TETRA TECH

Technical Memorandum

To:	Daniel Roth – M3
Cc:	Jamie Joggerst – Tt
From:	Joel Carrasco
Doc #:	057/09-320807-5.3
Subject:	**Rosemont Copper Project Design Storm and Precipitation Data/Design Criteria**
Date:	April 7, 2009

1.0 Introduction

This memo was developed in order to solidify various design criteria for use at the Rosemont Copper Project (Project) site by various consulting groups. The goal of this analysis was to review information generated from various weather stations and select appropriate precipitation and pan evaporation data applicable to the Project site. Baseline information provided in Tetra Tech's Stormwater Management Plan (2007) was supplemented with updated weather station information. Hydraulic design parameters needed to update the site-wide stormwater management plan is required as a supplement to this memorandum.

2.0 Precipitation and Pan Evaporation

Meteorological records for the immediate vicinity of the Rosemont Project site are of limited use for selecting appropriate precipitation and pan evaporation data. A meteorological station was installed at the Rosemont site in early-2006 to record precipitation. Pan evaporation was added to this station in mid-2008. The station is located at the center of the proposed open pit at an elevation of 5,350 feet above mean sea level (amsl).

Weather stations located within an approximate 30 mile radius of the Project site are shown on Figure 1 and listed in Table 2.1.

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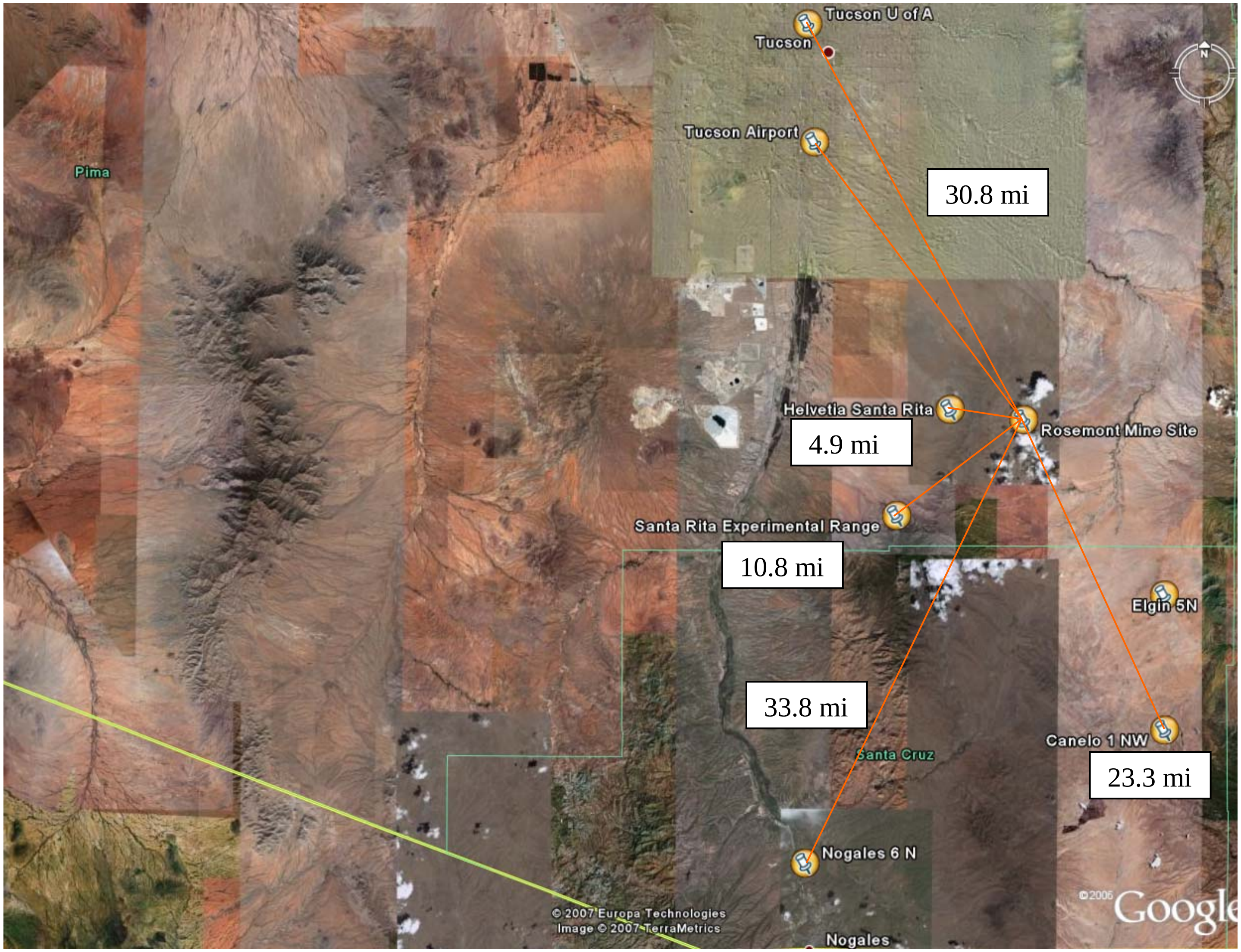


Figure 1: Meteorology Station Locations

Table 2.1: Station Summary

Name	ID No.	Latitude	Longitude	Elevation (feet amsl)	Period of Record
Canelo 1 NW	021231	31^0 33’	110^0 32’	5,010	1910 – 2007
Helvetia	023981	31^0 52’	110^0 47’	4,300	1916 – 1950
Santa Rita	027593	31^0 46’	110^0 51’	4,300	1950 – 2005
Tucson U of A	028815	32^0 15’	110^0 57’	2,440	1894 – 2007
Nogales 6 N	025924	31^0 25’	110^0 57’	3,560	1952 – 2007

Note: The on-site Rosemont weather station is at 5,350’ amsl.
The Santa Rita station has inconsistent readings from 2006-2007; therefore these years were not used in any analysis.

Canelo is located about 23 miles to the southeast of the Project site at an elevation of 5,010 feet amsl. Helvetia is located 5 miles to the west at an elevation of 4,300 feet amsl. The Santa Rita Experimental Range, located about 11 miles to the southwest of the site, is at 4,300 feet amsl. The Tucson U of A station is located about 31 miles to the north at an elevation of 2,440 feet amsl, and Nogales 6 N, located about 34 miles southeast, is at an elevation of 3,560 feet amsl.

The annual average precipitation for the Rosemont area, estimated by Sellers (University of Arizona, 1977) for the period 1931 through 1970, was approximately 16 inches. Based on records available from the Western Regional Climate Center (WRCC, 2006), the average annual precipitation for Helvetia for the period 1916 through 1950 was 19.72 inches.

For comparison with more recent information, the average annual precipitation recorded at the Santa Rita Experimental Range station for the period from 1971 through 2005 was 22.19 inches. Average annual precipitation for Canelo for the period 1971 through 2007 was 18.10 inches. Average annual precipitation for the Tucson U of A station for the period from 1894 through 2007 was 11.13 inches, and the average annual precipitation for Nogales 6 N for the period from 1952 through 2007 was 17.37 inches (WRCC, 2006).

Precipitation and evaporation summary data for the five (5) off-site stations shown in Figure 1 are summarized in Tables 2.2 and 2.3, respectively.

