible the soil is to liquefaction. Conditions that can create a higher confining pressure are a deeper groundwater table, soil that is located at a deeper depth below ground surface, and a surcharge pressure applied at ground surface. Case studies have shown that the possible zone of liquefaction usually extends from the ground surface to a maximum depth of about 15 m (50 ft). Deeper soils generally do not liquefy because of the higher confining pressures.

9. *Aging.* Newly deposited soils tend to be more susceptible to liquefaction than old deposits of soil. Older soil deposits may already have been subjected to seismic shaking or the soil particles may have deformed or been compressed into more stable arrangements.

Liquefaction Analysis. The most common type of analysis to determine the liquefaction potential is to use the standard penetration test (SPT) or the cone penetration test (CPT) (Seed et al., 1985; Stark and Olson, 1995). The analysis is based on the simplified method proposed by Seed and Idriss (1971). The method of analysis is as follows:

1. *Seismic shear stress ratio (SSR) caused by the earthquake.* The first step in the liquefaction analysis is to determine the seismic shear stress ratio (SSR). The seismic shear stress ratio induced by the earthquake at any point in the ground is estimated as follows (Seed and Idriss, 1971):

$$\mathrm{SSR} = 0.65\, r_d \left(\frac{a_{\max}}{g}\right)\left(\frac{\sigma_{v0}}{\sigma'_{v0}}\right) \qquad (11.1)$$

where SSR = seismic shear stress ratio (dimensionless parameter)
$a_{\max}$ = peak acceleration measured or estimated at the ground surface of the site ($\mathrm{m/s^2}$)
g = acceleration of gravity ($9.81\ \mathrm{m/s^2}$)*
σ_{v0} = total vertical stress at a particular depth where the liquefaction analysis is being performed (kPa) (in order to calculate the total vertical stress, the total unit weight γ_t of the soil layers must be known)
σ'_{v0} = vertical effective stress at that same depth in the soil deposit where σ_{v0} was calculated (kPa) (in order to calculate the vertical effective stress, the location of the groundwater table must be known).

The term r_d = depth reduction factor, which can be estimated in the upper 10 m of soil as (Kayan et al., 1992):

$$r_d = 1 - (0.012)(z) \qquad (11.2)$$

where z = depth in meters below the ground surface where the liquefaction analysis is being performed (i.e., the same depth used to calculate σ_{v0} and σ'_{v0})

2. *Seismic shear stress ratio that will cause liquefaction of the soil.* The second step is to determine the seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil. Figure 11.8 presents a chart that can be used to determine the seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil. In order to use this chart, the results of the standard penetration test (SPT) must be expressed in terms of the SPT $(N_1)_{60}$ value. In liquefaction analysis, the SPT N_{60} value [Eq. (4.3)] is corrected for the overburden pressure. When a correction is applied to the SPT N_{60} value to account for the effect of overburden pressure, these values are referred to as SPT $(N_1)_{60}$ values. The procedure consists of multiplying the N_{60} value by a correction C_N in order to calculate the SPT $(N_1)_{60}$ value, or:

$$(N_1)_{60} = C_N N_{60} = (100/\sigma'_{v0})^{0.5} N_{60} \qquad (11.3)$$

where $(N_1)_{60}$ = standard penetration N-value corrected for both field testing procedures and overburden pressure
C_N = correction factor to account for the overburden pressure [as indicated in Eq. (11.3), C_N is approximately equal to $(100/\sigma'_{v0})^{0.5}$, where σ'_{v0} is the vertical effective stress in kPa]
N_{60} = standard penetration N-value corrected for testing procedures [note that N_{60} is calculated by using Eq. (4.3)]

Once the corrected SPT $(N_1)_{60}$ has been calculated, Fig. 11.8 can be used to determine the seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil. Note that Fig. 11.8 is for a projected earthquake of 7.5 magnitude. The figure also has different curves that are to be used according to the percent fines in the soil. For a given $(N_1)_{60}$ value,

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*Usually the engineering geologist will determine the peak acceleration at the ground surface at the site from fault, seismicity, and attenuation studies. Typically the engineering geologist provides a peak ground acceleration in the form of $a_{\max}/g$ = a constant. For example, the engineering geologist may determine that the peak ground surface acceleration at a site is $a_{\max}/g = 0.1$, in which case the value of 0.1 (dimensionless) is substituted into Eq. (11.1) in place of $a_{\max}/g$.

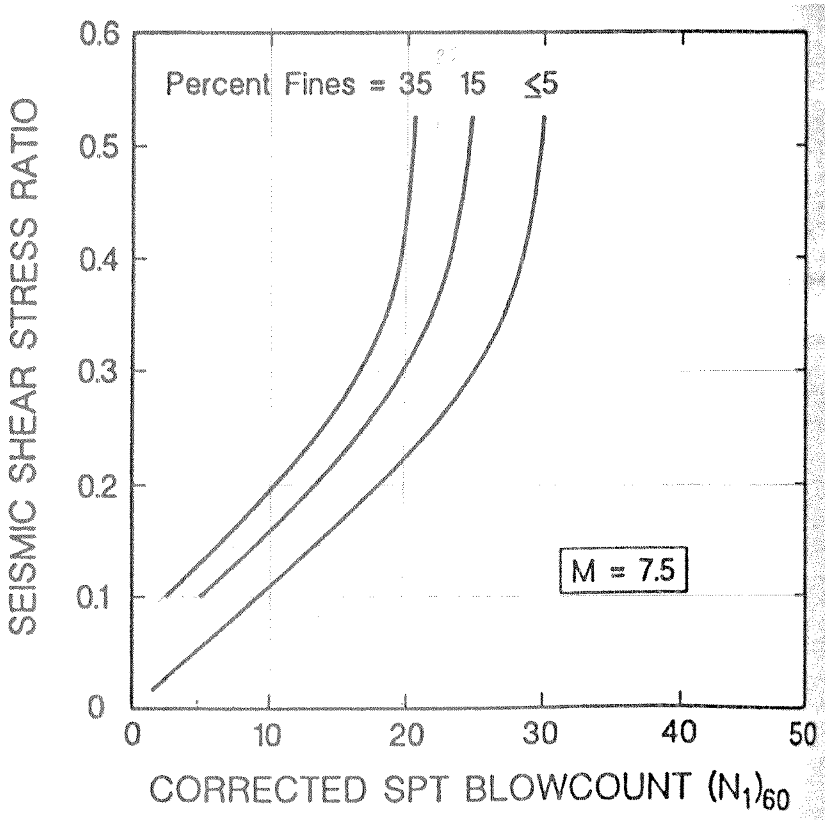

FIGURE 11.8 Relationship between seismic shear stress ratio (SSR) triggering liquefaction and $(N_1)_{60}$ values for clean and silty sands for $M = 7.5$ earthquakes. (*After Seed and DeAlba, 1986; reproduced from Stark and Olson, 1995; reprinted with permission of the American Society of Civil Engineers.*)

soils with more fines have a higher seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil.

Figure 11.9 presents a chart for clean sands (5 percent or less fines) and different magnitude earthquakes. The magnitude 7.5 curve in Fig. 11.9 is similar to the magnitude 7.5 curve for 5 percent or less fines in Fig. 11.8.

3. *Compare seismic shear stress ratios.* The final step in the liquefaction analysis is to compare the seismic shear stress ratio (SSR) values. If the SSR value from Eq. (11.1) is greater than the SSR value obtained from either Fig. 11.8 or Fig. 11.9, then liquefaction could occur during the earthquake, and vice versa.

Example. It is planned to construct a building on a cohesionless soil deposit (fines less than 5 percent). There is a nearby major active fault and the engineering geologist has determined that the peak ground acceleration $(a_{\max}) = 0.4g$. Assume the site conditions are the same as stated in Prob. 18 (Chap. 6), i.e., a level ground surface with the groundwater table located 1.5 m below ground surface and the standard penetration test performed at a depth of 3 m. If the earthquake magnitude $(M) = 7.5$, will the saturated clean sand located at a depth of 3 m below ground surface liquefy during the anticipated earthquake?

Solution. From Prob. 18 (Chap. 6), $\sigma'_{v0} = 43$ kPa and $N_{60} = 5$. Using the total unit weights from Prob. 18 (Chap. 6), $\sigma_{v0} = 58$ kPa. Since $z = 3$ m, $r_d = 0.96$. Using the following values:

$r_d = 0.96$

$a_{\max}/g = 0.4$

$(\sigma_{v0}/\sigma'_{v0}) = (58/43) = 1.35$

and inserting the above values into Eq. (11.1), we find the seismic shear stress ratio (SSR) caused by the earthquake is 0.34.

The next step is to determine the seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil. From Prob. 18 (Chap. 6), the N-value corrected for field testing procedures $(N_{60}) = 5$. Using Eq. (11.3) with $\sigma'_{v0} = 43$ kPa and $N_{60} = 5$, we find

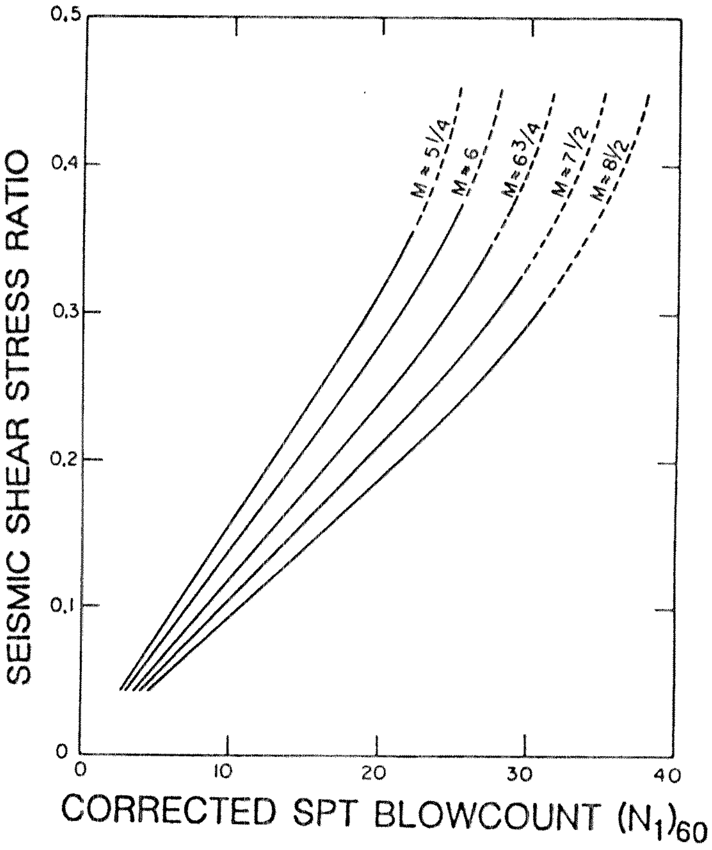

FIGURE 11.9 Relationship between seismic shear stress ratio (SSR) triggering liquefaction and $(N_1)_{60}$ values for clean sand for different magnitude earthquakes. (*After Seed et al., 1983; reprinted with permission of the American Society of Civil Engineers.*)

$(N_1)_{60} = 8$. Entering Fig. 11.8 with $(N_1)_{60} = 8$ and intersecting the curve labeled ≤ 5% fines, the seismic shear stress ratio (SSR) that will cause liquefaction of the *in situ* soil at a depth of 3 m = 0.08.

The final step is to compare the SSR caused by the earthquake (SSR = 0.34) with the SSR that will cause liquefaction of the *in situ* soil (SSR = 0.08). From a comparison of the SSR values, it is probable that during the earthquake the *in situ* sand located at a depth of 3 m below ground surface will liquefy.

In the above liquefaction analysis, there are many different equations and corrections that are applied to the seismic shear stress ratio (SSR). For example, there are four different corrections (E_m, C_b, C_r, and σ'_{v0}) that are applied to the SPT N-value in order to calculate the $(N_1)_{60}$ value. All of these different equations and various corrections may provide the engineer with a sense of high accuracy, when in fact, the entire analysis is only a gross approximation. The analysis should be treated as such and engineering experience and judgment are essential in the final determination of whether or not a site has liquefaction potential.

11.2.3 Slope Movement and Settlement

Besides liquefaction of loose saturated sands, other soil conditions can result in slope movement or settlement during an earthquake. For example, Grantz et al. (1964) describe an interesting case of ground vibrations from the 1964 Alaskan earthquake that caused 0.8 m (2.6 ft) of alluvium settlement. Other loose soils, such as cohesionless sand and gravel, will also be susceptible to settlement due to the ground vibrations from earthquakes.

Slopes having a low factor of safety can experience large horizontal movement during an earthquake. Types of slopes most susceptible to movement during earthquakes include those slopes composed of soil that loses shear strength with strain (such as sensitive soil) and ancient landslides that can become reactivated by seismic forces (Day and Poland, 1996).

11.2.4 Translation and Rotation

An unusual effect caused by earthquakes is translation and rotation of objects. For example, Fig. 11.10 shows a photograph of a brick mailbox that rotated and translated (moved laterally) during the Northridge earthquake. The initial position in Fig. 11.10 refers to the pre-earthquake position of the mailbox.

Earthquakes have caused the rotation of other movable objects, such as grave markers (Athanasopoulos, 1995; Yegian et al., 1994). According to Athanasopoulos (1995), such objects will rotate in such a manner as to be aligned with the strong component of the earthquake. Besides rotation, translation (lateral movement) can also occur during an earthquake. The objects will tend to move in the same direction as the propagation of energy waves, i.e., in a direction away from the epicenter of the earthquake.

11.3 ESTIMATING EARTHQUAKE GROUND MOVEMENT

Often the geotechnical engineer will be required to estimate the amount of foundation displacement caused by earthquake-induced soil movement. For example, the *Uniform Building Code* (1997), which is the building code required for construction in California, states (code provision submitted by the author, adopted in May 1994):

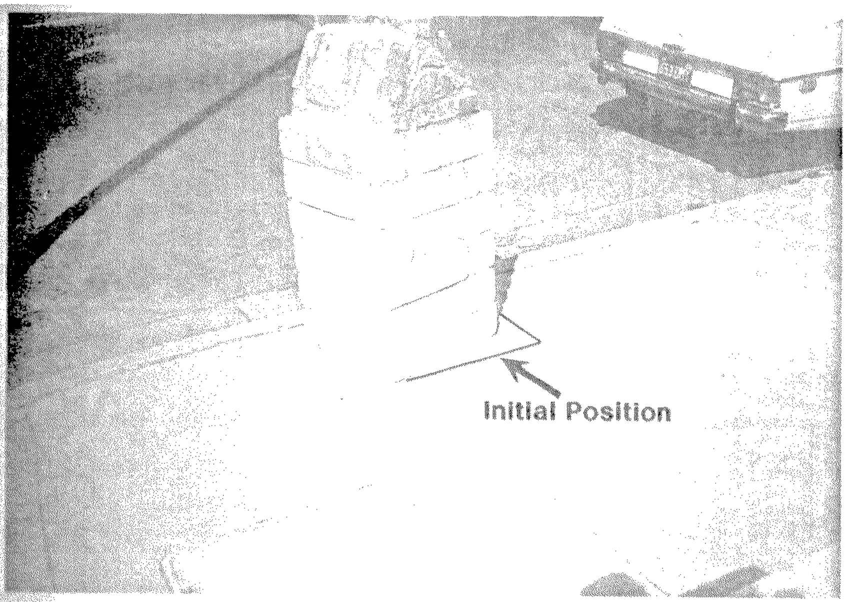

FIGURE 11.10 Rotation of brick mailbox, 1994 Northridge, California, earthquake.

> The potential for soil liquefaction and soil strength loss during earthquakes shall be evaluated during the geotechnical investigation. The geotechnical report shall assess potential consequences of any liquefaction and soil strength loss, including estimation of differential settlement, lateral movement or reduction in foundation soil-bearing capacity, and discuss mitigating measures. Such measures shall be given consideration in the design of the building and may include, but are not limited to, ground stabilization, selection of appropriate foundation type and depths, selection of appropriate structural systems to accommodate anticipated displacement or any combination of these measures.

The intent of this building code requirement is to obtain an approximate estimate of the foundation displacement caused by the earthquake induced soil movement. In terms of accuracy of the calculations used to determine the earthquake induced soil movement, Tokimatsu and Seed (1984) conclude:

> It should be recognized that, even under static loading conditions, the error associated with the estimation of settlement is on the order of ±25 to 50%. It is therefore reasonable to expect less accuracy in predicting settlements for the more complicated conditions associated with earthquake loadin. . . . In the application of the methods, it is essential to check that the final results are reasonable in light of available experience.

Pseudostatic Approach. A vast majority of foundation and earthwork designs are based on the pseudostatic approach (Coduto, 1994). This method ignores the cyclic nature of earthquakes and treats them as if they apply an additional static force upon the slope, retaining wall, or foundation element. For example, as will be discussed in Sec. 15.3, a common

GEOTECHNICAL AND FOUNDATION ENGINEERING

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Appendix B

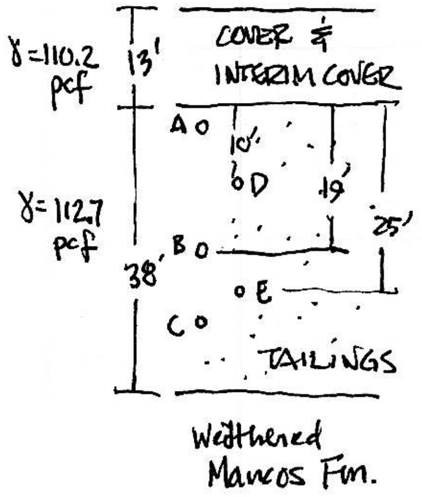
Settlement Analyses

MWH

By as Date 6 May 07 Client Stoller / DOE Sheet 1 of 2

Chkd. By ____ Description ____ Job No. ____

ESTIMATING PRIMARY SETTLEMENT OF TAILINGS



STRESSES AT A: $\sigma_1' = 113$ $\sigma_2' = 1433$ (in psf)

B: $\sigma_1' = 1578$ $\sigma_2' = 1433 + 1578$
$= 3011$

C: $\sigma_1' = 3156$ $\sigma_2' = 3156 + 1433$
$= 4589$

D: $\sigma_1' = 1127$ $\sigma_2' = 1127 + 1433$
$= 2560$

E: $\sigma_1' = 2818$ $\sigma_2' = 2818 + 1433$
$= 4251$

SETTLEMENT AT A: $\sigma_2'/\sigma_1' = 12.7$, $\log \sigma_2'/\sigma_1' = 1.10$

$$S = \frac{C_c}{1+e_0} H_0 \log \sigma_2'/\sigma_1' = \frac{0.2}{1+0.8}\, 1.0 \cdot 1.10 = 0.12 \text{ ft}$$

B: $\sigma_2'/\sigma_1' = 1.908$, $\log \sigma_2'/\sigma_1' = 0.28$

$$S = \frac{0.2}{1+0.8} \cdot 18 \cdot 0.28 = 0.56 \text{ ft}$$

C: $\sigma_2'/\sigma_1' = 1.454$, $\log \sigma_2'/\sigma_1' = 0.16$

$$S = \frac{0.2}{1+0.8} \cdot 19 \cdot 0.16 = 0.34 \text{ ft}$$

D: $\sigma_2'/\sigma_1' = 2.27$, $\log \sigma_2'/\sigma_1' = 0.356$

$$S = \frac{0.2}{1+0.8} \cdot 19 \cdot 0.356 = 0.75 \text{ ft}$$

E: $\sigma_2'/\sigma_1' = 1.509$, $\log \sigma_2'/\sigma_1' = 0.179$

$$S = \frac{0.2}{1+0.8} \cdot 19 \cdot 0.179 = 0.38 \text{ ft}$$

A+B+C = 1.02 ft, D+E = 1.13 ft

MWH

By CAS Date 6 May 07 Client Sheet 2 of 2

Chkd. By Description Job No.

ESTIMATING SECONDARY SETTLEMENT OF TAILINGS

From Keshian and Larson (1988) and Holtz and Kovacs (1981):

Secondary settlement, $S = C_\alpha H \log (t_2/t_1)$

H = tailings thickness = 38 ft

t_1 = 10 years (from tailings placement to cover construction)

t_2 = 1000 years (design life of disposal cell)

$\log(t_2/t_1) = 2.0$

C_α = secondary compression index

- From Keshian and Rager (1988), C_α for remolded sand/slime tailings ranged from 0.003 to 0.01
- From testing on Moab tailings (Shaw, 2006a and 2006b), C_α for remolded tailings ranged from 0.003 to 0.013
- From Holtz and Kovacs (1981), $C_\alpha/C_c = 0.05$ for inorganic soils. For $C_c = 0.20$, $C_\alpha = 0.01$

For $C_\alpha = 0.01$, $S = 0.01 \cdot 38 \cdot 2.0 = 0.76$ ft

0.003, $S = 0.003 \cdot 38 \cdot 2.0 = 0.23$ ft

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/8/2007**
Detail:	**Estimate Primary Settlement of Tailings**	**Computed By**	**CLS/RTS**

Tailings Property	Value	Source
Cc:	0.19	Shaw laboratory testing (2006b) mean value for transitional tailings
Specific Gravity:	2.8	Shaw laboratory testing (2006a) mean value for transitional tailings
Dry Unit Weight (pcf)	98	90% of Standard Proctor from average of transitional tailings (Golder 2006)
Moisture Content	19%	optimum mc of Standard Proctor from average of transitional tailings (Golder 2006)
eo	0.78	calculated

Layer	Moist Unit Weight (pcf)	H_o (ft)	Overburden Stress (soil) (psf)	Cover Soil Pressure (psf)	Total Stress (overburden + cover) (psf)	$C_c/1+e_o$	Incremental Settlement (ft)	Incremental Settlement (in)
0-2'	116.6	2.00	116.62	1433	1549.35	0.10	0.233	2.80
2-4'	116.6	2.00	349.86	1433	1782.59	0.10	0.147	1.76
4-6'	116.6	2.00	583.10	1433	2015.83	0.10	0.112	1.34
6-8'	116.6	2.00	816.34	1433	2249.07	0.10	0.091	1.10
8-10'	116.6	2.00	1049.58	1433	2482.31	0.10	0.078	0.93
10-12'	116.6	2.00	1282.82	1433	2715.55	0.10	0.068	0.81
12-14'	116.6	2.00	1516.06	1433	2948.79	0.10	0.060	0.72
14-16'	116.6	2.00	1749.30	1433	3182.03	0.10	0.054	0.65
16-18'	116.6	2.00	1982.54	1433	3415.27	0.10	0.049	0.59
18-20'	116.6	2.00	2215.78	1433	3648.51	0.10	0.045	0.54
20-22'	116.6	2.00	2449.02	1433	3881.75	0.10	0.042	0.50
22-24'	116.6	2.00	2682.26	1433	4114.99	0.10	0.039	0.46
24-26'	116.6	2.00	2915.50	1433	4348.23	0.10	0.036	0.43
26-28'	116.6	2.00	3148.74	1433	4581.47	0.10	0.034	0.41
28-30'	116.6	2.00	3381.98	1433	4814.71	0.10	0.032	0.38
30-32'	116.6	2.00	3615.22	1433	5047.95	0.10	0.030	0.36
32-34'	116.6	2.00	3848.46	1433	5281.19	0.10	0.029	0.34
34-36'	116.6	2.00	4081.70	1433	5514.43	0.10	0.027	0.33
36-38'	116.6	2.00	4314.94	1433	5747.67	0.10	0.026	0.31
						Total:	**1.23**	**14.8**

Appendix C

Cover Cracking Analyses

MWH

By CLS Date 6 May 2007 Client DOE / Stoller Sheet 1 of 1
Chkd. By RTS 5/10/07 Description Job No.

EVALUATION OF COVER CRACKING

From Caldwell and Reith (1993): allowable cover strain ~~ef~~ at failure = e_f (%)

$e_f = 0.05 + 0.003\ PI$

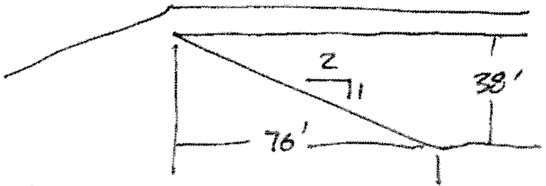
where PI = plasticity index of cover soil

for alluvial material / weathered Mancos cover soil PI is 5 to 10

for PI = 5, $e_f = 0.05 + 0.003(5) = 0.065\ \%$
10, $e_f = 0.05 + 0.003(10) = 0.080\ \%$

The location of maximum differential settlement is along the inside slope of the embankment, from 0 to ~~1.8~~ 2.0 ft of settlement in 76 ft (for both primary and secondary settlement)

$$\left.\begin{array}{l}\Delta = \overset{2.0}{\cancel{1.8}} \\ L = 76\end{array}\right\} \Delta/L = \overset{0.026}{\cancel{0.024}}$$



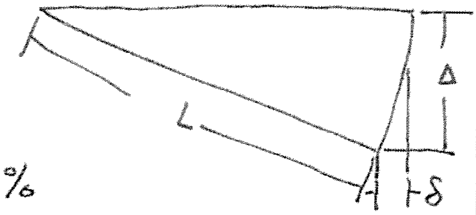
Checking Figure 2-16 in EPA (1991):
for distortion (Δ/L) of ~~0.024~~ 0.026, tensile strain < 0.1 %

checking by geometry and linear distortion:

$$\delta = (L^2 + \Delta^2)^{\frac{1}{2}} - L = (76^2 + \overset{2.0}{\cancel{1.8}}{}^2)^{\frac{1}{2}} - 76$$

$$= \overset{0.0263}{\cancel{0.0213}}\ ft$$

$$\text{tensile strain} = \epsilon = \frac{\delta}{L} = \frac{\overset{0.0263}{\cancel{0.0213}}}{76} = 0.03\ \%$$



$\epsilon < e_f$ – therefore cover settlement is acceptable

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-09-2005-2-08-01 **Discipline:** Hydrology **No. of Sheets:** 4
Doc. No.: X0113000

Location: RAP Attachment 1, Appendix E

Project: Moab Project

Site: Crescent Junction Site Characterization

Feature: Site Drainage—Hydrology Parameters

Sources of Data:

Sources of Formulae and References:

DOE (U.S. Department of Energy), 1989. *Technical Approach Document*, *Revision II*, UMTRA-DOE/AL 050424.0002, U.S. Department of Energy Uranium Mill Tailings Remedial Action Project, December.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** MOA-02-08-2005-2-08-00

Author: Name 5-31-07 Date

Checked by: Name 6-7-07 Date

Approved by: John E Elmer Name 5/31/07 Date

Name Date

Name Date

Name May 31, 07 Date

No text for this page

Problem Statement:

To determine the hydrometeorological characteristics of the Crescent Junction site, Utah, at 38.96° North, 109.80° West, elevation 4,950 feet (ft) above mean sea level (amsl) for the following designs during and after remedial action:

A. During remedial action at the disposal site:

   1. 10-year, 60-minute storm to size ditches and erosion protection.
   2. 10-year, 24-hour storm to size wastewater retention basins.
   3. 25-year, 60-minute storm to size emergency spillway of the basins.

B. After remedial action at the disposal site:

   1. Probable Maximum Precipitation (PMP) storm intensity and duration to size ditches and design erosion protection for ditches and embankment.

Method of Solution:

For remedial action at the disposal site, look up point-precipitation frequency estimates on the National Oceanic and Atmospheric Administration (NOAA) website and download the results.

For post-remedial action at the disposal site, use Hydrometeorological Report (HMR) No. 49 to calculate PMP storm intensity for general-storm PMP and the local-storm PMP. Select most intense storm for design purposes.

Assumptions:

Standard procedures used to calculate design storms and PMP will be protective of human life, infrastructure, and environment.

Calculation:

During remedial action, rainfall will be determined from the NOAA precipitation-frequency atlas for Utah (Appendix A).

The design storm information was downloaded from the NOAA website: http://hdsc.nws.noaa.gov/hdsc/pfds/sa/ut_pfds.html.

Point precipitation frequency estimates were drawn directly from http://hdsc.nws.noaa.gov/cgi-bin/hdsc/buildout.perl?type=pf&series=pd&units=us&statename=UTAH&stateabv=ut&study=sa&season=All&intype=3&plat=&plon=&liststation=THOMPSON++++++++++++++++UT+%2C+42-8705&slat=38.96&slon=-109.8&mlat=40.051&mlon=-108.490&elev=0&xy0=lat&xy1=-lon&xy2=lat&xy3=-lon&xy4=lat&xy5=-lon&xy6=lat&xy7=-lon&xy8=lat&xy9=-lon&xy10=lat&xy11=-lon&xy12=lat&xy13=-lon&xy14=lat&xy15=-lon&xy16=lat&xy17=-lon&xy18=lat&xy19=-lon&xy20=lat&xy21=-lon&xy22=lat&xy23=-lon. The data from this website are presented in Appendix A. The design-storm data are presented in Table 1.

After remediation, rainfall will be determined for the Crescent Junction Disposal Site from the general storm PMP or the local-storm PMP; whichever is more severe, according to HMR No. 49 (Appendix B). The watershed areas of the proposed diversion ditch (if required), and the proposed tailings site are each less than 10 square miles (mi^2); therefore, no depth-area correction is required for the PMP. The basin area of the Crescent Wash drainage is 22 mi^2; therefore a depth-area correction of 98 percent is required to compute the general storm PMP. The minimum site elevation for the project is approximately 4,950 ft amsl. The wet season of the site is from July to October. The general-storm PMP and the local-storm PMP are calculated as shown in Appendix B. The maximum general-storm PMP, which occurs during the month of August, has an estimated maximum intensity of 4.7 inches in 6 hours. A comparison of the general-storm and the local-storm PMPs indicates that the intensity of the local-storm PMP, which carries an estimated depth of 7.4 inches in 6 hours, exceeds the intensity of the general-storm PMP; consequently, the local-storm PMP should be used for engineering design purposes in accordance with Section 4.1.3 of the Technical Approach Document (DOE 1989). The estimated precipitation depths for the local-storm PMP are presented in Table 2.

Discussion:

Not applicable.

Conclusions and Recommendations:

Table 1. Summary of Design Storm Data for the Crescent Junction, Utah, Site

Recurrence Interval (years)	**Rainfall Inches for Duration Hours**	
	60 minute	24 hour
10	0.8 inches	1.63 inches
25	1.07 inches	

Table 2. Estimated Precipitation Depths for Local-Storm PMP, Crescent Junction, Utah, Site

Hourly Increments	**First Hour**	**Second Hour**	**Third Hour**				**Fourth Hour**	**Fifth Hour**	**Sixth Hour**
PMP Depths (inches)	0.1	0.3	6.0				0.7	0.2	0.1
Third-Hour Component Depths (inches)			4.3	0.8	0.6	0.3			

Computer Source:

Not applicable

Appendix A

Point Precipitation Frequency Estimates From NOAA Atlas 14

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Utah 38.96 N 109.8 W 4954 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 3
G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2003
Extracted: Thu Jul 7 2005

Confidence Limits | Seasonality | Location Maps | Other Info. | Grids | Maps | Help | Docs

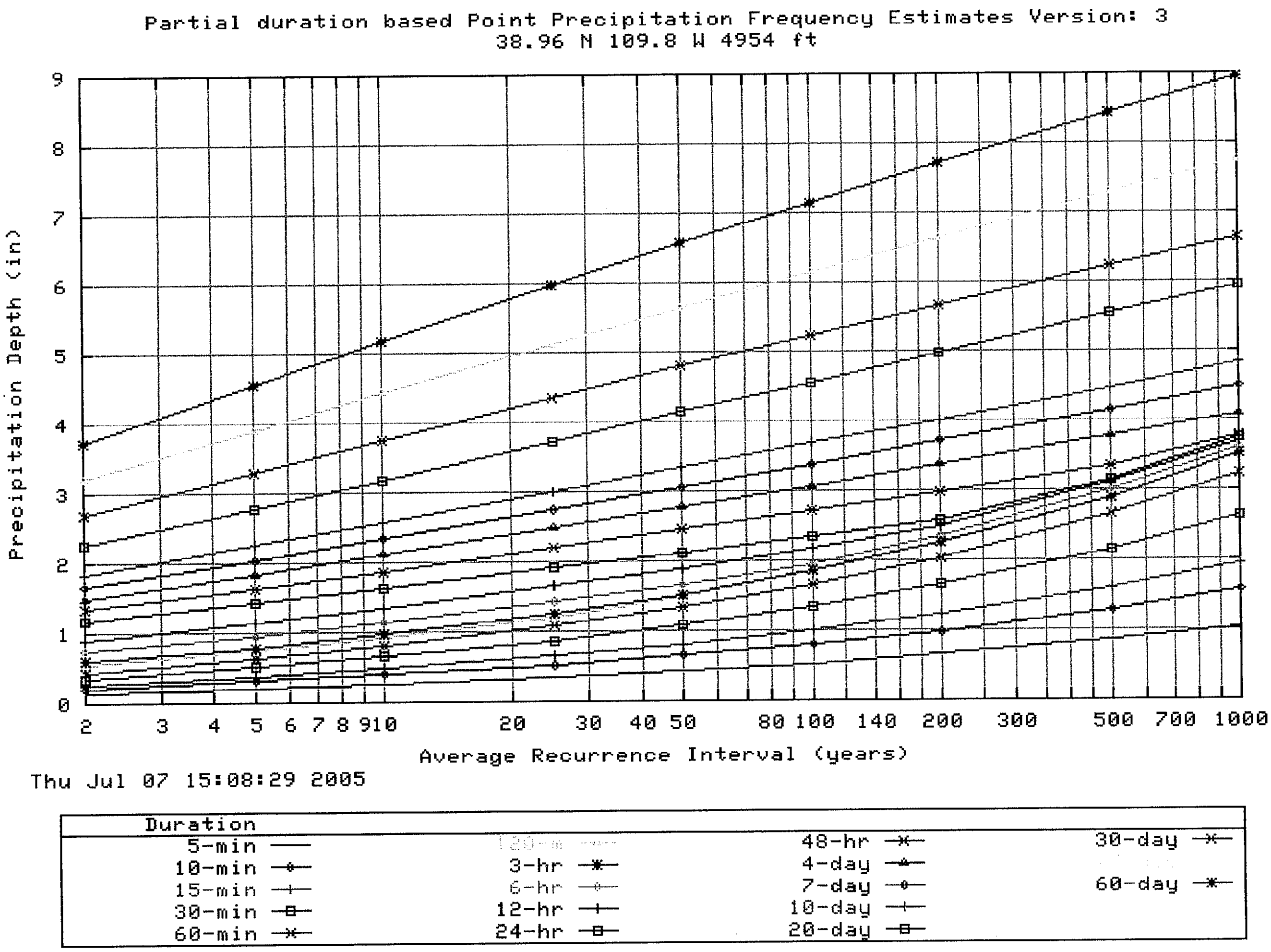
Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.14	0.21	0.26	0.35	0.44	0.53	0.59	0.73	0.89	1.16	1.34	1.49	1.66	1.83	2.25	2.70	3.19	3.71
5	0.20	0.30	0.38	0.51	0.62	0.73	0.79	0.94	1.15	1.42	1.64	1.83	2.03	2.24	2.77	3.29	3.89	4.54
10	0.25	0.39	0.48	0.65	0.80	0.91	0.97	1.13	1.36	1.63	1.87	2.10	2.33	2.57	3.18	3.75	4.42	5.16
25	0.34	0.52	0.64	0.87	1.07	1.21	1.26	1.42	1.65	1.91	2.20	2.47	2.75	3.01	3.73	4.34	5.12	5.97
50	0.42	0.65	0.80	1.08	1.34	1.49	1.52	1.66	1.90	2.12	2.45	2.76	3.05	3.34	4.14	4.79	5.64	6.56
100	0.53	0.80	0.99	1.33	1.65	1.82	1.84	1.95	2.16	2.35	2.71	3.05	3.38	3.68	4.56	5.23	6.15	7.14
200	0.65	0.98	1.22	1.64	2.03	2.23	2.25	2.35	2.47	2.58	2.98	3.36	3.71	4.01	4.97	5.66	6.64	7.71
500	0.84	1.28	1.59	2.15	2.65	2.88	2.89	3.00	3.11	3.15	3.34	3.77	4.15	4.47	5.54	6.22	7.28	8.43
1000	1.03	1.57	1.94	2.62	3.24	3.49	3.50	3.60	3.69	3.73	3.77	4.09	4.50	4.82	5.95	6.63	7.75	8.95

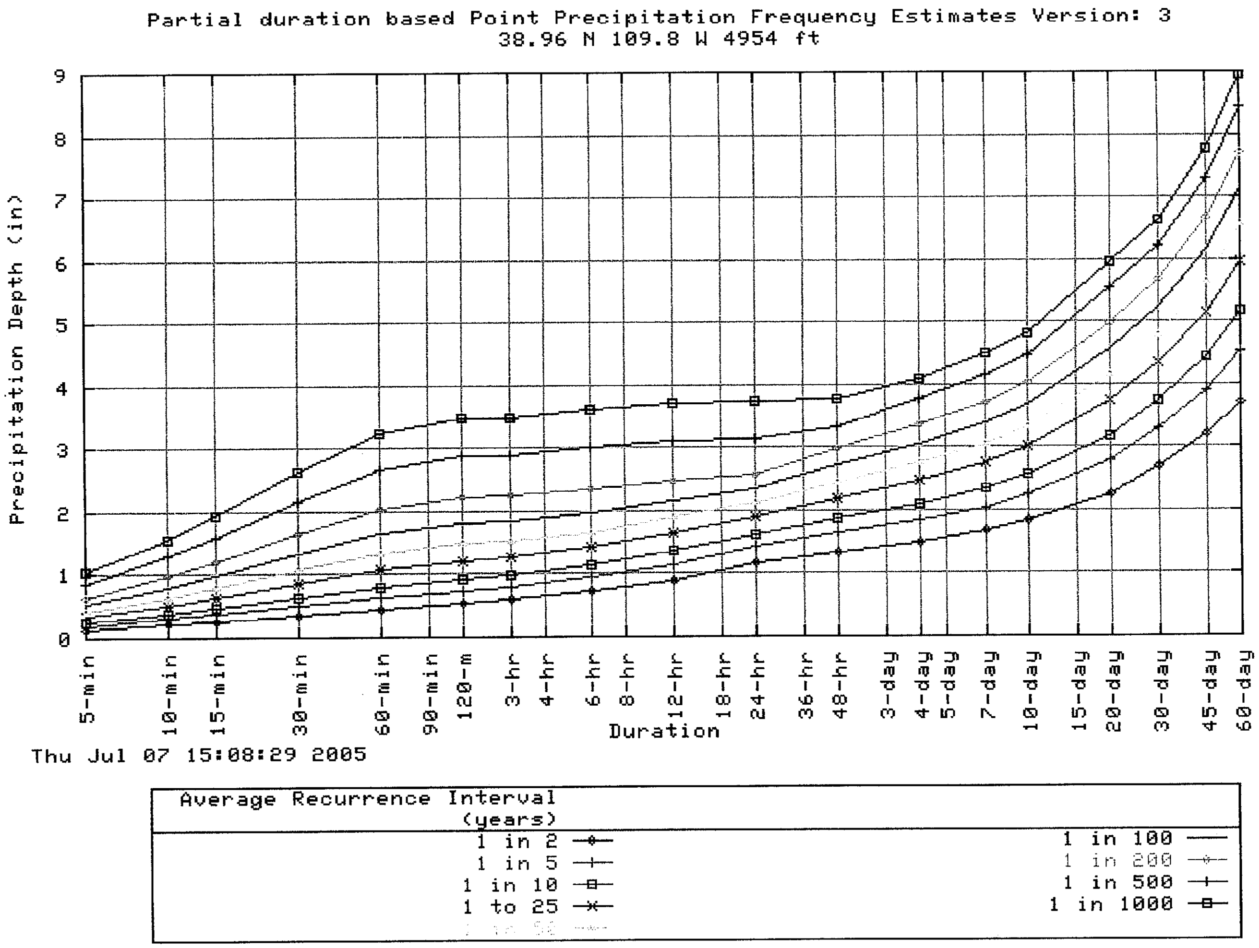
Text version of table

* These precipitation frequency estimates are based on a partial duration series. **ARI** is the Average Recurrence Interval. Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Partial duration based Point Precipitation Frequency Estimates Version: 3
38.96 N 109.8 W 4954 ft



Thu Jul 07 15:08:29 2005



Confidence Limits -

*** Upper bound of the 90% confidence interval**
Precipitation Frequency Estimates (inches)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.16	0.25	0.30	0.41	0.51	0.60	0.66	0.82	1.00	1.25	1.43	1.61	1.80	1.99	2.46	2.92	3.45	4.02
5	0.23	0.35	0.43	0.58	0.72	0.83	0.88	1.06	1.27	1.52	1.74	1.96	2.19	2.42	3.02	3.56	4.19	4.89
10	0.29	0.44	0.55	0.74	0.92	1.03	1.09	1.28	1.50	1.75	1.99	2.24	2.51	2.77	3.45	4.06	4.76	5.55
25	0.40	0.60	0.75	1.00	1.24	1.38	1.43	1.60	1.85	2.06	2.35	2.65	2.96	3.25	4.04	4.71	5.51	6.41
50	0.50	0.76	0.94	1.26	1.56	1.71	1.73	1.90	2.12	2.32	2.63	2.95	3.29	3.62	4.50	5.20	6.08	7.08
100	0.62	0.94	1.16	1.56	1.94	2.11	2.13	2.25	2.46	2.59	2.94	3.28	3.66	4.01	4.99	5.71	6.65	7.74
200	0.77	1.17	1.45	1.95	2.41	2.61	2.63	2.75	2.86	2.87	3.26	3.65	4.05	4.41	5.47	6.22	7.21	8.41
500	1.02	1.55	1.93	2.60	3.21	3.47	3.49	3.58	3.67	3.70	3.71	4.15	4.62	4.96	6.15	6.91	7.97	9.27
1000	1.27	1.94	2.40	3.24	4.01	4.28	4.30	4.37	4.42	4.47	4.51	4.58	5.08	5.43	6.69	7.42	8.55	9.96

* The **upper** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **greater** than.
** These precipitation frequency estimates are based on a partial duration series. **ARI** is the Average Recurrence Interval.
Please refer to the documentation for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

*** Lower bound of the 90% confidence interval**
Precipitation Frequency Estimates (inches)

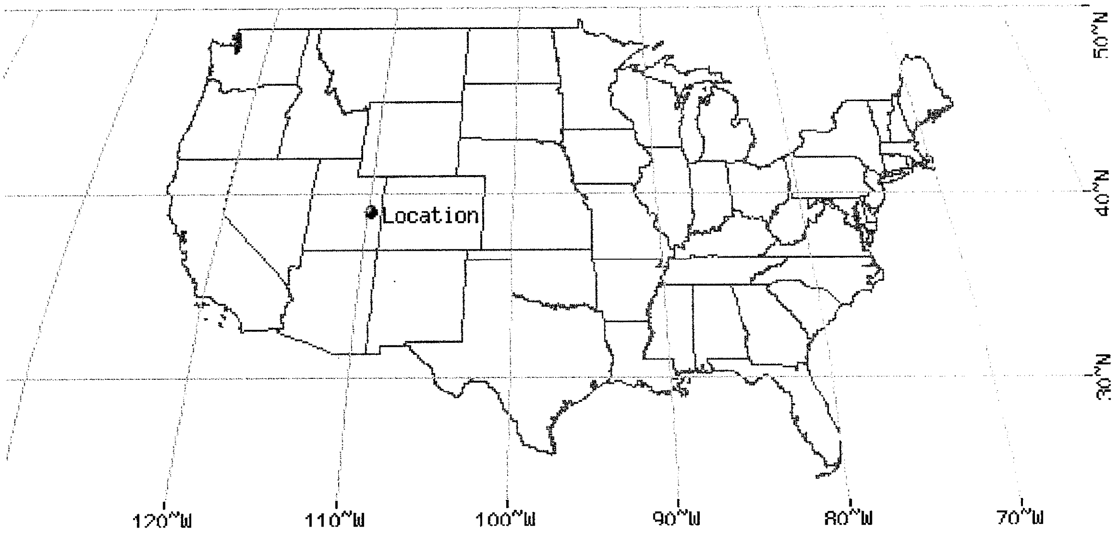
ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.12	0.19	0.23	0.31	0.39	0.47	0.53	0.66	0.81	1.09	1.26	1.40	1.56	1.71	2.08	2.50	2.94	3.44
5	0.17	0.26	0.33	0.44	0.54	0.65	0.70	0.85	1.03	1.33	1.53	1.70	1.89	2.08	2.56	3.03	3.58	4.19
10	0.22	0.33	0.41	0.55	0.69	0.79	0.86	1.01	1.21	1.52	1.75	1.95	2.16	2.38	2.91	3.44	4.07	4.76
25	0.29	0.44	0.54	0.73	0.91	1.03	1.09	1.25	1.47	1.78	2.04	2.27	2.52	2.76	3.40	3.98	4.67	5.47
50	0.35	0.53	0.66	0.89	1.10	1.24	1.29	1.44	1.67	1.97	2.25	2.51	2.77	3.04	3.75	4.36	5.12	5.98
100	0.42	0.64	0.80	1.07	1.33	1.48	1.54	1.66	1.88	2.17	2.46	2.74	3.02	3.30	4.09	4.71	5.53	6.45
200	0.50	0.76	0.94	1.27	1.57	1.75	1.82	1.96	2.12	2.35	2.66	2.98	3.27	3.55	4.41	5.05	5.91	6.88
500	0.62	0.94	1.17	1.58	1.95	2.16	2.25	2.43	2.61	2.64	2.92	3.27	3.59	3.87	4.83	5.46	6.39	7.42
1000	0.73	1.11	1.37	1.85	2.29	2.51	2.63	2.85	3.06	3.09	3.12	3.49	3.81	4.10	5.12	5.74	6.73	7.80

* The **lower** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **less** than.

** These precipitation frequency estimates are based on a partial duration maxima series. **ARI** is the Average Recurrence Interval.

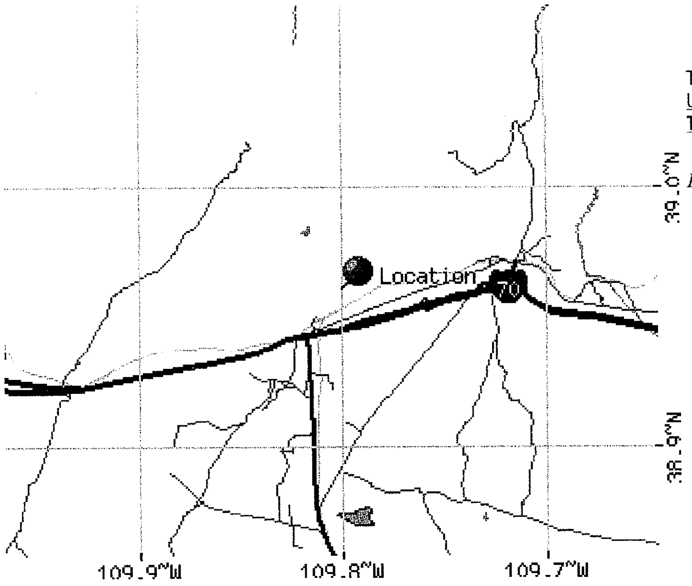
Please refer to the documentation for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

Maps -



These maps were produced using a direct map request from the U.S. Census Bureau Mapping and Cartographic Resources **Tiger Map Server**.

Please read disclaimer for more information.



Other Maps/Photographs -

View USGS digital orthophoto quadrangle (DOQ) covering this location from TerraServer; **USGS Aerial Photograph** may also be available
from this site. A DOQ is a computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map. Visit the USGS for more information.

Watershed/Stream Flow Information -

Find the Watershed for this location using the U.S. Environmental Protection Agency's site.

Climate Data Sources -

Precipitation frequency results are based on data from a variety of sources, but largely NCDC. The following links provide general information
about observing sites in the area, regardless of if their data was used in this study. For detailed information about the stations used in this study,
please refer to our documentation.

Using the **National Climatic Data Center's (NCDC)** station search engine, locate other climate stations within:

+/-30 minutes ...OR... +/-1 degree of this location (38.96/-109.8). Digital ASCII data can be obtained directly from **NCDC**.

Find Natural Resources Conservation Service (NRCS) SNOTEL (SNOwpack TELemetry) stations by visiting the **Western Regional Climate Center's state-specific SNOTEL station maps**.

Hydrometeorological Design Studies Center
DOC/NOAA/National Weather Service
1325 East-West Highway
Silver Spring, MD 20910

(301) 713-1669
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Appendix B

General-Storm and Local-Storm PMP Estimates

General Storm PMP Computation
July

Table 6.1.--General-storm PMP computations for the Colorado River and Great basin

Drainage Crescent Junction Disposal Site Elev 5000 Area less than 1 mi^2 (km^2)
Latitude 38°57'50"N (38.96°N) Longitude ___ of basin center 109° 48' 00" W (109.80°W)
Month July

Step

Duration (hrs)

	6	12	18	24	48	72	
A. Convergence PMP							
1. Drainage average value from one of figures 2.5 to 2.16 11.5 in. (~~mm~~)							
2. Reduction for barrier-elevation [fig. 2.18] 50 %							
3. Barrier-elevation reduced PMP [step 1 X step 2] 5.8 in. (~~mm~~)							
4. Durational variation [figs. 2.25 to 2.27 and table 2.7].	69	86	94	100	115	121	%
5. Convergence PMP for indicated durations [steps 3 X 4]	4.0	5.0	5.4	5.8	6.7	7.0	in. (~~mm~~)
6. Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]	4.0	1.0	0.4	0.4	0.9	0.3	in. (~~mm~~)
7. Areal reduction [select from figs. [✓ 2.28] and 2.29]	95	98	98	100	100	100	%
8. Areally reduced PMP [step 6 X step 7]	3.8	1.0	0.4	0.4	0.9	0.3	in. (~~mm~~)
9. Drainage average PMP [accumulated values of step 8]	3.8	4.8	5.2	5.6	6.5	6.8	in. (~~mm~~)
B. Orographic PMP							
1. Drainage average orographic index from figure 3.11a to d. 2.0 in. (~~mm~~)							
2. Areal reduction [figure 3.20] 98 %							
3. Adjustment for month [one of figs. 3.12 to 3.17] 99 %							
4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3] 1.94 in. (~~mm~~)							
5. Durational variation [table 3.[illegible]] 9	30	57	80	100	157	185	%
6. Orographic PMP for given durations [steps 4 X 5]	0.6	1.1	1.6	2.0	3.1	3.7	in. (~~mm~~)
C. Total PMP							
1. Add steps A9 and B6	4.4	5.9	6.8	7.6	9.6	10.5	in. (~~mm~~)

2. PMP for other durations from smooth curve fitted to plot of computed data.
3. Comparison with local-storm PMP (see sec. 6.3).

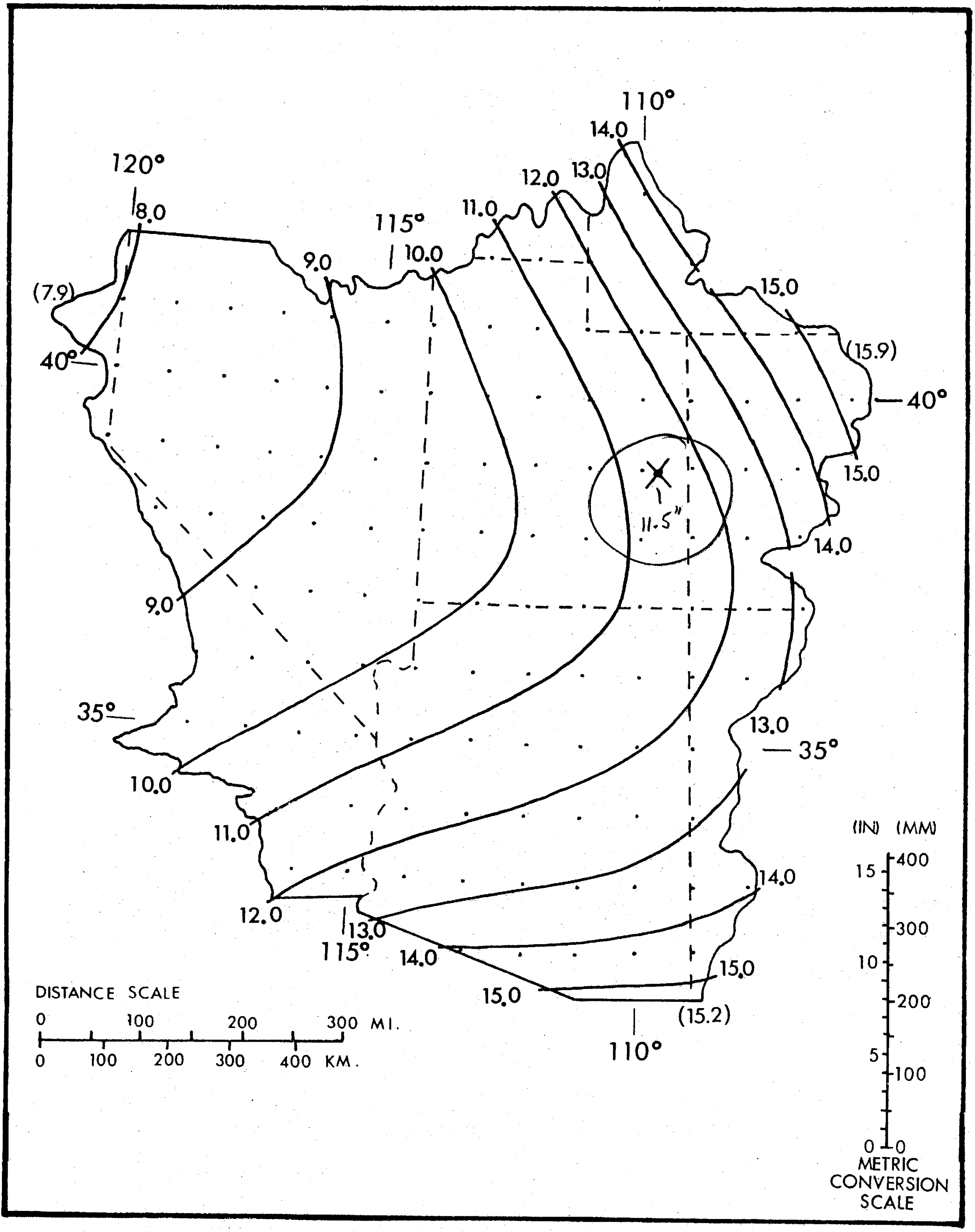


Figure 2.11.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi2 (26 km2) for July. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

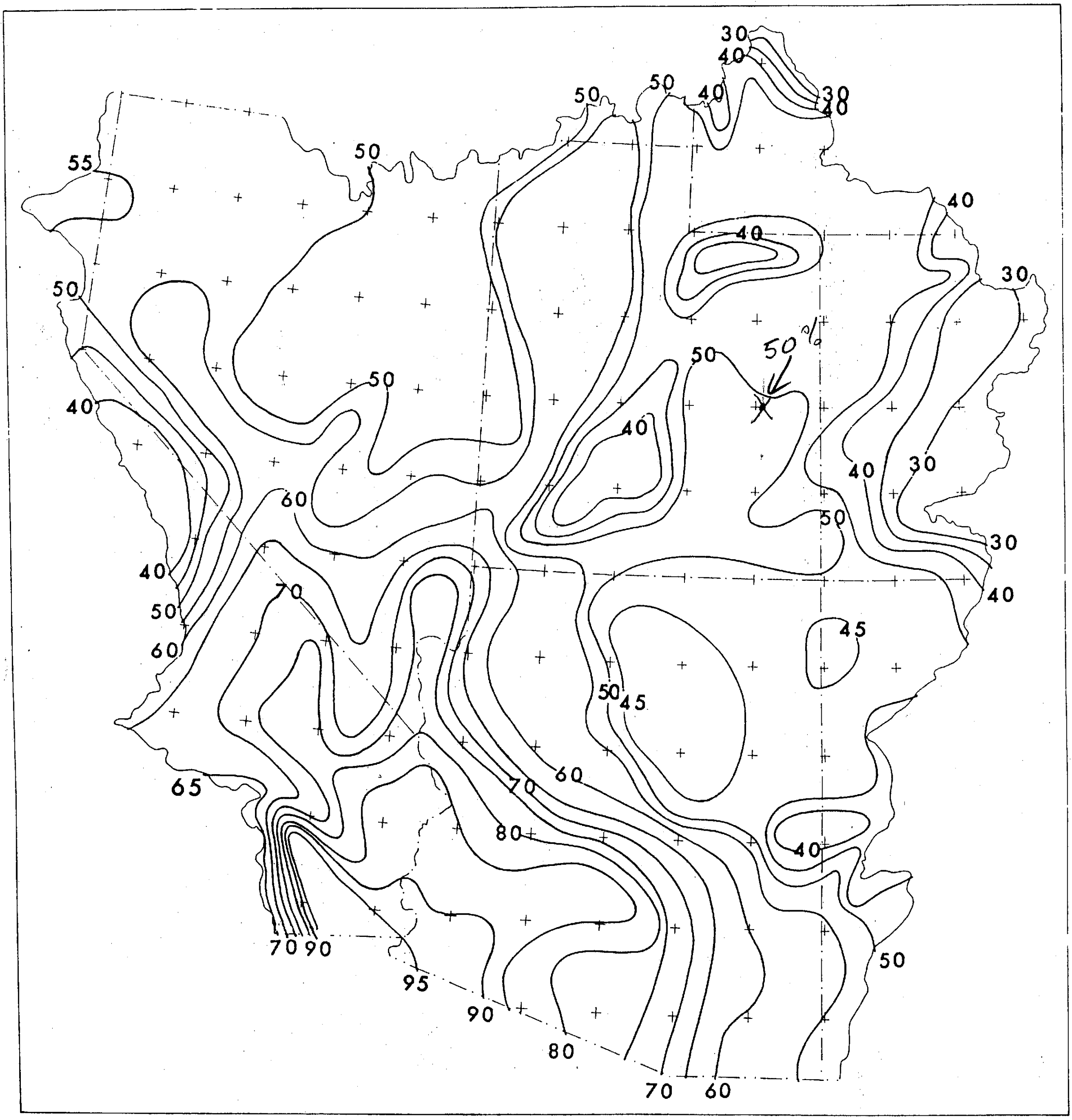
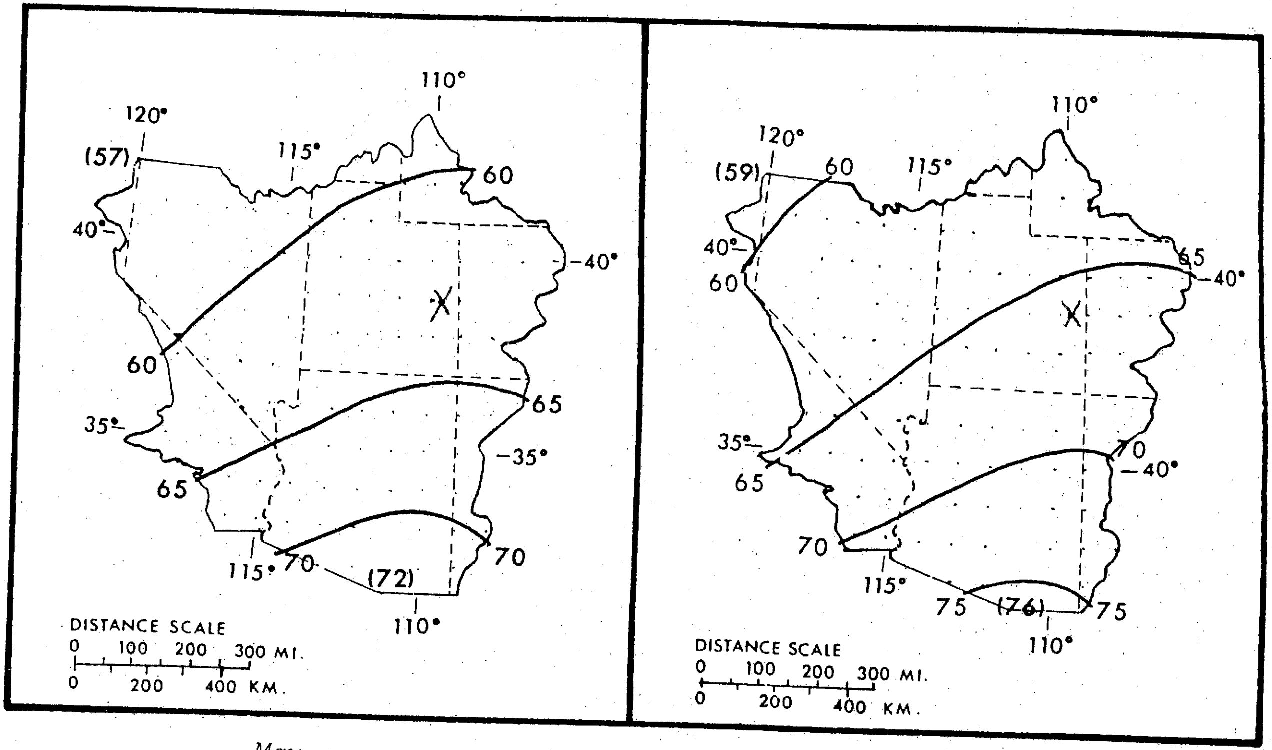
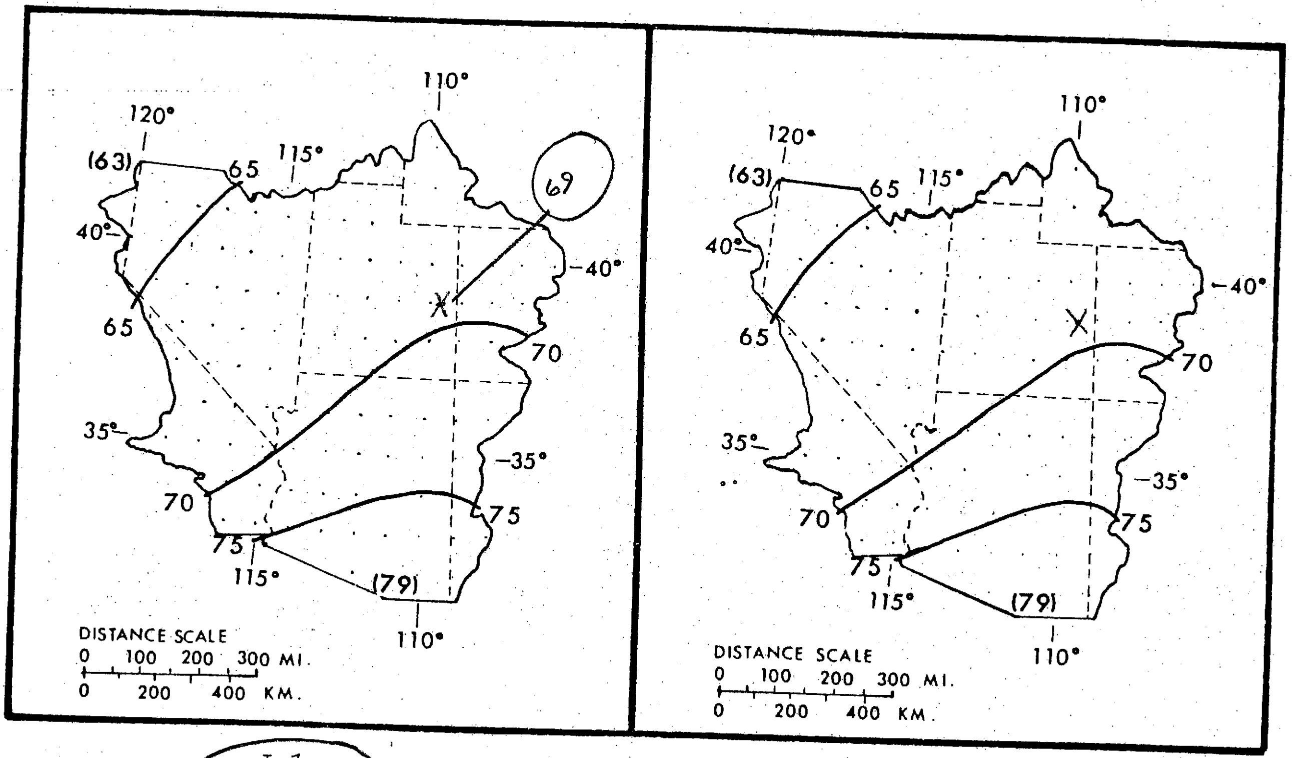


Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.



May

June



July

August

Figure 2.26.--Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

July PMP

For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

Table 2.7.--Durational variation of convergence PMP (in percent of 24-hr amount).

Duration (Hrs)					
6	12	18	24	48	72
50	76	90	100	129	150
51	77	90	100	128	148
52	77	90	100	127	146
53	77	91	100	127	144
54	78	91	100	126	142
55	78	91	100	125	140
56	79	91	100	124	138
57	79	92	100	123	137
58	80	92	100	122	135
59	80	92	100	121	134
60	81	92	100	120	132
61	81	92	100	120	131
62	82	93	100	119	129
63	82	93	100	118	128
64	83	93	100	117	126
65	84	93	100	117	125
66	84	93	100	116	124
67	85	94	100	116	123
68	85	94	100	115	122
69	86	94	100	115	121
70	87	94	100	114	120
71	87	95	100	114	119
72	88	95	100	113	118
73	88	95	100	113	118
74	89	95	100	112	117
75	89	96	100	112	116
76	90	96	100	111	115
77	90	96	100	110	114
78	91	96	100	110	114
79	92	97	100	109	113
80	92	97	100	109	113

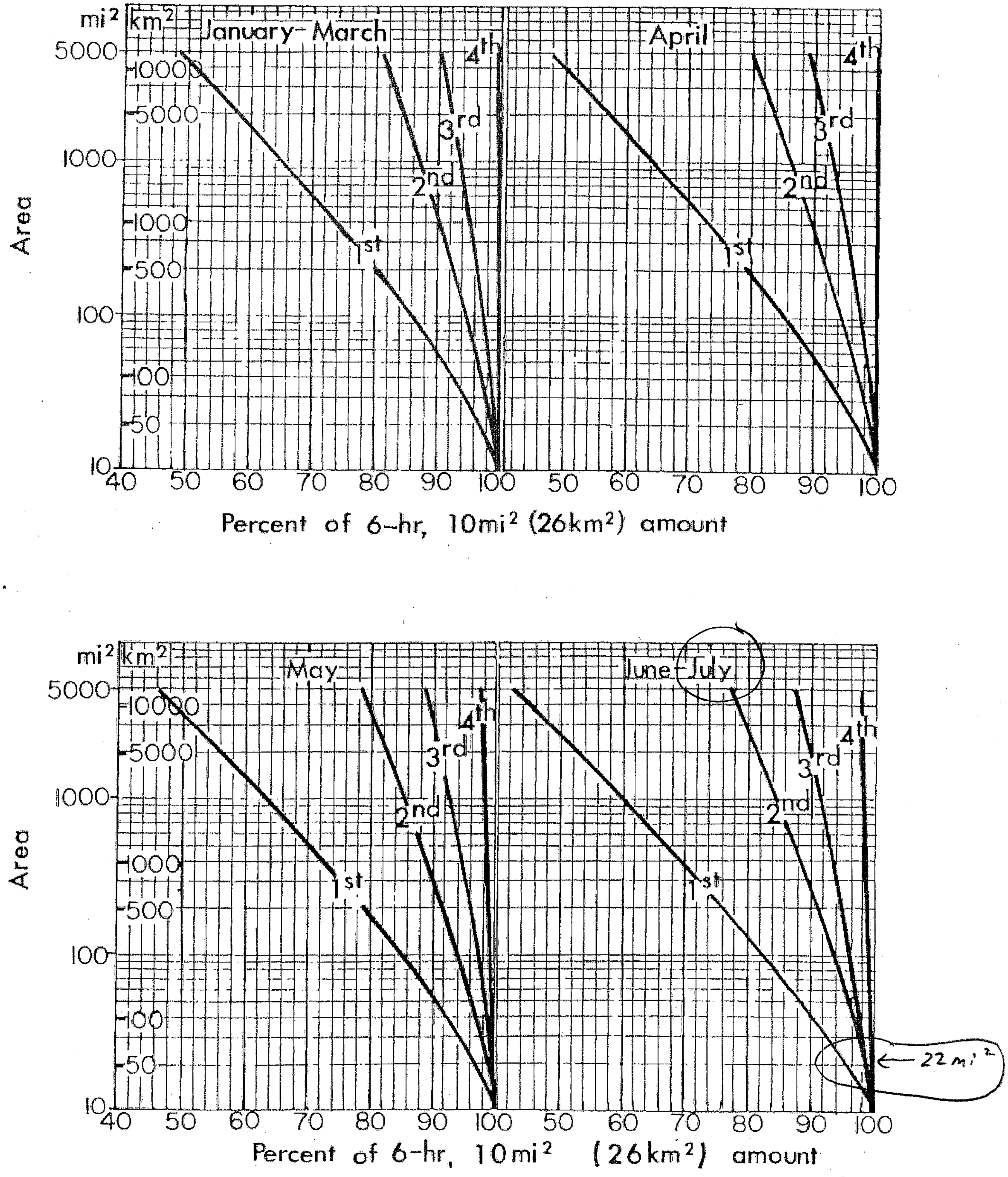
Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

2.5 Areal Reduction for Basin Size

For operational use, basin average values of convergence PMP are needed rather than 10-mi^2 (26-km^2) values. Preferably, the method for reducing 10-mi^2 (26-km^2) values to basin average rainfalls should be derived from depth-area relations of storms in the region. However, all general storms in the region include large proportions of orographic precipitation.

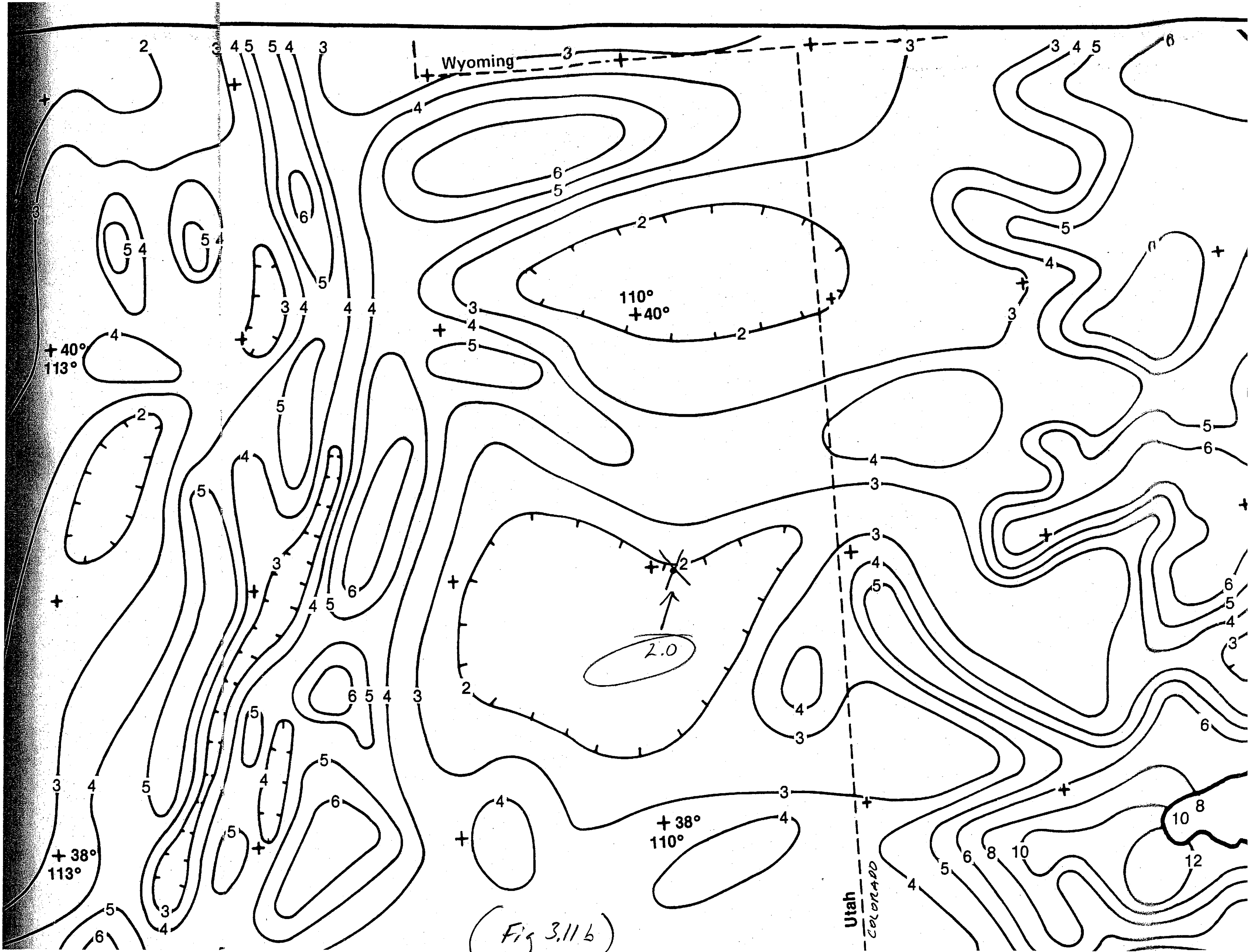
Our solution was to use generalized depth-area relations developed for PMP estimates within bordering zones in the Central and Eastern United States (Riedel et al. 1956). The smoothed areal variations adopted for the Southwestern States are shown in figures 2.28 and 2.29 for each month or a combination of months where differences are insignificant.

Figures 2.28 and 2.29 give depth-area relations that reduce 10-mi^2 (26-km^2) convergence PMP for basin sizes up to 5,000 mi^2 (12,950 km^2) for each month. Areal variations are given for the 4 greatest (1st to 4th) 6-hr PMP increments. After the 4th increment no reduction for basin size is required. Application of these figures will become clear through consideration of an example of PMP computation in chapter 6.



Basin Area Crescent Wash = 22 mi²

Figure 2.28.--Depth-area variation for convergence PMP for first to fourth 6-hr increments.


Wyoming
Utah
COLORADO
110°
+40°
+40°
113°
+38°
110°
+38°
113°
2.0
2
3
4
5
6
8
10
12

(Fig 3.11 b)

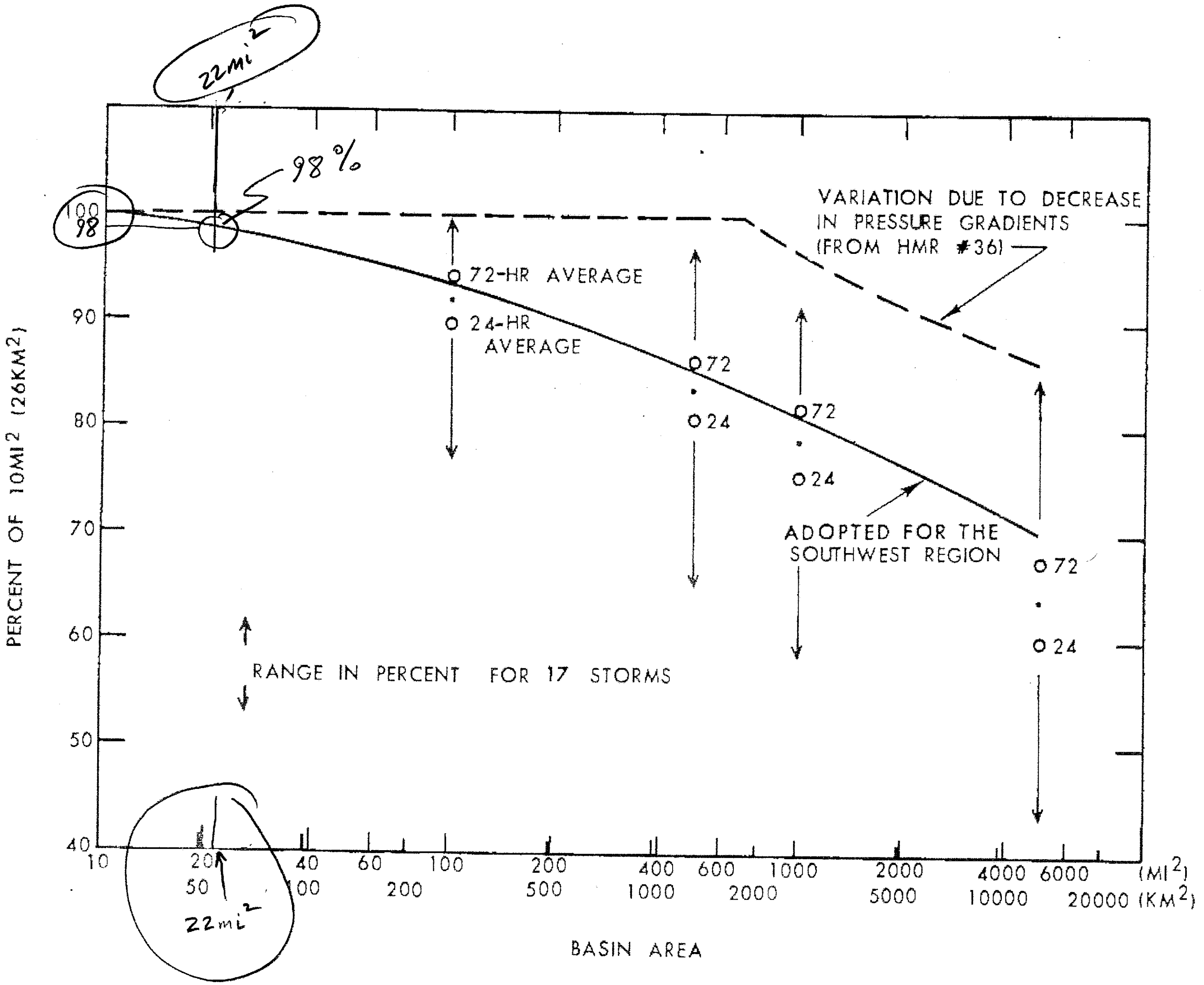
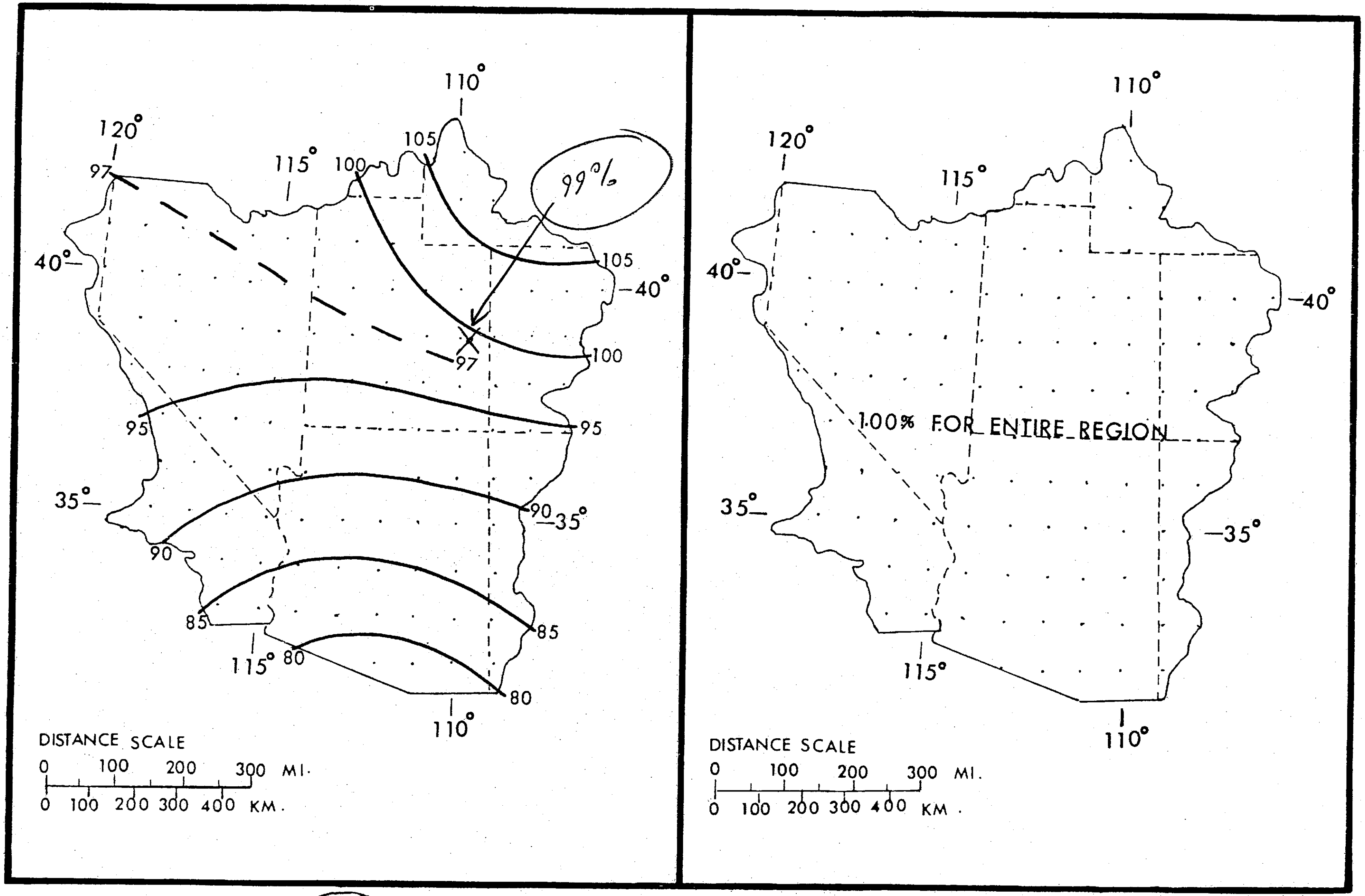


Figure 3.20.--Variation of orographic PMP with basin size.



July

August

Figure 3.15.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).

Table 3.9.--Durational variation of orographic PMP

Latitude °N	Percent of 24-hr value 6 hr	12	18	24	48	72
42	28	55	79	100	161	190
41	29	56	79	100	160	189
40	30	57	80	100	159	187
39	30	57	80	100	157	185
38	31	58	81	100	155	182
37	32	59	81	100	152	177
36	33	60	82	100	149	172
35	34	61	82	100	146	167
34	35	62	83	100	143	162
33	36	63	84	100	139	157
32	37	64	84	100	135	152
31	39	66	85	100	132	146

4. LOCAL-STORM PMP FOR THE SOUTHWESTERN REGION AND CALIFORNIA

4.1 Introduction

This chapter provides generalized estimates of local or thunderstorm probable maximum precipitation. By "generalized" is meant that mapped values are given from which estimates of PMP may be determined for any selected drainage.

4.1.1 Region of Interest

Local-storm PMP was not included in the "Interim Report, Probable Maximum Precipitation in California" (HMR No. 36). During the formulation of the present study, we decided that the local-storm part of the study should include California west of the Sierra Nevada. It was also noted that PMP for summer thunderstorms was not considered west of the Cascade Divide in the Northwestern Region (HMR No. 43). As stated in the latter report, "No summer thunderstorms have been reported there (west of the Divide) of an intensity of those to the east, for which the moisture source is often the Gulf of Mexico or Gulf of California. The Cascade Divide offers an additional barrier to such moisture inflows to coastal areas where, in addition, the Pacific Ocean to the west has a stabilizing influence on the air to hinder the occurrence of intense summer local storms." Therefore, it was necessary to establish some continuation of the Cascade Divide into California so that the local-storm PMP definition would have continuity between the two regions.

The stabilizing influence of the Pacific air is at times interrupted by the warm moist tropical air from the south pushing into California, although it is difficult to determine where the limit of southerly flow occurs. General storms having the tropical characteristic of excessive thunderstorm rains are observed as far north as the northern end of the Sacramento Valley. Thus, a northern boundary has been selected for this study, excluding that portion of

General Storm PMP Computation
August

Table 6.1.--General-storm PMP computations for the Colorado River and Great basin

Drainage Crescent Junction Disposal Site (Elev 5000) Area less than 1 mi^2 (km^2)
Latitude 38°57'50"N (38.96°N), Longitude ___ of basin center 109°48'00"W (109.80°W)
Month August

Step		Duration (hrs) 6	12	18	24	48	72	
A. Convergence PMP								
1. Drainage average value from one of figures 2.5 to 2.16	12.6 in. (~~mm~~)							
2. Reduction for barrier-elevation [fig. 2.18]	50 %							
3. Barrier-elevation reduced PMP [step 1 X step 2]	6.3 in. (~~mm~~)							
4. Durational variation [figs. 2.25 to 2.27 and table 2.7].		69	86	94	100	115	121	%
5. Convergence PMP for indicated durations [steps 3 X 4]		4.3	5.4	5.9	6.3	7.2	7.6	in. (~~mm~~)
6. Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]		4.3	1.1	0.5	0.4	0.9	0.4	in. (~~mm~~)
7. Areal reduction [select from figs. 2.28 and [✓ 2.29]]		95	100	100	100	100	100	%
8. Areally reduced PMP [step 6 X step 7]		4.1	1.1	0.5	0.4	0.9	0.4	in. (~~mm~~)
9. Drainage average PMP [accumulated values of step 8]		4.1	5.2	5.7	6.1	7.0	7.4	in. (~~mm~~)
B. Orographic PMP								
1. Drainage average orographic index from figure 3.11a to d.	2.0 in. (~~mm~~)							
2. Areal reduction [figure 3.20]	98 %							
3. Adjustment for month [one of figs. 3.12 to 3.17]	100%							
4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3]	1.96 in. (~~mm~~)							
5. Durational variation [table 3.~~6~~9]		30	57	80	100	157	185	%
6. Orographic PMP for given durations [steps 4 X 5]		0.6	1.1	1.6	2.0	3.1	3.7	in. (~~mm~~)
C. Total PMP								
1. Add steps A9 and B6		4.7	6.3	7.3	8.1	10.1	11.1	in. (~~mm~~)

2. PMP for other durations from smooth curve fitted to plot of computed data.
3. Comparison with local-storm PMP (see sec. 6.3).

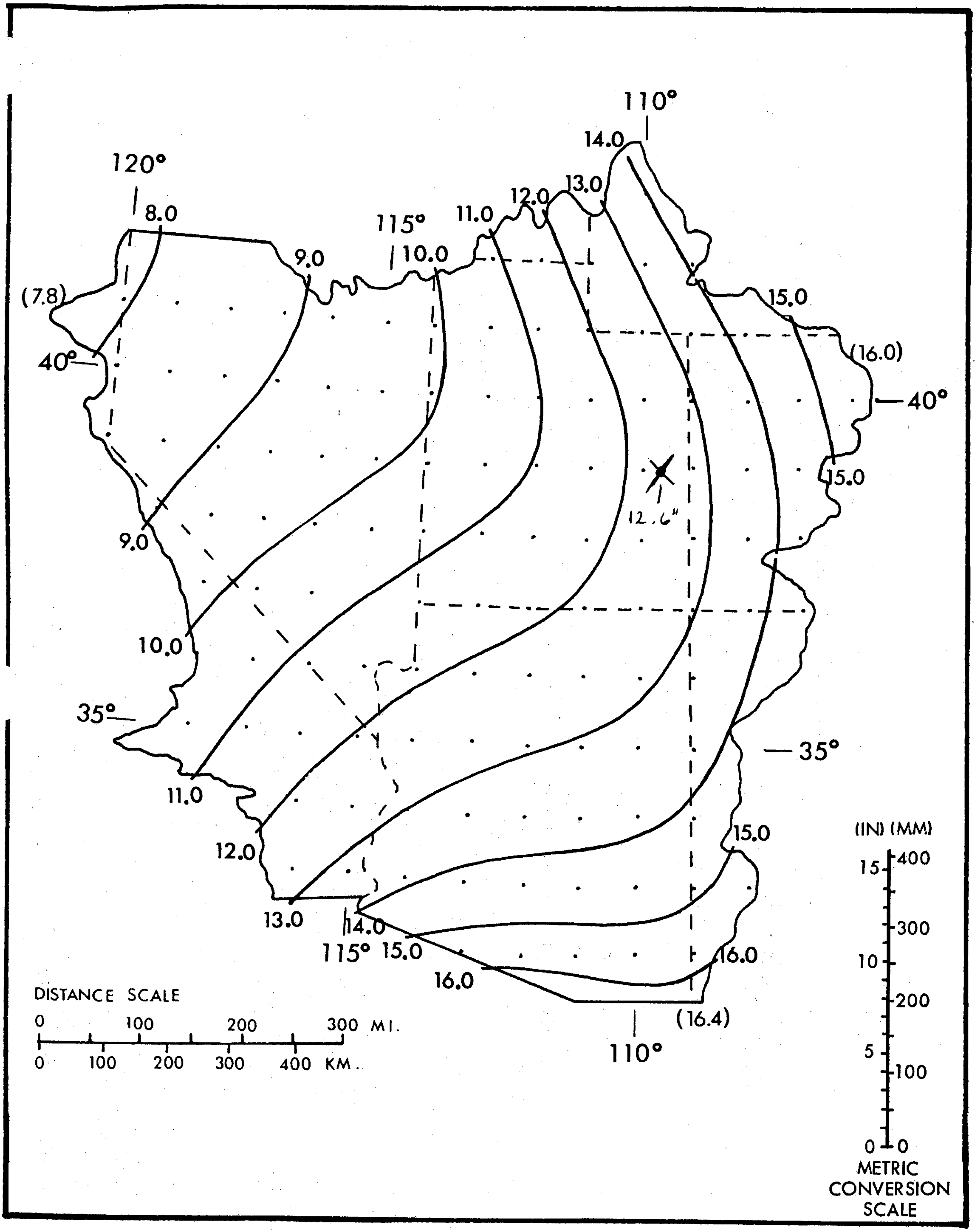


Figure 2.12.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi^2 (26 km^2) for August. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

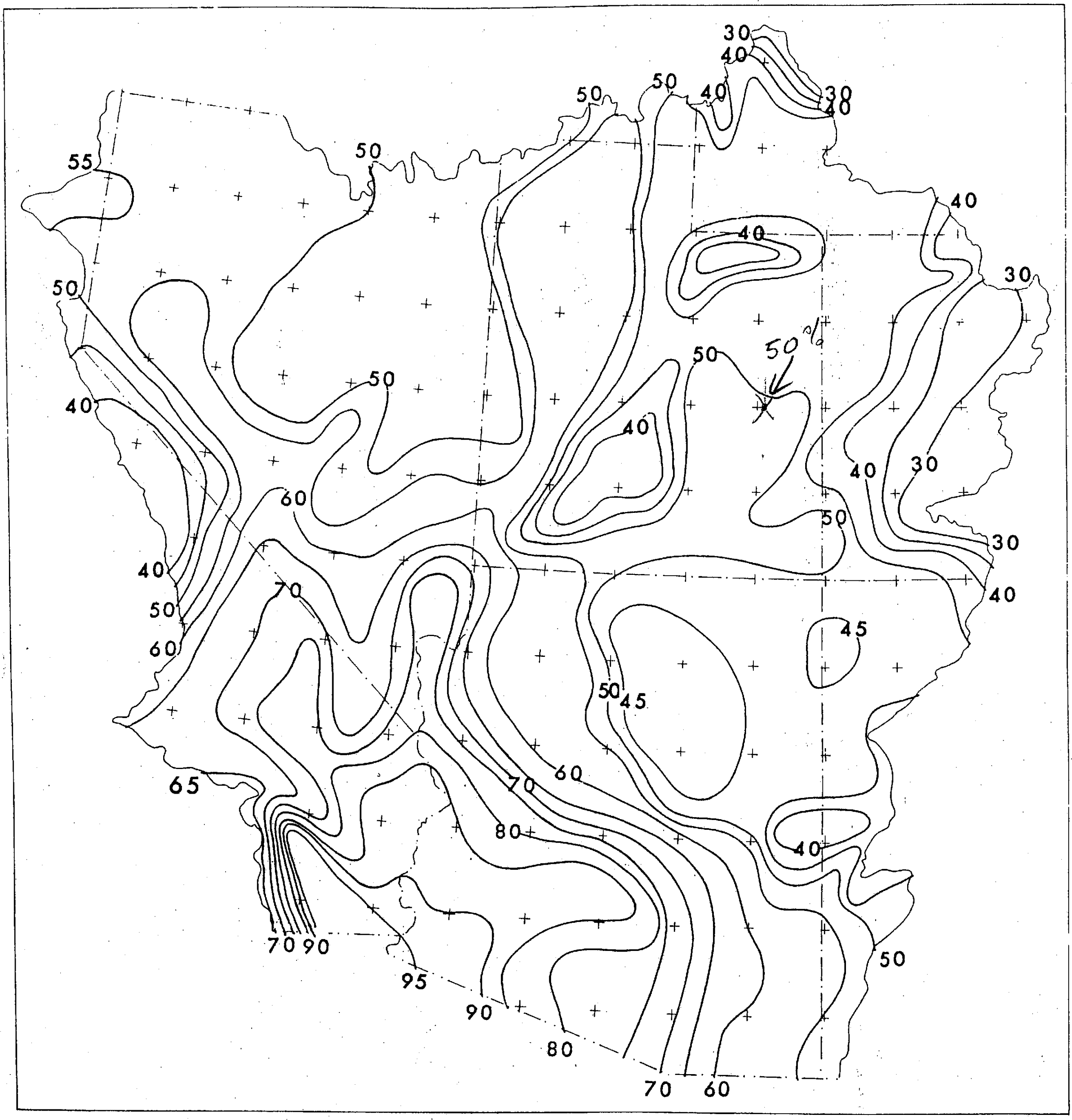
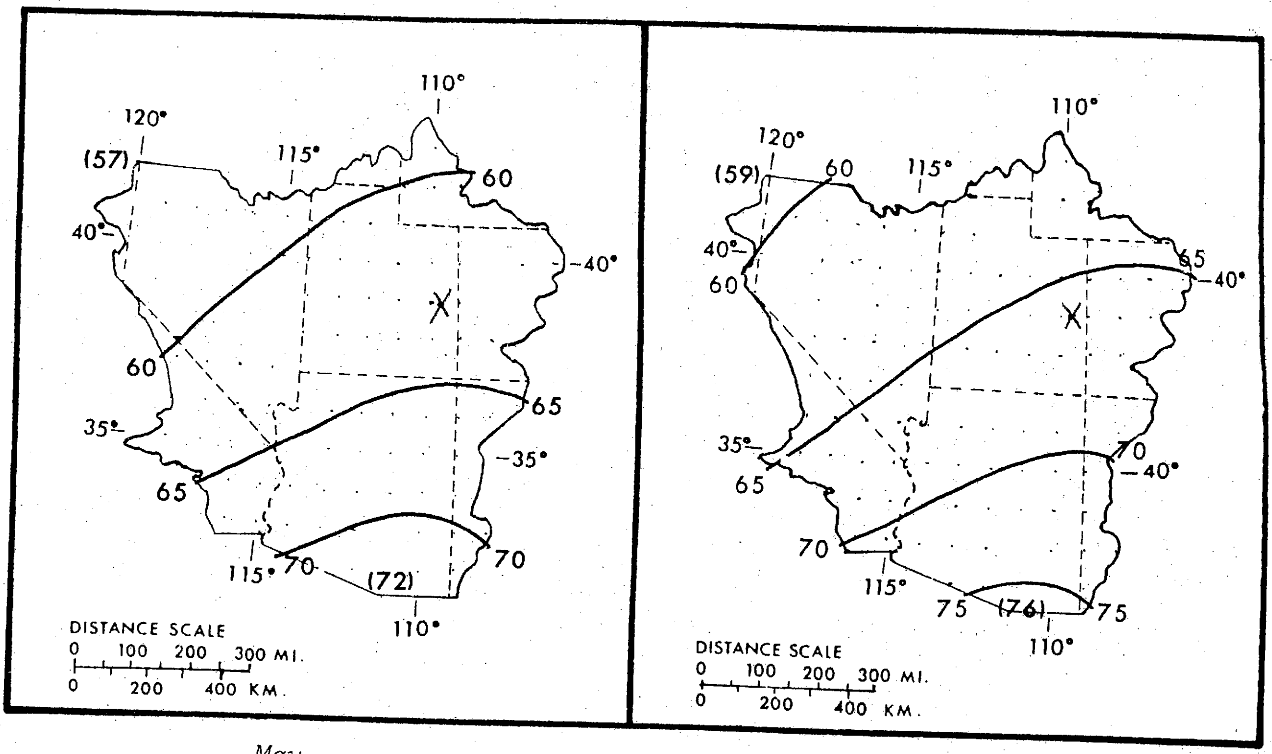
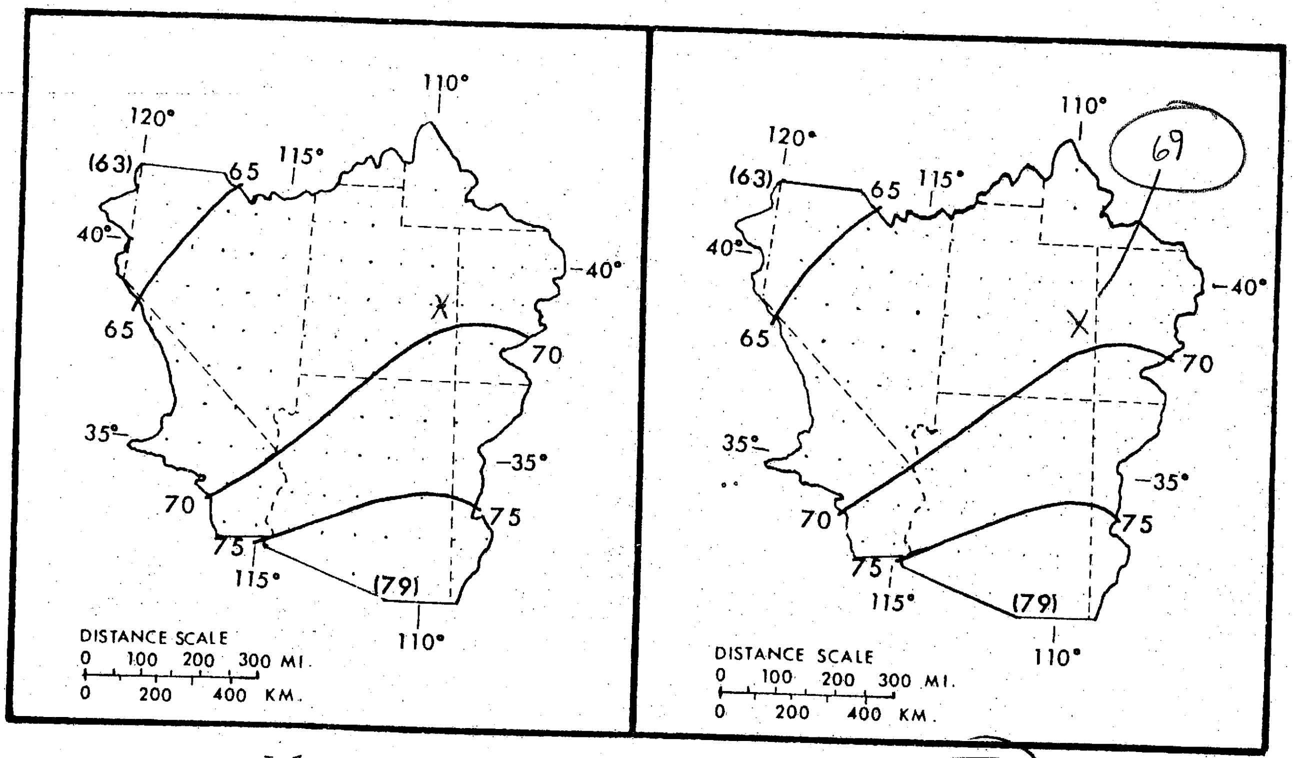


Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.



