ATTACHMENT 2

MWH

BUILDING A BETTER WORLD

TECHNICAL MEMORANDUM

TO:	*Roy Blickwedel*	DATE:	*September 3, 2010*
FROM:	*Jed Thompson, Carmen Bernedo*	REFERENCE:	*1008506*
SUBJECT:	*St. Anthony Mine, Conceptual Hydrological Analysis*		

1.0 INTRODUCTION

1.1 Background Information

The St. Anthony mine is an open pit uranium mine located on the Cebolleta Land Grant approximately 40 miles West of Albuquerque, New Mexico. The mine is located in a remote, sparsely populated area. UNC produced uranium ore during operation of the St. Anthony mine from 1977 to 1980, pursuant to a mineral lease with the Cebolleta Land Grant. The lease covered approximately 2,560 acres. This lease was obtained on February 10, 1964 and was surrendered by a Release of Mineral Lease dated October 24, 1988.

The site facilities include underground workings consisting of one shaft and one vent shaft that are sealed at the surface, two open pits (one containing a pond), five inactive ponds, seven piles of non-economical mine materials with some vegetation, numerous smaller piles of non-economical mine materials, and three topsoil piles. The underground mine workings have been sealed at the surface and no open shafts or vents for the underground mines were located during site investigation activities.

The two open pits include a large pit on the west side of the site that perennially contains standing water and a smaller pit southeast of the large pit, that intermittently contains pooled water. There are several large overburden piles on the eastern portion of the site, located next to Meyer Draw. Meyer Draw is an ephemeral drainage that runs only during and shortly after storms large enough to produce run-off. From the north boundary of the site, the arroyo passes between the open pits and several large overburden piles in a southeasterly direction and is joined by Arroyo de Pedro Padilla from the northeast before leaving the site and entering the Laguna Pueblo, which is directly south of the site.

1.2 Facility Location and Brief Description

The two open pits at the mine site are located in Sections 19 and 30, Township 11 North, Range 4 West, and the entrance to the underground mine is located in Section 24, Township 11 North, Range 5 West. The actively mined area encompasses approximately 430 disturbed acres, including roads and other disturbed areas along with the open pits and non-economical mine materials piles. The site remains in the condition it was left at the time of lease termination as part of the terms of the site lease from the Cebolleta Land Grant. There are no remaining building structures on the site, except concrete foundations in the West Shaft Area. Besides the pits and overburden piles, some of the mine infrastructure equipment and components still exist, including roads, utility lines across the site, utility connection locations, a surface completion of an old well, and the concrete foundations of former structures in the West Shaft Area. The site remains inactive and unstaffed

1.3 Objective

The main objective of the Conceptual Hydrological Analysis, as presented in this report, is to quantify the peak runoff flow for a design storm event (e.g., 100-yr 24 hr) from the drainage basin upgradient from the St. Anthony Mine, as shown on **Figure 1**, and from the area immediately surrounding the mine.

1.4 Limitations

Professional judgments are presented in this report. These are based partly on evaluation of technical information gathered, partly on our experience with similar projects, and partly on our understanding of the characteristics of the project. The findings, interpretations of data, recommendations, professional opinions and conclusions that are presented in this report are within the limits prescribed by available information at the time the report was prepared, and in accordance with generally accepted professional engineering practice. In the event that there are any changes in the nature, design, or characteristics of the project, or if additional data are obtained, the conclusions and recommendations contained in the report will need to be reevaluated by MWH. Variations from results presented in the report may be expected, due to uncertainties that are inherent in these types of analyses. Therefore, decisions that are based on these results should consider these variations.

MWH's services were performed within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession. No other representation, expressed or implied, is included or intended in our proposals, contracts, or reports.

2.0 RAINFALL FREQUENCY ANALYSIS AND STORM DEPTH DETERMINATION

2.1 General

The 25-year 24-hour, 100-year 24-hour, and 500-year 24-hour storm events for the St. Anthony Mine were estimated for use in the Conceptual Hydrologic Analysis. The design criteria to be used for stormwater management alternatives has not been decided. Therefore, these three storm events were selected to provide UNC a general idea of the magnitude of the storm events in the area. The estimates were based on the following data:

- Daily precipitation data:
  - Laguna Station. The data was obtained from the National Climatic Data Center (NCDC).
  - Laguna2 Station. The data was obtained from the Western Regional Climate Center (WRCC) Remote Automated Weather Station (RAWS) Project.
  - Cubero Station. The data was obtained from NCDC.
  - Marquez Station. The data was obtained from NCDC.

- Hourly precipitation data:
  - Laguna2 Station from WRCC-RAWS.

This report presents the results of the rainfall frequency analysis performed and the results of the rainfall-runoff modeling performed to obtain the peak runoff flow for different storm events conditions for different points along the main drainage that runs through the St. Anthony Mine.