Table 2.2: Average Monthly Total Precipitation Summary (in)

Month	Tucson U of A (1894-2007)	Nogales (1952-2007)	Canelo 1 NW (1910-2007)	Helvetia (1916-1950)	Santa Rita Experimental Range (1950-2005)
JAN	0.88	1.10	1.22	1.58	1.63
FEB	0.83	0.85	1.17	1.72	1.46
MAR	0.76	0.90	0.93	1.14	1.48
APR	0.39	0.39	0.45	0.52	0.69
MAY	0.18	0.22	0.20	0.28	0.24
JUNE	0.26	0.47	0.72	0.67	0.62
JULY	2.06	4.34	4.41	4.05	4.87
AUG	2.15	4.13	4.04	4.15	4.32
SEPT	1.15	1.55	1.70	2.19	2.15
OCT	0.74	1.33	1.03	0.68	1.62
NOV	0.77	0.66	0.84	1.22	1.15
DEC	0.96	1.43	1.39	1.52	1.96
TOTAL	**11.13**	**17.37**	**18.10**	**19.72**	**22.19**

Note: Average over recorded history.

Only two of the stations, U of A and Nogales, recorded pan evaporation data over an extended period of time. This data is shown in Table 2.2.

Table 2.3: Average Monthly Pan Evaporation Summary (in)

Month	Tucson U of A (1894-2007)	Nogales (1952-2007)
JAN	3.25	3.59
FEB	4.57	4.46
MAR	6.95	7.01
APR	9.88	9.35
MAY	12.87	11.91
JUNE	14.91	13.31
JULY	13.17	10.00
AUG	11.65	8.28
SEPT	10.35	8.06
OCT	7.81	7.17
NOV	4.73	4.49
DEC	3.37	3.57
TOTAL	**103.51**	**91.20**

Note: U of A Station is at 2,440' amsl.
Nogales Station is at 3,560' amsl.
Rosemont Station is at 5,350' amsl.

As indicated, Rosemont Copper installed an on-site monitoring station that began recording meteorological data in April 2006. This station is monitored by Applied Environmental Consultants (AEC), and the monitoring program includes data processing and instrument audits, calibrations, and maintenance. Measurements of pan evaporation were added at the Rosemont Weather Station in June 2008. However, they were not included in any analysis due to the short period of recorded data.

The Rosemont meteorological monitoring site is located at the center of the proposed open pit at an elevation of 5,350 feet amsl. Table 2.4 summarizes the average monthly precipitation for the data recorded over the last two (2) years (April 2006 through September 2008). Detailed precipitation information, as needed, can be found on the quarterly reports provided by AEC. Data is recorded daily and provided to Rosemont on a quarterly basis.

Table 2.4: Average Monthly Precipitation Summary (in)

Month	Rosemont Station (2006-2008)
JAN	0.59
FEB	0.79
MAR	0.45
APR	0.45
MAY	0.51
JUNE	0.98
JULY	5.51
AUG	3.74
SEPT	1.62
OCT	0.24
NOV	1.11
DEC	1.16
TOTAL	**17.12**

Note: Rosemont Station is at 5,350' amsl.

3.0 Climatology

Rainfall totals for various rainfall events were taken from the online National Oceanic and Atmospheric Administration (NOAA) site. The methods used to determine the temporal distribution of the various rainfall events are discussed in Appendix A1 of Atlas 14 (NOAA, 2004). Arizona lies in the convective precipitation area (Figure A.1.1 from Atlas 14), and 52% of the convective storms have the majority of rainfall occurring in the first quartile (first one and a half hours) of the rainfall event. Figure A.1.9.A from Atlas 14 was used for the temporal distribution. Pertinent climatology data derived from the NOAA Atlas is presented in the Attachment A of this memo.

Table 3.1 presents the flood frequency analysis rainfall depths from the NOAA Atlas, i.e. rainfall depths recommended for the use of the Rosemont Copper Project. The temporal distributions for runoff modeling are derived from the 6-hr temporal distributions compressed into a 1-hr distribution and are summarized in Table 3.2. Attachment A provides backup information from the NOAA Atlas.

Table 3.1: Flood Frequency Storm Precipitation Summary (in)

Event	1-Hour	3-Hour	6-Hour	24-Hour
2-Year	1.42	1.60	1.83	2.21
5-Year	1.85	2.03	2.30	2.75
10-Year	2.16	2.38	2.68	3.18
25-Year	2.57	2.86	3.22	3.77
50-Year	2.87	3.24	3.66	4.23
100-Year	3.17	3.63	4.12	4.75
500-Year	3.84	4.59	5.24	6.00
1000-Year	4.14	5.03	5.76	6.57

Table 3.2: 1-hr Flood Frequency Design Precipitation Hyetographs

% of	% of	Time	Storm Depth (in)				
Duration	Rainfall	(min)	2-Yr	5-Yr	10-Yr	25-Yr	100-Yr
0.0%	0.0%	0	0.00	0.00	0.00	0.00	0.00
8.3%	23.1%	5	0.33	0.43	0.50	0.59	0.73
16.7%	44.8%	10	0.64	0.83	0.97	1.15	1.42
25.0%	65.0%	15	0.92	1.20	1.40	1.67	2.06
33.3%	81.6%	20	1.16	1.51	1.76	2.10	2.59
41.7%	90.1%	25	1.28	1.67	1.95	2.32	2.86
50.0%	93.6%	30	1.33	1.73	2.02	2.41	2.97
58.3%	96.5%	35	1.37	1.79	2.08	2.48	3.06
66.7%	98.6%	40	1.40	1.82	2.13	2.53	3.13
75.0%	99.7%	45	1.42	1.84	2.15	2.56	3.16
83.3%	99.9%	50	1.42	1.85	2.16	2.57	3.17
91.7%	100.0%	55	1.42	1.85	2.16	2.57	3.17
100.0%	100.0%	60	1.42	1.85	2.16	2.57	3.17

Storm depths and temporal distributions illustrated above were based on the latitude and longitude of the Rosemont Project site. These values are applicable to sizing stormwater conveyance channels, etc.

4.0 Results

Data derived from the Nogales weather station was selected to represent the long-term weather conditions at the Rosemont site. In comparison to Rosemont, the total average annual rainfall for the Nogales station is 17.37 inches which is less than a 2% difference (0.25 inches) of the Rosemont station. Although the Nogales station is located at an elevation of 3,560 feet amsl versus 5,350 feet amsl for the Rosemont station, the Nogales station is the closest station to the Rosemont that includes more than 50 years of continuous data for both precipitation and evaporation measurements. Pan evaporation data from the Nogales was adjusted to the Rosemont project site based on a linear trend with the each station's elevation. Table 4.1 summaries the Nogales station meteorological measurements and the projected Rosemont pan evaporation values. This data is recommended where precipitation and pan evaporation data is required, such as infiltration modeling.

Table 4.1: Average Monthly Nogales Station Summary (in)

Month	Precipitation	Pan Evaporation	Rosemont Projected Pan Evaporation
JAN	1.10	3.59	4.13
FEB	0.85	4.46	4.28
MAR	0.90	7.01	7.11
APR	0.39	9.35	8.50
MAY	0.22	11.91	10.38
JUNE	0.47	13.31	10.75
JULY	4.34	10.00	4.93
AUG	4.13	8.28	2.89
SEPT	1.55	8.06	4.40
OCT	1.33	7.17	6.15
NOV	0.66	4.49	4.11
DEC	1.43	3.57	3.89
TOTAL	**17.37**	**91.20**	**71.52**

Note: Nogales Station is at 3,560' amsl.
Rosemont Station is at 5,350' amsl.