May

June



July

August

Figure 2.26.--Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

Table 2.7.--Durational variation of convergence PMP (in percent of 24-hr amount).

Duration (Hrs)					
6	12	18	24	48	72
50	76	90	100	129	150
51	77	90	100	128	148
52	77	90	100	127	146
53	77	91	100	127	144
54	78	91	100	126	142
55	78	91	100	125	140
56	79	91	100	124	138
57	79	92	100	123	137
58	80	92	100	122	135
59	80	92	100	121	134
60	81	92	100	120	132
61	81	92	100	120	131
62	82	93	100	119	129
63	82	93	100	118	128
64	83	93	100	117	126
65	84	93	100	117	125
66	84	93	100	116	124
67	85	94	100	116	123
68	85	94	100	115	122
69	86	94	100	115	121
70	87	94	100	114	120
71	87	95	100	114	119
72	88	95	100	113	118
73	88	95	100	113	118
74	89	95	100	112	117
75	89	96	100	112	116
76	90	96	100	111	115
77	90	96	100	110	114
78	91	96	100	110	114
79	92	97	100	109	113
80	92	97	100	109	113

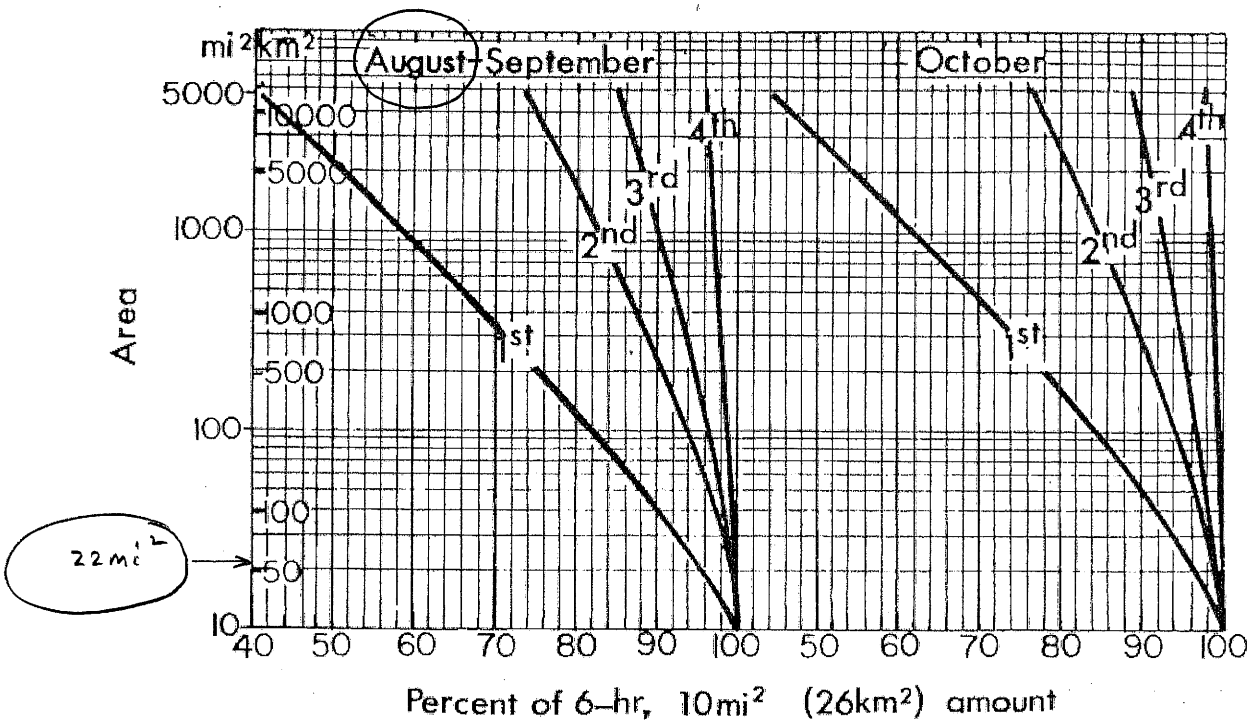
Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

2.5 Areal Reduction for Basin Size

For operational use, basin average values of convergence PMP are needed rather than 10-mi^2 (26-km^2) values. Preferably, the method for reducing 10-mi^2 (26-km^2) values to basin average rainfalls should be derived from depth-area relations of storms in the region. However, all general storms in the region include large proportions of orographic precipitation.

Our solution was to use generalized depth-area relations developed for PMP estimates within bordering zones in the Central and Eastern United States (Riedel et al. 1956). The smoothed areal variations adopted for the Southwestern States are shown in figures 2.28 and 2.29 for each month or a combination of months where differences are insignificant.

Figures 2.28 and 2.29 give depth-area relations that reduce 10-mi^2 (26-km^2) convergence PMP for basin sizes up to 5,000 mi^2 (12,950 km^2) for each month. Areal variations are given for the 4 greatest (1st to 4th) 6-hr PMP increments. After the 4th increment no reduction for basin size is required. Application of these figures will become clear through consideration of an example of PMP computation in chapter 6.



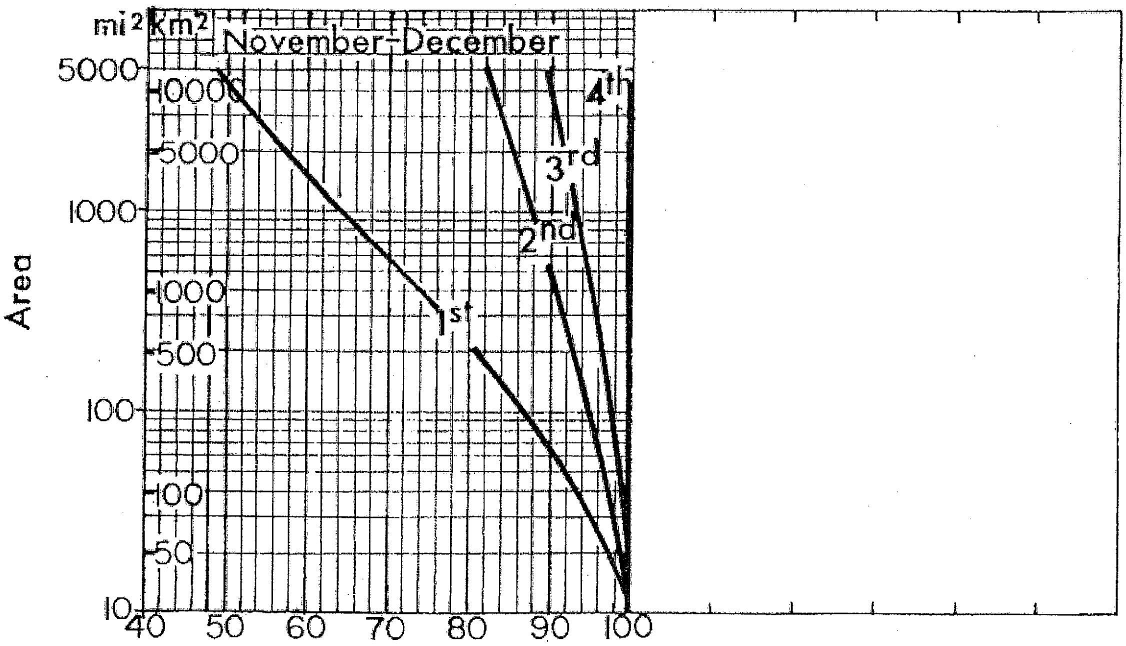
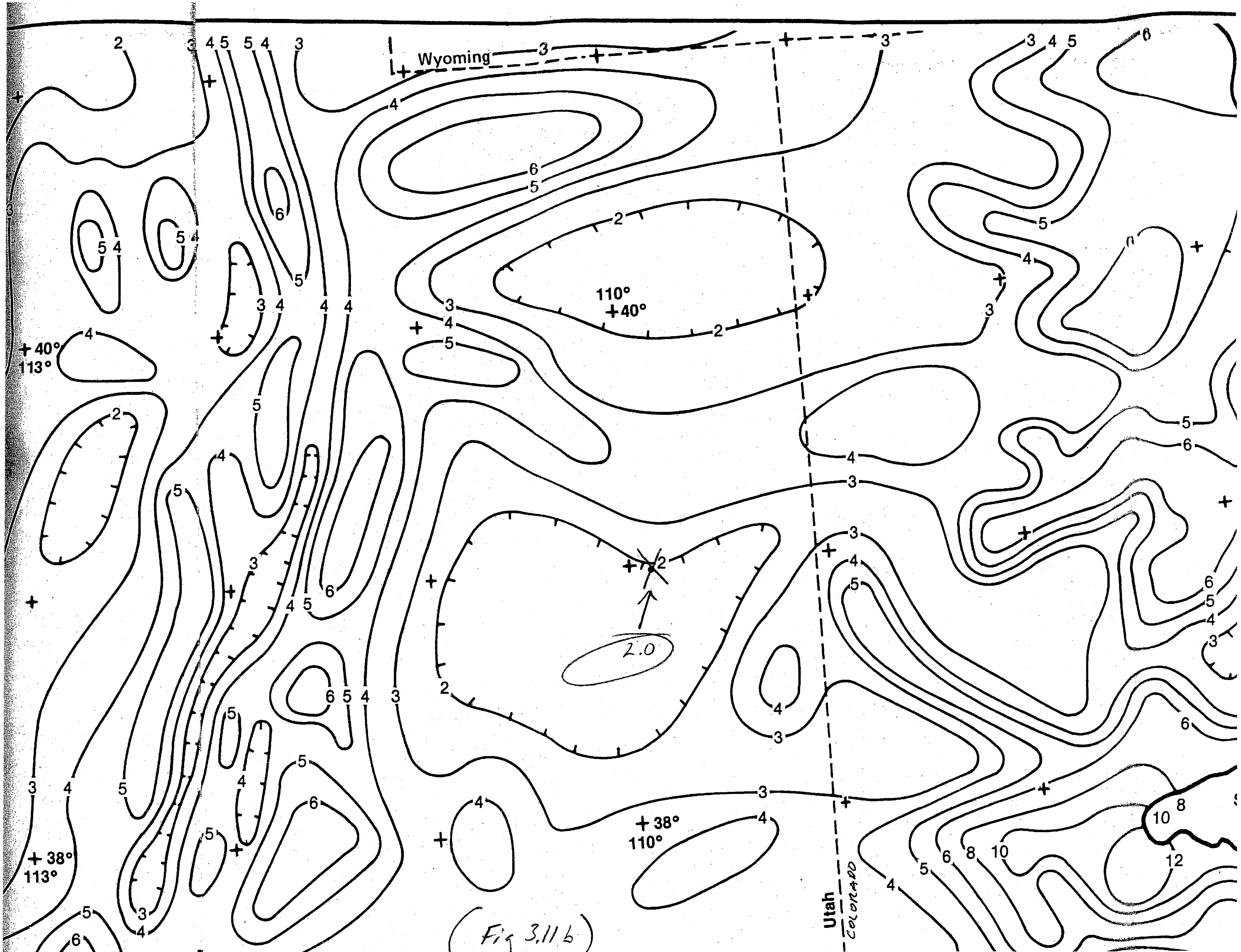


Figure 2.29.—*Depth-area variation for convergence PMP for first to fourth 6-hr increments.*


Wyoming
Utah
COLORADO
110°
40°
40°
113°
38°
113°
38°
110°
2.0
2
3
4
5
6
8
10
12

(Fig 3.11 b)

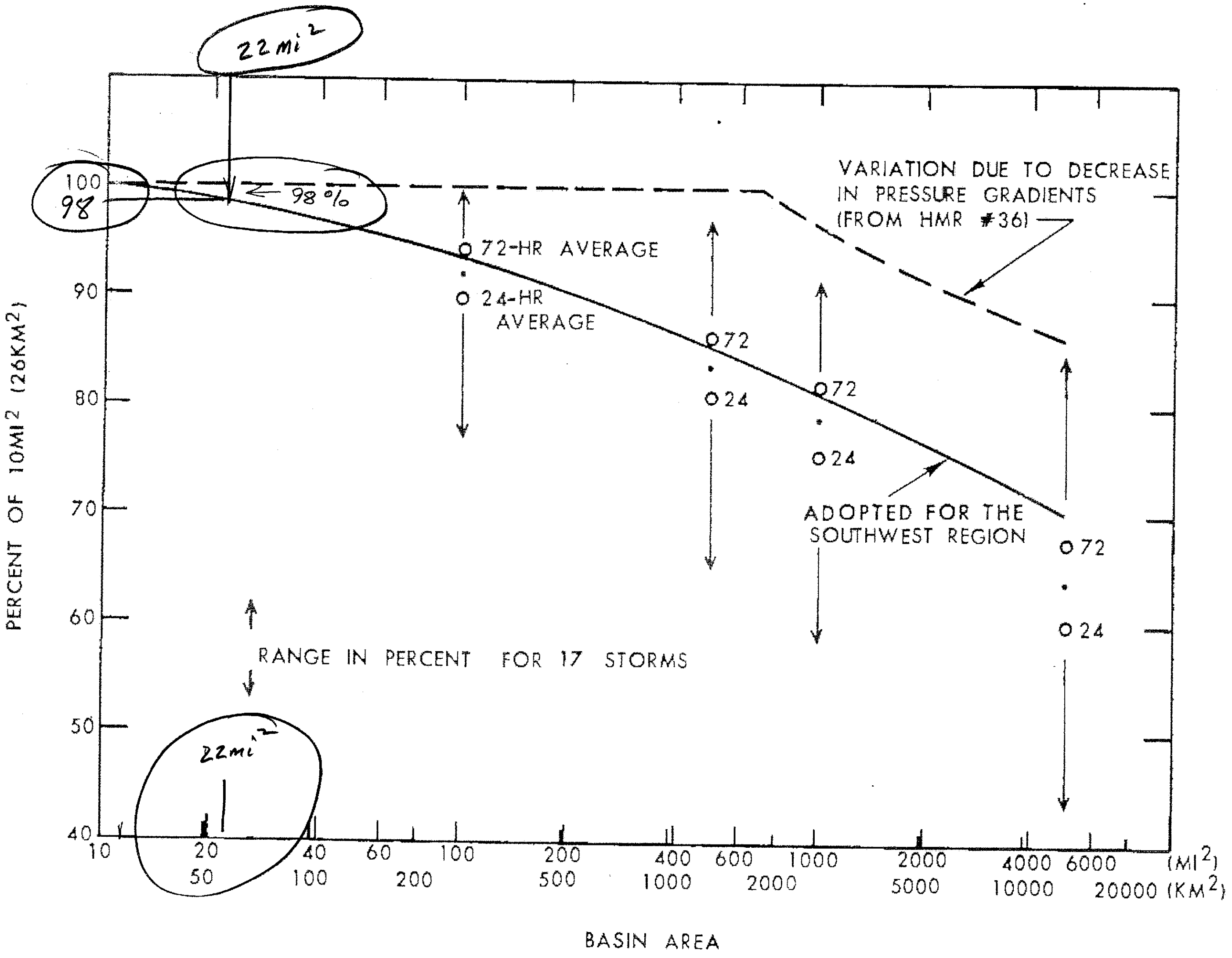
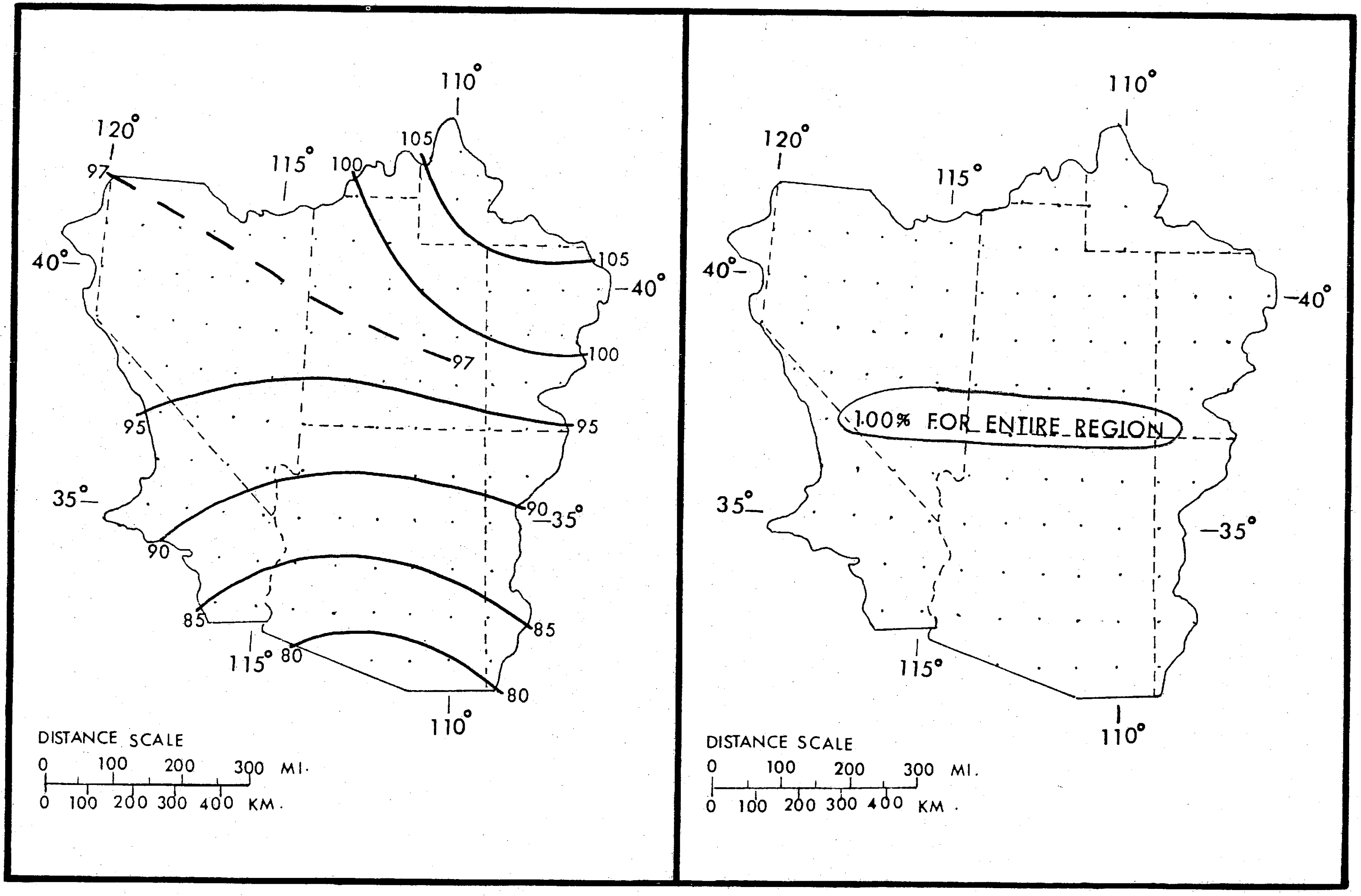


Figure 3.20.--Variation of orographic PMP with basin size.



July

August

Figure 3.15.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).

Table 3.9.--Durational variation of orographic PMP

Latitude °N	Percent of 24-hr value					
	6 hr	12	18	24	48	72
42	28	55	79	100	161	190
41	29	56	79	100	160	189
40	30	57	80	100	159	187
39	30	57	80	100	157	185
38	31	58	81	100	155	182
37	32	59	81	100	152	177
36	33	60	82	100	149	172
35	34	61	82	100	146	167
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33	36	63	84	100	139	157
32	37	64	84	100	135	152
31	39	66	85	100	132	146

4. LOCAL-STORM PMP FOR THE SOUTHWESTERN REGION AND CALIFORNIA

4.1 Introduction

This chapter provides generalized estimates of local or thunderstorm probable maximum precipitation. By "generalized" is meant that mapped values are given from which estimates of PMP may be determined for any selected drainage.

4.1.1 Region of Interest

Local-storm PMP was not included in the "Interim Report, Probable Maximum Precipitation in California" (HMR No. 36). During the formulation of the present study, we decided that the local-storm part of the study should include California west of the Sierra Nevada. It was also noted that PMP for summer thunderstorms was not considered west of the Cascade Divide in the Northwestern Region (HMR No. 43). As stated in the latter report, "No summer thunderstorms have been reported there (west of the Divide) of an intensity of those to the east, for which the moisture source is often the Gulf of Mexico or Gulf of California. The Cascade Divide offers an additional barrier to such moisture inflows to coastal areas where, in addition, the Pacific Ocean to the west has a stabilizing influence on the air to hinder the occurrence of intense summer local storms." Therefore, it was necessary to establish some continuation of the Cascade Divide into California so that the local-storm PMP definition would have continuity between the two regions.

The stabilizing influence of the Pacific air is at times interrupted by the warm moist tropical air from the south pushing into California, although it is difficult to determine where the limit of southerly flow occurs. General storms having the tropical characteristic of excessive thunderstorm rains are observed as far north as the northern end of the Sacramento Valley. Thus, a northern boundary has been selected for this study, excluding that portion of

General Storm PMP Computation
September

Table 6.1.--General-storm PMP computations for the Colorado River and Great basin

Drainage Crescent Junction Disposal Site
Area less than 1 mi^2 ~~(km^2)~~
Latitude 38°57'50" N, (38.96°N) Longitude ___ of basin center 109°48'00" W (109.80 W)
Month September

Step		Duration (hrs)						
		6	12	18	24	48	72	
A. Convergence PMP								
1. Drainage average value from one of figures 2.5 to 2.16	12.4 in. ~~(mm)~~							
2. Reduction for barrier-elevation [fig. 2.18]	50 %							
3. Barrier-elevation reduced PMP [step 1 X step 2]	6.2 in. ~~(mm)~~							
4. Durational variation [figs. 2.25 to 2.27 and table 2.7].		69	86	94	100	115	121	%
5. Convergence PMP for indicated durations [steps 3 X 4]		4.3	5.3	5.8	6.2	7.1	7.5	in. ~~(mm)~~
6. Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]		4.3	1.0	0.5	0.4	0.9	0.4	in. ~~(mm)~~
7. Areal reduction [select from figs. 2.28 and [✓ 2.29]]		95	100	100	100	100	100	%
8. Areally reduced PMP [step 6 X step 7]		4.1	1.0	0.5	0.4	0.9	0.4	in. ~~(mm)~~
9. Drainage average PMP [accumulated values of step 8]		4.1	5.1	5.6	6.0	6.9	7.3	in. ~~(mm)~~
B. Orographic PMP								
1. Drainage average orographic index from figure 3.11a to d.	2.0 in. ~~(mm)~~							
2. Areal reduction [figure 3.20]	98 %							
3. Adjustment for month [one of figs. 3.12 to 3.17]	100 %							
4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3]	1.96 in. ~~(mm)~~							
5. Durational variation [table 3.~~8~~9]		30	57	80	100	157	185	%
6. Orographic PMP for given durations [steps 4 X 5]		0.6	1.1	1.6	2.0	3.1	3.7	in. ~~(mm)~~
C. Total PMP								
1. Add steps A9 and B6		4.7	6.2	7.2	8.0	10.0	11.0	in. ~~(mm)~~

2. PMP for other durations from smooth curve fitted to plot of computed data.
3. Comparison with local-storm PMP (see sec. 6.3).

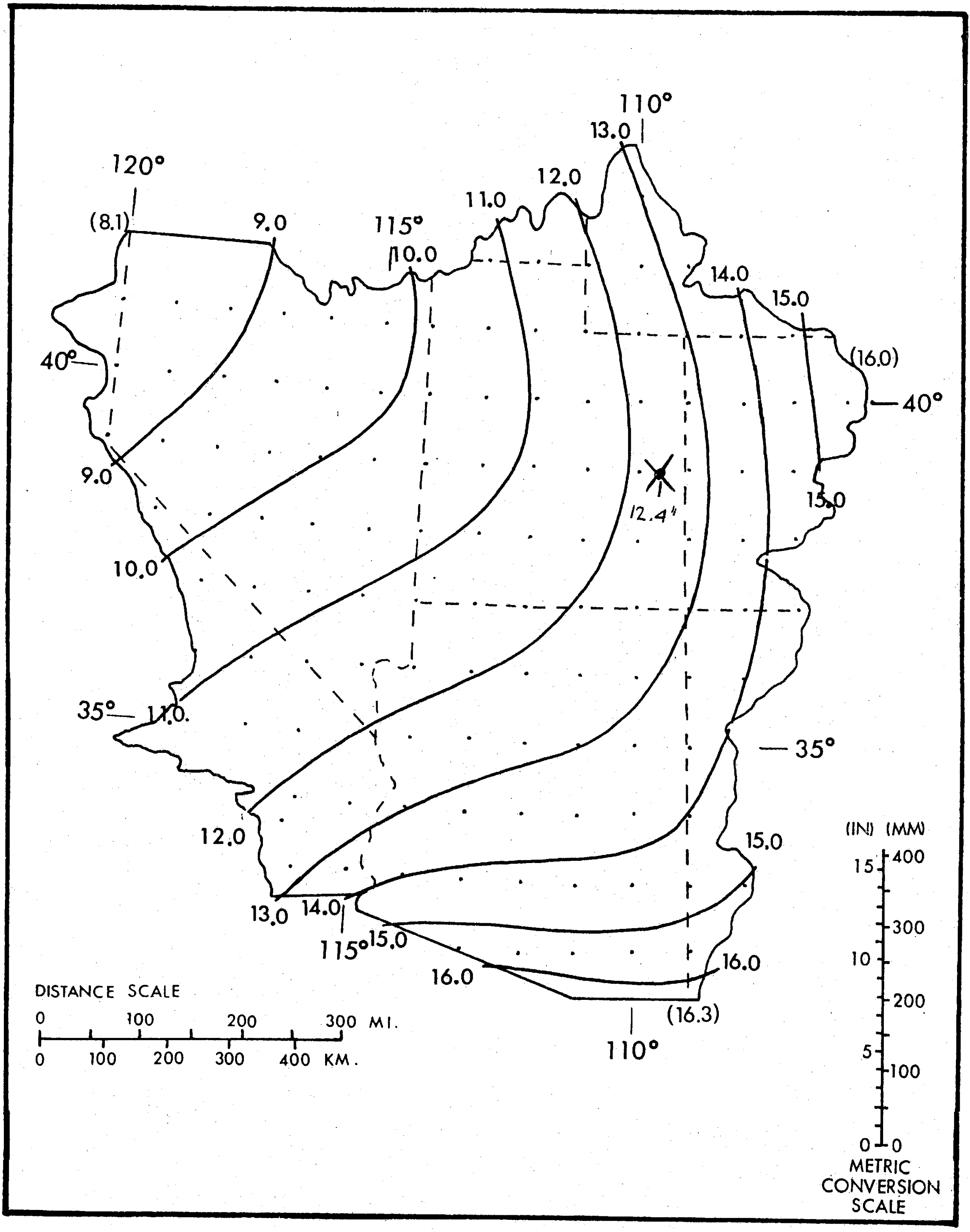


Figure 2.13.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi^2 (26 km^2) for September. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

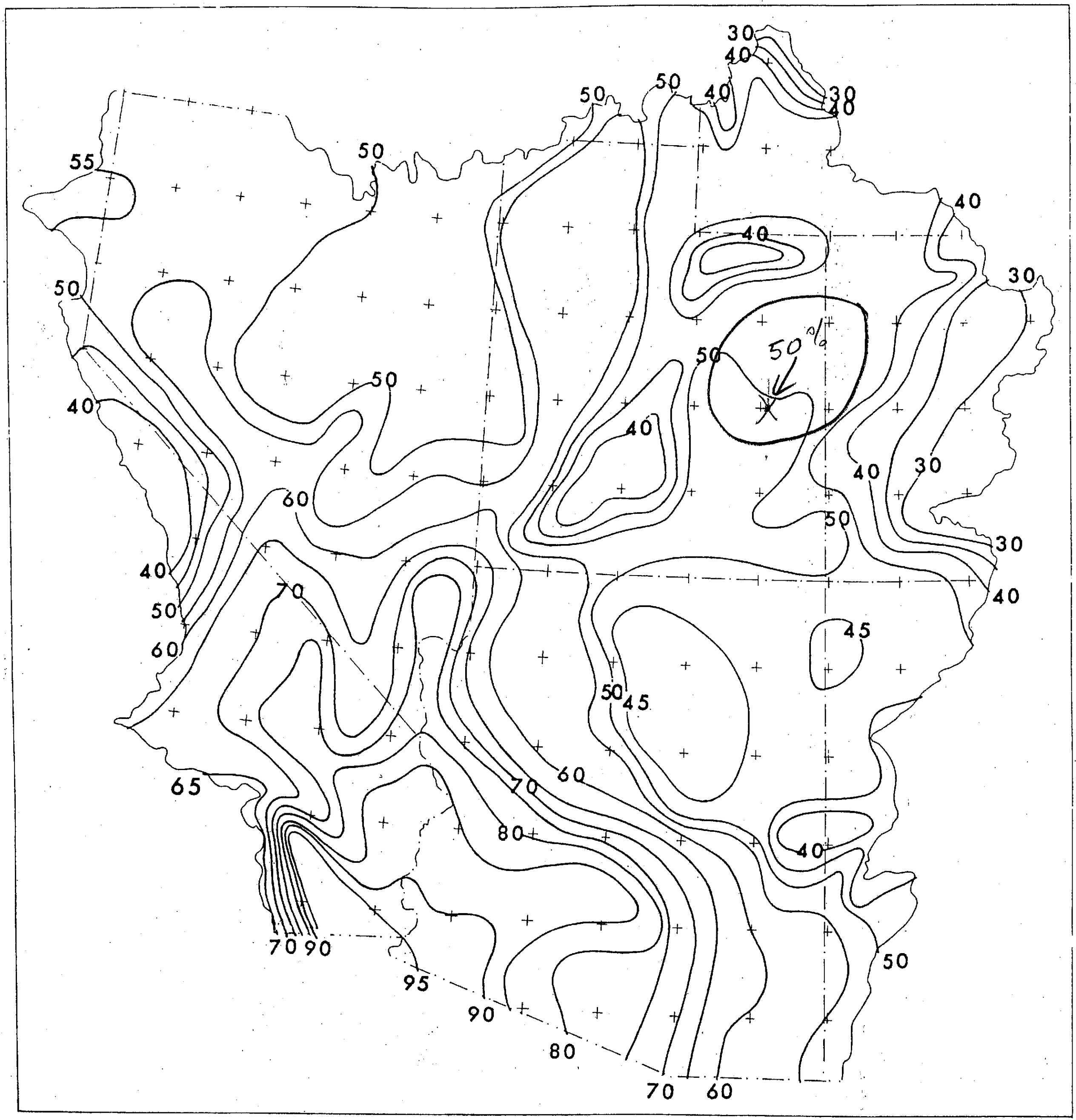
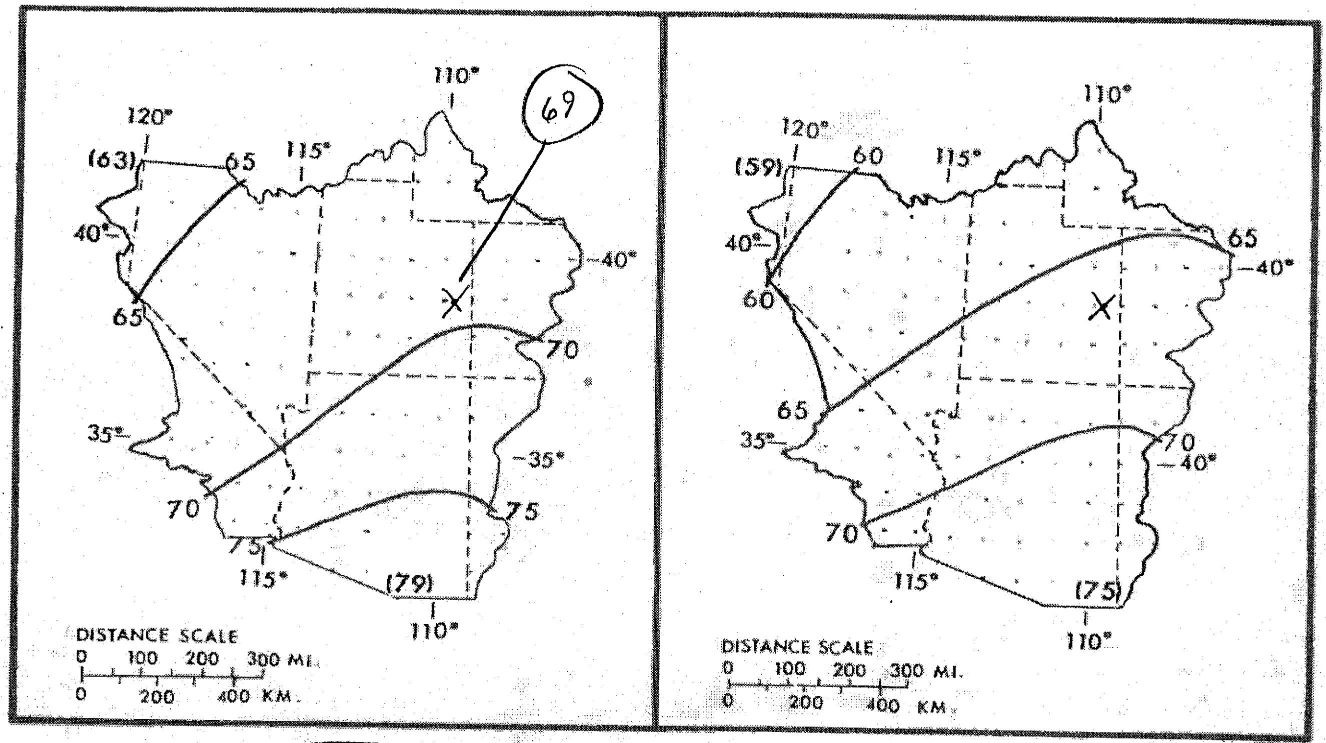
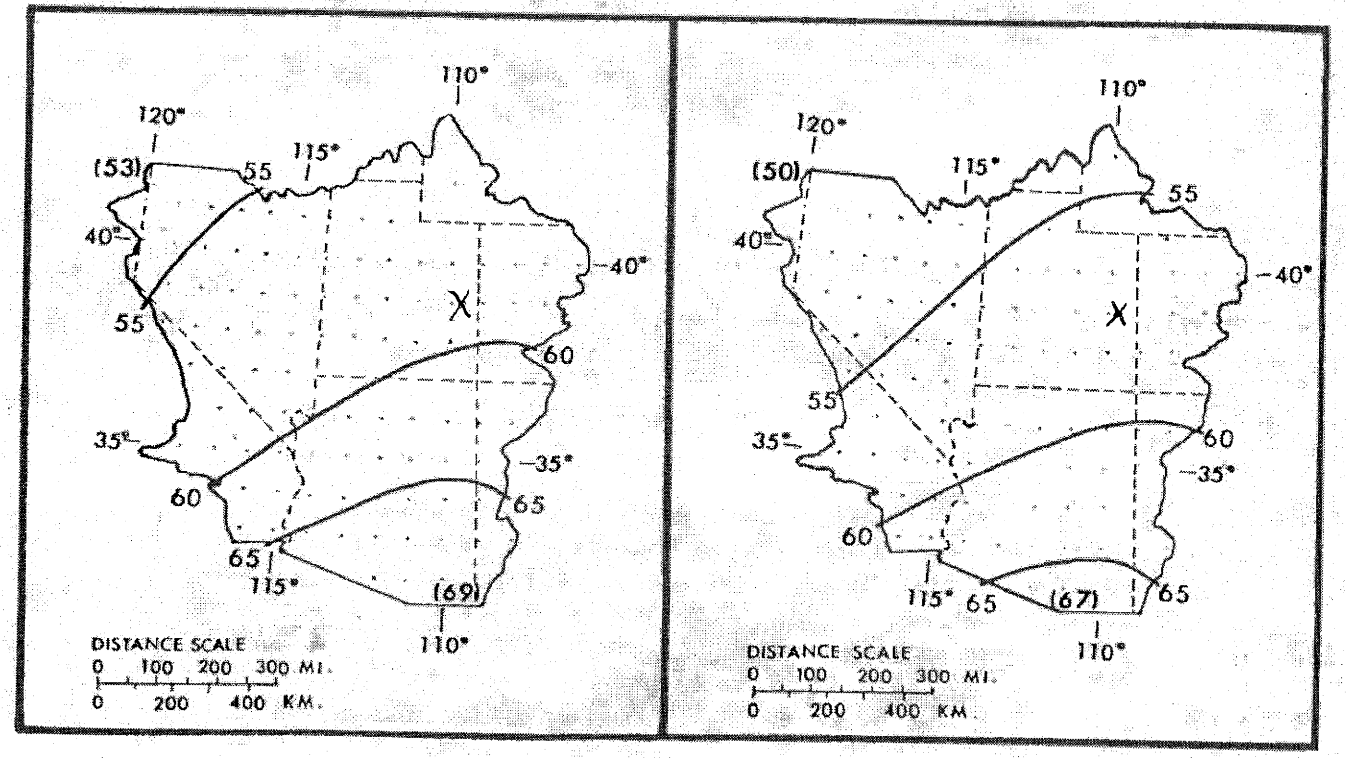


Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.



September

October



November

December

Figure 2.27.--Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

Table 2.7.--Durational variation of convergence PMP (in percent of 24-hr amount).

Duration (Hrs)					
6	12	18	24	48	72
50	76	90	100	129	150
51	77	90	100	128	148
52	77	90	100	127	146
53	77	91	100	127	144
54	78	91	100	126	142
55	78	91	100	125	140
56	79	91	100	124	138
57	79	92	100	123	137
58	80	92	100	122	135
59	80	92	100	121	134
60	81	92	100	120	132
61	81	92	100	120	131
62	82	93	100	119	129
63	82	93	100	118	128
64	83	93	100	117	126
65	84	93	100	117	125
66	84	93	100	116	124
67	85	94	100	116	123
68	85	94	100	115	122
69	86	94	100	115	121
70	87	94	100	114	120
71	87	95	100	114	119
72	88	95	100	113	118
73	88	95	100	113	118
74	89	95	100	112	117
75	89	96	100	112	116
76	90	96	100	111	115
77	90	96	100	110	114
78	91	96	100	110	114
79	92	97	100	109	113
80	92	97	100	109	113

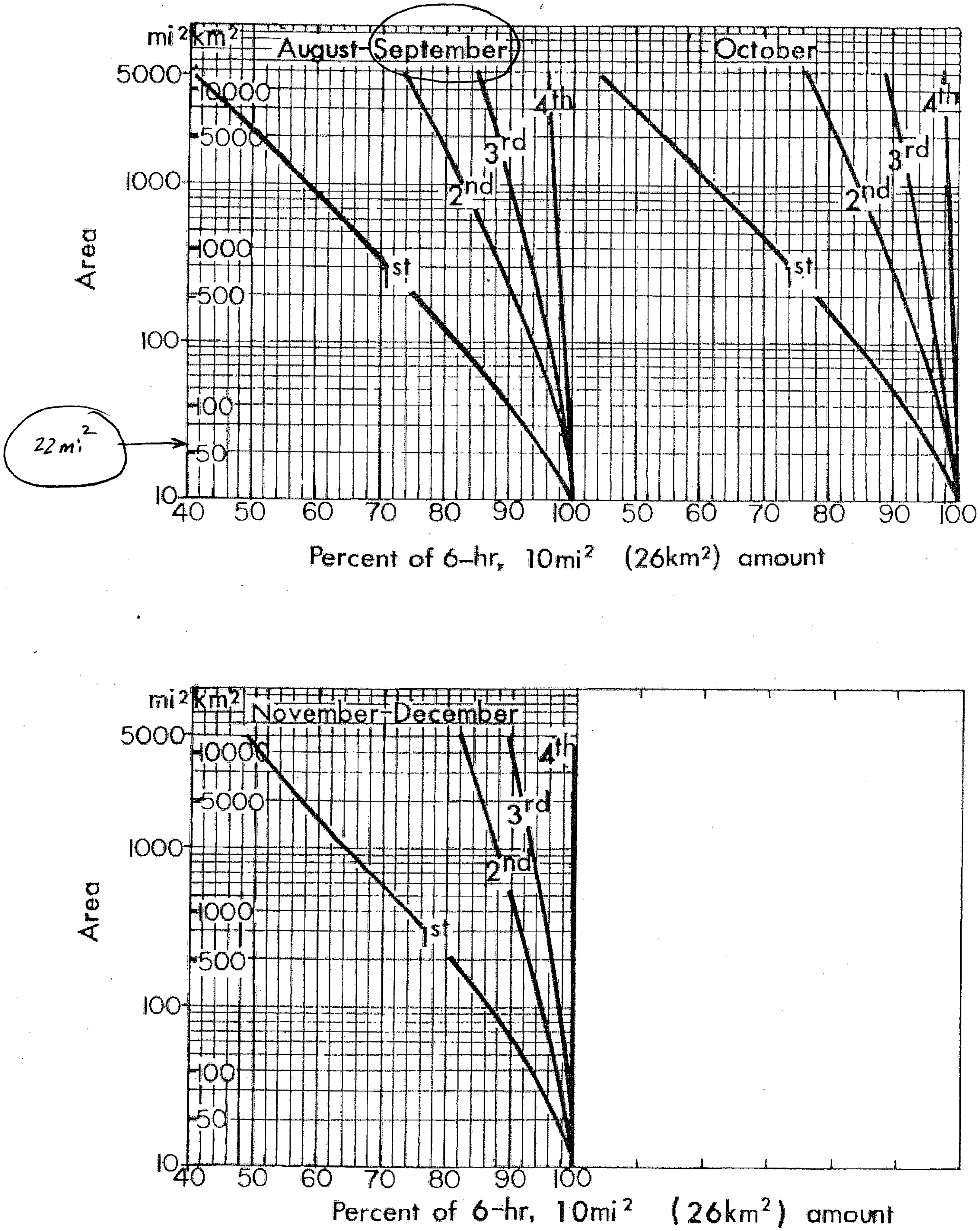
Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

2.5 Areal Reduction for Basin Size

For operational use, basin average values of convergence PMP are needed rather than 10-mi^2 (26-km^2) values. Preferably, the method for reducing 10-mi^2 (26-km^2) values to basin average rainfalls should be derived from depth-area relations of storms in the region. However, all general storms in the region include large proportions of orographic precipitation.

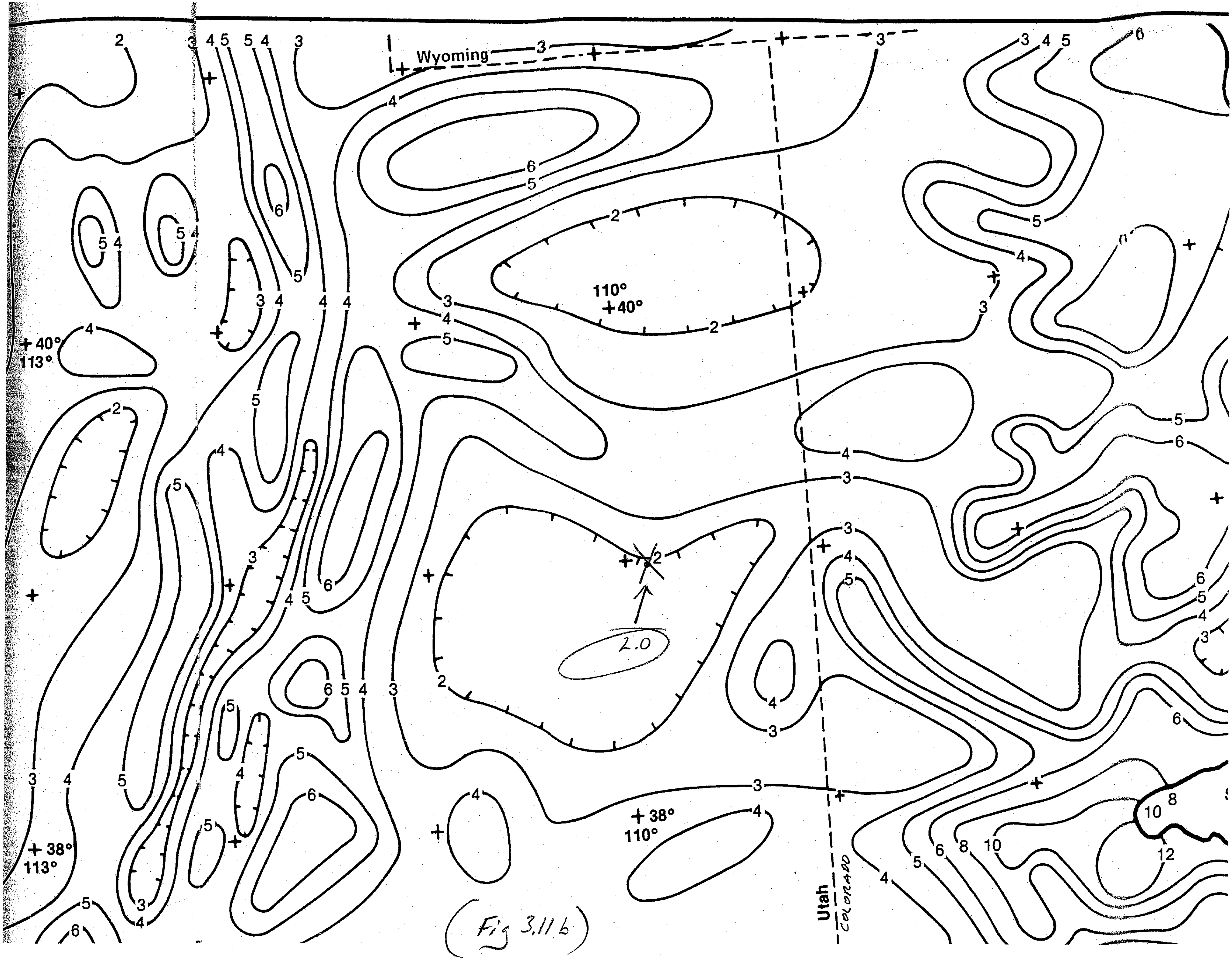
Our solution was to use generalized depth-area relations developed for PMP estimates within bordering zones in the Central and Eastern United States (Riedel et al. 1956). The smoothed areal variations adopted for the Southwestern States are shown in figures 2.28 and 2.29 for each month or a combination of months where differences are insignificant.

Figures 2.28 and 2.29 give depth-area relations that reduce 10-mi^2 (26-km^2) convergence PMP for basin sizes up to 5,000 mi^2 (12,950 km^2) for each month. Areal variations are given for the 4 greatest (1st to 4th) 6-hr PMP increments. After the 4th increment no reduction for basin size is required. Application of these figures will become clear through consideration of an example of PMP computation in chapter 6.

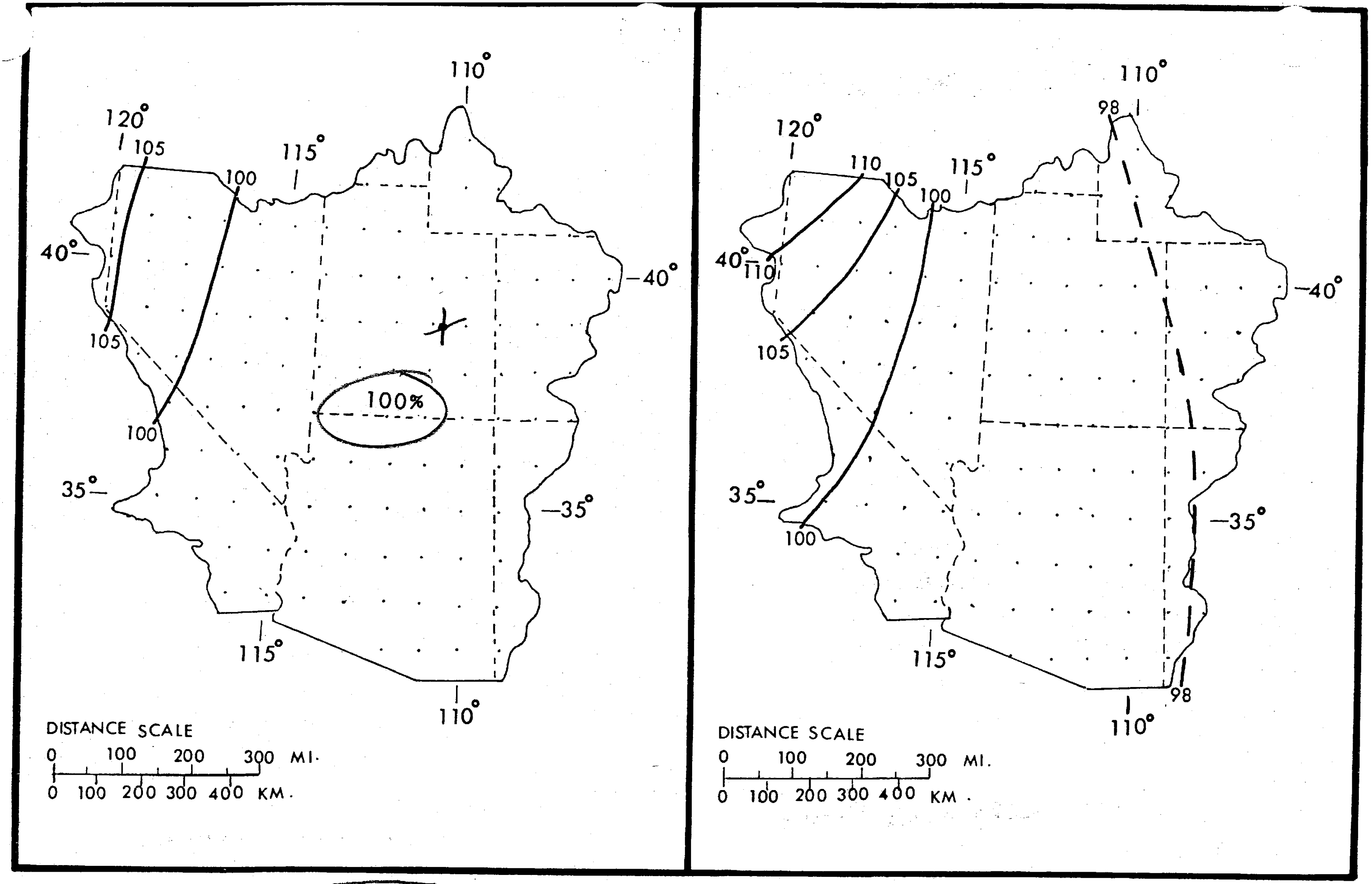


22 mi²

Figure 2.29.--Depth-area variation for convergence PMP for first to fourth 6-hr increments.


Wyoming
110°
40°
40°
113°
38°
113°
38°
110°
Utah
COLORADO
2.0
2
3
4
5
6
8
10
12

(Fig 3.11 b)



September

October

Figure 3.16.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).

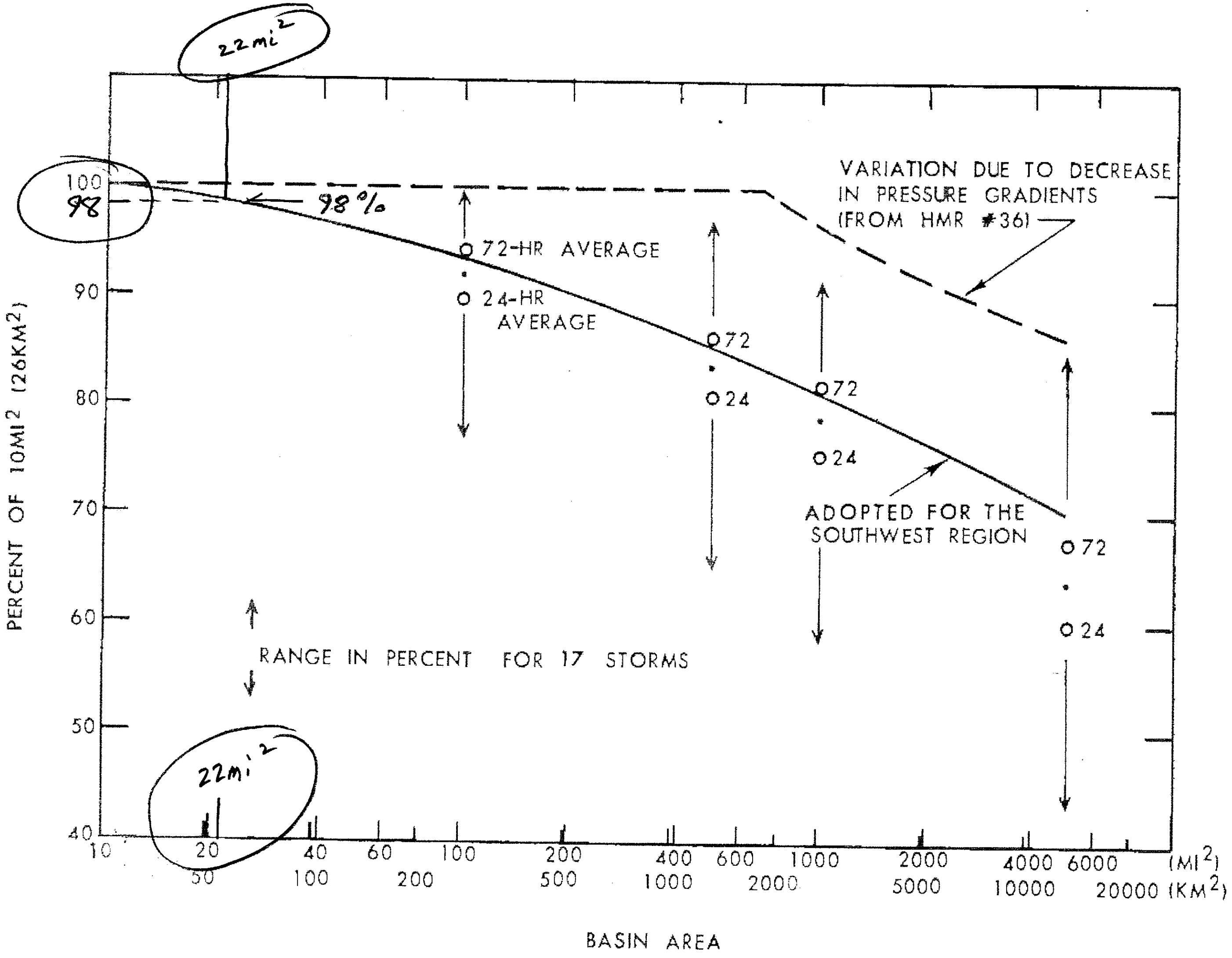


Figure 3.20.--Variation of orographic PMP with basin size.

Table 3.9.--Durational variation of orographic PMP

Latitude °N	Percent of 24-hr value					
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42	28	55	79	100	161	190
41	29	56	79	100	160	189
40	30	57	80	100	159	187
39	30	57	80	100	157	185
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General Storm PMP Computation
October

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Drainage Crescent Junction Disposal Site
Area less than 1 mi^2 (~~km^2~~)
Latitude 38°57'50"N (38.96°N), Longitude ___ of basin center 109°48'00" W (109.80°W)
Month October

Step		Duration (hrs)						
		6	12	18	24	48	72	
A. Convergence PMP								
1. Drainage average value from one of figures 2.5 to 2.16	11.6 in. (~~mm~~)							
2. Reduction for barrier-elevation [fig. 2.18]	50 %							
3. Barrier-elevation reduced PMP [step 1 X step 2]	5.8 in. (~~mm~~)							
4. Durational variation [figs. 2.25 to 2.27 and table 2.7].		67	85	94	100	116	123	%
5. Convergence PMP for indicated durations [steps 3 X 4]		3.9	4.9	5.5	5.8	6.7	7.1	in. (~~mm~~)
6. Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]		3.9	1.0	0.6	0.3	0.9	0.4	in. (~~mm~~)
7. Areal reduction [select from figs. 2.28 and [✓ 2.29]]		96	99	99	100	100	100	%
8. Areally reduced PMP [step 6 X step 7]		3.7	1.0	0.6	0.3	0.9	0.4	in. (~~mm~~)
9. Drainage average PMP [accumulated values of step 8]		3.7	4.7	5.3	5.6	6.5	6.9	in. (~~mm~~)
B. Orographic PMP								
1. Drainage average orographic index from figure 3.11a to d.	2.0 in. (~~mm~~)							
2. Areal reduction [figure 3.20]	98 %							
3. Adjustment for month [one of figs. 3.12 to 3.17]	98 %							
4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3]	1.92 in. (~~mm~~)							
5. Durational variation [table 3.~~6~~9]		30	57	80	100	157	185	%
6. Orographic PMP for given durations [steps 4 X 5]		0.6	1.1	1.5	1.9	3.0	3.6	in. (~~mm~~)
C. Total PMP								
1. Add steps A9 and B6		4.3	5.8	6.8	7.5	9.5	10.5	in. (~~mm~~)

2. PMP for other durations from smooth curve fitted to plot of computed data.
3. Comparison with local-storm PMP (see sec. 6.3).

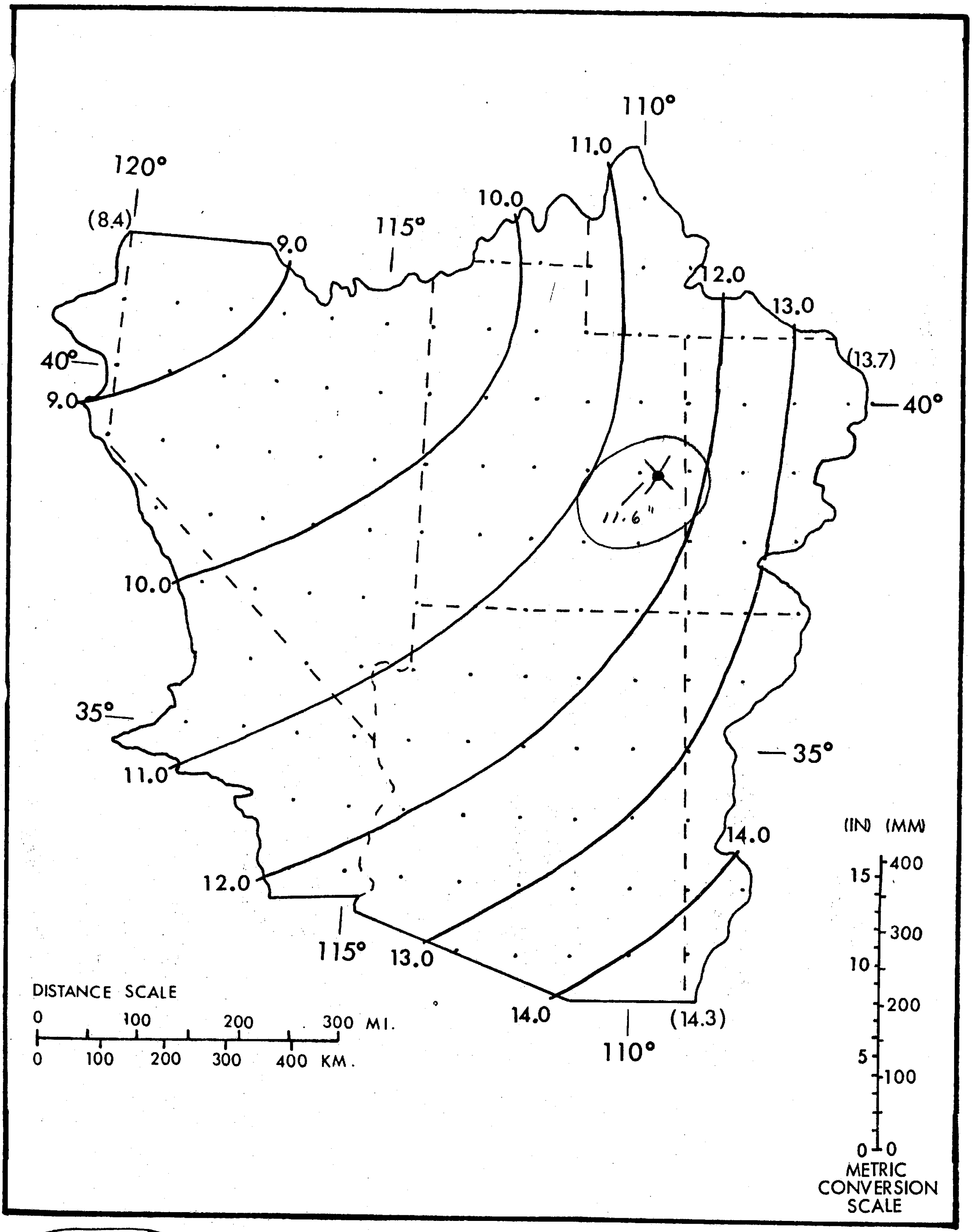


Figure 2.14.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi^2 (26 km^2) for October. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

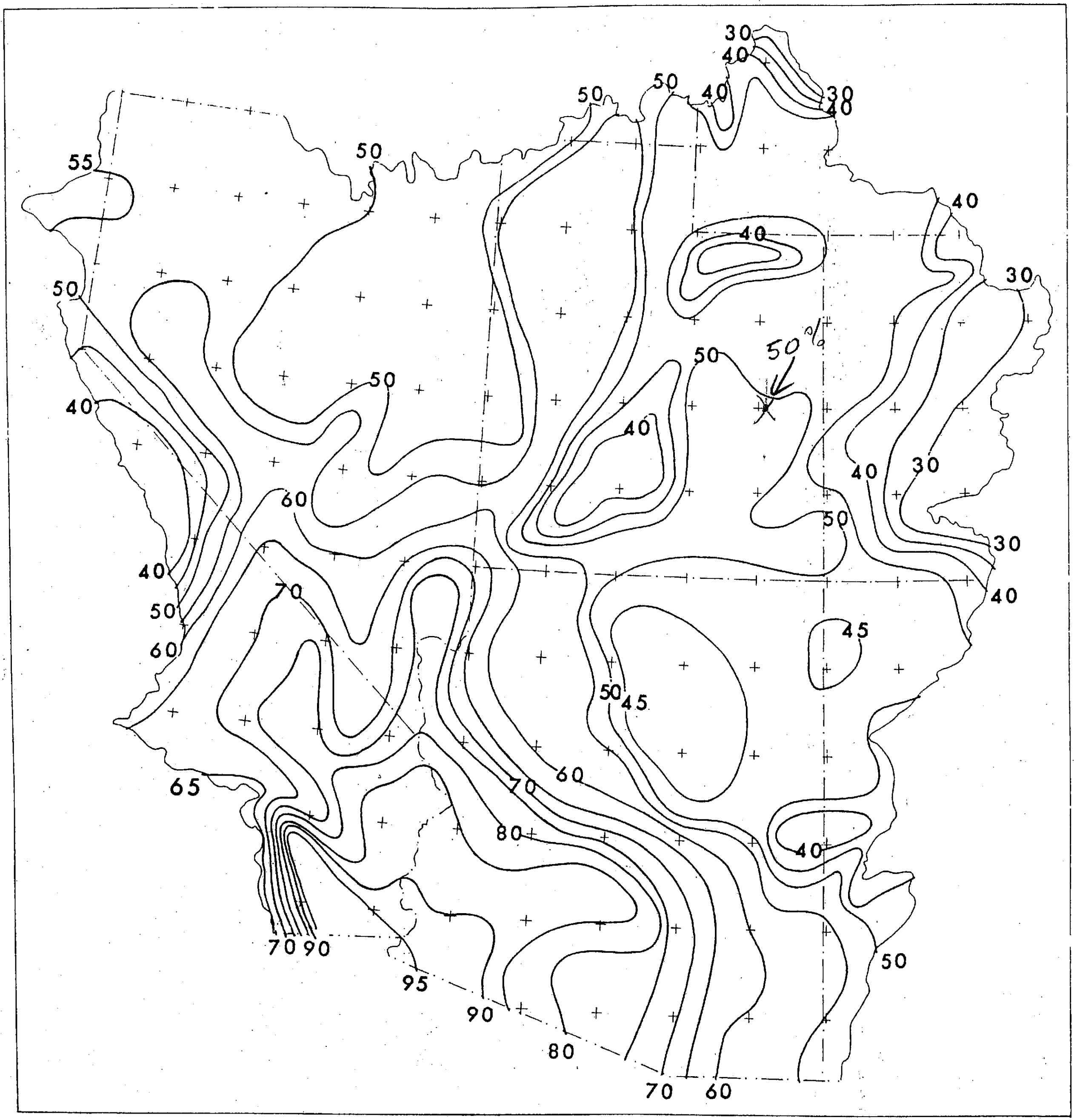
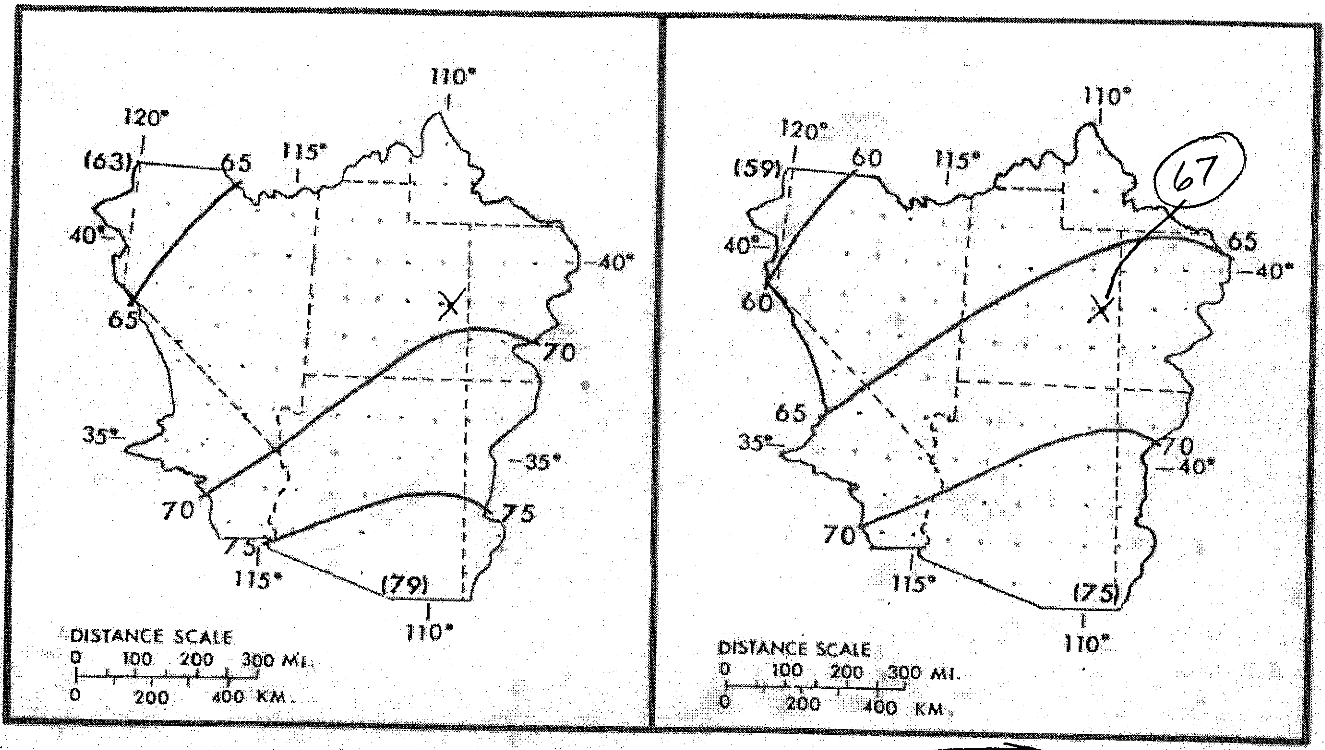
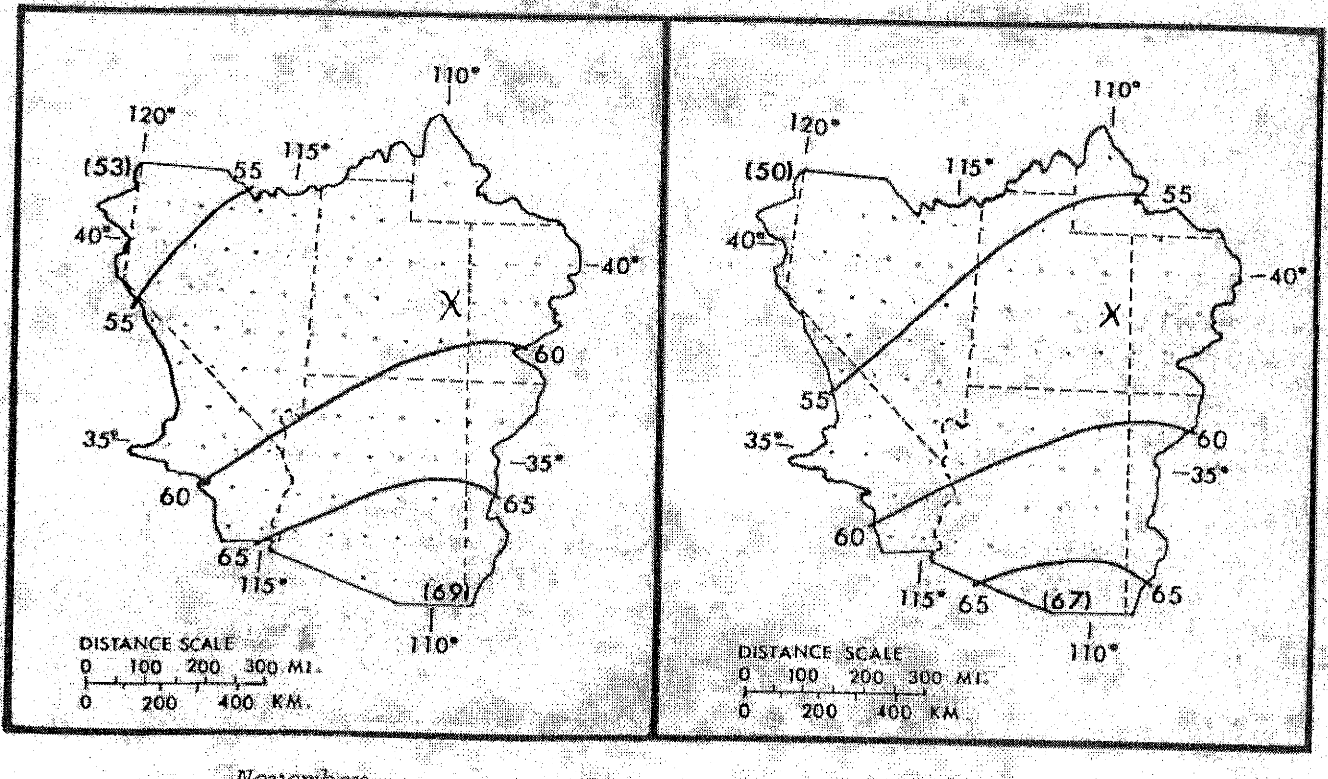


Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.



September

October



November

December

Figure 2.27.--*Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.*

For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

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Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

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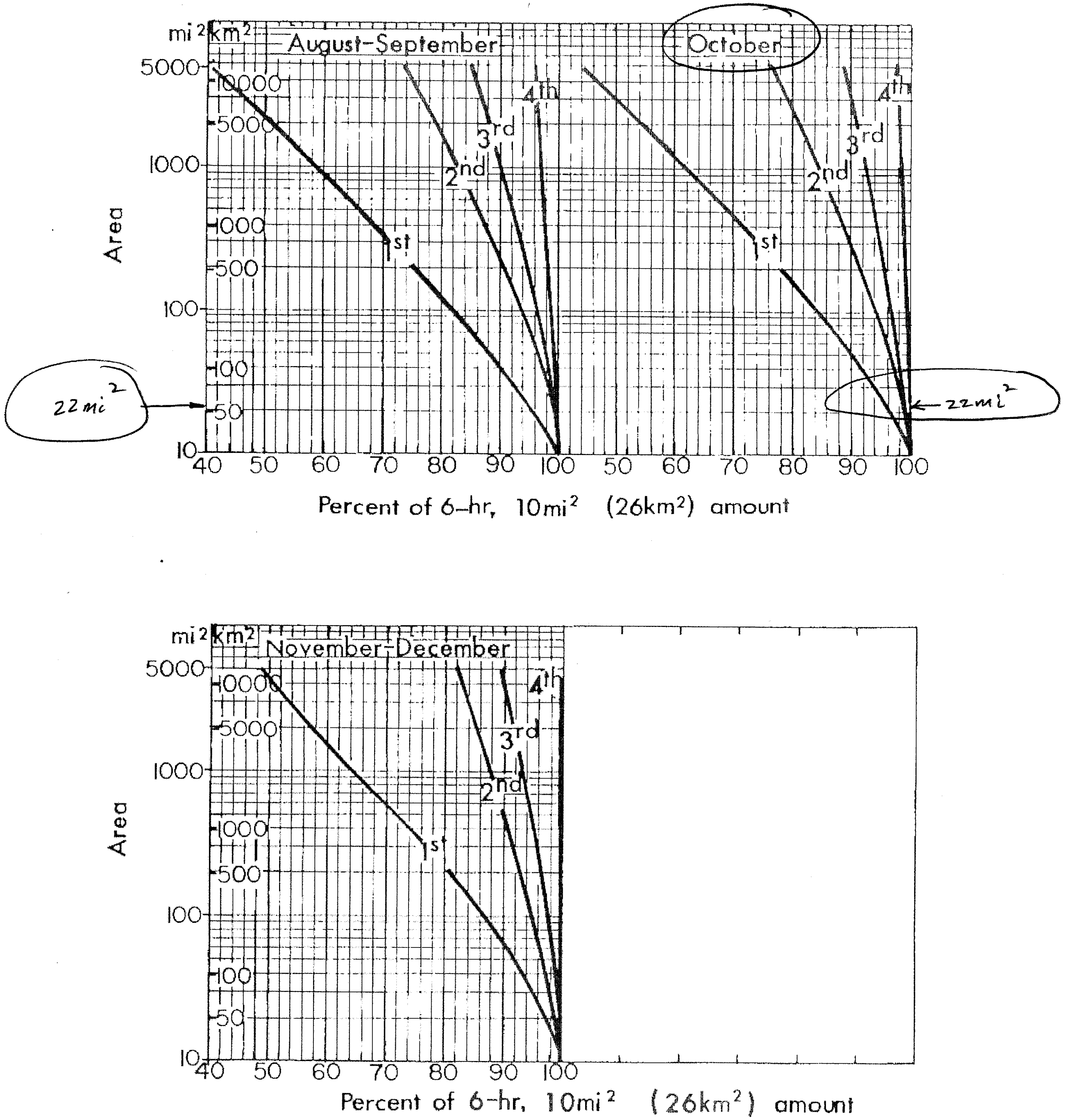
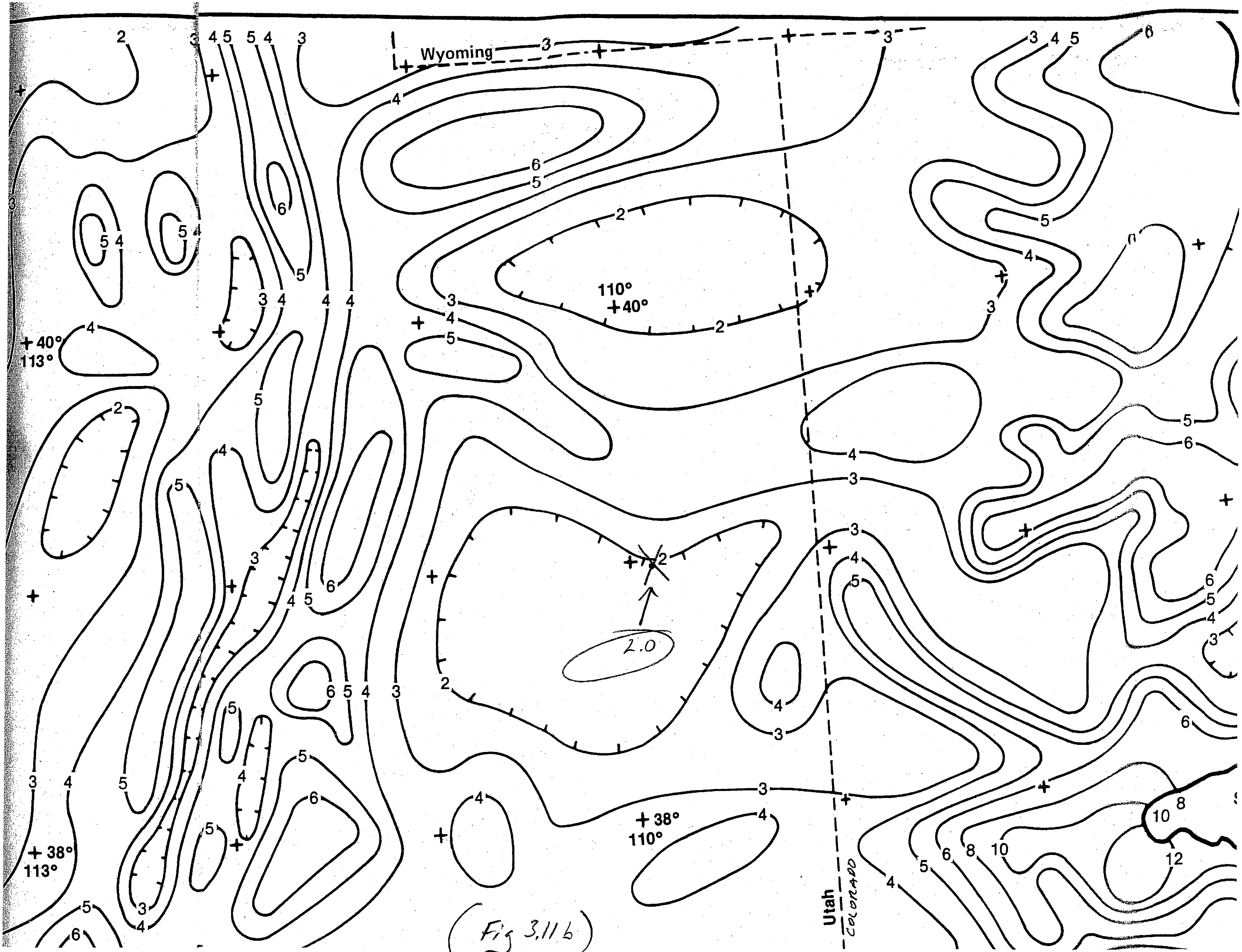


Figure 2.29--Depth-area variation for convergence PMP for first to fourth 6-hr increments.



(Fig 3.11 b)

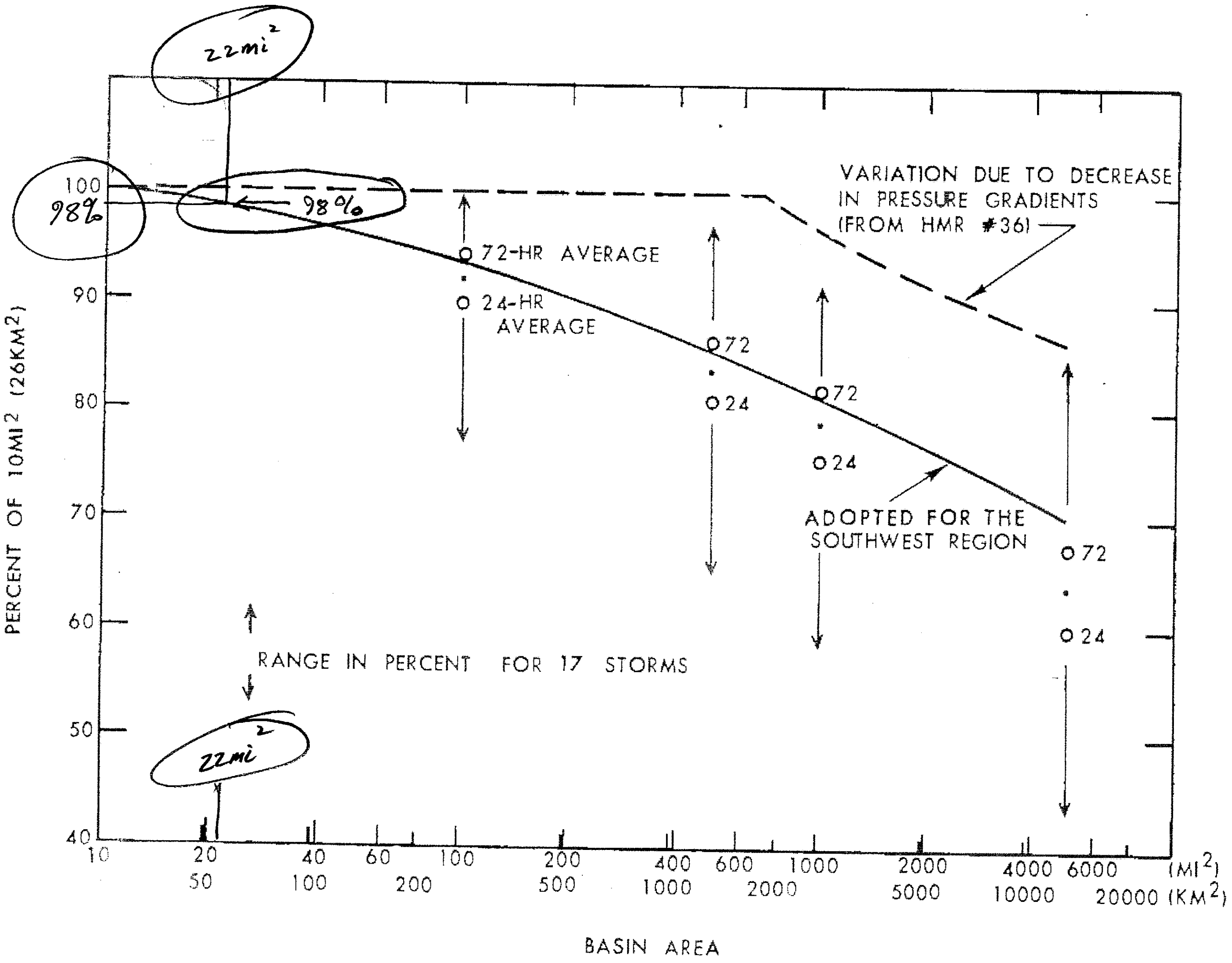
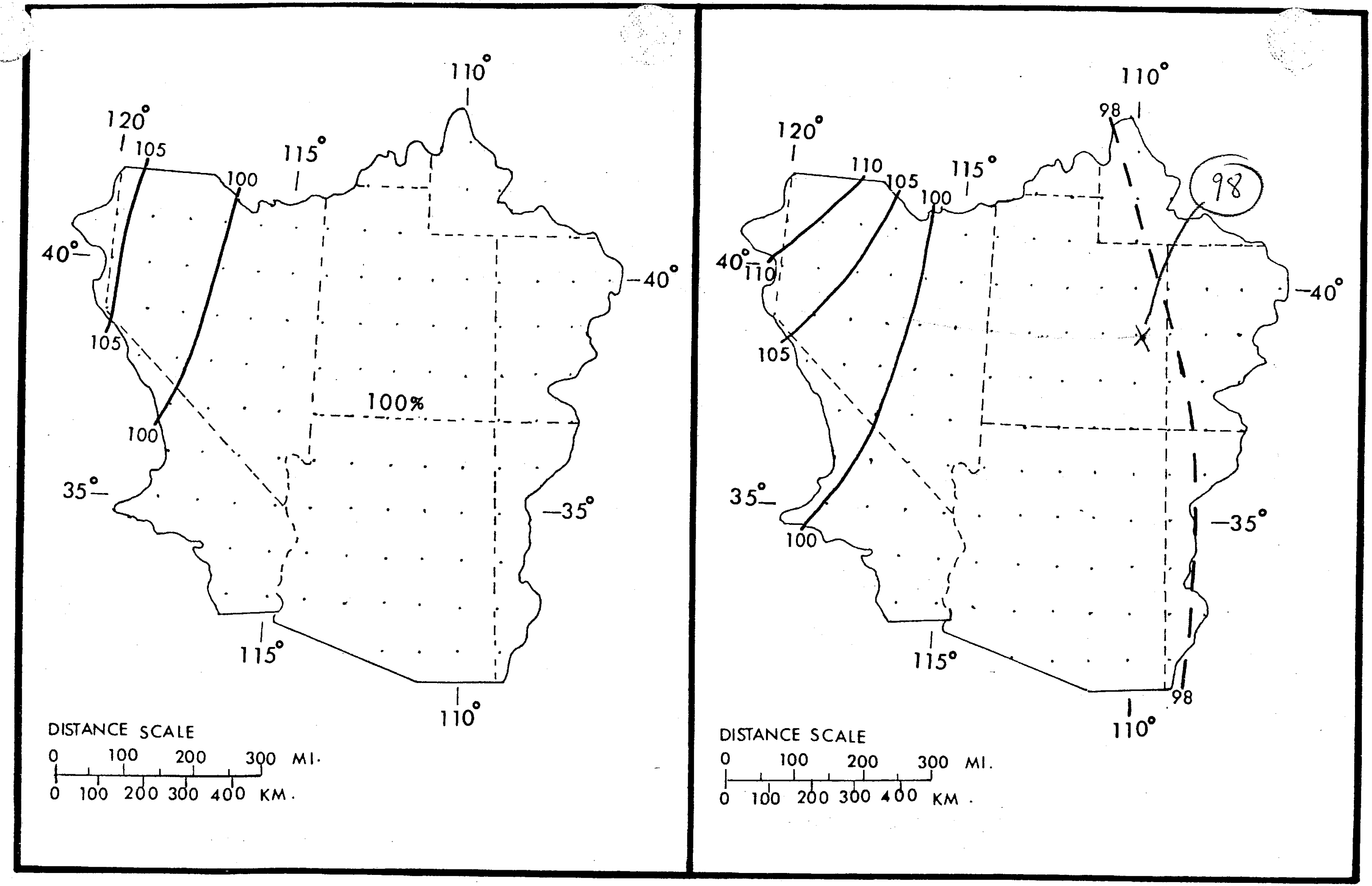


Figure 3.20.--Variation of orographic PMP with basin size.



September

October

Figure 3.16.--Seasonal variation in 10-mi^2 (26-km^2) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).

Table 3.9.--Durational variation of orographic PMP

Latitude °N	Percent of 24-hr value					
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Local Storm PMP Computation

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area less than 1 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)									
	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	61	67	71	73	76	78	80	81	82	%
7. Areal reduced PMP [steps 5 X 6].	4.3	5.1	5.7	6.0	6.7	6.9	7.2	7.3	7.4	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].				6.0	0.7	0.2	0.3	0.1	0.1	in. ~~(mm)~~
	4.3	0.8	0.6	0.3	} 15-min. increments					

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 6.0 0.7 0.2 0.1 in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8]. 4.3 0.8 0.6 0.3 in. ~~(mm)~~

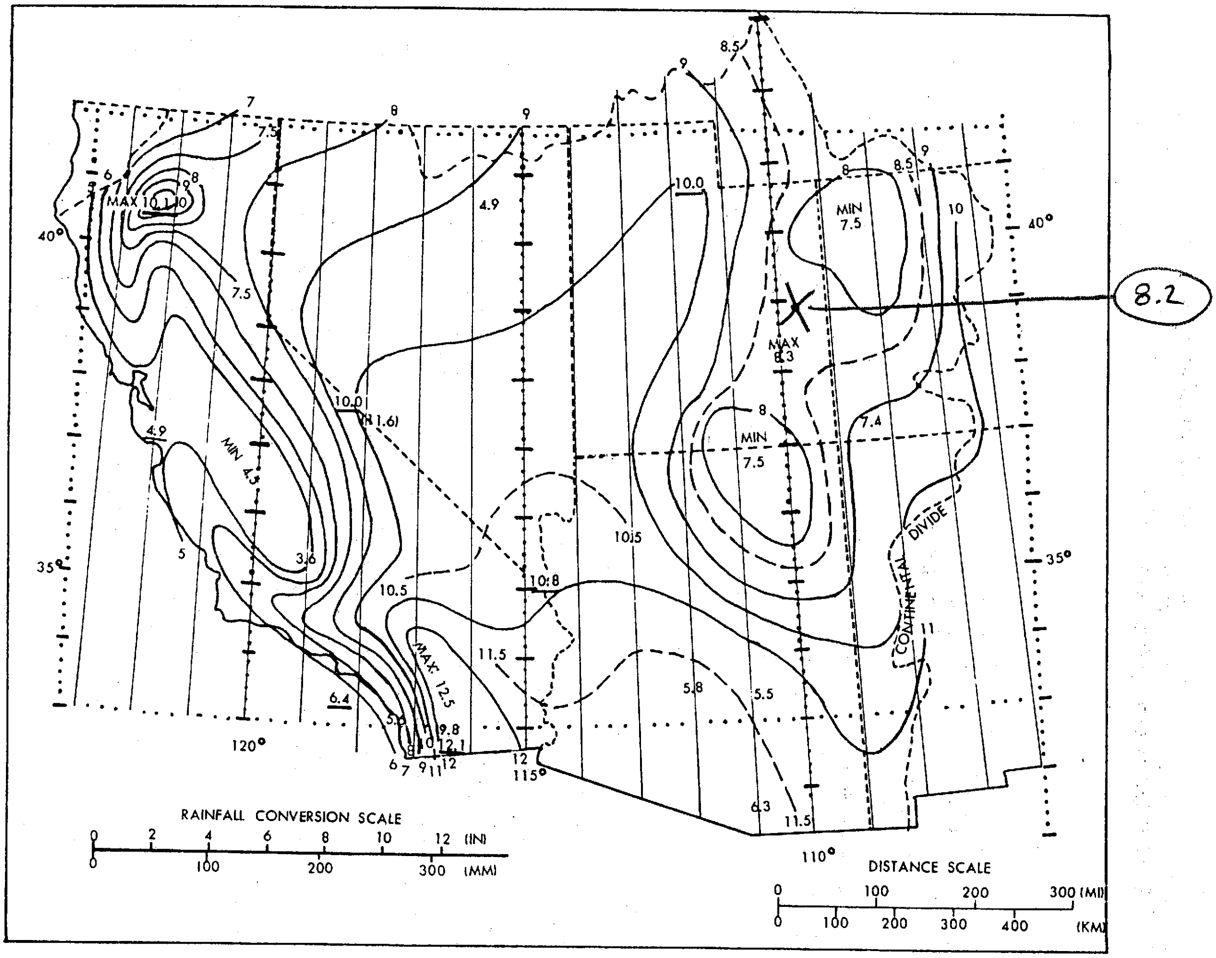


Figure 4.5--Local-storm PMP for 1 mi^2 (2.6 km^2) 1 hr. Directly applicable for locations between sea level and 5000 ft (1524 m). Elevation adjustment must be applied for locations above 5000 ft.

events. In contrast to figure 4.4, figure 4.5 maintains a maximum between these two locations. There is no known meteorological basis for a different solution. The analysis suggests that in the northern portion of the region maximum PMP occurs between the Sierra Nevada on the west and the Wasatch range on the east.

A discrete maximum (> 10 inches, 254 mm) occurs at the north end of the Sacramento Valley in northern California because the northward-flowing moist air is increasingly channeled and forced upslope. Support for this PMP center comes from the Newton, Kennett, and Red Bluff storms (fig. 4.1). Although the analysis in this region appears to be an extension of the broad maximum through the center of the Southwestern Region, it does not indicate the direction of moist inflow. The pattern has evolved primarily as a result of attempts to tie plotted maxima into a reasonable picture while considering inflow directions, terrain effects, and moisture potential.