2.2 Available Data

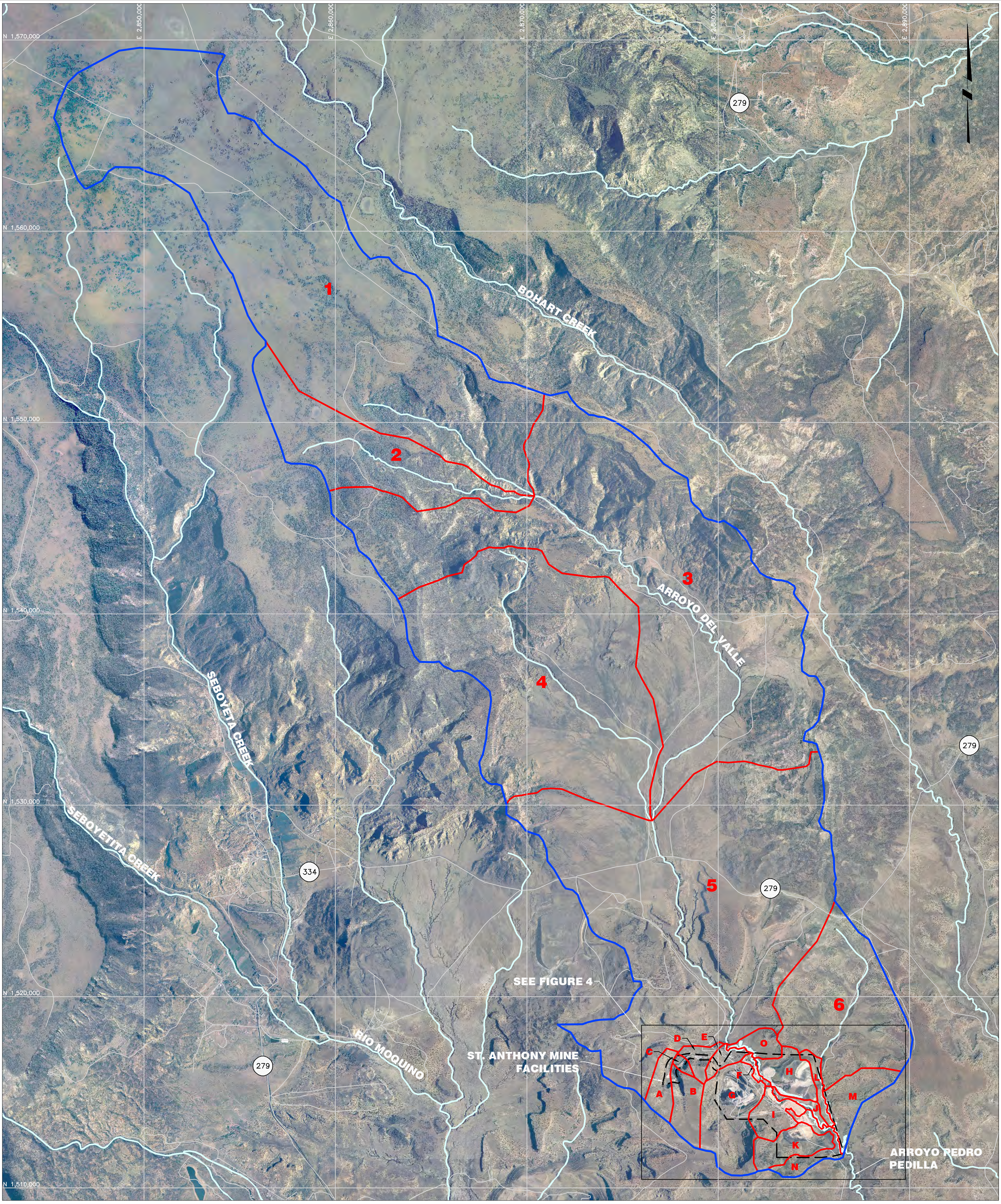
The rainfall data that were collected and reviewed for this analysis are presented in **Table 2-1** below.

TABLE 2-1
METEROLOGICAL STATION INFORMATION

Meteorological Station	Latitude (DM)	Longitude (DM)	Elevation (feet)	Distance from Project Site (miles)	Years of Record	Data Description
Laguna	35°02'	107°24'	5800	10.8	1905-1914, 1919-1921, 1927-1934, 1936-1945, 1949-1969, 1971-2004	Daily Data
Laguna2	35°03'	107°25'	5805	9.5	2005-2006, 2008-2009	Daily and Hourly Data
Cubero	35°06'	107°31'	6200	13.2	1977-1980, 1982, 1984-2009	Daily Data
Marquez	35°18'	107°18'	7630	9.5	1942-1975	Daily Data

Figure 2 displays the station locations relative to the St. Anthony mine as well as the drainage area.