5.0 Hydrology Methodology

Rosemont Copper site can be divided into two (2) types of areas for hydrologic purposes. The two (2) types of areas include small watersheds and large watersheds.

One hour storms will be utilized for the peak design flow for sizing of channels. 24-hour storms will be utilized where volume design is required such as pond sizing.

Small Watersheds (5 acres or less):

The Rational Method will be used for estimating peak run-off rates from small watersheds such as building roofs, walkways, parking lots, and other small structures. For volume design requirements, the 24-hour storm should be used.

The Peak Flow Rate can be estimated using:

$$Q = CIA$$

Q = Flow rate, ft^3/s
C = Run-off Coefficient
I = Rainfall Intensity, in/hr
A = Area, acres

Large Watersheds (more than 5 acres):

The SCS procedure will be utilized for watershed basins greater than 5 acres. The SCS procedure consists of selecting a design storm and computing direct run-off with the use of curve numbers and numerous soil cover combinations.

Lag Time equation:

$$Lg = \frac{L^{0.8}(S+1)^{0.7}}{1900y^{0.5}}$$

Lg = Lag Time, hrs.
L = Distance of the Longest Watercourse, ft.
Y = Average watercourse slope, %.

$$S = \frac{1000}{CN} - 10$$

Curve Number

The Natural Resource Conservation Service (NRCS) has developed a widely used curve number procedure for estimating run-off. This procedure will be used to estimate the direct runoff for each watershed basin.

Rainfall infiltration losses depend primarily on soil characteristics and land use (surface cover). The NRCS method uses a combination of soil conditions and land use to assign run-off factors known as run-off curve numbers. These represent the run-off potential of an area when the soil is not frozen (i.e. the higher the CN, the higher the run-off potential).

Hydrologic soil data is compiled by the NRCS as part of soil surveys developed for the through the United States. The data used is from the detailed Soil Survey Geographic Database (SSURGO) data set. The hydrologic soil group is an indication of the run-off potential of the soil. Soils are classified A, B, C, D according to run-off potential. 'A' type soils, such as sandy soil, have very low run-off potential. Heavy clay and mucky soils are of type 'D' and have very high run-off potential. Land use areas are tabulated in the SCS TR-55 manual and correspond to specific curve numbers based on soil types. These curve numbers are applicable to average antecedent moisture conditions.

6.0 References

Applied Environmental Consultants Meteorological Data (2007-2008)

NOAA Atlas 14 Vol. 1 Version 4- Precipitation-Frequency Atlas of the United States (NOAA, 2008); http://hdsc.nws.noaa.gov/hdsc/pfds/sa/az_pfds.html

Site Water Management Plan (Tetra Tech, 2007)

U.S. Department of Agriculture, Soil Conservation Service. 1993. National Engineering Handbook, Section 4, Hydrology (NEH-4).

U.S. Soil Conservation Service. Technical Release 55: Urban Hydrology for Small Watersheds. USDA (U.S. Department of Agriculture). June 1986.

Western Regional Climate Center (WRCC, 2008)

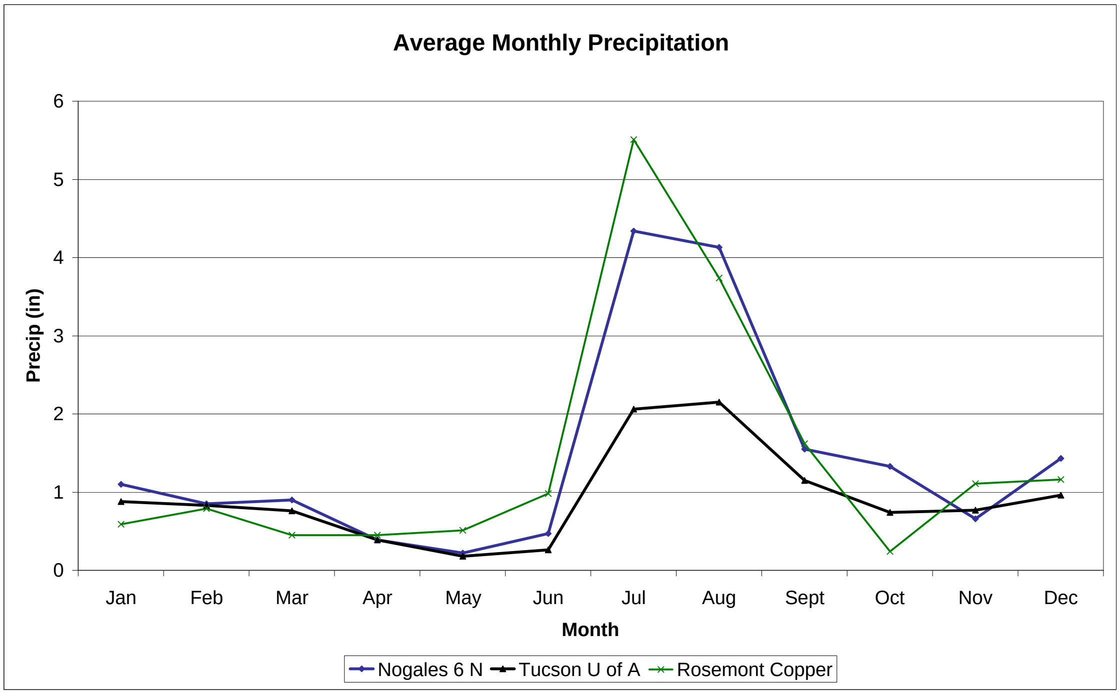
Attachment A

TETRA TECH

CLIENT: Rosemont Copper	
PROJECT: Rosemont Copper Project	JOB NO: 114-320807
SUBJECT: Climatology	BY: J. Carrasco
DETAILS Average Monthly Total Precipitation	Date: 12/19/2008

Total Precipitation(in)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Nogales 6 N	1.1	0.85	0.9	0.39	0.22	0.47	4.34	4.13	1.55	1.33	0.66	1.43	17.37
Tucson U of A	0.88	0.83	0.76	0.39	0.18	0.26	2.06	2.15	1.15	0.74	0.77	0.96	11.13
Rosemont Copper	0.59	0.79	0.45	0.45	0.51	0.98	5.51	3.74	1.62	0.24	1.11	1.16	17.15