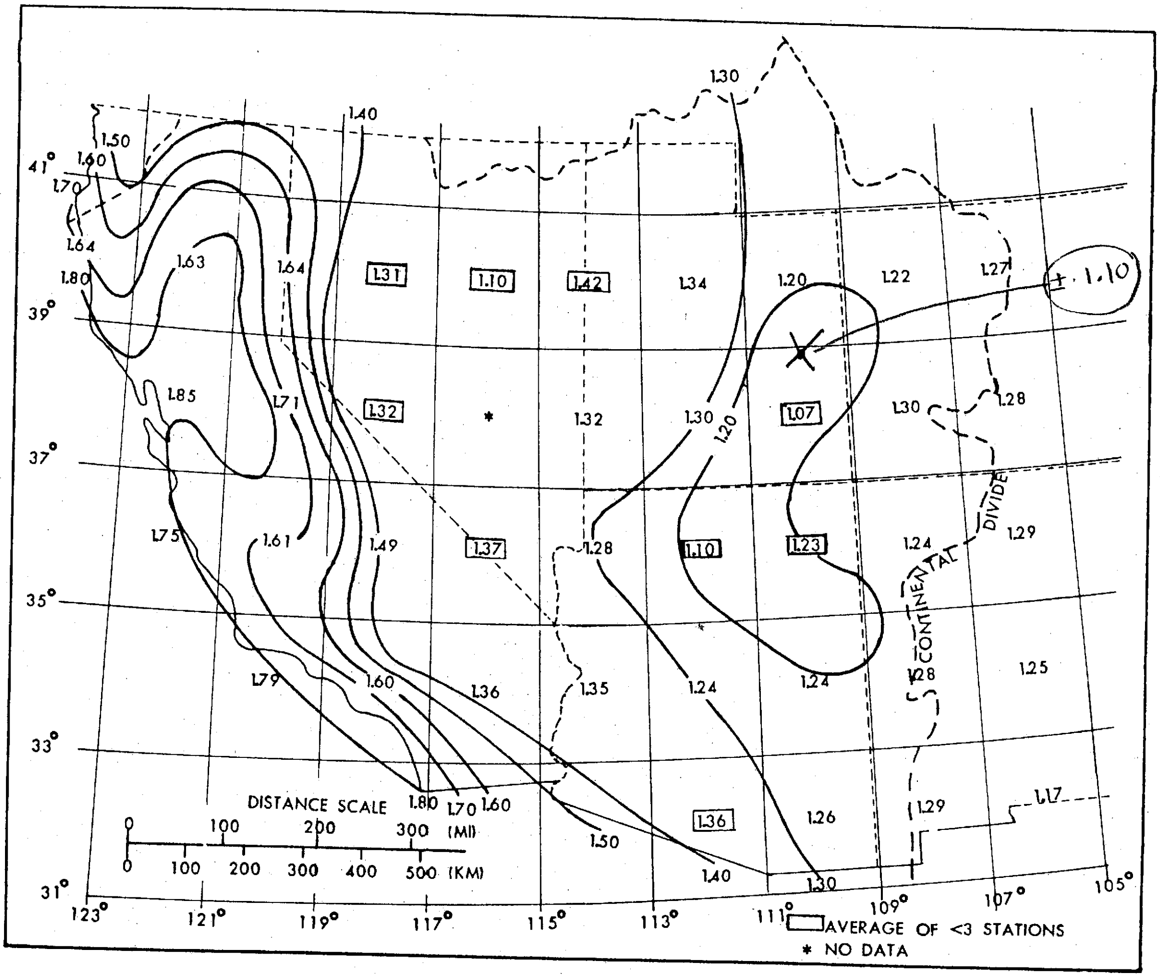


Figure 4.7--*Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).*

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945-). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi^2 (2.6-km^2) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi^2 (2.6-km^2) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

6/1-hr ratio	Duration (hr) 1/4	1/2	3/4	1	2	3	4	5	6
1.1	86	93	97	100	107	109	110	110	110
1.2	74	89	95	100	110	115	118	119	120
1.3	74	89	95	100	114	121	125	128	130
1.4	63	83	93	100	118	126	132	137	140
1.5	63	83	93	100	121	132	140	145	150
1.6	43	70	87	100	124	138	147	154	160
1.8	43	70	87	100	130	149	161	171	180
2.0	43	70	87	100	137	161	175	188	200

4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi^2 (2.6 km^2). To apply PMP to a basin, we need to determine how 1-mi^2 (2.6-km^2) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

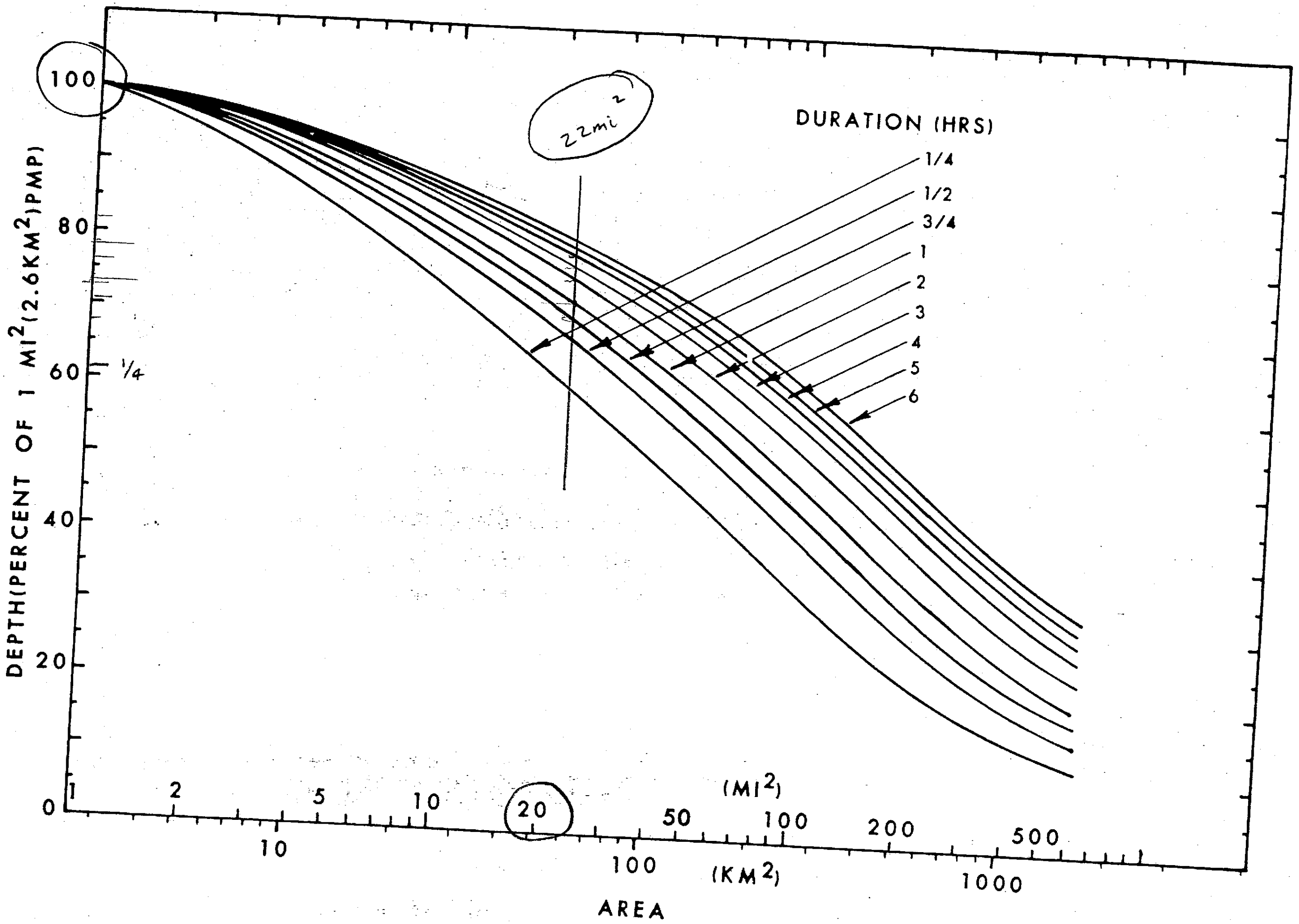
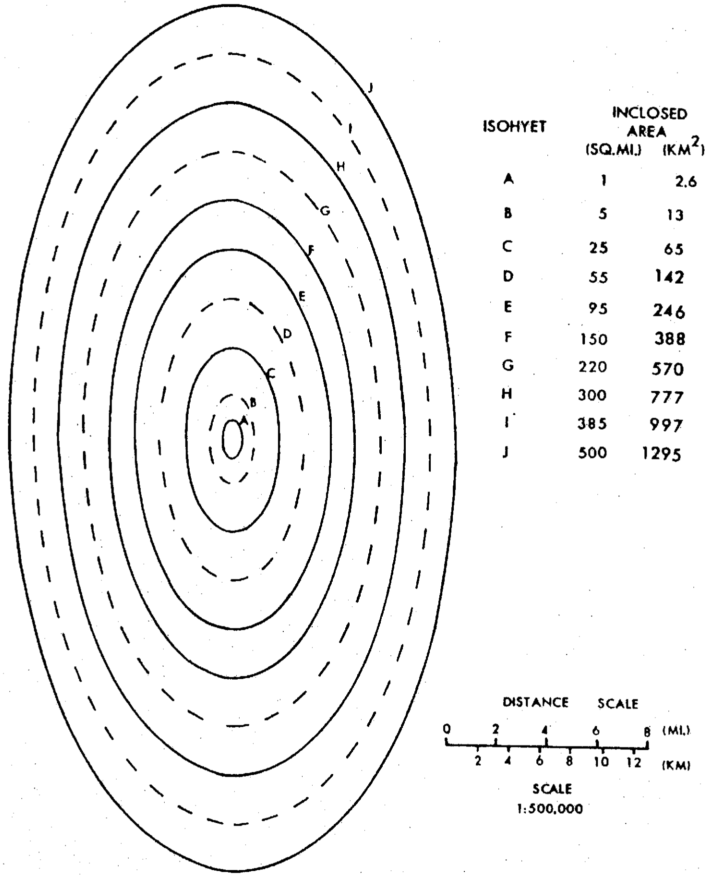


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

Figure 4.10.--Idealized local-storm isohyetal pattern.



ISOHYET	INCLOSED AREA (SQ.MI.)	INCLOSED AREA (KM^2)
A	1	2.6
B	5	13
C	25	65
D	55	142
E	95	246
F	150	388
G	220	570
H	300	777
I	385	997
J	500	1295

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, the choice of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

Increment	HMR No. 5[1] Sequence Position	EM1110-2-1411[2] Sequence Position
Largest hourly amount	Third	Fourth
2nd largest	Fourth	Third
3rd largest	Second	Fifth
4th largest	Fifth	Second
5th largest	First	Last
least	Last	First

---

[1] U. S. Weather Bureau 1947.

[2] U. S. Corps of Engineers 1952.

Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.--Time sequence for 15-min incremental PMP within 1 hr.

Increment	Sequence Position
Largest 15-min amount	First
2nd largest	Second
3rd largest	Third
least	Last

4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

	Month						
	M	J	J	A	S	O	No. of Cases
Utah	1	5	9	14	5		34
Arizona		4	16	19	4		43
S. Calif.*		14	10	7			31
No. of cases/mo.	1	23	35	40	9	0	

*South of 37°N and east of Sierra Nevada ridgeline.

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-06-2006-5-08-00 **Discipline:** Geotechnical **No. of Sheets:** 8
Doc. No.: X0176000

Location: Attachment 1, Appendix F

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Crescent Junction Site Hydrology Report

Sources of Data:

Remedial Action Plan (RAP) calculations as referenced in the text.

Sources of Formulae and References:

See "References."

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Peggy Bailey 5-29-07
Name Date

Checked by: S. Gary 5/30/07
Name Date

Roslyn Ste 6/11/07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Name Date

May 31, 07
Name Date

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Problem Statement:

Peak runoff flow rates are determined at specific locations in the vicinity of the Crescent Junction Site for the following storms:

- 25-year, 24-hour storm.
- 100-year, 24-hour storm.
- Probable Maximum Precipitation (PMP), Local Storm.

The 25-year, 24-hour storm is determined for sizing culverts and swales along the access road and Trailer Staging Area. These facilities will be in-place for approximately 25-years to facilitate the placement of the disposal cell. The 100-year flood is used to size the detention facility at the Trailer Staging Area, in compliance with Grand County drainage regulations. A separate drainage report for submittal to the County is being prepared with detention basin calculations. One-hundred-year flows are also generated to compare existing versus “developed” conditions at key drainage points located downhill from the disposal cell. This includes flows at West Kendall Wash at the Railroad crossing located immediately south of the southwest corner of the disposal cell, Kendall Wash at the I-70 crossing and Crescent Wash at the I-70 crossing immediately west of Kendall Wash. The Probable Maximum Flood (PMF) is calculated for use in design of facilities associated with the disposal cell. This includes the PMF for the cell drainage facilities to control run-on and run-off. Major drainages are shown on Figure 1. Sub-basins and proposed-conditions basins are shown in detail on the Master Drainage Plan (Plan), Appendix F of this report.

Method of Solution:

Calculations for runoff hydrographs, routing reaches, and combination of hydrographs for all basins greater than 20 acres are determined using the U.S. Army Corps of Engineers’ Hydrologic Modeling System (HEC-HMS) Version 3.0.1. Within this computer model, the following runoff and routing methods are used:

- NRCS classification of the soils within the project site is Type B (Toddler-Ravola-Glenton) described as well draining sands and sandy loams, with a range of final infiltration rates of 4 to 8 millimeters (mm) per hour (0.16 to 0.31 inches per hour). The U.S. Bureau of Reclamation also recommends 0.3 to 0.15 inches per hour (USBR 1987) as the minimum infiltration rates for B soils. For the purpose of this analysis use 0.3 inches per hour in the existing undisturbed watershed and 0.15 inches per hour for the cell site.
- Soil Conservation Service (SCS) curve number (CN) values for B soils with sparse vegetation use 70.
- Manning’s N value, $K_{n,}$ representing the hydraulic characteristics of the drainage network, varies with flow (see discussion in the “User-Specified Unit Hydrograph” subsection), use 0.042 for the PMF and 0.054 for the 25-year and 100-year flow.

For the PMF:

- Loss Method in existing watershed – Initial loss of 0.0 inches, constant loss of 0.3 inches per hour.
- Loss Method for the disposal cell – Initial loss of 0.0 inches, constant loss of 0.15 inches per hour.
- Transform Method – User-specified unit hydrograph.
- Baseflow Method – None.
- Routing Reaches – Kinematic wave.
- Meteorology Model – PMP calculations, no evapotranspiration, no snowmelt.

For the 25-year and 100-year, 24 hour storms:

- Loss Method in existing watershed − SCS CN method with initial loss of 0.86 inches based on CN of 70 and constant loss of 0.3 inches per hour.
- Loss Method for the disposal cell- SCS CN method with initial loss of 0.86 inches based on CN of 70 and constant loss of 0.15 inches per hour

- Transform Method – User-specified unit hydrograph.
- Baseflow Method – None.
- Routing Reaches – Kinematic wave.
- Meteorology Model – Precipitation from National Oceanic and Atmospheric Administration (NOAA) Atlas 14, no evapotranspiration, no snowmelt.

Note that for basins less than 20 acres that do not require PMF determination, runoff is calculated using the Rational Method.

Assumptions:

Standard methods were used to calculate the runoff to the design points for the specific frequency storms.

Calculations:

Basin Delineation

Drainage basins are delineated based on locations of bridges/culverts or other points of concentration. There are four major basins encompassing the study area: Crescent Wash, Basin 1, Basin 2, and Basin 3. These major basins are shown on Figure 1. Seven sub-basins within the major basins are created due to the re-routing of flows around the disposal cell and the access road. These sub-basins are shown on the Plan (Appendix F).

The disposal cell will be isolated from run-on with the construction of a diversion channel, labeled as "North Ditch" on the Plan. These flows, which are ultimately tributary to West Kendall Wash, will be routed to the west past the Disposal Site, and then south in the "West Ditch", back into West Kendall Wash. Runoff from the cell will be diverted to the west at the south toe of the disposal cell, and confluence with the West Ditch at Design Point 4 as shown on the Plan.

User-Specified Unit Hydrograph

The methodology for determining the unit hydrograph is detailed in *Design of Small Dams* (USBR 1987) using the dimensionless unit hydrograph data for the Colorado Plateau regions of Southern California, Nevada, Utah, Arizona, and western Colorado and New Mexico. Basins in this arid region are generally typified by sparse vegetation, fairly well defined drainage networks, and terrain varying from rolling to very rugged in the more mountainous areas. The unit hydrograph lag time is defined as:

$$L_g = C(LL_{ca}/S^{.5})$$

where:

L_g = unit hydrograph lag time, hours
The USBR (1987) defines the unit hydrograph lag time as the time from the midpoint of the unit rainfall excess to the time that 50 percent of the volume of unit runoff from the drainage basin has passed the concentration point (USBR 1987).

C = constant=26K_n
K_n = average Manning's n value representing the hydraulic characteristics of the drainage basin. K_n is a function of the magnitude of the flows and normally decreases with increasing discharge. K_n values for the PMF are based on recommendations from *Design of Small Dams* (USBR 1987), which suggests the lowest value representative of the region be used. A regional K_n value of 0.042 represents the lower limit of the accepted range for PMF determination and is typical of the usual desert terrain. For other storm events a higher value is appropriate. Based on the *Design of Small Dams,* the Colorado Plateau regions K_n range from 0.042 to 0.070. A value of 0.054 is selected for the 25-year and 100-year storm events, representing an area of Utah that is relatively close proximity to the project site on the White River (USBR 1987).

L = the length of the longest watercourse from the point of concentration to the boundary of the drainage basin.

L_{ca} = the length along the longest watercourse from the point of concentration to a point opposite the centroid of the drainage basin.

S = the overall slope of the longest watercourse (along *L*).

Hydrologic parameters and spreadsheets are used to create the basin-specific unit hydrographs for use by the HEC-HMS models and are presented in Appendix A.

Frequency Storms

Design storm information is provided in the "Site Drainage—Hydrology Parameters" calculation (RAP Attachment 1, Appendix E), which calculates the local storm PMP for storms of <1 square mile (mi^2) and 22 $mi^{2.}$ This analysis also includes determination of storms in basins covering 1.4, 2.7, 3.5, 9, and 15 mi^2. Thus additional depth-duration models are developed so that the size of the storm is equivalent to the drainage area contributing to the design point. Calculations are included in Appendix B.

The depth-duration relationships for all of the modeled storms are summarized in Table 1.

Table 1. Depth-Duration for Modeled Storms

Precipitation Depth (inches) for Specified Duration								
Storm Event	**5 min**	**15 min**	**1 hr**	**2 hr**	**3 hr**	**6 hr**	**12 hr**	**24 hr**
25-yr, 24-hr	0.34	0.64	1.07	1.21	1.26	1.42	1.65	1.91
100-yr, 24-hr	0.53	0.99	1.65	1.82	1.84	1.95	2.16	2.35
200-yr, 24-hr	0.65	1.22	2.03	2.23	2.25	2.35	2.47	2.58
PMP – Local								
<1 mi^2	4.5	7.1	8.2	8.8	8.9	9.0		
1.4 mi^2	4.3	6.8	8.0	8.6	8.7	8.9		
2.7 mi^2	4.1	6.5	7.9	8.4	8.5	8.7		
3.5 mi^2	4.0	6.2	7.6	8.3	8.5	8.6		
9 mi^2	3.4	5.4	6.9	7.6	7.7	8.0		
15 mi^2	3.0	4.8	6.4	7.0	7.2	7.7		
22 mi^2	2.7	4.3	6.0	6.7	6.9	7.4		

Routing Reaches

Reach routing is performed in the HEC-HMS modeling using kinematic wave to route hydrographs along ditches and between design points. Design parameters and input are summarized in Appendix B.

HEC-HMS Results

The HEC-HMS model is used to determine hydrographs at the specific design points for each of the four storm events. Model output is provided in Appendix C and summarized in Table 2. For basins less than 20 acres that do not require PMF determination, runoff is calculated using the Rational Method. Rational Method calculations are presented in Appendix D.

Conclusions and Recommendations:

The peak flow rates at each of the design points are summarized in Table 2.

Table 2. Peak Flow Rates, Major Storm Events

Design Point	Area (mi^2)	Peak Flow Rate (cfs)		
		25-yr, 24-hr	**100-yr, 24-hr**	**PMP - Local**
Crescent Wash at RR Bridge and I-70 Existing and Proposed	22.56	2,975	5,983	45,197
Basin 1 at RR Bridge (Design Point 6)	2.63			
Existing conditions		-	2,135	21,288
Proposed conditions		-	2,210	21,322
Basin 2 at RR Bridge Existing and Proposed	8.96	1,726	3,453	29,869
Basins 1, 2, and 3 at I-70 CMP	15.09			
Existing conditions		-	5,109	40,835
Proposed conditions		-	5,098	40,871
Proposed Drainage Facilities				
North Ditch	0.52	291	-	5,859
West Ditch (Design Point 4)	0.52	291	-	5,859
Design Point 5	0.90	448	-	8,722
Existing Culvert (Design Point 3)	0.17	75	147	1,488
Culvert C1*	0.09	42	-	-
Culvert C2*	0.05	9	-	-
Culvert C3*	0.02	4	-	-
Culvert C4*	0.10	18	-	-
Culvert C5	1.25	611	-	-
Culvert C6*	0.05	9	-	-
Culvert C7*	0.41	239	-	-

Discussion:

Parameters used to calculate the 25-year and 100-year flows are checked using gaged data available for Crescent Wash through the U.S. Geological Survey (USGS). Two sets of information are available. The first includes 10 years of gaging information (USGS 1999), which indicates the highest flow on record of 4,160 cfs in 1965. The second is a flood-frequency analysis performed by the USGS (Vaill 2000) indicating a 100-year event with a peak discharge of 6,460 cfs. Due to the limited amount of data, this information is considered only a relative check for order of magnitude compared to the computations; however, the results of this analysis are within 3 percent of the USGS results, when adjusted for drainage area. Several additional gaged sites were also checked for peak flows per square mile. Sites selected for comparison are similar in elevation and size and are in similar environmental conditions as the project site. Peak flows were calculated by the USGS using Log-Pearson Type III probability distribution (Vaill 2000). See Appendix E for a detailed discussion and comparison of flows.

References:

U.S. Army Corps of Engineers. *HEC-HMS Hydrologic Modeling System*, Version 3.0.1, Hydrologic Engineering Center, Davis, California.

USGS (U.S. Geological Survey), 1999. *The National Flood-Frequency Program-Methods for Estimating Flood Magnitude and Frequency in Rural Areas in Utah*, U.S. Geological Survey, September.

USBR (U.S. Bureau of Reclamation), 1987. *Design of Small Dams, 3rd Ed.*, U.S. Department of the Interior, U.S. Bureau of Reclamation.

Vaill, J.E., 2000. *Analysis of the Magnitude and Frequency of Floods in Colorado*, U.S. Geological Survey Water-Resources Investigations Report 99-4190.

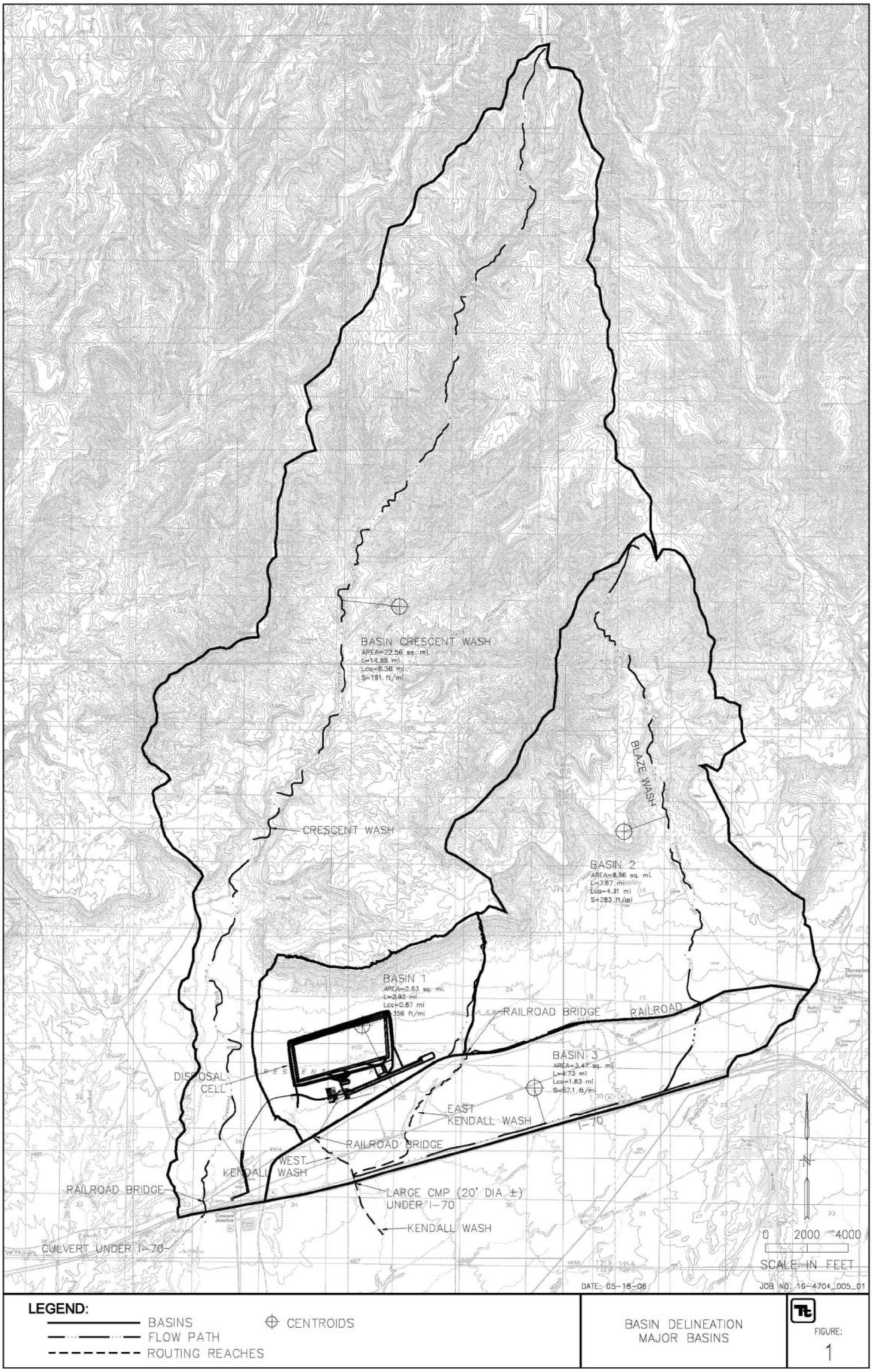

Figure 1. Major Drainage Basins for the Crescent Junction Site

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Appendix A

Unit Hydrographs

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

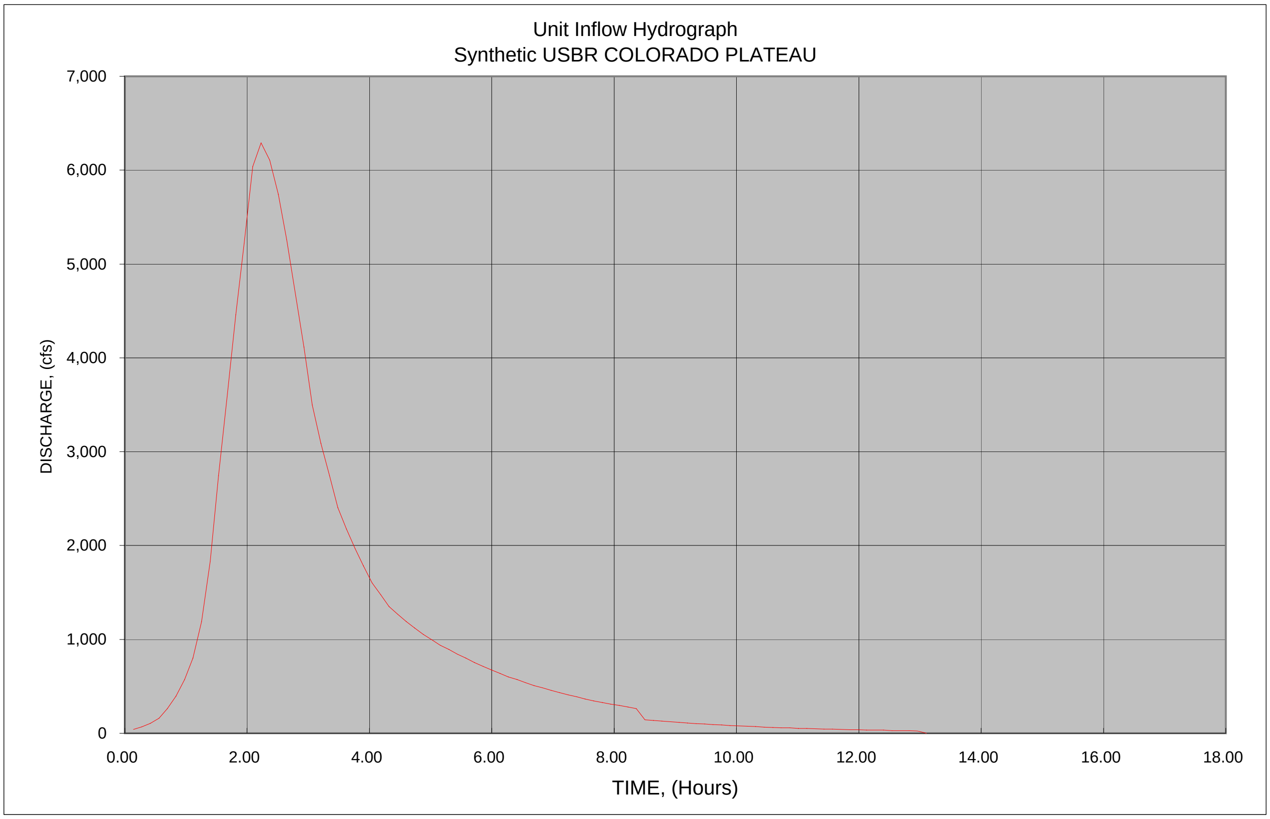
Crescent Wash-10, 25, 100, 200 Existing Conditions

Drainage Area = 22.56 sq. miles
Basin Slope = 209 ft./mile
L = 13.56 mi., Length of Watercourse
Lca = 7.07 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 2.79 Hours
Basin Factor = 6.63
V' = 606.64 cfs/Day
Qs = 217.6 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 2.62 Hours
Unit Duration, D = 28.59 minutes
Calculated Timestep = 8.36 minutes

Data to be used in Analysis
Unit Duration, D = 20 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



UI Record - Unit Graph 5 **minute interval**

UI	25	47	64	83	104	138	180	241	313	391
UI	497	612	749	945	1178	1552	1979	2526	3048	3554
UI	4073	4576	5027	5502	5994	6176	6265	6156	5984	5764
UI	5485	5187	4845	4503	4160	3794	3450	3204	2979	2774
UI	2569	2377	2241	2111	1987	1876	1766	1657	1564	1489
UI	1414	1342	1294	1246	1200	1157	1115	1075	1037	1002
UI	968	935	908	879	849	823	798	771	745	720
UI	696	673	651	628	605	587	571	550	531	512
UI	497	482	467	452	437	423	409	396	383	370
UI	358	346	334	323	314	305	296	286	276	267
UI	258	251	241	233	225	218	211	204	196	190
UI	184	179	174	168	163	157	151	147	143	139
UI	134	129	125	121	117	113	109	105	102	99
UI	96	92	89	87	84	81	79	76	74	72

UI	70	66	63	61	59	58	57	54	52	51
UI	49	48	47	46	44	43	42	40	39	38
UI	36	35	34	33	33	32	29	27	26	26
UI	26	24	14							
UI										
UI										
UI										
UI										

USBR calculated unitgraph peak = 6291 Interpolated Peak = 6265

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.14	8.4	0.19	41	305.0	8.50	510.2	0.66	144
10.0	0.28	16.7	0.32	70	310.0	8.64	518.5	0.63	137
15.0	0.42	25.1	0.48	104	315.0	8.78	526.9	0.59	128
20.0	0.56	33.5	0.74	161	320.0	8.92	535.3	0.56	122
25.0	0.70	41.8	1.21	263	325.0	9.06	543.6	0.53	115
30.0	0.84	50.2	1.81	394	330.0	9.20	552.0	0.50	109
35.0	0.98	58.5	2.63	572	335.0	9.34	560.4	0.47	102
40.0	1.12	66.9	3.68	801	340.0	9.48	568.7	0.45	98
45.0	1.25	75.3	5.47	1,190	345.0	9.62	577.1	0.42	91
50.0	1.39	83.6	8.41	1,830	350.0	9.76	585.4	0.40	87
55.0	1.53	92.0	12.61	2,744	355.0	9.90	593.8	0.38	83
60.0	1.67	100.4	16.50	3,590	360.0	10.04	602.2	0.36	78
65.0	1.81	108.7	20.50	4,461	365.0	10.18	610.5	0.34	74
70.0	1.95	117.1	23.97	5,216	370.0	10.32	618.9	0.33	72
75.0	2.09	125.5	27.75	6,038	375.0	10.45	627.3	0.30	65
80.0	2.23	133.8	28.91	6,291	380.0	10.59	635.6	0.28	61
85.0	2.37	142.2	28.07	6,108	385.0	10.73	644.0	0.27	59
90.0	2.51	150.5	26.38	5,740	390.0	10.87	652.4	0.26	57
95.0	2.65	158.9	24.18	5,262	395.0	11.01	660.7	0.24	52
100.0	2.79	167.3	21.55	4,689	400.0	11.15	669.1	0.23	50
105.0	2.93	175.6	18.92	4,117	405.0	11.29	677.4	0.22	48
110.0	3.07	184.0	16.08	3,499	410.0	11.43	685.8	0.21	46
115.0	3.21	192.4	14.19	3,088	415.0	11.57	694.2	0.20	44
120.0	3.35	200.7	12.61	2,744	420.0	11.71	702.5	0.19	41
125.0	3.48	209.1	11.04	2,402	425.0	11.85	710.9	0.18	39
130.0	3.62	217.5	9.99	2,174	430.0	11.99	719.3	0.17	37
135.0	3.76	225.8	9.04	1,967	435.0	12.13	727.6	0.16	35
140.0	3.90	234.2	8.20	1,784	440.0	12.27	736.0	0.15	33
145.0	4.04	242.5	7.36	1,602	445.0	12.41	744.4	0.15	33
150.0	4.18	250.9	6.78	1,475	450.0	12.55	752.7	0.13	28
155.0	4.32	259.3	6.20	1,349	455.0	12.68	761.1	0.12	26
160.0	4.46	267.6	5.83	1,269	460.0	12.82	769.4	0.12	26
165.0	4.60	276.0	5.47	1,190	465.0	12.96	777.8	0.11	24
170.0	4.74	284.4	5.15	1,121	470.0	13.10	786.2		
175.0	4.88	292.7	4.84	1,053	475.0	13.24	794.5		
180.0	5.02	301.1	4.57	994	480.0	13.38	802.9		
185.0	5.16	309.5	4.31	938	485.0	13.52	811.3		
190.0	5.30	317.8	4.10	892	490.0	13.66	819.6		
195.0	5.44	326.2	3.87	842	495.0	13.80	828.0		
200.0	5.58	334.5	3.68	801	500.0	13.94	836.4		
205.0	5.72	342.9	3.47	755	505.0	14.08	844.7		
210.0	5.85	351.3	3.28	714	510.0	14.22	853.1		
215.0	5.99	359.6	3.10	675	515.0	14.36	861.4		
220.0	6.13	368.0	2.93	638	520.0	14.50	869.8		
225.0	6.27	376.4	2.75	598	525.0	14.64	878.2		
230.0	6.41	384.7	2.63	572	530.0	14.78	886.5		
235.0	6.55	393.1	2.47	537	535.0	14.91	894.9		
240.0	6.69	401.5	2.33	507	540.0	15.05	903.3		
245.0	6.83	409.8	2.22	483	545.0	15.19	911.6		
250.0	6.97	418.2	2.10	457	550.0	15.33	920.0		
255.0	7.11	426.5	1.99	433	555.0	15.47	928.4		
260.0	7.25	434.9	1.88	409	560.0	15.61	936.7		
265.0	7.39	443.3	1.78	387	565.0	15.75	945.1		
270.0	7.53	451.6	1.68	366	570.0	15.89	953.4		
275.0	7.67	460.0	1.59	346	575.0	16.03	961.8		
280.0	7.81	468.4	1.50	326	580.0	16.17	970.2		
285.0	7.95	476.7	1.43	311	585.0	16.31	978.5		
290.0	8.08	485.1	1.36	296	590.0	16.45	986.9		
295.0	8.22	493.4	1.28	279	595.0	16.59	995.3		
300.0	8.36	501.8	1.21	263	600.0	16.73	1003.6		

NOTES : Use for models including the Crescent Wash Basin for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

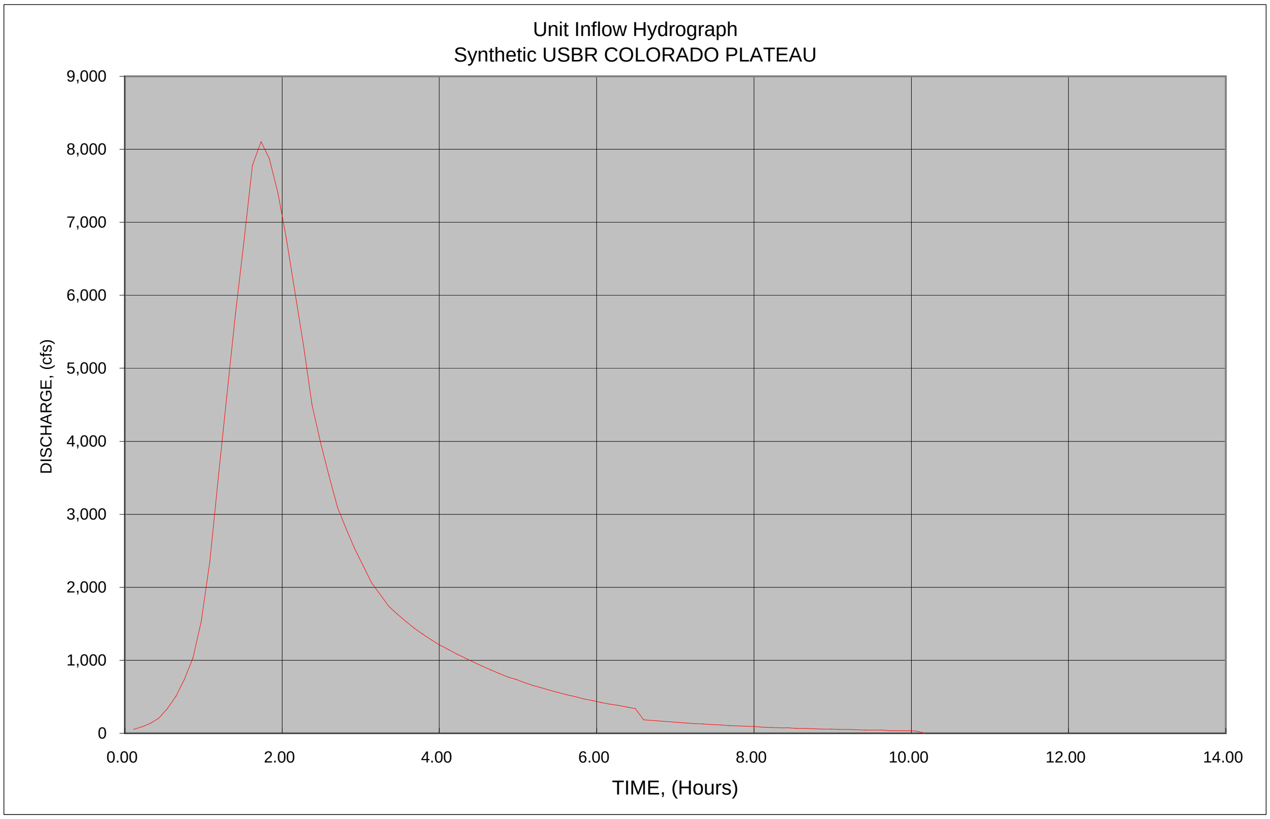
Crescent Wash-PMP Existing Conditions

Drainage Area = 22.56 sq. miles
Basin Slope = 209 ft./mile
L = 13.56 mi., Length of Watercourse
Lca = 7.07 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 2.16 Hours
Basin Factor = 6.63
V' = 606.64 cfs/Day
Qs = 280.4 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 2.04 Hours
Unit Duration, D = 22.24 minutes
Calculated Timestep = 6.49 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



UI Record - Unit Graph 5 **minute interval**

UI	41	73	104	140	197	289	405	545	722	944
UI	1269	1734	2374	3281	4140	4990	5840	6589	7394	7912
UI	8064	7883	7530	7096	6590	6022	5454	4852	4329	3930
UI	3589	3250	2972	2750	2545	2363	2181	2019	1894	1769
UI	1678	1599	1523	1454	1386	1324	1266	1210	1165	1116
UI	1070	1029	983	941	901	863	826	787	756	728
UI	693	663	637	612	587	563	539	516	495	473
UI	454	434	416	401	386	369	353	338	325	310
UI	296	284	273	260	248	238	230	221	212	203
UI	193	186	180	172	164	157	151	144	138	132
UI	127	121	116	112	107	103	99	95	93	86
UI	81	78	76	73	70	66	64	62	60	58
UI	56	53	51	49	47	45	43	42	40	36
UI	34	34	32	24	0					

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USBR calculated unitgraph peak = 8106 Interpolated Peak = 8064

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.11	6.5	0.19	53	305.0	6.60	396.0	0.66	185
10.0	0.22	13.0	0.32	90	310.0	6.71	402.4	0.63	177
15.0	0.32	19.5	0.48	135	315.0	6.82	408.9	0.59	165
20.0	0.43	26.0	0.74	207	320.0	6.92	415.4	0.56	157
25.0	0.54	32.5	1.21	339	325.0	7.03	421.9	0.53	149
30.0	0.65	38.9	1.81	507	330.0	7.14	428.4	0.50	140
35.0	0.76	45.4	2.63	737	335.0	7.25	434.9	0.47	132
40.0	0.87	51.9	3.68	1,032	340.0	7.36	441.4	0.45	126
45.0	0.97	58.4	5.47	1,534	345.0	7.46	447.9	0.42	118
50.0	1.08	64.9	8.41	2,358	350.0	7.57	454.4	0.40	112
55.0	1.19	71.4	12.61	3,535	355.0	7.68	460.9	0.38	107
60.0	1.30	77.9	16.50	4,626	360.0	7.79	467.4	0.36	101
65.0	1.41	84.4	20.50	5,748	365.0	7.90	473.8	0.34	95
70.0	1.51	90.9	23.97	6,720	370.0	8.01	480.3	0.33	93
75.0	1.62	97.4	27.75	7,780	375.0	8.11	486.8	0.30	84
80.0	1.73	103.9	28.91	8,106	380.0	8.22	493.3	0.28	79
85.0	1.84	110.3	28.07	7,870	385.0	8.33	499.8	0.27	76
90.0	1.95	116.8	26.38	7,396	390.0	8.44	506.3	0.26	73
95.0	2.06	123.3	24.18	6,779	395.0	8.55	512.8	0.24	67
100.0	2.16	129.8	21.55	6,042	400.0	8.65	519.3	0.23	64
105.0	2.27	136.3	18.92	5,305	405.0	8.76	525.8	0.22	62
110.0	2.38	142.8	16.08	4,508	410.0	8.87	532.3	0.21	59
115.0	2.49	149.3	14.19	3,978	415.0	8.98	538.8	0.20	56
120.0	2.60	155.8	12.61	3,535	420.0	9.09	545.3	0.19	53
125.0	2.70	162.3	11.04	3,095	425.0	9.20	551.7	0.18	50
130.0	2.81	168.8	9.99	2,801	430.0	9.30	558.2	0.17	48
135.0	2.92	175.3	9.04	2,535	435.0	9.41	564.7	0.16	45
140.0	3.03	181.8	8.20	2,299	440.0	9.52	571.2	0.15	42
145.0	3.14	188.2	7.36	2,064	445.0	9.63	577.7	0.15	42
150.0	3.25	194.7	6.78	1,901	450.0	9.74	584.2	0.13	36
155.0	3.35	201.2	6.20	1,738	455.0	9.84	590.7	0.12	34
160.0	3.46	207.7	5.83	1,635	460.0	9.95	597.2	0.12	34
165.0	3.57	214.2	5.47	1,534	465.0	10.06	603.7	0.11	31
170.0	3.68	220.7	5.15	1,444	470.0	10.17	610.2		
175.0	3.79	227.2	4.84	1,357	475.0	10.28	616.7		
180.0	3.89	233.7	4.57	1,281	480.0	10.39	623.1		
185.0	4.00	240.2	4.31	1,208	485.0	10.49	629.6		
190.0	4.11	246.7	4.10	1,150	490.0	10.60	636.1		
195.0	4.22	253.2	3.87	1,085	495.0	10.71	642.6		
200.0	4.33	259.6	3.68	1,032	500.0	10.82	649.1		
205.0	4.44	266.1	3.47	973	505.0	10.93	655.6		
210.0	4.54	272.6	3.28	920	510.0	11.03	662.1		
215.0	4.65	279.1	3.10	869	515.0	11.14	668.6		
220.0	4.76	285.6	2.93	821	520.0	11.25	675.1		
225.0	4.87	292.1	2.75	771	525.0	11.36	681.6		
230.0	4.98	298.6	2.63	737	530.0	11.47	688.1		
235.0	5.08	305.1	2.47	693	535.0	11.58	694.5		
240.0	5.19	311.6	2.33	653	540.0	11.68	701.0		
245.0	5.30	318.1	2.22	622	545.0	11.79	707.5		
250.0	5.41	324.6	2.10	589	550.0	11.90	714.0		
255.0	5.52	331.0	1.99	558	555.0	12.01	720.5		
260.0	5.63	337.5	1.88	527	560.0	12.12	727.0		
265.0	5.73	344.0	1.78	499	565.0	12.22	733.5		
270.0	5.84	350.5	1.68	471	570.0	12.33	740.0		
275.0	5.95	357.0	1.59	446	575.0	12.44	746.5		
280.0	6.06	363.5	1.50	421	580.0	12.55	753.0		
285.0	6.17	370.0	1.43	401	585.0	12.66	759.5		
290.0	6.27	376.5	1.36	381	590.0	12.77	765.9		
295.0	6.38	383.0	1.28	359	595.0	12.87	772.4		
300.0	6.49	389.5	1.21	339	600.0	12.98	778.9		

NOTES : Use for models including the Crescent Wash Basin for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin 1-10, 25, 100, 200 Existing Conditions

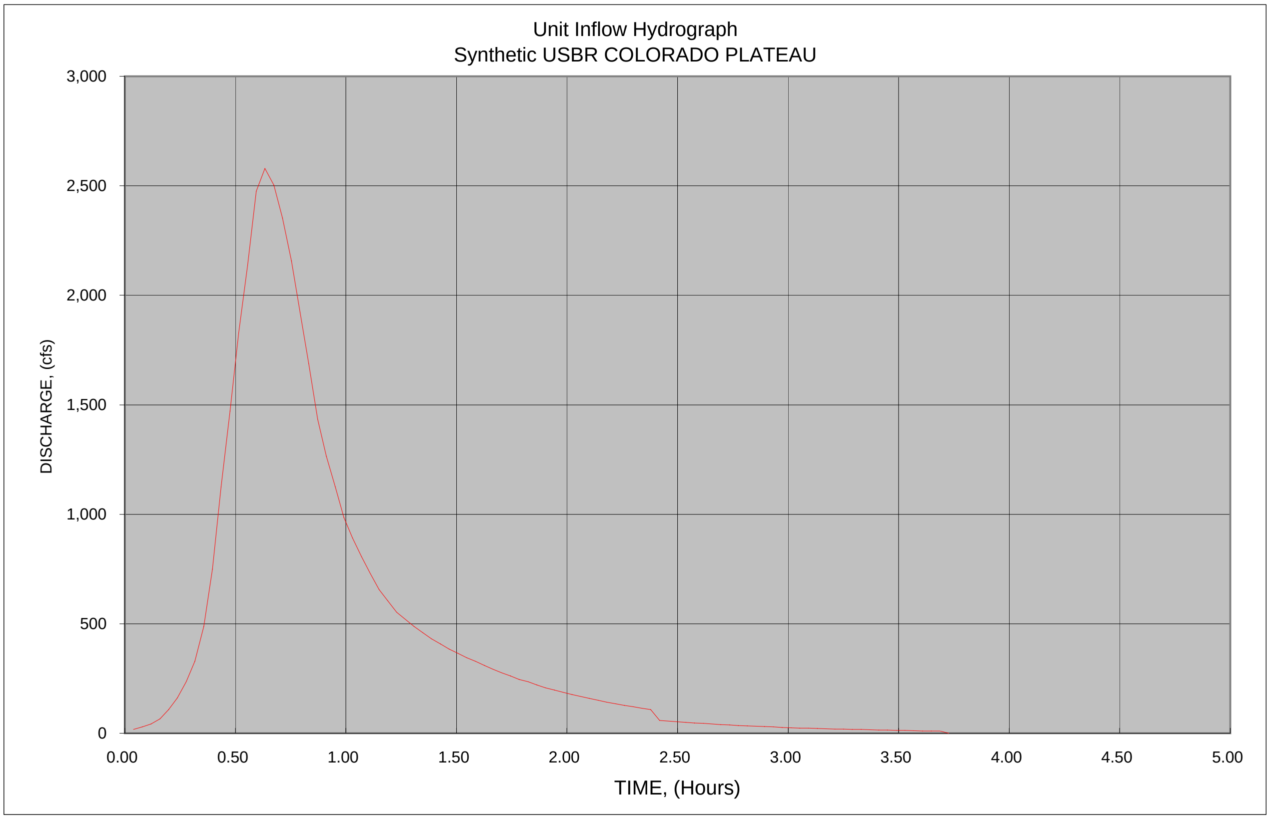
Drainage Area = 2.63 sq. miles
Basin Slope = 356 ft./mile
L = 2.92 mi., Length of Watercourse
Lca = 0.87 mi., Distance to Centroid
Kn = 0.056 -, Ave. Weighted Manning's n

Lg+D/2 = 0.79 Hours
Basin Factor = 0.13
V' = 70.72 cfs/Day
Qs = 89.2 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.75 Hours
Unit Duration, D = 8.20 minutes
Calculated Timestep = 2.38 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	30	75	184	393	941	1690	2378	2517	2173	1683
UI	1249	964	782	634	536	470	414	369	329	292
UI	259	231	204	183	163	145	129	115	103	91
UI	80	72	64	58	51	45	41	36	32	29
UI	25	23	20	18	16	15	13	11	10	
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USBR calculated unitgraph peak = 2578 Interpolated Peak = 2517

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.4	0.19	17	305.0	2.42	145.1	0.66	59
10.0	0.08	4.8	0.32	29	310.0	2.46	147.5	0.63	56
15.0	0.12	7.1	0.48	43	315.0	2.50	149.9	0.59	53
20.0	0.16	9.5	0.74	66	320.0	2.54	152.2	0.56	50
25.0	0.20	11.9	1.21	108	325.0	2.58	154.6	0.53	47
30.0	0.24	14.3	1.81	161	330.0	2.62	157.0	0.50	45
35.0	0.28	16.7	2.63	235	335.0	2.66	159.4	0.47	42
40.0	0.32	19.0	3.68	328	340.0	2.70	161.8	0.45	40
45.0	0.36	21.4	5.47	488	345.0	2.74	164.1	0.42	37
50.0	0.40	23.8	8.41	750	350.0	2.78	166.5	0.40	36
55.0	0.44	26.2	12.61	1,125	355.0	2.81	168.9	0.38	34
60.0	0.48	28.5	16.50	1,472	360.0	2.85	171.3	0.36	32
65.0	0.52	30.9	20.50	1,828	365.0	2.89	173.7	0.34	30
70.0	0.56	33.3	23.97	2,138	370.0	2.93	176.0	0.33	29
75.0	0.59	35.7	27.75	2,475	375.0	2.97	178.4	0.30	27
80.0	0.63	38.1	28.91	2,578	380.0	3.01	180.8	0.28	25
85.0	0.67	40.4	28.07	2,504	385.0	3.05	183.2	0.27	24
90.0	0.71	42.8	26.38	2,353	390.0	3.09	185.5	0.26	23
95.0	0.75	45.2	24.18	2,157	395.0	3.13	187.9	0.24	21
100.0	0.79	47.6	21.55	1,922	400.0	3.17	190.3	0.23	21
105.0	0.83	50.0	18.92	1,687	405.0	3.21	192.7	0.22	20
110.0	0.87	52.3	16.08	1,434	410.0	3.25	195.1	0.21	19
115.0	0.91	54.7	14.19	1,266	415.0	3.29	197.4	0.20	18
120.0	0.95	57.1	12.61	1,125	420.0	3.33	199.8	0.19	17
125.0	0.99	59.5	11.04	985	425.0	3.37	202.2	0.18	16
130.0	1.03	61.8	9.99	891	430.0	3.41	204.6	0.17	15
135.0	1.07	64.2	9.04	806	435.0	3.45	207.0	0.16	14
140.0	1.11	66.6	8.20	731	440.0	3.49	209.3	0.15	13
145.0	1.15	69.0	7.36	656	445.0	3.53	211.7	0.15	13
150.0	1.19	71.4	6.78	605	450.0	3.57	214.1	0.13	12
155.0	1.23	73.7	6.20	553	455.0	3.61	216.5	0.12	11
160.0	1.27	76.1	5.83	520	460.0	3.65	218.8	0.12	11
165.0	1.31	78.5	5.47	488	465.0	3.69	221.2	0.11	10
170.0	1.35	80.9	5.15	459	470.0	3.73	223.6		
175.0	1.39	83.3	4.84	432	475.0	3.77	226.0		
180.0	1.43	85.6	4.57	408	480.0	3.81	228.4		
185.0	1.47	88.0	4.31	384	485.0	3.85	230.7		
190.0	1.51	90.4	4.10	366	490.0	3.89	233.1		
195.0	1.55	92.8	3.87	345	495.0	3.92	235.5		
200.0	1.59	95.2	3.68	328	500.0	3.96	237.9		
205.0	1.63	97.5	3.47	309	505.0	4.00	240.3		
210.0	1.67	99.9	3.28	293	510.0	4.04	242.6		
215.0	1.70	102.3	3.10	276	515.0	4.08	245.0		
220.0	1.74	104.7	2.93	261	520.0	4.12	247.4		
225.0	1.78	107.0	2.75	245	525.0	4.16	249.8		
230.0	1.82	109.4	2.63	235	530.0	4.20	252.2		
235.0	1.86	111.8	2.47	220	535.0	4.24	254.5		
240.0	1.90	114.2	2.33	208	540.0	4.28	256.9		
245.0	1.94	116.6	2.22	198	545.0	4.32	259.3		
250.0	1.98	118.9	2.10	187	550.0	4.36	261.7		
255.0	2.02	121.3	1.99	177	555.0	4.40	264.0		
260.0	2.06	123.7	1.88	168	560.0	4.44	266.4		
265.0	2.10	126.1	1.78	159	565.0	4.48	268.8		
270.0	2.14	128.5	1.68	150	570.0	4.52	271.2		
275.0	2.18	130.8	1.59	142	575.0	4.56	273.6		
280.0	2.22	133.2	1.50	134	580.0	4.60	275.9		
285.0	2.26	135.6	1.43	128	585.0	4.64	278.3		
290.0	2.30	138.0	1.36	121	590.0	4.68	280.7		
295.0	2.34	140.3	1.28	114	595.0	4.72	283.1		
300.0	2.38	142.7	1.21	108	600.0	4.76	285.5		

NOTES : Use for models including Basin 1 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

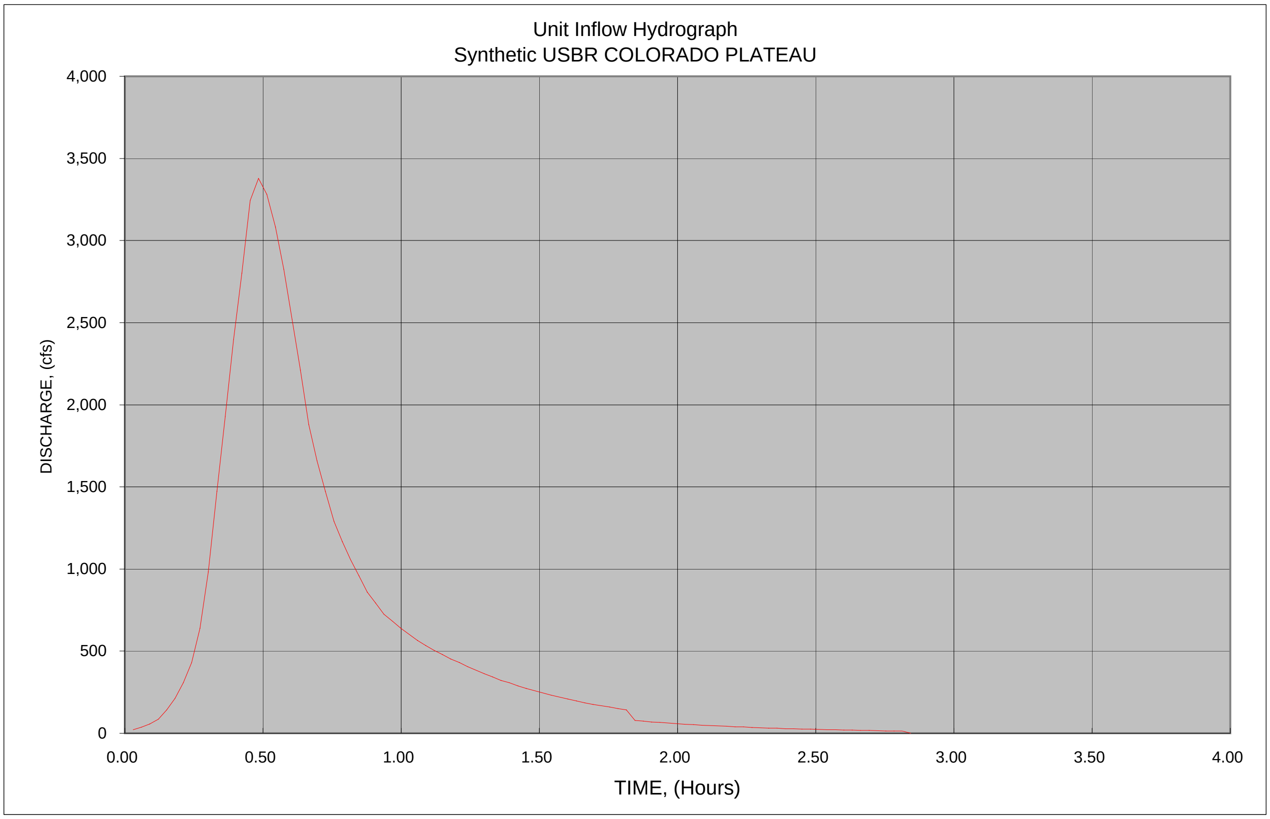
Basin 1-PMP Existing Conditions

Drainage Area = 2.63 sq. miles
Basin Slope = 356 ft./mile
L = 2.92 mi., Length of Watercourse
Lca = 0.87 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.61 Hours
Basin Factor = 0.13
V' = 70.72 cfs/Day
Qs = 116.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.56 Hours
Unit Duration, D = 6.15 minutes
Calculated Timestep = 1.82 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	52	177	485	1482	2709	3327	2740	1872	1329	1003
UI	772	637	540	464	399	341	292	251	216	185
UI	160	137	117	100	87	75	64	55	47	41
UI	34	30	26	23	19	17	14			
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USBR calculated unitgraph peak = 3379 Interpolated Peak = 3327

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.8	0.19	22
10.0	0.06	3.6	0.32	37
15.0	0.09	5.4	0.48	56
20.0	0.12	7.3	0.74	86
25.0	0.15	9.1	1.21	141
30.9	0.18	10.9	1.81	212
35.0	0.21	12.7	2.63	307
40.0	0.24	14.5	3.68	430
45.0	0.27	16.3	5.47	639
50.0	0.30	18.2	8.41	983
55.0	0.33	20.0	12.61	1,474
60.0	0.36	21.8	16.50	1,928
65.0	0.39	23.6	20.50	2,396
70.0	0.42	25.4	23.97	2,801
75.0	0.45	27.2	27.75	3,243
80.0	0.48	29.0	28.91	3,379
85.0	0.51	30.9	28.07	3,281
90.0	0.54	32.7	26.38	3,083
95.0	0.57	34.5	24.18	2,826
100.0	0.61	36.3	21.55	2,519
105.0	0.64	38.1	18.92	2,211
110.0	0.67	39.9	16.08	1,879
115.0	0.70	41.8	14.19	1,658
120.0	0.73	43.6	12.61	1,474
125.0	0.76	45.4	11.04	1,290
130.0	0.79	47.2	9.99	1,168
135.0	0.82	49.0	9.04	1,057
140.0	0.85	50.8	8.20	958
145.0	0.88	52.6	7.36	860
150.0	0.91	54.5	6.78	792
155.0	0.94	56.3	6.20	725
160.0	0.97	58.1	5.83	681
165.0	1.00	59.9	5.47	639
170.0	1.03	61.7	5.15	602
175.0	1.06	63.5	4.84	566
180.0	1.09	65.4	4.57	534
185.0	1.12	67.2	4.31	504
190.0	1.15	69.0	4.10	479
195.0	1.18	70.8	3.87	452
200.0	1.21	72.6	3.68	430
205.0	1.24	74.4	3.47	406
210.0	1.27	76.2	3.28	383
215.0	1.30	78.1	3.10	362
220.0	1.33	79.9	2.93	342
225.0	1.36	81.7	2.75	321
230.0	1.39	83.5	2.63	307
235.0	1.42	85.3	2.47	289
240.0	1.45	87.1	2.33	272
245.0	1.48	89.0	2.22	259
250.0	1.51	90.8	2.10	245
255.0	1.54	92.6	1.99	233
260.0	1.57	94.4	1.88	220
265.0	1.60	96.2	1.78	208
270.0	1.63	98.0	1.68	196
275.0	1.66	99.8	1.59	186
280.0	1.69	101.7	1.50	175
285.0	1.72	103.5	1.43	167
290.0	1.75	105.3	1.36	159
295.0	1.79	107.1	1.28	150
300.0	1.82	108.9	1.21	141
305.0	1.85	110.7	0.66	77
310.0	1.88	112.6	0.63	74
315.0	1.91	114.4	0.59	69
320.0	1.94	116.2	0.56	65
325.0	1.97	118.0	0.53	62
330.0	2.00	119.8	0.50	58
335.0	2.03	121.6	0.47	55
340.0	2.06	123.4	0.45	53
345.0	2.09	125.3	0.42	49
350.0	2.12	127.1	0.40	47
355.0	2.15	128.9	0.38	44
360.0	2.18	130.7	0.36	42
365.0	2.21	132.5	0.34	40
370.0	2.24	134.3	0.33	39
375.0	2.27	136.1	0.30	35
380.0	2.30	138.0	0.28	33
385.0	2.33	139.8	0.27	32
390.0	2.36	141.6	0.26	30
395.0	2.39	143.4	0.24	28
400.0	2.42	145.2	0.23	27
405.0	2.45	147.0	0.22	26
410.0	2.48	148.9	0.21	25
415.0	2.51	150.7	0.20	23
420.0	2.54	152.5	0.19	22
425.0	2.57	154.3	0.18	21
430.0	2.60	156.1	0.17	20
435.0	2.63	157.9	0.16	19
440.0	2.66	159.7	0.15	18
445.0	2.69	161.6	0.15	18
450.0	2.72	163.4	0.13	15
455.0	2.75	165.2	0.12	14
460.0	2.78	167.0	0.12	14
465.0	2.81	168.8	0.11	13
470.0	2.84	170.6		
475.0	2.87	172.5		
480.0	2.90	174.3		
485.0	2.93	176.1		
490.0	2.97	177.9		
495.0	3.00	179.7		
500.0	3.03	181.5		
505.0	3.06	183.3		
510.0	3.09	185.2		
515.0	3.12	187.0		
520.0	3.15	188.8		
525.0	3.18	190.6		
530.0	3.21	192.4		
535.0	3.24	194.2		
540.0	3.27	196.1		
545.0	3.30	197.9		
550.0	3.33	199.7		
555.0	3.36	201.5		
560.0	3.39	203.3		
565.0	3.42	205.1		
570.0	3.45	206.9		
575.0	3.48	208.8		
580.0	3.51	210.6		
585.0	3.54	212.4		
590.0	3.57	214.2		
595.0	3.60	216.0		
600.0	3.63	217.8		

NOTES : Use for models including Basin 1 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

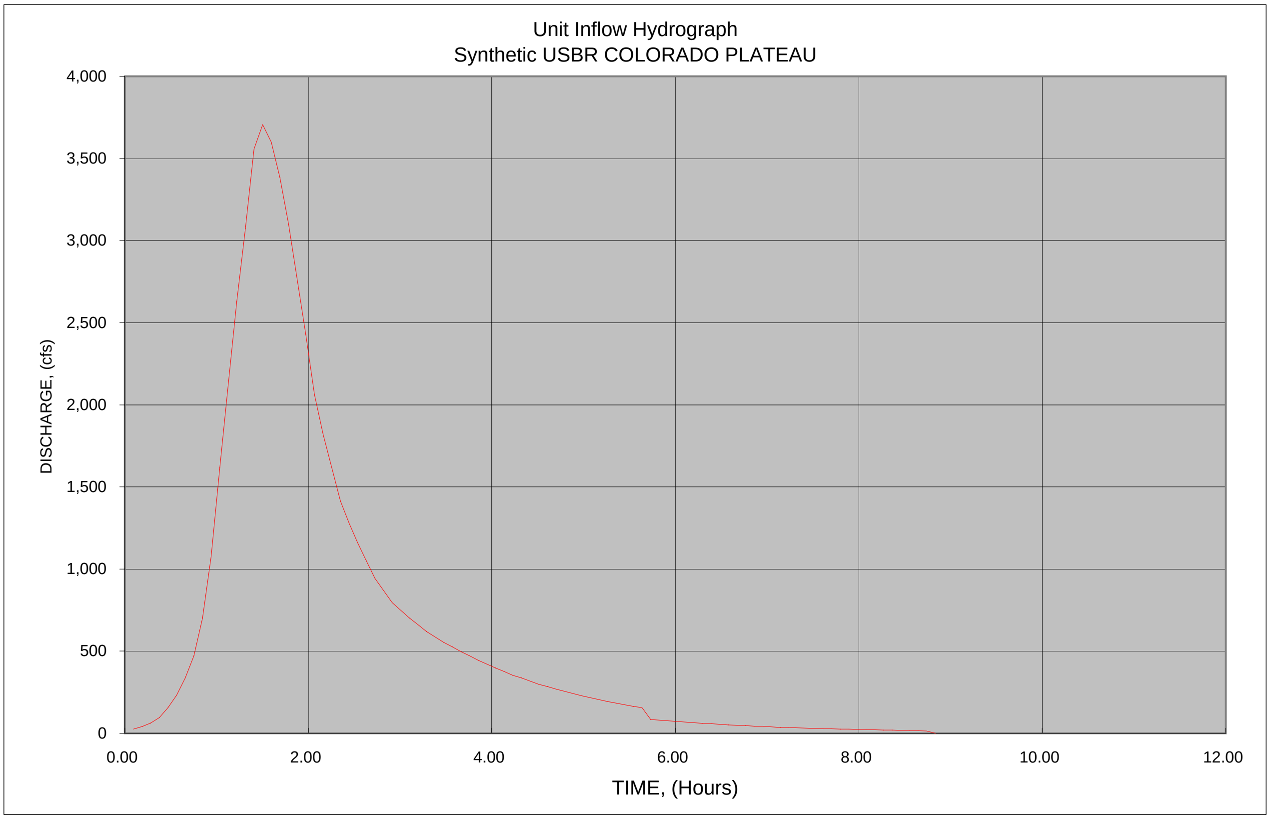
Basin 2-10, 25, 100, 200 Existing Conditions

Drainage Area = 8.96 sq. miles
Basin Slope = 283 ft./mile
L = 7.67 mi., Length of Watercourse
Lca = 4.31 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 1.88 Hours
Basin Factor = 1.97
V' = 240.93 cfs/Day
Qs = 128.2 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 1.75 Hours
Unit Duration, D = 19.14 minutes
Calculated Timestep = 5.64 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



UI Record - Unit Graph 5 **minute interval**

UI	22	37	55	80	121	180	254	350	469	671
UI	985	1423	1879	2327	2761	3163	3568	3700	3615	3439
UI	3206	2928	2629	2323	2021	1808	1628	1450	1319	1207
UI	1106	1011	924	858	793	751	710	673	637	604
UI	574	546	522	496	474	450	428	407	388	368
UI	349	335	317	301	288	274	262	249	237	226
UI	214	204	194	186	178	169	160	153	146	138
UI	131	125	119	113	108	103	99	94	88	85
UI	81	77	73	70	67	63	60	58	54	52
UI	50	47	45	43	41	38	36	35	34	32
UI	30	29	28	27	26	24	23	22	21	20
UI	19	18	16	15	15	14	4			
UI										
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USBR calculated unitgraph peak = 3706 Interpolated Peak = 3700

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.09	5.6	0.19	24	305.0	5.73	344.0	0.66	85
10.0	0.19	11.3	0.32	41	310.0	5.83	349.6	0.63	81
15.0	0.28	16.9	0.48	62	315.0	5.92	355.2	0.59	76
20.0	0.38	22.6	0.74	95	320.0	6.01	360.9	0.56	72
25.0	0.47	28.2	1.21	155	325.0	6.11	366.5	0.53	68
30.0	0.56	33.8	1.81	232	330.0	6.20	372.2	0.50	64
35.0	0.66	39.5	2.63	337	335.0	6.30	377.8	0.47	60
40.0	0.75	45.1	3.68	472	340.0	6.39	383.4	0.45	58
45.0	0.85	50.7	5.47	701	345.0	6.48	389.1	0.42	54
50.0	0.94	56.4	8.41	1,078	350.0	6.58	394.7	0.40	51
55.0	1.03	62.0	12.61	1,616	355.0	6.67	400.4	0.38	49
60.0	1.13	67.7	16.50	2,115	360.0	6.77	406.0	0.36	46
65.0	1.22	73.3	20.50	2,628	365.0	6.86	411.6	0.34	44
70.0	1.32	78.9	23.97	3,073	370.0	6.95	417.3	0.33	42
75.0	1.41	84.6	27.75	3,557	375.0	7.05	422.9	0.30	38
80.0	1.50	90.2	28.91	3,706	380.0	7.14	428.6	0.28	36
85.0	1.60	95.9	28.07	3,598	385.0	7.24	434.2	0.27	35
90.0	1.69	101.5	26.38	3,381	390.0	7.33	439.8	0.26	33
95.0	1.79	107.1	24.18	3,099	395.0	7.42	445.5	0.24	31
100.0	1.88	112.8	21.55	2,762	400.0	7.52	451.1	0.23	29
105.0	1.97	118.4	18.92	2,425	405.0	7.61	456.7	0.22	28
110.0	2.07	124.1	16.08	2,061	410.0	7.71	462.4	0.21	27
115.0	2.16	129.7	14.19	1,819	415.0	7.80	468.0	0.20	26
120.0	2.26	135.3	12.61	1,616	420.0	7.89	473.7	0.19	24
125.0	2.35	141.0	11.04	1,415	425.0	7.99	479.3	0.18	23
130.0	2.44	146.6	9.99	1,281	430.0	8.08	484.9	0.17	22
135.0	2.54	152.2	9.04	1,159	435.0	8.18	490.6	0.16	21
140.0	2.63	157.9	8.20	1,051	440.0	8.27	496.2	0.15	19
145.0	2.73	163.5	7.36	943	445.0	8.36	501.9	0.15	19
150.0	2.82	169.2	6.78	869	450.0	8.46	507.5	0.13	17
155.0	2.91	174.8	6.20	795	455.0	8.55	513.1	0.12	15
160.0	3.01	180.4	5.83	747	460.0	8.65	518.8	0.12	15
165.0	3.10	186.1	5.47	701	465.0	8.74	524.4	0.11	14
170.0	3.20	191.7	5.15	660	470.0	8.83	530.1		
175.0	3.29	197.4	4.84	620	475.0	8.93	535.7		
180.0	3.38	203.0	4.57	586	480.0	9.02	541.3		
185.0	3.48	208.6	4.31	552	485.0	9.12	547.0		
190.0	3.57	214.3	4.10	526	490.0	9.21	552.6		
195.0	3.67	219.9	3.87	496	495.0	9.30	558.2		
200.0	3.76	225.6	3.68	472	500.0	9.40	563.9		
205.0	3.85	231.2	3.47	445	505.0	9.49	569.5		
210.0	3.95	236.8	3.28	420	510.0	9.59	575.2		
215.0	4.04	242.5	3.10	397	515.0	9.68	580.8		
220.0	4.14	248.1	2.93	376	520.0	9.77	586.4		
225.0	4.23	253.7	2.75	353	525.0	9.87	592.1		
230.0	4.32	259.4	2.63	337	530.0	9.96	597.7		
235.0	4.42	265.0	2.47	317	535.0	10.06	603.4		
240.0	4.51	270.7	2.33	299	540.0	10.15	609.0		
245.0	4.61	276.3	2.22	285	545.0	10.24	614.6		
250.0	4.70	281.9	2.10	269	550.0	10.34	620.3		
255.0	4.79	287.6	1.99	255	555.0	10.43	625.9		
260.0	4.89	293.2	1.88	241	560.0	10.53	631.6		
265.0	4.98	298.9	1.78	228	565.0	10.62	637.2		
270.0	5.07	304.5	1.68	215	570.0	10.71	642.8		
275.0	5.17	310.1	1.59	204	575.0	10.81	648.5		
280.0	5.26	315.8	1.50	192	580.0	10.90	654.1		
285.0	5.36	321.4	1.43	183	585.0	11.00	659.7		
290.0	5.45	327.1	1.36	174	590.0	11.09	665.4		
295.0	5.54	332.7	1.28	164	595.0	11.18	671.0		
300.0	5.64	338.3	1.21	155	600.0	11.28	676.7		

NOTES : Use for models including Basin 2 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Basin 2-PMP Existing Conditions

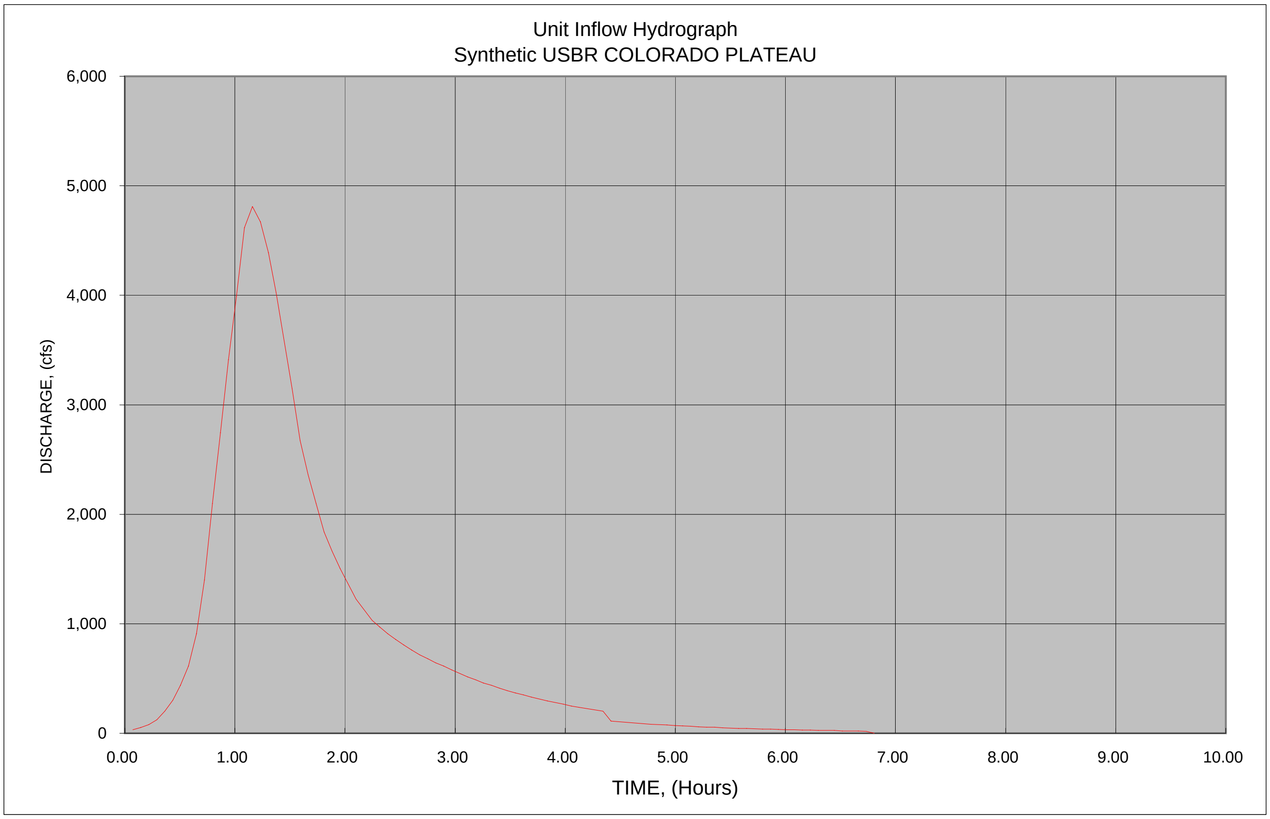
Drainage Area = 8.96 sq. miles
Basin Slope = 283 ft./mile
L = 7.67 mi., Length of Watercourse
Lca = 4.31 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 1.45 Hours
Basin Factor = 1.97
V' = 240.93 cfs/Day
Qs = 166.4 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 1.36 Hours
Unit Duration, D = 14.89 minutes
Calculated Timestep = 4.34 minutes

Data to be used in Analysis
Unit Duration, D = 10 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



UI Record - Unit Graph 5 **minute interval**

UI	35	61	99	170	277	425	629	1012	1650	2428
UI	3185	3880	4594	4794	4596	4237	3775	3272	2738	2356
UI	2054	1781	1587	1417	1256	1135	1027	956	890	830
UI	775	724	683	640	602	564	528	495	461	437
UI	407	381	360	338	317	297	278	261	245	232
UI	217	203	191	178	167	157	146	138	130	123
UI	114	108	101	95	89	83	78	74	68	65
UI	61	57	55	49	46	44	41	39	37	35
UI	33	31	29	27	25	25	21	20	19	8
UI										
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USBR calculated unitgraph peak = 4810 Interpolated Peak = 4794

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.07	4.3	0.19	32
10.0	0.14	8.7	0.32	53
15.0	0.22	13.0	0.48	80
20.0	0.29	17.4	0.74	123
25.0	0.36	21.7	1.21	201
30.0	0.43	26.1	1.81	301
35.0	0.51	30.4	2.63	438
40.0	0.58	34.8	3.68	612
45.0	0.65	39.1	5.47	910
50.0	0.72	43.4	8.41	1,399
55.0	0.80	47.8	12.61	2,098
60.0	0.87	52.1	16.50	2,745
65.0	0.94	56.5	20.50	3,411
70.0	1.01	60.8	23.97	3,988
75.0	1.09	65.2	27.75	4,617
80.0	1.16	69.5	28.91	4,810
85.0	1.23	73.8	28.07	4,670
90.0	1.30	78.2	26.38	4,389
95.0	1.38	82.5	24.18	4,023
100.0	1.45	86.9	21.55	3,586
105.0	1.52	91.2	18.92	3,148
110.0	1.59	95.6	16.08	2,676
115.0	1.67	99.9	14.19	2,361
120.0	1.74	104.3	12.61	2,098
125.0	1.81	108.6	11.04	1,837
130.0	1.88	112.9	9.99	1,662
135.0	1.95	117.3	9.04	1,504
140.0	2.03	121.6	8.20	1,364
145.0	2.10	126.0	7.36	1,225
150.0	2.17	130.3	6.78	1,128
155.0	2.24	134.7	6.20	1,032
160.0	2.32	139.0	5.83	970
165.0	2.39	143.4	5.47	910
170.0	2.46	147.7	5.15	857
175.0	2.53	152.0	4.84	805
180.0	2.61	156.4	4.57	760
185.0	2.68	160.7	4.31	717
190.0	2.75	165.1	4.10	682
195.0	2.82	169.4	3.87	644
200.0	2.90	173.8	3.68	612
205.0	2.97	178.1	3.47	577
210.0	3.04	182.5	3.28	546
215.0	3.11	186.8	3.10	516
220.0	3.19	191.1	2.93	488
225.0	3.26	195.5	2.75	458
230.0	3.33	199.8	2.63	438
235.0	3.40	204.2	2.47	411
240.0	3.48	208.5	2.33	388
245.0	3.55	212.9	2.22	369
250.0	3.62	217.2	2.10	349
255.0	3.69	221.5	1.99	331
260.0	3.76	225.9	1.88	313
265.0	3.84	230.2	1.78	296
270.0	3.91	234.6	1.68	280
275.0	3.98	238.9	1.59	265
280.0	4.05	243.3	1.50	250
285.0	4.13	247.6	1.43	238
290.0	4.20	252.0	1.36	226
295.0	4.27	256.3	1.28	213
300.0	4.34	260.6	1.21	201
305.0	4.42	265.0	0.66	110
310.0	4.49	269.3	0.63	105
315.0	4.56	273.7	0.59	98
320.0	4.63	278.0	0.56	93
325.0	4.71	282.4	0.53	88
330.0	4.78	286.7	0.50	83
335.0	4.85	291.1	0.47	78
340.0	4.92	295.4	0.45	75
345.0	5.00	299.7	0.42	70
350.0	5.07	304.1	0.40	67
355.0	5.14	308.4	0.38	63
360.0	5.21	312.8	0.36	60
365.0	5.29	317.1	0.34	57
370.0	5.36	321.5	0.33	55
375.0	5.43	325.8	0.30	50
380.0	5.50	330.2	0.28	47
385.0	5.57	334.5	0.27	45
390.0	5.65	338.8	0.26	43
395.0	5.72	343.2	0.24	40
400.0	5.79	347.5	0.23	38
405.0	5.86	351.9	0.22	37
410.0	5.94	356.2	0.21	35
415.0	6.01	360.6	0.20	33
420.0	6.08	364.9	0.19	32
425.0	6.15	369.2	0.18	30
430.0	6.23	373.6	0.17	28
435.0	6.30	377.9	0.16	27
440.0	6.37	382.3	0.15	25
445.0	6.44	386.6	0.15	25
450.0	6.52	391.0	0.13	22
455.0	6.59	395.3	0.12	20
460.0	6.66	399.7	0.12	20
465.0	6.73	404.0	0.11	18
470.0	6.81	408.3		
475.0	6.88	412.7		
480.0	6.95	417.0		
485.0	7.02	421.4		
490.0	7.10	425.7		
495.0	7.17	430.1		
500.0	7.24	434.4		
505.0	7.31	438.8		
510.0	7.38	443.1		
515.0	7.46	447.4		
520.0	7.53	451.8		
525.0	7.60	456.1		
530.0	7.67	460.5		
535.0	7.75	464.8		
540.0	7.82	469.2		
545.0	7.89	473.5		
550.0	7.96	477.9		
555.0	8.04	482.2		
560.0	8.11	486.5		
565.0	8.18	490.9		
570.0	8.25	495.2		
575.0	8.33	499.6		
580.0	8.40	503.9		
585.0	8.47	508.3		
590.0	8.54	512.6		
595.0	8.62	516.9		
600.0	8.69	521.3		

NOTES : Use for models including Basin 2 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Basin 3-10, 25, 100, 200 Existing Conditions

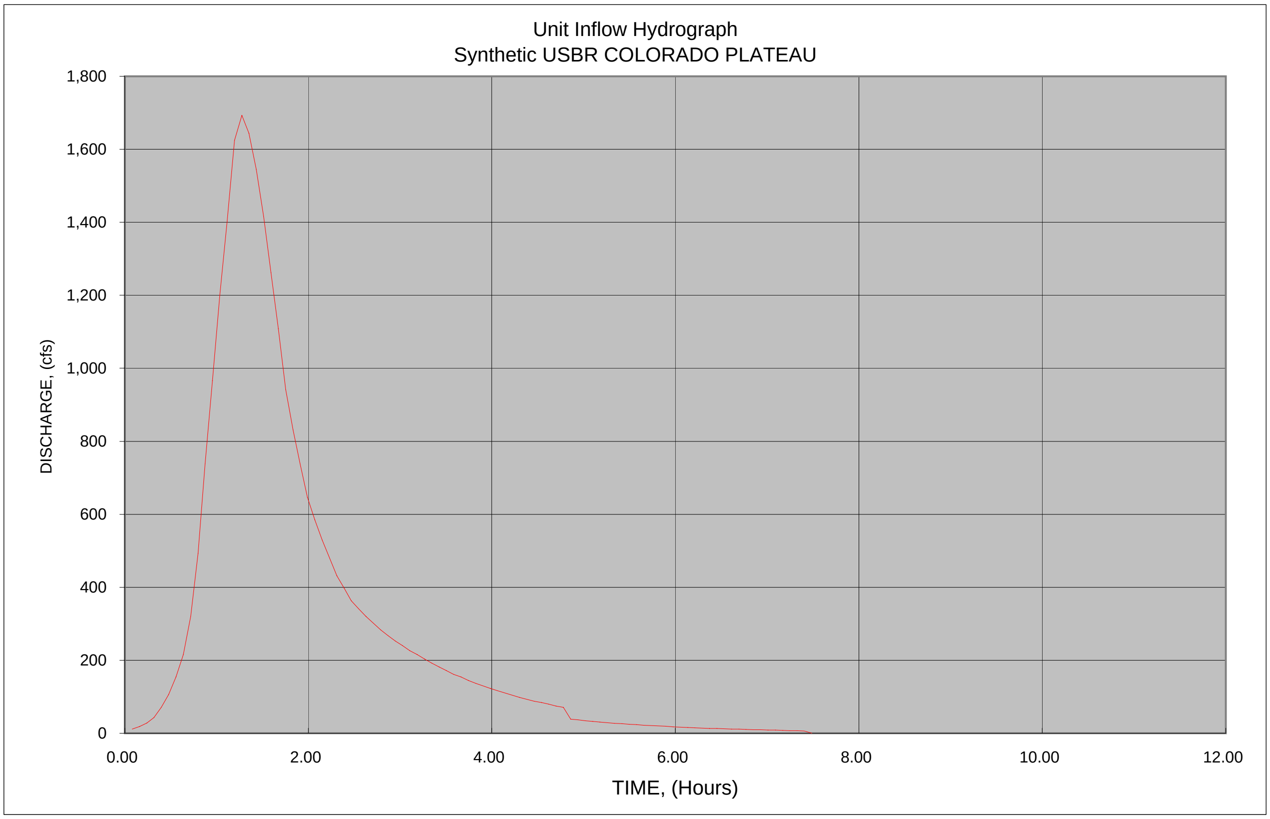
Drainage Area = 3.47 sq. miles
Basin Slope = 57.1 ft./mile
L = 4.73 mi., Length of Watercourse
Lca = 1.83 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 1.59 Hours
Basin Factor = 1.15
V' = 93.31 cfs/Day
Qs = 58.6 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 1.47 Hours
Unit Duration, D = 16.02 minutes
Calculated Timestep = 4.78 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



UI Record - Unit Graph 5 **minute interval**

UI	11	20	30	48	79	119	174	254	392	606
UI	854	1096	1322	1546	1672	1657	1566	1438	1281	1120
UI	947	830	733	640	577	520	468	421	386	355
UI	332	311	292	275	258	244	231	218	206	194
UI	183	172	161	154	144	136	129	122	115	108
UI	102	96	91	86	82	77	72	69	64	61
UI	57	54	51	48	46	43	40	38	36	34
UI	32	30	29	27	26	24	23	22	20	20
UI	18	17	16	15	14	13	13	12	12	11
UI	10	10	9	9	8	7	7	7	3	
UI										
UI										
UI										
UI										

UI
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USBR calculated unitgraph peak = 1693 Interpolated Peak = 1672

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.08	4.8	0.19	11	305.0	4.86	291.6	0.66	39
10.0	0.16	9.6	0.32	19	310.0	4.94	296.4	0.63	37
15.0	0.24	14.3	0.48	28	315.0	5.02	301.1	0.59	35
20.0	0.32	19.1	0.74	43	320.0	5.10	305.9	0.56	33
25.0	0.40	23.9	1.21	71	325.0	5.18	310.7	0.53	31
30.0	0.48	28.7	1.81	106	330.0	5.26	315.5	0.50	29
35.0	0.56	33.5	2.63	154	335.0	5.34	320.3	0.47	28
40.0	0.64	38.2	3.68	216	340.0	5.42	325.0	0.45	26
45.0	0.72	43.0	5.47	320	345.0	5.50	329.8	0.42	25
50.0	0.80	47.8	8.41	492	350.0	5.58	334.6	0.40	23
55.0	0.88	52.6	12.61	738	355.0	5.66	339.4	0.38	22
60.0	0.96	57.4	16.50	966	360.0	5.74	344.2	0.36	21
65.0	1.04	62.1	20.50	1,200	365.0	5.82	348.9	0.34	20
70.0	1.12	66.9	23.97	1,404	370.0	5.90	353.7	0.33	19
75.0	1.20	71.7	27.75	1,625	375.0	5.98	358.5	0.30	18
80.0	1.27	76.5	28.91	1,693	380.0	6.05	363.3	0.28	16
85.0	1.35	81.3	28.07	1,644	385.0	6.13	368.1	0.27	16
90.0	1.43	86.0	26.38	1,545	390.0	6.21	372.8	0.26	15
95.0	1.51	90.8	24.18	1,416	395.0	6.29	377.6	0.24	14
100.0	1.59	95.6	21.55	1,262	400.0	6.37	382.4	0.23	13
105.0	1.67	100.4	18.92	1,108	405.0	6.45	387.2	0.22	13
110.0	1.75	105.2	16.08	942	410.0	6.53	392.0	0.21	12
115.0	1.83	109.9	14.19	831	415.0	6.61	396.7	0.20	12
120.0	1.91	114.7	12.61	738	420.0	6.69	401.5	0.19	11
125.0	1.99	119.5	11.04	647	425.0	6.77	406.3	0.18	11
130.0	2.07	124.3	9.99	585	430.0	6.85	411.1	0.17	10
135.0	2.15	129.1	9.04	529	435.0	6.93	415.9	0.16	9
140.0	2.23	133.8	8.20	480	440.0	7.01	420.6	0.15	9
145.0	2.31	138.6	7.36	431	445.0	7.09	425.4	0.15	9
150.0	2.39	143.4	6.78	397	450.0	7.17	430.2	0.13	8
155.0	2.47	148.2	6.20	363	455.0	7.25	435.0	0.12	7
160.0	2.55	153.0	5.83	341	460.0	7.33	439.8	0.12	7
165.0	2.63	157.7	5.47	320	465.0	7.41	444.5	0.11	6
170.0	2.71	162.5	5.15	302	470.0	7.49	449.3		
175.0	2.79	167.3	4.84	283	475.0	7.57	454.1		
180.0	2.87	172.1	4.57	268	480.0	7.65	458.9		
185.0	2.95	176.9	4.31	252	485.0	7.73	463.7		
190.0	3.03	181.6	4.10	240	490.0	7.81	468.5		
195.0	3.11	186.4	3.87	227	495.0	7.89	473.2		
200.0	3.19	191.2	3.68	216	500.0	7.97	478.0		
205.0	3.27	196.0	3.47	203	505.0	8.05	482.8		
210.0	3.35	200.8	3.28	192	510.0	8.13	487.6		
215.0	3.43	205.5	3.10	182	515.0	8.21	492.4		
220.0	3.51	210.3	2.93	172	520.0	8.29	497.1		
225.0	3.59	215.1	2.75	161	525.0	8.37	501.9		
230.0	3.66	219.9	2.63	154	530.0	8.44	506.7		
235.0	3.74	224.7	2.47	145	535.0	8.52	511.5		
240.0	3.82	229.4	2.33	136	540.0	8.60	516.3		
245.0	3.90	234.2	2.22	130	545.0	8.68	521.0		
250.0	3.98	239.0	2.10	123	550.0	8.76	525.8		
255.0	4.06	243.8	1.99	117	555.0	8.84	530.6		
260.0	4.14	248.6	1.88	110	560.0	8.92	535.4		
265.0	4.22	253.3	1.78	104	565.0	9.00	540.2		
270.0	4.30	258.1	1.68	98	570.0	9.08	544.9		
275.0	4.38	262.9	1.59	93	575.0	9.16	549.7		
280.0	4.46	267.7	1.50	88	580.0	9.24	554.5		
285.0	4.54	272.5	1.43	84	585.0	9.32	559.3		
290.0	4.62	277.2	1.36	80	590.0	9.40	564.1		
295.0	4.70	282.0	1.28	75	595.0	9.48	568.8		
300.0	4.78	286.8	1.21	71	600.0	9.56	573.6		

NOTES : Use for models including Basin 3 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

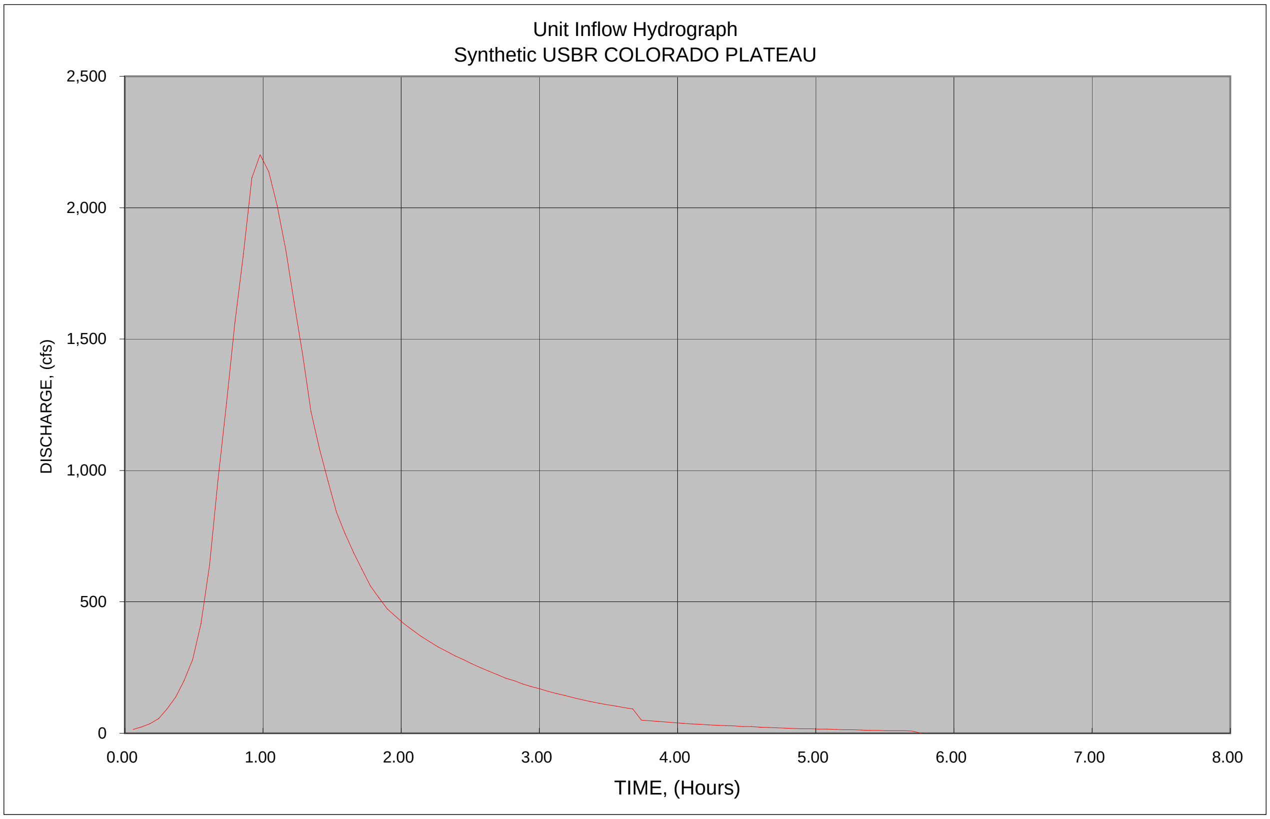
Basin 3-PMP Existing Conditions

Drainage Area = 3.47 sq. miles
Basin Slope = 57.1 ft./mile
L = 4.73 mi., Length of Watercourse
Lca = 1.83 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 1.23 Hours
Basin Factor = 1.15
V' = 93.31 cfs/Day
Qs = 76.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 1.14 Hours
Unit Duration, D = 12.46 minutes
Calculated Timestep = 3.68 minutes

Data to be used in Analysis
Unit Duration, D = 10 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