The Laguna, Cubero, and Marquez station data were obtained from the NCDC. Laguna has the longest period of record that ends in 2006. The Laguna2 station data is part of a remote automated weather station climate archive operated by WRCC. The station was added at the end of 2004 and provides hourly records. The two stations in Laguna were combined and considered representative for the current analysis due to their proximity to the site and period of record. A copy of the daily rainfall data is included in **Attachment A**. A summary of the annual maximum 24-hr rainfalls and the corresponding dates of occurrence for Laguna and Laguna2 are listed in **Table 2-2**. It is observed that the maximum daily rainfall depth recorded has been 3.1 inches.



LEGEND:

- NATURAL DRAINAGE
- ST. ANTHONY MINE PERMIT BOUNDARY
- BASIN BOUNDARY
- SUBBASIN BOUNDARY
- A — SUBBASIN NAME
- ROAD

PLAN

SCALE

2500' 0 2500' 5000'

DRAWING REFERENCES:

1. ORTHORECTIFIED IMAGE GENERATED FROM NATIONAL AGRICULTURE IMAGERY PROGRAM (NAIP) 1M RESOLUTION. ORIGINAL FILE IS LOCATED AT: \\USSBS1S01\CAD_ENGINEERING_SUPPORT\DESIGN-DRAFTING\CLIENTS_Q-Z\UNITED NUCLEAR CORPORATION\ST.ANTHONY\006-PHOTOS-IMAGES\ST. ANTHONY BASIN FINAL.TIF
2. DRAINAGE AND ROADS GENERATED FROM U.S. CENSUS BUREAU 2007 TIGER LINE DATA ORIGINAL FILE LOCATED AT: \\USSBS1S01\DOCUMENT LIBRARY\US CENSUS TIGER LINE FILES\CIBOLA COUNTY, NM\FE_2007_35006_EDGES.ZIP

PROJECTION: STATE PLANE COORDINATE SYSTEM
ZONE: NEW MEXICO WEST
DATUM: NAD83
UNITS: U.S. FEET

DESIGNED BY	L. FUHRIG	09/17/10
DRAWN BY	E. MARKS	09/17/10
CHECKED BY	B. COLEMAN	09/17/10
APPROVED BY	C. BERNEDO	09/17/10
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P.O. BOX 3077
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PROJECT LOCATION: ST. ANTHONY MINE

PROJECT: CONCEPTUAL HYDROLOGIC ANALYSIS

TITLE: GENERAL OVERVIEW

MWH

FIGURE: 1 | REVISION: 0

FILE NAME: 1008506D008

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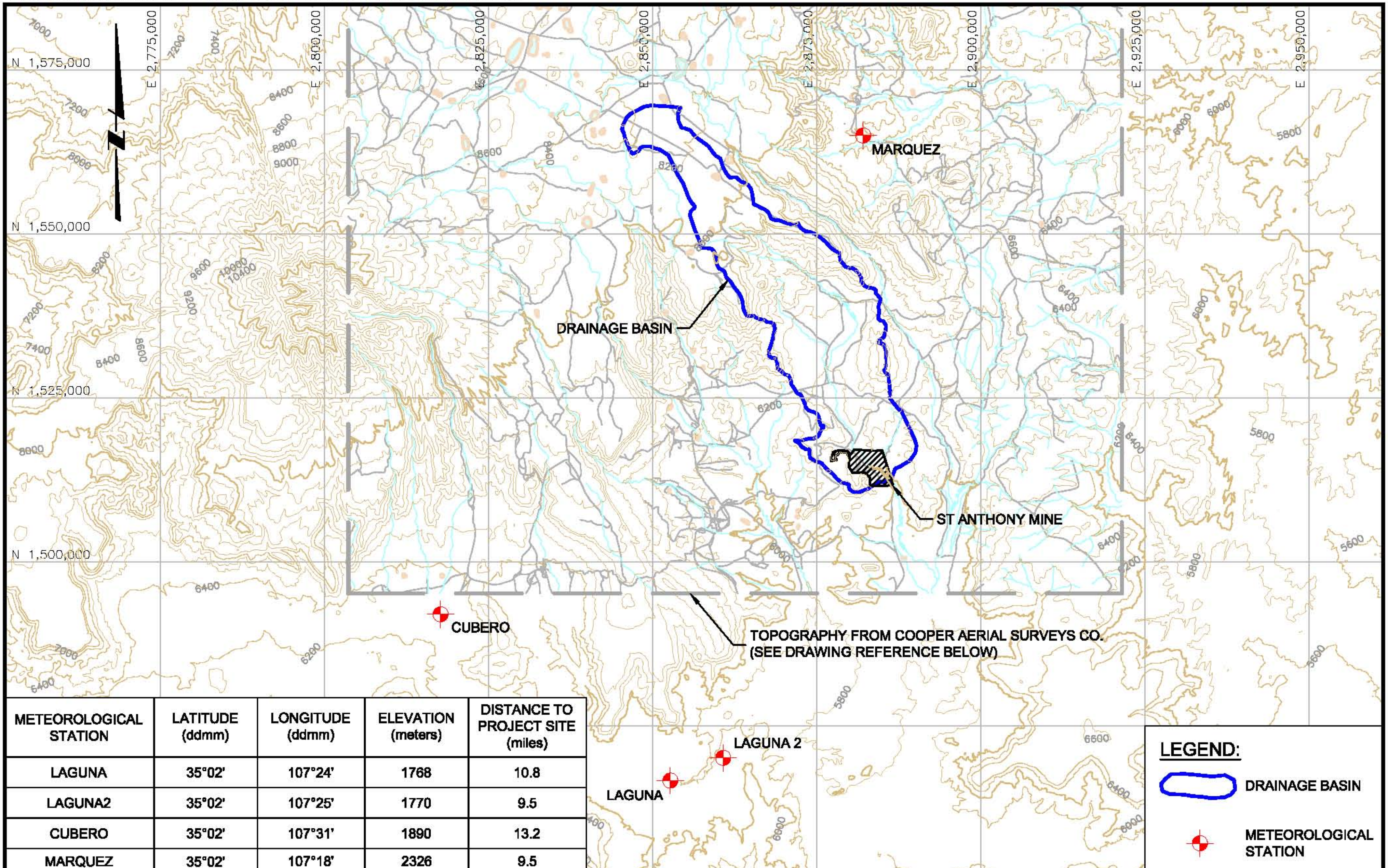