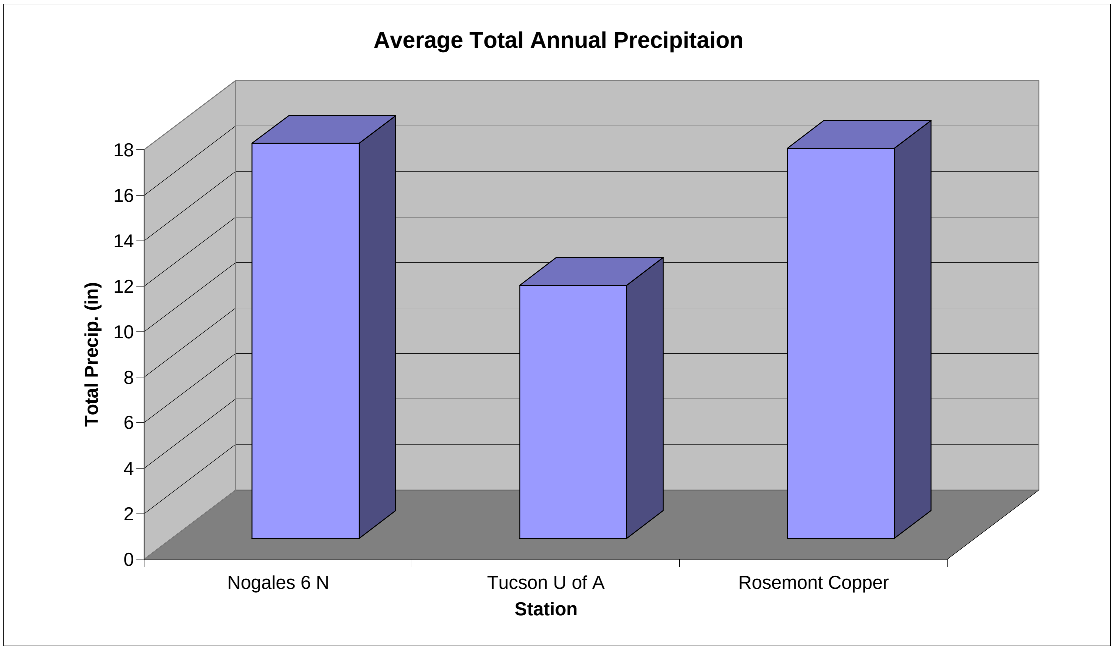
Source: http://www.wrcc.dri.edu/summary/Climsmaz.html

TETRA TECH

CLIENT: Rosemont Copper	
PROJECT: Rosemont Copper Project	JOB NO: 114-320807
SUBJECT: Climatology	BY: J. Carrasco
DETAILS Average Annual Total Precipitation	Date: 12/19/2008

Total Precipitation(in)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Nogales 6 N	1.1	0.85	0.9	0.39	0.22	0.47	4.34	4.13	1.55	1.33	0.66	1.43	17.37
Tucson U of A	0.88	0.83	0.76	0.39	0.18	0.26	2.06	2.15	1.15	0.74	0.77	0.96	11.13
Rosemont Copper	0.59	0.79	0.45	0.45	0.51	0.98	5.51	3.74	1.62	0.24	1.11	1.16	17.15

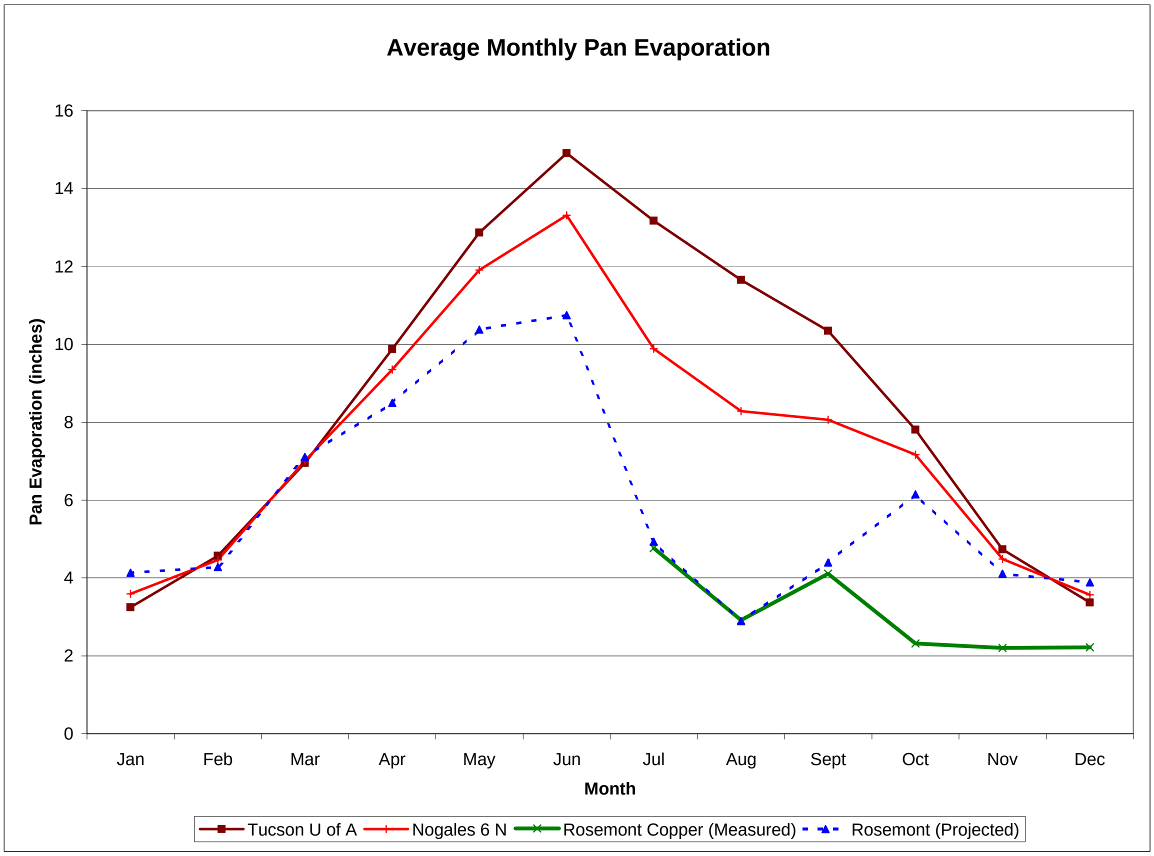


Source: http://www.wrcc.dri.edu/summary/Climsmaz.html

TETRA TECH

CLIENT: Rosemont Copper	
PROJECT: Rosemont Copper Project	JOB NO: 114-320807
SUBJECT: Climatology	BY: J. Carrasco
DETAILS Average Monthly Pan Evaporation	Date: 1/16/2009

	Pan Evaporation(in)													
Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**	**Elevation**
Tucson U of A	3.25	4.57	6.95	9.88	12.87	14.91	13.17	11.65	10.35	7.81	4.73	3.37	103.51	2440
Nogales 6 N	3.59	4.46	7.01	9.35	11.91	13.31	9.89	8.28	8.06	7.17	4.49	3.57	91.09	3560
Rosemont Copper (Measured)							4.77	2.92	4.11	2.32	2.20	2.22	18.53	5350
Rosemont (Projected)	4.13	4.28	7.11	8.5	10.38	10.75	4.93	2.89	4.4	6.15	4.11	3.89	71.52	5350



Source: http://www.wrcc.dri.edu/summary/Climsmaz.html

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Arizona 31.862 N 110.692 W 4429 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 4
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2006