UI Record - Unit Graph 5 **minute interval**

UI	18	33	59	112	188	302	533	922	1330	1720
UI	2102	2181	2050	1833	1561	1276	1066	903	773	675
UI	588	520	464	426	392	361	334	311	288	267
UI	248	229	211	197	182	169	157	146	135	125
UI	116	108	101	93	86	80	74	68	64	59
UI	55	51	48	44	41	38	35	32	30	28
UI	26	24	22	21	19	18	17	16	15	14
UI	13	11	11	9	9	5				
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UI										
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USBR calculated unitgraph peak = 2201 Interpolated Peak = 2181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.06	3.7	0.19	14	305.0	3.74	224.2	0.66	50
10.0	0.12	7.4	0.32	24	310.0	3.80	227.9	0.63	48
15.0	0.18	11.0	0.48	37	315.0	3.86	231.6	0.59	45
20.0	0.25	14.7	0.74	56	320.0	3.92	235.3	0.56	43
25.0	0.31	18.4	1.21	92	325.0	3.98	239.0	0.53	40
30.0	0.37	22.1	1.81	138	330.0	4.04	242.6	0.50	38
35.0	0.43	25.7	2.63	200	335.0	4.11	246.3	0.47	36
40.0	0.49	29.4	3.68	280	340.0	4.17	250.0	0.45	34
45.0	0.55	33.1	5.47	417	345.0	4.23	253.7	0.42	32
50.0	0.61	36.8	8.41	640	350.0	4.29	257.3	0.40	30
55.0	0.67	40.4	12.61	960	355.0	4.35	261.0	0.38	29
60.0	0.74	44.1	16.50	1,256	360.0	4.41	264.7	0.36	27
65.0	0.80	47.8	20.50	1,561	365.0	4.47	268.4	0.34	26
70.0	0.86	51.5	23.97	1,825	370.0	4.53	272.0	0.33	25
75.0	0.92	55.1	27.75	2,113	375.0	4.60	275.7	0.30	23
80.0	0.98	58.8	28.91	2,201	380.0	4.66	279.4	0.28	21
85.0	1.04	62.5	28.07	2,137	385.0	4.72	283.1	0.27	21
90.0	1.10	66.2	26.38	2,009	390.0	4.78	286.7	0.26	20
95.0	1.16	69.8	24.18	1,841	395.0	4.84	290.4	0.24	18
100.0	1.23	73.5	21.55	1,641	400.0	4.90	294.1	0.23	18
105.0	1.29	77.2	18.92	1,441	405.0	4.96	297.8	0.22	17
110.0	1.35	80.9	16.08	1,224	410.0	5.02	301.4	0.21	16
115.0	1.41	84.6	14.19	1,081	415.0	5.09	305.1	0.20	15
120.0	1.47	88.2	12.61	960	420.0	5.15	308.8	0.19	14
125.0	1.53	91.9	11.04	841	425.0	5.21	312.5	0.18	14
130.0	1.59	95.6	9.99	761	430.0	5.27	316.2	0.17	13
135.0	1.65	99.3	9.04	688	435.0	5.33	319.8	0.16	12
140.0	1.72	102.9	8.20	624	440.0	5.39	323.5	0.15	11
145.0	1.78	106.6	7.36	560	445.0	5.45	327.2	0.15	11
150.0	1.84	110.3	6.78	516	450.0	5.51	330.9	0.13	10
155.0	1.90	114.0	6.20	472	455.0	5.58	334.5	0.12	9
160.0	1.96	117.6	5.83	444	460.0	5.64	338.2	0.12	9
165.0	2.02	121.3	5.47	417	465.0	5.70	341.9	0.11	8
170.0	2.08	125.0	5.15	392	470.0	5.76	345.6		
175.0	2.14	128.7	4.84	369	475.0	5.82	349.2		
180.0	2.21	132.3	4.57	348	480.0	5.88	352.9		
185.0	2.27	136.0	4.31	328	485.0	5.94	356.6		
190.0	2.33	139.7	4.10	312	490.0	6.00	360.3		
195.0	2.39	143.4	3.87	295	495.0	6.07	363.9		
200.0	2.45	147.0	3.68	280	500.0	6.13	367.6		
205.0	2.51	150.7	3.47	264	505.0	6.19	371.3		
210.0	2.57	154.4	3.28	250	510.0	6.25	375.0		
215.0	2.63	158.1	3.10	236	515.0	6.31	378.6		
220.0	2.70	161.8	2.93	223	520.0	6.37	382.3		
225.0	2.76	165.4	2.75	209	525.0	6.43	386.0		
230.0	2.82	169.1	2.63	200	530.0	6.49	389.7		
235.0	2.88	172.8	2.47	188	535.0	6.56	393.4		
240.0	2.94	176.5	2.33	177	540.0	6.62	397.0		
245.0	3.00	180.1	2.22	169	545.0	6.68	400.7		
250.0	3.06	183.8	2.10	160	550.0	6.74	404.4		
255.0	3.12	187.5	1.99	152	555.0	6.80	408.1		
260.0	3.19	191.2	1.88	143	560.0	6.86	411.7		
265.0	3.25	194.8	1.78	136	565.0	6.92	415.4		
270.0	3.31	198.5	1.68	128	570.0	6.98	419.1		
275.0	3.37	202.2	1.59	121	575.0	7.05	422.8		
280.0	3.43	205.9	1.50	114	580.0	7.11	426.4		
285.0	3.49	209.5	1.43	109	585.0	7.17	430.1		
290.0	3.55	213.2	1.36	104	590.0	7.23	433.8		
295.0	3.61	216.9	1.28	97	595.0	7.29	437.5		
300.0	3.68	220.6	1.21	92	600.0	7.35	441.1		

NOTES : Use for models including Basin 3 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

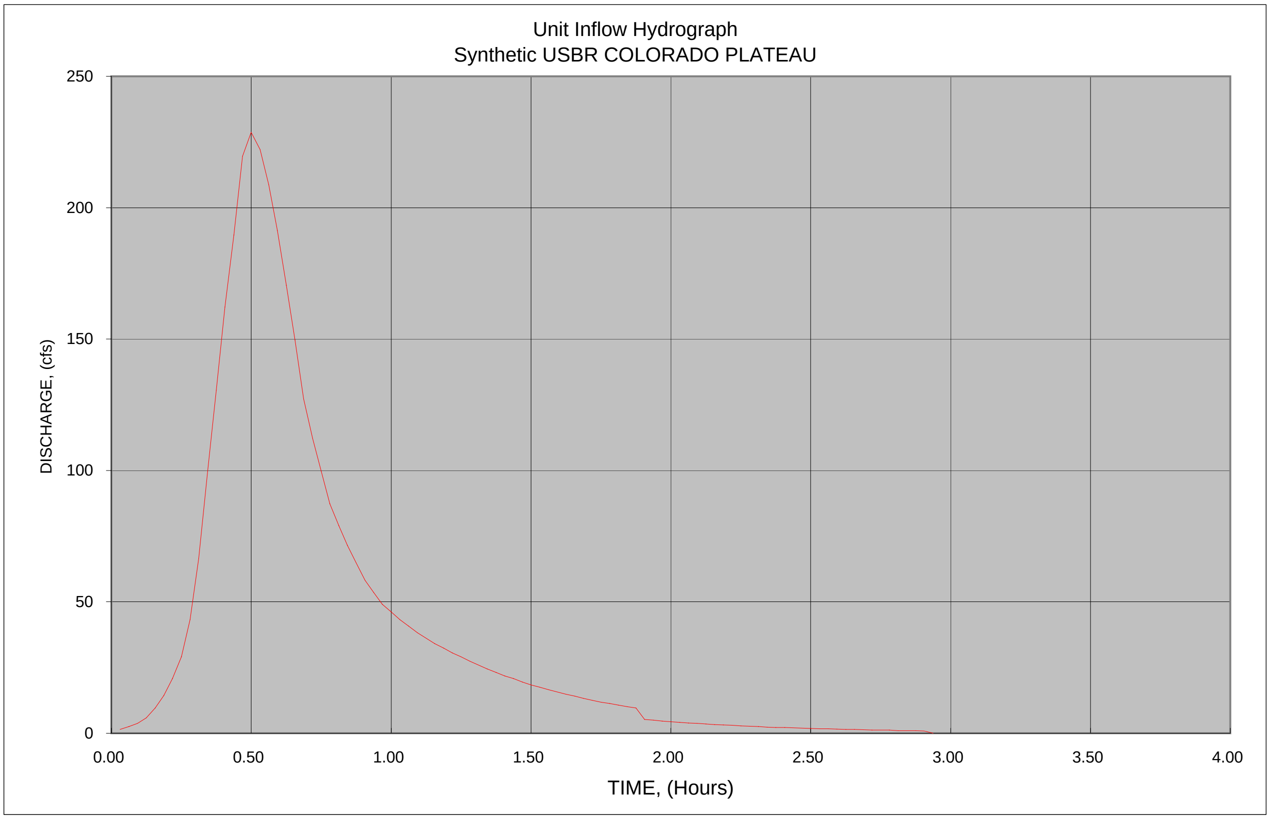
Design Point 1-10, 25, 100, 200 Existing Conditions

Drainage Area = 0.1839 sq. miles
Basin Slope = 70.74 ft./mile
L = 1.13 mi., Length of Watercourse
Lca = 0.52 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.63 Hours
Basin Factor = 0.07
V' = 4.95 cfs/Day
Qs = 7.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.58 Hours
Unit Duration, D = 6.36 minutes
Calculated Timestep = 1.88 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	3	11	29	89	171	229	197	142	100	74
UI	57	46	39	34	29	25	21	18	16	14
UI	12	10	9	8	7	6	5	4	4	3
UI	3	2	2	2	2	1	1	1	0	
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USBR calculated unitgraph peak = 229 Interpolated Peak = 229

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.9	0.19	2
10.0	0.06	3.8	0.32	3
15.0	0.09	5.6	0.48	4
20.0	0.13	7.5	0.74	6
25.0	0.16	9.4	1.21	10
30.0	0.19	11.3	1.81	14
35.0	0.22	13.1	2.63	21
40.0	0.25	15.0	3.68	29
45.0	0.28	16.9	5.47	43
50.0	0.31	18.8	8.41	67
55.0	0.34	20.6	12.61	100
60.0	0.38	22.5	16.50	131
65.0	0.41	24.4	20.50	162
70.0	0.44	26.3	23.97	190
75.0	0.47	28.1	27.75	220
80.0	0.50	30.0	28.91	229
85.0	0.53	31.9	28.07	222
90.0	0.56	33.8	26.38	209
95.0	0.59	35.6	24.18	191
100.0	0.63	37.5	21.55	170
105.0	0.66	39.4	18.92	150
110.0	0.69	41.3	16.08	127
115.0	0.72	43.1	14.19	112
120.0	0.75	45.0	12.61	100
125.0	0.78	46.9	11.04	87
130.0	0.81	48.8	9.99	79
135.0	0.84	50.6	9.04	72
140.0	0.88	52.5	8.20	65
145.0	0.91	54.4	7.36	58
150.0	0.94	56.3	6.78	54
155.0	0.97	58.1	6.20	49
160.0	1.00	60.0	5.83	46
165.0	1.03	61.9	5.47	43
170.0	1.06	63.8	5.15	41
175.0	1.09	65.6	4.84	38
180.0	1.13	67.5	4.57	36
185.0	1.16	69.4	4.31	34
190.0	1.19	71.3	4.10	32
195.0	1.22	73.1	3.87	31
200.0	1.25	75.0	3.68	29
205.0	1.28	76.9	3.47	27
210.0	1.31	78.8	3.28	26
215.0	1.34	80.6	3.10	25
220.0	1.38	82.5	2.93	23
225.0	1.41	84.4	2.75	22
230.0	1.44	86.3	2.63	21
235.0	1.47	88.1	2.47	20
240.0	1.50	90.0	2.33	18
245.0	1.53	91.9	2.22	18
250.0	1.56	93.8	2.10	17
255.0	1.59	95.6	1.99	16
260.0	1.63	97.5	1.88	15
265.0	1.66	99.4	1.78	14
270.0	1.69	101.3	1.68	13
275.0	1.72	103.1	1.59	13
280.0	1.75	105.0	1.50	12
285.0	1.78	106.9	1.43	11
290.0	1.81	108.8	1.36	11
295.0	1.84	110.6	1.28	10
300.0	1.88	112.5	1.21	10
305.0	1.91	114.4	0.66	5
310.0	1.94	116.3	0.63	5
315.0	1.97	118.1	0.59	5
320.0	2.00	120.0	0.56	4
325.0	2.03	121.9	0.53	4
330.0	2.06	123.8	0.50	4
335.0	2.09	125.6	0.47	4
340.0	2.13	127.5	0.45	4
345.0	2.16	129.4	0.42	3
350.0	2.19	131.3	0.40	3
355.0	2.22	133.1	0.38	3
360.0	2.25	135.0	0.36	3
365.0	2.28	136.9	0.34	3
370.0	2.31	138.8	0.33	3
375.0	2.34	140.6	0.30	2
380.0	2.38	142.5	0.28	2
385.0	2.41	144.4	0.27	2
390.0	2.44	146.3	0.26	2
395.0	2.47	148.1	0.24	2
400.0	2.50	150.0	0.23	2
405.0	2.53	151.9	0.22	2
410.0	2.56	153.8	0.21	2
415.0	2.59	155.6	0.20	2
420.0	2.63	157.5	0.19	2
425.0	2.66	159.4	0.18	1
430.0	2.69	161.3	0.17	1
435.0	2.72	163.1	0.16	1
440.0	2.75	165.0	0.15	1
445.0	2.78	166.9	0.15	1
450.0	2.81	168.8	0.13	1
455.0	2.84	170.6	0.12	1
460.0	2.88	172.5	0.12	1
465.0	2.91	174.4	0.11	1
470.0	2.94	176.3		
475.0	2.97	178.1		
480.0	3.00	180.0		
485.0	3.03	181.9		
490.0	3.06	183.8		
495.0	3.09	185.6		
500.0	3.13	187.5		
505.0	3.16	189.4		
510.0	3.19	191.3		
515.0	3.22	193.1		
520.0	3.25	195.0		
525.0	3.28	196.9		
530.0	3.31	198.8		
535.0	3.34	200.6		
540.0	3.38	202.5		
545.0	3.41	204.4		
550.0	3.44	206.3		
555.0	3.47	208.1		
560.0	3.50	210.0		
565.0	3.53	211.9		
570.0	3.56	213.8		
575.0	3.59	215.6		
580.0	3.63	217.5		
585.0	3.66	219.4		
590.0	3.69	221.3		
595.0	3.72	223.2		
600.0	3.75	225.0		

NOTES : Use for models including Design Point 1 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

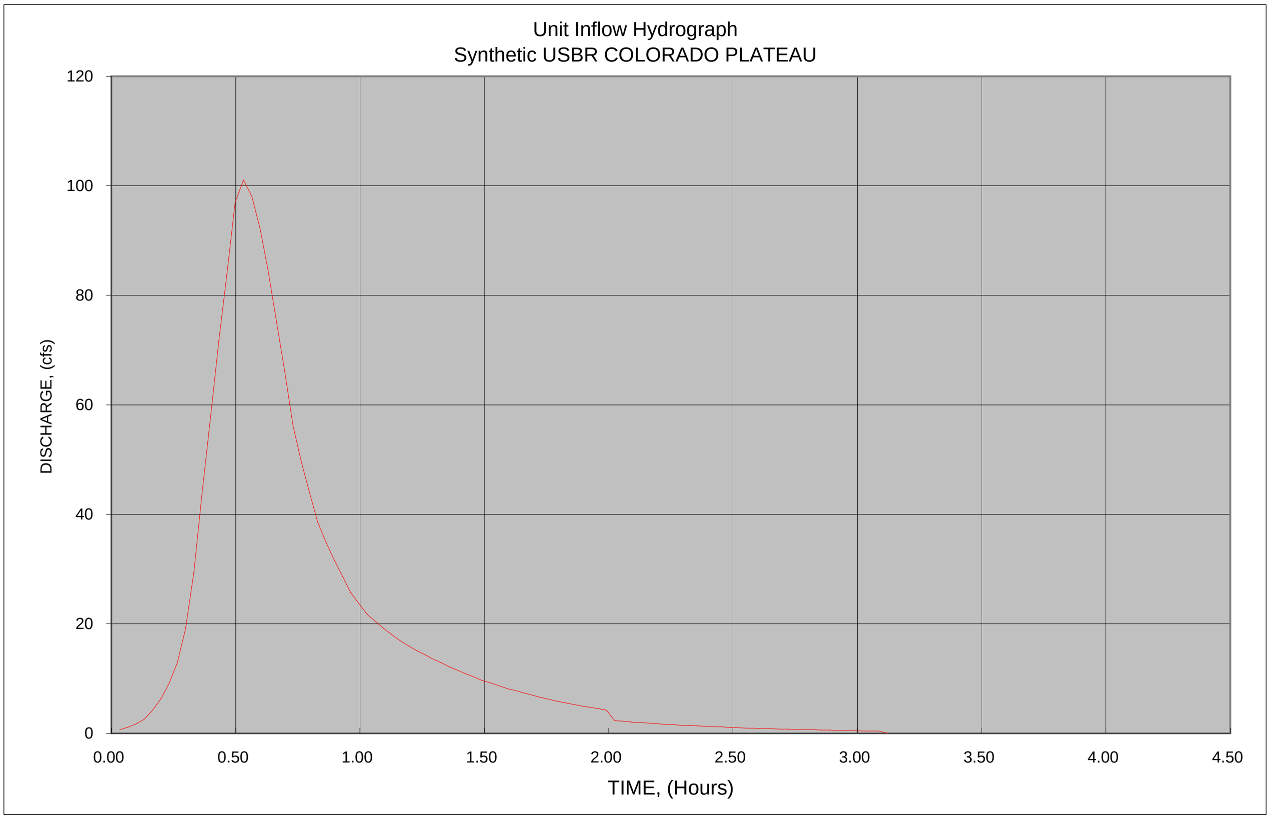
Design Point 2-10, 25, 100, 200 Existing Conditions

Drainage Area = 0.0863 sq. miles
Basin Slope = 52.14 ft./mile
L = 1.04 mi., Length of Watercourse
Lca = 0.59 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.66 Hours
Basin Factor = 0.08
V' = 2.32 cfs/Day
Qs = 3.5 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.62 Hours
Unit Duration, D = 6.79 minutes
Calculated Timestep = 1.99 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	1	4	11	30	65	97	95	75	52	38
UI	30	23	20	17	15	13	11	10	8	7
UI	6	5	5	4	4	3	3	2	2	2
UI	2	1	1	1	1	1	1	1	1	0
UI	0									
UI										
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USBR calculated unitgraph peak = 101 Interpolated Peak = 97

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	2.0	0.19	1	305.0	2.03	121.5	0.66	2
10.0	0.07	4.0	0.32	1	310.0	2.06	123.5	0.63	2
15.0	0.10	6.0	0.48	2	315.0	2.09	125.5	0.59	2
20.0	0.13	8.0	0.74	3	320.0	2.12	127.5	0.56	2
25.0	0.17	10.0	1.21	4	325.0	2.16	129.5	0.53	2
30.0	0.20	12.0	1.81	6	330.0	2.19	131.5	0.50	2
35.0	0.23	13.9	2.63	9	335.0	2.22	133.5	0.47	2
40.0	0.27	15.9	3.68	13	340.0	2.26	135.5	0.45	2
45.0	0.30	17.9	5.47	19	345.0	2.29	137.5	0.42	1
50.0	0.33	19.9	8.41	29	350.0	2.32	139.4	0.40	1
55.0	0.37	21.9	12.61	44	355.0	2.36	141.4	0.38	1
60.0	0.40	23.9	16.50	58	360.0	2.39	143.4	0.36	1
65.0	0.43	25.9	20.50	72	365.0	2.42	145.4	0.34	1
70.0	0.46	27.9	23.97	84	370.0	2.46	147.4	0.33	1
75.0	0.50	29.9	27.75	97	375.0	2.49	149.4	0.30	1
80.0	0.53	31.9	28.91	101	380.0	2.52	151.4	0.28	1
85.0	0.56	33.9	28.07	98	385.0	2.56	153.4	0.27	1
90.0	0.60	35.9	26.38	92	390.0	2.59	155.4	0.26	1
95.0	0.63	37.8	24.18	85	395.0	2.62	157.4	0.24	1
100.0	0.66	39.8	21.55	75	400.0	2.66	159.4	0.23	1
105.0	0.70	41.8	18.92	66	405.0	2.69	161.4	0.22	1
110.0	0.73	43.8	16.08	56	410.0	2.72	163.3	0.21	1
115.0	0.76	45.8	14.19	50	415.0	2.76	165.3	0.20	1
120.0	0.80	47.8	12.61	44	420.0	2.79	167.3	0.19	1
125.0	0.83	49.8	11.04	39	425.0	2.82	169.3	0.18	1
130.0	0.86	51.8	9.99	35	430.0	2.86	171.3	0.17	1
135.0	0.90	53.8	9.04	32	435.0	2.89	173.3	0.16	1
140.0	0.93	55.8	8.20	29	440.0	2.92	175.3	0.15	1
145.0	0.96	57.8	7.36	26	445.0	2.95	177.3	0.15	1
150.0	1.00	59.8	6.78	24	450.0	2.99	179.3	0.13	0
155.0	1.03	61.8	6.20	22	455.0	3.02	181.3	0.12	0
160.0	1.06	63.7	5.83	20	460.0	3.05	183.3	0.12	0
165.0	1.10	65.7	5.47	19	465.0	3.09	185.3	0.11	0
170.0	1.13	67.7	5.15	18	470.0	3.12	187.3		
175.0	1.16	69.7	4.84	17	475.0	3.15	189.2		
180.0	1.20	71.7	4.57	16	480.0	3.19	191.2		
185.0	1.23	73.7	4.31	15	485.0	3.22	193.2		
190.0	1.26	75.7	4.10	14	490.0	3.25	195.2		
195.0	1.29	77.7	3.87	14	495.0	3.29	197.2		
200.0	1.33	79.7	3.68	13	500.0	3.32	199.2		
205.0	1.36	81.7	3.47	12	505.0	3.35	201.2		
210.0	1.39	83.7	3.28	11	510.0	3.39	203.2		
215.0	1.43	85.7	3.10	11	515.0	3.42	205.2		
220.0	1.46	87.7	2.93	10	520.0	3.45	207.2		
225.0	1.49	89.6	2.75	10	525.0	3.49	209.2		
230.0	1.53	91.6	2.63	9	530.0	3.52	211.2		
235.0	1.56	93.6	2.47	9	535.0	3.55	213.1		
240.0	1.59	95.6	2.33	8	540.0	3.59	215.1		
245.0	1.63	97.6	2.22	8	545.0	3.62	217.1		
250.0	1.66	99.6	2.10	7	550.0	3.65	219.1		
255.0	1.69	101.6	1.99	7	555.0	3.69	221.1		
260.0	1.73	103.6	1.88	7	560.0	3.72	223.1		
265.0	1.76	105.6	1.78	6	565.0	3.75	225.1		
270.0	1.79	107.6	1.68	6	570.0	3.78	227.1		
275.0	1.83	109.6	1.59	6	575.0	3.82	229.1		
280.0	1.86	111.6	1.50	5	580.0	3.85	231.1		
285.0	1.89	113.5	1.43	5	585.0	3.88	233.1		
290.0	1.93	115.5	1.36	5	590.0	3.92	235.1		
295.0	1.96	117.5	1.28	4	595.0	3.95	237.1		
300.0	1.99	119.5	1.21	4	600.0	3.98	239.0		

NOTES : Use for models including Design Point 2 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Design Point 3-10, 25, 100, 200 Existing Conditions

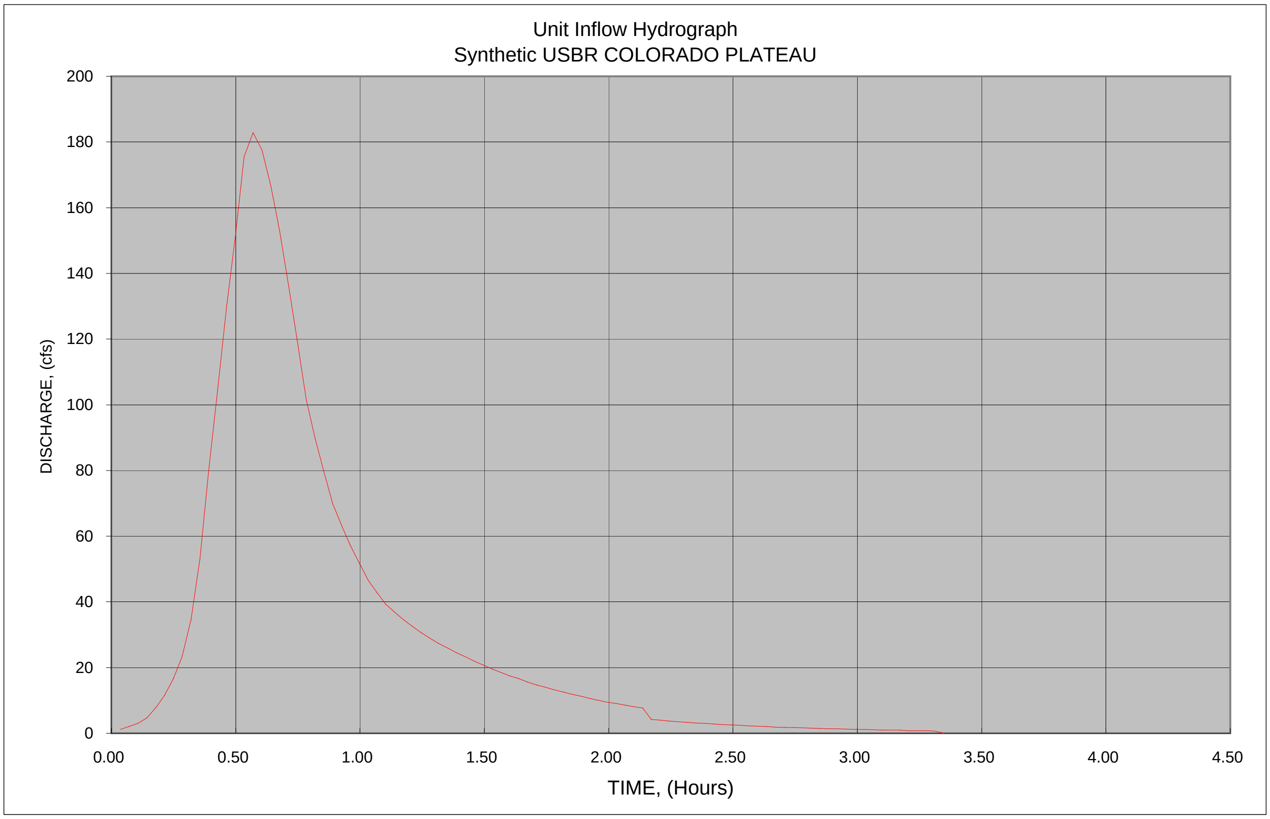
Drainage Area = 0.1675 sq. miles
Basin Slope = 77.56 ft./mile
L = 1.34 mi., Length of Watercourse
Lca = 0.7 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.71 Hours
Basin Factor = 0.11
V' = 4.50 cfs/Day
Qs = 6.3 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.67 Hours
Unit Duration, D = 7.31 minutes
Calculated Timestep = 2.14 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	2	7	17	41	97	153	181	157	119	86
UI	65	51	41	35	30	27	24	21	18	16
UI	14	12	11	9	8	7	6	6	5	4
UI	4	3	3	3	2	2	2	2	1	1
UI	1	1	1	1						
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USBR calculated unitgraph peak = 183 Interpolated Peak = 181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.1	0.19	1	305.0	2.17	130.3	0.66	4
10.0	0.07	4.3	0.32	2	310.0	2.21	132.5	0.63	4
15.0	0.11	6.4	0.48	3	315.0	2.24	134.6	0.59	4
20.0	0.14	8.5	0.74	5	320.0	2.28	136.7	0.56	4
25.0	0.18	10.7	1.21	8	325.0	2.31	138.9	0.53	3
30.0	0.21	12.8	1.81	11	330.0	2.35	141.0	0.50	3
35.0	0.25	15.0	2.63	17	335.0	2.39	143.1	0.47	3
40.0	0.28	17.1	3.68	23	340.0	2.42	145.3	0.45	3
45.0	0.32	19.2	5.47	35	345.0	2.46	147.4	0.42	3
50.0	0.36	21.4	8.41	53	350.0	2.49	149.6	0.40	3
55.0	0.39	23.5	12.61	80	355.0	2.53	151.7	0.38	2
60.0	0.43	25.6	16.50	104	360.0	2.56	153.8	0.36	2
65.0	0.46	27.8	20.50	130	365.0	2.60	156.0	0.34	2
70.0	0.50	29.9	23.97	152	370.0	2.64	158.1	0.33	2
75.0	0.53	32.0	27.75	176	375.0	2.67	160.2	0.30	2
80.0	0.57	34.2	28.91	183	380.0	2.71	162.4	0.28	2
85.0	0.61	36.3	28.07	178	385.0	2.74	164.5	0.27	2
90.0	0.64	38.5	26.38	167	390.0	2.78	166.6	0.26	2
95.0	0.68	40.6	24.18	153	395.0	2.81	168.8	0.24	2
100.0	0.71	42.7	21.55	136	400.0	2.85	170.9	0.23	1
105.0	0.75	44.9	18.92	120	405.0	2.88	173.1	0.22	1
110.0	0.78	47.0	16.08	102	410.0	2.92	175.2	0.21	1
115.0	0.82	49.1	14.19	90	415.0	2.96	177.3	0.20	1
120.0	0.85	51.3	12.61	80	420.0	2.99	179.5	0.19	1
125.0	0.89	53.4	11.04	70	425.0	3.03	181.6	0.18	1
130.0	0.93	55.5	9.99	63	430.0	3.06	183.7	0.17	1
135.0	0.96	57.7	9.04	57	435.0	3.10	185.9	0.16	1
140.0	1.00	59.8	8.20	52	440.0	3.13	188.0	0.15	1
145.0	1.03	62.0	7.36	47	445.0	3.17	190.2	0.15	1
150.0	1.07	64.1	6.78	43	450.0	3.20	192.3	0.13	1
155.0	1.10	66.2	6.20	39	455.0	3.24	194.4	0.12	1
160.0	1.14	68.4	5.83	37	460.0	3.28	196.6	0.12	1
165.0	1.18	70.5	5.47	35	465.0	3.31	198.7	0.11	1
170.0	1.21	72.6	5.15	33	470.0	3.35	200.8		
175.0	1.25	74.8	4.84	31	475.0	3.38	203.0		
180.0	1.28	76.9	4.57	29	480.0	3.42	205.1		
185.0	1.32	79.1	4.31	27	485.0	3.45	207.2		
190.0	1.35	81.2	4.10	26	490.0	3.49	209.4		
195.0	1.39	83.3	3.87	24	495.0	3.53	211.5		
200.0	1.42	85.5	3.68	23	500.0	3.56	213.7		
205.0	1.46	87.6	3.47	22	505.0	3.60	215.8		
210.0	1.50	89.7	3.28	21	510.0	3.63	217.9		
215.0	1.53	91.9	3.10	20	515.0	3.67	220.1		
220.0	1.57	94.0	2.93	19	520.0	3.70	222.2		
225.0	1.60	96.1	2.75	17	525.0	3.74	224.3		
230.0	1.64	98.3	2.63	17	530.0	3.77	226.5		
235.0	1.67	100.4	2.47	16	535.0	3.81	228.6		
240.0	1.71	102.6	2.33	15	540.0	3.85	230.7		
245.0	1.74	104.7	2.22	14	545.0	3.88	232.9		
250.0	1.78	106.8	2.10	13	550.0	3.92	235.0		
255.0	1.82	109.0	1.99	13	555.0	3.95	237.2		
260.0	1.85	111.1	1.88	12	560.0	3.99	239.3		
265.0	1.89	113.2	1.78	11	565.0	4.02	241.4		
270.0	1.92	115.4	1.68	11	570.0	4.06	243.6		
275.0	1.96	117.5	1.59	10	575.0	4.10	245.7		
280.0	1.99	119.6	1.50	9	580.0	4.13	247.8		
285.0	2.03	121.8	1.43	9	585.0	4.17	250.0		
290.0	2.07	123.9	1.36	9	590.0	4.20	252.1		
295.0	2.10	126.1	1.28	8	595.0	4.24	254.2		
300.0	2.14	128.2	1.21	8	600.0	4.27	256.4		

NOTES : Use for models including Design Point 3 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin 1-10, 25, 100, 200 Proposed Conditions

Drainage Area = 2.63 sq. miles
Basin Slope = 356 ft./mile
L = 2.92 mi., Length of Watercourse
Lca = 0.87 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.77 Hours
Basin Factor = 0.13
V' = 70.72 cfs/Day
Qs = 92.3 * q, cfs

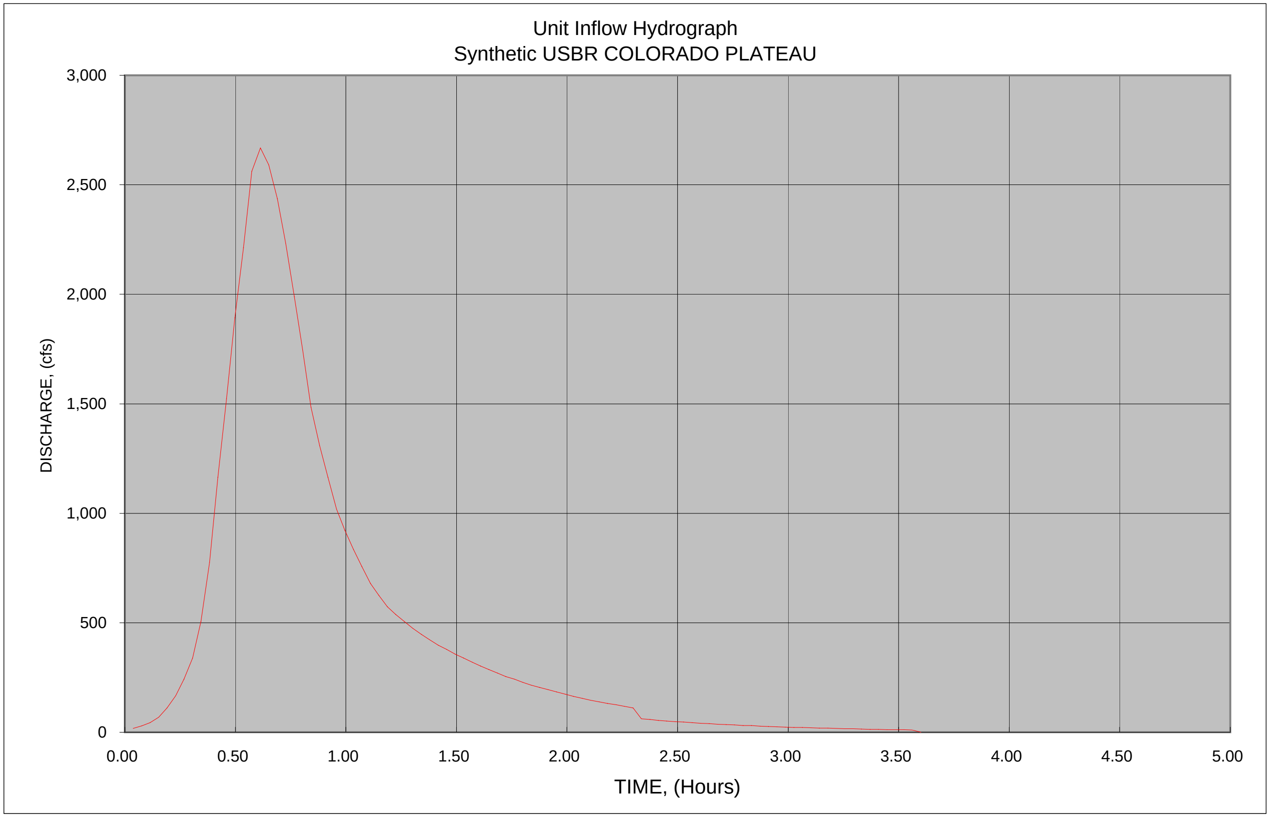
PARAMETERS:

Calculated: Lag Time, Lg = 0.72 Hours

Unit Duration, D = 7.90 minutes
Calculated Timestep = 2.30 minutes

Data to be used in Analysis

Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	32	84	207	456	1117	1909	2586	2528	2091	1549
UI	1174	913	735	601	517	452	398	354	314	278
UI	246	217	193	172	152	135	120	107	94	83
UI	74	65	59	52	46	41	36	32	28	25
UI	22	20	18	16	14	12	11			
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USBR calculated unitgraph peak = 2669 Interpolated Peak = 2586

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.3	0.19	18
10.0	0.08	4.6	0.32	30
15.0	0.11	6.9	0.48	44
20.0	0.15	9.2	0.74	68
25.0	0.19	11.5	1.21	112
30.0	0.23	13.8	1.81	167
35.0	0.27	16.1	2.63	243
40.0	0.31	18.4	3.68	340
45.0	0.34	20.7	5.47	505
50.0	0.38	23.0	8.41	776
55.0	0.42	25.3	12.61	1,164
60.0	0.46	27.6	16.50	1,523
65.0	0.50	29.9	20.50	1,892
70.0	0.54	32.2	23.97	2,213
75.0	0.57	34.5	27.75	2,562
80.0	0.61	36.8	28.91	2,669
85.0	0.65	39.1	28.07	2,591
90.0	0.69	41.4	26.38	2,435
95.0	0.73	43.7	24.18	2,232
100.0	0.77	46.0	21.55	1,989
105.0	0.80	48.3	18.92	1,747
110.0	0.84	50.6	16.08	1,484
115.0	0.88	52.9	14.19	1,310
120.0	0.92	55.2	12.61	1,164
125.0	0.96	57.5	11.04	1,019
130.0	1.00	59.8	9.99	922
135.0	1.03	62.1	9.04	835
140.0	1.07	64.4	8.20	757
145.0	1.11	66.7	7.36	679
150.0	1.15	68.9	6.78	626
155.0	1.19	71.2	6.20	572
160.0	1.23	73.5	5.83	538
165.0	1.26	75.8	5.47	505
170.0	1.30	78.1	5.15	475
175.0	1.34	80.4	4.84	447
180.0	1.38	82.7	4.57	422
185.0	1.42	85.0	4.31	398
190.0	1.46	87.3	4.10	378
195.0	1.49	89.6	3.87	357
200.0	1.53	91.9	3.68	340
205.0	1.57	94.2	3.47	320
210.0	1.61	96.5	3.28	303
215.0	1.65	98.8	3.10	286
220.0	1.69	101.1	2.93	270
225.0	1.72	103.4	2.75	254
230.0	1.76	105.7	2.63	243
235.0	1.80	108.0	2.47	228
240.0	1.84	110.3	2.33	215
245.0	1.88	112.6	2.22	205
250.0	1.92	114.9	2.10	194
255.0	1.95	117.2	1.99	184
260.0	1.99	119.5	1.88	174
265.0	2.03	121.8	1.78	164
270.0	2.07	124.1	1.68	155
275.0	2.11	126.4	1.59	147
280.0	2.15	128.7	1.50	138
285.0	2.18	131.0	1.43	132
290.0	2.22	133.3	1.36	126
295.0	2.26	135.6	1.28	118
300.0	2.30	137.9	1.21	112
305.0	2.34	140.2	0.66	61
310.0	2.37	142.5	0.63	58
315.0	2.41	144.8	0.59	54
320.0	2.45	147.1	0.56	52
325.0	2.49	149.4	0.53	49
330.0	2.53	151.7	0.50	46
335.0	2.57	154.0	0.47	43
340.0	2.60	156.3	0.45	42
345.0	2.64	158.6	0.42	39
350.0	2.68	160.9	0.40	37
355.0	2.72	163.2	0.38	35
360.0	2.76	165.5	0.36	33
365.0	2.80	167.8	0.34	31
370.0	2.83	170.1	0.33	30
375.0	2.87	172.4	0.30	28
380.0	2.91	174.7	0.28	26
385.0	2.95	177.0	0.27	25
390.0	2.99	179.3	0.26	24
395.0	3.03	181.6	0.24	22
400.0	3.06	183.9	0.23	21
405.0	3.10	186.2	0.22	20
410.0	3.14	188.5	0.21	19
415.0	3.18	190.8	0.20	18
420.0	3.22	193.1	0.19	18
425.0	3.26	195.4	0.18	17
430.0	3.29	197.7	0.17	16
435.0	3.33	200.0	0.16	15
440.0	3.37	202.2	0.15	14
445.0	3.41	204.5	0.15	14
450.0	3.45	206.8	0.13	12
455.0	3.49	209.1	0.12	11
460.0	3.52	211.4	0.12	11
465.0	3.56	213.7	0.11	10
470.0	3.60	216.0		
475.0	3.64	218.3		
480.0	3.68	220.6		
485.0	3.72	222.9		
490.0	3.75	225.2		
495.0	3.79	227.5		
500.0	3.83	229.8		
505.0	3.87	232.1		
510.0	3.91	234.4		
515.0	3.95	236.7		
520.0	3.98	239.0		
525.0	4.02	241.3		
530.0	4.06	243.6		
535.0	4.10	245.9		
540.0	4.14	248.2		
545.0	4.18	250.5		
550.0	4.21	252.8		
555.0	4.25	255.1		
560.0	4.29	257.4		
565.0	4.33	259.7		
570.0	4.37	262.0		
575.0	4.41	264.3		
580.0	4.44	266.6		
585.0	4.48	268.9		
590.0	4.52	271.2		
595.0	4.56	273.5		
600.0	4.60	275.8		

NOTES : Use for models including Basin 1 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

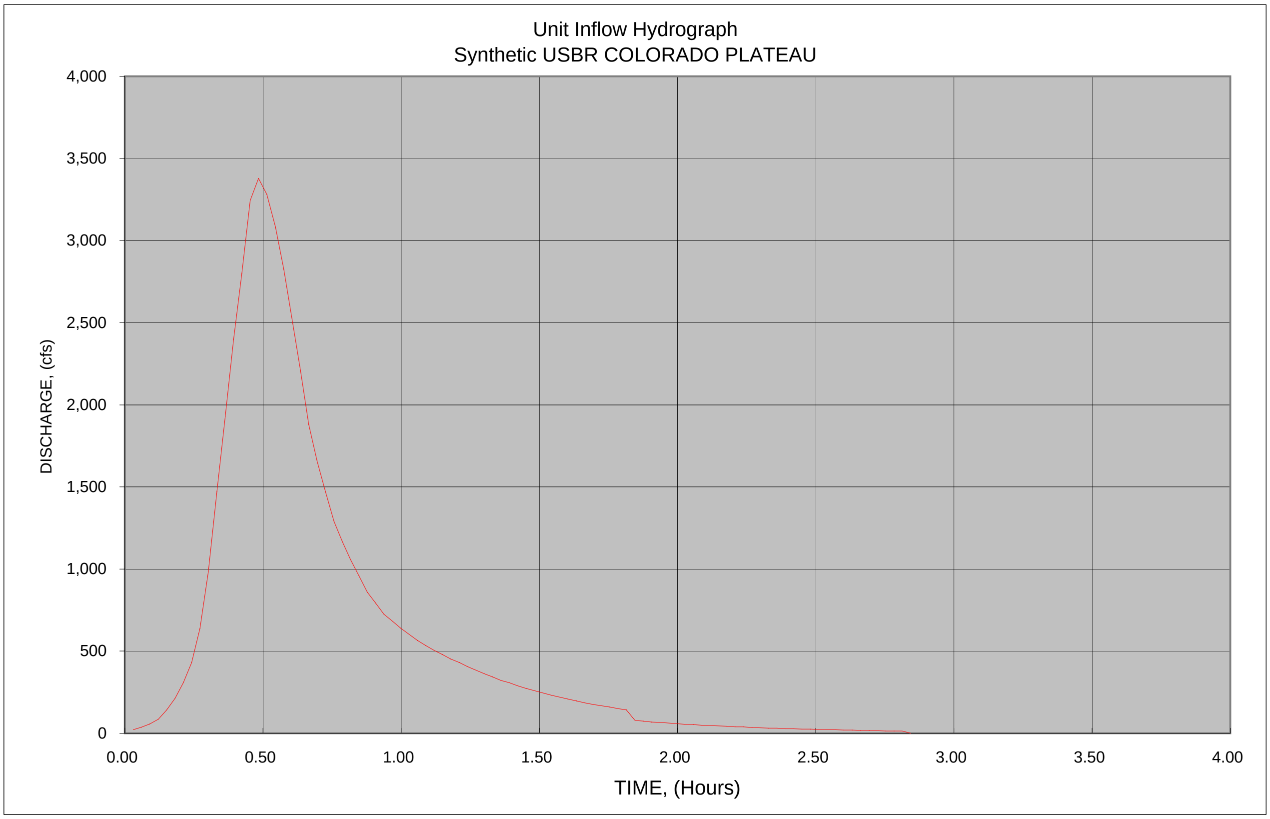
Basin 1-PMP Proposed Conditions

Drainage Area = 2.63 sq. miles
Basin Slope = 356 ft./mile
L = 2.92 mi., Length of Watercourse
Lca = 0.87 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.61 Hours
Basin Factor = 0.13
V' = 70.72 cfs/Day
Qs = 116.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.56 Hours
Unit Duration, D = 6.15 minutes
Calculated Timestep = 1.82 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	52	177	485	1482	2709	3327	2740	1872	1329	1003
UI	772	637	540	464	399	341	292	251	216	185
UI	160	137	117	100	87	75	64	55	47	41
UI	34	30	26	23	19	17	14			
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USBR calculated unitgraph peak = 3379 Interpolated Peak = 3327

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.8	0.19	22	305.0	1.85	110.7	0.66	77
10.0	0.06	3.6	0.32	37	310.0	1.88	112.6	0.63	74
15.0	0.09	5.4	0.48	56	315.0	1.91	114.4	0.59	69
20.0	0.12	7.3	0.74	86	320.0	1.94	116.2	0.56	65
25.0	0.15	9.1	1.21	141	325.0	1.97	118.0	0.53	62
30.0	0.18	10.9	1.81	212	330.0	2.00	119.8	0.50	58
35.0	0.21	12.7	2.63	307	335.0	2.03	121.6	0.47	55
40.0	0.24	14.5	3.68	430	340.0	2.06	123.4	0.45	53
45.0	0.27	16.3	5.47	639	345.0	2.09	125.3	0.42	49
50.0	0.30	18.2	8.41	983	350.0	2.12	127.1	0.40	47
55.0	0.33	20.0	12.61	1,474	355.0	2.15	128.9	0.38	44
60.0	0.36	21.8	16.50	1,928	360.0	2.18	130.7	0.36	42
65.0	0.39	23.6	20.50	2,396	365.0	2.21	132.5	0.34	40
70.0	0.42	25.4	23.97	2,801	370.0	2.24	134.3	0.33	39
75.0	0.45	27.2	27.75	3,243	375.0	2.27	136.1	0.30	35
80.0	0.48	29.0	28.91	3,379	380.0	2.30	138.0	0.28	33
85.0	0.51	30.9	28.07	3,281	385.0	2.33	139.8	0.27	32
90.0	0.54	32.7	26.38	3,083	390.0	2.36	141.6	0.26	30
95.0	0.57	34.5	24.18	2,826	395.0	2.39	143.4	0.24	28
100.0	0.61	36.3	21.55	2,519	400.0	2.42	145.2	0.23	27
105.0	0.64	38.1	18.92	2,211	405.0	2.45	147.0	0.22	26
110.0	0.67	39.9	16.08	1,879	410.0	2.48	148.9	0.21	25
115.0	0.70	41.8	14.19	1,658	415.0	2.51	150.7	0.20	23
120.0	0.73	43.6	12.61	1,474	420.0	2.54	152.5	0.19	22
125.0	0.76	45.4	11.04	1,290	425.0	2.57	154.3	0.18	21
130.0	0.79	47.2	9.99	1,168	430.0	2.60	156.1	0.17	20
135.0	0.82	49.0	9.04	1,057	435.0	2.63	157.9	0.16	19
140.0	0.85	50.8	8.20	958	440.0	2.66	159.7	0.15	18
145.0	0.88	52.6	7.36	860	445.0	2.69	161.6	0.15	18
150.0	0.91	54.5	6.78	792	450.0	2.72	163.4	0.13	15
155.0	0.94	56.3	6.20	725	455.0	2.75	165.2	0.12	14
160.0	0.97	58.1	5.83	681	460.0	2.78	167.0	0.12	14
165.0	1.00	59.9	5.47	639	465.0	2.81	168.8	0.11	13
170.0	1.03	61.7	5.15	602	470.0	2.84	170.6		
175.0	1.06	63.5	4.84	566	475.0	2.87	172.5		
180.0	1.09	65.4	4.57	534	480.0	2.90	174.3		
185.0	1.12	67.2	4.31	504	485.0	2.93	176.1		
190.0	1.15	69.0	4.10	479	490.0	2.97	177.9		
195.0	1.18	70.8	3.87	452	495.0	3.00	179.7		
200.0	1.21	72.6	3.68	430	500.0	3.03	181.5		
205.0	1.24	74.4	3.47	406	505.0	3.06	183.3		
210.0	1.27	76.2	3.28	383	510.0	3.09	185.2		
215.0	1.30	78.1	3.10	362	515.0	3.12	187.0		
220.0	1.33	79.9	2.93	342	520.0	3.15	188.8		
225.0	1.36	81.7	2.75	321	525.0	3.18	190.6		
230.0	1.39	83.5	2.63	307	530.0	3.21	192.4		
235.0	1.42	85.3	2.47	289	535.0	3.24	194.2		
240.0	1.45	87.1	2.33	272	540.0	3.27	196.1		
245.0	1.48	89.0	2.22	259	545.0	3.30	197.9		
250.0	1.51	90.8	2.10	245	550.0	3.33	199.7		
255.0	1.54	92.6	1.99	233	555.0	3.36	201.5		
260.0	1.57	94.4	1.88	220	560.0	3.39	203.3		
265.0	1.60	96.2	1.78	208	565.0	3.42	205.1		
270.0	1.63	98.0	1.68	196	570.0	3.45	206.9		
275.0	1.66	99.8	1.59	186	575.0	3.48	208.8		
280.0	1.69	101.7	1.50	175	580.0	3.51	210.6		
285.0	1.72	103.5	1.43	167	585.0	3.54	212.4		
290.0	1.75	105.3	1.36	159	590.0	3.57	214.2		
295.0	1.79	107.1	1.28	150	595.0	3.60	216.0		
300.0	1.82	108.9	1.21	141	600.0	3.63	217.8		

NOTES : Use for models including Basin 1 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

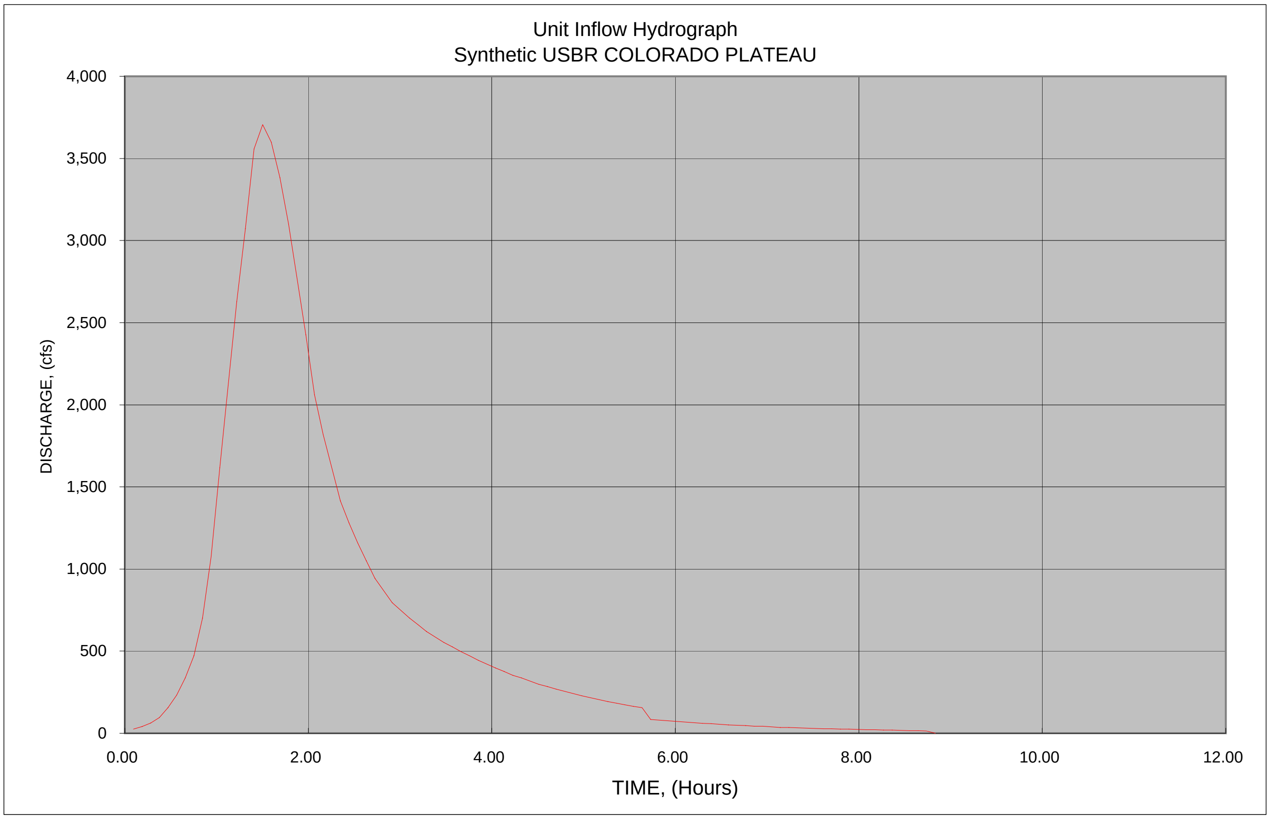
Basin 2-10, 25, 100, 200 Proposed Conditions

Drainage Area = 8.96 sq. miles
Basin Slope = 283 ft./mile
L = 7.67 mi., Length of Watercourse
Lca = 4.31 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 1.88 Hours
Basin Factor = 1.97
V' = 240.93 cfs/Day
Qs = 128.2 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 1.75 Hours
Unit Duration, D = 19.14 minutes
Calculated Timestep = 5.64 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



UI Record - Unit Graph 5 **minute interval**

UI	22	37	55	80	121	180	254	350	469	671
UI	985	1423	1879	2327	2761	3163	3568	3700	3615	3439
UI	3206	2928	2629	2323	2021	1808	1628	1450	1319	1207
UI	1106	1011	924	858	793	751	710	673	637	604
UI	574	546	522	496	474	450	428	407	388	368
UI	349	335	317	301	288	274	262	249	237	226
UI	214	204	194	186	178	169	160	153	146	138
UI	131	125	119	113	108	103	99	94	88	85
UI	81	77	73	70	67	63	60	58	54	52
UI	50	47	45	43	41	38	36	35	34	32
UI	30	29	28	27	26	24	23	22	21	20
UI	19	18	16	15	15	14	4			
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USBR calculated unitgraph peak = 3706 Interpolated Peak = 3700

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.09	5.6	0.19	24	305.0	5.73	344.0	0.66	85
10.0	0.19	11.3	0.32	41	310.0	5.83	349.6	0.63	81
15.0	0.28	16.9	0.48	62	315.0	5.92	355.2	0.59	76
20.0	0.38	22.6	0.74	95	320.0	6.01	360.9	0.56	72
25.0	0.47	28.2	1.21	155	325.0	6.11	366.5	0.53	68
30.0	0.56	33.8	1.81	232	330.0	6.20	372.2	0.50	64
35.0	0.66	39.5	2.63	337	335.0	6.30	377.8	0.47	60
40.0	0.75	45.1	3.68	472	340.0	6.39	383.4	0.45	58
45.0	0.85	50.7	5.47	701	345.0	6.48	389.1	0.42	54
50.0	0.94	56.4	8.41	1,078	350.0	6.58	394.7	0.40	51
55.0	1.03	62.0	12.61	1,616	355.0	6.67	400.4	0.38	49
60.0	1.13	67.7	16.50	2,115	360.0	6.77	406.0	0.36	46
65.0	1.22	73.3	20.50	2,628	365.0	6.86	411.6	0.34	44
70.0	1.32	78.9	23.97	3,073	370.0	6.95	417.3	0.33	42
75.0	1.41	84.6	27.75	3,557	375.0	7.05	422.9	0.30	38
80.0	1.50	90.2	28.91	3,706	380.0	7.14	428.6	0.28	36
85.0	1.60	95.9	28.07	3,598	385.0	7.24	434.2	0.27	35
90.0	1.69	101.5	26.38	3,381	390.0	7.33	439.8	0.26	33
95.0	1.79	107.1	24.18	3,099	395.0	7.42	445.5	0.24	31
100.0	1.88	112.8	21.55	2,762	400.0	7.52	451.1	0.23	29
105.0	1.97	118.4	18.92	2,425	405.0	7.61	456.7	0.22	28
110.0	2.07	124.1	16.08	2,061	410.0	7.71	462.4	0.21	27
115.0	2.16	129.7	14.19	1,819	415.0	7.80	468.0	0.20	26
120.0	2.26	135.3	12.61	1,616	420.0	7.89	473.7	0.19	24
125.0	2.35	141.0	11.04	1,415	425.0	7.99	479.3	0.18	23
130.0	2.44	146.6	9.99	1,281	430.0	8.08	484.9	0.17	22
135.0	2.54	152.2	9.04	1,159	435.0	8.18	490.6	0.16	21
140.0	2.63	157.9	8.20	1,051	440.0	8.27	496.2	0.15	19
145.0	2.73	163.5	7.36	943	445.0	8.36	501.9	0.15	19
150.0	2.82	169.2	6.78	869	450.0	8.46	507.5	0.13	17
155.0	2.91	174.8	6.20	795	455.0	8.55	513.1	0.12	15
160.0	3.01	180.4	5.83	747	460.0	8.65	518.8	0.12	15
165.0	3.10	186.1	5.47	701	465.0	8.74	524.4	0.11	14
170.0	3.20	191.7	5.15	660	470.0	8.83	530.1		
175.0	3.29	197.4	4.84	620	475.0	8.93	535.7		
180.0	3.38	203.0	4.57	586	480.0	9.02	541.3		
185.0	3.48	208.6	4.31	552	485.0	9.12	547.0		
190.0	3.57	214.3	4.10	526	490.0	9.21	552.6		
195.0	3.67	219.9	3.87	496	495.0	9.30	558.2		
200.0	3.76	225.6	3.68	472	500.0	9.40	563.9		
205.0	3.85	231.2	3.47	445	505.0	9.49	569.5		
210.0	3.95	236.8	3.28	420	510.0	9.59	575.2		
215.0	4.04	242.5	3.10	397	515.0	9.68	580.8		
220.0	4.14	248.1	2.93	376	520.0	9.77	586.4		
225.0	4.23	253.7	2.75	353	525.0	9.87	592.1		
230.0	4.32	259.4	2.63	337	530.0	9.96	597.7		
235.0	4.42	265.0	2.47	317	535.0	10.06	603.4		
240.0	4.51	270.7	2.33	299	540.0	10.15	609.0		
245.0	4.61	276.3	2.22	285	545.0	10.24	614.6		
250.0	4.70	281.9	2.10	269	550.0	10.34	620.3		
255.0	4.79	287.6	1.99	255	555.0	10.43	625.9		
260.0	4.89	293.2	1.88	241	560.0	10.53	631.6		
265.0	4.98	298.9	1.78	228	565.0	10.62	637.2		
270.0	5.07	304.5	1.68	215	570.0	10.71	642.8		
275.0	5.17	310.1	1.59	204	575.0	10.81	648.5		
280.0	5.26	315.8	1.50	192	580.0	10.90	654.1		
285.0	5.36	321.4	1.43	183	585.0	11.00	659.7		
290.0	5.45	327.1	1.36	174	590.0	11.09	665.4		
295.0	5.54	332.7	1.28	164	595.0	11.18	671.0		
300.0	5.64	338.3	1.21	155	600.0	11.28	676.7		

NOTES : Use for models including Basin 2 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

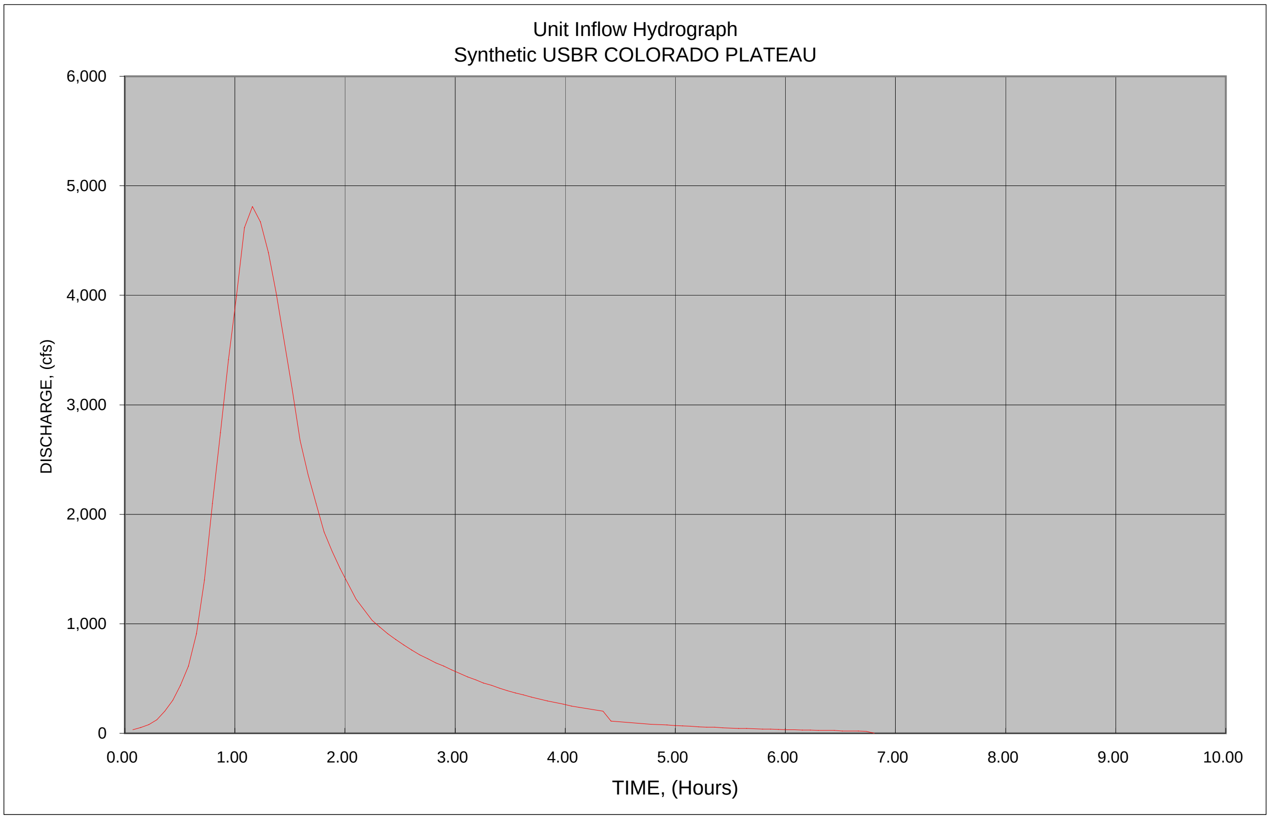
Basin 2-PMP Proposed Conditions

Drainage Area = 8.96 sq. miles
Basin Slope = 283 ft./mile
L = 7.67 mi., Length of Watercourse
Lca = 4.31 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 1.45 Hours
Basin Factor = 1.97
V' = 240.93 cfs/Day
Qs = 166.4 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 1.36 Hours
Unit Duration, D = 14.89 minutes
Calculated Timestep = 4.34 minutes

Data to be used in Analysis
Unit Duration, D = 10 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



UI Record - Unit Graph 5 **minute interval**

UI	35	61	99	170	277	425	629	1012	1650	2428
UI	3185	3880	4594	4794	4596	4237	3775	3272	2738	2356
UI	2054	1781	1587	1417	1256	1135	1027	956	890	830
UI	775	724	683	640	602	564	528	495	461	437
UI	407	381	360	338	317	297	278	261	245	232
UI	217	203	191	178	167	157	146	138	130	123
UI	114	108	101	95	89	83	78	74	68	65
UI	61	57	55	49	46	44	41	39	37	35
UI	33	31	29	27	25	25	21	20	19	8
UI										
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USBR calculated unitgraph peak = 4810 Interpolated Peak = 4794

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.07	4.3	0.19	32	305.0	4.42	265.0	0.66	110
10.0	0.14	8.7	0.32	53	310.0	4.49	269.3	0.63	105
15.0	0.22	13.0	0.48	80	315.0	4.56	273.7	0.59	98
20.0	0.29	17.4	0.74	123	320.0	4.63	278.0	0.56	93
25.0	0.36	21.7	1.21	201	325.0	4.71	282.4	0.53	88
30.0	0.43	26.1	1.81	301	330.0	4.78	286.7	0.50	83
35.0	0.51	30.4	2.63	438	335.0	4.85	291.1	0.47	78
40.0	0.58	34.8	3.68	612	340.0	4.92	295.4	0.45	75
45.0	0.65	39.1	5.47	910	345.0	5.00	299.7	0.42	70
50.0	0.72	43.4	8.41	1,399	350.0	5.07	304.1	0.40	67
55.0	0.80	47.8	12.61	2,098	355.0	5.14	308.4	0.38	63
60.0	0.87	52.1	16.50	2,745	360.0	5.21	312.8	0.36	60
65.0	0.94	56.5	20.50	3,411	365.0	5.29	317.1	0.34	57
70.0	1.01	60.8	23.97	3,988	370.0	5.36	321.5	0.33	55
75.0	1.09	65.2	27.75	4,617	375.0	5.43	325.8	0.30	50
80.0	1.16	69.5	28.91	4,810	380.0	5.50	330.2	0.28	47
85.0	1.23	73.8	28.07	4,670	385.0	5.57	334.5	0.27	45
90.0	1.30	78.2	26.38	4,389	390.0	5.65	338.8	0.26	43
95.0	1.38	82.5	24.18	4,023	395.0	5.72	343.2	0.24	40
100.0	1.45	86.9	21.55	3,586	400.0	5.79	347.5	0.23	38
105.0	1.52	91.2	18.92	3,148	405.0	5.86	351.9	0.22	37
110.0	1.59	95.6	16.08	2,676	410.0	5.94	356.2	0.21	35
115.0	1.67	99.9	14.19	2,361	415.0	6.01	360.6	0.20	33
120.0	1.74	104.3	12.61	2,098	420.0	6.08	364.9	0.19	32
125.0	1.81	108.6	11.04	1,837	425.0	6.15	369.2	0.18	30
130.0	1.88	112.9	9.99	1,662	430.0	6.23	373.6	0.17	28
135.0	1.95	117.3	9.04	1,504	435.0	6.30	377.9	0.16	27
140.0	2.03	121.6	8.20	1,364	440.0	6.37	382.3	0.15	25
145.0	2.10	126.0	7.36	1,225	445.0	6.44	386.6	0.15	25
150.0	2.17	130.3	6.78	1,128	450.0	6.52	391.0	0.13	22
155.0	2.24	134.7	6.20	1,032	455.0	6.59	395.3	0.12	20
160.0	2.32	139.0	5.83	970	460.0	6.66	399.7	0.12	20
165.0	2.39	143.4	5.47	910	465.0	6.73	404.0	0.11	18
170.0	2.46	147.7	5.15	857	470.0	6.81	408.3		
175.0	2.53	152.0	4.84	805	475.0	6.88	412.7		
180.0	2.61	156.4	4.57	760	480.0	6.95	417.0		
185.0	2.68	160.7	4.31	717	485.0	7.02	421.4		
190.0	2.75	165.1	4.10	682	490.0	7.10	425.7		
195.0	2.82	169.4	3.87	644	495.0	7.17	430.1		
200.0	2.90	173.8	3.68	612	500.0	7.24	434.4		
205.0	2.97	178.1	3.47	577	505.0	7.31	438.8		
210.0	3.04	182.5	3.28	546	510.0	7.38	443.1		
215.0	3.11	186.8	3.10	516	515.0	7.46	447.4		
220.0	3.19	191.1	2.93	488	520.0	7.53	451.8		
225.0	3.26	195.5	2.75	458	525.0	7.60	456.1		
230.0	3.33	199.8	2.63	438	530.0	7.67	460.5		
235.0	3.40	204.2	2.47	411	535.0	7.75	464.8		
240.0	3.48	208.5	2.33	388	540.0	7.82	469.2		
245.0	3.55	212.9	2.22	369	545.0	7.89	473.5		
250.0	3.62	217.2	2.10	349	550.0	7.96	477.9		
255.0	3.69	221.5	1.99	331	555.0	8.04	482.2		
260.0	3.76	225.9	1.88	313	560.0	8.11	486.5		
265.0	3.84	230.2	1.78	296	565.0	8.18	490.9		
270.0	3.91	234.6	1.68	280	570.0	8.25	495.2		
275.0	3.98	238.9	1.59	265	575.0	8.33	499.6		
280.0	4.05	243.3	1.50	250	580.0	8.40	503.9		
285.0	4.13	247.6	1.43	238	585.0	8.47	508.3		
290.0	4.20	252.0	1.36	226	590.0	8.54	512.6		
295.0	4.27	256.3	1.28	213	595.0	8.62	516.9		
300.0	4.34	260.6	1.21	201	600.0	8.69	521.3		

NOTES : Use for models including Basin 2 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Basin 3-10, 25, 100, 200 Proposed Conditions

Drainage Area =	3.47	sq. miles	Lg+D/2 =	1.59	Hours
Basin Slope =	57.1	ft./mile	Basin Factor =	1.15	
L =	4.73	mi., Length of Watercourse	V' =	93.31	cfs/Day
Lca =	1.83	mi., Distance to Centroid	Qs =	58.6	* q, cfs
Kn =	0.054	-, Ave. Weighted Manning's n			

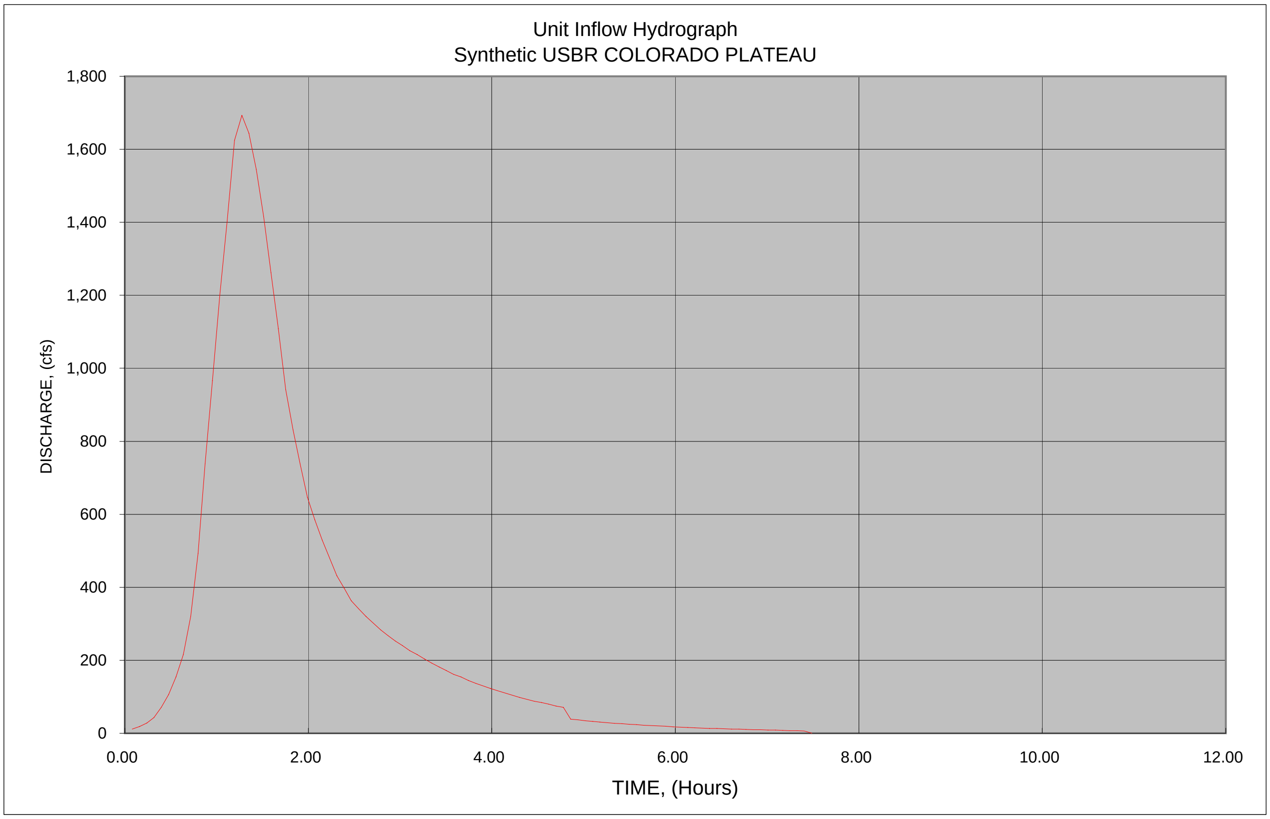
PARAMETERS:

Calculated: Lag Time, Lg = 1.47 Hours Unit Duration, D = 16.02 minutes

Calculated Timestep = 4.78 minutes

Data to be used Unit Duration, D = 15 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360

in Analysis Selected Timestep = 5 minutes, integer value evenly divisible into 60



Unit Inflow Hydrograph

Synthetic USBR COLORADO PLATEAU

UI Record - Unit Graph 5 **minute interval**

UI	11	20	30	48	79	119	174	254	392	606
UI	854	1096	1322	1546	1672	1657	1566	1438	1281	1120
UI	947	830	733	640	577	520	468	421	386	355
UI	332	311	292	275	258	244	231	218	206	194
UI	183	172	161	154	144	136	129	122	115	108
UI	102	96	91	86	82	77	72	69	64	61
UI	57	54	51	48	46	43	40	38	36	34
UI	32	30	29	27	26	24	23	22	20	20
UI	18	17	16	15	14	13	13	12	12	11
UI	10	10	9	9	8	7	7	7	3	
UI										
UI										
UI										
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USBR calculated unitgraph peak = 1693 Interpolated Peak = 1672

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.08	4.8	0.19	11	305.0	4.86	291.6	0.66	39
10.0	0.16	9.6	0.32	19	310.0	4.94	296.4	0.63	37
15.0	0.24	14.3	0.48	28	315.0	5.02	301.1	0.59	35
20.0	0.32	19.1	0.74	43	320.0	5.10	305.9	0.56	33
25.0	0.40	23.9	1.21	71	325.0	5.18	310.7	0.53	31
30.0	0.48	28.7	1.81	106	330.0	5.26	315.5	0.50	29
35.0	0.56	33.5	2.63	154	335.0	5.34	320.3	0.47	28
40.0	0.64	38.2	3.68	216	340.0	5.42	325.0	0.45	26
45.0	0.72	43.0	5.47	320	345.0	5.50	329.8	0.42	25
50.0	0.80	47.8	8.41	492	350.0	5.58	334.6	0.40	23
55.0	0.88	52.6	12.61	738	355.0	5.66	339.4	0.38	22
60.0	0.96	57.4	16.50	966	360.0	5.74	344.2	0.36	21
65.0	1.04	62.1	20.50	1,200	365.0	5.82	348.9	0.34	20
70.0	1.12	66.9	23.97	1,404	370.0	5.90	353.7	0.33	19
75.0	1.20	71.7	27.75	1,625	375.0	5.98	358.5	0.30	18
80.0	1.27	76.5	28.91	1,693	380.0	6.05	363.3	0.28	16
85.0	1.35	81.3	28.07	1,644	385.0	6.13	368.1	0.27	16
90.0	1.43	86.0	26.38	1,545	390.0	6.21	372.8	0.26	15
95.0	1.51	90.8	24.18	1,416	395.0	6.29	377.6	0.24	14
100.0	1.59	95.6	21.55	1,262	400.0	6.37	382.4	0.23	13
105.0	1.67	100.4	18.92	1,108	405.0	6.45	387.2	0.22	13
110.0	1.75	105.2	16.08	942	410.0	6.53	392.0	0.21	12
115.0	1.83	109.9	14.19	831	415.0	6.61	396.7	0.20	12
120.0	1.91	114.7	12.61	738	420.0	6.69	401.5	0.19	11
125.0	1.99	119.5	11.04	647	425.0	6.77	406.3	0.18	11
130.0	2.07	124.3	9.99	585	430.0	6.85	411.1	0.17	10
135.0	2.15	129.1	9.04	529	435.0	6.93	415.9	0.16	9
140.0	2.23	133.8	8.20	480	440.0	7.01	420.6	0.15	9
145.0	2.31	138.6	7.36	431	445.0	7.09	425.4	0.15	9
150.0	2.39	143.4	6.78	397	450.0	7.17	430.2	0.13	8
155.0	2.47	148.2	6.20	363	455.0	7.25	435.0	0.12	7
160.0	2.55	153.0	5.83	341	460.0	7.33	439.8	0.12	7
165.0	2.63	157.7	5.47	320	465.0	7.41	444.5	0.11	6
170.0	2.71	162.5	5.15	302	470.0	7.49	449.3		
175.0	2.79	167.3	4.84	283	475.0	7.57	454.1		
180.0	2.87	172.1	4.57	268	480.0	7.65	458.9		
185.0	2.95	176.9	4.31	252	485.0	7.73	463.7		
190.0	3.03	181.6	4.10	240	490.0	7.81	468.5		
195.0	3.11	186.4	3.87	227	495.0	7.89	473.2		
200.0	3.19	191.2	3.68	216	500.0	7.97	478.0		
205.0	3.27	196.0	3.47	203	505.0	8.05	482.8		
210.0	3.35	200.8	3.28	192	510.0	8.13	487.6		
215.0	3.43	205.5	3.10	182	515.0	8.21	492.4		
220.0	3.51	210.3	2.93	172	520.0	8.29	497.1		
225.0	3.59	215.1	2.75	161	525.0	8.37	501.9		
230.0	3.66	219.9	2.63	154	530.0	8.44	506.7		
235.0	3.74	224.7	2.47	145	535.0	8.52	511.5		
240.0	3.82	229.4	2.33	136	540.0	8.60	516.3		
245.0	3.90	234.2	2.22	130	545.0	8.68	521.0		
250.0	3.98	239.0	2.10	123	550.0	8.76	525.8		
255.0	4.06	243.8	1.99	117	555.0	8.84	530.6		
260.0	4.14	248.6	1.88	110	560.0	8.92	535.4		
265.0	4.22	253.3	1.78	104	565.0	9.00	540.2		
270.0	4.30	258.1	1.68	98	570.0	9.08	544.9		
275.0	4.38	262.9	1.59	93	575.0	9.16	549.7		
280.0	4.46	267.7	1.50	88	580.0	9.24	554.5		
285.0	4.54	272.5	1.43	84	585.0	9.32	559.3		
290.0	4.62	277.2	1.36	80	590.0	9.40	564.1		
295.0	4.70	282.0	1.28	75	595.0	9.48	568.8		
300.0	4.78	286.8	1.21	71	600.0	9.56	573.6		

NOTES : Use for models including Basin 3 for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

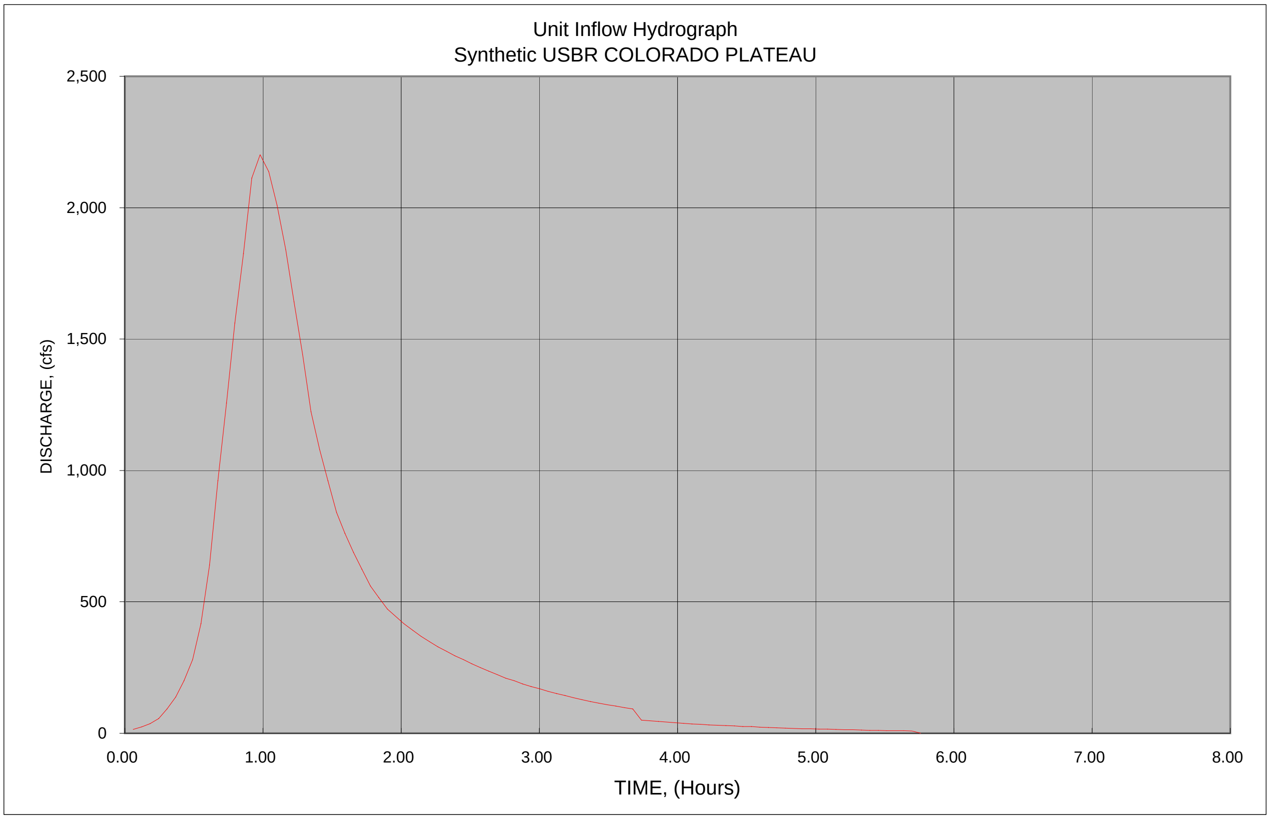
Basin 3-PMP Proposed Conditions

Drainage Area = 3.47 sq. miles
Basin Slope = 57.1 ft./mile
L = 4.73 mi., Length of Watercourse
Lca = 1.83 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 1.23 Hours
Basin Factor = 1.15
V' = 93.31 cfs/Day
Qs = 76.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 1.14 Hours
Unit Duration, D = 12.46 minutes
Calculated Timestep = 3.68 minutes

Data to be used in Analysis
Unit Duration, D = 10 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



UI Record - Unit Graph 5 **minute interval**

UI	18	33	59	112	188	302	533	922	1330	1720
UI	2102	2181	2050	1833	1561	1276	1066	903	773	675
UI	588	520	464	426	392	361	334	311	288	267
UI	248	229	211	197	182	169	157	146	135	125
UI	116	108	101	93	86	80	74	68	64	59
UI	55	51	48	44	41	38	35	32	30	28
UI	26	24	22	21	19	18	17	16	15	14
UI	13	11	11	9	9	5				
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USBR calculated unitgraph peak = 2201 Interpolated Peak = 2181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.06	3.7	0.19	14
10.0	0.12	7.4	0.32	24
15.0	0.18	11.0	0.48	37
20.0	0.25	14.7	0.74	56
25.0	0.31	18.4	1.21	92
30.0	0.37	22.1	1.81	138
35.0	0.43	25.7	2.63	200
40.0	0.49	29.4	3.68	280
45.0	0.55	33.1	5.47	417
50.0	0.61	36.8	8.41	640
55.0	0.67	40.4	12.61	960
60.0	0.74	44.1	16.50	1,256
65.0	0.80	47.8	20.50	1,561
70.0	0.86	51.5	23.97	1,825
75.0	0.92	55.1	27.75	2,113
80.0	0.98	58.8	28.91	2,201
85.0	1.04	62.5	28.07	2,137
90.0	1.10	66.2	26.38	2,009
95.0	1.16	69.8	24.18	1,841
100.0	1.23	73.5	21.55	1,641
105.0	1.29	77.2	18.92	1,441
110.0	1.35	80.9	16.08	1,224
115.0	1.41	84.6	14.19	1,081
120.0	1.47	88.2	12.61	960
125.0	1.53	91.9	11.04	841
130.0	1.59	95.6	9.99	761
135.0	1.65	99.3	9.04	688
140.0	1.72	102.9	8.20	624
145.0	1.78	106.6	7.36	560
150.0	1.84	110.3	6.78	516
155.0	1.90	114.0	6.20	472
160.0	1.96	117.6	5.83	444
165.0	2.02	121.3	5.47	417
170.0	2.08	125.0	5.15	392
175.0	2.14	128.7	4.84	369
180.0	2.21	132.3	4.57	348
185.0	2.27	136.0	4.31	328
190.0	2.33	139.7	4.10	312
195.0	2.39	143.4	3.87	295
200.0	2.45	147.0	3.68	280
205.0	2.51	150.7	3.47	264
210.0	2.57	154.4	3.28	250
215.0	2.63	158.1	3.10	236
220.0	2.70	161.8	2.93	223
225.0	2.76	165.4	2.75	209
230.0	2.82	169.1	2.63	200
235.0	2.88	172.8	2.47	188
240.0	2.94	176.5	2.33	177
245.0	3.00	180.1	2.22	169
250.0	3.06	183.8	2.10	160
255.0	3.12	187.5	1.99	152
260.0	3.19	191.2	1.88	143
265.0	3.25	194.8	1.78	136
270.0	3.31	198.5	1.68	128
275.0	3.37	202.2	1.59	121
280.0	3.43	205.9	1.50	114
285.0	3.49	209.5	1.43	109
290.0	3.55	213.2	1.36	104
295.0	3.61	216.9	1.28	97
300.0	3.68	220.6	1.21	92
305.0	3.74	224.2	0.66	50
310.0	3.80	227.9	0.63	48
315.0	3.86	231.6	0.59	45
320.0	3.92	235.3	0.56	43
325.0	3.98	239.0	0.53	40
330.0	4.04	242.6	0.50	38
335.0	4.11	246.3	0.47	36
340.0	4.17	250.0	0.45	34
345.0	4.23	253.7	0.42	32
350.0	4.29	257.3	0.40	30
355.0	4.35	261.0	0.38	29
360.0	4.41	264.7	0.36	27
365.0	4.47	268.4	0.34	26
370.0	4.53	272.0	0.33	25
375.0	4.60	275.7	0.30	23
380.0	4.66	279.4	0.28	21
385.0	4.72	283.1	0.27	21
390.0	4.78	286.7	0.26	20
395.0	4.84	290.4	0.24	18
400.0	4.90	294.1	0.23	18
405.0	4.96	297.8	0.22	17
410.0	5.02	301.4	0.21	16
415.0	5.09	305.1	0.20	15
420.0	5.15	308.8	0.19	14
425.0	5.21	312.5	0.18	14
430.0	5.27	316.2	0.17	13
435.0	5.33	319.8	0.16	12
440.0	5.39	323.5	0.15	11
445.0	5.45	327.2	0.15	11
450.0	5.51	330.9	0.13	10
455.0	5.58	334.5	0.12	9
460.0	5.64	338.2	0.12	9
465.0	5.70	341.9	0.11	8
470.0	5.76	345.6		
475.0	5.82	349.2		
480.0	5.88	352.9		
485.0	5.94	356.6		
490.0	6.00	360.3		
495.0	6.07	363.9		
500.0	6.13	367.6		
505.0	6.19	371.3		
510.0	6.25	375.0		
515.0	6.31	378.6		
520.0	6.37	382.3		
525.0	6.43	386.0		
530.0	6.49	389.7		
535.0	6.56	393.4		
540.0	6.62	397.0		
545.0	6.68	400.7		
550.0	6.74	404.4		
555.0	6.80	408.1		
560.0	6.86	411.7		
565.0	6.92	415.4		
570.0	6.98	419.1		
575.0	7.05	422.8		
580.0	7.11	426.4		
585.0	7.17	430.1		
590.0	7.23	433.8		
595.0	7.29	437.5		
600.0	7.35	441.1		

NOTES : Use for models including Basin 3 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

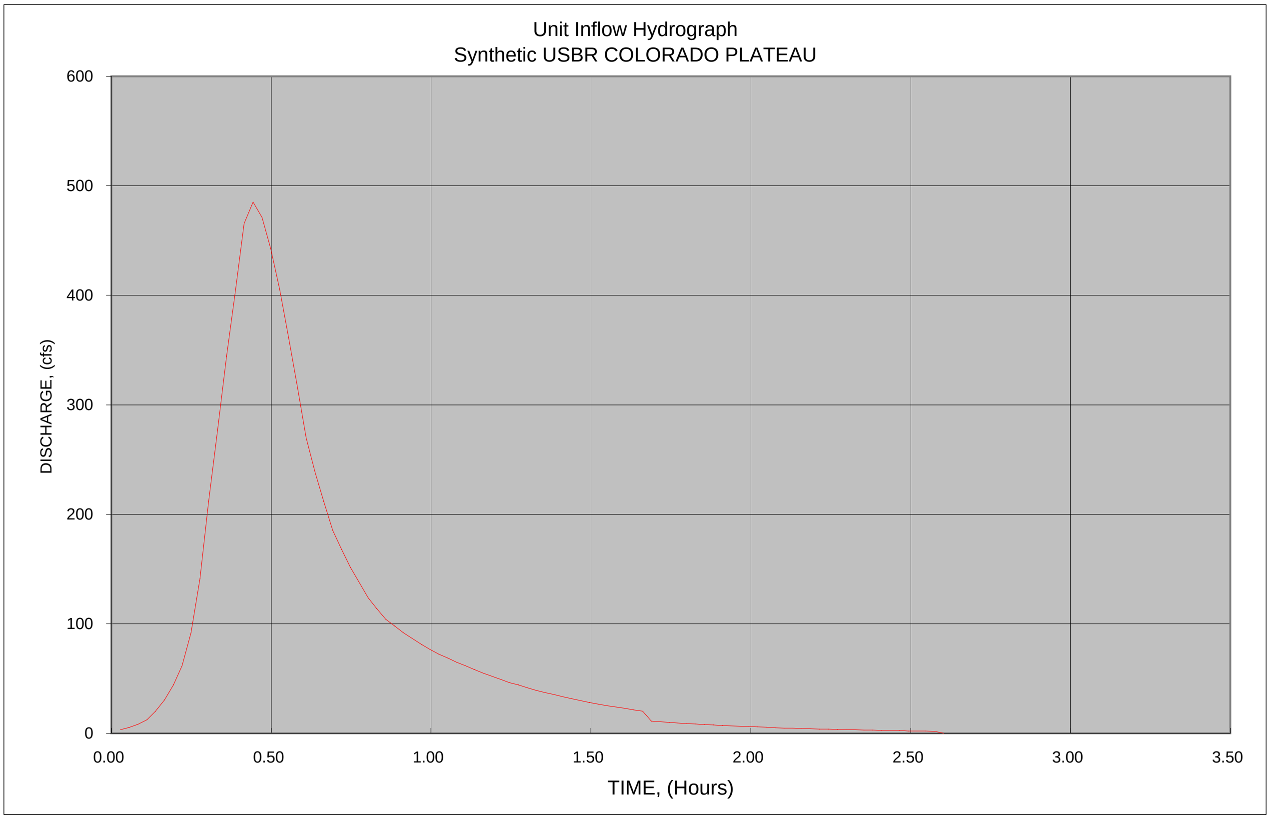
Basin A-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.3456 sq. miles
Basin Slope = 501 ft./mile
L = 1.55 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.55 Hours
Basin Factor = 0.05
V' = 9.29 cfs/Day
Qs = 16.8 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.51 Hours
Unit Duration, D = 5.59 minutes
Calculated Timestep = 1.66 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	8	31	93	279	467	441	314	210	151	113
UI	91	76	65	55	46	39	33	28	24	20
UI	17	14	12	10	9	7	6	5	4	4
UI	3	3	2	2						
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USBR calculated unitgraph peak = 485 Interpolated Peak = 467

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	3
10.0	0.06	3.3	0.32	5
15.0	0.08	5.0	0.48	8
20.0	0.11	6.6	0.74	12
25.0	0.14	8.3	1.21	20
30.0	0.17	10.0	1.81	30
35.0	0.19	11.6	2.63	44
40.0	0.22	13.3	3.68	62
45.0	0.25	15.0	5.47	92
50.0	0.28	16.6	8.41	141
55.0	0.30	18.3	12.61	212
60.0	0.33	19.9	16.50	277
65.0	0.36	21.6	20.50	344
70.0	0.39	23.3	23.97	402
75.0	0.42	24.9	27.75	466
80.0	0.44	26.6	28.91	485
85.0	0.47	28.2	28.07	471
90.0	0.50	29.9	26.38	443
95.0	0.53	31.6	24.18	406
100.0	0.55	33.2	21.55	362
105.0	0.58	34.9	18.92	317
110.0	0.61	36.6	16.08	270
115.0	0.64	38.2	14.19	238
120.0	0.66	39.9	12.61	212
125.0	0.69	41.5	11.04	185
130.0	0.72	43.2	9.99	168
135.0	0.75	44.9	9.04	152
140.0	0.78	46.5	8.20	138
145.0	0.80	48.2	7.36	123
150.0	0.83	49.8	6.78	114
155.0	0.86	51.5	6.20	104
160.0	0.89	53.2	5.83	98
165.0	0.91	54.8	5.47	92
170.0	0.94	56.5	5.15	86
175.0	0.97	58.2	4.84	81
180.0	1.00	59.8	4.57	77
185.0	1.02	61.5	4.31	72
190.0	1.05	63.1	4.10	69
195.0	1.08	64.8	3.87	65
200.0	1.11	66.5	3.68	62
205.0	1.14	68.1	3.47	58
210.0	1.16	69.8	3.28	55
215.0	1.19	71.4	3.10	52
220.0	1.22	73.1	2.93	49
225.0	1.25	74.8	2.75	46
230.0	1.27	76.4	2.63	44
235.0	1.30	78.1	2.47	41
240.0	1.33	79.8	2.33	39
245.0	1.36	81.4	2.22	37
250.0	1.38	83.1	2.10	35
255.0	1.41	84.7	1.99	33
260.0	1.44	86.4	1.88	32
265.0	1.47	88.1	1.78	30
270.0	1.50	89.7	1.68	28
275.0	1.52	91.4	1.59	27
280.0	1.55	93.0	1.50	25
285.0	1.58	94.7	1.43	24
290.0	1.61	96.4	1.36	23
295.0	1.63	98.0	1.28	21
300.0	1.66	99.7	1.21	20
305.0	1.69	101.4	0.66	11
310.0	1.72	103.0	0.63	11
315.0	1.74	104.7	0.59	10
320.0	1.77	106.3	0.56	9
325.0	1.80	108.0	0.53	9
330.0	1.83	109.7	0.50	8
335.0	1.86	111.3	0.47	8
340.0	1.88	113.0	0.45	8
345.0	1.91	114.6	0.42	7
350.0	1.94	116.3	0.40	7
355.0	1.97	118.0	0.38	6
360.0	1.99	119.6	0.36	6
365.0	2.02	121.3	0.34	6
370.0	2.05	123.0	0.33	6
375.0	2.08	124.6	0.30	5
380.0	2.10	126.3	0.28	5
385.0	2.13	127.9	0.27	5
390.0	2.16	129.6	0.26	4
395.0	2.19	131.3	0.24	4
400.0	2.22	132.9	0.23	4
405.0	2.24	134.6	0.22	4
410.0	2.27	136.2	0.21	4
415.0	2.30	137.9	0.20	3
420.0	2.33	139.6	0.19	3
425.0	2.35	141.2	0.18	3
430.0	2.38	142.9	0.17	3
435.0	2.41	144.6	0.16	3
440.0	2.44	146.2	0.15	3
445.0	2.46	147.9	0.15	3
450.0	2.49	149.5	0.13	2
455.0	2.52	151.2	0.12	2
460.0	2.55	152.9	0.12	2
465.0	2.58	154.5	0.11	2
470.0	2.60	156.2		
475.0	2.63	157.8		
480.0	2.66	159.5		
485.0	2.69	161.2		
490.0	2.71	162.8		
495.0	2.74	164.5		
500.0	2.77	166.2		
505.0	2.80	167.8		
510.0	2.82	169.5		
515.0	2.85	171.1		
520.0	2.88	172.8		
525.0	2.91	174.5		
530.0	2.94	176.1		
535.0	2.96	177.8		
540.0	2.99	179.4		
545.0	3.02	181.1		
550.0	3.05	182.8		
555.0	3.07	184.4		
560.0	3.10	186.1		
565.0	3.13	187.8		
570.0	3.16	189.4		
575.0	3.18	191.1		
580.0	3.21	192.7		
585.0	3.24	194.4		
590.0	3.27	196.1		
595.0	3.30	197.7		
600.0	3.32	199.4		

NOTES : Use for models including Basin A for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

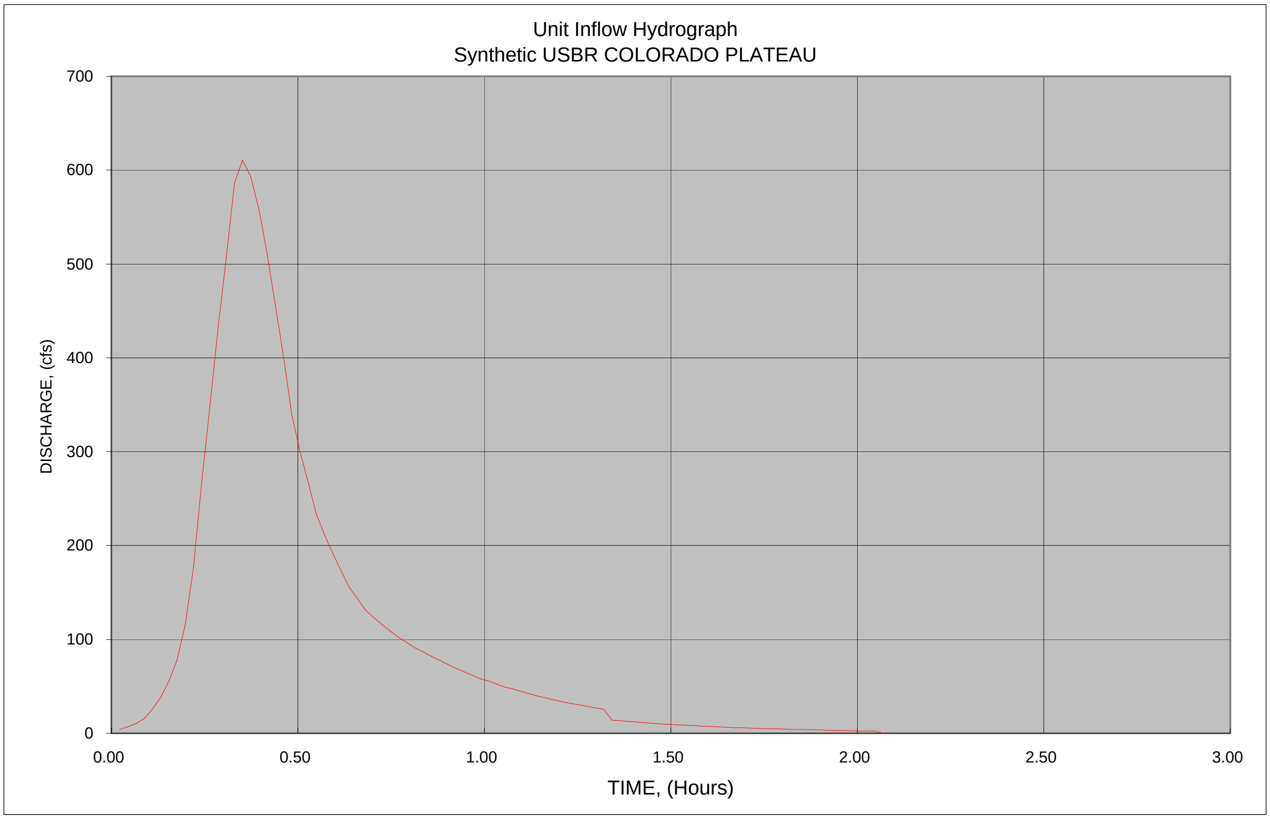
Basin A-PMP Proposed Conditions

Drainage Area = 0.3456 sq. miles
Basin Slope = 501 ft./mile
L = 1.55 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.44 Hours
Basin Factor = 0.05
V' = 9.29 cfs/Day
Qs = 21.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.40 Hours
Unit Duration, D = 4.35 minutes
Calculated Timestep = 1.32 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	14	68	296	590	514	311	201	140	108	87
UI	71	57	46	38	30	25	20	16	13	11
UI	9	7	6	5	4	3	2			
UI										
UI										
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USBR calculated unitgraph peak = 611 Interpolated Peak = 590

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.3	0.19	4
10.0	0.04	2.6	0.32	7
15.0	0.07	4.0	0.48	10
20.0	0.09	5.3	0.74	16
25.0	0.11	6.6	1.21	26
30.0	0.13	7.9	1.81	38
35.0	0.15	9.2	2.63	56
40.0	0.18	10.6	3.68	78
45.0	0.20	11.9	5.47	116
50.0	0.22	13.2	8.41	178
55.0	0.24	14.5	12.61	266
60.0	0.26	15.8	16.50	348
65.0	0.29	17.2	20.50	433
70.0	0.31	18.5	23.97	506
75.0	0.33	19.8	27.75	586
80.0	0.35	21.1	28.91	611
85.0	0.37	22.4	28.07	593
90.0	0.40	23.8	26.38	557
95.0	0.42	25.1	24.18	511
100.0	0.44	26.4	21.55	455
105.0	0.46	27.7	18.92	400
110.0	0.48	29.0	16.08	340
115.0	0.51	30.4	14.19	300
120.0	0.53	31.7	12.61	266
125.0	0.55	33.0	11.04	233
130.0	0.57	34.3	9.99	211
135.0	0.59	35.6	9.04	191
140.0	0.62	37.0	8.20	173
145.0	0.64	38.3	7.36	155
150.0	0.66	39.6	6.78	143
155.0	0.68	40.9	6.20	131
160.0	0.70	42.2	5.83	123
165.0	0.73	43.6	5.47	116
170.0	0.75	44.9	5.15	109
175.0	0.77	46.2	4.84	102
180.0	0.79	47.5	4.57	97
185.0	0.81	48.8	4.31	91
190.0	0.84	50.2	4.10	87
195.0	0.86	51.5	3.87	82
200.0	0.88	52.8	3.68	78
205.0	0.90	54.1	3.47	73
210.0	0.92	55.4	3.28	69
215.0	0.95	56.8	3.10	65
220.0	0.97	58.1	2.93	62
225.0	0.99	59.4	2.75	58
230.0	1.01	60.7	2.63	56
235.0	1.03	62.0	2.47	52
240.0	1.06	63.4	2.33	49
245.0	1.08	64.7	2.22	47
250.0	1.10	66.0	2.10	44
255.0	1.12	67.3	1.99	42
260.0	1.14	68.6	1.88	40
265.0	1.17	70.0	1.78	38
270.0	1.19	71.3	1.68	35
275.0	1.21	72.6	1.59	34
280.0	1.23	73.9	1.50	32
285.0	1.25	75.2	1.43	30
290.0	1.28	76.6	1.36	29
295.0	1.30	77.9	1.28	27
300.0	1.32	79.2	1.21	26
305.0	1.34	80.5	0.66	14
310.0	1.36	81.8	0.63	13
315.0	1.39	83.2	0.59	12
320.0	1.41	84.5	0.56	12
325.0	1.43	85.8	0.53	11
330.0	1.45	87.1	0.50	11
335.0	1.47	88.4	0.47	10
340.0	1.50	89.8	0.45	10
345.0	1.52	91.1	0.42	9
350.0	1.54	92.4	0.40	8
355.0	1.56	93.7	0.38	8
360.0	1.58	95.0	0.36	8
365.0	1.61	96.4	0.34	7
370.0	1.63	97.7	0.33	7
375.0	1.65	99.0	0.30	6
380.0	1.67	100.3	0.28	6
385.0	1.69	101.6	0.27	6
390.0	1.72	103.0	0.26	5
395.0	1.74	104.3	0.24	5
400.0	1.76	105.6	0.23	5
405.0	1.78	106.9	0.22	5
410.0	1.80	108.2	0.21	4
415.0	1.83	109.6	0.20	4
420.0	1.85	110.9	0.19	4
425.0	1.87	112.2	0.18	4
430.0	1.89	113.5	0.17	4
435.0	1.91	114.8	0.16	3
440.0	1.94	116.2	0.15	3
445.0	1.96	117.5	0.15	3
450.0	1.98	118.8	0.13	3
455.0	2.00	120.1	0.12	3
460.0	2.02	121.5	0.12	3
465.0	2.05	122.8	0.11	2
470.0	2.07	124.1		
475.0	2.09	125.4		
480.0	2.11	126.7		
485.0	2.13	128.1		
490.0	2.16	129.4		
495.0	2.18	130.7		
500.0	2.20	132.0		
505.0	2.22	133.3		
510.0	2.24	134.7		
515.0	2.27	136.0		
520.0	2.29	137.3		
525.0	2.31	138.6		
530.0	2.33	139.9		
535.0	2.35	141.3		
540.0	2.38	142.6		
545.0	2.40	143.9		
550.0	2.42	145.2		
555.0	2.44	146.5		
560.0	2.46	147.9		
565.0	2.49	149.2		
570.0	2.51	150.5		
575.0	2.53	151.8		
580.0	2.55	153.1		
585.0	2.57	154.5		
590.0	2.60	155.8		
595.0	2.62	157.1		
600.0	2.64	158.4		

NOTES : Use for models including Basin A for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

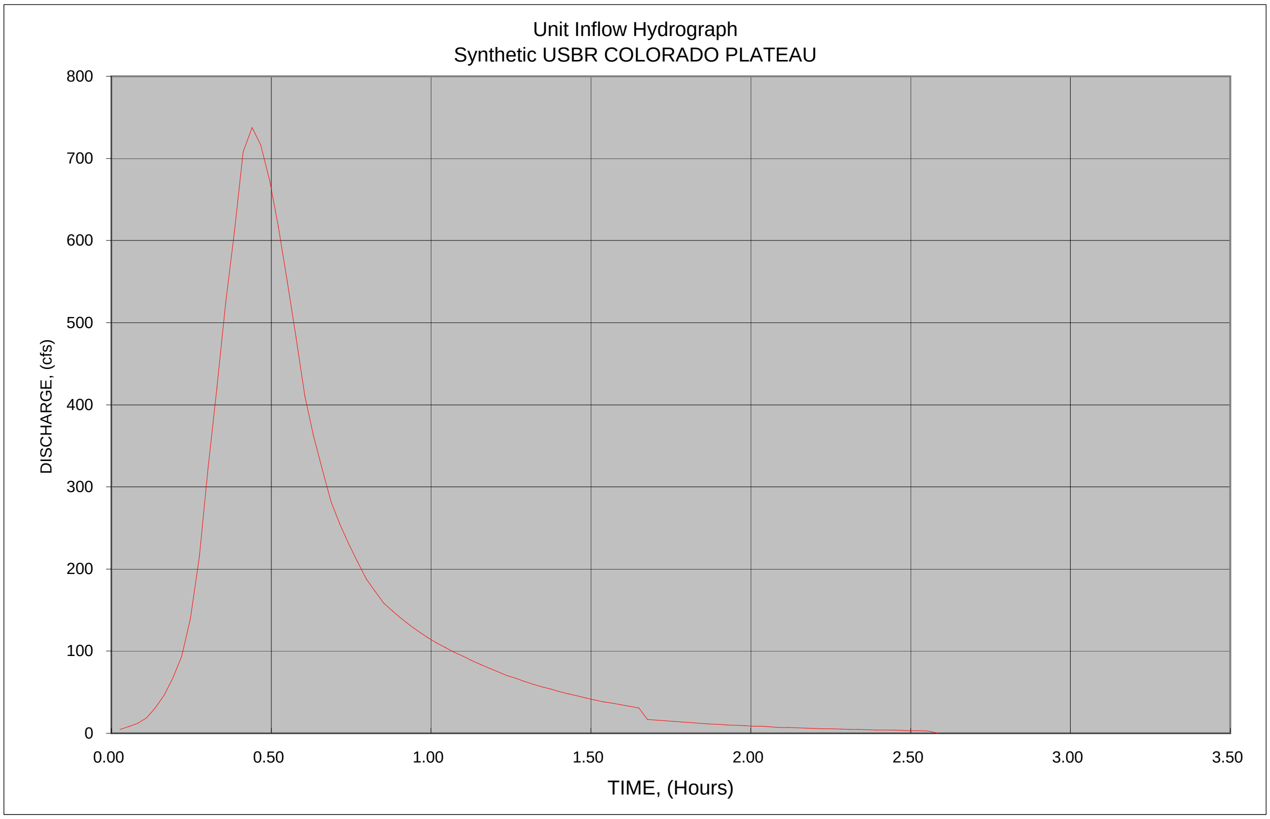
Basin B-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.5218 sq. miles
Basin Slope = 666 ft./mile
L = 1.38 mi., Length of Watercourse
Lca = 0.86 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.55 Hours
Basin Factor = 0.05
V' = 14.03 cfs/Day
Qs = 25.5 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.51 Hours
Unit Duration, D = 5.54 minutes
Calculated Timestep = 1.65 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	12	47	147	434	713	663	467	312	225	168
UI	137	114	97	82	69	58	49	42	35	30
UI	25	21	18	15	13	11	9	8	7	6
UI	5	4	3	3						
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USBR calculated unitgraph peak = 738 Interpolated Peak = 713

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.6	0.19	5	305.0	1.68	100.6	0.66	17
10.0	0.05	3.3	0.32	8	310.0	1.70	102.3	0.63	16
15.0	0.08	4.9	0.48	12	315.0	1.73	103.9	0.59	15
20.0	0.11	6.6	0.74	19	320.0	1.76	105.6	0.56	14
25.0	0.14	8.2	1.21	31	325.0	1.79	107.2	0.53	14
30.0	0.16	9.9	1.81	46	330.0	1.81	108.9	0.50	13
35.0	0.19	11.5	2.63	67	335.0	1.84	110.5	0.47	12
40.0	0.22	13.2	3.68	94	340.0	1.87	112.2	0.45	11
45.0	0.25	14.8	5.47	140	345.0	1.90	113.8	0.42	11
50.0	0.27	16.5	8.41	215	350.0	1.92	115.5	0.40	10
55.0	0.30	18.1	12.61	322	355.0	1.95	117.1	0.38	10
60.0	0.33	19.8	16.50	421	360.0	1.98	118.8	0.36	9
65.0	0.36	21.4	20.50	523	365.0	2.01	120.4	0.34	9
70.0	0.38	23.1	23.97	612	370.0	2.03	122.1	0.33	8
75.0	0.41	24.7	27.75	708	375.0	2.06	123.7	0.30	8
80.0	0.44	26.4	28.91	738	380.0	2.09	125.4	0.28	7
85.0	0.47	28.0	28.07	716	385.0	2.12	127.0	0.27	7
90.0	0.49	29.7	26.38	673	390.0	2.14	128.7	0.26	7
95.0	0.52	31.3	24.18	617	395.0	2.17	130.3	0.24	6
100.0	0.55	33.0	21.55	550	400.0	2.20	132.0	0.23	6
105.0	0.58	34.6	18.92	483	405.0	2.23	133.6	0.22	6
110.0	0.60	36.3	16.08	410	410.0	2.25	135.3	0.21	5
115.0	0.63	37.9	14.19	362	415.0	2.28	136.9	0.20	5
120.0	0.66	39.6	12.61	322	420.0	2.31	138.6	0.19	5
125.0	0.69	41.2	11.04	282	425.0	2.34	140.2	0.18	5
130.0	0.71	42.9	9.99	255	430.0	2.36	141.9	0.17	4
135.0	0.74	44.5	9.04	231	435.0	2.39	143.5	0.16	4
140.0	0.77	46.2	8.20	209	440.0	2.42	145.2	0.15	4
145.0	0.80	47.8	7.36	188	445.0	2.45	146.8	0.15	4
150.0	0.82	49.5	6.78	173	450.0	2.47	148.5	0.13	3
155.0	0.85	51.1	6.20	158	455.0	2.50	150.1	0.12	3
160.0	0.88	52.8	5.83	149	460.0	2.53	151.8	0.12	3
165.0	0.91	54.4	5.47	140	465.0	2.56	153.4	0.11	3
170.0	0.93	56.1	5.15	131	470.0	2.58	155.1		
175.0	0.96	57.7	4.84	124	475.0	2.61	156.7		
180.0	0.99	59.4	4.57	117	480.0	2.64	158.4		
185.0	1.02	61.0	4.31	110	485.0	2.67	160.0		
190.0	1.04	62.7	4.10	105	490.0	2.69	161.7		
195.0	1.07	64.3	3.87	99	495.0	2.72	163.3		
200.0	1.10	66.0	3.68	94	500.0	2.75	165.0		
205.0	1.13	67.6	3.47	89	505.0	2.78	166.6		
210.0	1.15	69.3	3.28	84	510.0	2.80	168.3		
215.0	1.18	70.9	3.10	79	515.0	2.83	169.9		
220.0	1.21	72.6	2.93	75	520.0	2.86	171.6		
225.0	1.24	74.2	2.75	70	525.0	2.89	173.2		
230.0	1.26	75.9	2.63	67	530.0	2.91	174.9		
235.0	1.29	77.5	2.47	63	535.0	2.94	176.5		
240.0	1.32	79.2	2.33	59	540.0	2.97	178.2		
245.0	1.35	80.8	2.22	57	545.0	3.00	179.8		
250.0	1.37	82.5	2.10	54	550.0	3.02	181.5		
255.0	1.40	84.1	1.99	51	555.0	3.05	183.1		
260.0	1.43	85.8	1.88	48	560.0	3.08	184.8		
265.0	1.46	87.4	1.78	45	565.0	3.11	186.4		
270.0	1.48	89.1	1.68	43	570.0	3.13	188.1		
275.0	1.51	90.7	1.59	41	575.0	3.16	189.7		
280.0	1.54	92.4	1.50	38	580.0	3.19	191.4		
285.0	1.57	94.0	1.43	36	585.0	3.22	193.0		
290.0	1.59	95.7	1.36	35	590.0	3.24	194.7		
295.0	1.62	97.3	1.28	33	595.0	3.27	196.3		
300.0	1.65	99.0	1.21	31	600.0	3.30	198.0		

NOTES : Use for models including Basin B for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

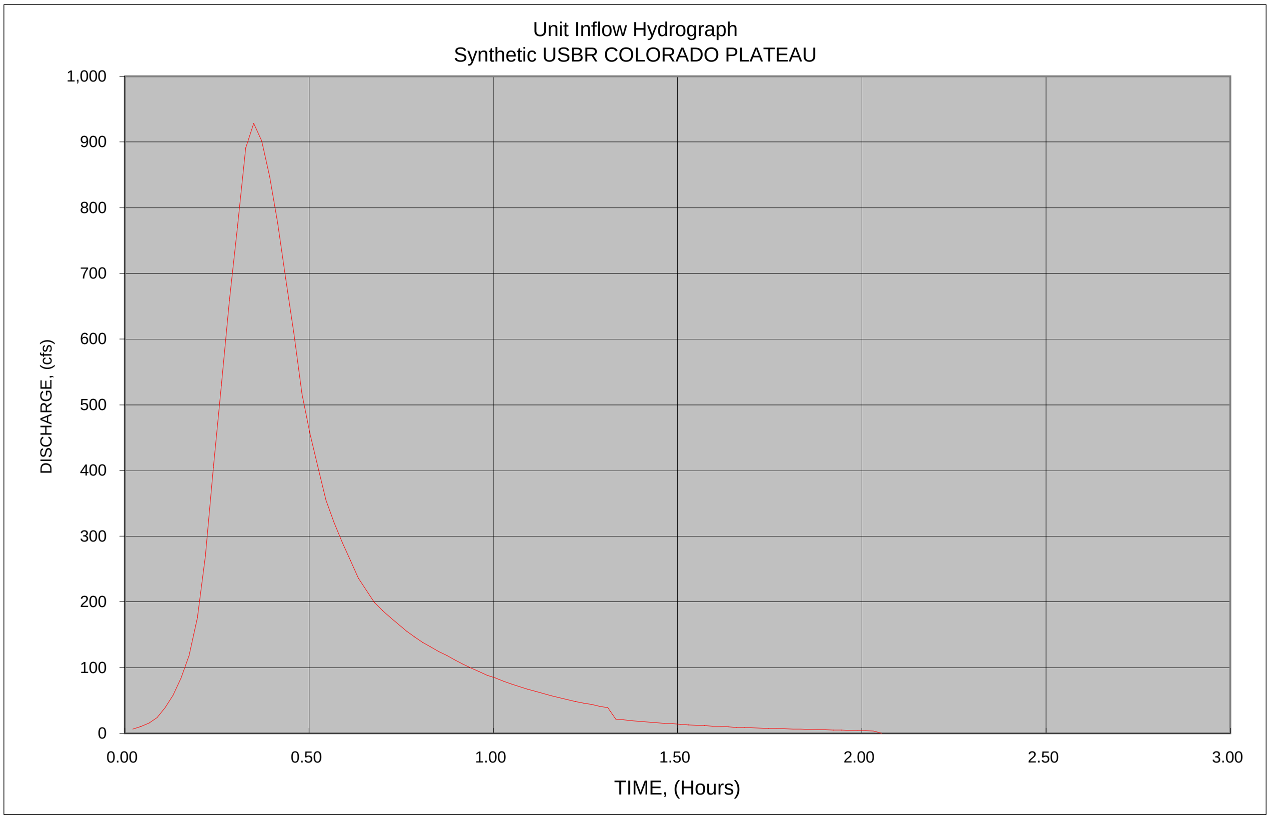
Basin B-PMP Proposed Conditions

Drainage Area = 0.5218 sq. miles
Basin Slope = 666 ft./mile
L = 1.38 mi., Length of Watercourse
Lca = 0.86 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.44 Hours
Basin Factor = 0.05
V' = 14.03 cfs/Day
Qs = 32.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.40 Hours
Unit Duration, D = 4.31 minutes
Calculated Timestep = 1.31 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	22	106	460	901	770	463	299	208	162	131
UI	106	85	69	56	45	37	30	24	20	16
UI	13	11	8	7	6	5	4			
UI										
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USBR calculated unitgraph peak = 928 Interpolated Peak = 901

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.3	0.19	6	305.0	1.33	80.0	0.66	21
10.0	0.04	2.6	0.32	10	310.0	1.35	81.3	0.63	20
15.0	0.07	3.9	0.48	15	315.0	1.38	82.6	0.59	19
20.0	0.09	5.2	0.74	24	320.0	1.40	83.9	0.56	18
25.0	0.11	6.6	1.21	39	325.0	1.42	85.2	0.53	17
30.0	0.13	7.9	1.81	58	330.0	1.44	86.5	0.50	16
35.0	0.15	9.2	2.63	84	335.0	1.46	87.8	0.47	15
40.0	0.17	10.5	3.68	118	340.0	1.49	89.1	0.45	14
45.0	0.20	11.8	5.47	176	345.0	1.51	90.4	0.42	13
50.0	0.22	13.1	8.41	270	350.0	1.53	91.8	0.40	13
55.0	0.24	14.4	12.61	405	355.0	1.55	93.1	0.38	12
60.0	0.26	15.7	16.50	530	360.0	1.57	94.4	0.36	12
65.0	0.28	17.0	20.50	658	365.0	1.59	95.7	0.34	11
70.0	0.31	18.4	23.97	770	370.0	1.62	97.0	0.33	11
75.0	0.33	19.7	27.75	891	375.0	1.64	98.3	0.30	10
80.0	0.35	21.0	28.91	928	380.0	1.66	99.6	0.28	9
85.0	0.37	22.3	28.07	901	385.0	1.68	100.9	0.27	9
90.0	0.39	23.6	26.38	847	390.0	1.70	102.2	0.26	8
95.0	0.42	24.9	24.18	776	395.0	1.73	103.6	0.24	8
100.0	0.44	26.2	21.55	692	400.0	1.75	104.9	0.23	7
105.0	0.46	27.5	18.92	608	405.0	1.77	106.2	0.22	7
110.0	0.48	28.8	16.08	516	410.0	1.79	107.5	0.21	7
115.0	0.50	30.1	14.19	456	415.0	1.81	108.8	0.20	6
120.0	0.52	31.5	12.61	405	420.0	1.84	110.1	0.19	6
125.0	0.55	32.8	11.04	355	425.0	1.86	111.4	0.18	6
130.0	0.57	34.1	9.99	321	430.0	1.88	112.7	0.17	5
135.0	0.59	35.4	9.04	290	435.0	1.90	114.0	0.16	5
140.0	0.61	36.7	8.20	263	440.0	1.92	115.4	0.15	5
145.0	0.63	38.0	7.36	236	445.0	1.94	116.7	0.15	5
150.0	0.66	39.3	6.78	218	450.0	1.97	118.0	0.13	4
155.0	0.68	40.6	6.20	199	455.0	1.99	119.3	0.12	4
160.0	0.70	41.9	5.83	187	460.0	2.01	120.6	0.12	4
165.0	0.72	43.3	5.47	176	465.0	2.03	121.9	0.11	4
170.0	0.74	44.6	5.15	165	470.0	2.05	123.2		
175.0	0.76	45.9	4.84	155	475.0	2.08	124.5		
180.0	0.79	47.2	4.57	147	480.0	2.10	125.8		
185.0	0.81	48.5	4.31	138	485.0	2.12	127.1		
190.0	0.83	49.8	4.10	132	490.0	2.14	128.5		
195.0	0.85	51.1	3.87	124	495.0	2.16	129.8		
200.0	0.87	52.4	3.68	118	500.0	2.18	131.1		
205.0	0.90	53.7	3.47	111	505.0	2.21	132.4		
210.0	0.92	55.1	3.28	105	510.0	2.23	133.7		
215.0	0.94	56.4	3.10	100	515.0	2.25	135.0		
220.0	0.96	57.7	2.93	94	520.0	2.27	136.3		
225.0	0.98	59.0	2.75	88	525.0	2.29	137.6		
230.0	1.00	60.3	2.63	84	530.0	2.32	138.9		
235.0	1.03	61.6	2.47	79	535.0	2.34	140.3		
240.0	1.05	62.9	2.33	75	540.0	2.36	141.6		
245.0	1.07	64.2	2.22	71	545.0	2.38	142.9		
250.0	1.09	65.5	2.10	67	550.0	2.40	144.2		
255.0	1.11	66.9	1.99	64	555.0	2.42	145.5		
260.0	1.14	68.2	1.88	60	560.0	2.45	146.8		
265.0	1.16	69.5	1.78	57	565.0	2.47	148.1		
270.0	1.18	70.8	1.68	54	570.0	2.49	149.4		
275.0	1.20	72.1	1.59	51	575.0	2.51	150.7		
280.0	1.22	73.4	1.50	48	580.0	2.53	152.1		
285.0	1.25	74.7	1.43	46	585.0	2.56	153.4		
290.0	1.27	76.0	1.36	44	590.0	2.58	154.7		
295.0	1.29	77.3	1.28	41	595.0	2.60	156.0		
300.0	1.31	78.6	1.21	39	600.0	2.62	157.3		

NOTES : Use for models including Basin B for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Basin for Culvert C7-10, 25, 100, 200 Proposed Conditions

Drainage Area =	0.4087	sq. miles	Lg+D/2 =	0.51	Hours
Basin Slope =	501	ft./mile	Basin Factor =	0.04	
L =	1.27	mi., Length of Watercourse	V' =	10.99	cfs/Day
Lca =	0.62	mi., Distance to Centroid	Qs =	21.7	* q, cfs
Kn =	0.054	-, Ave. Weighted Manning's n			

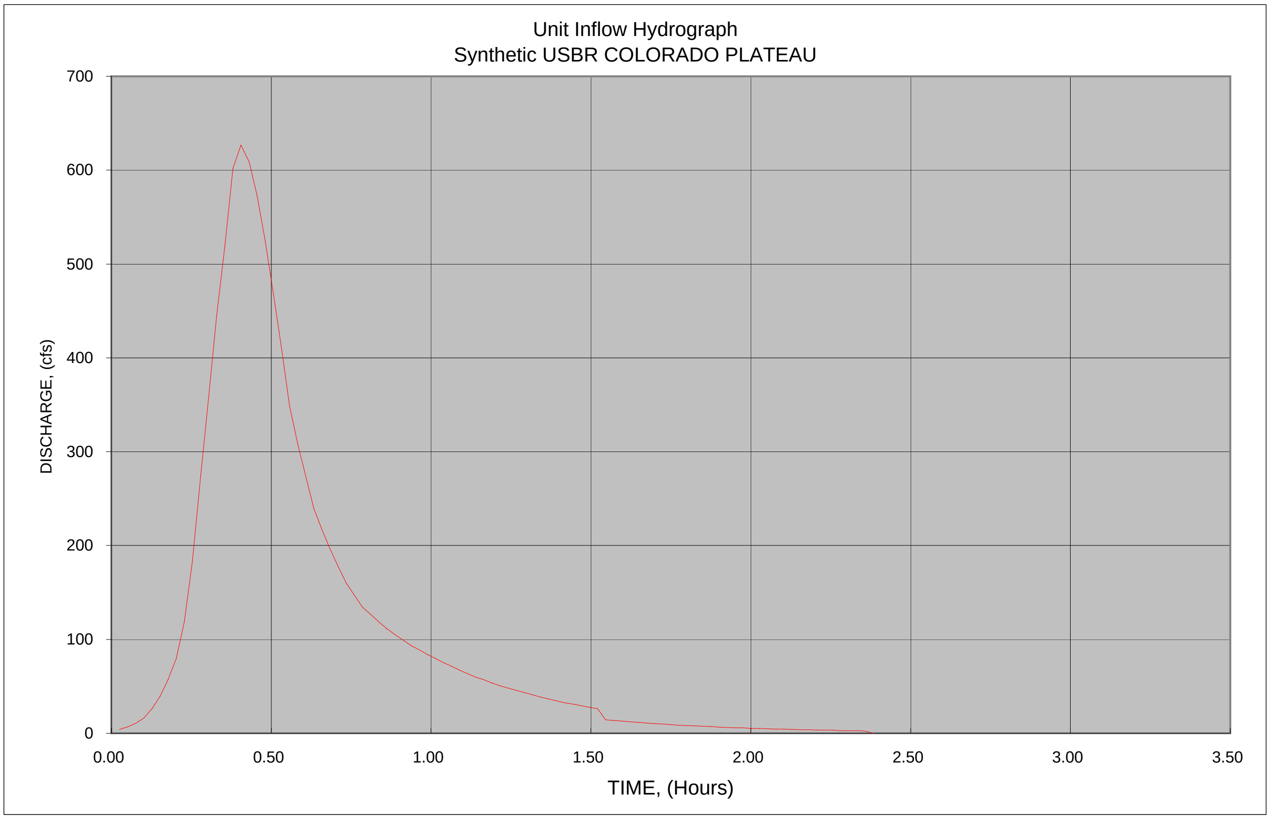
PARAMETERS:

Calculated: Lag Time, Lg = 0.47 Hours Unit Duration, D = 5.07 minutes

Calculated Timestep = 1.52 minutes

Data to be used Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360

in Analysis Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	12	49	174	456	619	483	307	210	152	120
UI	98	82	68	57	47	39	33	27	23	19
UI	16	13	11	9	8	6	5	5	4	3
UI	3									
UI										
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USBR calculated unitgraph peak = 627 Interpolated Peak = 619

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.5	0.19	4	305.0	1.55	92.8	0.66	14
10.0	0.05	3.0	0.32	7	310.0	1.57	94.3	0.63	14
15.0	0.08	4.6	0.48	10	315.0	1.60	95.8	0.59	13
20.0	0.10	6.1	0.74	16	320.0	1.62	97.3	0.56	12
25.0	0.13	7.6	1.21	26	325.0	1.65	98.8	0.53	11
30.0	0.15	9.1	1.81	39	330.0	1.67	100.4	0.50	11
35.0	0.18	10.6	2.63	57	335.0	1.70	101.9	0.47	10
40.0	0.20	12.2	3.68	80	340.0	1.72	103.4	0.45	10
45.0	0.23	13.7	5.47	119	345.0	1.75	104.9	0.42	9
50.0	0.25	15.2	8.41	182	350.0	1.77	106.4	0.40	9
55.0	0.28	16.7	12.61	273	355.0	1.80	108.0	0.38	8
60.0	0.30	18.2	16.50	358	360.0	1.82	109.5	0.36	8
65.0	0.33	19.8	20.50	444	365.0	1.85	111.0	0.34	7
70.0	0.35	21.3	23.97	520	370.0	1.88	112.5	0.33	7
75.0	0.38	22.8	27.75	602	375.0	1.90	114.0	0.30	7
80.0	0.41	24.3	28.91	627	380.0	1.93	115.6	0.28	6
85.0	0.43	25.9	28.07	609	385.0	1.95	117.1	0.27	6
90.0	0.46	27.4	26.38	572	390.0	1.98	118.6	0.26	6
95.0	0.48	28.9	24.18	524	395.0	2.00	120.1	0.24	5
100.0	0.51	30.4	21.55	467	400.0	2.03	121.6	0.23	5
105.0	0.53	31.9	18.92	410	405.0	2.05	123.2	0.22	5
110.0	0.56	33.5	16.08	349	410.0	2.08	124.7	0.21	5
115.0	0.58	35.0	14.19	308	415.0	2.10	126.2	0.20	4
120.0	0.61	36.5	12.61	273	420.0	2.13	127.7	0.19	4
125.0	0.63	38.0	11.04	239	425.0	2.15	129.3	0.18	4
130.0	0.66	39.5	9.99	217	430.0	2.18	130.8	0.17	4
135.0	0.68	41.1	9.04	196	435.0	2.20	132.3	0.16	3
140.0	0.71	42.6	8.20	178	440.0	2.23	133.8	0.15	3
145.0	0.73	44.1	7.36	160	445.0	2.26	135.3	0.15	3
150.0	0.76	45.6	6.78	147	450.0	2.28	136.9	0.13	3
155.0	0.79	47.1	6.20	134	455.0	2.31	138.4	0.12	3
160.0	0.81	48.7	5.83	126	460.0	2.33	139.9	0.12	3
165.0	0.84	50.2	5.47	119	465.0	2.36	141.4	0.11	2
170.0	0.86	51.7	5.15	112	470.0	2.38	142.9		
175.0	0.89	53.2	4.84	105	475.0	2.41	144.5		
180.0	0.91	54.7	4.57	99	480.0	2.43	146.0		
185.0	0.94	56.3	4.31	93	485.0	2.46	147.5		
190.0	0.96	57.8	4.10	89	490.0	2.48	149.0		
195.0	0.99	59.3	3.87	84	495.0	2.51	150.5		
200.0	1.01	60.8	3.68	80	500.0	2.53	152.1		
205.0	1.04	62.3	3.47	75	505.0	2.56	153.6		
210.0	1.06	63.9	3.28	71	510.0	2.59	155.1		
215.0	1.09	65.4	3.10	67	515.0	2.61	156.6		
220.0	1.12	66.9	2.93	64	520.0	2.64	158.1		
225.0	1.14	68.4	2.75	60	525.0	2.66	159.7		
230.0	1.17	69.9	2.63	57	530.0	2.69	161.2		
235.0	1.19	71.5	2.47	54	535.0	2.71	162.7		
240.0	1.22	73.0	2.33	51	540.0	2.74	164.2		
245.0	1.24	74.5	2.22	48	545.0	2.76	165.7		
250.0	1.27	76.0	2.10	46	550.0	2.79	167.3		
255.0	1.29	77.6	1.99	43	555.0	2.81	168.8		
260.0	1.32	79.1	1.88	41	560.0	2.84	170.3		
265.0	1.34	80.6	1.78	39	565.0	2.86	171.8		
270.0	1.37	82.1	1.68	36	570.0	2.89	173.3		
275.0	1.39	83.6	1.59	34	575.0	2.91	174.9		
280.0	1.42	85.2	1.50	33	580.0	2.94	176.4		
285.0	1.44	86.7	1.43	31	585.0	2.97	177.9		
290.0	1.47	88.2	1.36	29	590.0	2.99	179.4		
295.0	1.50	89.7	1.28	28	595.0	3.02	181.0		
300.0	1.52	91.2	1.21	26	600.0	3.04	182.5		

NOTES : Use for models including the Culvert C7 Basin for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

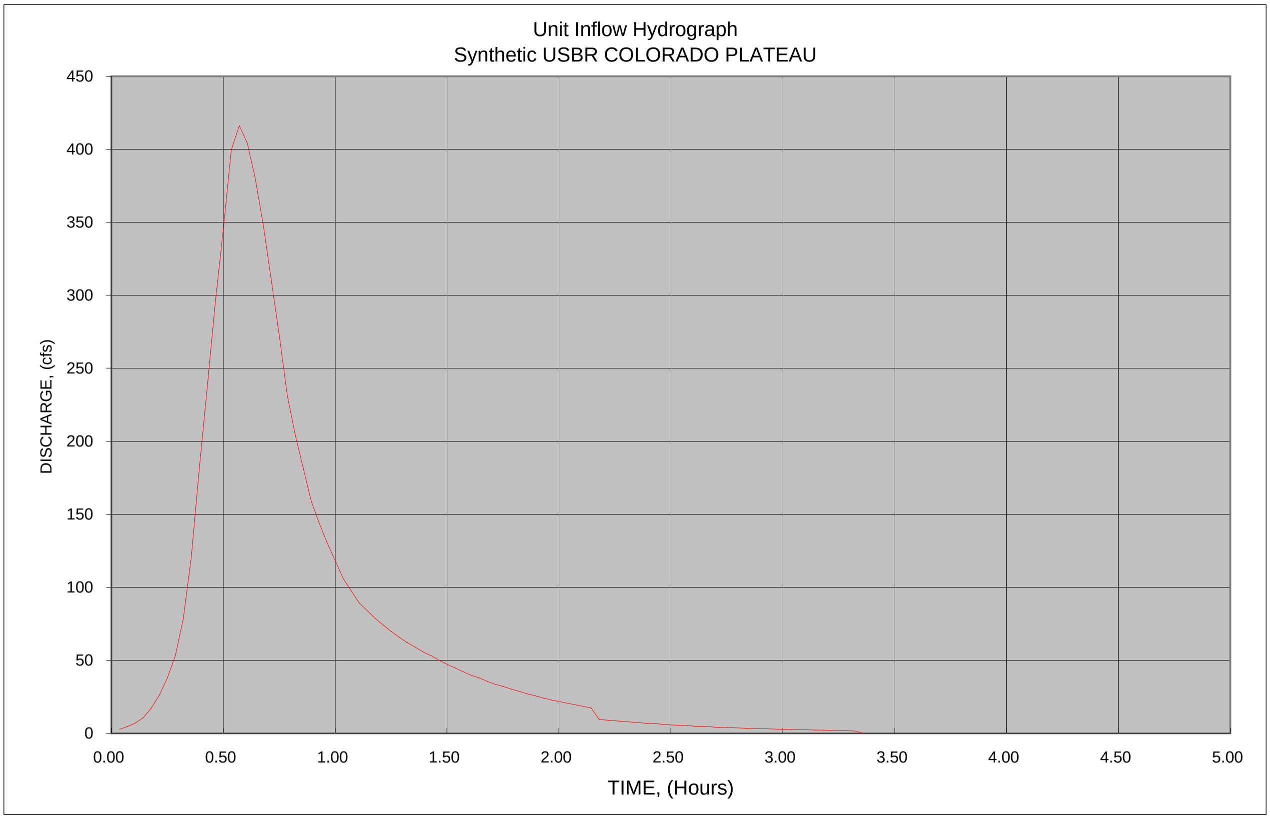
Basin D-10, 25, 100, 200 Proposed Conditions

Drainage Area =	0.3827	sq. miles	Lg+D/2 =	0.71	Hours
Basin Slope =	62.23	ft./mile	Basin Factor =	0.11	
L =	1.25	mi., Length of Watercourse	V' =	10.29	cfs/Day
Lca =	0.68	mi., Distance to Centroid	Qs =	14.4	* q, cfs
Kn =	0.054	-, Ave. Weighted Manning's n			

PARAMETERS:

Calculated:	Lag Time, Lg =	0.67 Hours	Unit Duration, D =	7.34	minutes
			Calculated Timestep =	2.14	minutes

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



UI Record - Unit Graph 5 **minute interval**

UI	5	15	38	93	218	345	412	359	273	197
UI	149	118	95	81	70	61	54	47	41	36
UI	32	28	25	22	19	17	15	13	11	10
UI	9	8	7	6	5	5	4	4	3	3
UI	3	2	2	2						
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USBR calculated unitgraph peak = 416 Interpolated Peak = 412

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.1	0.19	3
10.0	0.07	4.3	0.32	5
15.0	0.11	6.4	0.48	7
20.0	0.14	8.6	0.74	11
25.0	0.18	10.7	1.21	17
30.0	0.21	12.9	1.81	26
35.0	0.25	15.0	2.63	38
40.0	0.29	17.2	3.68	53
45.0	0.32	19.3	5.47	79
50.0	0.36	21.4	8.41	121
55.0	0.39	23.6	12.61	182
60.0	0.43	25.7	16.50	238
65.0	0.46	27.9	20.50	295
70.0	0.50	30.0	23.97	345
75.0	0.54	32.2	27.75	400
80.0	0.57	34.3	28.91	416
85.0	0.61	36.5	28.07	404
90.0	0.64	38.6	26.38	380
95.0	0.68	40.7	24.18	348
100.0	0.71	42.9	21.55	310
105.0	0.75	45.0	18.92	272
110.0	0.79	47.2	16.08	232
115.0	0.82	49.3	14.19	204
120.0	0.86	51.5	12.61	182
125.0	0.89	53.6	11.04	159
130.0	0.93	55.8	9.99	144
135.0	0.96	57.9	9.04	130
140.0	1.00	60.0	8.20	118
145.0	1.04	62.2	7.36	106
150.0	1.07	64.3	6.78	98
155.0	1.11	66.5	6.20	89
160.0	1.14	68.6	5.83	84
165.0	1.18	70.8	5.47	79
170.0	1.22	72.9	5.15	74
175.0	1.25	75.0	4.84	70
180.0	1.29	77.2	4.57	66
185.0	1.32	79.3	4.31	62
190.0	1.36	81.5	4.10	59
195.0	1.39	83.6	3.87	56
200.0	1.43	85.8	3.68	53
205.0	1.47	87.9	3.47	50
210.0	1.50	90.1	3.28	47
215.0	1.54	92.2	3.10	45
220.0	1.57	94.3	2.93	42
225.0	1.61	96.5	2.75	40
230.0	1.64	98.6	2.63	38
235.0	1.68	100.8	2.47	36
240.0	1.72	102.9	2.33	34
245.0	1.75	105.1	2.22	32
250.0	1.79	107.2	2.10	30
255.0	1.82	109.4	1.99	29
260.0	1.86	111.5	1.88	27
265.0	1.89	113.6	1.78	26
270.0	1.93	115.8	1.68	24
275.0	1.97	117.9	1.59	23
280.0	2.00	120.1	1.50	22
285.0	2.04	122.2	1.43	21
290.0	2.07	124.4	1.36	20
295.0	2.11	126.5	1.28	18
300.0	2.14	128.7	1.21	17
305.0	2.18	130.8	0.66	10
310.0	2.22	132.9	0.63	9
315.0	2.25	135.1	0.59	8
320.0	2.29	137.2	0.56	8
325.0	2.32	139.4	0.53	8
330.0	2.36	141.5	0.50	7
335.0	2.39	143.7	0.47	7
340.0	2.43	145.8	0.45	6
345.0	2.47	148.0	0.42	6
350.0	2.50	150.1	0.40	6
355.0	2.54	152.2	0.38	5
360.0	2.57	154.4	0.36	5
365.0	2.61	156.5	0.34	5
370.0	2.64	158.7	0.33	5
375.0	2.68	160.8	0.30	4
380.0	2.72	163.0	0.28	4
385.0	2.75	165.1	0.27	4
390.0	2.79	167.3	0.26	4
395.0	2.82	169.4	0.24	3
400.0	2.86	171.5	0.23	3
405.0	2.89	173.7	0.22	3
410.0	2.93	175.8	0.21	3
415.0	2.97	178.0	0.20	3
420.0	3.00	180.1	0.19	3
425.0	3.04	182.3	0.18	3
430.0	3.07	184.4	0.17	2
435.0	3.11	186.5	0.16	2
440.0	3.14	188.7	0.15	2
445.0	3.18	190.8	0.15	2
450.0	3.22	193.0	0.13	2
455.0	3.25	195.1	0.12	2
460.0	3.29	197.3	0.12	2
465.0	3.32	199.4	0.11	2
470.0	3.36	201.6		
475.0	3.40	203.7		
480.0	3.43	205.8		
485.0	3.47	208.0		
490.0	3.50	210.1		
495.0	3.54	212.3		
500.0	3.57	214.4		
505.0	3.61	216.6		
510.0	3.65	218.7		
515.0	3.68	220.9		
520.0	3.72	223.0		
525.0	3.75	225.1		
530.0	3.79	227.3		
535.0	3.82	229.4		
540.0	3.86	231.6		
545.0	3.90	233.7		
550.0	3.93	235.9		
555.0	3.97	238.0		
560.0	4.00	240.2		
565.0	4.04	242.3		
570.0	4.07	244.4		
575.0	4.11	246.6		
580.0	4.15	248.7		
585.0	4.18	250.9		
590.0	4.22	253.0		
595.0	4.25	255.2		
600.0	4.29	257.3		

NOTES : Use for models including Basin D for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin D-PMP Proposed Conditions

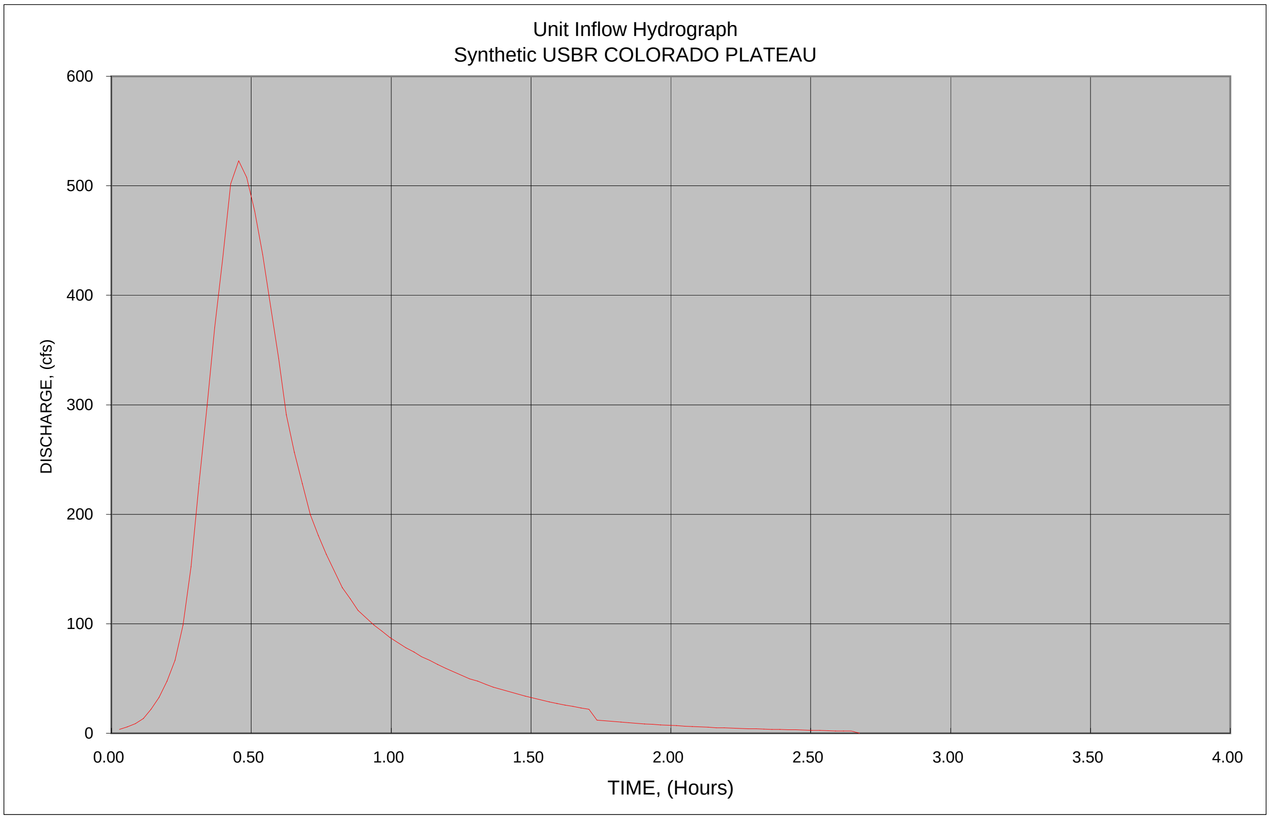
Drainage Area = 0.3827 sq. miles
Basin Slope = 62.37 ft./mile
L = 1.28 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.57 Hours
Basin Factor = 0.11
V' = 10.29 cfs/Day
Qs = 18.1 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.53 Hours
Unit Duration, D = 5.75 minutes
Calculated Timestep = 1.71 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	8	31	92	278	477	490	366	244	175	130
UI	104	87	74	63	53	45	38	33	28	24
UI	20	17	15	12	11	9	8	7	5	5
UI	4	3	3	3	2					
UI										
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USBR calculated unitgraph peak = 523 Interpolated Peak = 490

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	3	305.0	1.74	104.1	0.66	12
10.0	0.06	3.4	0.32	6	310.0	1.76	105.9	0.63	11
15.0	0.09	5.1	0.48	9	315.0	1.79	107.6	0.59	11
20.0	0.11	6.8	0.74	13	320.0	1.82	109.3	0.56	10
25.0	0.14	8.5	1.21	22	325.0	1.85	111.0	0.53	10
30.0	0.17	10.2	1.81	33	330.0	1.88	112.7	0.50	9
35.0	0.20	12.0	2.63	48	335.0	1.91	114.4	0.47	8
40.0	0.23	13.7	3.68	67	340.0	1.93	116.1	0.45	8
45.0	0.26	15.4	5.47	99	345.0	1.96	117.8	0.42	8
50.0	0.28	17.1	8.41	152	350.0	1.99	119.5	0.40	7
55.0	0.31	18.8	12.61	228	355.0	2.02	121.2	0.38	7
60.0	0.34	20.5	16.50	298	360.0	2.05	122.9	0.36	7
65.0	0.37	22.2	20.50	371	365.0	2.08	124.6	0.34	6
70.0	0.40	23.9	23.97	433	370.0	2.11	126.3	0.33	6
75.0	0.43	25.6	27.75	502	375.0	2.13	128.0	0.30	5
80.0	0.46	27.3	28.91	523	380.0	2.16	129.8	0.28	5
85.0	0.48	29.0	28.07	508	385.0	2.19	131.5	0.27	5
90.0	0.51	30.7	26.38	477	390.0	2.22	133.2	0.26	5
95.0	0.54	32.4	24.18	437	395.0	2.25	134.9	0.24	4
100.0	0.57	34.1	21.55	390	400.0	2.28	136.6	0.23	4
105.0	0.60	35.9	18.92	342	405.0	2.30	138.3	0.22	4
110.0	0.63	37.6	16.08	291	410.0	2.33	140.0	0.21	4
115.0	0.65	39.3	14.19	257	415.0	2.36	141.7	0.20	4
120.0	0.68	41.0	12.61	228	420.0	2.39	143.4	0.19	3
125.0	0.71	42.7	11.04	200	425.0	2.42	145.1	0.18	3
130.0	0.74	44.4	9.99	181	430.0	2.45	146.8	0.17	3
135.0	0.77	46.1	9.04	163	435.0	2.48	148.5	0.16	3
140.0	0.80	47.8	8.20	148	440.0	2.50	150.2	0.15	3
145.0	0.83	49.5	7.36	133	445.0	2.53	151.9	0.15	3
150.0	0.85	51.2	6.78	123	450.0	2.56	153.7	0.13	2
155.0	0.88	52.9	6.20	112	455.0	2.59	155.4	0.12	2
160.0	0.91	54.6	5.83	105	460.0	2.62	157.1	0.12	2
165.0	0.94	56.3	5.47	99	465.0	2.65	158.8	0.11	2
170.0	0.97	58.0	5.15	93	470.0	2.67	160.5		
175.0	1.00	59.8	4.84	88	475.0	2.70	162.2		
180.0	1.02	61.5	4.57	83	480.0	2.73	163.9		
185.0	1.05	63.2	4.31	78	485.0	2.76	165.6		
190.0	1.08	64.9	4.10	74	490.0	2.79	167.3		
195.0	1.11	66.6	3.87	70	495.0	2.82	169.0		
200.0	1.14	68.3	3.68	67	500.0	2.85	170.7		
205.0	1.17	70.0	3.47	63	505.0	2.87	172.4		
210.0	1.20	71.7	3.28	59	510.0	2.90	174.1		
215.0	1.22	73.4	3.10	56	515.0	2.93	175.8		
220.0	1.25	75.1	2.93	53	520.0	2.96	177.6		
225.0	1.28	76.8	2.75	50	525.0	2.99	179.3		
230.0	1.31	78.5	2.63	48	530.0	3.02	181.0		
235.0	1.34	80.2	2.47	45	535.0	3.04	182.7		
240.0	1.37	81.9	2.33	42	540.0	3.07	184.4		
245.0	1.39	83.7	2.22	40	545.0	3.10	186.1		
250.0	1.42	85.4	2.10	38	550.0	3.13	187.8		
255.0	1.45	87.1	1.99	36	555.0	3.16	189.5		
260.0	1.48	88.8	1.88	34	560.0	3.19	191.2		
265.0	1.51	90.5	1.78	32	565.0	3.22	192.9		
270.0	1.54	92.2	1.68	30	570.0	3.24	194.6		
275.0	1.56	93.9	1.59	29	575.0	3.27	196.3		
280.0	1.59	95.6	1.50	27	580.0	3.30	198.0		
285.0	1.62	97.3	1.43	26	585.0	3.33	199.8		
290.0	1.65	99.0	1.36	25	590.0	3.36	201.5		
295.0	1.68	100.7	1.28	23	595.0	3.39	203.2		
300.0	1.71	102.4	1.21	22	600.0	3.41	204.9		

NOTES : Use for models including Basin D for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

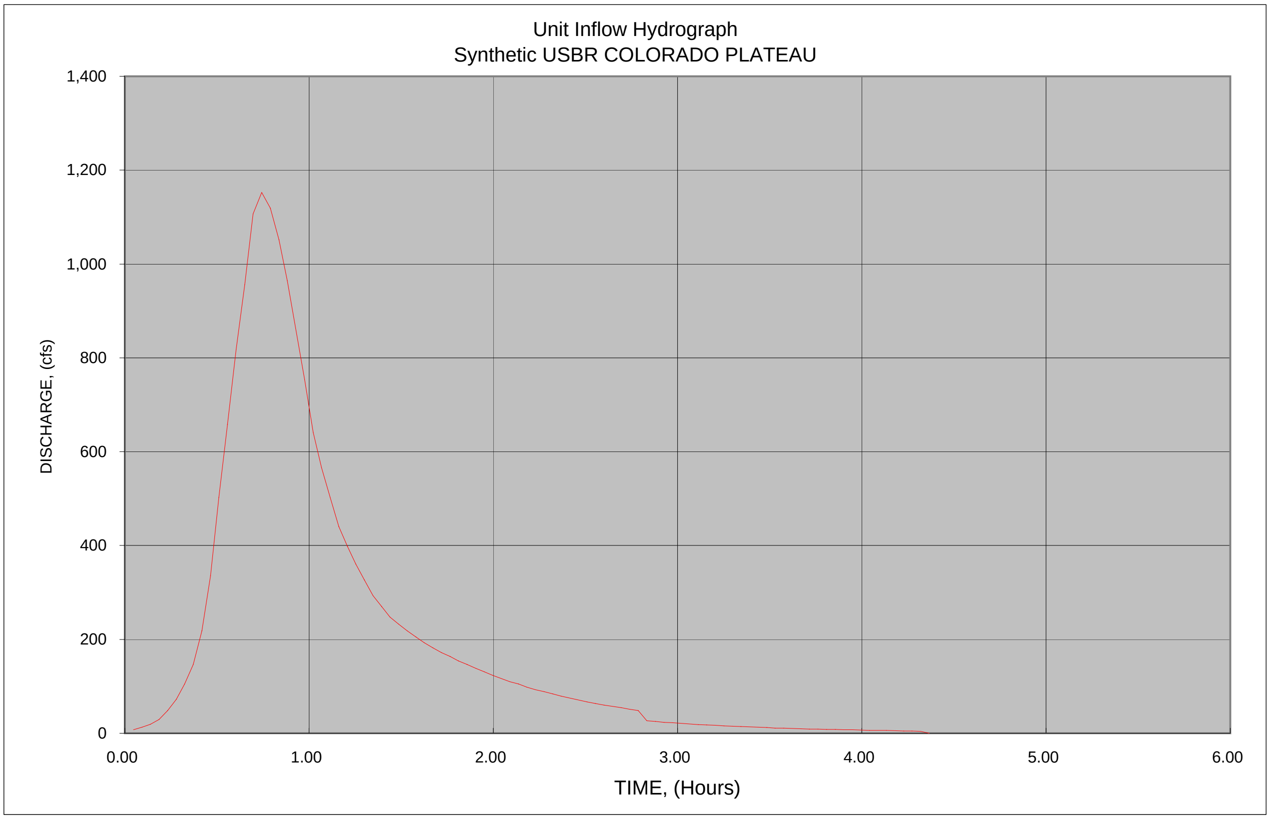
Basin G-10, 25, 100, 200 Proposed Conditions

Drainage Area = 1.3775 sq. miles
Basin Slope = 353 ft./mile
L = 2.96 mi., Length of Watercourse
Lca = 1.58 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.93 Hours
Basin Factor = 0.25
V' = 37.04 cfs/Day
Qs = 39.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.89 Hours
Unit Duration, D = 9.68 minutes
Calculated Timestep = 2.79 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	12	25	57	112	216	463	747	1009	1148	1056
UI	887	694	545	435	364	303	259	228	204	183
UI	166	151	136	123	111	101	91	83	75	68
UI	61	56	50	46	41	37	34	31	28	25
UI	23	21	19	17	15	14	13	11	10	9
UI	9	8	7	6	6	5	5			
UI										
UI										
UI										
UI										
UI										
UI										
UI										
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USBR calculated unitgraph peak = 1153 Interpolated Peak = 1148

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.05	2.8	0.19	8
10.0	0.09	5.6	0.32	13
15.0	0.14	8.4	0.48	19
20.0	0.19	11.1	0.74	30
25.0	0.23	13.9	1.21	48
30.0	0.28	16.7	1.81	72
35.0	0.33	19.5	2.63	105
40.0	0.37	22.3	3.68	147
45.0	0.42	25.1	5.47	218
50.0	0.46	27.9	8.41	335
55.0	0.51	30.7	12.61	503
60.0	0.56	33.4	16.50	658
65.0	0.60	36.2	20.50	817
70.0	0.65	39.0	23.97	956
75.0	0.70	41.8	27.75	1,106
80.0	0.74	44.6	28.91	1,153
85.0	0.79	47.4	28.07	1,119
90.0	0.84	50.2	26.38	1,052
95.0	0.88	53.0	24.18	964
100.0	0.93	55.7	21.55	859
105.0	0.98	58.5	18.92	754
110.0	1.02	61.3	16.08	641
115.0	1.07	64.1	14.19	566
120.0	1.11	66.9	12.61	503
125.0	1.16	69.7	11.04	440
130.0	1.21	72.5	9.99	398
135.0	1.25	75.2	9.04	360
140.0	1.30	78.0	8.20	327
145.0	1.35	80.8	7.36	293
150.0	1.39	83.6	6.78	270
155.0	1.44	86.4	6.20	247
160.0	1.49	89.2	5.83	232
165.0	1.53	92.0	5.47	218
170.0	1.58	94.8	5.15	205
175.0	1.63	97.5	4.84	193
180.0	1.67	100.3	4.57	182
185.0	1.72	103.1	4.31	172
190.0	1.77	105.9	4.10	163
195.0	1.81	108.7	3.87	154
200.0	1.86	111.5	3.68	147
205.0	1.90	114.3	3.47	138
210.0	1.95	117.0	3.28	131
215.0	2.00	119.8	3.10	124
220.0	2.04	122.6	2.93	117
225.0	2.09	125.4	2.75	110
230.0	2.14	128.2	2.63	105
235.0	2.18	131.0	2.47	98
240.0	2.23	133.8	2.33	93
245.0	2.28	136.6	2.22	89
250.0	2.32	139.3	2.10	84
255.0	2.37	142.1	1.99	79
260.0	2.42	144.9	1.88	75
265.0	2.46	147.7	1.78	71
270.0	2.51	150.5	1.68	67
275.0	2.55	153.3	1.59	63
280.0	2.60	156.1	1.50	60
285.0	2.65	158.9	1.43	57
290.0	2.69	161.6	1.36	54
295.0	2.74	164.4	1.28	51
300.0	2.79	167.2	1.21	48
305.0	2.83	170.0	0.66	26
310.0	2.88	172.8	0.63	25
315.0	2.93	175.6	0.59	24
320.0	2.97	178.4	0.56	22
325.0	3.02	181.1	0.53	21
330.0	3.07	183.9	0.50	20
335.0	3.11	186.7	0.47	19
340.0	3.16	189.5	0.45	18
345.0	3.20	192.3	0.42	17
350.0	3.25	195.1	0.40	16
355.0	3.30	197.9	0.38	15
360.0	3.34	200.7	0.36	14
365.0	3.39	203.4	0.34	14
370.0	3.44	206.2	0.33	13
375.0	3.48	209.0	0.30	12
380.0	3.53	211.8	0.28	11
385.0	3.58	214.6	0.27	11
390.0	3.62	217.4	0.26	10
395.0	3.67	220.2	0.24	10
400.0	3.72	223.0	0.23	9
405.0	3.76	225.7	0.22	9
410.0	3.81	228.5	0.21	8
415.0	3.86	231.3	0.20	8
420.0	3.90	234.1	0.19	8
425.0	3.95	236.9	0.18	7
430.0	3.99	239.7	0.17	7
435.0	4.04	242.5	0.16	6
440.0	4.09	245.2	0.15	6
445.0	4.13	248.0	0.15	6
450.0	4.18	250.8	0.13	5
455.0	4.23	253.6	0.12	5
460.0	4.27	256.4	0.12	5
465.0	4.32	259.2	0.11	4
470.0	4.37	262.0		
475.0	4.41	264.8		
480.0	4.46	267.5		
485.0	4.51	270.3		
490.0	4.55	273.1		
495.0	4.60	275.9		
500.0	4.64	278.7		
505.0	4.69	281.5		
510.0	4.74	284.3		
515.0	4.78	287.0		
520.0	4.83	289.8		
525.0	4.88	292.6		
530.0	4.92	295.4		
535.0	4.97	298.2		
540.0	5.02	301.0		
545.0	5.06	303.8		
550.0	5.11	306.6		
555.0	5.16	309.3		
560.0	5.20	312.1		
565.0	5.25	314.9		
570.0	5.30	317.7		
575.0	5.34	320.5		
580.0	5.39	323.3		
585.0	5.43	326.1		
590.0	5.48	328.9		
595.0	5.53	331.6		
600.0	5.57	334.4		

NOTES : Use for models including Basin G for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin G-PMP Proposed Conditions

Drainage Area = 1.3775 sq. miles
Basin Slope = 353 ft./mile
L = 2.96 mi., Length of Watercourse
Lca = 1.58 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

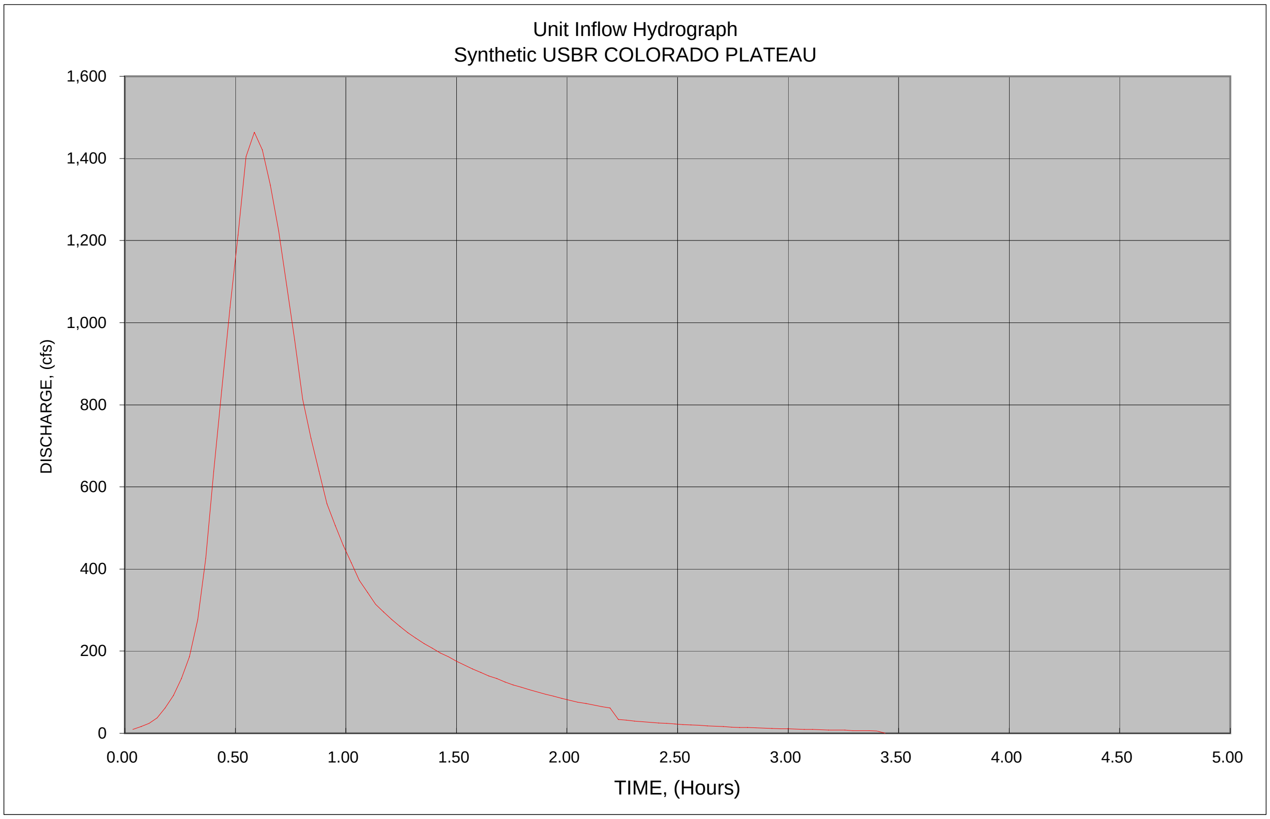
Lg+D/2 = 0.73 Hours
Basin Factor = 0.25
V' = 37.04 cfs/Day
Qs = 50.6 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.69 Hours
Unit Duration, D = 7.53 minutes
Calculated Timestep = 2.20 minutes

Data to be used in Analysis

Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	18	51	126	293	715	1154	1460	1311	1025	740
UI	556	444	355	297	258	226	199	176	155	136
UI	119	106	93	82	73	64	56	50	43	39
UI	34	30	27	23	21	18	16	14	12	11
UI	10	9	8	6	6					
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USBR calculated unitgraph peak = 1463 Interpolated Peak = 1460

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.2	0.19	10
10.0	0.07	4.4	0.32	16
15.0	0.11	6.6	0.48	24
20.0	0.15	8.8	0.74	37
25.0	0.18	11.0	1.21	61
30.0	0.22	13.2	1.81	92
35.0	0.26	15.4	2.63	133
40.0	0.29	17.6	3.68	186
45.0	0.33	19.8	5.47	277
50.0	0.37	22.0	8.41	426
55.0	0.40	24.1	12.61	638
60.0	0.44	26.3	16.50	835
65.0	0.48	28.5	20.50	1,038
70.0	0.51	30.7	23.97	1,213
75.0	0.55	32.9	27.75	1,405
80.0	0.59	35.1	28.91	1,463
85.0	0.62	37.3	28.07	1,421
90.0	0.66	39.5	26.38	1,335
95.0	0.70	41.7	24.18	1,224
100.0	0.73	43.9	21.55	1,091
105.0	0.77	46.1	18.92	958
110.0	0.80	48.3	16.08	814
115.0	0.84	50.5	14.19	718
120.0	0.88	52.7	12.61	638
125.0	0.91	54.9	11.04	559
130.0	0.95	57.1	9.99	506
135.0	0.99	59.3	9.04	458
140.0	1.02	61.5	8.20	415
145.0	1.06	63.7	7.36	373
150.0	1.10	65.9	6.78	343
155.0	1.13	68.1	6.20	314
160.0	1.17	70.3	5.83	295
165.0	1.21	72.4	5.47	277
170.0	1.24	74.6	5.15	261
175.0	1.28	76.8	4.84	245
180.0	1.32	79.0	4.57	231
185.0	1.35	81.2	4.31	218
190.0	1.39	83.4	4.10	208
195.0	1.43	85.6	3.87	196
200.0	1.46	87.8	3.68	186
205.0	1.50	90.0	3.47	176
210.0	1.54	92.2	3.28	166
215.0	1.57	94.4	3.10	157
220.0	1.61	96.6	2.93	148
225.0	1.65	98.8	2.75	139
230.0	1.68	101.0	2.63	133
235.0	1.72	103.2	2.47	125
240.0	1.76	105.4	2.33	118
245.0	1.79	107.6	2.22	112
250.0	1.83	109.8	2.10	106
255.0	1.87	112.0	1.99	101
260.0	1.90	114.2	1.88	95
265.0	1.94	116.4	1.78	90
270.0	1.98	118.5	1.68	85
275.0	2.01	120.7	1.59	80
280.0	2.05	122.9	1.50	76
285.0	2.09	125.1	1.43	72
290.0	2.12	127.3	1.36	69
295.0	2.16	129.5	1.28	65
300.0	2.20	131.7	1.21	61
305.0	2.23	133.9	0.66	33
310.0	2.27	136.1	0.63	32
315.0	2.31	138.3	0.59	30
320.0	2.34	140.5	0.56	28
325.0	2.38	142.7	0.53	27
330.0	2.41	144.9	0.50	25
335.0	2.45	147.1	0.47	24
340.0	2.49	149.3	0.45	23
345.0	2.52	151.5	0.42	21
350.0	2.56	153.7	0.40	20
355.0	2.60	155.9	0.38	19
360.0	2.63	158.1	0.36	18
365.0	2.67	160.3	0.34	17
370.0	2.71	162.5	0.33	17
375.0	2.74	164.7	0.30	15
380.0	2.78	166.8	0.28	14
385.0	2.82	169.0	0.27	14
390.0	2.85	171.2	0.26	13
395.0	2.89	173.4	0.24	12
400.0	2.93	175.6	0.23	12
405.0	2.96	177.8	0.22	11
410.0	3.00	180.0	0.21	11
415.0	3.04	182.2	0.20	10
420.0	3.07	184.4	0.19	10
425.0	3.11	186.6	0.18	9
430.0	3.15	188.8	0.17	9
435.0	3.18	191.0	0.16	8
440.0	3.22	193.2	0.15	8
445.0	3.26	195.4	0.15	8
450.0	3.29	197.6	0.13	7
455.0	3.33	199.8	0.12	6
460.0	3.37	202.0	0.12	6
465.0	3.40	204.2	0.11	6
470.0	3.44	206.4		
475.0	3.48	208.6		
480.0	3.51	210.8		
485.0	3.55	212.9		
490.0	3.59	215.1		
495.0	3.62	217.3		
500.0	3.66	219.5		
505.0	3.70	221.7		
510.0	3.73	223.9		
515.0	3.77	226.1		
520.0	3.81	228.3		
525.0	3.84	230.5		
530.0	3.88	232.7		
535.0	3.92	234.9		
540.0	3.95	237.1		
545.0	3.99	239.3		
550.0	4.02	241.5		
555.0	4.06	243.7		
560.0	4.10	245.9		
565.0	4.13	248.1		
570.0	4.17	250.3		
575.0	4.21	252.5		
580.0	4.24	254.7		
585.0	4.28	256.9		
590.0	4.32	259.1		
595.0	4.35	261.2		
600.0	4.39	263.4		

NOTES : Use for models including Basin G for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

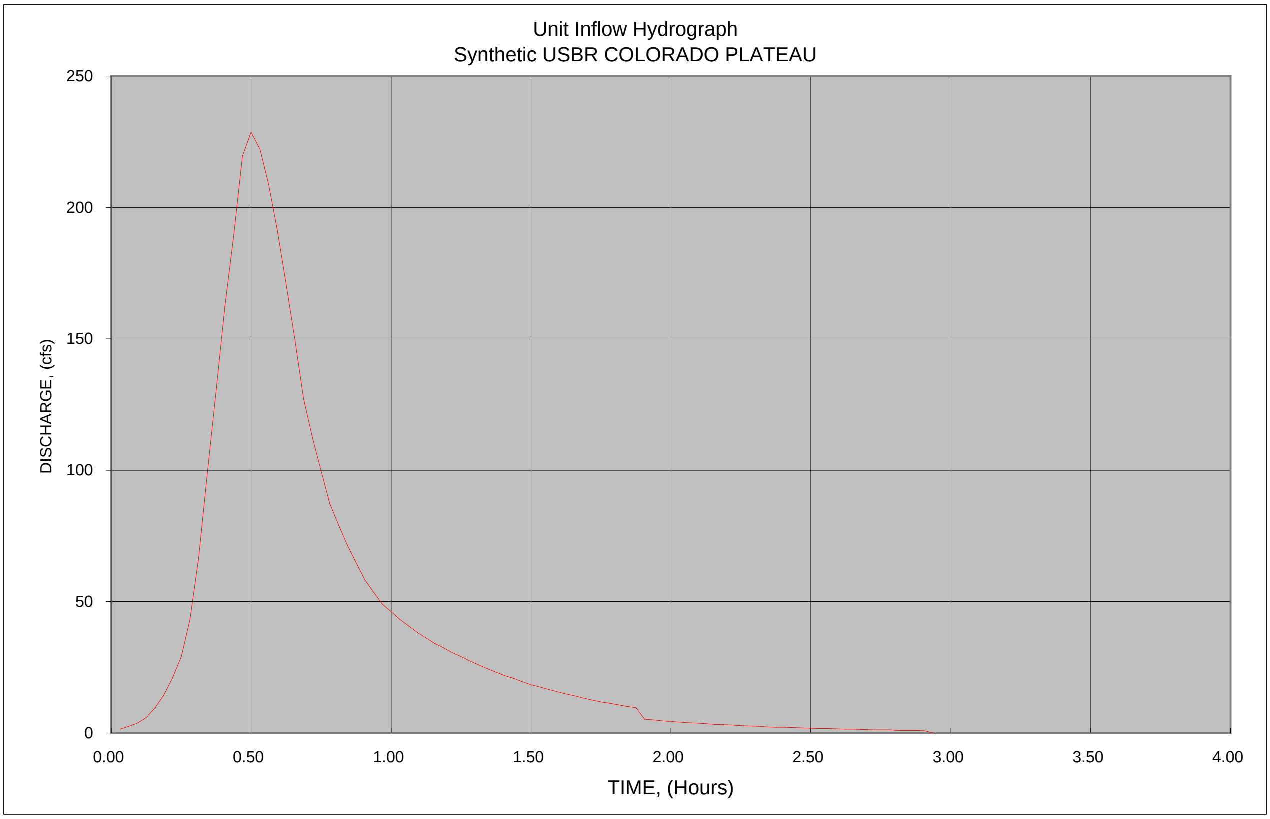
Design Point 1-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.1839 sq. miles
Basin Slope = 70.74 ft./mile
L = 1.13 mi., Length of Watercourse
Lca = 0.52 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.63 Hours
Basin Factor = 0.07
V' = 4.95 cfs/Day
Qs = 7.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.58 Hours
Unit Duration, D = 6.36 minutes
Calculated Timestep = 1.88 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	6	24	88	220	282	210	133	91	66	53
UI	43	36	30	25	20	17	14	12	10	8
UI	7	6	5	4	3	3	2	2	2	1
UI										
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USBR calculated unitgraph peak = 229 Interpolated Peak = 282

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.9	0.19	2
10.0	0.06	3.8	0.32	3
15.0	0.09	5.6	0.48	4
20.0	0.13	7.5	0.74	6
25.0	0.16	9.4	1.21	10
30.0	0.19	11.3	1.81	14
35.0	0.22	13.1	2.63	21
40.0	0.25	15.0	3.68	29
45.0	0.28	16.9	5.47	43
50.0	0.31	18.8	8.41	67
55.0	0.34	20.6	12.61	100
60.0	0.38	22.5	16.50	131
65.0	0.41	24.4	20.50	162
70.0	0.44	26.3	23.97	190
75.0	0.47	28.1	27.75	220
80.0	0.50	30.0	28.91	229
85.0	0.53	31.9	28.07	222
90.0	0.56	33.8	26.38	209
95.0	0.59	35.6	24.18	191
100.0	0.63	37.5	21.55	170
105.0	0.66	39.4	18.92	150
110.0	0.69	41.3	16.08	127
115.0	0.72	43.1	14.19	112
120.0	0.75	45.0	12.61	100
125.0	0.78	46.9	11.04	87
130.0	0.81	48.8	9.99	79
135.0	0.84	50.6	9.04	72
140.0	0.88	52.5	8.20	65
145.0	0.91	54.4	7.36	58
150.0	0.94	56.3	6.78	54
155.0	0.97	58.1	6.20	49
160.0	1.00	60.0	5.83	46
165.0	1.03	61.9	5.47	43
170.0	1.06	63.8	5.15	41
175.0	1.09	65.6	4.84	38
180.0	1.13	67.5	4.57	36
185.0	1.16	69.4	4.31	34
190.0	1.19	71.3	4.10	32
195.0	1.22	73.1	3.87	31
200.0	1.25	75.0	3.68	29
205.0	1.28	76.9	3.47	27
210.0	1.31	78.8	3.28	26
215.0	1.34	80.6	3.10	25
220.0	1.38	82.5	2.93	23
225.0	1.41	84.4	2.75	22
230.0	1.44	86.3	2.63	21
235.0	1.47	88.1	2.47	20
240.0	1.50	90.0	2.33	18
245.0	1.53	91.9	2.22	18
250.0	1.56	93.8	2.10	17
255.0	1.59	95.6	1.99	16
260.0	1.63	97.5	1.88	15
265.0	1.66	99.4	1.78	14
270.0	1.69	101.3	1.68	13
275.0	1.72	103.1	1.59	13
280.0	1.75	105.0	1.50	12
285.0	1.78	106.9	1.43	11
290.0	1.81	108.8	1.36	11
295.0	1.84	110.6	1.28	10
300.0	1.88	112.5	1.21	10
305.0	1.91	114.4	0.66	5
310.0	1.94	116.3	0.63	5
315.0	1.97	118.1	0.59	5
320.0	2.00	120.0	0.56	4
325.0	2.03	121.9	0.53	4
330.0	2.06	123.8	0.50	4
335.0	2.09	125.6	0.47	4
340.0	2.13	127.5	0.45	4
345.0	2.16	129.4	0.42	3
350.0	2.19	131.3	0.40	3
355.0	2.22	133.1	0.38	3
360.0	2.25	135.0	0.36	3
365.0	2.28	136.9	0.34	3
370.0	2.31	138.8	0.33	3
375.0	2.34	140.6	0.30	2
380.0	2.38	142.5	0.28	2
385.0	2.41	144.4	0.27	2
390.0	2.44	146.3	0.26	2
395.0	2.47	148.1	0.24	2
400.0	2.50	150.0	0.23	2
405.0	2.53	151.9	0.22	2
410.0	2.56	153.8	0.21	2
415.0	2.59	155.6	0.20	2
420.0	2.63	157.5	0.19	2
425.0	2.66	159.4	0.18	1
430.0	2.69	161.3	0.17	1
435.0	2.72	163.1	0.16	1
440.0	2.75	165.0	0.15	1
445.0	2.78	166.9	0.15	1
450.0	2.81	168.8	0.13	1
455.0	2.84	170.6	0.12	1
460.0	2.88	172.5	0.12	1
465.0	2.91	174.4	0.11	1
470.0	2.94	176.3		
475.0	2.97	178.1		
480.0	3.00	180.0		
485.0	3.03	181.9		
490.0	3.06	183.8		
495.0	3.09	185.6		
500.0	3.13	187.5		
505.0	3.16	189.4		
510.0	3.19	191.3		
515.0	3.22	193.1		
520.0	3.25	195.0		
525.0	3.28	196.9		
530.0	3.31	198.8		
535.0	3.34	200.6		
540.0	3.38	202.5		
545.0	3.41	204.4		
550.0	3.44	206.3		
555.0	3.47	208.1		
560.0	3.50	210.0		
565.0	3.53	211.9		
570.0	3.56	213.8		
575.0	3.59	215.6		
580.0	3.63	217.5		
585.0	3.66	219.4		
590.0	3.69	221.3		
595.0	3.72	223.2		
600.0	3.75	225.0		

NOTES : Use for models including Design Point 1 (Basin E) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Design Point 1-PMP Proposed Conditions

Drainage Area =	0.1839	sq. miles	Lg+D/2 =	0.50	Hours
Basin Slope =	70.74	ft./mile	Basin Factor =	0.07	
L =	1.13	mi., Length of Watercourse	V' =	4.95	cfs/Day
Lca =	0.52	mi., Distance to Centroid	Qs =	10.0	* q, cfs
Kn =	0.042	-, Ave. Weighted Manning's n			

PARAMETERS:

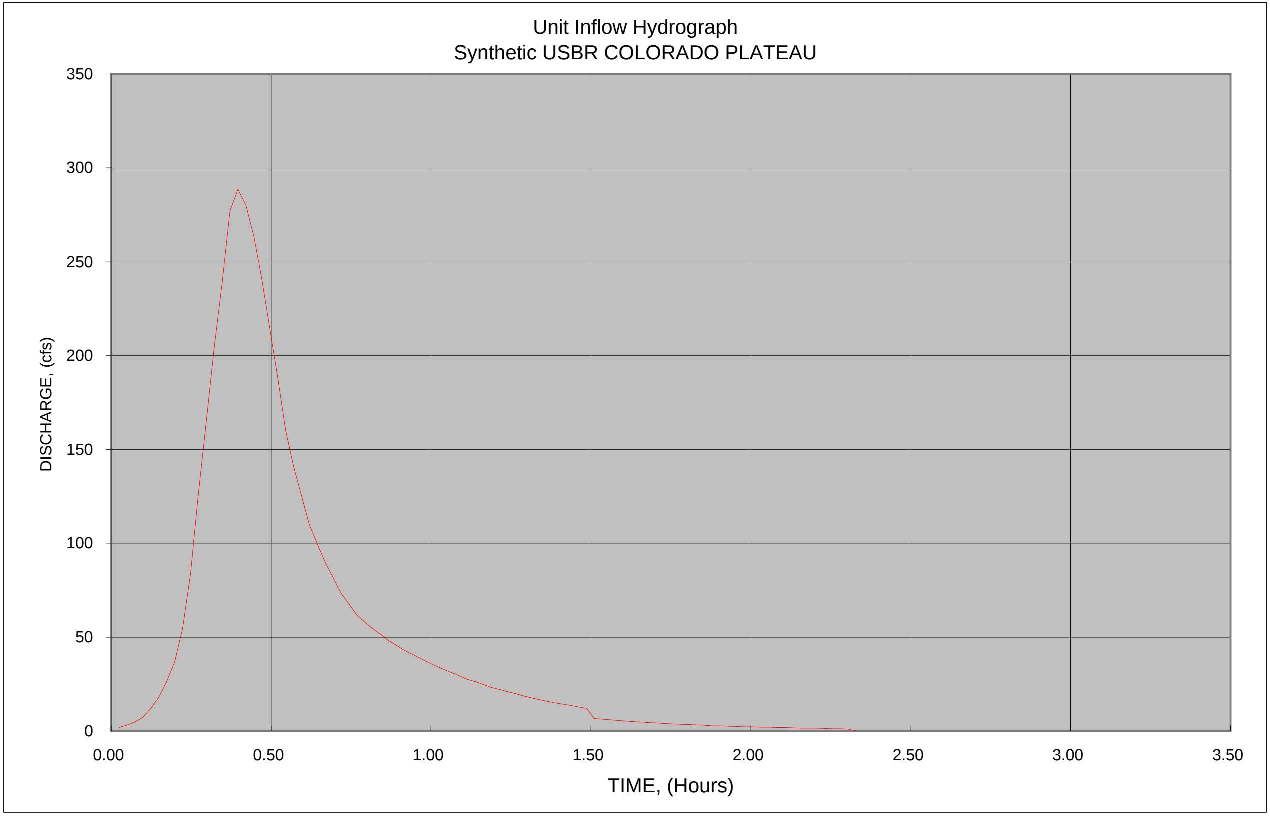
Calculated: Lag Time, Lg = 0.45 Hours Unit Duration, D = 4.95 minutes

Calculated Timestep = 1.49 minutes

Data to be used in Analysis

Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	6	24	88	220	282	210	133	91	66	53
UI	43	36	30	25	20	17	14	12	10	8
UI	7	6	5	4	3	3	2	2	2	1
UI										
UI										
UI										
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USBR calculated unitgraph peak = 289 Interpolated Peak = 282

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.5	0.19	2	305.0	1.51	90.7	0.66	7
10.0	0.05	3.0	0.32	3	310.0	1.54	92.1	0.63	6
15.0	0.07	4.5	0.48	5	315.0	1.56	93.6	0.59	6
20.0	0.10	5.9	0.74	7	320.0	1.59	95.1	0.56	6
25.0	0.12	7.4	1.21	12	325.0	1.61	96.6	0.53	5
30.0	0.15	8.9	1.81	18	330.0	1.63	98.1	0.50	5
35.0	0.17	10.4	2.63	26	335.0	1.66	99.6	0.47	5
40.0	0.20	11.9	3.68	37	340.0	1.68	101.1	0.45	4
45.0	0.22	13.4	5.47	55	345.0	1.71	102.6	0.42	4
50.0	0.25	14.9	8.41	84	350.0	1.73	104.0	0.40	4
55.0	0.27	16.3	12.61	126	355.0	1.76	105.5	0.38	4
60.0	0.30	17.8	16.50	165	360.0	1.78	107.0	0.36	4
65.0	0.32	19.3	20.50	205	365.0	1.81	108.5	0.34	3
70.0	0.35	20.8	23.97	239	370.0	1.83	110.0	0.33	3
75.0	0.37	22.3	27.75	277	375.0	1.86	111.5	0.30	3
80.0	0.40	23.8	28.91	289	380.0	1.88	113.0	0.28	3
85.0	0.42	25.3	28.07	280	385.0	1.91	114.4	0.27	3
90.0	0.45	26.8	26.38	263	390.0	1.93	115.9	0.26	3
95.0	0.47	28.2	24.18	241	395.0	1.96	117.4	0.24	2
100.0	0.50	29.7	21.55	215	400.0	1.98	118.9	0.23	2
105.0	0.52	31.2	18.92	189	405.0	2.01	120.4	0.22	2
110.0	0.54	32.7	16.08	161	410.0	2.03	121.9	0.21	2
115.0	0.57	34.2	14.19	142	415.0	2.06	123.4	0.20	2
120.0	0.59	35.7	12.61	126	420.0	2.08	124.8	0.19	2
125.0	0.62	37.2	11.04	110	425.0	2.11	126.3	0.18	2
130.0	0.64	38.6	9.99	100	430.0	2.13	127.8	0.17	2
135.0	0.67	40.1	9.04	90	435.0	2.16	129.3	0.16	2
140.0	0.69	41.6	8.20	82	440.0	2.18	130.8	0.15	1
145.0	0.72	43.1	7.36	73	445.0	2.20	132.3	0.15	1
150.0	0.74	44.6	6.78	68	450.0	2.23	133.8	0.13	1
155.0	0.77	46.1	6.20	62	455.0	2.25	135.3	0.12	1
160.0	0.79	47.6	5.83	58	460.0	2.28	136.7	0.12	1
165.0	0.82	49.0	5.47	55	465.0	2.30	138.2	0.11	1
170.0	0.84	50.5	5.15	51	470.0	2.33	139.7		
175.0	0.87	52.0	4.84	48	475.0	2.35	141.2		
180.0	0.89	53.5	4.57	46	480.0	2.38	142.7		
185.0	0.92	55.0	4.31	43	485.0	2.40	144.2		
190.0	0.94	56.5	4.10	41	490.0	2.43	145.7		
195.0	0.97	58.0	3.87	39	495.0	2.45	147.1		
200.0	0.99	59.5	3.68	37	500.0	2.48	148.6		
205.0	1.02	60.9	3.47	35	505.0	2.50	150.1		
210.0	1.04	62.4	3.28	33	510.0	2.53	151.6		
215.0	1.07	63.9	3.10	31	515.0	2.55	153.1		
220.0	1.09	65.4	2.93	29	520.0	2.58	154.6		
225.0	1.11	66.9	2.75	27	525.0	2.60	156.1		
230.0	1.14	68.4	2.63	26	530.0	2.63	157.5		
235.0	1.16	69.9	2.47	25	535.0	2.65	159.0		
240.0	1.19	71.3	2.33	23	540.0	2.68	160.5		
245.0	1.21	72.8	2.22	22	545.0	2.70	162.0		
250.0	1.24	74.3	2.10	21	550.0	2.72	163.5		
255.0	1.26	75.8	1.99	20	555.0	2.75	165.0		
260.0	1.29	77.3	1.88	19	560.0	2.77	166.5		
265.0	1.31	78.8	1.78	18	565.0	2.80	167.9		
270.0	1.34	80.3	1.68	17	570.0	2.82	169.4		
275.0	1.36	81.7	1.59	16	575.0	2.85	170.9		
280.0	1.39	83.2	1.50	15	580.0	2.87	172.4		
285.0	1.41	84.7	1.43	14	585.0	2.90	173.9		
290.0	1.44	86.2	1.36	14	590.0	2.92	175.4		
295.0	1.46	87.7	1.28	13	595.0	2.95	176.9		
300.0	1.49	89.2	1.21	12	600.0	2.97	178.4		

NOTES : Use for models including Design Point 1 (Basin E) for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Design Point 2-10, 25, 100, 200 Proposed Conditions

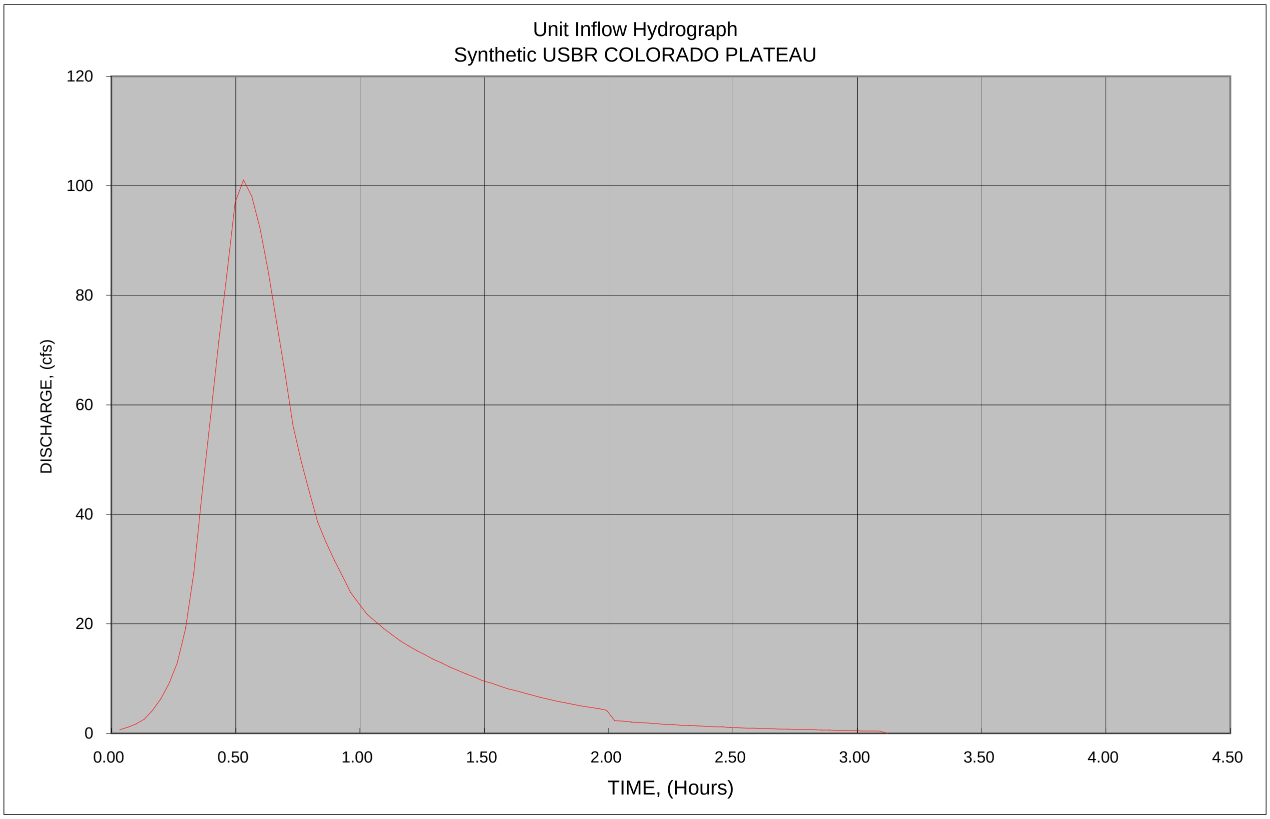
Drainage Area = 0.0863 sq. miles
Basin Slope = 52.14 ft./mile
L = 1.04 mi., Length of Watercourse
Lca = 0.59 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.66 Hours
Basin Factor = 0.08
V' = 2.32 cfs/Day
Qs = 3.5 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.62 Hours
Unit Duration, D = 6.79 minutes
Calculated Timestep = 1.99 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	1	4	11	30	65	97	95	75	52	38
UI	30	23	20	17	15	13	11	10	8	7
UI	6	5	5	4	4	3	3	2	2	2
UI	2	1	1	1	1	1	1	1	1	0
UI	0									
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USBR calculated unitgraph peak = 101 Interpolated Peak = 97

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	2.0	0.19	1
10.0	0.07	4.0	0.32	1
15.0	0.10	6.0	0.48	2
20.0	0.13	8.0	0.74	3
25.0	0.17	10.0	1.21	4
30.0	0.20	12.0	1.81	6
35.0	0.23	13.9	2.63	9
40.0	0.27	15.9	3.68	13
45.0	0.30	17.9	5.47	19
50.0	0.33	19.9	8.41	29
55.0	0.37	21.9	12.61	44
60.0	0.40	23.9	16.50	58
65.0	0.43	25.9	20.50	72
70.0	0.46	27.9	23.97	84
75.0	0.50	29.9	27.75	97
80.0	0.53	31.9	28.91	101
85.0	0.56	33.9	28.07	98
90.0	0.60	35.9	26.38	92
95.0	0.63	37.8	24.18	85
100.0	0.66	39.8	21.55	75
105.0	0.70	41.8	18.92	66
110.0	0.73	43.8	16.08	56
115.0	0.76	45.8	14.19	50
120.0	0.80	47.8	12.61	44
125.0	0.83	49.8	11.04	39
130.0	0.86	51.8	9.99	35
135.0	0.90	53.8	9.04	32
140.0	0.93	55.8	8.20	29
145.0	0.96	57.8	7.36	26
150.0	1.00	59.8	6.78	24
155.0	1.03	61.8	6.20	22
160.0	1.06	63.7	5.83	20
165.0	1.10	65.7	5.47	19
170.0	1.13	67.7	5.15	18
175.0	1.16	69.7	4.84	17
180.0	1.20	71.7	4.57	16
185.0	1.23	73.7	4.31	15
190.0	1.26	75.7	4.10	14
195.0	1.29	77.7	3.87	14
200.0	1.33	79.7	3.68	13
205.0	1.36	81.7	3.47	12
210.0	1.39	83.7	3.28	11
215.0	1.43	85.7	3.10	11
220.0	1.46	87.7	2.93	10
225.0	1.49	89.6	2.75	10
230.0	1.53	91.6	2.63	9
235.0	1.56	93.6	2.47	9
240.0	1.59	95.6	2.33	8
245.0	1.63	97.6	2.22	8
250.0	1.66	99.6	2.10	7
255.0	1.69	101.6	1.99	7
260.0	1.73	103.6	1.88	7
265.0	1.76	105.6	1.78	6
270.0	1.79	107.6	1.68	6
275.0	1.83	109.6	1.59	6
280.0	1.86	111.6	1.50	5
285.0	1.89	113.5	1.43	5
290.0	1.93	115.5	1.36	5
295.0	1.96	117.5	1.28	4
300.0	1.99	119.5	1.21	4
305.0	2.03	121.5	0.66	2
310.0	2.06	123.5	0.63	2
315.0	2.09	125.5	0.59	2
320.0	2.12	127.5	0.56	2
325.0	2.16	129.5	0.53	2
330.0	2.19	131.5	0.50	2
335.0	2.22	133.5	0.47	2
340.0	2.26	135.5	0.45	2
345.0	2.29	137.5	0.42	1
350.0	2.32	139.4	0.40	1
355.0	2.36	141.4	0.38	1
360.0	2.39	143.4	0.36	1
365.0	2.42	145.4	0.34	1
370.0	2.46	147.4	0.33	1
375.0	2.49	149.4	0.30	1
380.0	2.52	151.4	0.28	1
385.0	2.56	153.4	0.27	1
390.0	2.59	155.4	0.26	1
395.0	2.62	157.4	0.24	1
400.0	2.66	159.4	0.23	1
405.0	2.69	161.4	0.22	1
410.0	2.72	163.3	0.21	1
415.0	2.76	165.3	0.20	1
420.0	2.79	167.3	0.19	1
425.0	2.82	169.3	0.18	1
430.0	2.86	171.3	0.17	1
435.0	2.89	173.3	0.16	1
440.0	2.92	175.3	0.15	1
445.0	2.95	177.3	0.15	1
450.0	2.99	179.3	0.13	0
455.0	3.02	181.3	0.12	0
460.0	3.05	183.3	0.12	0
465.0	3.09	185.3	0.11	0
470.0	3.12	187.3		
475.0	3.15	189.2		
480.0	3.19	191.2		
485.0	3.22	193.2		
490.0	3.25	195.2		
495.0	3.29	197.2		
500.0	3.32	199.2		
505.0	3.35	201.2		
510.0	3.39	203.2		
515.0	3.42	205.2		
520.0	3.45	207.2		
525.0	3.49	209.2		
530.0	3.52	211.2		
535.0	3.55	213.1		
540.0	3.59	215.1		
545.0	3.62	217.1		
550.0	3.65	219.1		
555.0	3.69	221.1		
560.0	3.72	223.1		
565.0	3.75	225.1		
570.0	3.78	227.1		
575.0	3.82	229.1		
580.0	3.85	231.1		
585.0	3.88	233.1		
590.0	3.92	235.1		
595.0	3.95	237.1		
600.0	3.98	239.0		