Extracted: Fri Dec 19 2008

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Docs | Return to State Map

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
1	0.35	0.54	0.66	0.89	1.10	1.22	1.27	1.47	1.72	1.77	1.98	2.37	2.84	3.30	4.54	5.76	7.17	8.48
2	0.45	0.69	0.85	1.15	1.42	1.55	1.60	1.83	2.15	2.21	2.47	2.95	3.55	4.13	5.67	7.19	8.95	10.57
5	0.59	0.90	1.11	1.49	1.85	1.99	2.03	2.30	2.68	2.75	3.07	3.69	4.46	5.15	7.01	8.80	10.84	12.78
10	0.69	1.04	1.30	1.75	2.16	2.33	2.38	2.68	3.11	3.18	3.57	4.31	5.20	5.97	8.03	10.02	12.23	14.38
25	0.82	1.24	1.54	2.08	2.57	2.80	2.86	3.22	3.72	3.77	4.26	5.19	6.24	7.09	9.39	11.58	13.97	16.36
50	0.91	1.39	1.72	2.32	2.87	3.16	3.24	3.66	4.20	4.23	4.81	5.90	7.07	7.96	10.42	12.73	15.22	17.77
100	1.01	1.53	1.90	2.56	3.17	3.53	3.63	4.12	4.71	4.75	5.39	6.65	7.94	8.87	11.46	13.86	16.44	19.13
200	1.10	1.68	2.08	2.80	3.46	3.90	4.04	4.59	5.23	5.28	5.99	7.44	8.85	9.81	12.49	14.97	17.61	20.43
500	1.22	1.86	2.31	3.10	3.84	4.40	4.59	5.24	5.94	6.00	6.82	8.55	10.12	11.09	13.86	16.39	19.09	22.06
1000	1.32	2.00	2.48	3.35	4.14	4.79	5.03	5.76	6.50	6.57	7.47	9.45	11.14	12.09	14.90	17.45	20.18	23.25

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

*** 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
1	0.40	0.60	0.75	1.00	1.24	1.37	1.42	1.65	1.92	1.93	2.17	2.60	3.13	3.64	4.97	6.28	7.80	9.22
2	0.51	0.77	0.96	1.29	1.60	1.74	1.79	2.06	2.40	2.42	2.71	3.25	3.92	4.56	6.22	7.85	9.74	11.50
5	0.66	1.00	1.24	1.67	2.07	2.23	2.27	2.58	2.99	3.00	3.37	4.07	4.92	5.68	7.69	9.61	11.81	13.92
10	0.77	1.17	1.45	1.95	2.41	2.60	2.66	3.01	3.47	3.48	3.92	4.74	5.74	6.58	8.82	10.95	13.33	15.67
25	0.91	1.39	1.72	2.31	2.86	3.12	3.19	3.62	4.15	4.19	4.67	5.70	6.90	7.83	10.32	12.68	15.25	17.87
50	1.02	1.55	1.93	2.59	3.21	3.53	3.62	4.12	4.70	4.75	5.29	6.49	7.83	8.80	11.47	13.95	16.66	19.45
100	1.13	1.72	2.14	2.88	3.56	3.96	4.08	4.66	5.30	5.35	5.93	7.33	8.82	9.84	12.64	15.22	18.04	21.00
200	1.24	1.89	2.35	3.16	3.91	4.40	4.57	5.22	5.93	5.99	6.63	8.24	9.87	10.93	13.84	16.48	19.38	22.49
500	1.40	2.12	2.63	3.55	4.39	5.01	5.25	6.03	6.82	6.88	7.60	9.55	11.36	12.43	15.46	18.16	21.12	24.43
1000	1.52	2.32	2.87	3.87	4.79	5.52	5.83	6.70	7.54	7.61	8.38	10.60	12.60	13.64	16.72	19.42	22.44	25.88

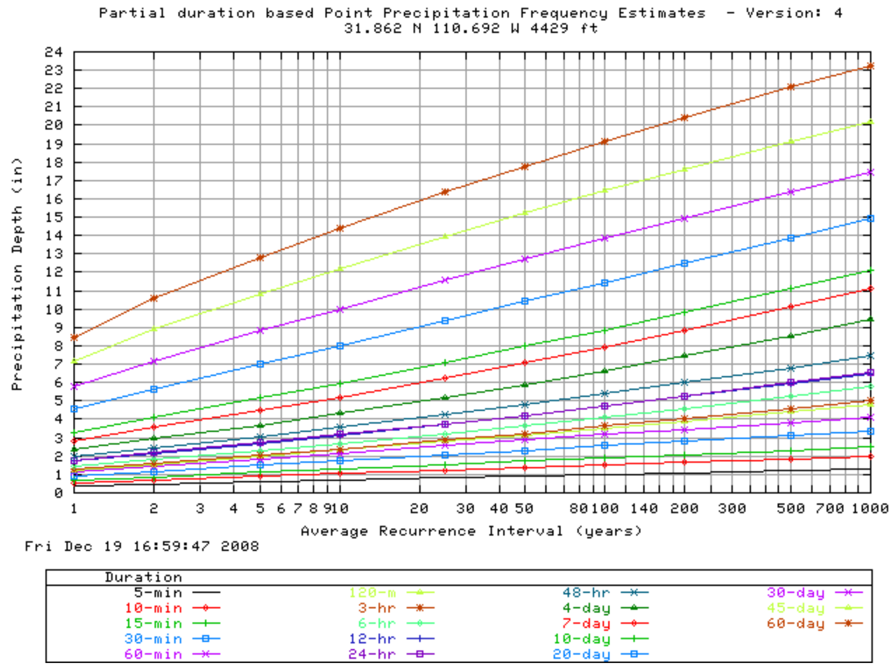
* The **upper** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **greater** than.
** These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document 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
1	0.32	0.48	0.60	0.80	0.99	1.10	1.15	1.31	1.55	1.62	1.82	2.17	2.60	3.02	4.16	5.29	6.61	7.79
2	0.41	0.62	0.77	1.03	1.28	1.40	1.45	1.64	1.93	2.03	2.27	2.71	3.24	3.77	5.20	6.61	8.24	9.71
5	0.52	0.80	0.99	1.33	1.65	1.78	1.83	2.05	2.39	2.52	2.82	3.38	4.06	4.69	6.41	8.07	9.98	11.73
10	0.61	0.93	1.15	1.55	1.92	2.07	2.13	2.38	2.77	2.91	3.27	3.93	4.72	5.42	7.33	9.17	11.24	13.18
25	0.72	1.09	1.36	1.83	2.26	2.47	2.54	2.83	3.28	3.43	3.88	4.69	5.63	6.41	8.54	10.57	12.80	14.95
50	0.80	1.21	1.50	2.02	2.50	2.76	2.83	3.18	3.67	3.82	4.34	5.29	6.34	7.15	9.43	11.58	13.89	16.20
100	0.87	1.32	1.64	2.21	2.74	3.05	3.14	3.52	4.05	4.22	4.83	5.92	7.07	7.91	10.30	12.56	14.93	17.38
200	0.94	1.43	1.77	2.39	2.96	3.32	3.43	3.86	4.43	4.62	5.32	6.56	7.81	8.66	11.15	13.48	15.91	18.47
500	1.02	1.56	1.93	2.60	3.22	3.67	3.81	4.30	4.93	5.14	5.98	7.41	8.79	9.65	12.24	14.63	17.12	19.80
1000	1.08	1.65	2.05	2.76	3.41	3.93	4.09	4.63	5.29	5.54	6.48	8.08	9.56	10.41	13.05	15.46	17.98	20.75