NOTES : Use for models including Design Point 2 (Basin F) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Design Point 2-PMP Proposed Conditions

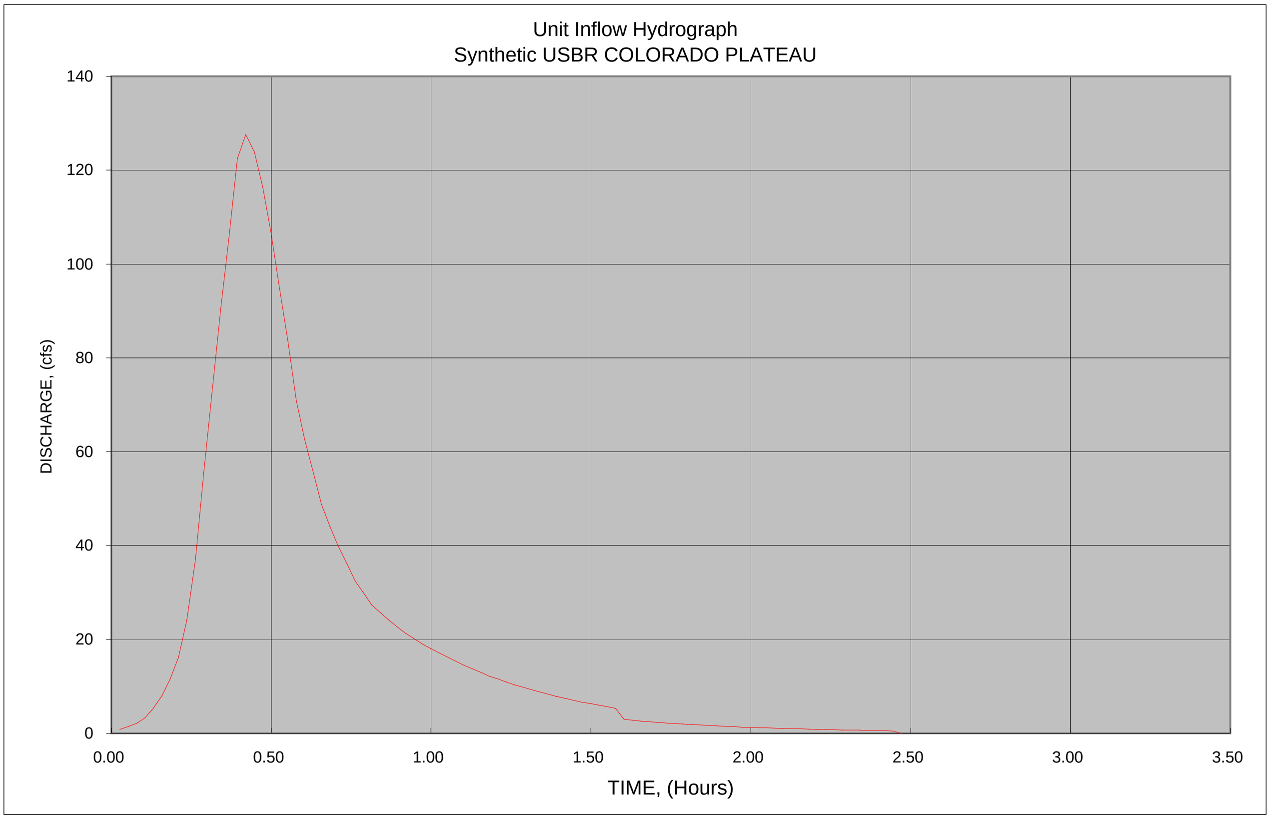
Drainage Area = 0.0863 sq. miles
Basin Slope = 52.14 ft./mile
L = 1.04 mi., Length of Watercourse
Lca = 0.59 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.53 Hours
Basin Factor = 0.08
V' = 2.32 cfs/Day
Qs = 4.4 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.48 Hours
Unit Duration, D = 5.28 minutes
Calculated Timestep = 1.58 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	2	9	31	85	127	106	69	47	34	26
UI	22	18	15	13	11	9	7	6	5	4
UI	4	3	3	2	2	2	1	1	1	1
UI	1	1								
UI										
UI										
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USBR calculated unitgraph peak = 128 Interpolated Peak = 127

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.6	0.19	1	305.0	1.60	96.2	0.66	3
10.0	0.05	3.2	0.32	1	310.0	1.63	97.8	0.63	3
15.0	0.08	4.7	0.48	2	315.0	1.66	99.4	0.59	3
20.0	0.11	6.3	0.74	3	320.0	1.68	100.9	0.56	2
25.0	0.13	7.9	1.21	5	325.0	1.71	102.5	0.53	2
30.0	0.16	9.5	1.81	8	330.0	1.73	104.1	0.50	2
35.0	0.18	11.0	2.63	12	335.0	1.76	105.7	0.47	2
40.0	0.21	12.6	3.68	16	340.0	1.79	107.2	0.45	2
45.0	0.24	14.2	5.47	24	345.0	1.81	108.8	0.42	2
50.0	0.26	15.8	8.41	37	350.0	1.84	110.4	0.40	2
55.0	0.29	17.3	12.61	56	355.0	1.87	112.0	0.38	2
60.0	0.32	18.9	16.50	73	360.0	1.89	113.6	0.36	2
65.0	0.34	20.5	20.50	90	365.0	1.92	115.1	0.34	2
70.0	0.37	22.1	23.97	106	370.0	1.95	116.7	0.33	1
75.0	0.39	23.7	27.75	122	375.0	1.97	118.3	0.30	1
80.0	0.42	25.2	28.91	128	380.0	2.00	119.9	0.28	1
85.0	0.45	26.8	28.07	124	385.0	2.02	121.4	0.27	1
90.0	0.47	28.4	26.38	116	390.0	2.05	123.0	0.26	1
95.0	0.50	30.0	24.18	107	395.0	2.08	124.6	0.24	1
100.0	0.53	31.5	21.55	95	400.0	2.10	126.2	0.23	1
105.0	0.55	33.1	18.92	84	405.0	2.13	127.7	0.22	1
110.0	0.58	34.7	16.08	71	410.0	2.16	129.3	0.21	1
115.0	0.60	36.3	14.19	63	415.0	2.18	130.9	0.20	1
120.0	0.63	37.9	12.61	56	420.0	2.21	132.5	0.19	1
125.0	0.66	39.4	11.04	49	425.0	2.23	134.1	0.18	1
130.0	0.68	41.0	9.99	44	430.0	2.26	135.6	0.17	1
135.0	0.71	42.6	9.04	40	435.0	2.29	137.2	0.16	1
140.0	0.74	44.2	8.20	36	440.0	2.31	138.8	0.15	1
145.0	0.76	45.7	7.36	32	445.0	2.34	140.4	0.15	1
150.0	0.79	47.3	6.78	30	450.0	2.37	141.9	0.13	1
155.0	0.81	48.9	6.20	27	455.0	2.39	143.5	0.12	1
160.0	0.84	50.5	5.83	26	460.0	2.42	145.1	0.12	1
165.0	0.87	52.0	5.47	24	465.0	2.44	146.7	0.11	0
170.0	0.89	53.6	5.15	23	470.0	2.47	148.3		
175.0	0.92	55.2	4.84	21	475.0	2.50	149.8		
180.0	0.95	56.8	4.57	20	480.0	2.52	151.4		
185.0	0.97	58.4	4.31	19	485.0	2.55	153.0		
190.0	1.00	59.9	4.10	18	490.0	2.58	154.6		
195.0	1.03	61.5	3.87	17	495.0	2.60	156.1		
200.0	1.05	63.1	3.68	16	500.0	2.63	157.7		
205.0	1.08	64.7	3.47	15	505.0	2.65	159.3		
210.0	1.10	66.2	3.28	14	510.0	2.68	160.9		
215.0	1.13	67.8	3.10	14	515.0	2.71	162.4		
220.0	1.16	69.4	2.93	13	520.0	2.73	164.0		
225.0	1.18	71.0	2.75	12	525.0	2.76	165.6		
230.0	1.21	72.5	2.63	12	530.0	2.79	167.2		
235.0	1.24	74.1	2.47	11	535.0	2.81	168.8		
240.0	1.26	75.7	2.33	10	540.0	2.84	170.3		
245.0	1.29	77.3	2.22	10	545.0	2.87	171.9		
250.0	1.31	78.9	2.10	9	550.0	2.89	173.5		
255.0	1.34	80.4	1.99	9	555.0	2.92	175.1		
260.0	1.37	82.0	1.88	8	560.0	2.94	176.6		
265.0	1.39	83.6	1.78	8	565.0	2.97	178.2		
270.0	1.42	85.2	1.68	7	570.0	3.00	179.8		
275.0	1.45	86.7	1.59	7	575.0	3.02	181.4		
280.0	1.47	88.3	1.50	7	580.0	3.05	182.9		
285.0	1.50	89.9	1.43	6	585.0	3.08	184.5		
290.0	1.52	91.5	1.36	6	590.0	3.10	186.1		
295.0	1.55	93.1	1.28	6	595.0	3.13	187.7		
300.0	1.58	94.6	1.21	5	600.0	3.15	189.3		

NOTES : Use for models including Design Point 2 (Basin F) for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Design Point 3-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.1675 sq. miles
Basin Slope = 77.56 ft./mile
L = 1.34 mi., Length of Watercourse
Lca = 0.7 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.71 Hours
Basin Factor = 0.11
V' = 4.50 cfs/Day
Qs = 6.3 * q, cfs

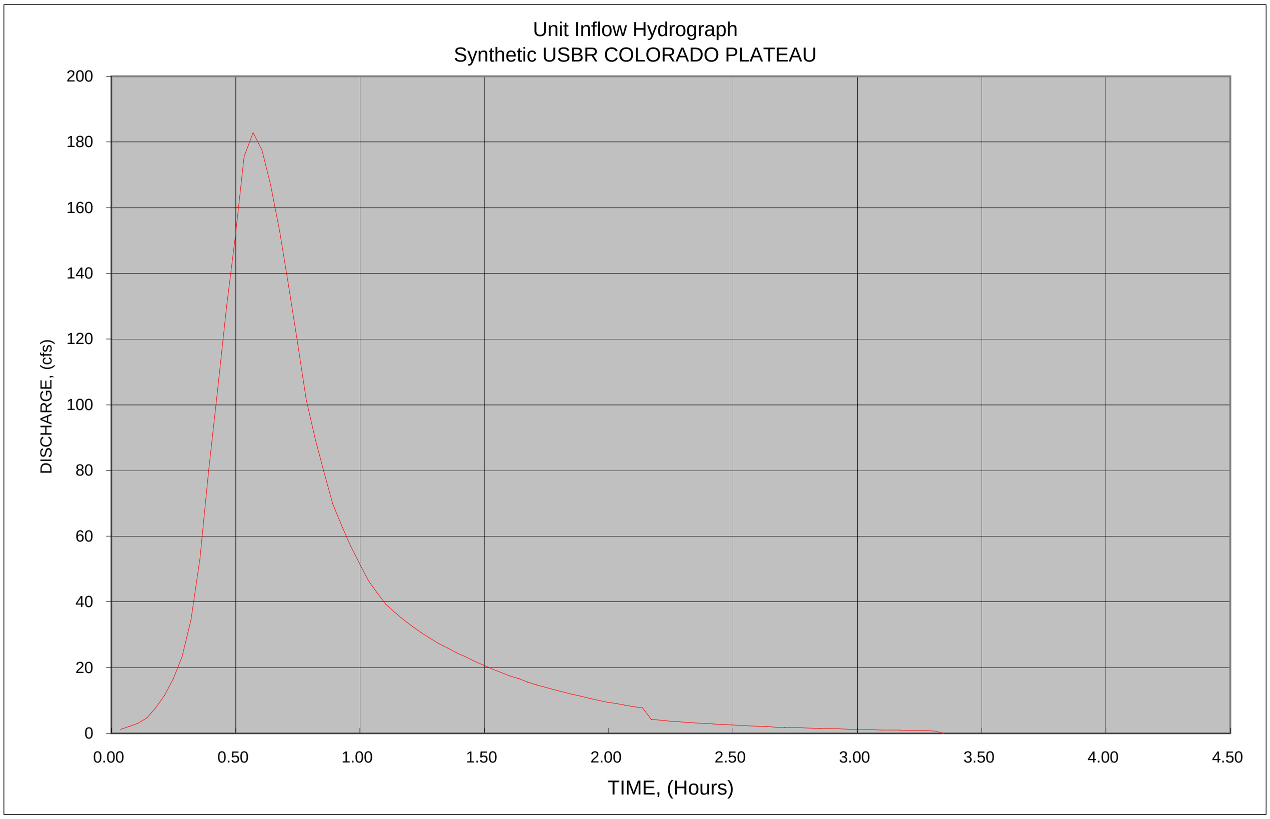
PARAMETERS:

Calculated: Lag Time, Lg = 0.67 Hours

Unit Duration, D = 7.31 minutes
Calculated Timestep = 2.14 minutes

Data to be used in Analysis

Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	2	7	17	41	97	153	181	157	119	86
UI	65	51	41	35	30	27	24	21	18	16
UI	14	12	11	9	8	7	6	6	5	4
UI	4	3	3	3	2	2	2	2	1	1
UI	1	1	1	1						
UI										
UI										
UI										
UI										
UI										
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UI										
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UI
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USBR calculated unitgraph peak = 183 Interpolated Peak = 181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.1	0.19	1
10.0	0.07	4.3	0.32	2
15.0	0.11	6.4	0.48	3
20.0	0.14	8.5	0.74	5
25.0	0.18	10.7	1.21	8
30.0	0.21	12.8	1.81	11
35.0	0.25	15.0	2.63	17
40.0	0.28	17.1	3.68	23
45.0	0.32	19.2	5.47	35
50.0	0.36	21.4	8.41	53
55.0	0.39	23.5	12.61	80
60.0	0.43	25.6	16.50	104
65.0	0.46	27.8	20.50	130
70.0	0.50	29.9	23.97	152
75.0	0.53	32.0	27.75	176
80.0	0.57	34.2	28.91	183
85.0	0.61	36.3	28.07	178
90.0	0.64	38.5	26.38	167
95.0	0.68	40.6	24.18	153
100.0	0.71	42.7	21.55	136
105.0	0.75	44.9	18.92	120
110.0	0.78	47.0	16.08	102
115.0	0.82	49.1	14.19	90
120.0	0.85	51.3	12.61	80
125.0	0.89	53.4	11.04	70
130.0	0.93	55.5	9.99	63
135.0	0.96	57.7	9.04	57
140.0	1.00	59.8	8.20	52
145.0	1.03	62.0	7.36	47
150.0	1.07	64.1	6.78	43
155.0	1.10	66.2	6.20	39
160.0	1.14	68.4	5.83	37
165.0	1.18	70.5	5.47	35
170.0	1.21	72.6	5.15	33
175.0	1.25	74.8	4.84	31
180.0	1.28	76.9	4.57	29
185.0	1.32	79.1	4.31	27
190.0	1.35	81.2	4.10	26
195.0	1.39	83.3	3.87	24
200.0	1.42	85.5	3.68	23
205.0	1.46	87.6	3.47	22
210.0	1.50	89.7	3.28	21
215.0	1.53	91.9	3.10	20
220.0	1.57	94.0	2.93	19
225.0	1.60	96.1	2.75	17
230.0	1.64	98.3	2.63	17
235.0	1.67	100.4	2.47	16
240.0	1.71	102.6	2.33	15
245.0	1.74	104.7	2.22	14
250.0	1.78	106.8	2.10	13
255.0	1.82	109.0	1.99	13
260.0	1.85	111.1	1.88	12
265.0	1.89	113.2	1.78	11
270.0	1.92	115.4	1.68	11
275.0	1.96	117.5	1.59	10
280.0	1.99	119.6	1.50	9
285.0	2.03	121.8	1.43	9
290.0	2.07	123.9	1.36	9
295.0	2.10	126.1	1.28	8
300.0	2.14	128.2	1.21	8
305.0	2.17	130.3	0.66	4
310.0	2.21	132.5	0.63	4
315.0	2.24	134.6	0.59	4
320.0	2.28	136.7	0.56	4
325.0	2.31	138.9	0.53	3
330.0	2.35	141.0	0.50	3
335.0	2.39	143.1	0.47	3
340.0	2.42	145.3	0.45	3
345.0	2.46	147.4	0.42	3
350.0	2.49	149.6	0.40	3
355.0	2.53	151.7	0.38	2
360.0	2.56	153.8	0.36	2
365.0	2.60	156.0	0.34	2
370.0	2.64	158.1	0.33	2
375.0	2.67	160.2	0.30	2
380.0	2.71	162.4	0.28	2
385.0	2.74	164.5	0.27	2
390.0	2.78	166.6	0.26	2
395.0	2.81	168.8	0.24	2
400.0	2.85	170.9	0.23	1
405.0	2.88	173.1	0.22	1
410.0	2.92	175.2	0.21	1
415.0	2.96	177.3	0.20	1
420.0	2.99	179.5	0.19	1
425.0	3.03	181.6	0.18	1
430.0	3.06	183.7	0.17	1
435.0	3.10	185.9	0.16	1
440.0	3.13	188.0	0.15	1
445.0	3.17	190.2	0.15	1
450.0	3.20	192.3	0.13	1
455.0	3.24	194.4	0.12	1
460.0	3.28	196.6	0.12	1
465.0	3.31	198.7	0.11	1
470.0	3.35	200.8		
475.0	3.38	203.0		
480.0	3.42	205.1		
485.0	3.45	207.2		
490.0	3.49	209.4		
495.0	3.53	211.5		
500.0	3.56	213.7		
505.0	3.60	215.8		
510.0	3.63	217.9		
515.0	3.67	220.1		
520.0	3.70	222.2		
525.0	3.74	224.3		
530.0	3.77	226.5		
535.0	3.81	228.6		
540.0	3.85	230.7		
545.0	3.88	232.9		
550.0	3.92	235.0		
555.0	3.95	237.2		
560.0	3.99	239.3		
565.0	4.02	241.4		
570.0	4.06	243.6		
575.0	4.10	245.7		
580.0	4.13	247.8		
585.0	4.17	250.0		
590.0	4.20	252.1		
595.0	4.24	254.2		
600.0	4.27	256.4		

NOTES : Use for models including Design Point 3 (Basin C) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

Design Point 3-PMP Proposed Conditions

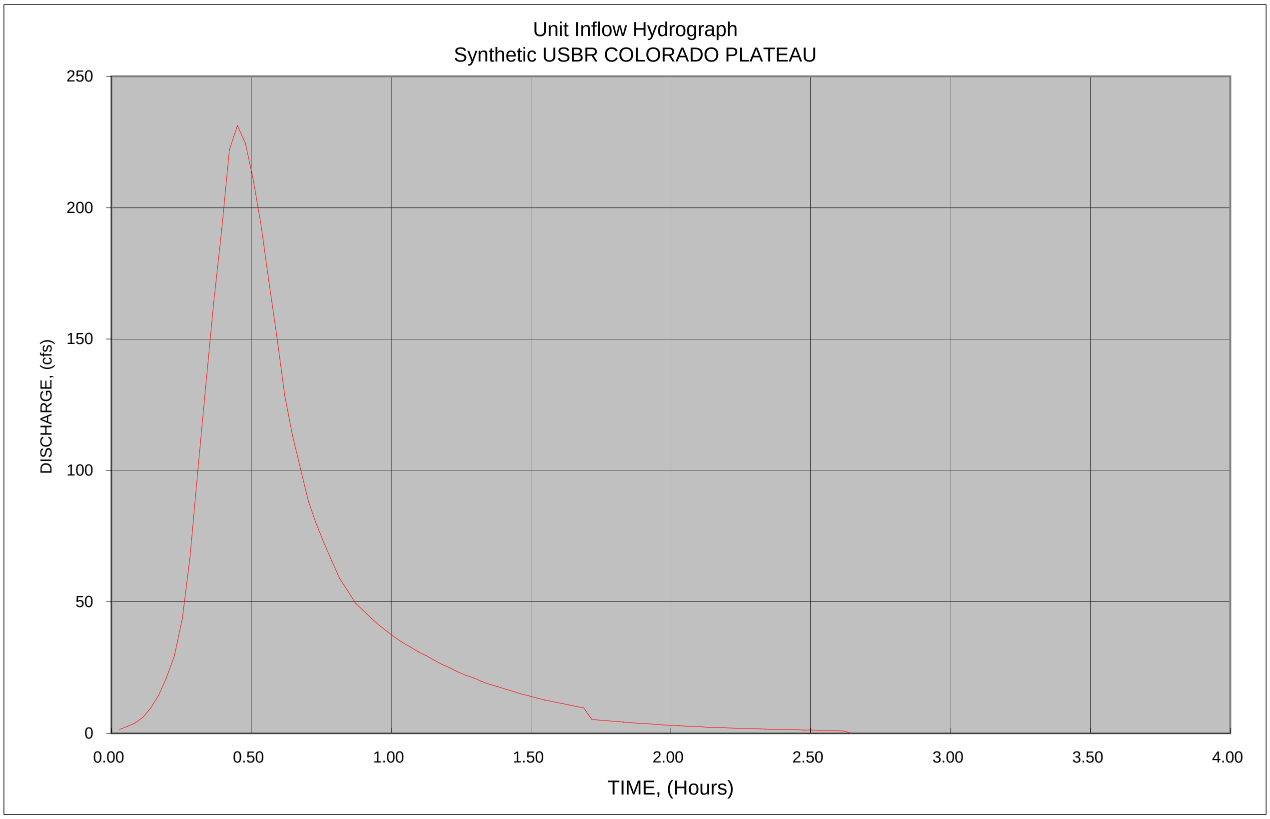
Drainage Area = 0.1675 sq. miles
Basin Slope = 77.56 ft./mile
L = 1.34 mi., Length of Watercourse
Lca = 0.7 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.56 Hours
Basin Factor = 0.11
V' = 4.50 cfs/Day
Qs = 8.0 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.52 Hours
Unit Duration, D = 5.69 minutes
Calculated Timestep = 1.69 minutes

Data to be used in Analysis
Unit Duration, D = 5 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



UI Record - Unit Graph 5 **minute interval**

UI	4	14	42	127	216	214	157	105	75	56
UI	45	38	32	27	23	19	17	14	12	10
UI	9	7	6	5	4	4	3	3	2	2
UI	2	1	1	1	0					
UI										
UI										
UI										
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USBR calculated unitgraph peak = 231 Interpolated Peak = 216

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	2
10.0	0.06	3.4	0.32	3
15.0	0.08	5.1	0.48	4
20.0	0.11	6.8	0.74	6
25.0	0.14	8.4	1.21	10
30.0	0.17	10.1	1.81	14
35.0	0.20	11.8	2.63	21
40.0	0.23	13.5	3.68	29
45.0	0.25	15.2	5.47	44
50.0	0.28	16.9	8.41	67
55.0	0.31	18.6	12.61	101
60.0	0.34	20.3	16.50	132
65.0	0.37	22.0	20.50	164
70.0	0.39	23.7	23.97	192
75.0	0.42	25.3	27.75	222
80.0	0.45	27.0	28.91	231
85.0	0.48	28.7	28.07	224
90.0	0.51	30.4	26.38	211
95.0	0.54	32.1	24.18	193
100.0	0.56	33.8	21.55	172
105.0	0.59	35.5	18.92	151
110.0	0.62	37.2	16.08	129
115.0	0.65	38.9	14.19	113
120.0	0.68	40.5	12.61	101
125.0	0.70	42.2	11.04	88
130.0	0.73	43.9	9.99	80
135.0	0.76	45.6	9.04	72
140.0	0.79	47.3	8.20	66
145.0	0.82	49.0	7.36	59
150.0	0.84	50.7	6.78	54
155.0	0.87	52.4	6.20	50
160.0	0.90	54.1	5.83	47
165.0	0.93	55.8	5.47	44
170.0	0.96	57.4	5.15	41
175.0	0.99	59.1	4.84	39
180.0	1.01	60.8	4.57	37
185.0	1.04	62.5	4.31	34
190.0	1.07	64.2	4.10	33
195.0	1.10	65.9	3.87	31
200.0	1.13	67.6	3.68	29
205.0	1.15	69.3	3.47	28
210.0	1.18	71.0	3.28	26
215.0	1.21	72.6	3.10	25
220.0	1.24	74.3	2.93	23
225.0	1.27	76.0	2.75	22
230.0	1.30	77.7	2.63	21
235.0	1.32	79.4	2.47	20
240.0	1.35	81.1	2.33	19
245.0	1.38	82.8	2.22	18
250.0	1.41	84.5	2.10	17
255.0	1.44	86.2	1.99	16
260.0	1.46	87.9	1.88	15
265.0	1.49	89.5	1.78	14
270.0	1.52	91.2	1.68	13
275.0	1.55	92.9	1.59	13
280.0	1.58	94.6	1.50	12
285.0	1.61	96.3	1.43	11
290.0	1.63	98.0	1.36	11
295.0	1.66	99.7	1.28	10
300.0	1.69	101.4	1.21	10
305.0	1.72	103.1	0.66	5
310.0	1.75	104.8	0.63	5
315.0	1.77	106.4	0.59	5
320.0	1.80	108.1	0.56	4
325.0	1.83	109.8	0.53	4
330.0	1.86	111.5	0.50	4
335.0	1.89	113.2	0.47	4
340.0	1.91	114.9	0.45	4
345.0	1.94	116.6	0.42	3
350.0	1.97	118.3	0.40	3
355.0	2.00	120.0	0.38	3
360.0	2.03	121.6	0.36	3
365.0	2.06	123.3	0.34	3
370.0	2.08	125.0	0.33	3
375.0	2.11	126.7	0.30	2
380.0	2.14	128.4	0.28	2
385.0	2.17	130.1	0.27	2
390.0	2.20	131.8	0.26	2
395.0	2.22	133.5	0.24	2
400.0	2.25	135.2	0.23	2
405.0	2.28	136.9	0.22	2
410.0	2.31	138.5	0.21	2
415.0	2.34	140.2	0.20	2
420.0	2.37	141.9	0.19	2
425.0	2.39	143.6	0.18	1
430.0	2.42	145.3	0.17	1
435.0	2.45	147.0	0.16	1
440.0	2.48	148.7	0.15	1
445.0	2.51	150.4	0.15	1
450.0	2.53	152.1	0.13	1
455.0	2.56	153.7	0.12	1
460.0	2.59	155.4	0.12	1
465.0	2.62	157.1	0.11	1
470.0	2.65	158.8		
475.0	2.68	160.5		
480.0	2.70	162.2		
485.0	2.73	163.9		
490.0	2.76	165.6		
495.0	2.79	167.3		
500.0	2.82	169.0		
505.0	2.84	170.6		
510.0	2.87	172.3		
515.0	2.90	174.0		
520.0	2.93	175.7		
525.0	2.96	177.4		
530.0	2.98	179.1		
535.0	3.01	180.8		
540.0	3.04	182.5		
545.0	3.07	184.2		
550.0	3.10	185.8		
555.0	3.13	187.5		
560.0	3.15	189.2		
565.0	3.18	190.9		
570.0	3.21	192.6		
575.0	3.24	194.3		
580.0	3.27	196.0		
585.0	3.29	197.7		
590.0	3.32	199.4		
595.0	3.35	201.1		
600.0	3.38	202.7		

NOTES : Use for models including Design Point 3 (Basin C) for the PMP Local event

Appendix B

Local Storm PMP Depth-Duration

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area less than 1 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	61	61	67	71	73	76	78	80	81	82	%
7. Areal reduced PMP [steps 5 X 6].	2.7	4.3	5.1	5.7	6.0	6.7	6.9	7.2	7.3	7.4	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].					6.0	0.7	0.2	0.3	0.1	0.1	in. ~~(mm)~~
		4.3	0.8	0.6	0.3	} 15-min. increments					

<1 mi^2

22 mi^2

9. Time sequence of incremental PMP according to:

HMR No. 5

Hourly increments [table 4.7]. 0.1 0.3 6.0 0.7 0.2 0.1 in. ~~(mm)~~

Four largest 15-min. increments [table 4.8]. 4.3 0.8 0.6 0.3 in. ~~(mm)~~

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 1.4 mi² (~~km²~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi² (2.6-km²) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi² (2.6-km²) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~) <1 mi²
6. Areal reduction [fig. 4.9].	96 ~~6X~~	96 ~~61~~	97 ~~65~~	97 ~~71~~	98 ~~73~~	98 ~~76~~	98 ~~78~~	99 ~~80~~	99 ~~81~~	99 ~~82~~	% 1.4 mi²
7. Areal reduced PMP [steps 5 X 6].	4.3 ~~2.7~~	6.8 ~~4.3~~	7.4 ~~5.1~~	7.8 ~~5.7~~	8.0 ~~6.0~~	8.6 ~~6.7~~	8.7 ~~6.9~~	8.9 ~~7.2~~	8.9 ~~7.3~~	8.9 ~~7.4~~	in. (~~mm~~)

8. Incremental PMP [successive subtraction in step 7].
8.0 0.6 0.1 0.2 0.0 0.0
~~6.0~~ ~~0.7~~ ~~0.2~~ ~~0.3~~ ~~0.1~~ ~~0.1~~ in. (~~mm~~)

~~4.3~~ ~~0.8~~ ~~0.6~~ ~~0.3~~ } 15-min. increments
6.8 0.6 0.4 0.2

9. Time sequence of incremental PMP according to:

HMR No. 5

Hourly increments [table 4.7].
0.0 0.2 8.0 0.6 .2 0.0
~~0.1~~ ~~0.3~~ ~~6.0~~ ~~0.7~~ ~~0.2~~ ~~0.1~~ in. (~~mm~~)

Four largest 15-min. increments [table 4.8].
~~4.3~~ ~~0.8~~ ~~0.6~~ ~~0.3~~ in. (~~mm~~)
6.8 0.6 0.4 0.2

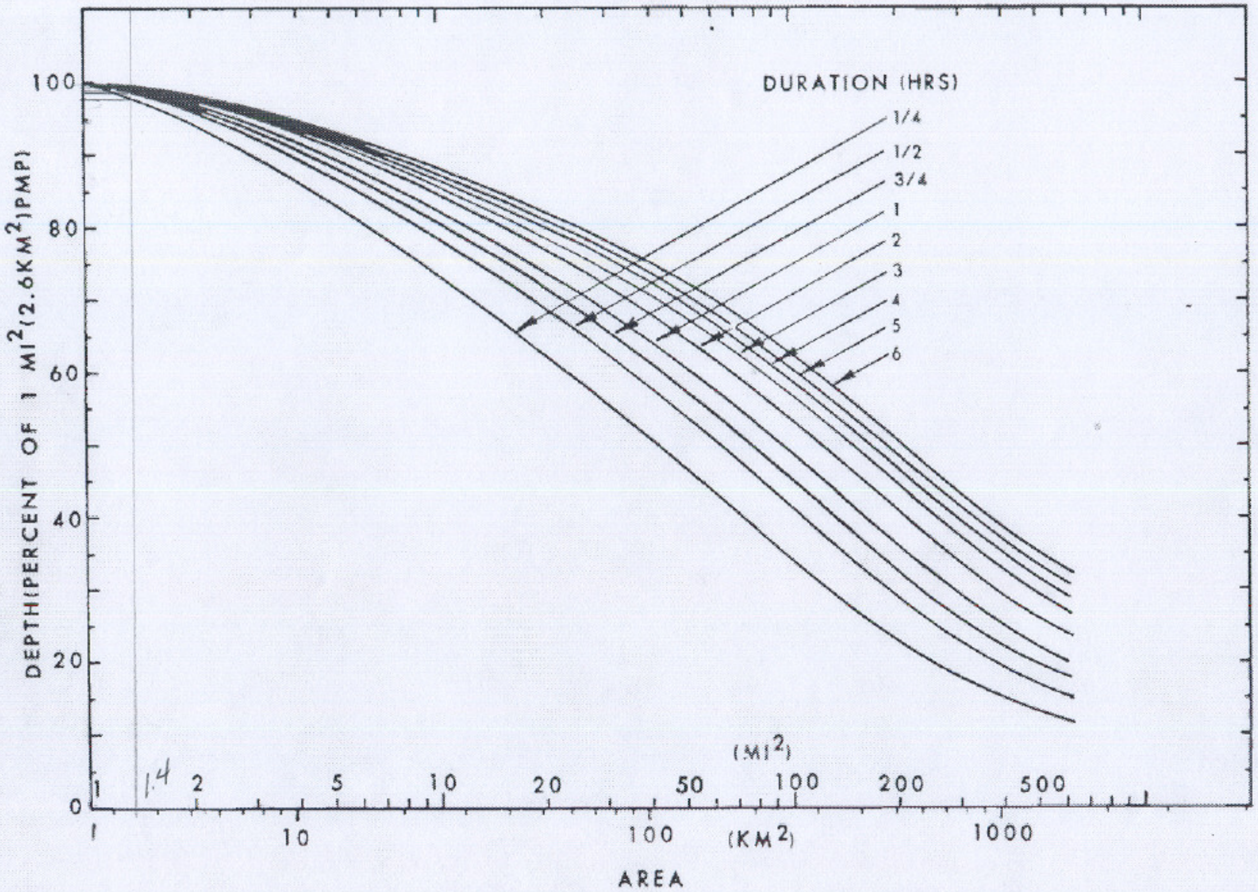

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

HMR No. 49

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 26 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00" W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr) 5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	92 ~~61~~	92 ~~61~~	94 ~~67~~	95 ~~71~~	96 ~~73~~	96 ~~76~~	97 ~~78~~	97 ~~80~~	97 ~~81~~	98 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.1 ~~2.7~~	6.5 ~~4.3~~	7.1 ~~5.1~~	7.6 ~~5.7~~	7.9 ~~6.0~~	8.4 ~~6.7~~	8.6 ~~6.9~~	8.7 ~~7.2~~	8.7 ~~7.3~~	8.8 ~~7.4~~	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].					7.9 ~~6.0~~	0.5 ~~0.7~~	0.2 ~~0.2~~	0.1 ~~0.3~~	0.0 0.1	0.1 0.1	in. ~~(mm)~~
} 15-min. increments		6.5 ~~4.3~~	0.6 ~~0.8~~	0.5 ~~0.6~~	0.3						

<1 mi^2

22 mi^2

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.1 ~~0.1~~ 0.2 ~~0.3~~ 7.9 ~~6.0~~ 0.5 0.7 0.1 ~~0.2~~ 0.0 0.1 in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8]. 6.5 ~~4.3~~ 0.6 ~~0.8~~ 0.5 0.6 0.3 in. ~~(mm)~~

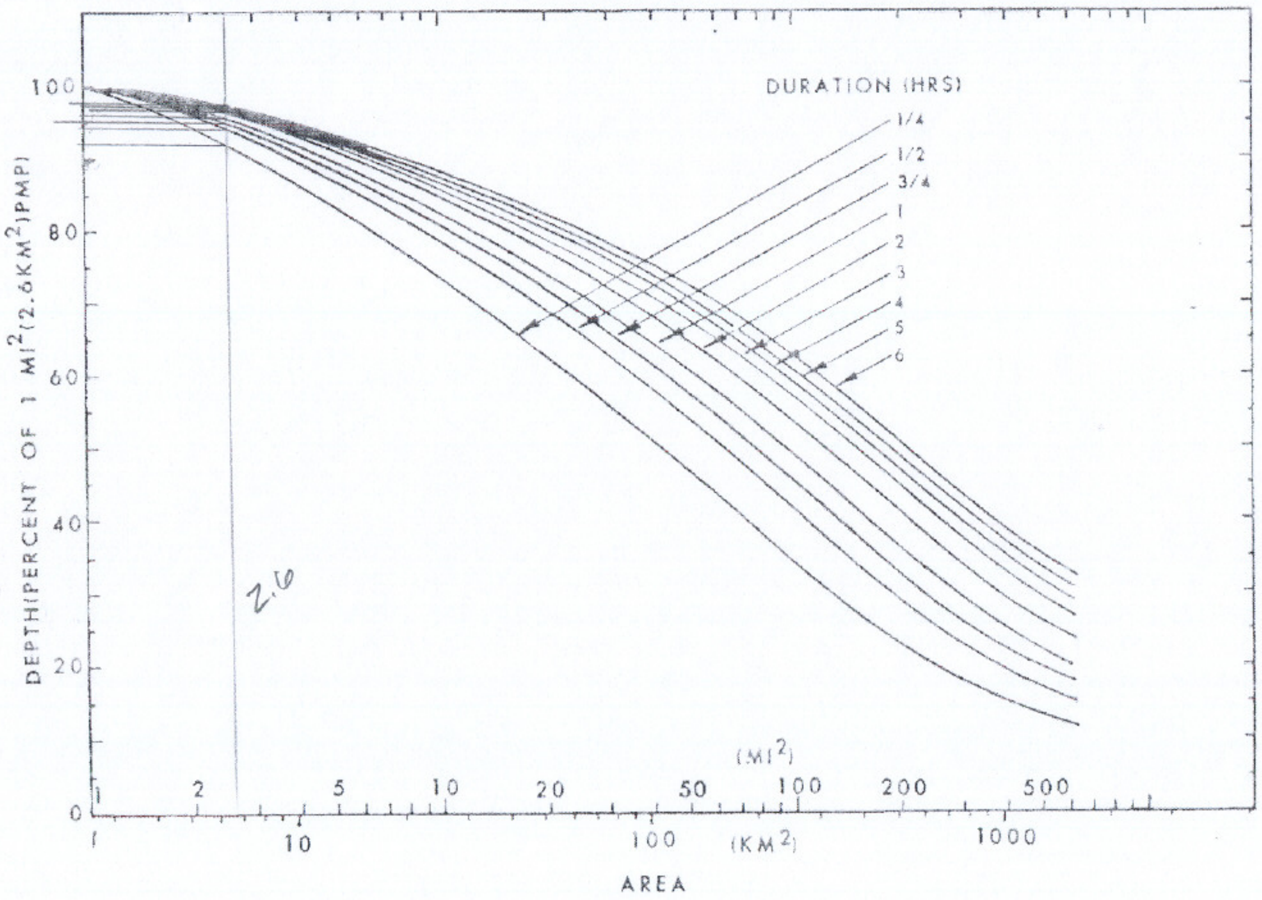

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area 2.7 ~~less than 1~~ mi^2 (~~km^2~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5 min.	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	92	92 ~~61~~	94 ~~67~~	95 ~~71~~	96 ~~73~~	96 ~~76~~	96 ~~78~~	97 ~~80~~	97 ~~81~~	97 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.1	6.5 ~~4.3~~	7.1 ~~5.1~~	7.6 ~~5.7~~	7.9 ~~6.0~~	8.4 ~~6.7~~	8.5 ~~6.9~~	8.7 ~~7.2~~	8.7 ~~7.3~~	8.7 ~~7.4~~	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].					7.9 ~~6.0~~	0.5 ~~0.7~~	0.1 ~~0.2~~	0.2 ~~0.3~~	0.0 ~~0.1~~	0.0 ~~0.1~~	in. (~~mm~~)
		6.5 ~~4.3~~	0.6 ~~0.8~~	0.5 ~~0.6~~	0.3	} 15-min. increments					

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.0 ~~0.1~~ 0.2 ~~0.5~~ 7.9 ~~6.0~~ 0.5 ~~0.7~~ 0.1 ~~0.2~~ 0.0 ~~0.1~~ in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. 6.5 ~~4.3~~ 0.6 ~~0.8~~ 0.5 ~~0.6~~ 0.3 in. (~~mm~~)

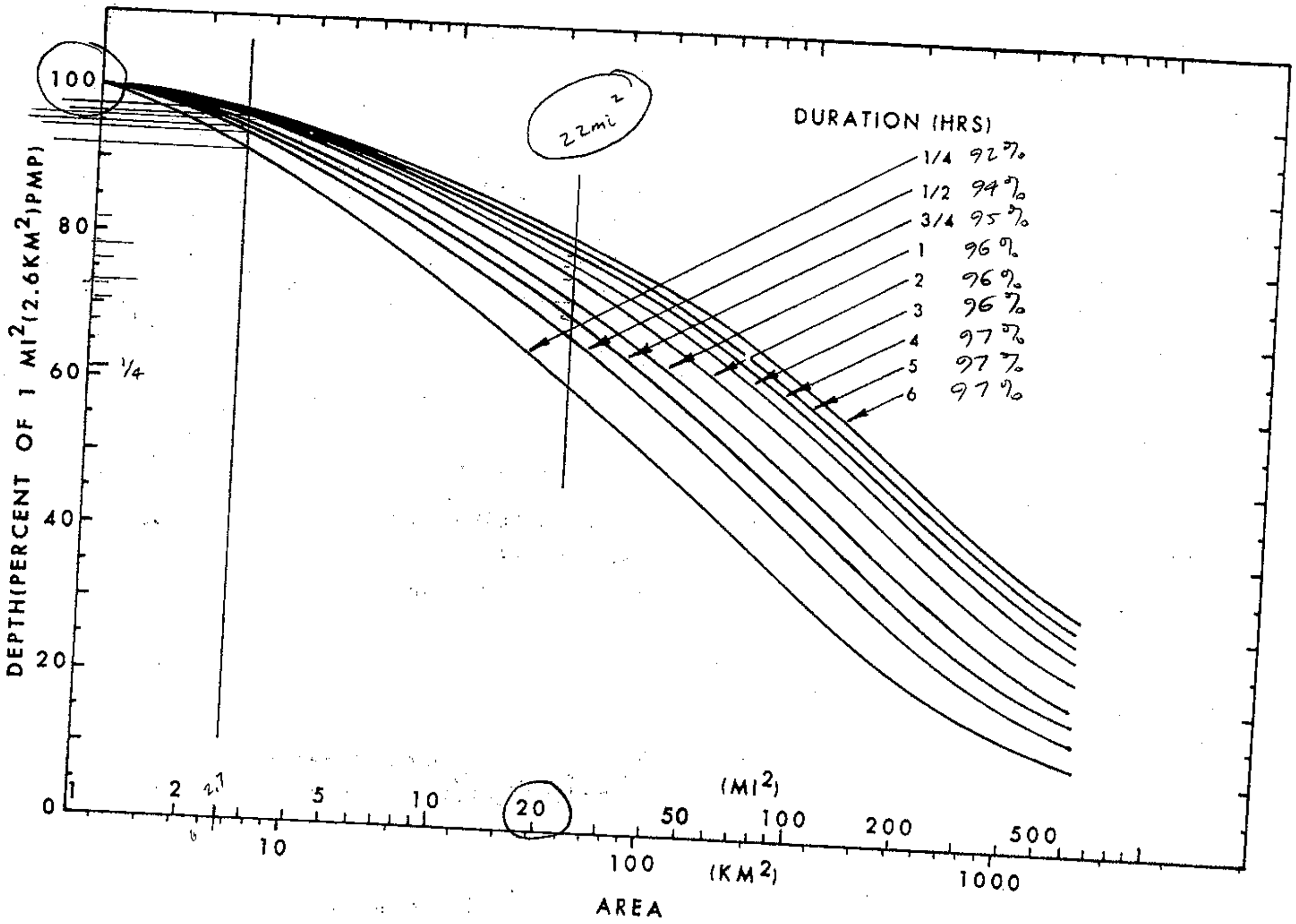

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

HMR No. 49

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 3.5 mi² (~~km²~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00" W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi² (2.6-km²) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m); 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi² (2.6-km²) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	88 ~~60~~	88 61	91 67	92 71	93 73	94 76	95 78	95 80	96 81	96 82	%
7. Areal reduced PMP [steps 5 X 6].	4.0 ~~2.7~~	6.2 4.3	6.9 5.1	7.4 5.7	7.6 6.0	8.3 6.7	8.5 6.9	8.6 7.2	8.6 7.3	8.6 7.4	in. (~~mm~~)

<1 mi²

22 mi²

8. Incremental PMP [successive subtraction in step 7]. 6.0 0.7 0.2 0.3 0.1 0.1 in. (~~mm~~)

   4.3 0.8 0.6 0.3 } 15-min. increments

9. Time sequence of incremental PMP according to:

   HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 6.0 0.7 0.2 0.1 in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. 4.3 0.8 0.6 0.3 in. (~~mm~~)

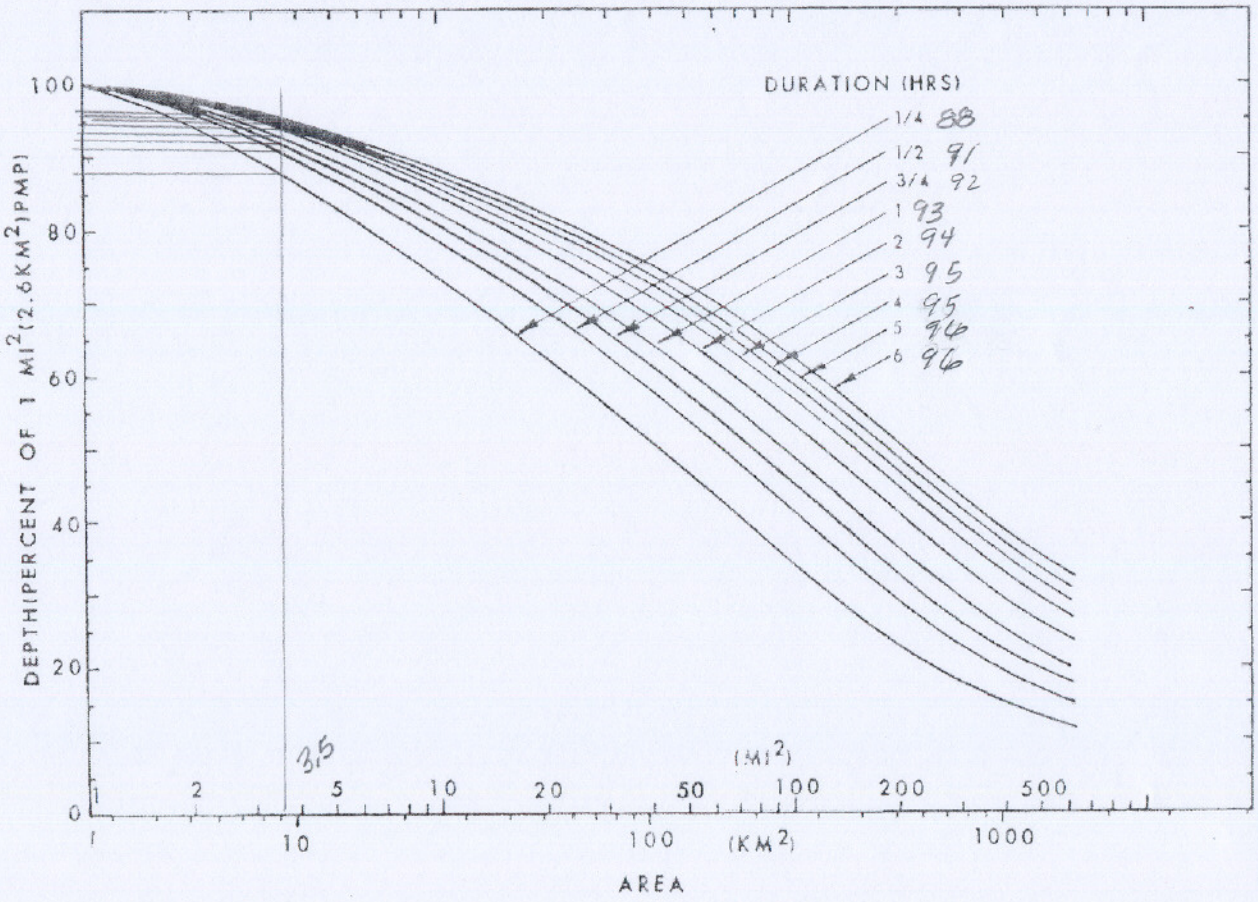

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

HMR No. 49

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Crescent Junction Disposal Site Area 9 ~~less than 1~~ mi^2 (~~km^2~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00" W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	76	76 ~~61~~	80 ~~67~~	82 ~~71~~	84 ~~73~~	86 ~~76~~	87 ~~78~~	88 ~~80~~	88 ~~81~~	89 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	3.4	5.4 ~~4.3~~	6.1 ~~5.1~~	6.6 ~~5.7~~	6.9 ~~6.0~~	7.6 ~~6.7~~	7.7 ~~6.9~~	7.9 ~~7.2~~	7.9 ~~7.3~~	8.0 ~~7.4~~	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].					6.9 ~~6.0~~	0.7	0.1 ~~0.2~~	0.2 ~~0.3~~	0.0 ~~0.1~~	0.1	in. (~~mm~~)
		5.4 ~~4.3~~	0.7 ~~0.8~~	0.5 ~~0.6~~	0.3	} 15-min. increments					

9. Time sequence of incremental PMP according to: HMR No. 5

Hourly increments [table 4.7]. 0.1 0.2 ~~0.3~~ 6.9 ~~6.0~~ 0.7 0.1 ~~0.2~~ 0.0 ~~0.1~~ in. (~~mm~~)

Four largest 15-min. increments [table 4.8]. 5.4 ~~4.3~~ 0.7 ~~0.8~~ 0.5 ~~0.6~~ 0.3 in. (~~mm~~)

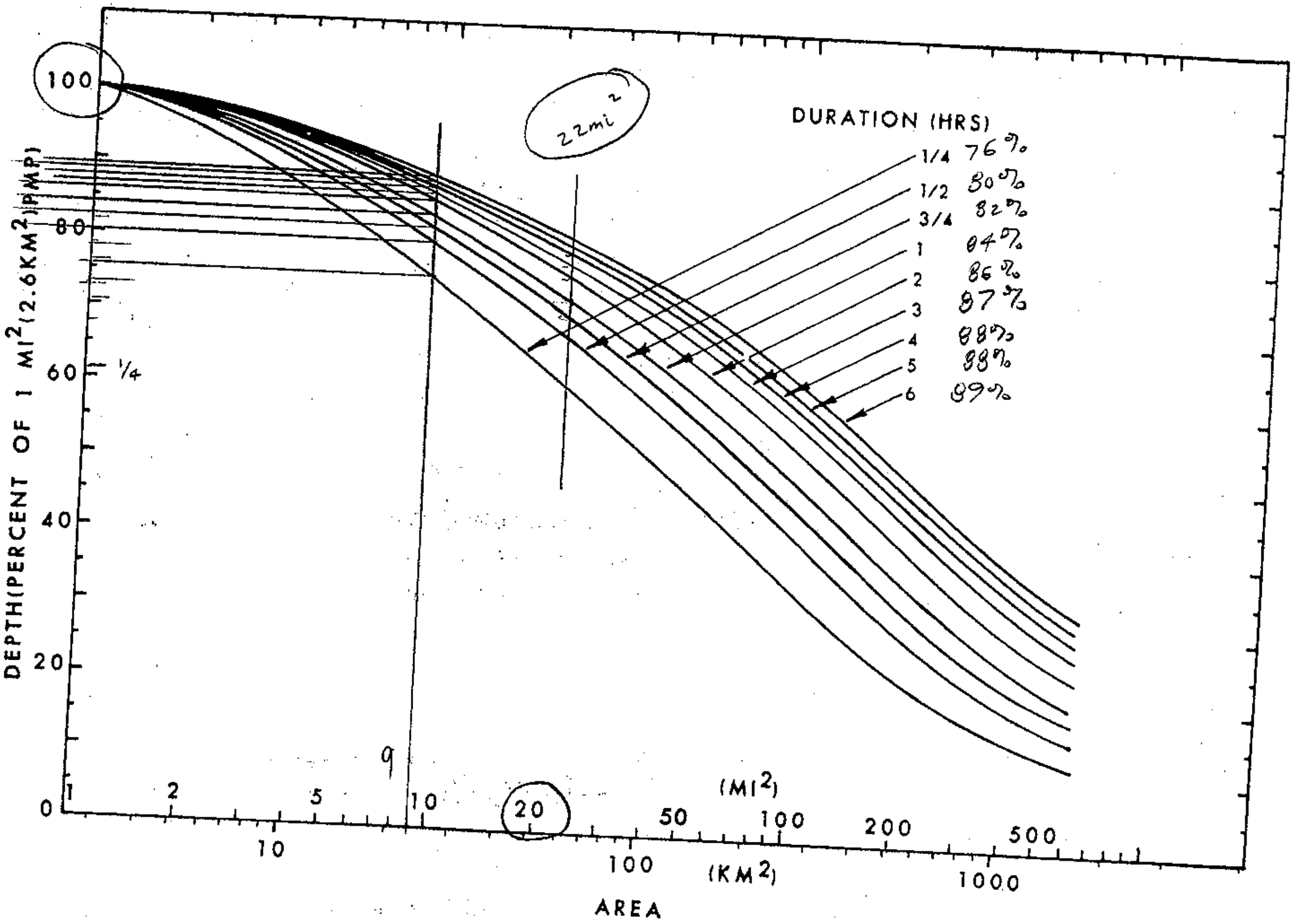

Figure 4.9.--*Adopted depth-area relations for local-storm PMP.*

HMR No. 49

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Crescent Junction Disposal Site Area 15 ~~less than 1~~ mi² ~~(km²)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi² (2.6-km²) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
		Duration (hr)									
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi² (2.6-km²) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	67	67 ~~61~~	73 ~~67~~	76 ~~71~~	78 ~~73~~	81 ~~76~~	81 ~~78~~	83 ~~80~~	84 ~~81~~	85 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	3.0	4.8 ~~4.3~~	5.5 ~~5.1~~	6.1 ~~5.7~~	6.4 ~~6.0~~	7.0 ~~6.7~~	7.2 ~~6.9~~	7.5 ~~7.2~~	7.6 ~~7.3~~	7.7 ~~7.4~~	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].					6.4 ~~6.0~~	0.6 ~~0.7~~	0.2	0.3	0.1	0.1	in. ~~(mm)~~
		4.8 ~~4.3~~	0.7 ~~0.8~~	0.6	0.3 } 15-min. increments						

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 6.4 ~~6.0~~ 0.6 ~~0.7~~ 0.2 0.1 in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8]. 4.8 ~~4.3~~ 0.7 ~~0.8~~ 0.6 0.3 in. ~~(mm)~~

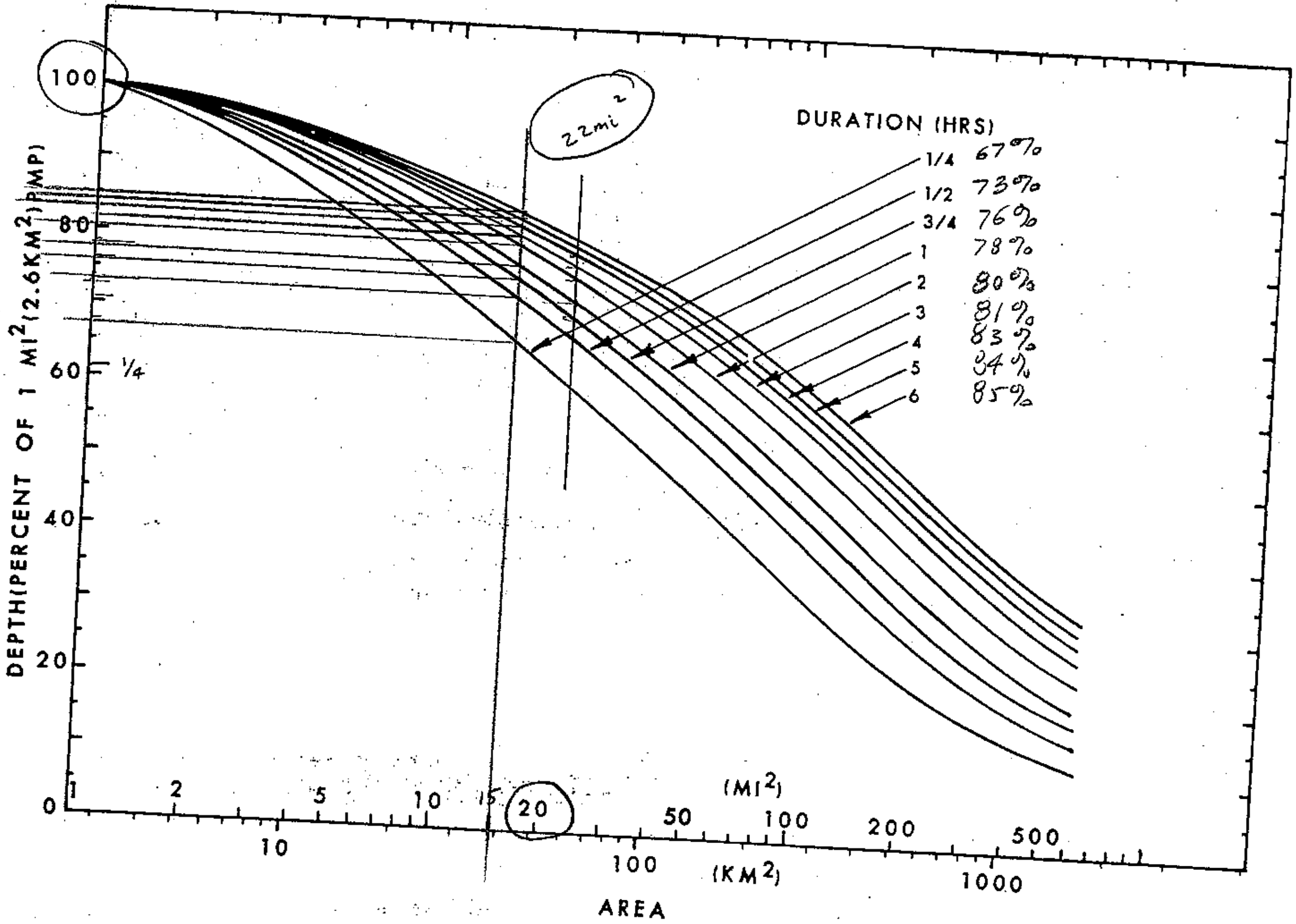

Figure 4.9.--Adopted depth-area relations for local-storm PMP.

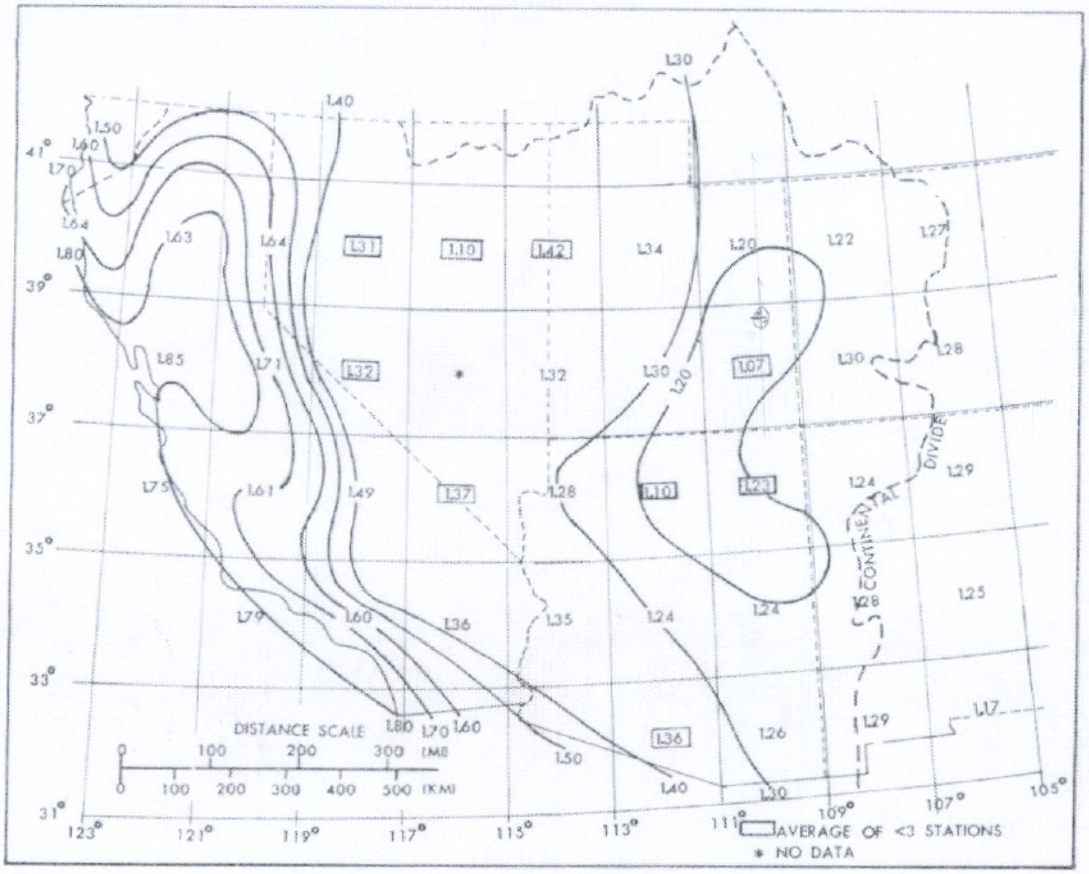

Figure 4.7.--Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945-). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi^2 (2.6-km^2) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi^2 (2.6-km^2) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

6/1-hr	Duration (hr)								
ratio	1/4	1/2	3/4	1	2	3	4	5	6
1.1	86	93	97	100	107	109	110	110	110
1.2	74	89	95	100	110	115	118	119	120
1.3	74	89	95	100	114	121	125	128	130
1.4	63	83	93	100	118	126	132	137	140
1.5	63	83	93	100	121	132	140	145	150
1.6	43	70	87	100	124	138	147	154	160
1.8	43	70	87	100	130	149	161	171	180
2.0	43	70	87	100	137	161	175	188	200

4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi^2 (2.6 km^2). To apply PMP to a basin, we need to determine how 1-mi^2 (2.6-km^2) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

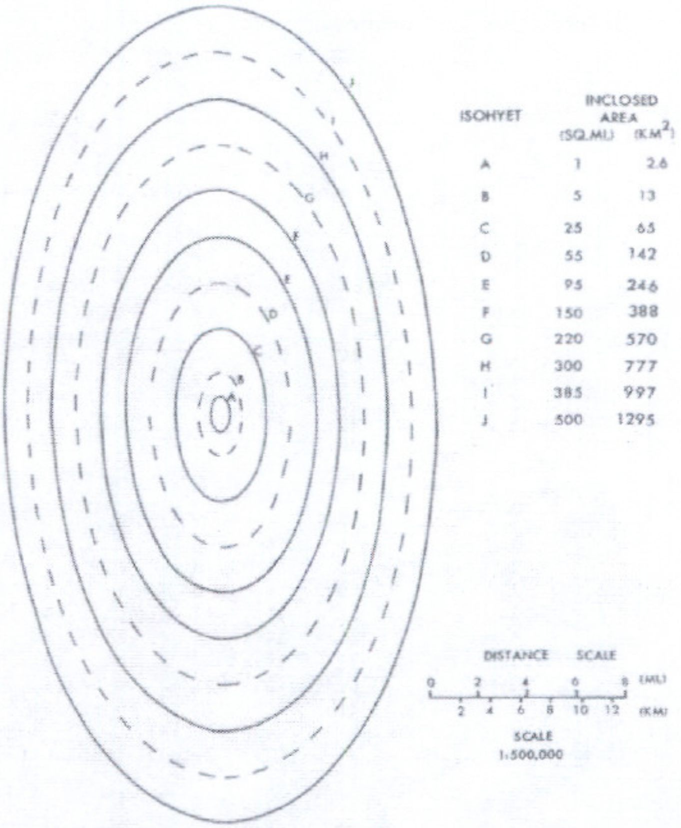

Figure 4.10.--Idealized local-storm isohyetal pattern.

ISOHYET	INCLOSED AREA (SQ.MI.)	(KM^2)
A	1	2.6
B	5	13
C	25	65
D	55	142
E	95	246
F	150	388
G	220	570
H	300	777
I	385	997
J	500	1295

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, the choice of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

	HMR No. 5[1]	EM1110-2-1411[2]
Increment	Sequence Position	
Largest hourly amount	Third	Fourth
2nd largest	Fourth	Third
3rd largest	Second	Fifth
4th largest	Fifth	Second
5th largest	First	Last
least	Last	First

---

[1] U. S. Weather Bureau 1947.

[2] U. S. Corps of Engineers 1952.

Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.--Time sequence for 15-min incremental PMP within 1 hr.

Increment	Sequence Position
Largest 15-min amount	First
2nd largest	Second
3rd largest	Third
least	Last

4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

	Month						
	M	J	J	A	S	O	No. of Cases
Utah	1	5	9	14	5		34
Arizona		4	16	19	4		43
S. Calif.*		14	10	7			31
No. of cases/mo.	1	23	35	40	9	0	

*South of 37°N and east of Sierra Nevada ridgeline.

Appendix C

HEC-HMS Output

Project: Crescent Junction Ex Simulation Run: CW 25

Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 13:20:23	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	2975.47	01Jan2006, 14:15	0.49
I-70	22.5600	2975.47	01Jan2006, 14:15	0.49

Project: Crescent Junction Ex Simulation Run: CW 100

Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:20:55	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	5982.86	01Jan2006, 14:10	0.98
I-70	22.5600	5982.86	01Jan2006, 14:10	0.98

Project: Crescent Junction Ex Simulation Run: CW PMP Local

Start of Run: 01Jan2006, 00:00 Basin Model: Crescent Wash-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local 22 sq mi
Compute Time: 18May2006, 13:06:09 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	45196.66	01Jan2006, 04:40	6.11
Sink-1	22.5600	45196.66	01Jan2006, 04:40	6.11

Project: Crescent Junction Ex Simulation Run: BASIN 1-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:22:10	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	2135.13	01Jan2006, 12:35	0.99
DP 6	2.6300	2135.13	01Jan2006, 12:35	0.99

Project: Crescent Junction Ex Simulation Run: BASIN 1-PMP LOCAL

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 2.7 sq mi
Compute Time:	18May2006, 13:22:40	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	21287.52	01Jan2006, 03:25	7.77
DP 6	2.6300	21287.52	01Jan2006, 03:25	7.77

Project: Crescent_Junction_Pr   Simulation Run: Basin 1-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:41:52	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	2210.10	01Jan2006, 12:35	1.00
DP 6	2.6300	2210.10	01Jan2006, 12:35	1.00

Project: Crescent_Junction_Pr Simulation Run: Basin 1-PMP

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 2.7 sq mi
Compute Time:	18May2006, 13:42:53	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	21321.77	01Jan2006, 03:25	10.80
DP 6	2.6300	21321.77	01Jan2006, 03:25	10.80

Project: Crescent Junction Ex Simulation Run: BASIN 2-25

Start of Run: 01Jan2006, 00:00 Basin Model: Basin 2-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 25-yr 24-hr
Compute Time: 18May2006, 13:24:57 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	1726.31	01Jan2006, 13:30	0.49
RR Bridge	8.9600	1726.31	01Jan2006, 13:30	0.49

Project: Crescent Junction Ex Simulation Run: BASIN 2-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 2-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:26:09	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
RR Bridge	8.9600	3453.04	01Jan2006, 13:30	0.99

Project: Crescent Junction Ex Simulation Run: BASIN 2-PMP

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 2-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 9 sq mi
Compute Time:	18May2006, 13:26:56	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	29868.86	01Jan2006, 04:05	7.01
RR Bridge	8.9600	29868.86	01Jan2006, 04:05	7.01

Project: Crescent Junction Ex Simulation Run: 123 100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basins 123-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:32:06	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	2135.13	01Jan2006, 12:35	0.99
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
Basin 3	3.4700	1553.39	01Jan2006, 13:15	0.99
I-70	15.0600	5108.83	01Jan2006, 13:30	0.99
I-70 Culvert	15.0600	5108.83	01Jan2006, 13:30	0.99
Kendall Wash E	8.9600	3441.54	01Jan2006, 13:35	0.99
Kendall Wash W	2.6300	2066.77	01Jan2006, 12:40	0.99

Project: Crescent Junction Ex	Simulation Run: 123 PMP Local		
Start of Run:	01Jan2006, 00:00	Basin Model:	Basins 123-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 15 sq mi
Compute Time:	18May2006, 13:33:12	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	16218.18	01Jan2006, 03:25	6.38
Basin 2	8.9600	27260.23	01Jan2006, 04:05	6.41
Basin 3	3.4700	12147.64	01Jan2006, 03:55	6.41
I-70	15.0600	40835.44	01Jan2006, 04:05	6.41
I-70 Culvert	15.0600	40835.44	01Jan2006, 04:05	6.41
Kendall Wash E	8.9600	26892.86	01Jan2006, 04:10	6.41
Kendall Wash W	2.6300	15865.63	01Jan2006, 03:25	6.39

HEC-HMS

Project : Crescent Junction Ex

Basin Model : Basins 123-PMP

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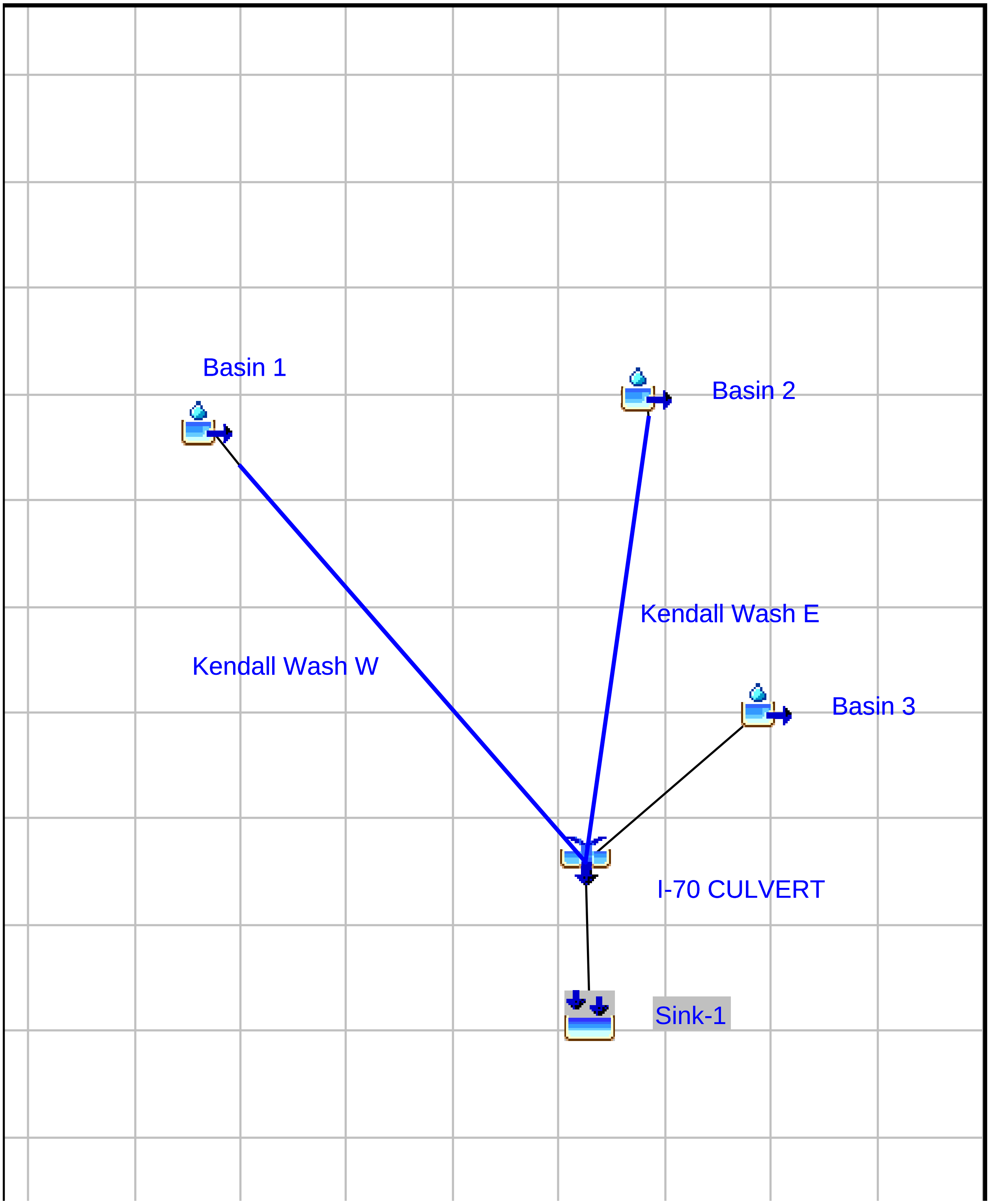

Project: Crescent_Junction_Pr Simulation Run: Basins 123-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basins 123-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:46:23	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	2210.10	01Jan2006, 12:35	1.00
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
Basin 3	3.4700	1553.39	01Jan2006, 13:15	0.99
I-70	15.0600	5098.41	01Jan2006, 13:30	0.99
I-70 Culvert	15.0600	5098.41	01Jan2006, 13:30	0.99
Kendall Wash E	8.9600	3441.54	01Jan2006, 13:35	0.99
Kendall Wash W	2.6300	2166.34	01Jan2006, 12:35	1.00

Project: Crescent_Junction_Pr Simulation Run: BASINS 123 PMP

Start of Run:	01Jan2006, 00:00	Basin Model:	Basins 123-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 15 sq mi
Compute Time:	18May2006, 13:48:35	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	16252.58	01Jan2006, 03:25	8.88
Basin 2	8.9600	27260.23	01Jan2006, 04:05	6.41
Basin 3	3.4700	12147.64	01Jan2006, 03:55	6.41
I-70	15.0600	40871.36	01Jan2006, 04:05	6.84
I-70 Culvert	15.0600	40871.36	01Jan2006, 04:05	6.84
Kendall Wash E	8.9600	26892.86	01Jan2006, 04:10	6.41
Kendall Wash W	2.6300	15899.38	01Jan2006, 03:25	8.89

HEC-HMS

Project : Crescent_Junction_Pr

Basin Model : Basins 123-PMP

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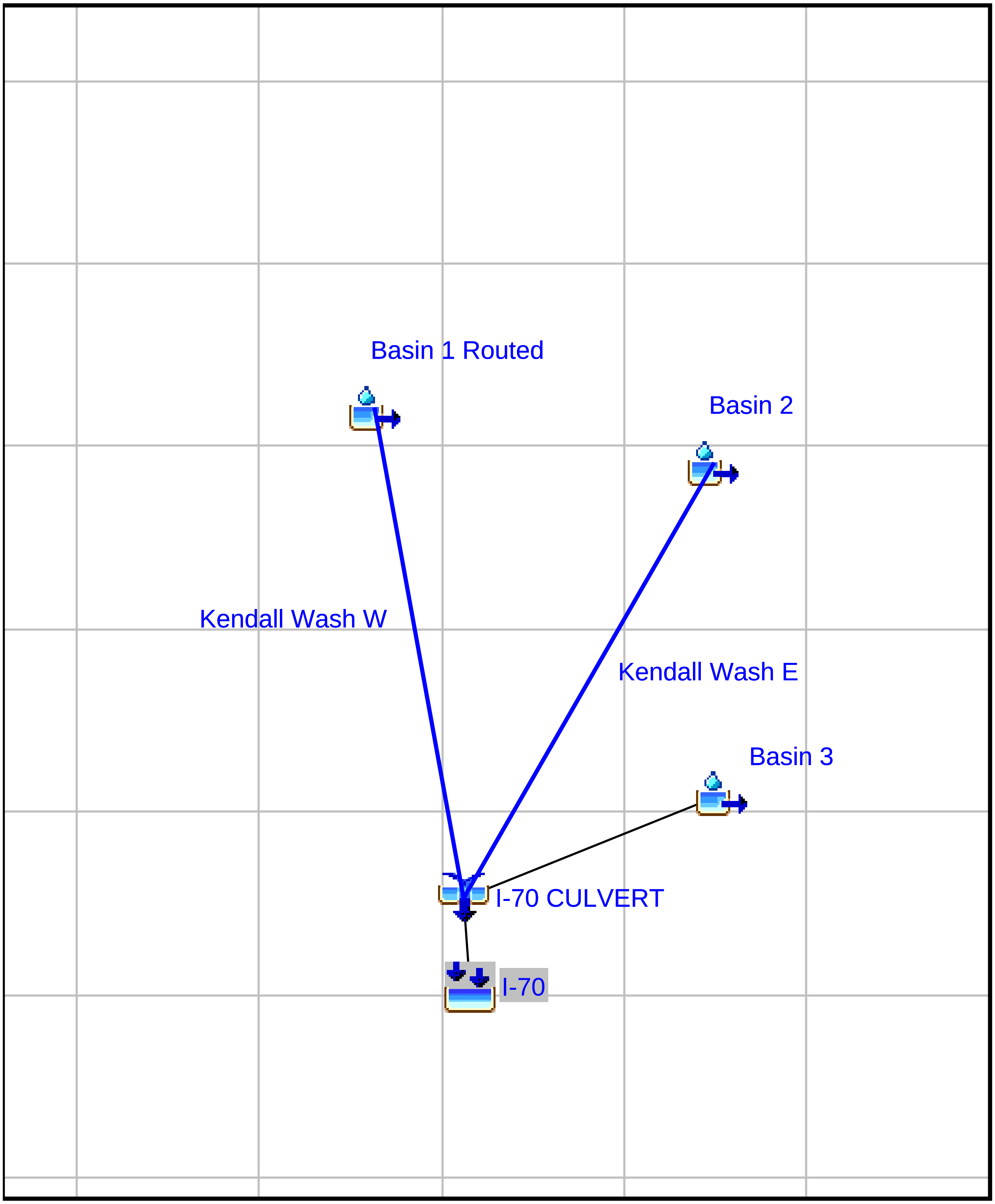

Project: Crescent_Junction_Pr Simulation Run: DP 4&5-25

Start of Run:	01Jan2006, 00:00	Basin Model:	P-DP 4&5-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 13:49:54	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin B	0.5218	291.31	01Jan2006, 12:25	0.49
Basin D	0.3827	187.06	01Jan2006, 12:35	0.57
DP 4	0.5218	291.31	01Jan2006, 12:25	0.49
DP 5	0.9045	447.59	01Jan2006, 12:30	0.52
West Ditch	0.5218	281.01	01Jan2006, 12:25	0.49

Project: Crescent_Junction_Pr Simulation Run: DP 4&5-PMP

Start of Run:	01Jan2006, 00:00	Basin Model:	P-DP 4&5-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local <1 sq mi
Compute Time:	18May2006, 13:51:38	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin B	0.5218	5858.79	01Jan2006, 03:15	8.21
Basin D	0.3827	3426.58	01Jan2006, 03:25	8.48
DP 4	0.5218	5858.79	01Jan2006, 03:15	8.21
DP 5	0.9045	8722.28	01Jan2006, 03:20	8.34
West Ditch	0.5218	5539.08	01Jan2006, 03:15	8.24

HEC-HMS

Project : Crescent Junction Pr

Basin Model : P-DP 4&5-event

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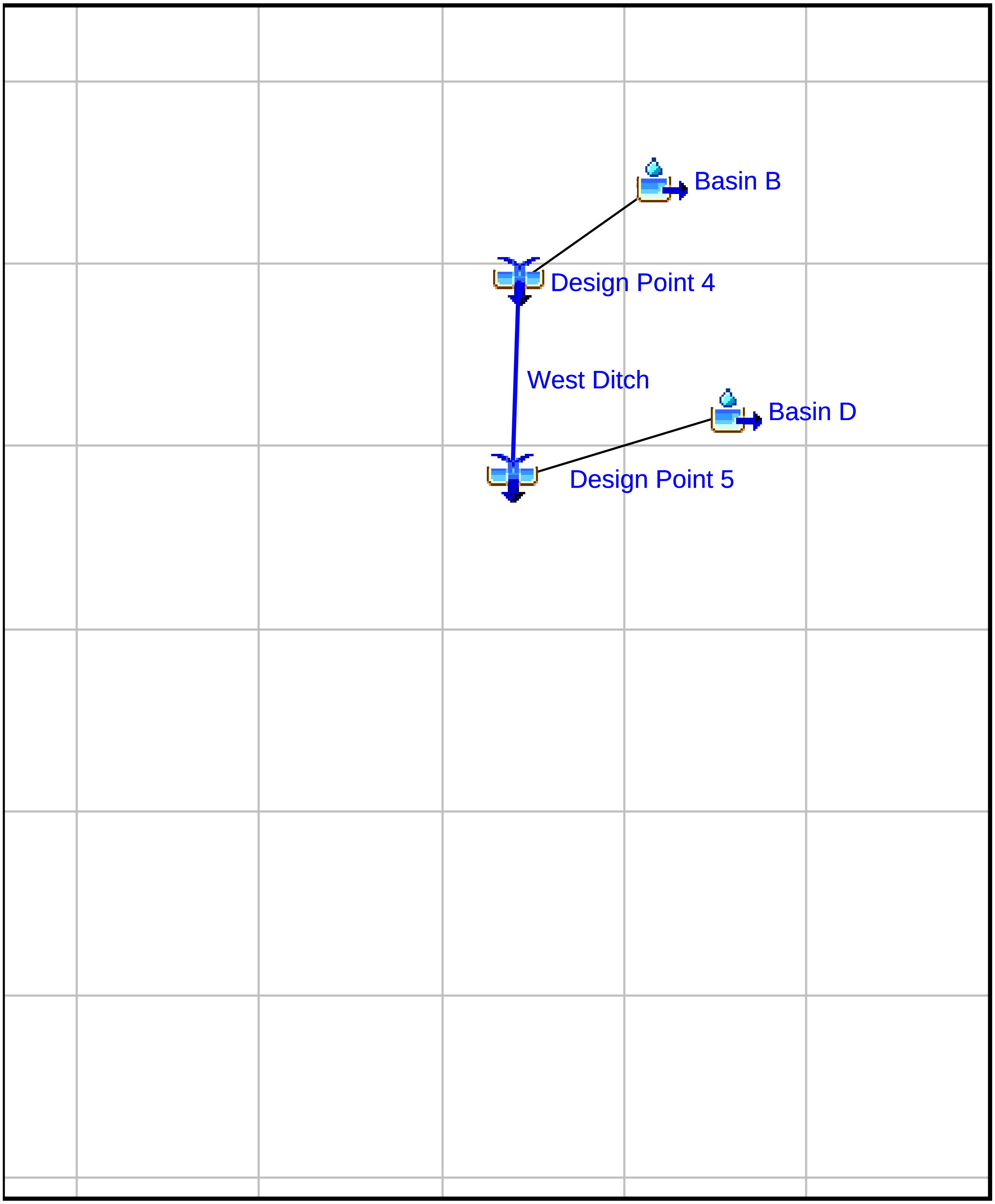


Project: Crescent_Junction_Pr	Simulation Run: BASIN C-25		
Start of Run:	01Jan2006, 00:00	Basin Model:	P-BASIN C-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 13:56:17	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	74.72	01Jan2006, 12:30	0.49
DP 3-ExCulv @ RR	0.1675	74.72	01Jan2006, 12:30	0.49

Project: Crescent_Junction_Pr Simulation Run: BASIN C-100

Start of Run:	01Jan2006, 00:00	Basin Model:	P-BASIN C-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:57:43	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	146.99	01Jan2006, 12:30	0.99
DP 3-ExCulv@RR	0.1675	146.99	01Jan2006, 12:30	0.99

Project: Crescent_Junction_Pr Simulation Run: BASIN C-PMP			
Start of Run:	01Jan2006, 00:00	Basin Model:	P-BASIN C-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local <1 sq mi
Compute Time:	18May2006, 13:58:25	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	1488.43	01Jan2006, 03:20	8.18
DP3-Ex Culv@RR	0.1675	1488.43	01Jan2006, 03:20	8.18

Project: Crescent_Junction_Pr Simulation Run: P-DRAINAGE 25

Start of Run:	01Jan2006, 00:00	Basin Model:	P-DRAINAGE-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 14:02:40	Control Specifications:	1 day at 5 min step

Volume Units: IN

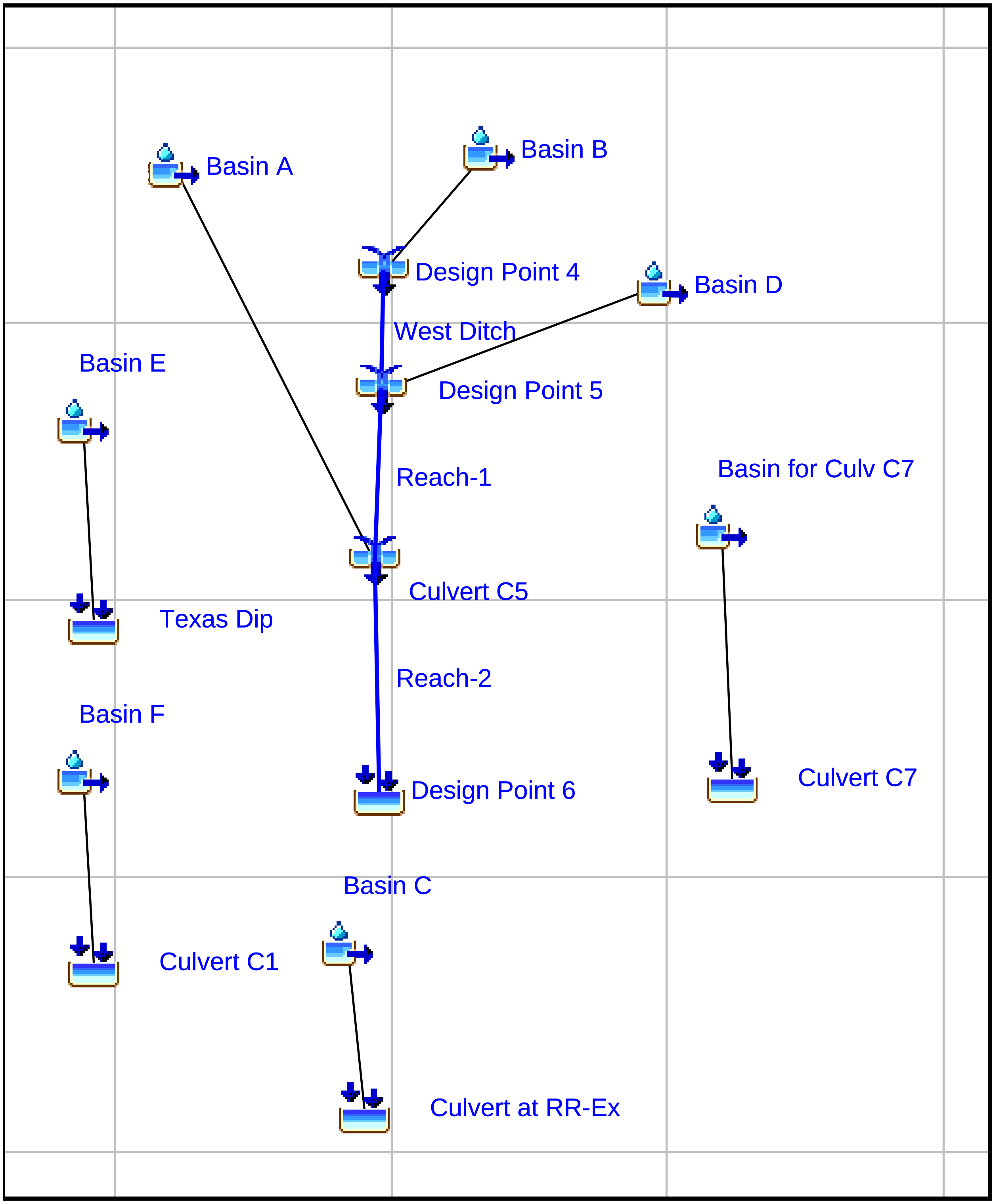
Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin A	0.3456	192.54	01Jan2006, 12:25	0.49
Basin B	0.5218	291.31	01Jan2006, 12:25	0.49
Basin C	0.1675	74.72	01Jan2006, 12:30	0.49
Basin D	0.3827	187.06	01Jan2006, 12:35	0.57
Basin E	0.1839	91.30	01Jan2006, 12:30	0.49
Basin F	0.0863	41.65	01Jan2006, 12:30	0.49
Basin for Culv C7	0.4087	238.92	01Jan2006, 12:20	0.49
Culv C1-DP 2	0.0863	41.65	01Jan2006, 12:30	0.49
Culv C5	1.2501	610.57	01Jan2006, 12:30	0.52
Culv C7	0.4087	238.92	01Jan2006, 12:20	0.49
DP 4	0.5218	291.31	01Jan2006, 12:25	0.49
DP 5	0.9045	447.59	01Jan2006, 12:30	0.52
DP 6	1.2501	608.41	01Jan2006, 12:30	0.52
Ex-Culv @ RR	0.1675	74.72	01Jan2006, 12:30	0.49
Reach-1	0.9045	445.60	01Jan2006, 12:30	0.53
Reach-2	1.2501	608.41	01Jan2006, 12:30	0.52
Texas Dip	0.1839	91.30	01Jan2006, 12:30	0.49
West Ditch	0.5218	281.01	01Jan2006, 12:25	0.49

HEC-HMS

Project : Crescent Junction Pr

Basin Model : P-DRAINAGE-event

May 16 16:49:09 MDT 2006



Appendix D

Rational Method Output

TIME OF CONCENTRATION

$t_c = t_i + t_t$

Initial or Overland Flow = ti
ti = $[0.395(1.1-C_5)SQRT(L)]/S^{0.33}$

Overland Travel Time = t_t
$V = C_v S_w^{0.5}$
Where: C_v = conveyance coefficient from UD Table RO-2
S_w = watercourse slope (ft/ft)
$t_t = L/60V$

CHECK:
$t_c = (L/180) + 10$ forUrbanized areas only
Minimum t_c = 10 minutes

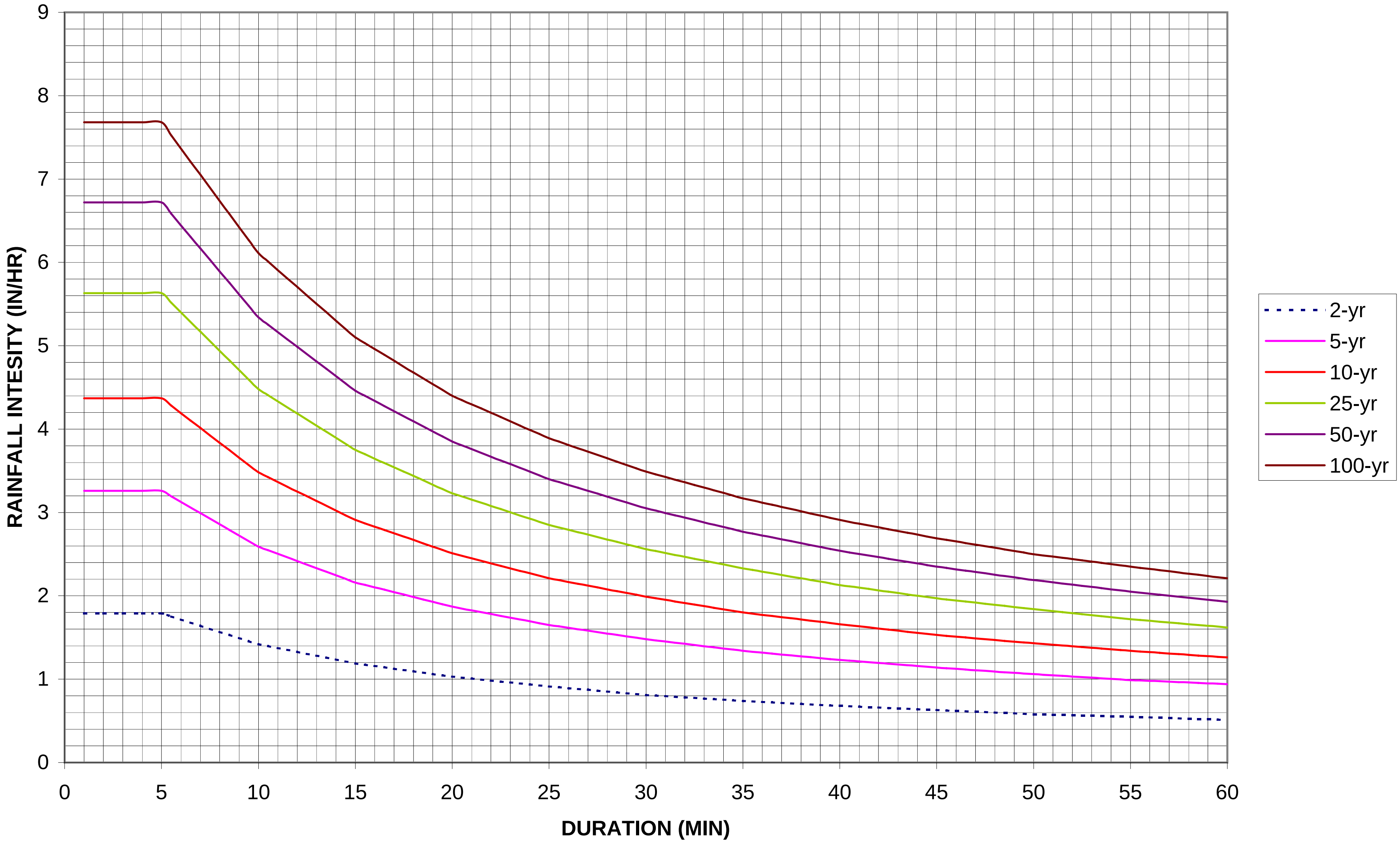
ONSITE CULVERTS

Initial/Overland Flow (t_i)					Gutter or Channelized Flow (t_t)					Total Travel Time	check max	check min	Use
Basin	L (ft)	Slope (ft/ft)	C_5	Ti (min)	L (ft)	Slope (%)	C_v[1]	V (ft/sec)	Tt (min)	Tc=Ti+Tt Tc (min)	Tc (min)	Tc (min)	Tc (min)
Culvert C2	500	0.014	0.09	36.56	1700	1.400	10.00	1.18	23.95	60.51	na	10.0	60.5
Culvert C3	500	0.014	0.09	36.56	900	1.400	10.00	1.18	12.68	49.24	na	10.0	49.2
Culvert C4	500	0.014	0.09	36.56	3500	1.400	10.00	1.18	49.30	85.86	na	10.0	85.9
Culvert C6	800	0.014	0.09	46.16	400	1.400	10.00	1.18	5.63	51.79	na	10.0	51.8

TABLE RO-2
Conveyance Coefficiant, C_v

Type of Land Surface	Conveyance Coefficient, C_v
Heavy Meadow	2.5
Tillage/Field	5
Short pasture & lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas	20

I-D-F CURVE FOR CRESCENT JUNCTION, UTAH



25 YEAR PEAK FLOWS

USE RATIONAL METHOD TO CALCULATE PEAK FLOWS"
Q = CIA

Basin	Area (ac)	Runoff Coeff. (C_{25})	T_C (min)	C*A (ac)	I (in/hr)	Q25 (cfs)
Culvert C2	32.0	0.17	60.51	5.44	1.62	8.81
Culvert C3	11.0	0.17	49.24	1.87	1.87	3.50
Culvert C4	64.0	0.17	85.86	10.88	1.62	17.63
Culvert C6	30.0	0.17	51.70	5.10	1.80	9.18

Appendix E

Calibration and Check of Flows in Crescent Wash

The purpose of this appendix is to document the calibration and provide a check of calculated flows in Crescent Wash. The USGS had a gaging station in Crescent Wash at a point slightly downstream of the analysis point for this project. The drainage area at the old gage is 23.3 square miles, as opposed to 22.5 sq miles at the I-70 crossing. There are 10 years of record taken between 1959 and 1969. It should be noted that the basin is relatively undeveloped so flows taken 37 to 47 years ago should be relatively typical of the basin today. However, there are only 10 years of record. Thus information derived from the gaging station is considered only as a relative check for order of magnitude compared to the computations.