* 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 NOAA Atlas 14 Document for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

Text version of tables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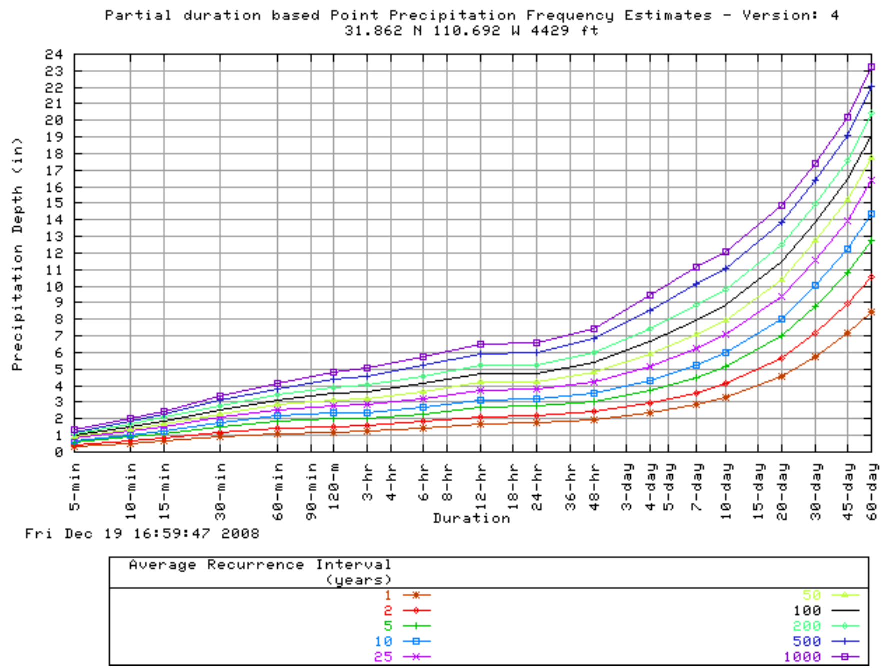
Precipitation Depth (in)
Average Recurrence Interval (years)
Fri Dec 19 16:59:47 2008
Duration
5-min
10-min
15-min
30-min
60-min
120-m
3-hr
6-hr
12-hr
24-hr
48-hr
4-day
7-day
10-day
20-day
30-day
45-day
60-day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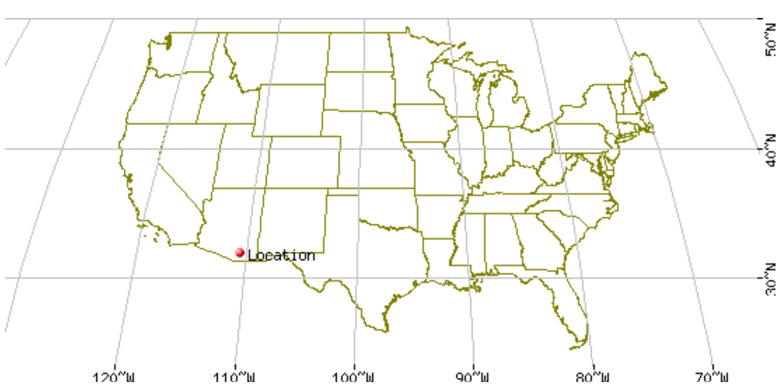
Precipitation Depth (in)
Duration
Fri Dec 19 16:59:47 2008
Average Recurrence Interval (years)
1
2
5
10
25
50
100
200
500
1000

Maps -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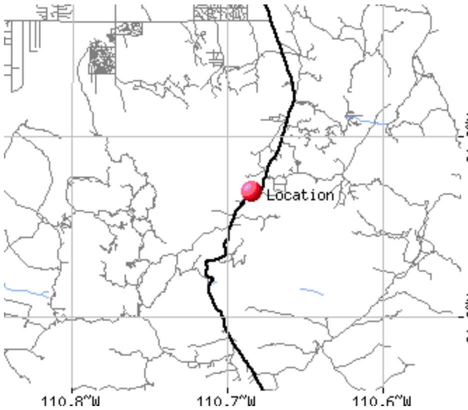
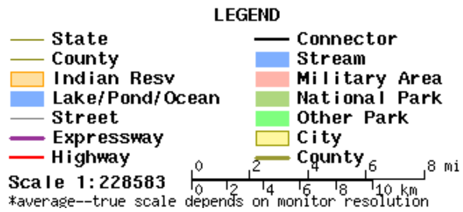
110°W
100°W
90°W
80°W
70°W



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 NOAA Atlas 14 Document.

Using the **National Climatic Data Center's (NCDC)** station search engine, locate other climate stations within:
+/-30 minutes ...OR... +/-1 degree of this location (31.862/-110.692). 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

NOAA Atlas 14

Precipitation-Frequency Atlas of the United States

Volume 1 Version 4.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah)

Geoffrey M. Bonnin, Deborah Martin, Bingzhang Lin, Tye Parzybok, Michael Yekta, David Riley

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Weather Service

Silver Spring, Maryland, 2004
revised 2006

Appendix A.1. Temporal distributions of heavy precipitation associated with NOAA Atlas 14 Volume 1

1. Introduction

Temporal distributions of heavy precipitation are provided for use with precipitation frequency estimates from NOAA Atlas 14 Volume 1 for 6-, 12-, 24- and 96-hour durations covering the semiarid southwestern United States. The temporal distributions are expressed in probabilistic terms as cumulative percentages of precipitation and duration at various percentiles. The starting time of precipitation accumulation was defined in the same fashion as it was for precipitation frequency estimates for consistency.

The project area was divided into two sub-regions based on the seasonality of observed heavy precipitation events. Figure A.1.1 shows the areal divisions for the temporal distribution regions.

Temporal distributions for each duration are presented in Figures A.1.2 and A.1.3. The data were also subdivided into quartiles based on where in the distribution the most precipitation occurred in order to provide more specific information on the varying distributions that were observed. Figures A.1.4 through A.1.11 depict temporal distributions for each quartile for the four durations. Digital data to generate all temporal distribution curves are available at http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_temporal.html. Table A.1.1 lists the number and proportion of cases in each quartile for each duration and region.

2. Methodology. This project largely followed the methodology used by the Illinois State Water Survey (Huff, 1990) except in the definition of the precipitation accumulation. This project computed precipitation accumulations for specific (6-, 12-, 24- and 96-hour) time periods as opposed to single events or storms in order to be consistent with the way duration was defined in the associated precipitation frequency project. As a result, the accumulation cases may contain parts of one, or more than one precipitation event. Accumulation computations were made moving from earlier to later in time resulting in an expected bias towards front loaded distributions when compared with distributions for single storm events.

The General and Convective Precipitation Areas (Figure A.1.1) were established using factors set forth in previous work (Gifford *et al.*, 1967; NOAA, 1989), including the seasonality of maximum precipitation and event types. Maximum events in the General Precipitation Area were dominated by cool season precipitation while maximum events in the Convective Precipitation Area occurred in the warm season.

For every precipitation observing station in the project area that recorded precipitation at least once an hour, the three largest precipitation accumulations were selected for each month in the entire period of record and for each of the four durations. A minimum threshold was applied to make sure only heavier precipitation cases were being captured. The precipitation with an average recurrence interval (ARI) of 2 years at each observing station for each duration was used as the minimum threshold at that station.

A minimum threshold of 25-year ARI was tested. It was found to produce results similar to using a 2-year ARI minimum threshold. The 25-year ARI threshold was rejected because it reduced the number of samples sufficiently to cause concern for the stability of the estimates.

Each of the accumulations was converted into a ratio of the cumulative hourly precipitation to the total precipitation for that duration, and a ratio of the cumulative time to the total time. Thus, the last value of the summation ratios always had a value of 100%. Within the General Area, and separately within the Convective Precipitation Area, the data were combined, cumulative deciles of precipitation were computed at each time step, and then results were plotted to provide the graphs presented in Figures A.1.2 and A.1.3. The data were also separated into categories by the quartile in which the greatest percentage of the total precipitation occurred and the procedure was repeated for each quartile category to produce the graphs shown in Figures A.1.4 through A.1.11. A moving window weighted average smoothing technique was performed on each curve.

3. Interpreting the Results

Figures A.1.2 and A.1.3 present cumulative probability plots of temporal distributions for the 6-, 12-, 24- and 96-hour durations for the General and the Convective Precipitation Areas. Figures A.1.4 through A.1.11 present the same information but for categories based on the quartile of most precipitation. The x-axis is the cumulative percentage of the time period. The y-axis is the cumulative percentage of total precipitation.

The data on the graph represent the average of many events illustrating the cumulative probability of occurrence at 10% increments. For example, the 10% of cases in which precipitation is concentrated closest to the beginning of the time period will have distributions that fall above and to the left of the 10% curve. At the other end of the spectrum, only 10% of cases are likely to have a temporal distribution falling to the right and below the 90% curve. In these latter cases the bulk of the precipitation falls toward the end of the time period. The 50% curve represents the median temporal distribution on each graph.

First-quartile graphs consist of cases where the greatest percentage of the total precipitation fell during the first quarter of the time period, i.e., the first 1.5 hours of a 6-hour period, the first 3 hours of a 12-hour period, etc. The second, third and fourth quartile plots, similarly are for cases where the most precipitation fell in the second, third or fourth quarter of the time period.

The time distributions consistently show a greater spread, and therefore greater variation, between the 10% and 90% probabilities as the duration increases. Longer durations are more likely to have captured more than one event separated by drier periods; however, this has not been objectively tested as the cause of the greater variation at longer durations. The median of the distributions gradually becomes steeper at longer durations. The cases of the Convective Precipitation Area had steeper gradients than the cases of the General Precipitation Area for all durations and quartiles.

The following is an example of how to interpret the results using Figure A.1.8a and Table A.1.1. Of the 1,728 cases in the General Precipitation Area, 630 of them were first-quartile events:

- In 10% of these cases, 50% of the total rainfall (y-axis) fell in the first 1.8 hours of event time (7.5% on the x-axis). By the 12th hour (50% on the x-axis), all of the precipitation (100% on the y-axis) had fallen.
- A median case of this type will drop half of its total rain (50% on the y-axis) in 5.4 hours (22.5% on the x-axis).
- In 90 percent of these events, 50% of the total precipitation fell by 10.2 hours (42.5% on the x-axis).

4. Application of Results

Care should be taken in the use of these data. The data are presented in order to show the range of possibilities and to show that the range can be broad. The data should be used in a way that reflects the goals of the user. For example while all cases represented in the data will preserve volume, there will be a broad range of peak flow that could be computed. In those instances where peak flow is a critical design criterion, users should consider temporal distributions likely to produce higher peaks rather than the 50^{th} percentile or median cases, for example. In addition, users should consider whether using results from one of the quartiles rather than from the "all cases" sample might achieve more appropriate results for their situation.

5. Summary and General Findings

The results presented here can be used for determining temporal distributions of heavy precipitation at particular durations and amounts and at particular levels of probability. The results are designed for use with precipitation frequency estimates and may not be the same as the temporal distributions of single storms or single precipitation events. A majority of the cases analyzed were first-quartile cases regardless of precipitation area or duration (Table A.1.1). Fewer and fewer cases fell into each of the subsequent quartile categories with the fourth quartile containing the fewest number of cases. The time distributions show a greater spread between the percentiles with increasing duration. The median of the distributions becomes steeper with increasing duration. Overall, the Convective Precipitation Area distributions showed a steeper gradient and therefore depicted more initially intense precipitation than the General Precipitation Area distributions regardless of duration.

Table A.1.1. Numbers and proportion of cases in each quartile for each duration and temporal distribution region associated with NOAA Atlas 14 Volume 1.

Convective Precipitation Area					
	1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**Total number of cases**
6-hour	1679 (52%)	744 (23%)	509 (16%)	284 (9%)	3216
12-hour	1753 (51%)	769 (22%)	567 (17%)	354 (10%)	3443
24-hour	1751 (50%)	645 (19%)	571 (17%)	492 (14%)	3459
96-hour	1952 (63%)	707 (19%)	530 (14%)	527 (14%)	3716

General Precipitation Area					
	1st Quartile	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	**Total number of cases**
6-hour	669 (36%)	471 (26%)	468 (25%)	243 (13%)	1851
12-hour	596 (33%)	465 (26%)	469 (26%)	277 (15%)	1807
24-hour	630 (36%)	442 (26%)	380 (22%)	276 (16%)	1728
96-hour	841 (46%)	376 (21%)	292 (16%)	320 (17%)	1829

Figure A.1.1. Regional division for temporal distributions associated with NOAA Atlas 14 Volume 1.