Using the 10 years of data the USGS developed a flood frequency curve using Log-Pearson Type III probability distribution (Vaill, 2000). The results of this analysis are shown in Table E1, below. These flows are compared to the 25-year and 100-year floods calculated in HEC-HMS using the specified unit hydrograph, a CN value of 70 for determining initial losses and a constant infiltration rate of 0.3 in/hour. Precipitation values are derived from NOAA Atlas 14. The results of the analysis are within 3% of the USGS results, when adjusted for drainage area. Thus the calculated values are utilized for this project and the parameters (CN, infiltration, and precipitation) are applied to the ungaged basins within the study area for determining the 25-year and 100-year floods.

Table E1. Flow comparison for Crescent Wash, 25-year storm

Storm Event	***USGS (23.3 mi^2)***		***HEC-HMS (22.5mi^2)***	
	cfs	***cfs/mi^2***	***cfs***	***cfs/mi^2***
25-year storm	3,260	140	3,021	134
100-year storm	6,460	277	6,073	270

Several additional gaged sites were also checked for peak flows per square mile. Sites selected for comparison are similar in elevation and size and are in similar environmental conditions as the project site. Peak flows were calculated by the USGS using Log-Pearson Type III probability distribution (Vaill, 2000). Table E2 indicates that the flows per square mile are conservative as compared to the other basins. However, given the gaged information available on Crescent Wash, the calculated values will be utilized.

Table E2. Comparison of Peak Flows per Square Miles

Station no.	Station Name	DA, mi^2	elev	Q_{25}, cfs	Q_{25}/DA, cfs/mi^2	Q_{100}, cfs	Q_{100}/DA, cfs/mi^2
9181000	Onion Creek nr Moab, Ut	18.8	5,702	2,470	131.4	3,380	179.8
9185200	Kane Springs Canyon nr La Sal, Ut	17.8	6,620	1,340	75.3	1,770	99.4
9306235	Corral Gulch below Water Gulch nr Rangely, Co	8 .6	7,740	382	44.4	1,120	130.2
9606242	Corral Gulch nr Rangely, Co	31.6	7,490	883	27.9	2,450	77.5
9328900	Crescent Wash nr Crescent Junction, Ut	23.3	6,180	3,260	139.9	6,460	277.3

Water Resources

Data Category: Surface Water ▾ Geographic Area: Utah ▾ go

News: Available soon in NWISWeb

Peak Streamflow for Utah

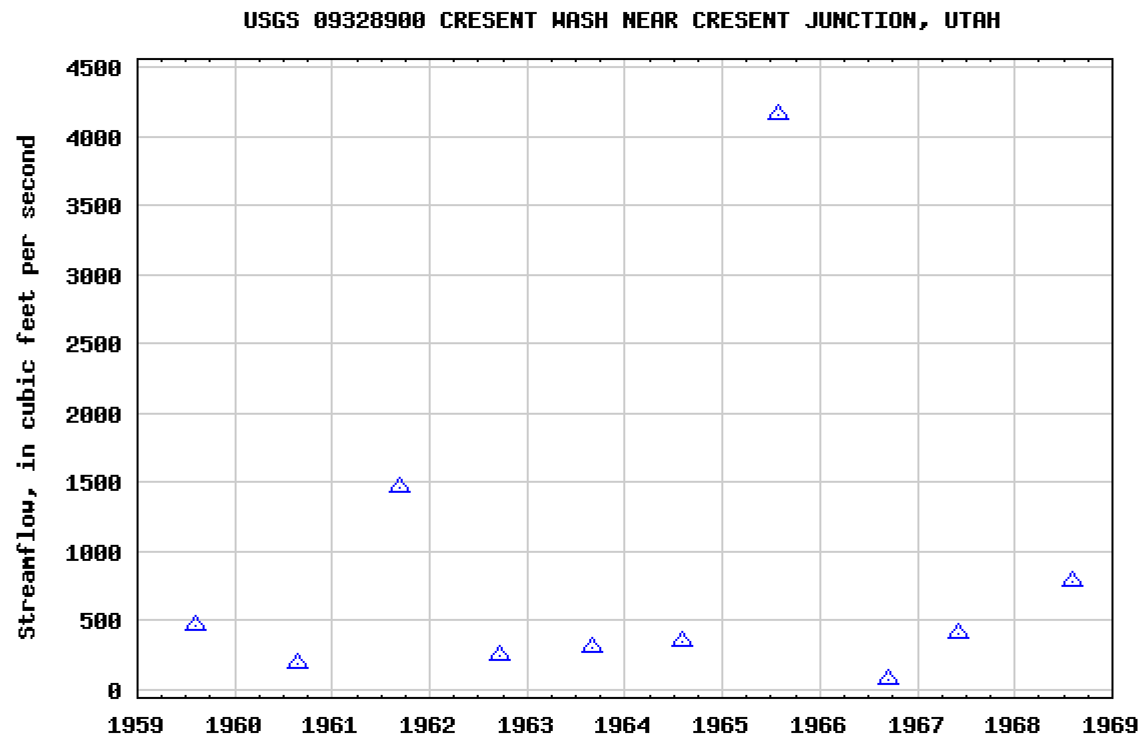
USGS 09328900 CRESENT WASH NEAR CRESENT JUNCTION, UTAH

Available data for this site Site home page ▾ GO

Grand County, Utah
Hydrologic Unit Code 14060008
Latitude 38°56'32", Longitude 109°49'14" NAD27
Drainage area 23.30 square miles
Gage datum 4,880.00 feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- WATSTORE formatted file
- Reselect output format



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Top
Explanation of terms

Surface Water for Utah: Peak Streamflow
http://waterdata.usgs.gov/ut/nwis/peak?

Analysis of the Magnitude and Frequency of Floods in Colorado

By J.E. Vaill

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 99–4190

Prepared in cooperation with the
COLORADO DEPARTMENT OF TRANSPORTATION
and the BUREAU OF LAND MANAGEMENT

Denver, Colorado
2000

Table 3. Drainage-basin characteristics and flood-frequency data at streamflow-gaging stations—Continued

[LATDEG, latitude in decimal degrees; LNGDEG, longitude in decimal degree; DAREA, drainage area in square miles; YRSPK, years
P2, P5, P10, P25, P100, P200, and P500 are the indicated recurrence intervals for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year,

Map number (fig. 1)	Station number	Station name	LATDEG	LNGDEG	DAREA	YRSPK	ELEV	PRECIP
271	09302500	Marvine Creek near Buford, Colo.	40.0383	107.4875	59.7	12	9,780	32.2
272	09303000	North Fork White River at Buford, Colo.	39.9875	107.6139	259.0	24	9,529	30.9
273	09303300	South Fork White River at Budges Resort, Colo.	39.8433	107.3342	52.3	19	10,569	40.0
274	09303320	Wagonwheel Creek at Budges Resort, Colo.	39.8428	107.3361	7.4	14	10,640	40.0
275	09303400	South Fork White River near Budges Resort, Colo.	39.8642	107.5333	128.0	19	10,250	40.0
276	09304000	South Fork White River at Buford, Colo.	39.9744	107.6247	177.0	25	9,800	36.3
277	09304300	Coal Creek near Meeker, Colo.	40.0914	107.7694	25.1	11	7,956	28.5
278	09304500	White River near Meeker, Colo.	40.0336	107.8617	755.0	66	8,940	29.6
279	09306007	Piceance Creek below Rio Blanco, Colo.	39.8261	108.1825	177.0	21	7,628	24.5
280	09306058	Willow Creek near Rio Blanco, Colo.	39.8372	108.2436	48.4	12	7,500	21.8
281	09306061	Piceance Creek above Hunter Creek, near Rio Blanco, Colo.	39.8506	108.2583	309.0	14	7,552	21.2
282	09306200	Piceance Creek below Ryan Gulch, near Rio Blanco, Colo.	39.9211	108.2969	506.0	11	7,415	20.8
283	09306235	Corral Gulch below Water Gulch, near Rangely, Colo.	39.9061	108.5322	8.6	14	7,740	20.0
284	09306242	Corral Gulch near Rangely, Colo.	39.9203	108.4722	31.6	21	7,490	20.0
285	09306255	Yellow Creek near White River, Colo.	40.1686	108.4006	262.0	17	6,877	17.3
286	09306800	Bitter Creek near Bonanza, Utah	39.7533	109.3542	324.0	10	7,146	16.1
287	09307500	Willow Creek above diversions near Ouray, Utah	39.5664	109.5867	297.0	24	7,650	16.8
288	09308000	Willow Creek near Ouray, Utah	39.9389	109.6478	897.0	23	7,080	13.7
289	09328900	Crescent Wash near Crescent Junction, Utah	38.9422	109.8206	23.3	10	6,180	12.7
290	09340000	East Fork San Juan River near Pagosa Springs, Colo.	37.3694	106.8917	86.9	41	10,200	39.0
291	09341500	West Fork San Juan River near Pagosa Springs, Colo.	37.3786	106.8989	87.9	26	10,000	42.0
292	09342500	San Juan River at Pagosa Springs, Colo.	37.2661	107.0103	298.0	46	9,700	36.0
293	09343000	Rio Blanco near Pagosa Springs, Colo.	37.2128	106.7939	58.0	37	10,000	39.0
294	09343500	Rito Blanco near Pagosa Springs, Colo.	37.1936	106.9047	23.3	18	9,400	34.0
295	09344000	Navajo River at Banded Peak Ranch, near Chromo, Colo.	37.0853	106.6889	69.8	41	10,500	37.0
296	09345500	Little Navajo River at Chromo, Colo.	37.0456	106.8425	21.9	17	8,900	26.0
297	09346000	Navajo River at Edith, Colo.	37.0028	106.9069	172.0	36	9,200	33.0
298	09346200	Rio Amargo at Dulce, N. Mex.	36.9333	107.0000	168.0	26	7,930	17.7
299	09349500	Piedra River near Piedra, Colo.	37.2222	107.3422	371.0	34	9,400	33.0
300	09349800	Piedra River near Arboles, Colo.	37.0883	107.3972	629.0	20	8,300	27.0
301	09350800	Vaqueros Canyon near Gobernador, N. Mex.	36.7333	107.2833	60.5	31	7,500	15.0
302	09352500	Los Pinos River below Snowslide Canyon, near Weminuche Pass, Colo.	37.6389	107.3333	25.3	13	11,200	45.0

of record; ELEV, mean basin elevation in feet; PRECIP, mean annual precipitation in inches; BSLOPE, mean basin slope in foot per foot; 200-year, and 500-year peak discharge; --, not available]

Station number	BSLOPE	P2	P5	P10	P25	P50	P100	P200	P500
09302500	0.245	318	400	447	498	532	563	591	626
09303000	0.237	1,380	1,890	2,230	2,640	2,940	3,240	3,540	3,930
09303300	0.198	924	1,380	1,700	2,120	2,440	2,760	3,090	3,540
09303320	0.159	188	260	307	365	406	447	488	540
09303400	0.256	1,700	2,480	3,030	3,770	4,350	4,940	5,570	6,440
09304000	0.259	1,800	2,310	2,600	2,920	3,140	3,340	3,530	3,760
09304300	0.285	50	80	100	126	144	162	180	203
09304500	0.222	3,170	4,210	4,840	5,600	6,140	6,650	7,150	7,780
09306007	0.283	148	294	411	576	710	851	1,000	1,210
09306058	0.272	14	36	58	99	140	191	254	360
09306061	0.263	193	381	534	758	943	1,140	1,360	1,660
09306200	0.243	145	255	345	479	594	723	867	1,080
09306235	0.253	14	69	158	382	673	1,120	1,780	3,110
09306242	0.236	39	175	383	883	1,510	2,450	3,810	6,490
09306255	0.197	154	508	982	2,040	3,310	5,170	7,850	13,200
09306800	0.287	115	451	894	1,820	2,840	4,210	6,000	9,150
09307500	--	241	476	692	1,050	1,380	1,780	2,260	3,030
09308000	--	636	1,860	3,170	5,510	7,810	10,600	14,000	19,300
09328900	--	439	1,140	1,890	3,260	4,670	6,460	8,720	12,600
09340000	0.387	924	1,350	1,640	2,020	2,300	2,600	2,900	3,310
09341500	0.400	1,320	1,830	2,170	2,590	2,910	3,230	3,550	3,970
09342500	0.342	2,610	4,160	5,480	7,570	9,460	11,700	14,300	18,400
09343000	0.428	853	1,200	1,450	1,780	2,030	2,290	2,570	2,950
09343500	0.239	190	313	401	519	610	704	800	932
09344000	0.368	650	897	1,070	1,280	1,450	1,620	1,790	2,020
09345500	0.225	146	253	334	447	538	633	733	874
09346000	0.277	852	1,310	1,660	2,160	2,570	3,020	3,510	4,230
09346200	--	1,030	1,490	1,830	2,280	2,650	3,040	3,440	4,030
09349500	0.344	2,090	3,480	4,640	6,400	7,950	9,710	11,700	14,800
09349800	0.290	2,420	3,960	5,130	6,790	8,150	9,610	11,200	13,500
09350800	--	196	490	822	1,470	2,180	3,130	4,410	6,760
09352500	--	324	518	656	839	981	1,130	1,280	1,480

Project: Crescent Junction Ex Simulation Run: CW 25

Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	16May2006, 17:21:41	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	3020.71	01Jan2006, 14:10	0.49
Sink-1	22.5600	3020.71	01Jan2006, 14:10	0.49

Project: Crescent Junction Ex Simulation Run: CW 100

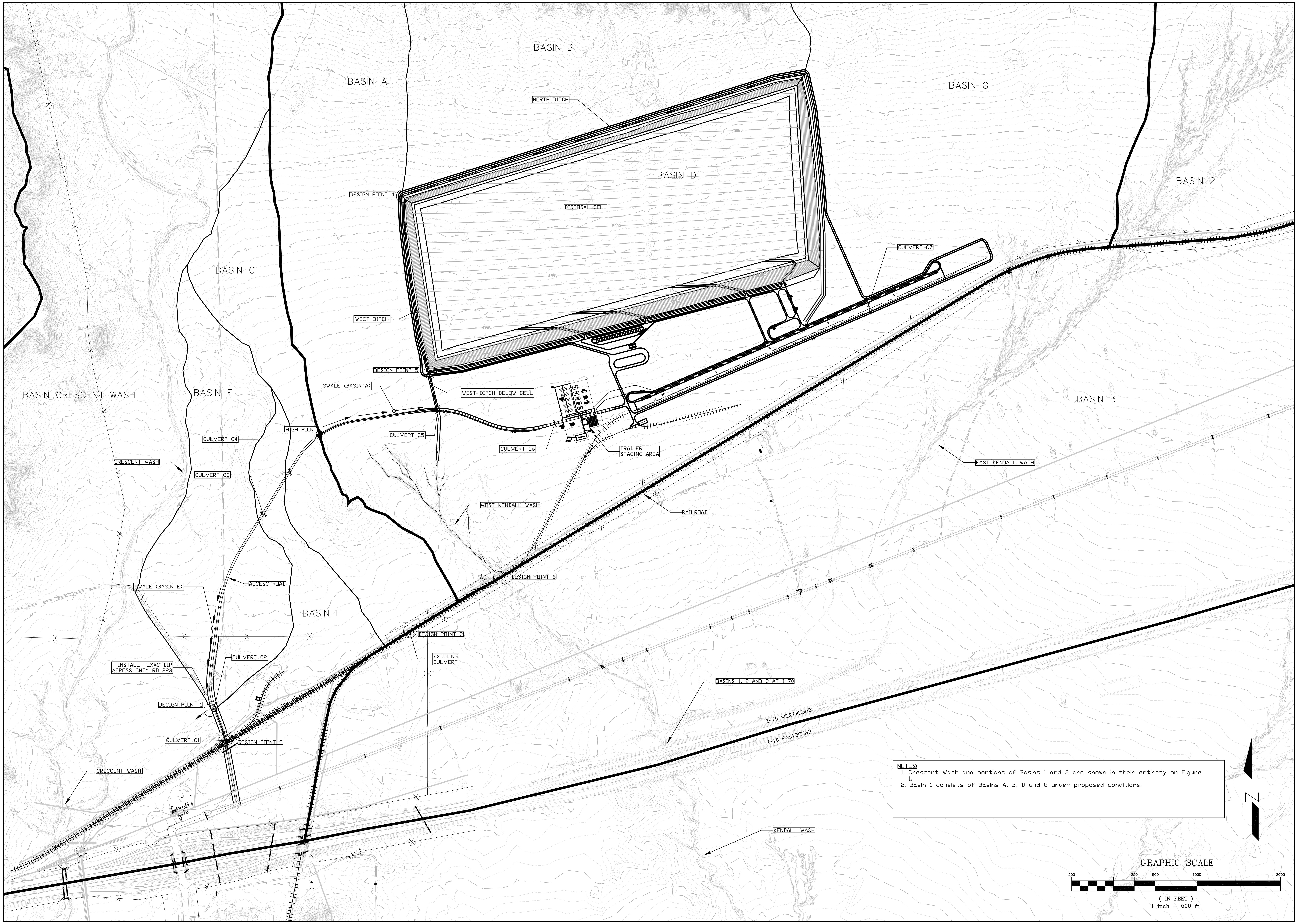
Start of Run: 01Jan2006, 00:00 Basin Model: Crescent Wash-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 100-yr 24-hr
Compute Time: 15May2006, 15:48:31 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5400	6072.68	01Jan2006, 14:10	0.98
Sink-1	22.5400	6072.68	01Jan2006, 14:10	0.98

Appendix F

Master Drainage Plan



NOTES:

1. Crescent Wash and portions of Basins 1 and 2 are shown in their entirety on Figure 1.
2. Basin 1 consists of Basins A, B, D and G under proposed conditions.

CRESCENT JUNCTION
MASTER DRAINAGE PLAN

DESIGNED BY: ETA	CHECKED BY: PMB	DRAWN BY: ETA
DATE: 5-17-06	SCALE: 1:500	PROJECT #: 4704-005-01
		CADD FILE: DRAINAGE-PROPOSED.dwg

TETRA TECH, INC.
410 S French Street, P.O. Box 1659
Breckenridge Co 80424
(970) 453-6394 Fax (970) 453-4579

DRAWING NUMBER:
C-1

REVISIONS

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-04-2007-5-25-02 **Discipline:** Engineering **No. of Sheets:** 10
Doc. No.: X0176400

Location: Attachment 1, Appendix G

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Diversion Channel Design, North Side Disposal Cell

Sources of Data:

Bonnin, G.M., D. Todd, T. Lin, T. Parzbok, T. A. Yekta, and D. Riley, 2003. "Precipitation-Frequency Atlas of the United States," *U. S. National Oceanic and Atmospheric Administration* (NOAA) *Atlas 14*, Volume I, Version 3, NOAA, National Weather Service, Silver Spring, Maryland, for Thompson, Utah.

"Crescent Junction Site Hydrology Report" calculation set, RAP Attachment 1, Appendix F.

Purpose of Revision:

Revision was issued to address Nuclear Regulatory Commission comments SW1–SW4.

Sources of Formulae and References:
See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-02-05-2006-5-25-01**

Author: 5/25/07
Name Date

Checked by: 5/30/07
Name Date

Approved by: 5/31/07
Name Date

5/31/07
Name Date

Name Date
May 31, 07
Name Date

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Problem Statement:

- Design erosion protection for the north slope of the disposal cell to prevent detrimental erosion from surface water flows from upland area, consistent with the requirements of 40 CFR Part 192 and NRC guidance in NUREG 1623 (Johnson 2002).
- Provide grading such that upland flow will drain to the west around the north side of the disposal cell.
- Provide protection at northwest corner of disposal cell to prevent headward erosion as flow is released to native ground.

Method of Solution:

The disposal cell needs protection against erosion from precipitation events occurring in the upland area. A traditional diversion channel will likely become inundated with silt over time, reducing its capacity to carry water. Therefore, water will be allowed to flow along the north slope of the disposal cell. The north slope of the disposal cell will be armored to allow water to flow at the toe without negatively impacting the disposal cell. Excavation along the toe of the north slope will create a uniform slope that drains to the west.

The magnitude of the probable maximum flood (PMF) is obtained from the “Crescent Junction Site Hydrology” calculation (RAP Attachment 1, Appendix F). The depth and velocity of flow associated with the PMF is calculated using Manning’s equation. The size of rock required to prevent erosion is calculated using the Safety Factor method as outlined in Chapter 3 of Appendix D of NUREG 1623 (Johnson 2002).

In addition to rock protection on the slopes of the disposal cell, sufficient riprap will be placed within the diversion channel bed to act as self-launching protection to prevent undercutting beneath the north slope of the disposal cell.

Assumptions:

- Topographic maps provided in the “Crescent Junction Site Hydrology” calculation (RAP Attachment 1, Appendix F) are accurate.
- Riprap stone is angular, possesses a specific gravity of 2.65, and has a minimum durability criteria score of 80 (Johnson 2002); thus it will not require oversizing for use in frequently saturated areas.
- Upland area contributes flow to the disposal cell uniformly, such that flows along any reach of the north toe can be calculated as a ratio of length of reach to total length of north toe multiplied by total flow at northwest corner.

Calculation:

- The upland drainage basin for the proposed disposal cell was determined in the “Crescent Junction Site Hydrology” calculation (RAP Attachment 1, Appendix F), and is shown in Figure 1. A PMF flow rate of 5,859 cubic feet (ft) per second (cfs) is the reported flow rate at the northwest corner of the cell.
- The north slope of the disposal cell is divided into five reaches, each of approximately 1,000 ft long.
- In areas not requiring excavation to meet the 0.5 percent channel bed grade, a V-shaped channel will convey flow, with the south slope consisting of the 5:1 (20 percent) side slope of the disposal cell, and the north slope consisting of natural ground at an approximate slope of 2.8 percent. In areas requiring excavation, the channel will consist of 5:1 side slopes with a 10-ft bottom width. Overbank flow will have a north slope of 2.8 percent.
- Invert slope of the channel is computed from the difference in elevation between the northeastern end to the southwest end, divided by the length between them:

$$(4{,}990 \text{ ft} - 5{,}014 \text{ ft}) / 4{,}955 \text{ ft} = 0.005, [-0.5\%]$$

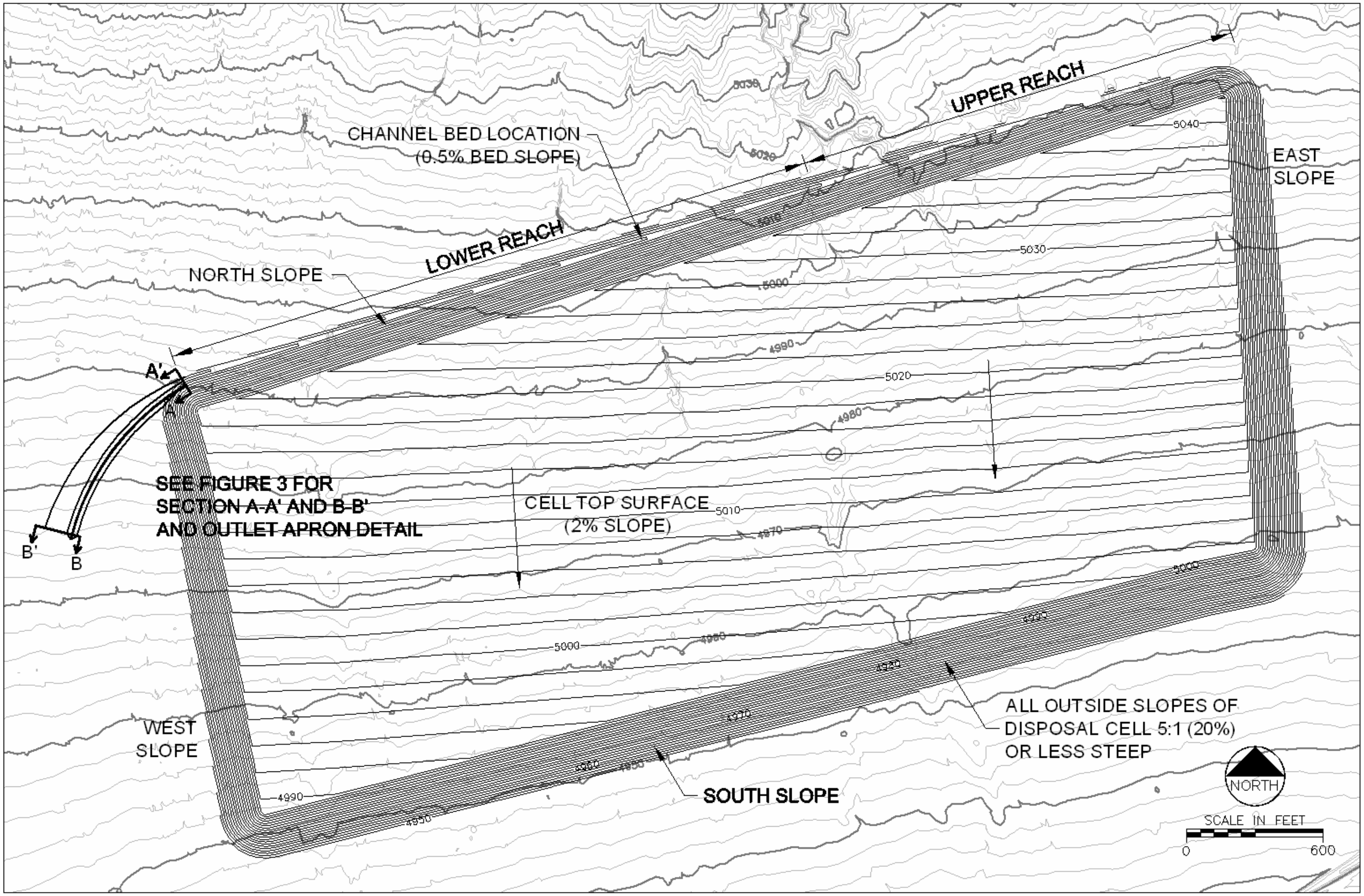

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FIGURE 1
DISPOSAL CELL LAYOUT
WITH EROSION PROTECTION FEATURES

Date:	APRIL 2007
Project:	181268
File:	CHANNEL-03.DWG

Figure 1. Diversion Channel Location Along the North Slope of the Disposal Cell

- Manning's *n* is computed using procedures discussed by Abt et al. (1987) and Abt and Johnson (1991) as follows:

$$n = 0.0456 * (D_{50} * S)^{0.159} \tag{1}$$

where: *n* is Manning's *n,*
D$_{50}$ is the mean riprap diameter in inches, and
S is the channel slope (ft/ft).

A weighted value for *n* is used based on the length of erosion riprap and native ground submerged as:

$$n_{ave} = \frac{\sqrt{p_1 * n_1^2 + p_2 * n_2^2 + \ldots p_n * n_n^2}}{\sqrt{p_1 + p_2 + \ldots p_n}} \tag{2}$$

where: *p* is the wetted perimeter. Manning’s *n* for the native ground is taken as 0.02.

The depth of flow along the toe is conservatively calculated for the point within the reach where the flow is most restricted (i.e. greatest cut required to meet 0.5 percent channel slope). The depth of flow during PMF flow is computed with Manning's equation for open-channel flow:

$$Q = \frac{1.486 * A * R_h^{\frac{2}{3}} * S^{\frac{1}{2}}}{n} \tag{3}$$

where: *Q* is the PMF flow rate,
A is the cross-sectional flow area,
R$_h$ is the hydraulic radius equal to the cross-sectional flow area divided by the wetted perimeter, and all other variables are previously defined.

Assuming a trapezoidal cross-section, flow area and hydraulic radius are expressed as a function of the flow depth (y), base width of the channel (B) and two side slopes, s$_1$ and s$_2$ (ft/ft), by:

$$A = \frac{0.5 * y^2}{s_1} + \frac{0.5 * y^2}{s_2} + y * B \tag{4}$$

Hydraulic radius is evaluated by:

$$R_h = \frac{A}{\sqrt{y^2 + \left(\frac{y}{s_1}\right)^2} + \sqrt{y^2 + \left(\frac{y}{s_2}\right)^2} + B} \tag{5}$$

For each reach of the north toe, equations (3), (4) and (5) are solved simultaneously to obtain depth of flow y.

Riprap to Protect Against Flows Within Channel:

Riprap size is determined using the Safety Factor Method (Johnson 2002) by computing the tractive shear stress (τ, psf) at the base of the channel as:

$$\tau = \gamma_w * S * y \qquad (6)$$

where: γ_w is the unit weight of water (62.4 pcf),
y is the depth of flow (ft),
S is the channel slope (ft/ft) as previously defined.

Tractive shear stress is related to the mean rock size through equation (6) of the Army Corps of Engineers (ACE) (ACE 1994) as:

$$\tau = \alpha * (\gamma_s - \gamma_w) * D_{50} \qquad (7)$$

where: γ_s is the unit weight of riprap (62.4 pcf times specific gravity of 2.65), and
α is a coefficient of 0.04.

Equation (6) and (7) are solved simultaneously. The resulting D_{50} is used as input into Equation (2), and all equations are solved iteratively until a depth of flow, computed rock size, and Manning's *n* converge.

For construction purposes, the diversion channel and north erosion protection are divided into two reaches. Results for computed parameters for each reach are shown in Table 1. Further calculations are shown in Appendix A.

Table 1. Computed Depth of Flow and Required Rock Size for North Diversion Channel.

Reach	Distance of Reach from Northeast Corner of Disposal Cell (ft)	Maximum Flow (cfs)	Maximum Depth of Flow (ft)	Minimum D_{50} Required (inches)
Upper Reach, Left Channel Slope	0 to 2,000	2,344	6.0	5.0
Lower Reach, Left Channel Slope	2,000 to 5,000	5,859	8.0	7.0
Channel Bottom	All Reaches	469	3.9	30

Riprap should extend from the base of channel to the maximum depth of flow, as shown on Figure 2.

Riprap to Protect Against Flow from Gullies Discharging Into Channel:

Existing and future gullies upstream of the diversion channel will discharge into the diversion channel. Due to the steeper slopes of the natural gullies, the riprap along the channel base is increased to protect against the higher flow velocities from the gullies. In order to estimate the potential scour depth and flow velocities from natural gullies, it is assumed that the 5,859 cfs of flow reporting to northwest corner of disposal cell ("Crescent Junction Site Hydrology," RAP Attachment 1, Appendix F) is accumulated uniformly along the 5,000 ft of the north toe of the disposal cell (i.e. unit flow is approximately 1.17 cfs/ft). It is conservatively assumed that some of the larger gullies have a swath of up to 400 ft that contribute to flow in the gully. Therefore, the PMF associated with a gully is calculated to be up to 470 cfs. Using this flow, an assumed v-channel configuration of the gully with 2:1 (50 percent) side slopes, and a gully slope of approximately 3 percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (DOT 1983).

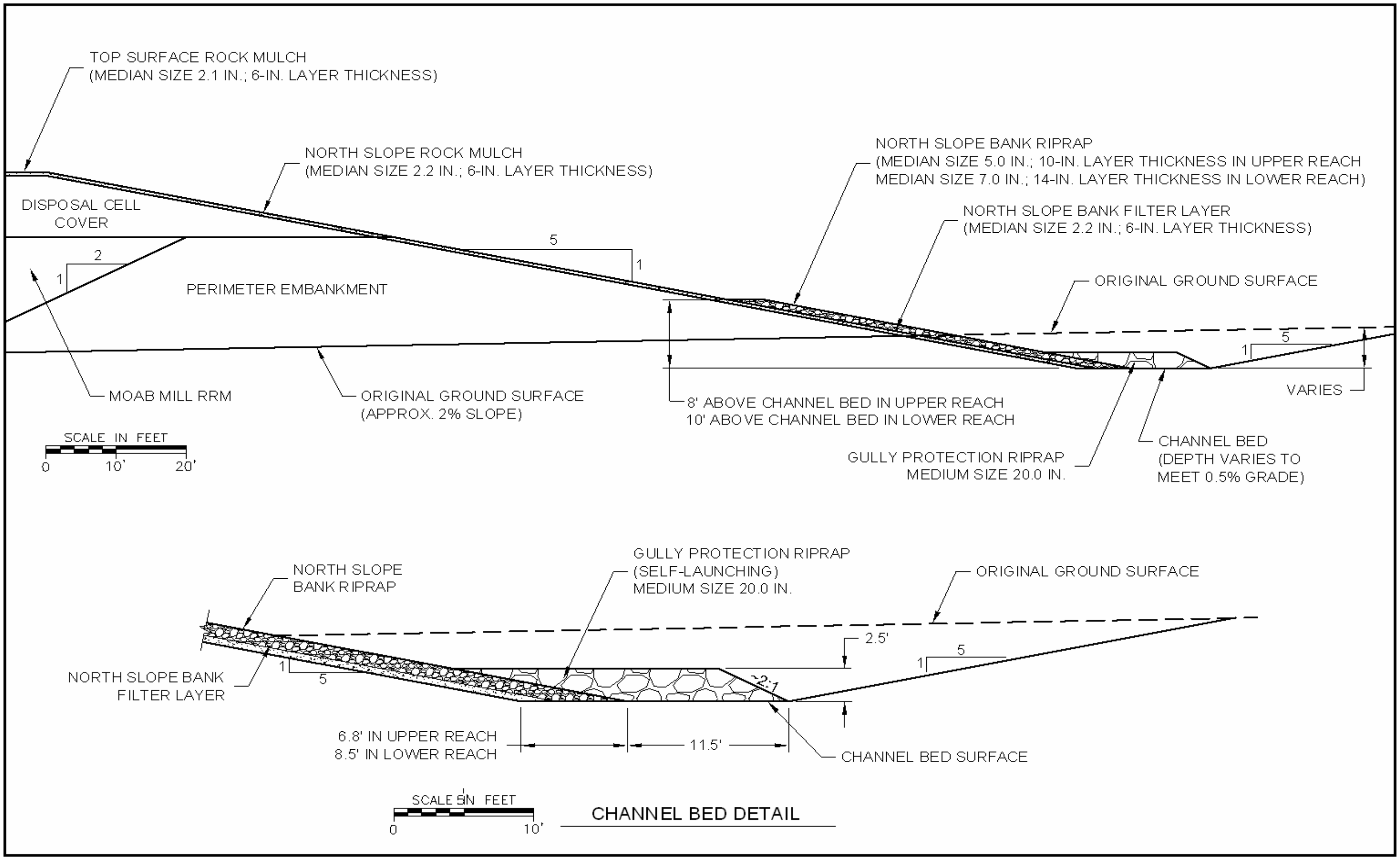

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FIGURE 2
TYPICAL CROSS SECTION THROUGH NORTH SLOPE OF DISPOSAL
CELL SHOWING EROSION PROTECTION MATERIAL

Date:	APRIL 2007
Project:	181268
File:	XS-TYP-02.DWG

Figure 2. Typical Cross Section Through North Slope of Disposal Cell.

The maximum scour depth associated with a gully is estimated to be 5.4 ft. Using the Safety Factor Method, the required rock size to protect against the gully flows is 20 inches. Following guidance given in NUREG 1623, the rock placed in the channel bottom is designed to collapse into the scoured area that occurs immediately upslope of the diversion channel. The thickness of launched rock should be a minimum of 1.5 times the average rock size. A rock volume of 38 cubic feet per linear foot of channel is required. This rock volume assumes the scour hole develops at a slope of 1V to 2H to a depth of 5.4 ft, the collapsed rock thickness in the scour hole is 1.5 times the average rock size, and assumes approximately 25 percent of the launched rock is lost downstream.

Riprap for Diversion Channel Outlet:

As the diversion channel reaches the west edge of the disposal cell, it continues approximately 500 ft west of the cell, turns south and discharges the flow onto natural ground. The channel extends an adequate distance west of the cell to minimize the possibility of gully headcutting to impact the disposal cell. A 4-ft-high riprap-protected berm is used to divert the water away from the cell. The channel width at the outlet will transition from 11.5 ft to 100 ft in order to slow flow velocities. The rock size within the outlet will increase as the flow velocities increase due to the steepening slope. Assuming a unit flow of 64 cfs/ft across the outlet apron, a maximum scour depth at the outlet is estimated to be approximately 5 ft. A pre-formed rock slope will be constructed extending vertically to the estimated depth of scour along a 10H:1V buried slope. Using the Abt and Johnson (1991) method, the required median rock size for this slope is 20 inches. The rock should be placed at a minimum rock depth of 1.5 times median rock size, or 30 inches.

Expected Operational Performance:

Run-on from frequent storm events will flow along the north edge of the disposal cell. Erosion and deposition of sediments from this run-on are expected to occur in the channel over the lifetime of the facility. Scour will occur locally where upstream gullies develop and discharge into the diversion channel. The 20-in rock placed in the bottom of the diversion channel is designed to launch into any formed scour hole and prevent undermining of the disposal cell. Erosion and deposition will occur along the channel as the channel system conforms to the local climate and ecology under frequent storm events.

During large-magnitude storm events, such as the design PMF, the higher flows may erode the sediments deposited during smaller events.

At the northwest corner of the disposal cell, at the termination of the channel, flow is spread out and transition to natural ground. It is expected that erosion will occur at this transition. The amount and distance of upstream migration of this scour will be limited by the buried rock slope. This rock slope is extended below the calculated depth of scour. Figure 3 shows the recommended channel cross-section and outlet.

Conclusion and Recommendations:

Riprap protection should follow minimum sizes specified in text and figures. Design should be re-evaluated once a specific rock source and actual durability test data are available.

Computer Source:

Not applicable.

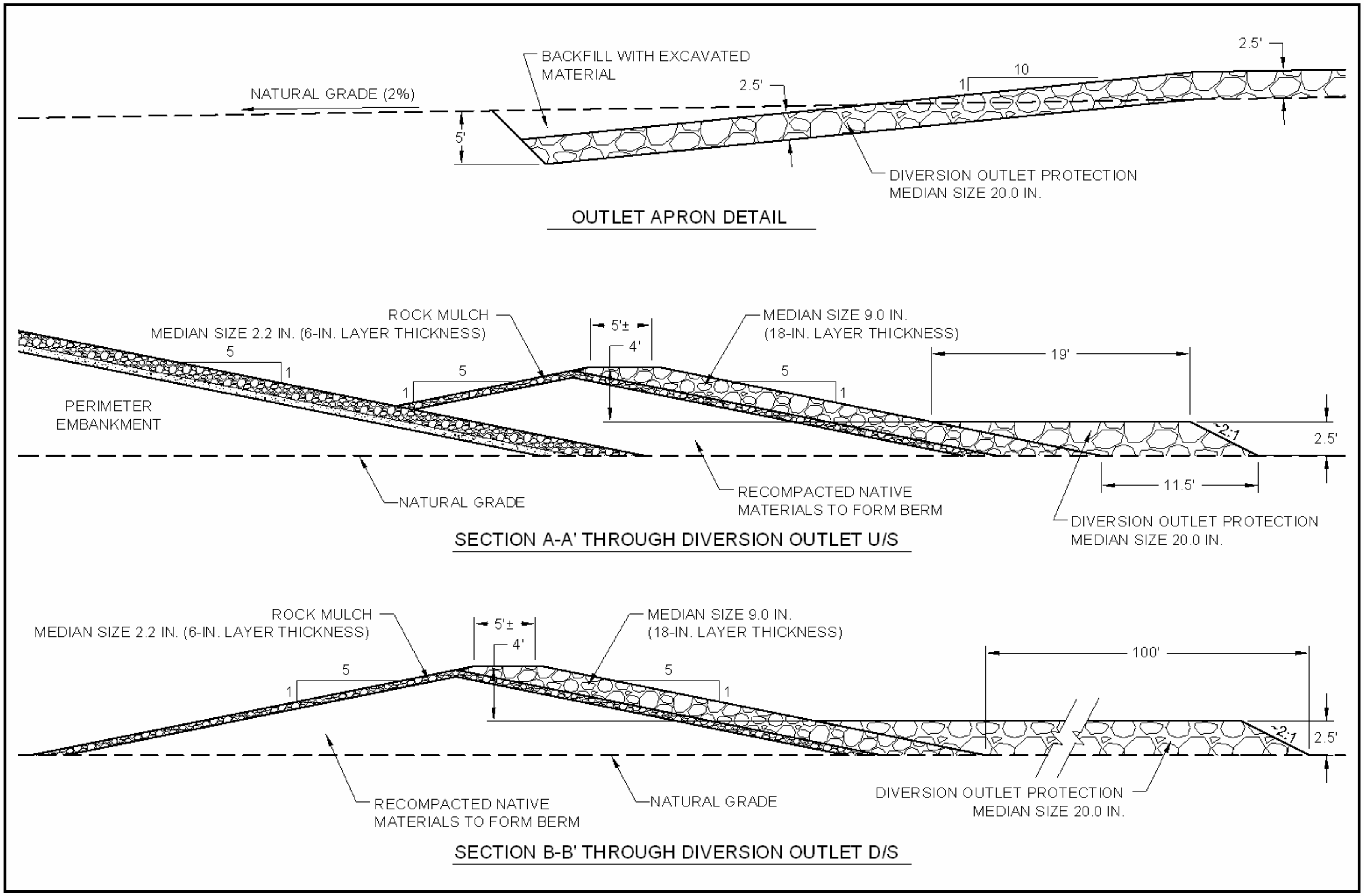

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FIGURE 3
DIVERSION CHANNEL OUTLET PLAN

Date:	APRIL 2007
Project:	181268
File:	XS-TYP-02.DWG

Figure 3. Diversion Channel Outlet Plan and Cross Section

References:

40 CFR 192. EPA (Environmental Protection Agency), “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,” *Code of Federal Regulations,* March 2007.

Abt, S.R., and T.L. Johnson, 1991. "Riprap Design for Overtopping Flow," *Journal of Hydraulic Engineering,* American Society of Civil Engineers, 117(8), pp.959–972.

Abt, S.R., M.S. Khattak, J.D. Nelson, J.F. Ruff, A. Shaikh, R.J. Wittler, D.W. Lee, and N.E. Hikle, 1987. *Development of Riprap Design Criteria by Riprap Testing in Flumes: Phase I*, NUREG/CR-4651.

ACE (U.S. Army Corps of Engineers), 1994. "Hydraulic Design of Flood Control Channels," EM 1110-2-1601, Office of the Chief of Engineers, Washington, D.C.

Chow, V.T., 1959. *Open-Channel Hydraulics,* McGraw-Hill Book Company, New York, New York.

DOT (U.S. Department of Transportation). 1983. *Hydraulic Design of Energy Dissipaters for Culverts and Channels*, Hydraulic Engineering Circular No. 14, September.

Graf, W., 2002. *Fluvial Processes in Dryland Rivers,* The Blackburn Press.

Johnson, T.L., 2002. *Design of Erosion Protection for Long-Term Stabilization Final Report,* NUREG 1623, U.S. Nuclear Regulatory Commission, September.

Schumm, S.A., M. D. Harvey, and C.C. Watson, 1988. *Incised Channels Morphology, Dynamics and Control,* Water Resource Publications, Littleton, Colorado.

Appendix A

Supporting Calculations

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell			
flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0	cfs	Flow was included in DP 45 PMP calc.
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 1	0 to 1000 feet from northeast corner of disposal cell		
max flow in reach:	1171.8	cfs	

Trapezoid or triangular channels		
slope (ft/ft)	0.005	ft/ft
Channel Side Slope 1 (ft/ft)	0.2	ft/ft
Channel Side Slope 2 (ft/ft)	0.2	ft/ft
maximum cut height in reach	2.5	ft
Channel Side Slope 3 (ft/ft)	0.028	
bottom width	19	ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow

Q	1171.8	cfs	
Assumed D50 on side slope (ft)	0.33	ft	
Assumed D50 on side slope (in)	4	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0245	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.023	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	178.65	ft^2	
Wetted Perimeter Rock Slope	19.81	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	62.20	ft	
Hydraulic Radius (R)	1.77	ft	
Top Width (T)	100.4	ft	
Maximum depth of flow (d)	3.88	ft	**iterate with d until Q calc equals Q design**
Q calc	1171.8	cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	6.559094	fps	
unit discharge	30.49921	cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)		
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	1171.8		
max shear stress, τ	1.21	psf	
Stability number for rock, η	0.742		
β	0.959		
Stability number for rock, η'	0.674		
Factor of Safety for side slope rock	1.19		**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell

flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0	cfs	Flow was included in DP 45 PMP calc.
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 2	1000 to 2000 feet from northeast corner of disposal cell	
max flow in reach:	2343.6	cfs

Trapezoid or triangular channels

slope (ft/ft)	0.005	ft/ft
Channel Side Slope 1 (ft/ft)	0.2	ft/ft
Channel Side Slope 2 (ft/ft)	0.2	ft/ft
maximum cut height in reach	5.5	ft
Channel Side Slope 3 (ft/ft)	0.028	
bottom width	19	ft

Assume flow is in trapezoidal channel with two 20% side slopes

Q	2343.6	cfs	
Assumed D50 on side slope (ft)	0.42	ft	
Assumed D50 on side slope (in)	5	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0254	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.025	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	250.98	ft^2	
Wetted Perimeter Rock Slope	27.71	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	27.71	ft	
Hydraulic Radius (R)	3.37	ft	
Top Width (T)	73.4	ft	
Maximum depth of flow (d)	5.44	ft	**iterate with d until Q calc equals Q design**
Q calc	2343.6	cfs	
average velocity (v)	9.33777	fps	
unit discharge	50.75327	cfs/ft	take as total Q divided by average flow width

Safety Factor Method (for rock on side slope of disposal cell)

Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	2343.6		
max shear stress, τ	1.70	psf	
Stability number for rock, η	0.830		
β	1.011		
Stability number for rock, η'	0.767		
Factor of Safety for side slope rock	1.08		**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell

flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0	cfs	Flow was included in DP 45 PMP calc.
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 3	2000 to 3000 feet from northeast corner of disposal cell	
max flow in reach:	3515.4	cfs

Trapezoid or triangular channels

slope (ft/ft)	0.005	ft/ft
Channel Side Slope 1 (ft/ft)	0.2	ft/ft
Channel Side Slope 2 (ft/ft)	0.2	ft/ft
maximum cut height in reach	7.5	ft
Channel Side Slope 3 (ft/ft)	0.028	
bottom width	19	ft

Assume flow is in trapezoidal channel with two 20% side slopes

Q	3515.4	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0261	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.025	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	338.58	ft^2	
Wetted Perimeter Rock Slope	33.38	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	33.38	ft	
Hydraulic Radius (R)	3.95	ft	
Top Width (T)	84.5	ft	
Maximum depth of flow (d)	6.55	ft	**iterate with d until Q calc equals Q design**
Q calc	3515.4	cfs	
average velocity (v)	10.3829	fps	
unit discharge	67.96047	cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)

Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	3515.4		
max shear stress, τ	2.04	psf	
Stability number for rock, η	0.833		
β	1.012		
Stability number for rock, η'	0.770		
Factor of Safety for side slope rock	1.08		**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell

flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0	cfs	Flow was included in DP 45 PMP calc.
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 4 — 3000 to 4000 feet from northeast corner of disposal cell

max flow in reach: 4687.2 cfs

Trapezoid or triangular channels

slope (ft/ft)	0.005	ft/ft
Channel Side Slope 1 (ft/ft)	0.2	ft/ft
Channel Side Slope 2 (ft/ft)	0.2	ft/ft
maximum cut height in reach	5.5	ft
Channel Side Slope 3 (ft/ft)	0.028	
bottom width	19	ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow

Q	4687.2	cfs	
Assumed D50 on side slope (ft)	0.58	ft	
Assumed D50 on side slope (in)	7	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0268	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.023	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	490.12	ft^2	
Wetted Perimeter Rock Slope	38.40	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	100.63	ft	
Hydraulic Radius (R)	3.10	ft	
Top Width (T)	156.7	ft	
Maximum depth of flow (d)	7.53	ft	**iterate with d until Q calc equals Q design**
Q calc	4687.2	cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	9.563429	fps	
unit discharge	82.72764	cfs/ft	take as total Q divided by average flow width

Safety Factor Method (for rock on side slope of disposal cell)

Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	4687.2		
max shear stress, τ	2.35	psf	
Stability number for rock, η	0.822		
β	1.006		
Stability number for rock, η'	0.758		
Factor of Safety for side slope rock	1.09		**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell			
flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0	cfs	Flow was included in DP 45 PMP calc.
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 5	4000 to 5000 feet from northeast corner of disposal cell	
max flow in reach:	5859	cfs

Trapezoid or triangular channels		
slope (ft/ft)	0.005	ft/ft
Channel Side Slope 1 (ft/ft)	0.2	ft/ft
Channel Side Slope 2 (ft/ft)	0.2	ft/ft
maximum cut height in reach	1.5	ft
Channel Side Slope 3 (ft/ft)	0.028	
bottom width	10	ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow

Q	5859.0	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0261	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.022	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	610.14	ft^2	
Wetted Perimeter Rock Slope	32.00	ft	
Wetted Perimeter Rock Bottom	10.00	ft	
Wetted Perimeter Soil Slope	178.31	ft	
Hydraulic Radius (R)	2.77	ft	
Top Width (T)	219.5	ft	
Maximum depth of flow (d)	6.28	ft	**iterate with d until Q calc equals Q design**
Q calc	5859.0	cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	9.602772	fps	
unit discharge	141.5795	cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)		
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	5859		
max shear stress, τ	1.96	psf	
Stability number for rock, η	0.799		
β	0.993		
Stability number for rock, η'	0.734		
Factor of Safety for side slope rock	1.12		**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Channel Outlet

Area: North side of disposal cell			
flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
additional flow from upland area west of cell area	0	cfs	
total flow:	5859	cfs	conservatively assumes peak flows are cummulative from cell and upland

Outlet1	immediately west of disposal cell		
max flow in reach:	5859	cfs	

Trapezoid or triangular channels			
slope (ft/ft)	0.005	ft/ft	
Channel Side Slope 1 (ft/ft)	0.333	ft/ft	
Channel Side Slope 2 (ft/ft)	0.01	ft/ft	
maximum cut height in reach	---	ft	
Channel Side Slope 3 (ft/ft)	---		
bottom width	19	ft	

Assume flow is in trapezoidal channel			
Q	5859.0	cfs	
Assumed D50 on side slope (ft)	0.75	ft	
Assumed D50 on side slope (in)	9	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0279	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.021	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	757.04	ft^2	
Wetted Perimeter Rock Slope	11.55	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	365.42	ft	
Hydraulic Radius (R)	1.91	ft	
Top Width (T)	395.4	ft	**iterate with d until Q calc equals Q design**
Maximum depth of flow (d)	3.65	ft	
Q calc	5859.0	cfs	
average velocity (v)	7.739383	fps	take as total Q divided by average flow width
unit discharge	28.279661	cfs/ft	1.0 for angular, 1.4 for rounded rock

Safety Factor Method	(for rock on side slopes of diversion channel)		
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	5859		
max shear stress, τ	1.14	psf	
Stability number for rock, η	0.310		
β	0.354		
Stability number for rock, η'	0.209		**Iterate with D50 until FS equal or greater than 1.0**
Factor of Safety for side slope rock	1.57		

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Channel Outlet

Area: North side of disposal cell

flow from upland area north of cell:	5859	cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
additional flow from upland area west of cell area	586	cfs	
total flow:	6445	cfs	conservatively assumes peak flows are cummulative from cell and upland

Outlet	approximately 5500 feet from northeast corner of disposal cell	
max flow in reach:	6445	cfs

Trapezoid or triangular channels

slope (ft/ft)	0.02	ft/ft
Channel Side Slope 1 (ft/ft)	0.333	ft/ft
Channel Side Slope 2 (ft/ft)	0.008	ft/ft
maximum cut height in reach	---	ft
Channel Side Slope 3 (ft/ft)	---	
bottom width	100	ft

Assume flow is in trapezoidal channel

Q	6444.9	cfs	
Assumed D50 on side slope (ft)	0.75	ft	
Assumed D50 on side slope (in)	9	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0347		Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0394		Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020		
weighted average n	0.026		EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	615.48	ft^2	
Wetted Perimeter Rock Slope	7.64	ft	
Wetted Perimeter Rock Bottom	100.00	ft	
Wetted Perimeter Soil Slope	302.10	ft	
Hydraulic Radius (R)	1.50	ft	
Top Width (T)	409.3	ft	**iterate with d until Q calc equals Q design**
Maximum depth of flow (d)	2.42	ft	
Q calc	6445.0	cfs	
average velocity (v)	10.471333	fps	take as total Q divided by average flow width
unit discharge	25.306641	cfs/ft	1.0 for angular, 1.4 for rounded rock

Safety Factor Method	(for rock on side slopes of diversion channel)		
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	5.0	XH:1V	
Angle of side slope (degrees)	11.310		
Angle of side slope (radians)	0.197		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	6444.9		
max shear stress, τ	3.02	psf	
Stability number for rock, η	0.820		
β	1.005		
Stability number for rock, η'	0.756		**Iterate with D50 until FS equal or greater than 1.0**
Factor of Safety for side slope rock	1.09		

Rock size of Channel Outlet Toe (Abt and Johnson, 1991 method)

q (cfs/ft)=	64	cfs/ft		
S (V/H)=	0.5	0.25	0.2	0.1
D50 (in)=	40	30	27	20

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**7/24/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Depth of Scour

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow over riprap	**upland of cell, sheet wash**		**upland of cell, gully**		
Flow, q	1.17	cfs/ft	468.72	cfs for gully picking up swath of 400 ft area	
Concentration factor	3		1		
Design Flow,q	3.52	cfs/ft	468.72	cfs	
gravity, g	32.2	ft/s^2	32.2	ft/s^2	
time, t	15	minutes	15	minutes	
base time, to	316	minutes	316	minutes	
D50	native soil		native soil		
D50					
Slope of gully	0.02	(ft/ft)	0.03	(ft/ft)	
Manning's n	0.025		0.025		
Side slopes of gully (XH:1V)			2.0		
angle of side slopes of gully			26.565	degrees	
Hydraulic radius of gully			1.764		
Flow area of gully			31.105	ft^2	
depth of flow (iterate until Qcalc=Qdesign)	0.59	ft	3.94	ft	
Q			468.72	CFS	
velocity	5.94	ft/s	15.07	ft/s	
Native soils					
plasticity index of alluvial soil	5	%	5	%	from GEG, 2005 lab data
unconfined compressive strength	1.4	psi	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.25414336		0.254143		
modified shear number	269.411592		1733.365		
d84 bedding	0.12	mm	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	mm	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.74596669		7.745967		
gradation classification	graded		graded		
	Depth				
α	0.86				coefficients for clay with PI 5-16
β	0.18				
θ	0.1				
αe	1.37				
equivalent depth, ye	0.59	ft	1.40	ft	
depth of scour (ft)	1.6	ft	5.4	ft	

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/20/2007**
Detail:	**Rock size to protect against high velocity gully flows upstream of disposal cell**	**Computed By:**	**RTS**

Safety Factor Method

Use for sizing rock to resist velocities from incoming gullies
Assume gully locations can migrate, but spacing will be similar to existing conditions of 400-ft spacing
Design for SF of 1.5 for non-PMF applications, and slightly greater than 1.0 for PMF
Use for slopes less than 10 percent

	Top Slope	
Slope (ft/ft)	0.03	
angle α (rad)	0.030	
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded
Angle of repose of rock (rad))	0.646	
Specific gravity of rock	2.65	
PMP flow in gully, Q (cfs)	468.72	cfs for gully picking up swath of 400 ft area
average width of flow in gully (ft)	7.89	area/depth assuming 2H:1V triagular shaped gully
PMP unit flow (cfs/ft)	59.43	Q/width
Depth of flow (ft)	3.94	from "Depth of Scour" calculation sheet
Flow velocity (ft/s)	15.07	from "Depth of Scour" calculation sheet
ave shear stress	7.38	
Assumed D50 (in) #1	20	
Stability number for rock #1	0.903	
Factor of Safety for rock #1	1.06	

Adjust assumed D50 until design criteria for Factor of Safety is greater than 1.0

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/20/2007**
Detail:	**Depth of potential scour at diversion channel outlet**	**Computed By:**	**RTS**

Depth of Scour

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow at Outlet

Flow, Q	6444.90	cfs	from "Outlet"
gravity, g	32.2	ft/s^2	
time, t	15	minutes	
base time, to	316	minutes	
D50	native soil		
D50			
natural slope downgradient of outlet	0.02	(ft/ft)	
Manning's n	0.025		
velocity	10.47	ft/s	from "Outlet"
depth of flow	2.42	ft	from "Outlet"
Native soils			
plasticity index of alluvial soil	5	%	from GEG, 2005 lab data
unconfined compressive strength	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.254143		
modified shear number	837.0029		
d84 bedding	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.745967		
gradation classification	graded		
α	0.86		coefficients for clay with PI 5-16
β	0.18		
θ	0.1		
αe	1.37		
equivalent depth, ye	1.10	ft	
depth of scour (ft)	3.73	ft	

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-6-01-00 **Discipline:** Geotechnical **No. of Sheets:** 22
Doc. No.: X0175500

Location: Attachment 1, Appendix H

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Erosional Protection of Disposal Cell Cover

Sources of Data:

Remedial Action Plan (RAP) calculation sets as referenced in the text.

Sources of Formulae and References:

See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Roslyn Stern 5/25/07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Checked by: 5/30/07
Name Date
5/31/07
Name Date

Name Date
May 31, 07
Name Date

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Problem Statement:

Determine the rock protection required to protect the cover of the disposal cell from erosion due to action of surface water and wind to meet the specifications of the *Code of Federal Regulations* (CFR) (40 CFR part 192).

Method of Solution:

- Determine the peak unit discharge from both the Probable Maximum Precipitation (PMP) and the 100-year precipitation event on the drainage basins of the disposal cell using the Rational method (Chow 1964).
- Evaluate erosional stability of soil cover on top slope of disposal cell using Temple method (Temple et al. 1987).
- Evaluate erosional stability of rock mulch on top slope of disposal cell using Safety Factor method (Nelson et al. 1986).
- Evaluate erosional stability of rock mulch or riprap on side slopes of disposal cell using Abt and Johnson method (Abt and Johnson 1991).
- Evaluate surface sheet erosion of top slope of disposal cell due to action of surface water and wind using Modified Universal Soil Loss Equation (MUSLE) method (Nelson et al. 1986).
- Evaluate required rock size for toe apron to accommodate flow transitioning from cell slope to native ground using method proposed by Abt et al. (1998).
- Evaluate scour potential of toe apron from headward erosion using methods in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983).
- Evaluate the need for bedding layer between cover soils and erosion protection material by estimating interstitial pore velocities using method proposed by Abt and Johnson (1991).

Assumptions:

- The 100-year precipitation event is applicable for evaluating drought, fire, and post-construction conditions when little or no vegetation is on the cover.
- The PMP precipitation event is applicable for long-term erosional stability analyses.
- The 1-hour PMP event is estimated to be 8.2 inches, and the 1-hour, 100-year event is estimated to be 1.65 inches ("Site Drainage—Hydrology Parameters" calculation, RAP Attachment 1, Appendix E).
- The layout of the disposal cell is shown in Figure 1. This layout shows a 2 percent top slope, 5:1 (horizontal:vertical) side slopes, and a total footprint area of 251 acres.
- Rock available for erosion protection will be angular, have a specific gravity of 2.65, and will meet Nuclear Regulatory Commission (NRC) durability requirements.

Calculation:

See Discussion section.

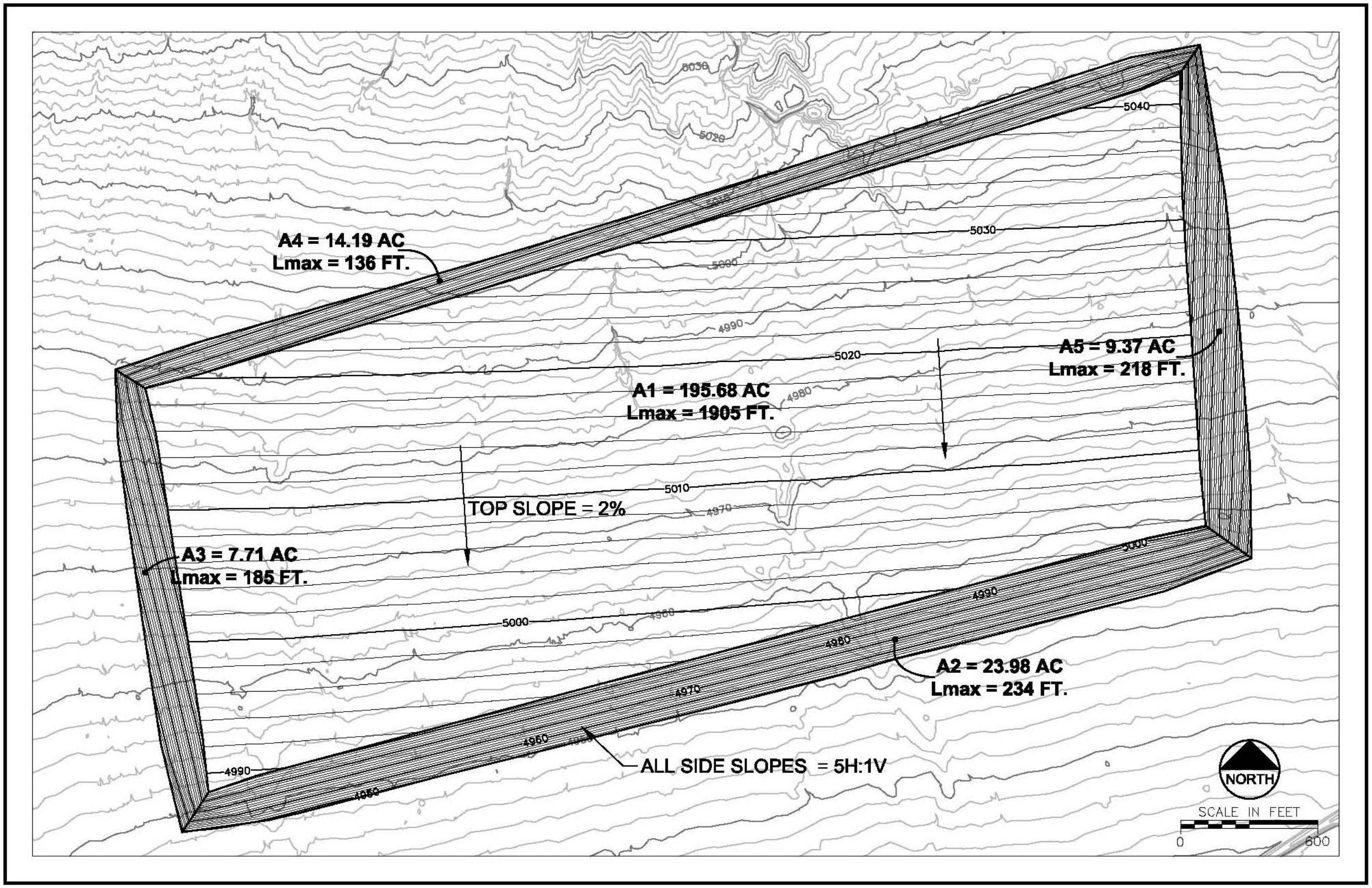

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FIGURE 1
DISPOSAL CELL LAYOUT

Date:	JULY 2006
Project:	181268
File:	CELL-DESIGN..07-2

Figure 1. Disposal Cell Layout

Discussion:

Drainage Area Characteristics

Five drainage areas were delineated on the cover of the disposal cell, as shown in Figure 1. The area and flow length of these drainage areas were calculated using computer-aided design (CAD) tools.

Peak flows occurring within each drainage area are calculated using a rainfall duration equivalent to the time of concentration for each drainage basin. The time of concentration is a characteristic of the geometry and slopes of the drainage areas, and is computed by three different methods, with the average of the three methods used to calculate peak discharges. The three methods used to calculate the time of concentration are described below.

1) The Kirpich equation as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = 0.0078 \frac{L^{0.77}}{S^{0.385}}$$

where:

T_c = time of concentration (minutes),

L = slope length (feet [ft]), and
S = slope (ft/ft).

2) The Soil Conservation Service (SCS) Triangular Hydrograph Theory, as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = \left(\frac{11.9L^3}{H} \right)^{0.385}$$

where:

T_c = time of concentration (hours),
L = slope length (miles), and
H = slope height (ft).

3) The Brant and Oberman equation as presented in the Uranium Mill Tailings Remedial Action Project (UMTRA) Technical Approach Document (TAD) (DOE 1989):

$$T_c = C\left(\frac{L}{Si^2} \right)^{\frac{1}{3}}$$

where:

T_c = time of concentration (minutes),
C = coefficient = 1.0 for bare earth,
S = slope (ft/ ft), and
i = one-hour rainfall intensity (inches/hour).

As specified in UMTRA TAD (DOE 1989), T_c is limited to a minimum of 2.5 minutes. Because precipitation falling on the top of the cover flows to the south slope, the time of concentration for the south side slope is equivalent to the time of concentration of precipitation on the top slope plus the time of concentration of precipitation occurring on the south side slope. The characteristics of the drainage areas on the disposal cell are summarized in Table 1.

Table 1. Drainage Area Characteristics

Drainage Area Description	Incremental Drainage Area (acres)	Slope (ft/ft)	Slope Length (ft)	Time of Concentration (min)			
				Kirpich	SCS	Brant and Oberman	Average
A1, top	195.7	0.02	1,950	12.0	12.0	11.3	11.8
A2, south slope	24.0	0.2	230	13.0	13.0	13.9	13.3
A3, west slope	7.7	0.2	190	0.8	0.8	2.4	2.5*
A4, north slope	14.2	0.2	140	0.7	0.7	2.2	2.5*
A5, east slope	9.4	0.2	220	0.9	0.9	2.5	2.5*

*Time of concentration is limited to a minimum of 2.5 minutes.

Peak Discharge

One of the technical criteria for the stability of the disposal cell is acceptable erosional stability from extreme storm events (10 CFR 40, Appendix A). NRC has interpreted this criterion to be able to safely pass the peak runoff from storms up to the PMP event (Johnson 2002). The PMP event has a 1-hour depth of 8.2 inches, and a 15-minute depth of 7.1 inches ("Site Drainage—Hydrology Parameters" calculation, RAP Attachment 1, Appendix E). For events with durations less than 15 minutes, precipitation depths as a percent of the 1-hour PMP are estimated using the following formula, as given in Table 4.1 of the UMTRA TAD (DOE 1989):

$$\%PMP_{1-hour} = \frac{RD}{0.0089RD + 0.0686}$$

where: RD = rainfall duration (minutes).

The precipitation depth of any given storm duration is then calculated as:

$$PD_{PMP} = \%PMP_{1-hour} \times PMP_{1-hour}$$

where: PD_{PMP} = precipitation depth of the PMP storm with duration equivalent to the time of concentration (inches).

The precipitation events for 100-year recurrence interval for several storm durations were taken from Appendix A of the "Site Drainage—Hydrology Parameters" calculation, (RAP Attachment 1, Appendix E) and are summarized in Table 2. Precipitation depths for durations other than those listed in Table 2 are interpolated.

Table 2. 100-Year Storm Event Precipitation Depths

Rainfall Duration (min)	Precipitation Depth (inches)	Intensity (inches/hr)
5	0.53	6.36
10	0.8	4.80
15	0.99	3.96
30	1.33	2.66
60	1.65	1.65
120	1.82	0.91

The rainfall intensity is calculated for a rainfall duration equivalent to the time of concentration for the drainage basin. Rainfall intensity (inches per hour) is calculated as follows:

$$I = \frac{PD \times 60}{RD}$$

The Rational method (Chow 1964) was used to determine the peak discharge from the PMP and the 100-year event for evaluation of cover erosion protection. For each drainage area, the peak flow was calculated with the Rational Formula, as follows:

$$Q = CIA$$

where:

Q = peak flow (cfs),
C = runoff coefficient,
I = rainfall intensity (inches per hour) corresponding to the time of concentration, and
A = area (acres).

The runoff coefficient is approximately 1.0 for PMP conditions, as discussed in UMTRA TAD (section 4.1.3). A runoff coefficient of 0.9 is used for 100-year storm events based on a conservative estimate for a riprap/rock surface.

Peak flow may also be expressed as a unit discharge as follows:

$$q = \frac{Q}{w} = \frac{CIL}{43200}$$

where:

q = unit discharge (cubic feet per second per foot [cfs/ft]),
w = unit width (ft),
C = runoff coefficient = 1.0,
I = rainfall intensity (inches per hour), and
L = slope length (ft).

Table 3 shows the results of the PMP peak flow in cubic feet per second (cfs) and the unit discharge calculations in cubic feet per second per foot (cfs/ft) for the areas shown in Figure 1. Table 4 shows results for the 100-year storm. These peak unit flows will be applied to the entire drainage area when evaluating erosional stability. Additional supporting calculations can be found in Appendix A.

Table 3. Results of PMP Peak Flow and Unit Discharge

Drainage Area Description	**Runoff Coef. C**	**Average T_c (min)**	**Percent PMP_{1-hr}**	**PD_{PMP} (inches)**	**Intensity (inches/hr)**	**Peak Flow, Q (cfs)**	**Unit Discharge, q (cfs/ft)**
A1, top	1.0	11.8	67.9	5.6	28.4	5,550	1.28
A2, south slope	1.0	13.3	71.1	5.8	26.3	5,787	1.33
A3, west slope	1.0	2.5	27.5	2.3	54.2	417	0.24
A4, north slope	1.0	2.5	27.5	2.3	54.2	769	0.18
A5, east slope	1.0	2.5	27.5	2.3	54.2	509	0.28

Table 4. Results of 100-Year Peak Flow and Unit Discharge

Drainage Area Description	Runoff Coef. C	Average T_c (min)	$PD_{100\text{-yr}}$ (inches)	Intensity (inches/hr)	Peak Flow, Q (cfs)	Unit Flow q (cfs/ft)
A1, top	0.9	11.8	0.9	4.6	817	0.19
A2, south slope	0.9	13.3	0.9	4.3	849	0.19
A3, west slope	0.9	2.5	0.5	6.4	44	0.03
A4, north slope	0.9	2.5	0.5	6.4	81	0.02
A5, east slope	0.9	2.5	0.5	6.4	54	0.03

Top Surface: Erosional Stability of Soil Cover

The top surface of the disposal cell was evaluated for erosional stability without a rock layer using the method developed by Temple et al. (1987). This procedure, developed to analyze grassy channels, estimates stresses from runoff on channel vegetation as well as the channel surface soils. The erosional stability of the cover surface was evaluated by calculating a factor of safety against erosion due to the peak runoff. Factor-of-safety values were calculated as the ratio of the allowable stresses (the resisting strength of the cover vegetation or soils) to the effective stresses (the stresses impacted by the runoff flowing over the cover). As outlined in UMTRA TAD (1989), the 100-year peak unit flows (Table 4) were used to analyze the stability of a non-vegetated slope, such as would be representative of post-construction, drought, or burn conditions. PMP peak unit flows (Table 3) were used to analyze the stability of a vegetated slope, assuming a poor to fair cover of grass eventually will be established on the cover. In addition, peak flows are multiplied by a concentration factor of 3.0 to account for channelization of flow.

The stress calculations are summarized below. Potential materials evaluated for use as cover soils were (1) low-plasticity silt and clayey material from excavated on-site alluvial and eolian deposits, (2) excavated on-site weathered Mancos Formation shale, and (3) imported coarse-grained sands and gravels.

Allowable Stresses

Allowable stresses for the non-vegetated cover soils were calculated using the equations in Temple et al. (1987). For cohesive soils, the resistance is based on the plastic limit and void ratio of the material. The equation for allowable shear strength for cohesive soils is:

$$\tau_a = \tau_{ab} C_e^{\,2}$$

where:

τ_a = allowable shear strength (pounds per square feet [psf]),
τ_{ab} = basis allowable shear strength (for a CL) = $(1.07\,[PI]^2 + 14.3[PI] + 47.7) \times 10^{-4}$,
C_e = soil parameter = $1.48 - 0.57e$,
PI = plasticity index, and
e = void ratio.

For non-cohesive soils, the resistance is based on particle size, specifically the size where 75 percent of the material is finer, or D_{75}. The equation for allowable shear strength for non-cohesive soils is:

$$\tau_a = 0.4 D_{75}$$

where D_{75} is in inches.

Plasticity index and void ratio are estimated from preliminary geotechnical laboratory testing results for on-site material (GEG 2005), assuming compaction to approximately 85 percent of maximum dry density as determined from the Modified Proctor test.

For vegetated slopes, the allowable stresses are a function of the quality of vegetation established on the cover, as given by the following equation:

$$\tau_{va} = 0.75C_i$$

where:

τ_{va} = allowable vegetation shear strength (psf),
C_I = cover index = $2.5 \times \left(h \times \sqrt{M}\right)^{\frac{1}{3}}$,
h = stem length (ft), and
M = stem density factor (stems per square foot).

Because of the arid climate at the site, vegetative properties are modeled as poor, with average stem height of 0.3 ft, and a stem density factor of 17 as given in Temple et al. (1987), conservatively using poor conditions represented by a poor stand of Sudan grass (a bunch grass providing incomplete surface cover).

Effective Stresses

The effective shear stress on soil due to peak runoff from the 100-year event on the non-vegetated slope is calculated as:

$$\tau_e = \gamma dS$$

where:

τ_e = effective shear stress (psf),
γ = unit weight of water = 62.4 pcf,
d = depth of flow (ft), and
S = slope of cover surface (ft/ft).

For vegetated slopes, the effective shear stress on soil due to peak runoff from the PMP event is calculated as:

$$\tau_e = \gamma dS\left(1 - C_f\right)\left(\frac{n_s}{n_v}\right)^2$$

where:

C_F = cover factor = 0.25 for poor vegetation, and
n_s = soil grain roughness factor, calculated by the following equation:

$n_s = 0.0156$, for cohesive soil

$n_s = 0.0256\left(d_{75}\right)^{\frac{1}{6}}$, for granular soil, where d is in inches.

n_v = combination of resistance due to soil roughness, n_s and vegetation, n_r, calculated by:

$$n_v = \sqrt{{n_r}^2 - 0.0156^2 + {n_s}^2}$$

where: n_r = resistance due to vegetation, calculated by:

$$n_r = \exp\left(0.01329C_i\left(\ln q\right)^2 - 0.09543C_i \ln q + 0.2971C_i - 4.16\right)$$

where: q = unit flow (cfs/ft).

The cover factor, C_f, is assumed to be 0.5 for good vegetation conditions, and 0.25 for poor vegetation, as given in Temple et al. (1987) for Sudan grass. The effective shear stress on vegetation is calculated as:

$$\tau_{ve} = \gamma dS - \tau_e$$

where τ_v = effective vegetal stress (psf).

The depth of flow is calculated by iteration of Manning's equation:

$$q = \frac{1.486dR^{\frac{2}{3}}\sqrt{S}}{n}$$

where:
q = unit flow (cfs/ft),
d = depth of flow (ft),
R = hydraulic radius = d for wide channels,
S = slope (ft/ft), and
n = Manning's coefficient.

For bare-soil conditions, n is equivalent to n_s, soil grain roughness. For vegetated conditions, n is equivalent to n_v, a combination of resistance due to soil roughness (n_s) and vegetation (n_r).

Table 5 summarizes the stability of the 100-year precipitation on bare-soil conditions, and Table 6 summarizes long-term stability of the PMP event on poorly vegetated cover. More detailed calculation tables can be found in Appendix A.

As shown by the resulting shear stress ratios in Table 5 and Table 6, both the eolian/sheet wash on-site soils and the weathered Mancos materials are too erosive to resist erosion (1) during the 100-year precipitation without vegetation or (2) during the PMP event with vegetation. Imported coarse sandy gravel with D_{75} of 1.1 inches would be adequate as a soil cover. The sandy gravel will adequately resist erosion to the 100-year precipitation without vegetation, and can also resist erosion from the PMP event, assuming at least a poor stand of grass or equivalent is established on the cover.

Table 5. Erosional Stability of 100-Year Precipitation on Bare Soil

Top Slope (ft/ft) 2.0 percent			
100-Year Flow (cfs/ft) 0.19			
Concentration Factor 3			
Cover Soil Eolian/Sheet Wash		**Weathered Mancos**	**Sandy Gravel**
Soil Characteristic	PI=5	PI=10	D_{75}=1.1 in
n_s	0.0156	0.0156	0.0260
Depth of flow, d (ft)	0.15	0.15	0.20
Allowable shear stress, τ_{∂} (psf)	0.018	0.038	0.440
Effective shear stress, τ_e (psf)	0.187	0.187	0.254
Shear stress ratio[a]	0.10	0.20	1.73

[a]Design criteria is shear stress ratio of 1.0 or greater

Table 6. Erosional Stability of PMP on Poorly Vegetated Cover

Top Slope (ft/ft) 2.0 percent			
PMP Flow (cfs/ft) 1.28			
Concentration Factor 3			
Cover Soil Eolian/Sheet Wash		**Weathered Mancos**	**Coarse Sand**
Soil Characteristic	PI=5	PI=10	D_{75}=1.1 in
n_s	0.0156	0.0156	0.0260
n_r	0.0261	0.0261	0.0261
n_v	0.0261	0.0261	0.0334
Depth of flow, d (ft)	0.64	0.64	0.74
Allowable soil shear stress, τ (psf)	0.018	0.038	0.440
Allowable vegetated shear stress, τ_{va} (psf)	2.01	2.01	2.01
Effective soil shear stress, τ_e (psf)	0.214	0.214	0.422
Effective vegetated shear stress, τ_{ve} (psf)	0.587	0.587	0.506
Shear stress ratio (soil)[a]	0.09	0.18	1.04
Shear stress ratio (vegetation)[a]	3.42	3.42	3.96

[a]Design criteria is shear stress ratio of 1.0 or greater

Rock Mulch Sizing for the Top Slopes

In addition to analyzing the top slope as a soil cover, the erosional stability of rock mulch is also analyzed, using the Safety Factor method, as recommended in NUREG/CR-4620 (Nelson et al. 1986) and NUREG-1623 (Johnson 2002) for slopes less than 10 percent. The safety factor against erosion for any given rock is calculated as:

$$SF = \frac{\cos\alpha \times \tan\phi}{\eta \times \tan\phi + \sin\alpha}$$

where:

α = angle of slope measured from horizontal,
ϕ = angle or repose of rock, and
η = stability number.

The stability number is calculated as:

$$\eta = \frac{21\tau_o}{(S_s - 1)\gamma D}$$

where:

τ_o = bed shear stress (psf),
S_s = specific weight of the rock,
γ = specific weight of water,
D = representative rock size (ft),

and:

$$\tau_o = \gamma ds$$

where:

d = depth of flow (ft), and
s = slope (ft/ft).

The key parameters used in the rock mulch sizing calculations are outlined in Table 7. For a PMP event, a factor of safety slightly greater than 1.0 is recommended (Nelson et al. 1986). The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 3) were used to represent flow conditions on the top slope. A concentration factor of 3 was used to account for potential flow channelization. The angle of repose and specific gravity of rock were assumed and will need to be verified for final design. More details of the calculation can be found in Appendix A.

Table 7. Rock Mulch Sizing for Top Slope Using Safety Factor Method

Top Slope (ft/ft)	2.0 percent
Angle of repose of rock (degrees)	37
Specific Gravity of rock	2.65
PMP unit flow (cfs/ft)	1.28
Concentration factor	3
Design flow (cfs/ft)	3.84
D_{50} rock mulch (in)	2.1
Factor of Safety	1.01

Riprap Sizing for the Side Slopes

The erosional stability of the side slopes is analyzed using the Abt and Johnson (1991) method, as discussed in NUREG-1623 (Johnson 2002). This method is recommended for slopes greater than 10 percent. The D_{50} rock sizes using the Abt and Johnson method is calculated as:

$$D_{50} = 5.23 S^{0.43} q^{0.56}$$

where:

q = unit discharge (cfs/ft), and
S = Slope (ft/ft).

The key parameters used in the rock mulch sizing calculations are outlined in Table 8. More details of the calculation can be found in Appendix A.

Table 8. Rock Mulch Sizing for Side Slopes

Method	**Abt and Johnson**			
Side Slope (ft/ft)	**20 Percent**			
Area	**A2 South**	**A3 West**	**A4 North**	**A5 East**
PMP unit flow (cfs/ft)	1.33	0.24	0.18	0.28
Concentration factor	3	3	3	3
Coefficient of Movement	1.35	1.35	1.35	1.35
Design flow (cfs/ft)	5.38	0.96	0.71	1.12
D_{50} for angular rock (inches)	6.7	2.6	2.2	2.8

The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 3) were used to represent flow conditions on the top slope. A concentration factor of 3 was used to account for flow channelization. The angle of repose and specific gravity of rock were assumed and will need to be adjusted (if necessary) with actual source characteristics.

Using Abt and Johnson's methods, the side slopes will have a median rock size ranging from 2.2 inches to 2.8 inches for the north, east, and west slopes, and a median rock size of 6.7 inches for the south slope. If rounded rock is used for erosion protection, the median rock size should be increased by approximately 40 percent (Abt and Johnson 1991). In addition, median rock size may be oversized for durability considerations once the rock source has been identified.

The rock protection layer thickness should be at least 1.5 to 2 times the median rock size.

Sensitivity of Required Rock Size of Rock Mulch and Riprap Protection to Cell Configuration

The rock mulch on the top of the disposal cell and the riprap on the side slopes has been designed for minimum D_{50} rock size based on the cell configuration given in Figure 1. Figure 2 and Figure 3 show how changes in the disposal cell configuration may affect the rock sizes required for erosion protection, or conversely, what changes in the disposal cell configuration would be required in order to be able to use an available rock size.

Wind Erosion

The potential for wind erosion of the top surface of disposal cell during drought conditions was evaluated using the MUSLE method, as presented in NUREG/CR-4620 (Nelson et al. 1986). Three potential cover materials were evaluated: (1) on-site sheet wash/eolian soils, (2) on-site excavated weathered Mancos Shale, and (3) imported coarse gravel.

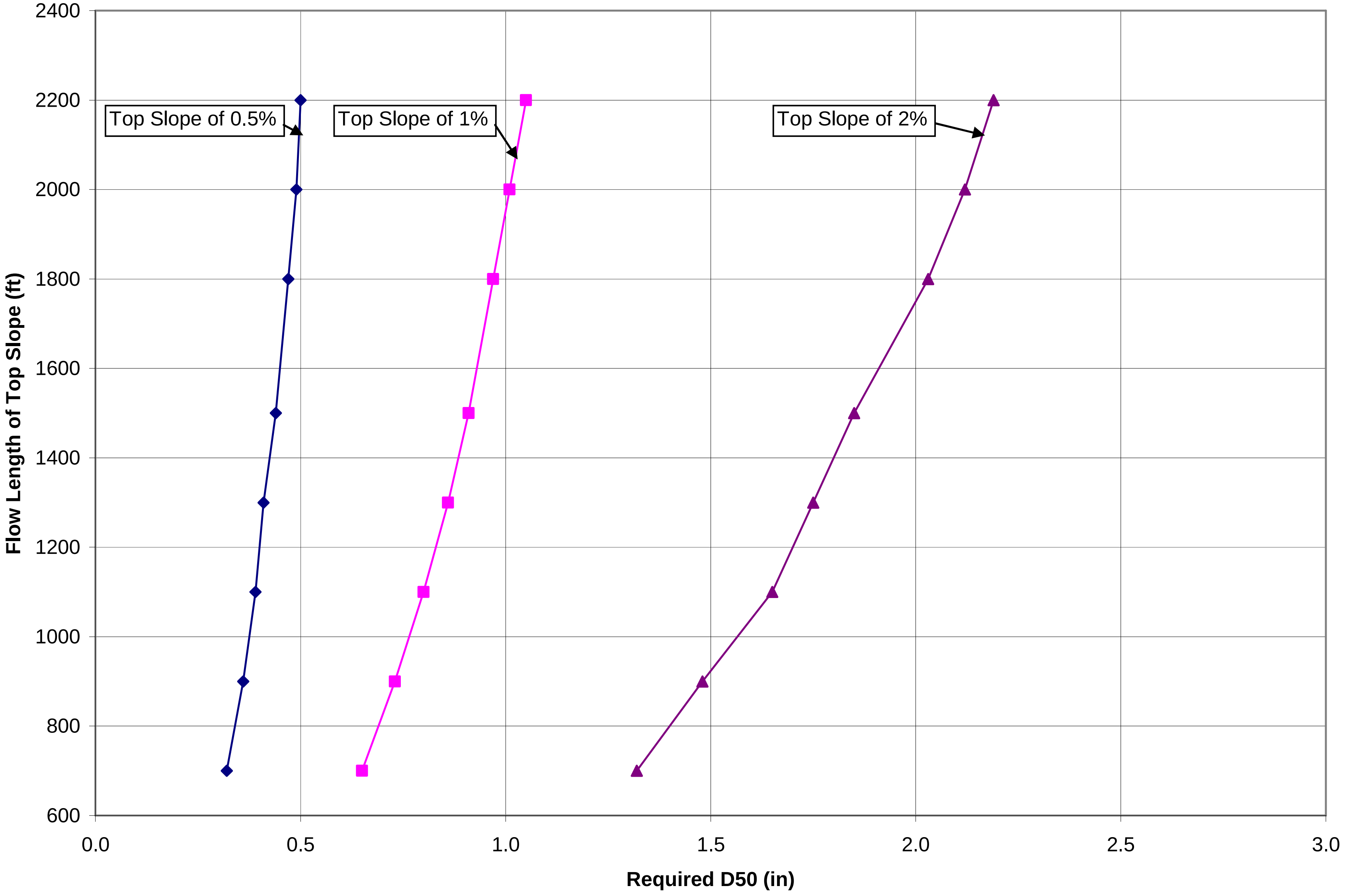


Figure 2. Required D_{50} for Top of Disposal Cell

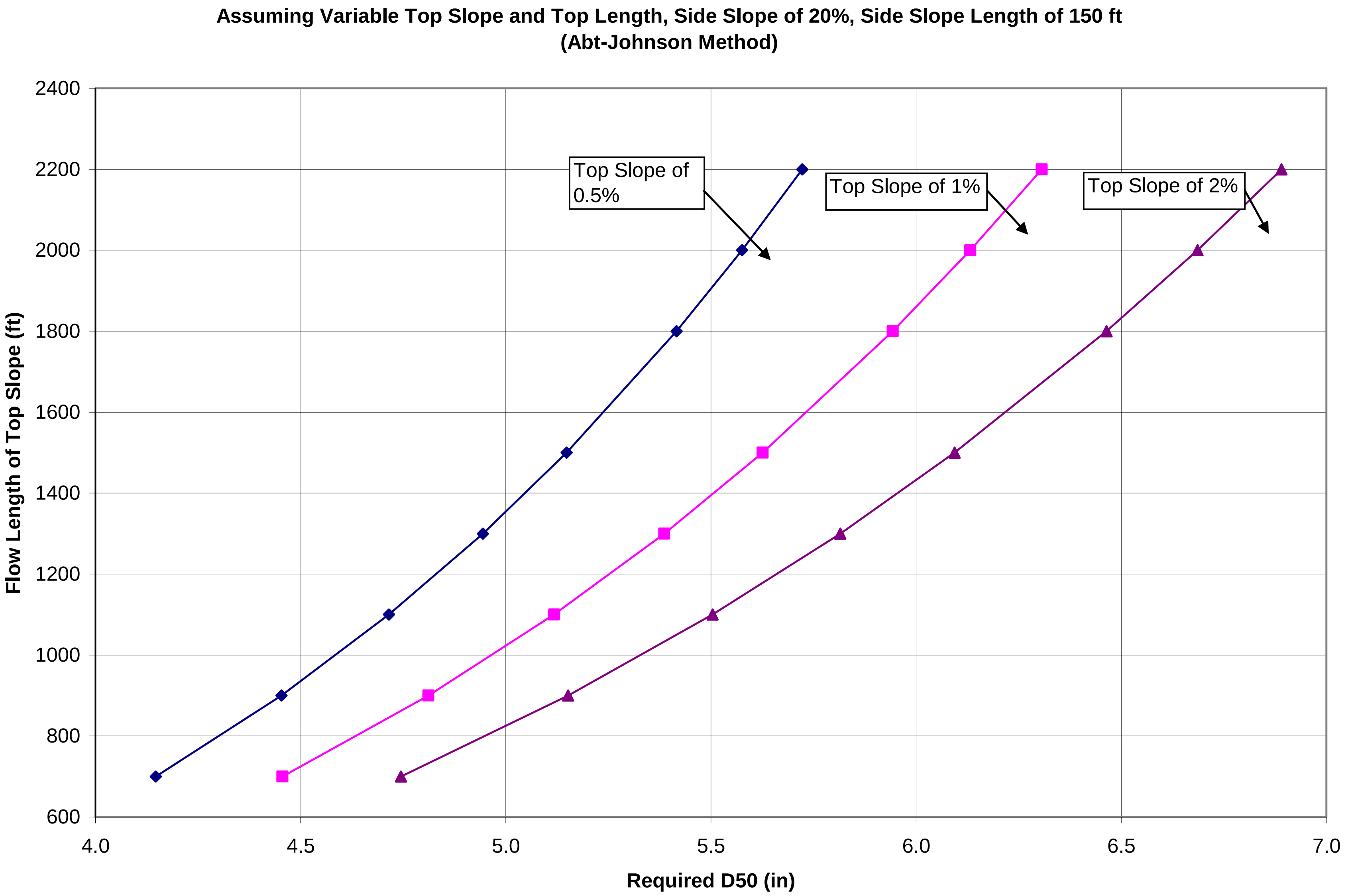


Figure 3. Required D_{50} for Side Slope With Contributed Flow From Top Slope

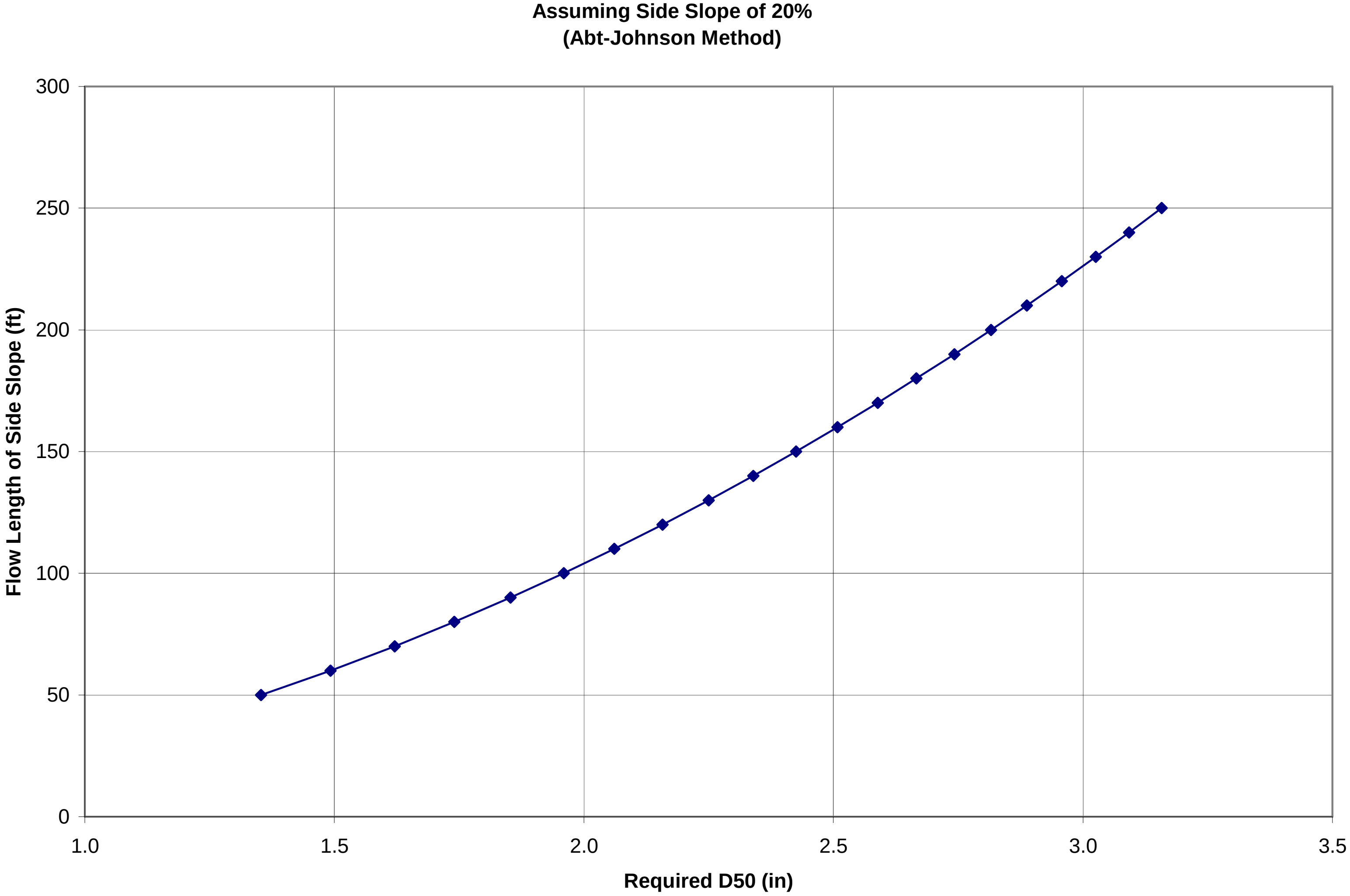
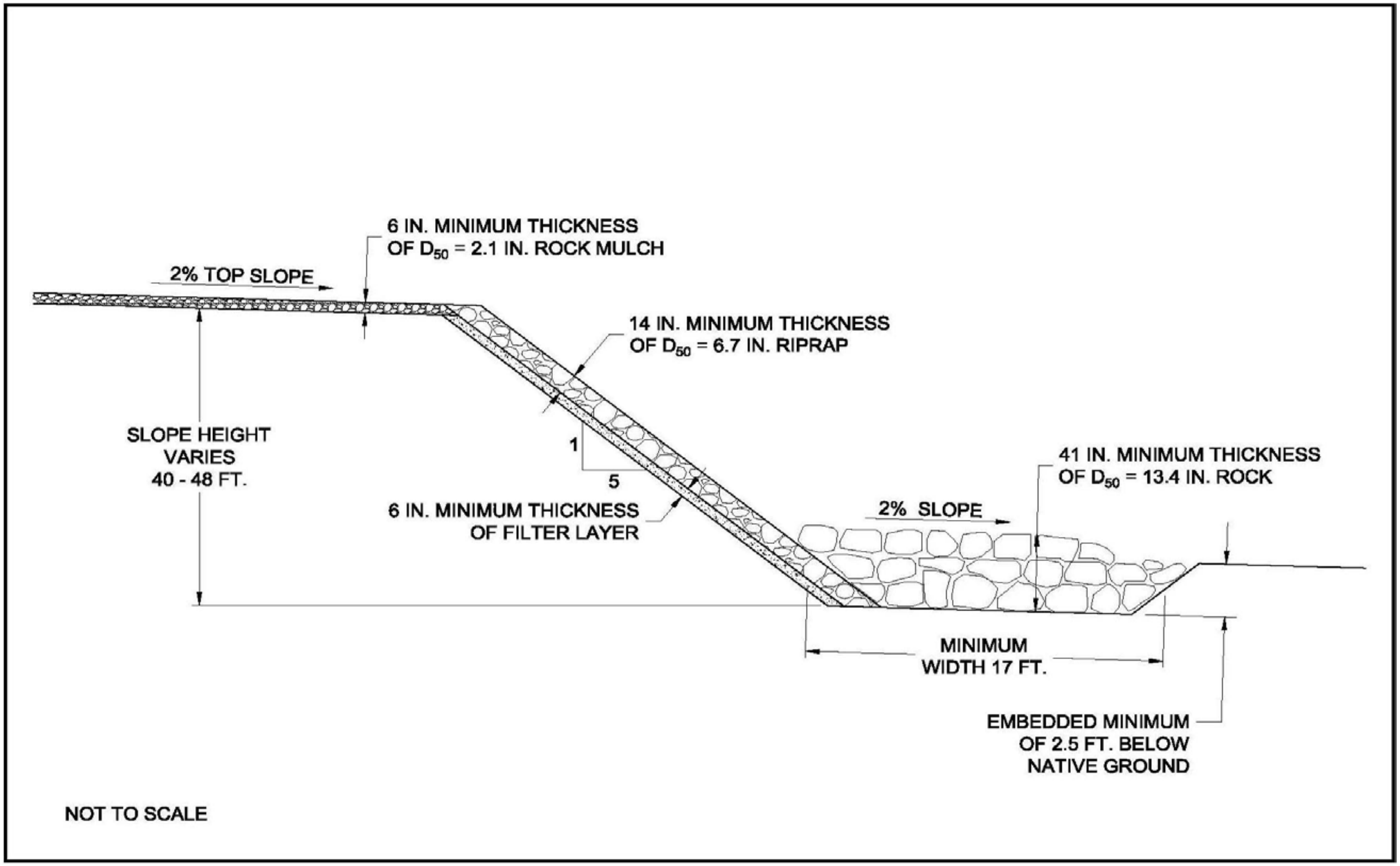


Figure 4. Required D50 for Side Slope with No Contributed Flow from Top Slope



MFG, Inc. *consulting scientists and engineers*	**FIGURE 5** **TYPICAL SECTION SHOWING SOUTH SLOPE** **REQUIRED EROSION PROTECTION**

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Project:	181268
File:	XS-TYP-01.DWG

Figure 5. Typical Section Showing South Slope Required Erosion Protection

The soil loss equation was calculated as follows:

$$A = R \times K \times LS \times VM$$

where:

A = soil loss in tons per acre per year,
R = rainfall factor,
K = soil erodibility factor,
LS = topographic factor, and
VM = dimensionless erosion control factor relating to vegetative and mechanical factors.