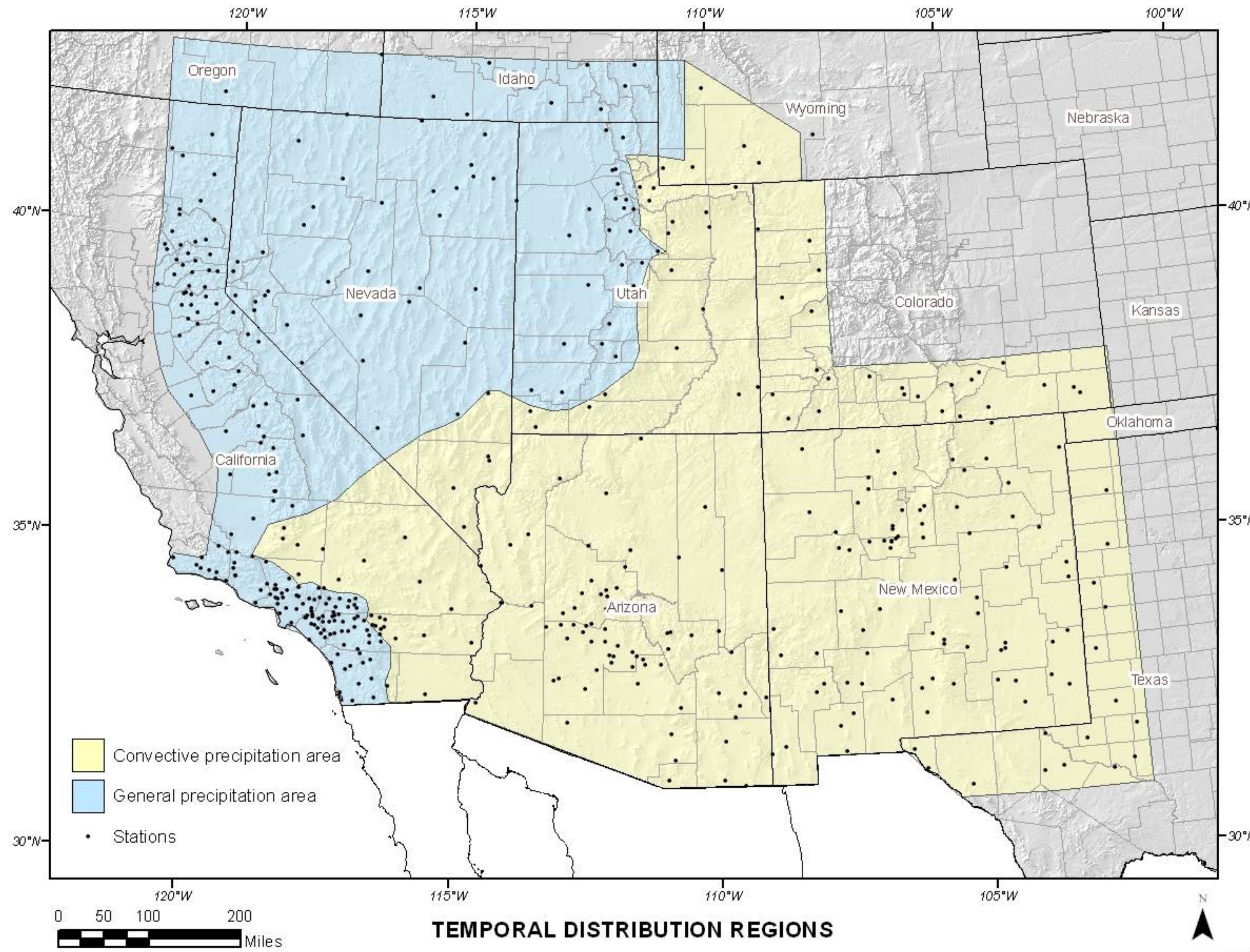
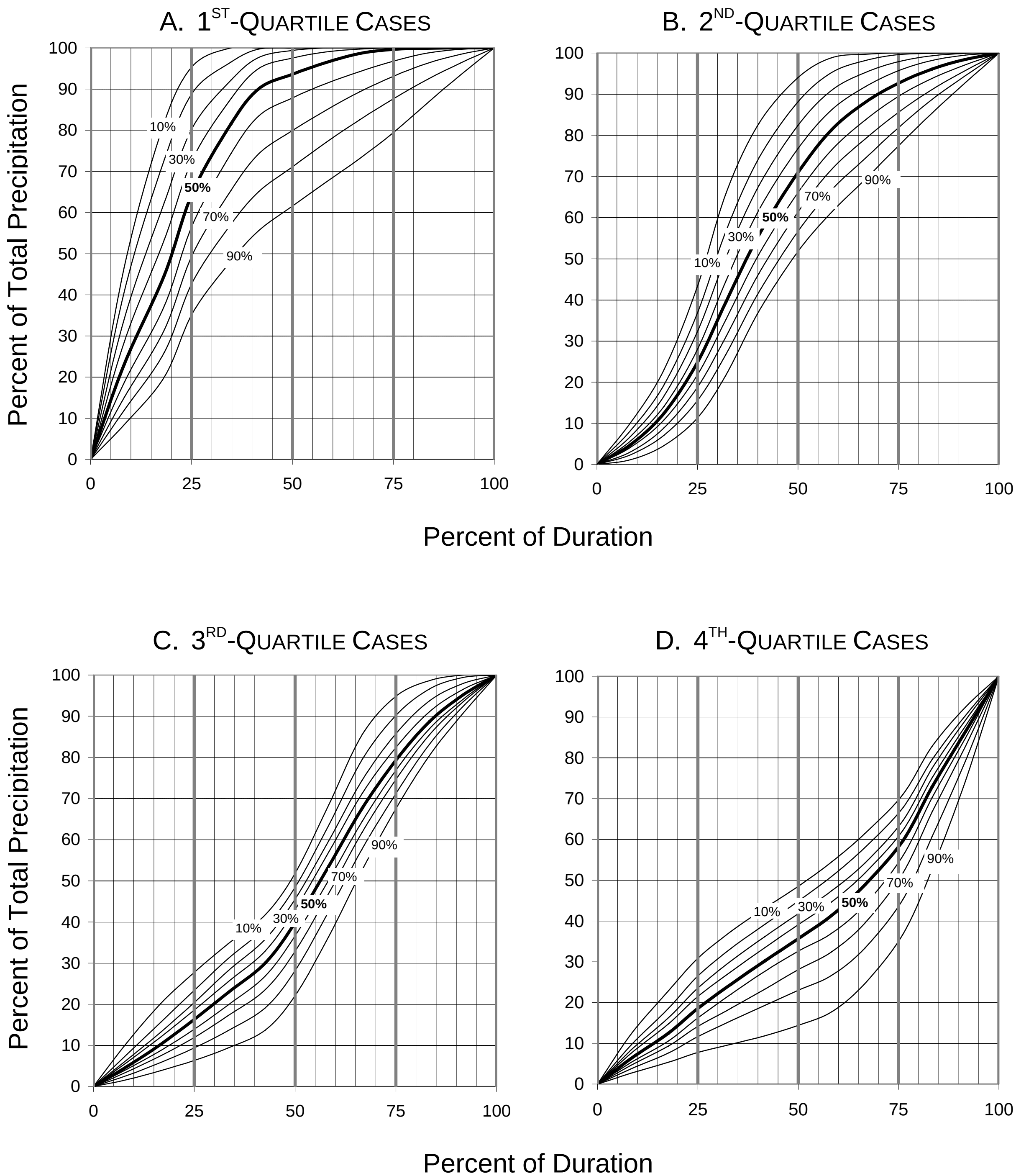


FIGURE A.1.5
TEMPORAL DISTRIBUTION: 6-HOUR DURATION
CONVECTIVE PRECIPITATION AREA



Melissa Reichard

From: Kathy Arnold [karnold@rosemontcopper.com]
Sent: Thursday, May 14, 2009 9:31 AM
To: Melissa Reichard
Subject: FW: Design Storm and Precipitation
Attachments: RCC_Design Storm and Precipitation_7April09.pdf; image001.jpg

Fyi...

Kathy Arnold | Director of Environmental and Regulatory Affairs
Cell: 520.784.1972 | Main: 520.297.7723 | Fax 520.297.7724
karnold@rosemontcopper.com

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From: Kathy Arnold
Sent: Thursday, April 09, 2009 9:45 AM
To: 'Beverley A Everson'
Cc: Tom Furgason; Jamie Sturgess
Subject: Design Storm and Precipitation

Bev –
Thought your team may find this technical memorandum interesting regarding precipitation and design elements we are using for ponds, diversions, etc. I had not planned on sending you a hard copy of this, but if you require one, please let me know.

Regards,
Kathy

Kathy Arnold | Director of Environmental and Regulatory Affairs
Cell: 520.784.1972 | Main: 520.297.7723 | Fax 520.297.7724
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