The rainfall factor is 30, as given in NUREG/CR-4620 (Nelson et al. 1986) for the eastern third of Utah. The soil erodibility factor was estimated using the nomograph given in NUREG/CR-4620 (Nelson et al. 1986).

The topographic factor is calculated by the following equation:

$$LS = \frac{650 + 450 \times s + 65 \times s^2}{10{,}000 + s^2} \times \left(\frac{L}{72.6}\right)^m$$

where:

s = slope steepness in percent,
L = slope length in ft, and
m = exponent dependent upon slope steepness.

The dimensionless erosion control factor used was 0.4, from Table 5.3 of NUREG/CR-4620 (Nelson et al. 1986), representing seedings of 0 to 60 days to mimic light vegetation on the cover. Table 9 summarizes the results of the soil loss equation.

Table 9. Results of Soil Loss Equation

Soil Cover	Sheet Wash/Eolian	Weathered Shale	Coarse Gravel
Rainfall factor, R	30	30	30
Silt and very fine sand (%)	60	55	10
Sand (%)	25	5	20
Organic matter (%)	2	2	0
Soil structure	Very fine granular	Blocky, platy or massive	Med. or coarse granular
Relative permeability	Moderate	Moderate	Moderate to rapid
Erodibility factor	0.35	0.26	0.05
Topographic factor, LS	0.49	0.49	0.49
VM (low density seedings)	0.4	0.4	0.4
Soil loss (tons/acre/year)	2.04	1.51	0.29
Soil loss (inches/1,000 years)	11.2	8.3	1.6

The soil loss equation shows that the potential for sheet erosion is unacceptably high if either the native sheet wash/eolian soils or weathered shale is used as a soil cover. The soil loss of less than 2 inches over the life of the disposal cell for coarse gravel is acceptable; especially considering vegetation is not required for stability of this material (but is required for stability of native soil cover to protect against PMP event).

Riprap Sizing for Rock Aprons

Additional erosion protection will be provided for runoff from the east, west, and south side slopes of the disposal cell with a rock apron. The north side of the disposal cell will receive runoff from the upland area north of the cell, and will require a diversion channel. The design of this diversion feature will be covered in the "Diversion Channel Design, North Side Disposal Cell" calculation (RAP Attachment 1, Appendix G).

The perimeter apron will: (1) serve as an impact basin and provide for energy dissipation of runoff, (2) provide erosion protection, and (3) transition flow from side slopes to natural ground. The median rock size required in the perimeter apron was calculated using the equations derived by Abt et al. (1998) as outlined in NUREG 1623 (Johnson 2002) as follows:

$$D_{50 energydissipation} = 10.46 S^{0.43} (C_f q_d)^{0.56}$$

where S is the slope, C_f is the concentration factor, and q_d is the design unit discharge.

Based on Table 10, the rock apron should have a median rock size of 13.4 inches along the south toe and between 5.1 and 5.6 inches along the east and west toes. Oversizing will be required for rounded rock or for durability considerations. The width of the apron should be a minimum of 15 times the median rock size or construction width. Rock apron thickness should be a minimum of 3 times the median rock size.

Table 10. Riprap for Toe Apron

Method Abt et al. (1998)			
Side Slope (ft/ft) 20 Percent			
Area	**A2 South**	**A3 West**	**A5 East**
PMP unit flow (cfs/ft)	1.33	0.24	0.28
Concentration factor	3	3	3
Coefficient of Movement	1.35	1.35	1.35
Design flow (cfs/ft)	5.38	0.96	1.12
D_{50} for angular rock (in)	13.4	5.1	5.6
Minimum apron width (ft)	17	6	7
Minimum apron thickness (in)	41	15	17

The maximum unit flow off the south toe is 1.33 cfs/ft. A concentration factor of 3 was used to account for flow channelization. Using this maximum flow, and an assumed slope of the rock apron of 2 percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983). The maximum scour depth from flow coming off the rock apron along the south side of the disposal cell is estimated to be 2.2 ft. Therefore, the bottom elevation of the rock apron should be placed approximately 2.5 ft below natural grade. The aprons along the east and sides of the disposal cell should be placed approximately 1.0 ft below natural grade. Details of calculations can be found in Appendix A.

Bedding Requirements

NUREG-1623, Appendix D (Johnson 2002), recommends a filter or bedding layer be placed under erosion protection if interstitial velocities are greater than 1 ft/sec, in order to prevent erosion of the underlying soils. Bedding is not required if interstitial velocities are less than 0.5 ft/sec, and recommended depending on the characteristics of the underlying soil if velocities are between 0.5 and 1 ft/sec.

Interstitial velocities are calculated by procedures presented by Abt and Johnson (1991) as given in the following equation:

$$V_i = 0.23 * (g * D_{10} * S)^{\frac{1}{2}}$$

where:

V_i = interstitial velocities (ft/s),
g = acceleration of gravity (ft/s^2),
D_{10} = stone diameter at which 10 percent is finer (inches), and
S = gradient in decimal form.

The maximum D_{10} of the erosion protection is estimated based on D_{50} required for erosion protection, assuming the erosion protection will have a coefficient of uniformity (CU) of 6 and a band width of 5. Band width refers to the ratio of the minimum and maximum allowed particle sizes acceptable for any given percent finer designation. USDA (1994) recommends CU to be a maximum of 6 in order to prevent gap-grading of filters. Table 11 summarizes the results.

Table 11. Results of Bedding Requirements

Location	**A1 Top**	**A2 South Side Slope**	**A3 West Side Slope**	**A4 North Side Slope**	**A5 East Side Slope**	**A2 South Apron**	**A3 West Apron**	**A5 East Apron**
Minimum D_{50} (inches)	2.1	6.7	2.3	2.2	2.8	13.4	5.1	5.6
Maximum D_{10} (inches)	0.9	2.1	0.9	0.9	0.9	4.2	1.6	1.7
Slope (%)	0.02	0.2	0.2	0.2	0.2	0.02	0.02	0.02
Interstitial Velocity (ft/s)	0.18	0.84	0.56	0.56	0.56	0.38	0.23	0.24

With the exception of the south side slope, the calculated interstitial velocities on the slopes and toe aprons are low enough that a bedding layer is not necessary. However, the interstitial velocities within the erosion protection on the south side slopes warrant a bedding layer beneath the rock protection.

Conclusion and Recommendations:

- Rock mulch with median rock size of 2.1 inches is recommended for the top slope of the disposal cell.
- Angular riprap protection with a median rock size of 6.7 inches is recommended for the south side slope, and a median rock size of 2.2 to 2.8 inches is recommended for the east, north, and west side slopes.
- Rock sizes should be adjusted if rock is not angular or does not meet NRC durability requirements (without oversizing). If rock is rounded, the median rock size should be increased by 40 percent. If rock has marginal durability, rock should be oversized using guidance given in NUREG-1623 (Johnson 2002).
- The riprap on the south side slope should be underlain with a bedding layer that meets filter criteria with the riprap and the underlying soils.
- A toe apron should be provided at the base of the east, south, and west side slopes. Median rock sizes of 5.6, 13.4, and 5.1 inches, respectively, should be provided. To protect against scour, the apron should be constructed such that the bottom elevation of the rock apron is a minimum of 2.5 ft below natural grade along the south side of cell and 1.0 ft below grade along the east and west sides.
- Figure 5 summarizes the different components of the erosion protection for a typical section drawn through the south side slope.

References:

10 CFR 40. U.S. Nuclear Regulatory Commission (NRC), “Domestic Licensing of Source Material,” Appendix A, *Code of Federal Regulations*, February 2007.

40 CFR 192. U.S. Environmental Protection Agency (EPA) “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,” *Code of Federal Regulations*, February 2007.

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End of current text

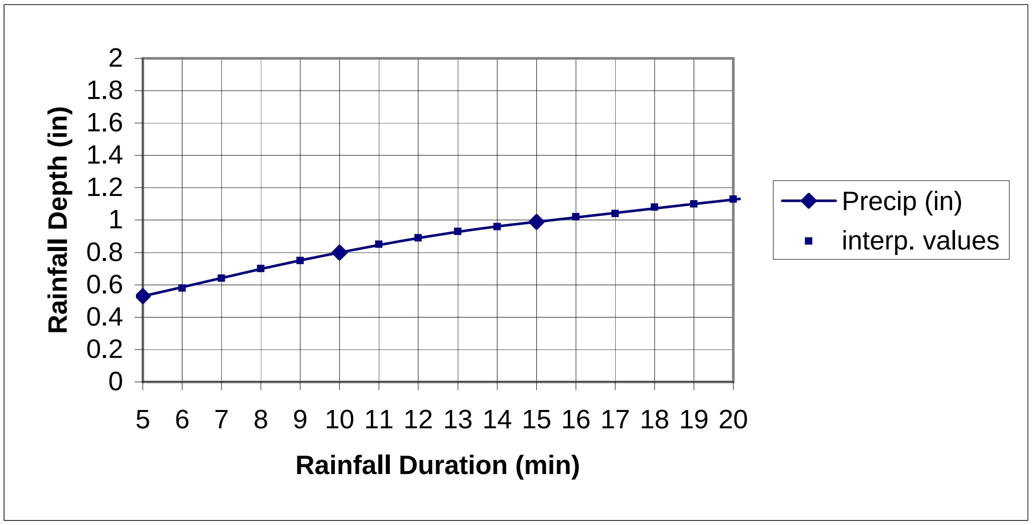
Appendix A

Supporting Calculations

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

100-year precipitation event

Values from NOAA Table (DOE 2005)			Interpolated Values		
Storm Duration (min)	Precip (in)	Intensity (in/hr)	Storm Duration (min)	Interpolated Precip (in)	Interpolated Intensity (in/hr)
5	0.53	6.36	0	0.53	6.36
10	0.8	4.8	5	0.53	6.36
15	0.99	3.96	6	0.58	5.80
30	1.33	2.66	7	0.64	5.49
60	1.65	1.65	8	0.7	5.25
120	1.82	0.91	9	0.75	5.00
			10	0.8	4.80
			11	0.85	4.64
			12	0.89	4.45
			13	0.93	4.29
			14	0.96	4.11
			15	0.99	3.96
			16	1.02	3.83
			17	1.04	3.67
			18	1.08	3.60
			19	1.1	3.47
			20	1.13	3.39



Client: **Stoller** **Job No.:** **181268**
Project: **Crescent Junction Disposal Cell** **Date:** **4/28/2006**
Detail: **Erosion Protection** **Computed By:** **RTS**

PMP Event

PMP calculation from Calc. No.: MOA-02-08-2005-2-08-00, Site Drainage--Hydrology Parameters
Use values for drainage area <1 square mile

Table 2. Estimated Precipitation Depths For Local-Storm PMP, Crescent Junction, Utah Site

Hourly Increments	**First Hour**	**Second Hour**	**Third Hour**				**Fourth Hour**	**Fifth Hour**	**Sixth Hour**
PMP Depths (inches)	0	0.1	8.2				0.6	0.1	0
Third-Hour Component Depths (inches)			7.1	0.5	0.4	0.2			

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Time of Concentration

1-hour PMP (in) 8.2

For top slopes of 2.0%, side slopes at 1V:5H

Description	Incremental Drainage Area (acres)	Slope (feet/feet)	Slope Length (feet)	Time of Concentration (minutes)				% of 1-hour PMP	PD_{PMP} (in)	Intensity (in/hr)
				Kirpich	SCS	Brant and Oberman	Average			
A1, top	213.91	0.02	2130	12.9	12.9	11.7	12.5	69.4	5.7	27.4
A2, slope	16.10	0.2	170	13.6	13.6	14.0	13.7	72.0	5.9	25.8
A3, slope	4.82	0.2	115	0.6	0.6	2.0	2.5	27.5	2.3	54.2
A4, slope	7.19	0.2	80	0.4	0.4	1.8	2.5	27.5	2.3	54.2
A5, slope	6.43	0.2	150	0.7	0.7	2.2	2.5	27.5	2.3	54.2

Note: Flow over A2 includes flow from A1

Source: Brant and Oberman(1975) as presented in UMTRA TAD (1989)
Formula: tc=C(L/Si^2)^(1/3).
Source:Kirpich (1940) as presented in NUREG 4620
Formula: tc=0.00013*L^0.77/S^0.385 with L in feet, tc in hours
Source: SCS as presented in NUREG 4620
Formula: tc=(11.9L^3/H)^0.385 with L in miles, H in feet, t in hours
% of one-hour PMP=RD/(0.0089*RD+0.0686) for tc<15 min based on Table 4.1 of TAD

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Unit discharge of PMP

Top slope =2.0%

Description	Total Drainage Area (acres)	C	Tc (min)	Intensity (in/hr)	Q (cfs)	longest slope length (ft)	unit discharge (cfs/ft)
A1, top	213.91	1	12.5	27.4	5863.3	2130	1.35
A2, slope	230.01	1	13.7	25.8	5928.1	2300	1.37
A3, slope	4.82	1	2.5	54.2	261.0	115	0.14
A4, slope	7.19	1	2.5	54.2	389.4	80	0.10
A5, slope	6.43	1	2.5	54.2	348.2	150	0.19

Note: Flow over A2 includes flow from A1

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Unit discharge of 100-year precipitation

Top slope =2.0%

Description	Total Drainage Area (acres)	C	Tc (min)	Precip. Depth (in)	Intensity (in/hr)	Q (cfs)	longest slope length (ft)	unit discharge (cfs/ft)
A1, top	213.91	0.9	12.5	0.9	4.5	856.7	2130	0.20
A2, slope	230.01	0.9	13.7	0.9	4.3	888.5	2300	0.21
A3, slope	4.82	0.9	2.5	0.5	6.4	27.6	115	0.02
A4, slope	7.19	0.9	2.5	0.5	6.4	41.2	80	0.01
A5, slope	6.43	0.9	2.5	0.5	6.4	36.8	150	0.02

Note: Flow over A2 includes flow from A1

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Temple Method for 2% Top Slope

Reference: Temple, D.M., Robinson, K.M., Ahring, R.M., and Davis, A.G., 1987. Stability Design of Grass-Lined Open Channels, USDA Handbook 667.
And as presented in UMTRA TAD Section 4.3.3 and NUREG 1623, Appendix A

native soil is classified as CL/ML with average values of LL=22, PI=4, %fines=70
This doesn't truly fit any of Temple's soil types, as PI is less than 10, but also not a sand

100-yr Design flow (cfs/ft)	0.20	
PMP Design flow (cfs/ft)	1.35	
Concentration Factor, F	3	
100-yr Design flow (cfs/ft), q	**0.6**	
PMP Design flow (cfs/ft), q	**4.05**	
Slope, S (ft/ft)	0.02	
average dry density (pcf)	103	(at 85% modified proctor)
average specific gravity	2.68	
void ratio, e	0.624	
unit weight water (pcf)	62.4	

	If SW or SP eolian/sheetwash	If CL eolian/sheetwash	if CL weathered mancos	If ML eolian/sheetwash	If imported coarse sand
d75 (inches)	<.05				1.1
Plasticity Index, PI		5	10	5	
End-of-construction, 100-yr precip					
Manning's n for non-veg slope	0.0156	0.0156	0.0156	0.0156	0.0260
assumed depth of flow, no veg (ft), d	0.15	0.15	0.15	0.15	0.21
calculated q (cfs/ft), no veg	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**
Iterate with d until calc. q equals design q					
velocity, v, no veg (ft/s)	3.88	3.88	3.88	3.88	2.86
base allowable tractive shear stress (psf) τab=		0.014595	0.02977	0.00744	
void ratio correction factor, Ce=		1.124541359	1.124541359	1.124541359	
allowable tractive shear stress (psf), τa=	0.020	0.018	0.038	0.009	0.440
effective shear stress (psf), τe (no veg)	0.193	0.193	0.193	0.193	0.262
shear stress ratio, end of construction	0.10	0.10	0.20	0.05	1.68
Limit slope such that shear stress ratio is 1.0					
Stable slope	0.08%	0.07%	0.19%	0.03%	4.17%
Long-term, PMP precip					
Repr. stem length (in) h(ave)					
good veg	1	1	1	1	1
poor veg	0.3	0.3	0.3	0.3	0.3
Repr. stem density (stems/sq in), M(ave)					
good veg	50	50	50	50	50
poor veg	17	17	17	17	17
Retardance curve index, Ci					
good veg	4.80	4.80	4.80	4.80	4.80
poor veg	2.67	2.67	2.67	2.67	2.67
Cover factor, Cf					
good veg	0.5	0.5	0.5	0.5	0.5
poor veg	0.25	0.25	0.25	0.25	0.25
allowable vegetated shear strength (psf), τva					
good veg	3.60	3.60	3.60	3.60	3.60
poor veg	2.01	2.01	2.01	2.01	2.01
Mannings n for soil roughness, ns=	0.0156	0.0156	0.0156	0.0156	0.0260
Mannings n for vegetal conditions, nr					
good veg	0.0388	0.0388	0.0388	0.0388	0.0388
poor veg	0.0259	0.0259	0.0259	0.0259	0.0259
Mannings n for vegetated slopes, nv					
good veg	0.0388	0.0388	0.0388	0.0388	0.0440
poor veg	0.0259	0.0259	0.0259	0.0259	0.0332
assumed depth of flow, d (ft)					
good veg	0.840	0.840	0.840	0.840	0.906
poor veg	0.659	0.659	0.659	0.659	0.766
calculated q (cfs/ft), with veg					
good veg	**4.05**	**4.05**	**4.05**	**4.05**	**4.05**
poor veg	**4.05**	**4.05**	**4.05**	**4.05**	**4.05**
Iterate with d until q calc equals q design					
velocity (ft/s), v					
good veg	4.82	4.82	4.82	4.82	4.47
poor veg	6.14	6.14	6.14	6.14	5.29
effective shear stress (psf), τe					
good veg	0.0848	0.0848	0.0848	0.0848	0.1975
poor veg	0.2236	0.2236	0.2236	0.2236	0.4387
effective veg shear stress (psf) τve					
good veg	0.9629	0.9629	0.9629	0.9629	0.9330
poor veg	0.5993	0.5993	0.5993	0.5993	0.5166
shear stress ratio, vegetated slope					
good veg	**3.74**	**3.74**	**3.74**	**3.74**	**3.86**
poor veg	**3.35**	**3.35**	**3.35**	**3.35**	**3.88**
shear stress ratio, soil on vegetated slope					
good veg	**0.24**	**0.22**	**0.44**	**0.11**	**2.23**
poor veg	**0.09**	**0.08**	**0.17**	**0.04**	**1.00**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Safety Factor Method

Appropriate for evaluating rock stability from flow parallel to cover and adjacent to the cover.
Design for SF of 1.5 for non-PMF applications, and slightly greater than 1.0 for PMF
Use for slopes less than 10 percent

	Top Slope	
Slope (ft/ft)	0.02	
angle α (rad)	0.020	
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded
Angle of repose of rock (rad))	0.646	
Specific gravity of rock	2.65	
PMP unit flow (cfs/ft)	1.35	(max from "flow-PMP" worksheet)
Concentration Factor	3	Typically between 1.1 to 3.2
design flow (cfs/ft)	4.05	

design flow over rock (cfs/ft)	**4.05**	assumes negligible flow through rock

Assumed D50 (in) #1	2	
Assumed D50 (in) #2	2.1	
Assumed D50 (in) #3	**2.2**	
Assumed D50 (in) #4	2.3	
Assumed D50 (in) #5	2.4	

Manning's n for rock #1	0.0273	Abt et al. 1987 as presented in UMTRA TAD
Manning's n for rock #2	0.0275	
Manning's n for rock #3	0.0278	
Manning's n for rock #4	0.0279	
Manning's n for rock #5	0.0281	

Assumed depth of flow for rock #1 (ft)	0.681
Assumed depth of flow for rock #2 (ft)	0.684
Assumed depth of flow for rock #3 (ft)	0.687
Assumed depth of flow for rock #4 (ft)	0.690
Assumed depth of flow for rock #5 (ft)	0.693

Calculated flow for rock #1 (cfs/ft)	4.05
Calculated flow for rock #2	4.05
Calculated flow for rock #3	4.05
Calculated flow for rock #4	4.05
Calculated flow for rock #5	4.05

modify depth of flow until calculated q = design q

calculated velocity for rock #1, (ft/s)	5.95
calculated velocity for rock #2, (ft/s)	5.92
calculated velocity for rock #3, (ft/s)	5.90
calculated velocity for rock #4, (ft/s)	5.87
calculated velocity for rock #5, (ft/s)	5.85

ave shear stress, τ for rock #1	0.85
ave shear stress, τ for rock #2	0.85
ave shear stress, τ for rock #3	0.86
ave shear stress, τ for rock #4	0.86
ave shear stress, τ for rock #5	0.86

Stability number for rock #1	1.040
Stability number for rock #2	0.995
Stability number for rock #3	0.954
Stability number for rock #4	0.916
Stability number for rock #5	0.882

Factor of Safety for rock #1	0.94
Factor of Safety for rock #2	0.98
Factor of Safety for rock #3	**1.02**
Factor of Safety for rock #4	1.06
Factor of Safety for rock #5	1.10

Adjust assumed D50 until design criteria for Factor of Safety is bracketed

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/9/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Abt METHOD (Abt and Johnson, 1991) applicable for slopes of 50% or less.

Equations assume specific gravity of rock is 2.65 or greater and angular rock.
For rounded rock, increase size by 40%.

ROCK SIZING EQUATION d50 = 5.23*S^0.43q*^0.56

Area	A2	A3	A4	A5	
Side Slope (ft/ft)	0.2	0.2	0.2	0.2	
angle α (rad)	0.197	0.197	0.197	0.197	
PMP unit flow (cfs/ft)	1.37	0.14	0.10	0.19	(max from "flow-PMP" worksheet)
Concentration Factor	3	3	3	3	Typically between 1.1 to 3.2
Coef. Of Movement	1.35	1.35	1.35	1.35	1.35 to prevent movement
design flow (cfs/ft)	5.56	0.58	0.41	0.76	
design flow over rock (cfs/ft)	5.56	0.58	0.41	0.76	assumes negligible flow through rock
D50 (inches) angular	6.8	1.9	1.6	2.2	
D50 (inches) rounded	9.6	2.7	2.2	3.1	

Client: Stoller
Project: Crescent Junction Disposal Cell
Detail: Erosion Protection
Job No.: 181268
Date: 5/9/2006
Computed By: RTS

STEPHENSON'S METHOD FOR SIZING RIPRAP

Applicable for shallow flow on slopes greater than 10%

Area	A2	A3	A4	A5	
slope (ft/ft)	0.2	0.2	0.2	0.2	
slope angle α (rad)	0.197	0.197	0.197	0.197	
Angle of repose of rock (degees)	41	41	41	41	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded
Angle of repose of rock (rad))	0.716	0.716	0.716	0.716	
Specific gravity of rock	2.65	2.65	2.65	2.65	
Dry unit weight of rock (pcf)	125	125	125	125	
Porosity of rock	0.32288	0.32288	0.32288	0.32288	
C	0.22	0.22	0.22	0.22	varies from 0.22 for gravel and pebbles to 0.27 for crushed granite
PMP unit flow (cfs/ft)	1.37	0.14	0.10	0.19	(max from from "flow" worksheet)
flow concentration	3	3	3	3	
design flow (cfs/ft)	4.12	0.43	0.30	0.56	
design flow over rock (cfs/ft)	4.12	0.43	0.30	0.56	assumes negligible flow through rock
D50 (inches) for angular rock	9.47	2.11	1.65	2.52	
D50 (inches) for rounded rock	13.25	2.95	2.32	3.52	

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**2/6/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Preliminary Gradations

This spreadsheet calculates preliminary gradations of riprap based on D50
Source: NUREG 4620
Source: USDA, National Engineering Handbook, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters, October 1994.

Area	A1	A2	A3	A4	A5	A2 Apron	A3 Apron	A5 Apron	Comment
Minimum D50 (in)	2.20	8.15	2.02	1.62	2.38	13.68	3.87	4.49	Assuming angular rock, average between Abt and Stephenson methods
Rock thickness (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Based on constructability: 2*D50. May consider 12" as minimum thickness for rock
Maximum D50 (in)	4.00	10.87	4.00	4.00	4.00	18.24	5.16	5.99	Based on constructability: Thickness/1.5
Maximum D50 (in)	11.00	40.77	10.11	8.09	11.91	68.40	19.37	22.47	Prevent gap-grading: minimum D50*5
Maximum D50 (in)	4.00	10.87	4.00	4.00	4.00	18.24	5.16	5.99	Smaller of two above criteria
Maximum D100 (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Based on constructability: 1*Thickness
Maximum D100 (in)	20.00	54.35	20.00	20.00	20.00	91.20	25.82	29.97	Based on internal stability?: 5*maximum D50
Maximum D100 (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Smaller of two above criteria
Minimum D100 (in)	4.40	16.31	4.04	3.24	4.76	27.36	7.75	8.99	Based on internal stability: 2*minimum D50
Minimum D15 (in)	0.38	1.02	0.38	0.38	0.38	1.71	0.48	0.56	Based on internal stability: Maximum D100/16
Maximum D15 (in)	1.88	5.10	1.88	1.88	1.88	8.55	2.42	2.81	Prevent gap-grading: Minimum D15*5
Minimum D60 (in)	3.08	11.41	2.83	2.26	3.33	19.15	5.42	6.29	Prevent gap-grading: D60/D10<=6
Maximum D60 (in)	5.60	15.22	5.60	5.60	5.60	25.54	7.23	8.39	Prevent gap-grading: D60/D10<=6
Minimum D10 (in)	0.51	1.90	0.47	0.38	0.56	3.19	0.90	1.05	Prevent gap-grading: D60/D10<=6
Maximum D10 (in)	0.93	2.54	0.93	0.93	0.93	4.26	1.21	1.40	Prevent gap-grading: D60/D10<=6

Summary

Percent Passing	Diameter (mm)							
50	56	207	51	41	60	347	98	114
50	102	276	102	102	102	463	131	152
100	152	414	152	152	152	695	197	228
100	112	414	103	82	121	695	197	228
15	10	26	10	10	10	43	12	14
15	48	129	48	48	48	217	61	71
60	78	290	72	58	85	486	138	160
60	142	387	142	142	142	649	184	213
10	13	48	12	10	14	81	23	27
10	24	64	24	24	24	108	31	36

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**2/6/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Interstitial Velocities

Source: NUREG 1623, Section D
Abt, SR, JF Ruff, RJ Wittler (1991). Estimating Flow Through Riprap, Journal of Hydraulic Engineering, Vol. 117, No. 5, May.

Area	A1	A2	A3	A4	A5	A2 apron	A3 apron	A5 apron	
Minimum D50 (inches)	2.20	8.15	2.02	1.62	2.38	13.68	3.87	4.49	from Safety Factor Method, or ave of Abt, Stephenson etc. assuming angular rock
Maximum D10 (inches)	0.93	2.54	0.93	0.93	0.93	4.26	1.21	1.40	from preliminary gradation specs
Slope (ft/ft)	0.02	0.2	0.2	0.2	0.2	0.02	0.02	0.02	from preliminary disposal cell layout
Velocity (ft/s)	0.18	0.93	0.56	0.56	0.56	0.38	0.20	0.22	calculated from Abt et al. (1991)
Underlying filter required?	no	maybe	maybe	maybe	maybe	no	no	no	Per NUREG 1623, Appendix D, section 2.1.1

Client: **Stoller** **Job No.:** **181268**
Project: **Crescent Junction Disposal Cell** **Date:** **5/9/2006**
Detail: **Erosion Protection** **Computed By:** **RTS**

Modified Universal Soil Loss Equation (MUSLE)

Source : Clyde et al. (1978) as presented in NUREG 4620, section 5.1.2
A=R*K*LS*VM

	Sheet wash/eolian	weathered shale	coarse gravel/sand	
Inputs for K factor				
Percent silt and very fine sand	60	55	10	
Percent sand (0.10-2.0 mm)	25	5	20	
Percent oganic matter	2	2	0	
Soil structure	No. 1	No. 3	No. 3	
Permeability	No. 3	No. 3	No. 2	
Inputs for LS factor				
Slope length (ft)	2130	2130	2130	
slope steepness (%)	2	2	2	
m exponent	0.3	0.3	0.3	from table 5.2 of NUREG 4620

		Sheet Wash/Eolian	Weathered Shale	Coarse Sand	
R	Rainfall Factor	30	30	30	From Table 5.1 of NUREG 4620 for eastern third of Utah
K	Soil Erodibility factor	0.35	0.26	0.05	From nomograph Fig. 5.1 of NUREG 4620
LS	Topographic factor	0.50	0.50	0.50	
VM	Dimensionless erosion control factor	0.4	0.4	0.4	From Table 5.3 of NUREG 4620 for seedings, 0-60 days
A	Soil Loss (tons/acre/year)	2.09	1.56	0.30	
A	Soil density (pcf)	100	100	100	
A	Soil Loss (inches/1000 years	11.5	8.6	1.6	

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/12/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

Source: Abt, SR, Johnson, TL, Thornton, CI, and Trabant, SC, Riprap Sizing at Toe of Embankment Slopes, Journal of Hydraulic Engineering, Vol. 124, No. 7, July 1998.

Equation: D50=10.46*S^0.43*qd^0.56

	North	South	East	West
unit discharge (cfs/ft)	0.10	1.37	0.19	0.14
Cr	1	1	1	1
Cf	3	3	3	3
Cm	1.35	1.35	1.35	1.35
design discharge (cfs/ft)	0.406164	5.557379	0.761558	0.583861
Slope (ft/ft)	0.2	0.2	0.2	0.2
D50 (in)	3.2	13.7	4.5	3.9

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/12/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow over riprap	**A2, south**	**A3, west**	**A5, east**		
Flow, q	1.37	0.14	0.19	cfs/ft	
gravity, g	32.2	32.2	32.2	ft/s^2	
time, t	15	15	15	minutes	
base time, to	316	316	316	minutes	
D50	13.7	3.9	4.5	in	
D50	1.14	0.32	0.37	ft	
Slope of Apron	0.02	0.02	0.02	(ft/ft)	
Manning's n	0.040	0.033	0.034	COE (1970) for submerged riprap	
depth of flow	0.45	0.10	0.12	ft	
velocity	3.06	1.41	1.54	ft/s	
Native soils					
plasticity index of alluvial soil	5	5	5	%	from GEG, 2005 lab data
unconfined compressive strength	1.4	1.4	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.254143	0.254143	0.254143		
modified shear number	71.41606	15.15466	18.19436		
d84 bedding	0.12	0.12	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	0.002	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.745967	7.745967	7.745967		
gradation classification	graded	graded	graded		
	Depth				
α	0.86				coefficients for clay with PI 5-16
β	0.18				
θ	0.1				
αe	1.37				
equivalent depth, ye	0.45	0.10	0.12	ft	
depth of scour (ft)	0.98	0.22	0.27		

P:\181268\RAP\erosional stability\ripraprev2

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-01-06-2006-5-02-01 **Discipline:** Geotechnical **No. of Sheets:** 14
Doc. No.: X0176600

Location: Attachment 1, Appendix I

Project: Moab UMTRA Project

Site: Moab Disposal Site

Feature: Volume Calculation for the Moab Tailings Pile

Sources of Data:

Various site topography files, including pre-2000 data, and 2003 and 2005 topography files.

Boring logs and CPTs from Steffen, Robertson, and Kirsten (2000) site investigation.

Boring logs from Dames & Moore (1981) site investigation.

Boring logs, test pit logs, CPT soundings, and laboratory test data from Golder (2005) field investigation.

Sources of Formulae and References:

ConeTec, Inc. (ConeTec), 2000. *Cone Penetration Test Report*, *Atlas Minerals Mill Tailings Impoundment, Moab, Utah*, Vols. I and II, Salt Lake City, Utah, May 12.

Dames & Moore (D&M), 1981. *Additions to Tailings Pond-Embankment System, Moab, Utah,* Report of Engineering Design Study for Atlas Minerals, Salt Lake City, Utah, May 26.

Steffen, Robertson, and Kirsten (SRK), 2000. *Dewatering Options for Placement of Cover, Moab Tailings Impoundment*, prepared for Moab Mill Reclamation Trust, Lakewood, Colorado, June.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-01-05-2006-5-02-00**

Author: Kimberly L. Manion 6/5/06
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No text for this page

Problem Statement:

Estimate the total volume of tailings and associated fill materials requiring removal and re-location from the Moab Tailings Impoundment, including an estimate of the various material types (i.e., cover fill, sands, transitional tailings and slimes).

Method of Solution:

Review site geotechnical data including boring logs, test pit logs, laboratory test results and cone penetration test soundings conducted at the Site. Using AutoCAD and Land Development Desktop, develop cross-sections both laterally (northwest to southeast) and transversely (southwest to northeast) across the site in order to estimate the volumes. Where laboratory test data are available, use the data to divide the material into the following general classifications:

- Sand: <30 percent fines (minus 74 micron).
- Transitional tailings: >30 percent and < 70 percent fines.
- Slimes: >70 percent fines.

Assumptions:

- Relative percent fines can be estimated from the cone penetration soundings based on relative resistance, whereby higher resistances infer presence of sandy soils and lower resistance infer presence of fine-grained soils.
- The average end area method, wherein averaged cross-sectional areas from two adjacent sections multiplied by the distance between those two sections provides a reasonable estimate of the volume of material between the same sections.

Calculation:

Volumes were calculated using the average-end area method, whereby cross-sections were developed across the site and the material constituents of each cross-section were averaged with the same from the adjacent cross-section and multiplied by the distance between the sections.

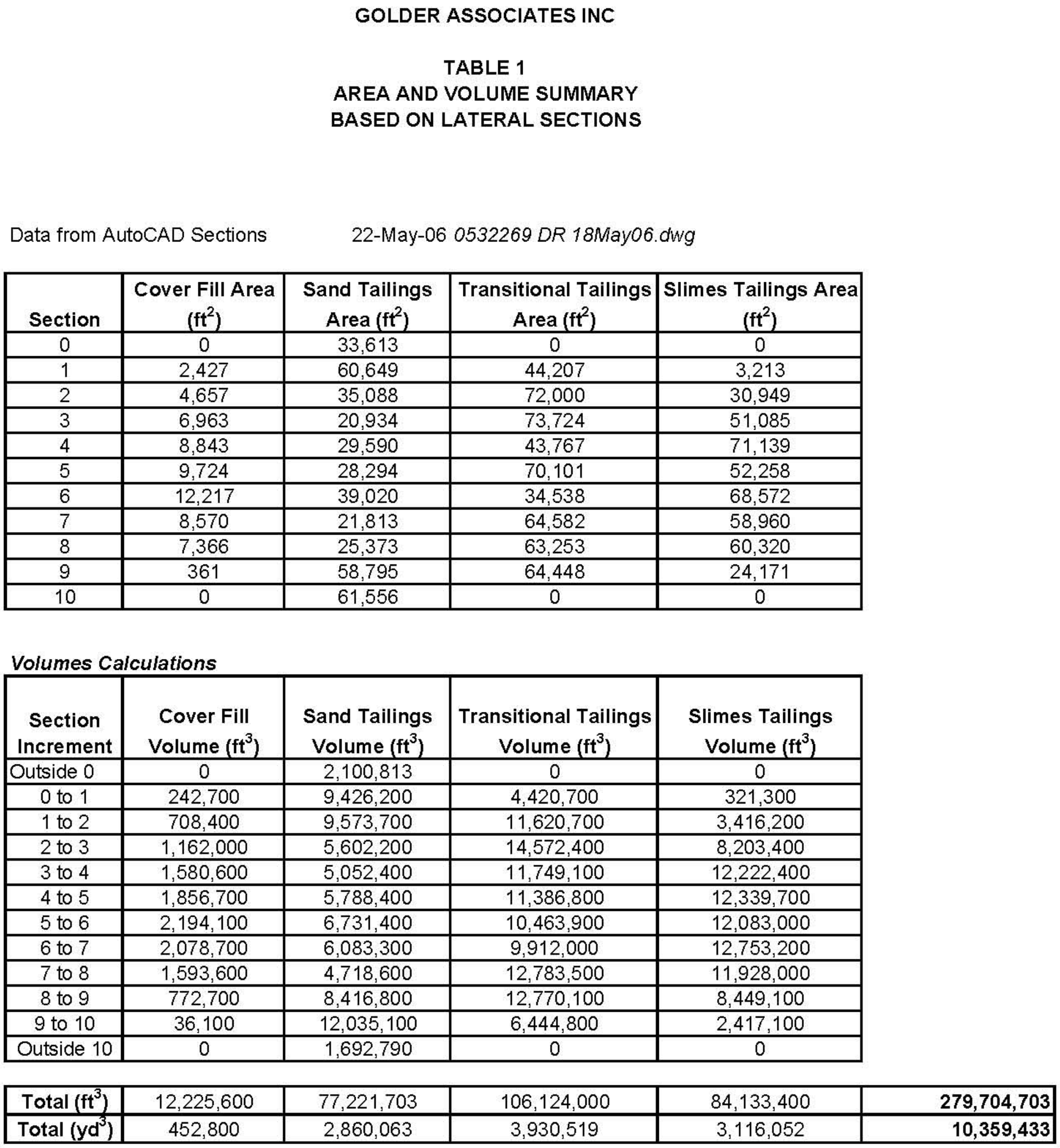
Discussion:

- Based on the method discussed herein, results of the volume evaluation using lateral cross-sections (0 through 10) and transverse cross-sections (11 through 25) are summarized as follows, with volumes presented in cubic yards (yd^3):

Material Type	Lateral Cross-Sections (yd^3)	Transverse Cross-Sections (yd3)
Cover Fill	452,800	440,800
Sand Tailings	2,860,100	2,736,700
Transitional Tailings	3,930,500	3,903,100
Slimes	3,116,100	3,236,600

- The total volume of tailings and cover soils was calculated to be 10.36 million yd^3 and 10.32 million yd^3 using the lateral and transverse cross-sections, respectively.
- See Tables 1 and 2 for summary of cross-sectional areas and volumes based on the lateral and transverse cross-sections, respectively.
- See Figures 1 through 8 for map and cross-sections.

Table 1. Area and Volume Summary



GOLDER ASSOCIATES INC

TABLE 1
AREA AND VOLUME SUMMARY
BASED ON LATERAL SECTIONS

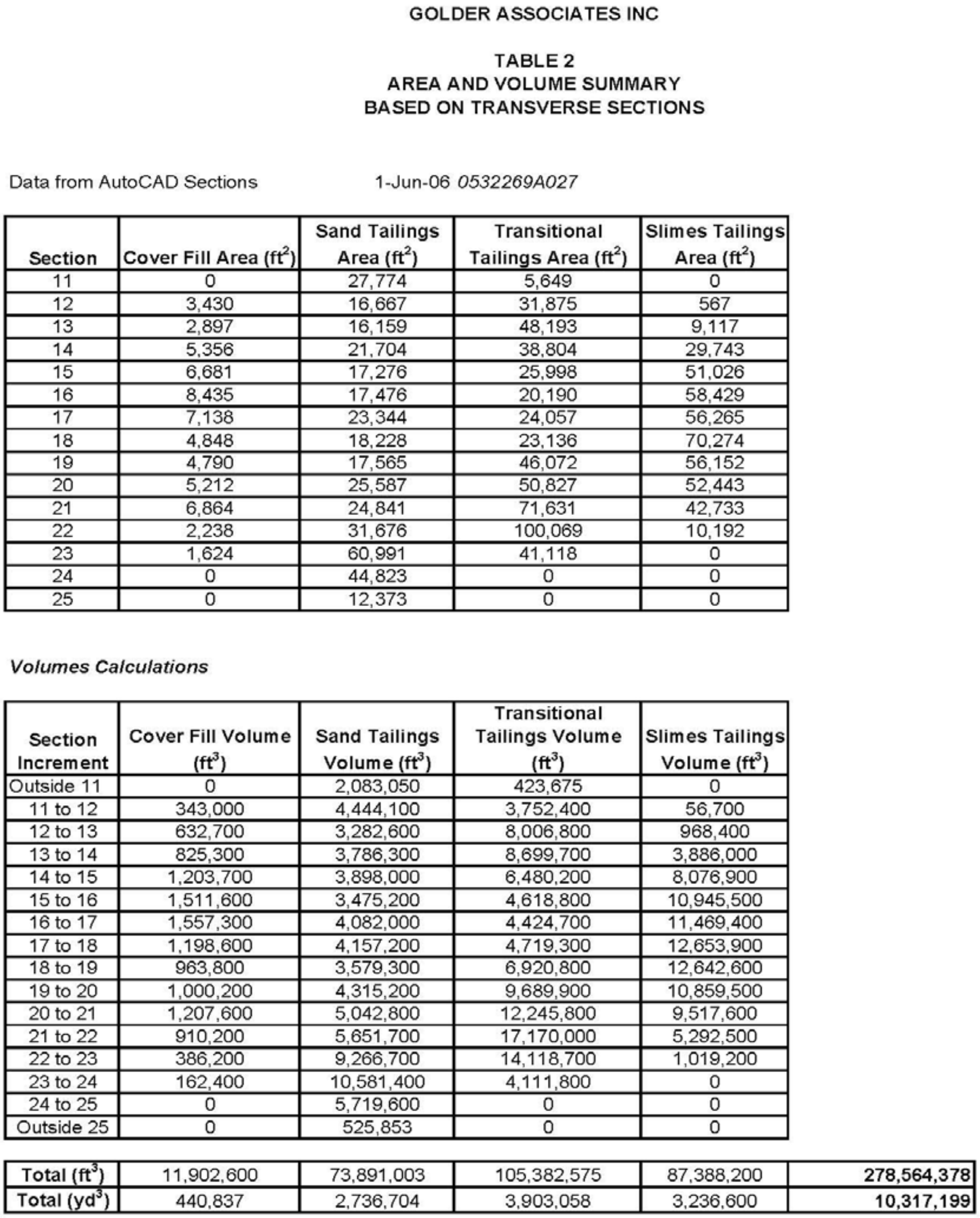
Data from AutoCAD Sections 22-May-06 *0532269 DR 18May06.dwg*

Section	Cover Fill Area (ft^2)	Sand Tailings Area (ft^2)	Transitional Tailings Area (ft^2)	Slimes Tailings Area (ft^2)
0	0	33,613	0	0
1	2,427	60,649	44,207	3,213
2	4,657	35,088	72,000	30,949
3	6,963	20,934	73,724	51,085
4	8,843	29,590	43,767	71,139
5	9,724	28,294	70,101	52,258
6	12,217	39,020	34,538	68,572
7	8,570	21,813	64,582	58,960
8	7,366	25,373	63,253	60,320
9	361	58,795	64,448	24,171
10	0	61,556	0	0

Volumes Calculations

Section Increment	Cover Fill Volume (ft^3)	Sand Tailings Volume (ft^3)	Transitional Tailings Volume (ft^3)	Slimes Tailings Volume (ft^3)	
Outside 0	0	2,100,813	0	0	
0 to 1	242,700	9,426,200	4,420,700	321,300	
1 to 2	708,400	9,573,700	11,620,700	3,416,200	
2 to 3	1,162,000	5,602,200	14,572,400	8,203,400	
3 to 4	1,580,600	5,052,400	11,749,100	12,222,400	
4 to 5	1,856,700	5,788,400	11,386,800	12,339,700	
5 to 6	2,194,100	6,731,400	10,463,900	12,083,000	
6 to 7	2,078,700	6,083,300	9,912,000	12,753,200	
7 to 8	1,593,600	4,718,600	12,783,500	11,928,000	
8 to 9	772,700	8,416,800	12,770,100	8,449,100	
9 to 10	36,100	12,035,100	6,444,800	2,417,100	
Outside 10	0	1,692,790	0	0	
Total (ft^3)	12,225,600	77,221,703	106,124,000	84,133,400	**279,704,703**
Total (yd^3)	452,800	2,860,063	3,930,519	3,116,052	**10,359,433**

Table 2. Area and Volume Summary Based on Transverse Sections



GOLDER ASSOCIATES INC

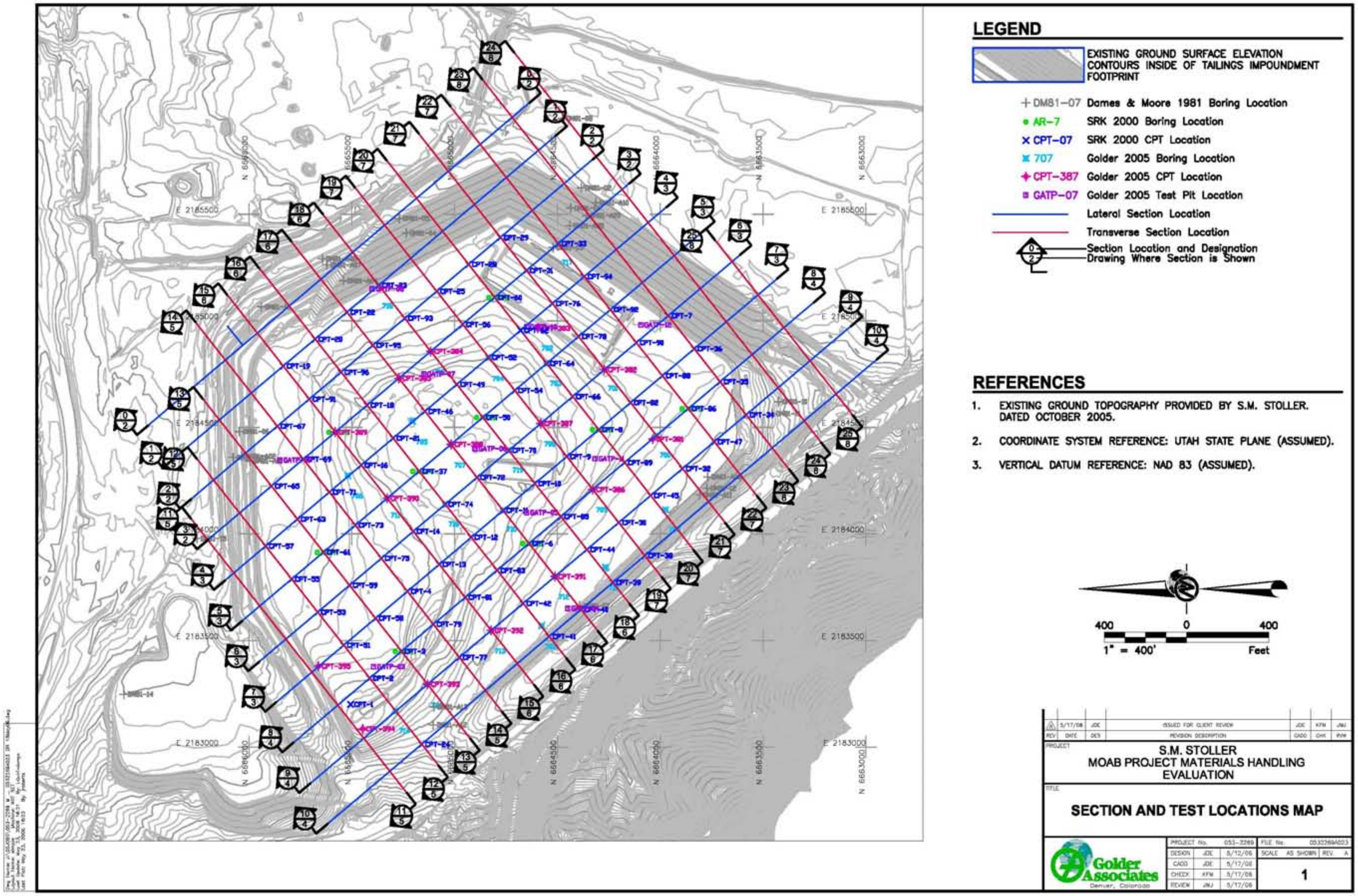
TABLE 2
AREA AND VOLUME SUMMARY
BASED ON TRANSVERSE SECTIONS

Data from AutoCAD Sections 1-Jun-06 *0532269A027*

Section	Cover Fill Area (ft^2)	Sand Tailings Area (ft^2)	Transitional Tailings Area (ft^2)	Slimes Tailings Area (ft^2)
11	0	27,774	5,649	0
12	3,430	16,667	31,875	567
13	2,897	16,159	48,193	9,117
14	5,356	21,704	38,804	29,743
15	6,681	17,276	25,998	51,026
16	8,435	17,476	20,190	58,429
17	7,138	23,344	24,057	56,265
18	4,848	18,228	23,136	70,274
19	4,790	17,565	46,072	56,152
20	5,212	25,587	50,827	52,443
21	6,864	24,841	71,631	42,733
22	2,238	31,676	100,069	10,192
23	1,624	60,991	41,118	0
24	0	44,823	0	0
25	0	12,373	0	0

Volumes Calculations

Section Increment	Cover Fill Volume (ft^3)	Sand Tailings Volume (ft^3)	Transitional Tailings Volume (ft^3)	Slimes Tailings Volume (ft^3)	
Outside 11	0	2,083,050	423,675	0	
11 to 12	343,000	4,444,100	3,752,400	56,700	
12 to 13	632,700	3,282,600	8,006,800	968,400	
13 to 14	825,300	3,786,300	8,699,700	3,886,000	
14 to 15	1,203,700	3,898,000	6,480,200	8,076,900	
15 to 16	1,511,600	3,475,200	4,618,800	10,945,500	
16 to 17	1,557,300	4,082,000	4,424,700	11,469,400	
17 to 18	1,198,600	4,157,200	4,719,300	12,653,900	
18 to 19	963,800	3,579,300	6,920,800	12,642,600	
19 to 20	1,000,200	4,315,200	9,689,900	10,859,500	
20 to 21	1,207,600	5,042,800	12,245,800	9,517,600	
21 to 22	910,200	5,651,700	17,170,000	5,292,500	
22 to 23	386,200	9,266,700	14,118,700	1,019,200	
23 to 24	162,400	10,581,400	4,111,800	0	
24 to 25	0	5,719,600	0	0	
Outside 25	0	525,853	0	0	
Total (ft^3)	11,902,600	73,891,003	105,382,575	87,388,200	**278,564,378**
Total (yd^3)	440,837	2,736,704	3,903,058	3,236,600	**10,317,199**



REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M. STOLLER. DATED OCTOBER 2005.
2. COORDINATE SYSTEM REFERENCE: UTAH STATE PLANE (ASSUMED).
3. VERTICAL DATUM REFERENCE: NAD 83 (ASSUMED).

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
A	5/17/06	JDE	ISSUED FOR CLIENT REVIEW	JDE	KFM	JNJ

PROJECT
S.M. STOLLER
MOAB PROJECT MATERIALS HANDLING
EVALUATION

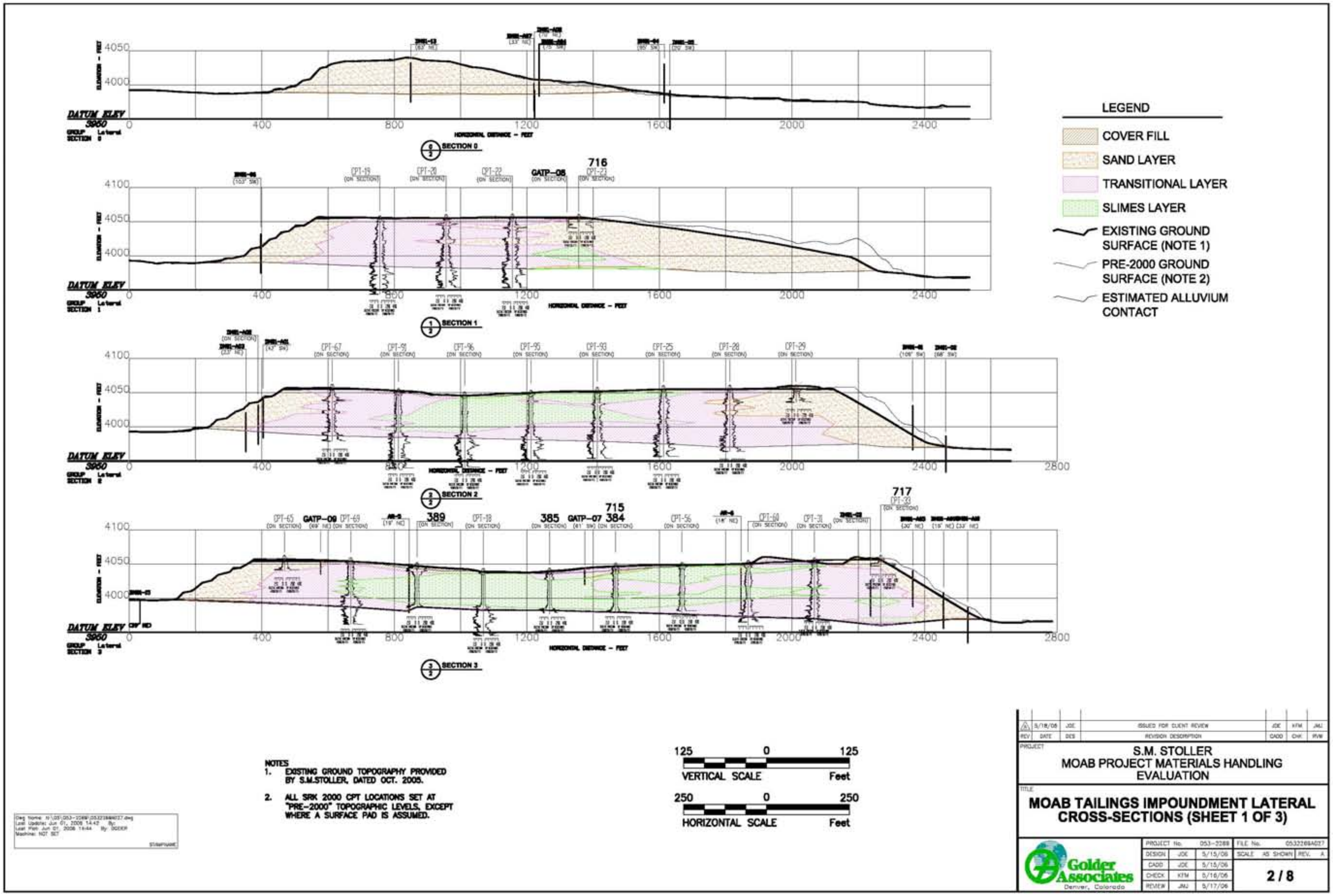
TITLE
SECTION AND TEST LOCATIONS MAP

Golder Associates
Denver, Colorado

PROJECT No.		053-2289
DESIGN	JDE	5/12/06
CADD	JDE	5/17/06
CHECK	KFM	5/17/06
REVIEW	JNJ	5/17/06

FILE No. 0532289A023
SCALE AS SHOWN REV. A
1

Figure 1. Section and Test Locations Map



NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

Figure 2. Moab Tailings Impoundment Lateral Cross-Section (Sheet 1 of 3)

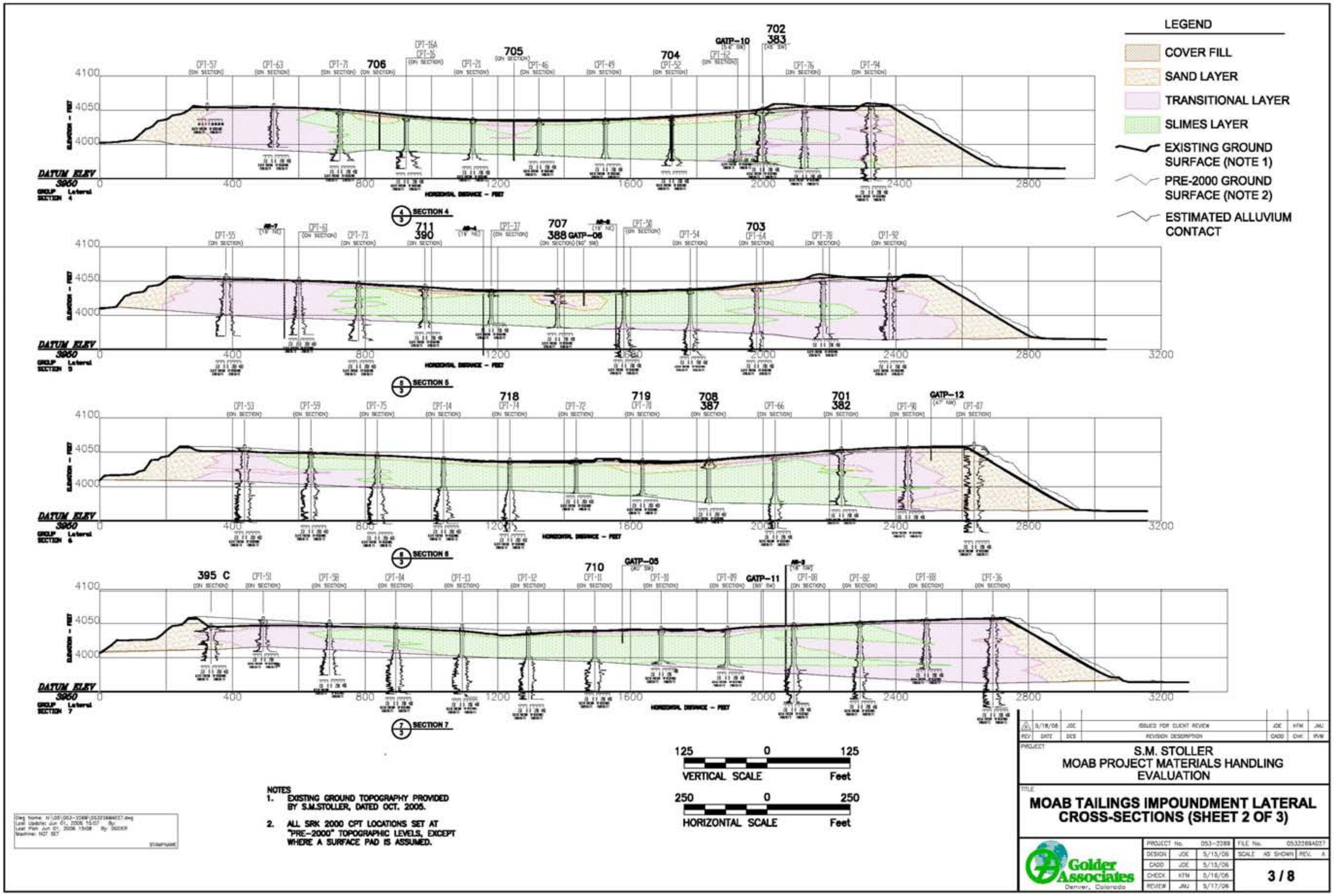
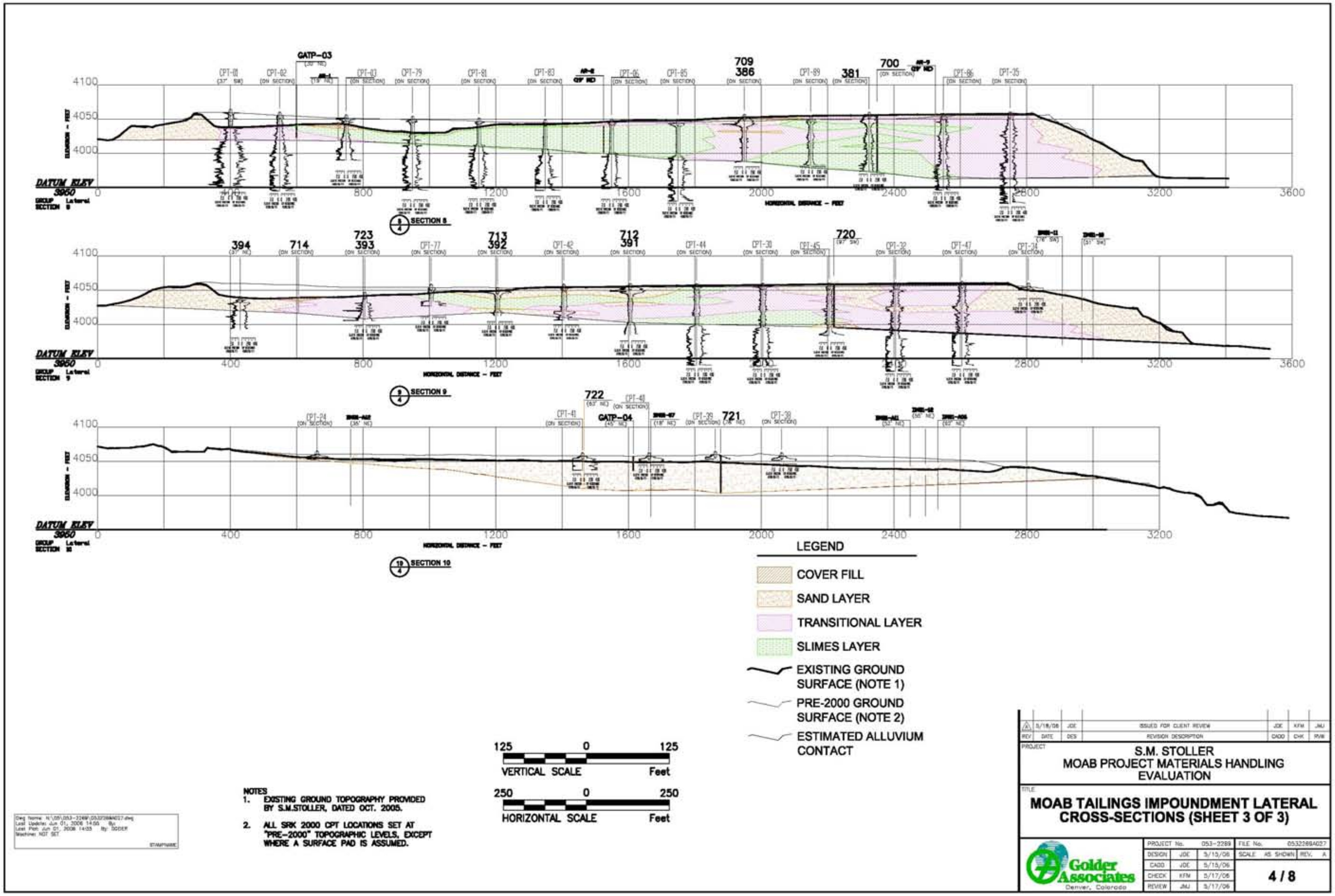
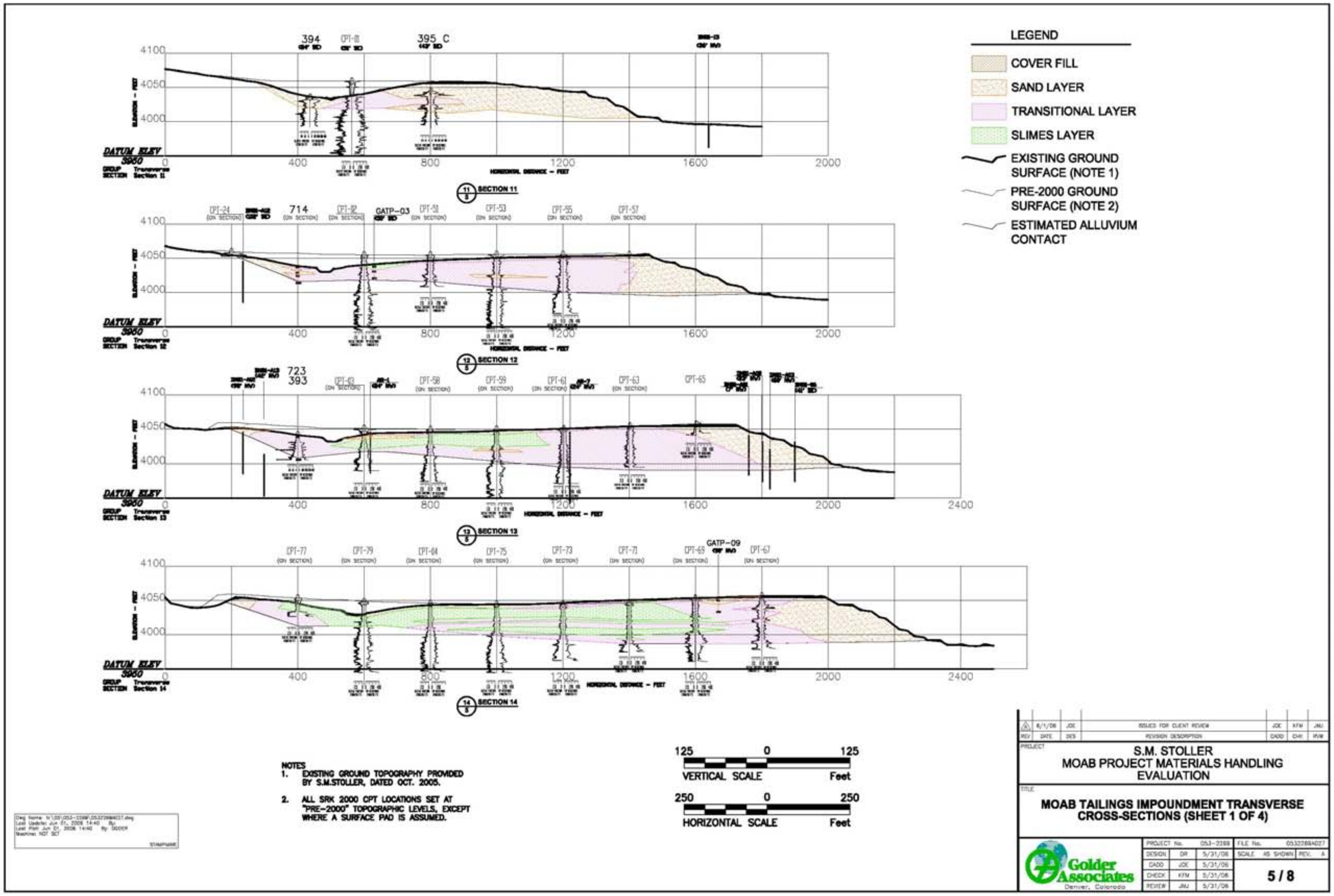


Figure 3. Moab Tailings Impoundment Lateral Cross-Section (Sheet 2 of 3)



NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

Figure 4. Moab Tailings Impoundment Lateral Cross-Sections (Sheet 3 of 3)



NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
A	6/1/06	JOE	ISSUED FOR CLIENT REVIEW	JOE	KFM	JMJ

PROJECT
S.M. STOLLER
MOAB PROJECT MATERIALS HANDLING
EVALUATION

TITLE
MOAB TAILINGS IMPOUNDMENT TRANSVERSE
CROSS-SECTIONS (SHEET 1 OF 4)

Golder Associates
Denver, Colorado

PROJECT No.	053-2288		FILE No.	0532288A027
DESIGN	DR	5/31/06	SCALE AS SHOWN	REV. A
CADD	JOE	5/31/06		
CHECK	KFM	5/31/06	5 / 8	
REVIEW	JMJ	5/31/06		

Figure 5. Moab Tailings Impoundment Transverse Cross Sections (Sheet 1 of 4)

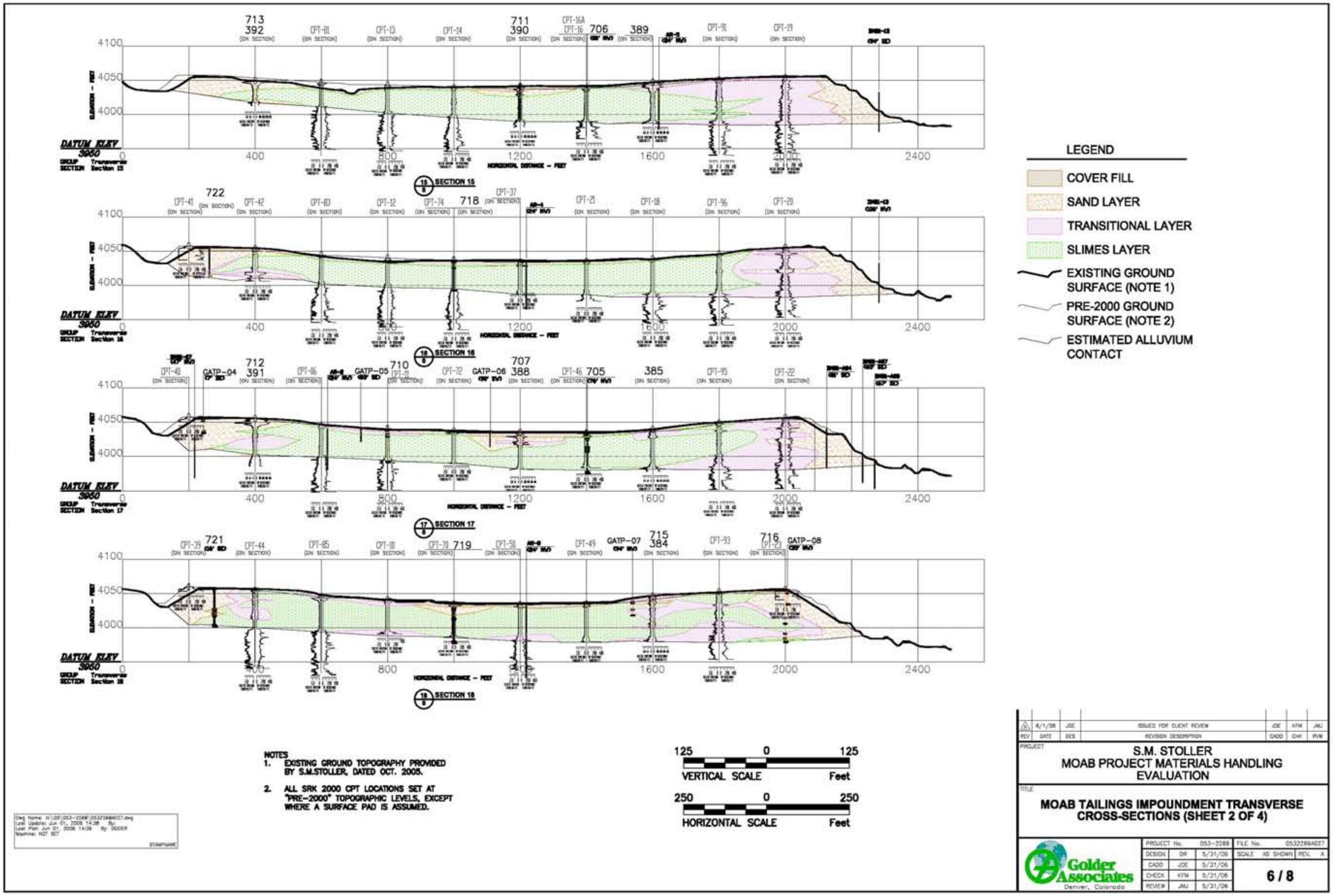
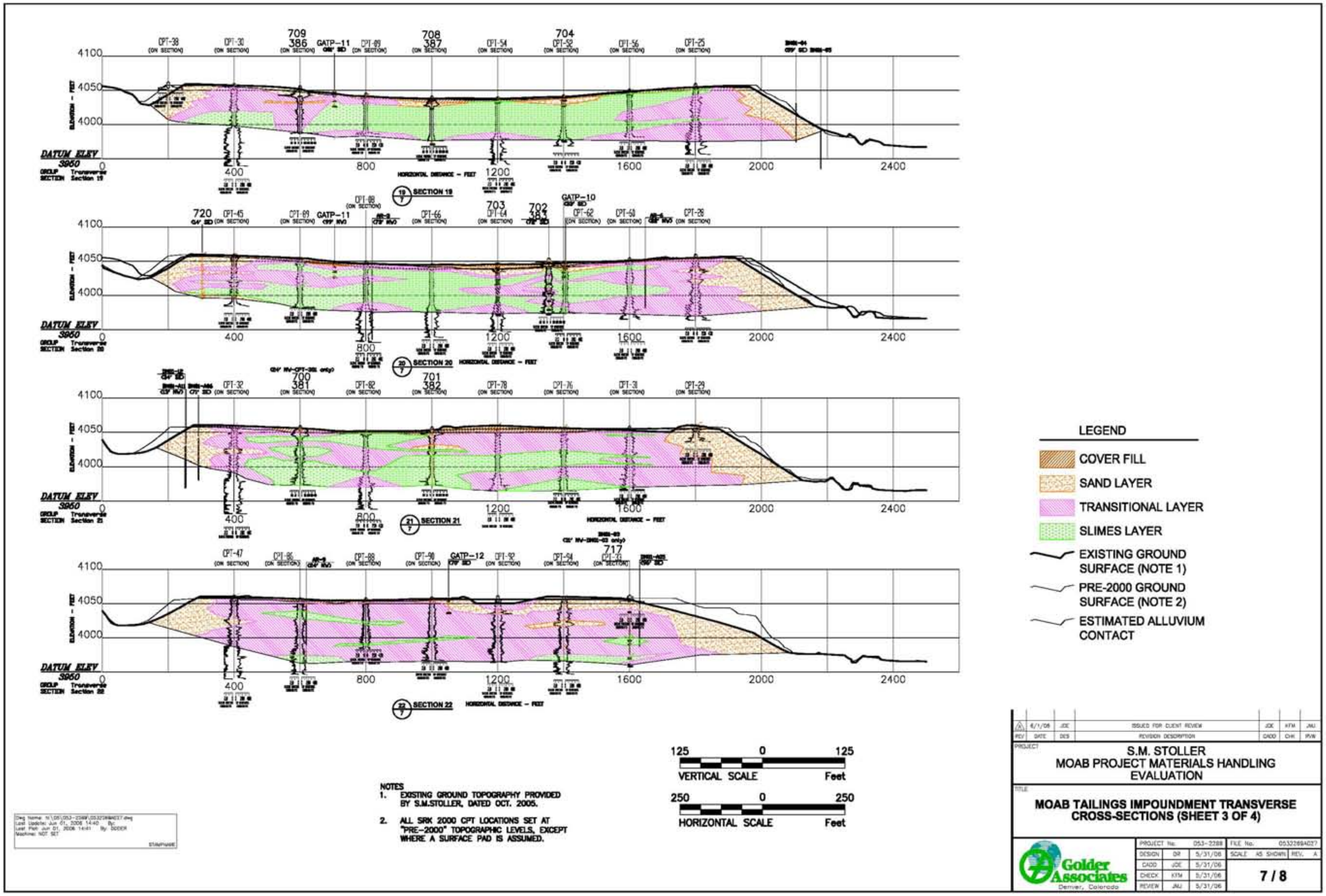


Figure 6. Moab Tailings Impoundment Transverse Cross Sections (Sheet 2 of 4)

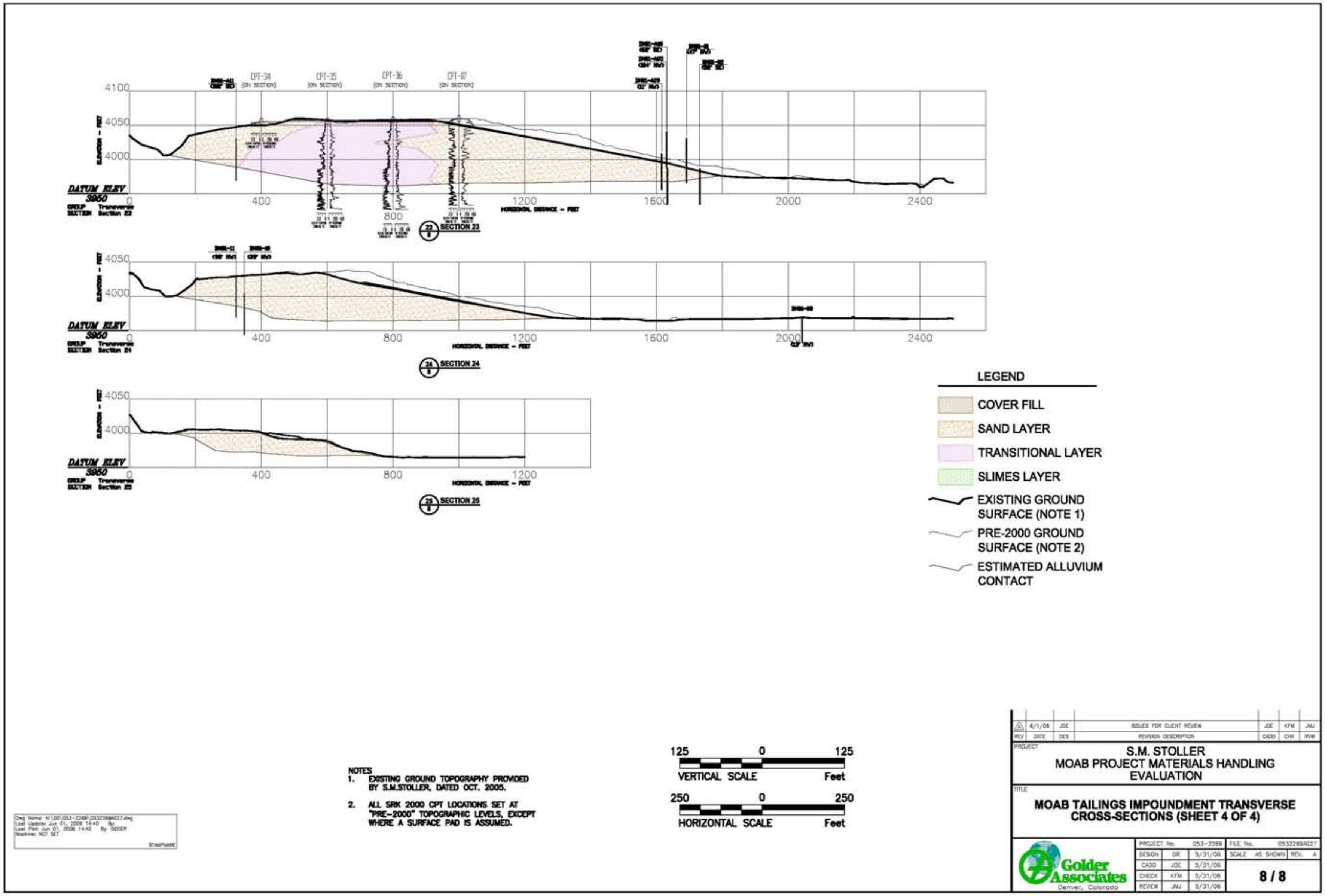


NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

S.M. STOLLER
MOAB PROJECT MATERIALS HANDLING EVALUATION

MOAB TAILINGS IMPOUNDMENT TRANSVERSE CROSS-SECTIONS (SHEET 3 OF 4)

Figure 7. Moab Tailings Impoundment Transverse Cross Sections (Sheet 3 of 4)



NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

Figure 8. Moab Tailings Impoundment Transverse Cross Sections (Sheet 4 of 4)

Conclusion and Recommendations:

- The total volume of tailings and cover soils requiring removal is approximately 10.3 to 10.4 million yd^3. This volume includes no allowance for excavation of contaminated alluvial soils at the base of the tailings pile.
- Volume estimates of the individual constituents were made by developing lateral and transverse cross-sections through the impoundment. The total volumes compare well for the two sets of calculations.

Computer Source:

Not applicable.

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-5-03-00 **Discipline:** Geotechnical **No. of Sheets:** 6
Doc. No.: X0181000

Location: Attachment 1, Appendix J

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Weight / Volume Calculation for the Moab Tailings Pile

Sources of Data:

Laboratory test data summaries listed below.

Test data from March 2006 bench scale testing on cover soils and uranium mill tailings.

Remedial Action Plan (RAP) calculations as referenced in the text.

Sources of Formulae and References:

D&M (Dames & Moore), 1981. *Additions to Tailings Pond-Embankment System, Moab, Utah*, Report of Engineering Design Study for Atlas Minerals, Salt Lake City, Utah, May 26.

D&M (Dames & Moore), 1984. Proposed 10-foot Tailings Embankment Raise, Moab, Utah, Report of Additional Geotechnical Work as Requested by the NRC, for Atlas Minerals, Salt Lake City, Utah, September 25.

Golder (Golder Associates, Inc.), 2005a. *Materials Handling Evaluation Study for the Moab Tailings Impoundment, Moab, Utah*, Report to S.M. Stoller, Lakewood, Colorado, September 21.

Golder (Golder Associates, Inc.), 2005b. "Results of Bench Scale Testing Program on Cover Soils and Uranium Mill Tailings from the Moab Tailings Impoundment, Grand County, Utah," Draft Technical Memorandum, Lakewood, Colorado, April 3.

SRK (Steffen, Robertson, and Kirsten), 2000. *Dewatering Options for Placement of Cover, Moab Tailings Impoundment*, Prepared for Moab Mill Reclamation Trust, Lakewood, Colorado, June.

Preliminary Calc ☐ **Final Calc.** ☒ **Supersedes Calc No.**

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5/30/07
Name Date
Greg Smith 5/31/07
Name Date
May 31, 07
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Approved by: John E Elmer 5/31/07
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No text for this page

Problem Statement:

Estimate the total weight and relocated volume of tailings and associated fill materials requiring removal and re-location from the Moab Tailings Impoundment, including an estimate of the various material types (i.e., cover fill, sands, transitional tailings, and slimes).

Method of Solution:

1. Determine the average in-place wet density and in-place moisture content for each material type based on data from earlier studies plus recent lab test data (D&M 1981, D&M 1984, SRK 2000, and Golder 2005b).

2. Determine the average Standard Proctor maximum dry density and optimum moisture content for each material type based on the bench-scale Standard Proctor test results.

3. Revise and update a working draft spreadsheet sent by Greg Lord of S.M. Stoller Corp. to calculate the following:
    - In-place total weight.
    - In-place water weight.
    - Solids weight.
    - Final water weight.
    - Final total weight.
    - Final wet density.
    - Final volume.

Assumptions:

Material to be placed and compacted in the Crescent Junction Disposal Cell at 90 percent of the Standard Proctor maximum dry density at the optimum water content for each material type, based on prior UMTRA experience.

Calculation:

Table 1 shows the resulting spreadsheet. Input data are located in columns 1, 2, 3, 7, and 10. Calculations are performed in columns 4, 5, 6, 8, 9, 11, and 12. The input data and calculations are discussed on a column-by-column basis below. Note that initial input values are wet densities.

- Column 1. The in-place volumes are calculated as the average of the volumes determined using the lateral and transverse cross-sections in the “Volume Calculation for the Moab Tailings Pile” calculation (RAP Attachment 1, Appendix I).
- Column 2. The in-place wet densities were calculated as the average of all wet density lab test data from recent lab tests performed by Shaw, E & I, Inc. These lab results were separated by material type before being averaged. This same method was used to average older lab test data, the results of which were compared to the more recent averages. The numbers used in Table 1 are slightly conservative estimates based on the most recent lab test data.
- Column 3. The in-place moisture contents were calculated in the same manner as the in-place densities in Column 2.
- Column 4. The in-place total weight was calculated by multiplying the in-place volume (1) with the in-place wet density (2).
- Column 5. The in-place water weight was calculated using the following two equations: $w = W_w/W_s$, and $W_t = W_s + W_w$. Where w is the moisture content, W_w is the weight of water, W_s is the weight of solids, and W_t is the total weight. Combining these equations, W_w can be solved for knowing w (3) and W_t (4).

- Column 6. The solids weight is calculated as the total weight less the water weight.
- Column 7. The final moisture content was assumed to be equal to the average optimum moisture content determined through the Standard Proctor tests, based on a limited number of Proctor density tests.
- Column 8. The final water weight is calculated as the solids weight multiplied by the final moisture content, as per the definition of moisture content.
- Column 9. The final total weight is calculated as the solids weight added to the final water weight.
- Column 10. The final wet density was calculated by first averaging the maximum dry density (MDD) results for each material type from the Standard Proctor tests. The assumption was then made that the material would be placed at 90 percent of the MDD, based on prior UMTRA projects. Lastly, 90 percent of the MDD was converted to a wet density using the final moisture content ($\gamma wet=0.9*MDD*(1+w)$).
- Column 11. The final volume is calculated by dividing the final total weight (9) by the final wet density (10).
- Column 12. The volume change is calculated by subtracting the in-place volume (1) from the final volume (11). A positive number in Column 12 indicates volume expansion, and a negative number indicates volume compression.
- Conversions Used:
    a. 1 cubic yard (yd^3) = 27 cubic feet (ft^3)
    b. 1 ton = 2,000 lbs

Discussion:

The input properties for the off-pile material, vicinity property, and subpile material were not calculated by Golder. With the exception of the in-place wet densities for these materials, the numbers in Table 1 were left unchanged from the original spreadsheet received from Stoller on June 6, 2006. The in-place wet densities were changed, as they previously appeared to represent the dry densities of these materials. All other input values for these materials appear to be reasonable based on available information.

The total in-place wet weight of the cover, sand tailings, transitional tailings, and slimes tailings is 15.8 million tons, and the equivalent dry weight of solids is 12.5 million tons. These values are slightly lower than predicted previously (Golder 2005a) (see also the “Volume Calculation for the Moab Tailings Pile” calculation, RAP Attachment 1, Appendix I) when the wet weight was estimated as 16.6 million tons and the equivalent dry weight as 13.2 million tons.

The final volume is nearly 600,000 yd^3 less than the in-place volume, indicating a net reduction in volume of material. This reduction can be attributed to a denser state following compaction, assuming sufficient water loss to achieve compactable moisture contents.

Conclusion and Recommendations:

- The total wet weight of tailings material plus interim cover soils is estimated to be 15.8 million tons. In place, this material occupies 10.3 million yd^3. When dried or wetted to the optimum moisture content and compacted, this material will occupy 9.7 million yd^3 of storage space.
- The total wet weight of tailings material and other residual radioactive material (RRM) is estimated to be 18.1 million tons. In-place, this material occupies an estimated 11.9 million yd^3. When dried or wetted to the optimum moisture content and compacted, this material will occupy 11.2 million yd^3 of storage space.

Computer Source:

Not applicable.

Table 1. Volume and Weight Calculations Per Material Type

Material	1	2	3	4	5	6	7	8	9	10	11	12
	In-Place Volume (yd^3)	**In-Place Wet Density (pcf)**	**In-Place Moisture Content**	**In-Place Total Weight (tons)**	**In-Place Water Weight (tons)**	**Solids Weight (tons)**	**Final Moisture Content**	**Final Water Weight (tons)**	**Final Total Weight (tons)**	**Final Wet Density (pcf)**	**Final Volume (yd^3)**	**Volume Change (yd^3)**
Tailings Material												
Sand Tailings	2,798,384	109	10%	4,117,821	374,347	3,743,474	14.3%	535,317	4,278,791	109	2,903,606	105,222
Transitional Tailings	3,916,789	115	25%	6,080,814	1,216,163	4,864,651	17.5%	851,314	5,715,965	115	3,676,985	–239,803
Slimes Tailings	3,176,326	114	50%	4,888,366	1,629,455	3,258,910	25.0%	814,728	4,073,638	111	2,712,368	–463,958
Subtotal	**9,891,498**			**15,087,001**	**3,219,965**	**11,867,036**		**2,201,358**	**14,068,394**		**9,292,959**	**–598,539**
Other RRM Material												
Interim Cover	452,800	109	9%	666,295	55,015	611,280	12.9%	78,855	690,135	115	443,053	–9,747
Off-Pile Material	700,000	105	9%	992,250	81,929	910,321	11.0%	100,135	1,010,456	113	659,796	–40,204
Vicinity Property	120,000	105	9%	170,100	14,045	156,055	11.0%	17,166	173,221	113	113,108	–6,892
Subpile Material	774,000	115	20%	1,201,635	200,273	1,001,363	12.0%	120,164	1,121,526	114	725,783	–48,217
Subtotal	**2,046,800**			**3,030,280**	**351,262**	**2,679,019**		**316,320**	**2,995,339**		**1,941,740**	**–105,060**
Total				18,117,281	3,571,227	14,546,054		2,517,678	17,063,733		11,234,699	–703,599

Notes:
Column 1 - In-Place Volume calculated as average of lateral and transverse method results
Column 2 - In-Place Wet Density calculated as average of lab test results per material type, conservative rounding
Column 3 - In-Place Moisture Content calculated as average of lab test results per material type
Column 4 - In-Place Total Weight calculated as In-Place Wet Density (2) times In-Place Volume (1) with appropriate unit conversion factors
Column 5 - In-Place Water Weight calculated as [(4) x (3)] / [1-(3)] (Das 1998, page 40)
Column 6 - Solids Weight calculated as Total Weight (4) less Water Weight (5)
Column 7 - Final Moisture Content calculated as average optimum moisture contents determined via Proctor tests conducted on bench-scale tests
Column 8 - Final Water Weight calculated as Solids Weight (6) times Final Moisture Content (7)
Column 9 - Final Total Weight calculated as Solids Weight (6) plus Final Water Weight (8)
Column 10 - Final Wet Density calculated as 90 percent of maximum dry density determined via Proctor tests, converted to wet density by multiplying by (1+w)
Column 11 - Final Volume calculated as Final Total Weight (9) divided by Final Wet Density (10) with appropriate unit conversion factors
Column 12 - Volume Change calculated as Final Volume (11) less In-Place Volume (1) (Positive numbers in this column indicate volume expansion)

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U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-01-08-2006-5-14-00 **Discipline:** Engineering **No. of Sheets:** 6
Doc. No.: X0187200

Location: Attachment 1, Appendix K

Project: Moab UMTRA Project

Site: Moab Tailings Pile

Feature: Average Radium-226 Concentrations for the Moab Tailings Pile

Sources of Data:

Oak Ridge National Lab, 1997. Limited Ground Water Investigation, December.

Remedial Action Plan (RAP) calculations as referenced in the text.

Stoller (SM Stoller Corporation), 2003. *Determination of Subpile Soil Concentrations*, GJO-MOA 19.1.2, January.

Stoller (SM Stoller Corporation), 2005. *Soil Sample Catalogue, Information for Shipping Soil Samples*, November.

SRK (Steffen, Robertson, and Kirsten), 2000. *Dewatering Options for Placement of Cover*, June.

Sources of Formulae and References:

None.

Information was statistically evaluated using Microsoft Excel.

Data on samples below the removal criteria from the *Determination of Subpile Soil Concentrations* were not used, since this material is below the pile and below the removal concentrations.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Name 5/30/07 Date

Checked by: Name Date

Approved by: Name 5/31/07 Date

Name Date

Name Date

May 31, 07
Name Date

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Problem Statement:

Evaluate the available radium-226 data to determine an average radium-226 concentration for the material that will be disposed of in the Crescent Junction Disposal Cell.

Method of Solution:

Review published literature and maps of radium-226 concentration at the Moab tailings pile.

Assumptions:

Literature sources are reliable and there is sufficient data, as well as geospatial variability, that the data is statistically suitable.

Calculation:

The data was averaged both on a volumetric-weighted basis and as a straight average. The straight average was determined to be the most conservative and is used in the “Radon Barrier Design Remedial Action Plan” calculation (RAP Attachment 1, Appendix B).

Discussion:

Although the data was acquired at different times by different groups and, in some cases, for different purposes, there is sufficient geospatial variability, both vertically and horizontally, to create a valid representative sampling.

Samples were obtained by Oak Ridge National Lab as part of a ground water modeling task; by Stoller as part of a task to determine the quantity of subpile soils requiring removal; by Steffen, Robertson, and Kirsten as part of a pile characterization task; and by Stoller to characterize samples for shipment.

Conclusion and Recommendations:

Based on the results of the averages, 707 pCi/g is the average radium-226 value to be used in the “Radon Barrier Design Remedial Action Plan” calculation (RAP Attachment 1, Appendix B)

Computer Source:

Not applicable.

Table 1. Moab Project, Crescent Junction Disposal Cell Tailings, and Other Contaminated Materials

Sample	Depth	Ra-226 Activity (pCi/g)	Material	Sample	Depth	Ra-226 Activity (pCi/g)	Material
BH-701	0-20	400.9	trans	PB-2	34-36	782	slime
BH-701	20-40	480.8	trans	PB-2	54-56	2070	slime
BH-703	0-20	457.6	trans	437	40.75-41	2194.9	slime
BH-703	20-40	610.1	trans	438	72.75-73	1891.7	slime
BH-705	20-40	616.9	trans	439	82-82.25	2157.5	slime
BH-709	20-40	546.6	trans	AR-10	75-86	588.8	slime
BH-713	20-36.5	631.1	trans	BH-700	30-60	466.5	slime
BH-715	20-40	278.9	trans	BH-701	40-60	758.9	slime
BH-718	0-20	717.8	trans	BH-701	60-80	1215.8	slime
BH-718	20-40	917.3	trans	BH-703	40-60	1396.3	slime
BH-719	0-20	357.4	trans	BH-703	65-73	1333	slime
PB-1	39-41	335	trans	BH-705	40-60	1232.8	slime
PB-1	44-46	464	trans	BH-709	40-60	1195.3	slime
PB-1	49-51	566	trans	BH-709	60-65	1205.8	slime
PB-1	64-66	418	trans	BH-715	0-20	1000.5	slime
PB-1	74-76	605	trans	BH-715	40-60	1225.9	slime
PB-1	76-81	220	trans	BH-715	60+	1518.6	slime
PB-1	81-83	201	trans	BH-718	40-43	1601.7	slime
PB-2	9-11	803	trans	BH-719	20-40	1117.7	slime
PB-2	29-31	192	trans	BH-719	40-51.5	1669.7	slime
PB-2	39-41	325	trans	PB-1	59-61	236	slime
PB-2	49-51	816	trans	PB-1	69-71	748	slime
PB-2	59-61	781	trans	PB-1	83-85	1600	slime
PB-2	61-66	711	trans	PB-1	85-87	2040	slime
PB-2	69-71	614	trans	PB-1	87-89	1640	slime
AR-4S	20-21	530.6	unconsol	PB-1	89-91	1690	slime
AR-8	21-22	594.8	unconsol	PB-2	44-46	1740	slime
AR-8	25-35	639.9	unconsol	PB-2	71-73	1390	slime
Impound 2	imp	12.7	imp	PB-2	73-75	1280	slime
Impound 3	imp	87.4	imp	PB-2	75-77	1130	slime
AR-10	3-4	311.8	sand	PB-2	77-79	1240	slime
AR-10	20-25	98	sand	PB-2	79-81	1550	slime
AR-6	35-40	100.4	sand	PB-2	84-86	1620	slime
AR-9	10-11	320.2	sand	437	44-44.25	135.5	alluvium
AR-9	30-32	87.2	sand	438	74-74.25	134.3	alluvium
BH-705	0-20	186.2	sand	438	75-75.25	92.8	alluvium
BH-709	0-20	289.9	sand	438	76-76.25	31.3	alluvium
PB-1	9-11	215	sand	438	78-78.25	118.4	alluvium
PB-1	14-16	99.7	sand	439	87-87.25	23.9	alluvium
PB-1	19-21	202	sand	AR-5	0-1	84.3	alluvium
PB-1	24-26	148	sand	AR-6	0-1	17.3	alluvium
PB-1	29-31	153	sand	PB-1	94-96	208	alluvium
PB-1	34-36	447	sand	PB-2	89-91	1.83	alluvium
PB-1	54-56	849	sand				

Sample	Depth	Ra-226 Activity (pCi/g)	Material	Sample	Depth	Ra-226 Activity (pCi/g)	Material
PB-2	14-16	269	sand				
PB-2	19-21	150	sand				
PB-2	24-26	100	sand				
AR-2	5.5-10	786.5	silt				
AR-7	20-25	562.2	silt				
AR-9	50-55	543.6	silt				
AR-9	60-62	239.1	silt				

Measurements	All Data	Sands	Transitional Tailings	Slimes	Subpile & Interim Cover Materials (Alluvium)	Average of All Samples Without Weighting
Max:	2,195	849	917	2,195	208	
Min:	2	13	192	236	2	
Average:	697	**272**	**530**	**1,349**	**85**	
Median:	564	202	556	1,333	89	
Std Dev.:	589	224	195	479	66	
Count:	94	23	28	33	10	
Material Dry Weight (tons)	14,546,054	3,743,474	4,864,651	3,258,910	2,679,019	
Dry Weight %:	100%	26%	33%	22%	18%	
Weighted Activity (pCi/g)	565	70	177	302	16	707

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