METEOROLOGICAL STATION	LATITUDE (ddmm)	LONGITUDE (ddmm)	ELEVATION (meters)	DISTANCE TO PROJECT SITE (miles)
LAGUNA	35°02'	107°24'	1768	10.8
LAGUNA2	35°02'	107°25'	1770	9.5
CUBERO	35°02'	107°31'	1890	13.2
MARQUEZ	35°02'	107°18'	2326	9.5

DRAWING REFERENCE:
- SURFACE TOPOGRAPHY GENERATED FROM AERIAL PHOTOGRAPHS DATED: MAY 2007, BY COOPER AERIAL SURVEYS CO.
- UNITED STATES ELEVATION DATA (NED) (30 m RESOLUTION)
- PROJECTION: STATE PLANE COORDINATE SYSTEM. ZONE: NEW MEXICO WEST. DATUM: NAD83. UNITS: U.S. FEET.

SCALE
0 20,000 FT

P.O. BOX 3077
Gallup, New Mexico 87305-3077

PROJECT LOCATION: NEW MEXICO
PROJECT: ST ANTHONY MINE
TITLE: METEOROLOGICAL STATION LOCATIONS

MWH

FIGURE: 2
REVISION: A
FILE NAME: 1008506D001

TABLE 2-2
ANNUAL MAXIMUM 24-HR RAINFALL AT LAGUNA

Date	24-hr Max Rainfall (in)	Date	24-hr Max Rainfall (in)
12/21/1905	2.7	10/17/1956	0.5
9/26/1906	1.3	3/20/1957	1.3
4/20/1907	1.6	9/11/1958	1.1
7/7/1908	1.4	10/30/1959	1.1
3/10/1909	3.1	10/17/1960	1.2
9/21/1910	1.8	10/29/1961	1.1
7/1/1911	1.6	10/19/1962	1.0
7/22/1912	2.0	2/12/1963	1.0
6/9/1913	1.4	7/12/1963	2.3
4/8/1914	1.0	8/2/1965	0.7
7/2/1919	1.4	7/20/1966	1.7
8/2/1920	1.9	8/19/1967	0.8
7/22/1921	1.8	7/25/1968	0.8
9/12/1927	0.9	10/22/1969	1.8
8/31/1928	0.8	8/6/1971	0.7
9/22/1929	1.3	10/31/1972	1.3
7/13/1930	1.5	5/14/1973	0.8
4/17/1931	1.2	10/11/1974	1.2
7/22/1932	1.5	7/11/1975	2.9
6/16/1933	1.5	8/19/1976	1.1
9/23/1934	0.9	5/13/1977	1.1
6/11/1936	1.1	5/2/1978	1.4
9/29/1937	1.0	9/15/1979	1.1
6/26/1938	1.3	8/15/1980	0.9
4/4/1939	1.5	7/12/1981	1.0
5/22/1940	1.0	8/25/1982	0.7
5/21/1941	1.2	1/21/1983	1.3
8/23/1942	0.7	10/3/1984	0.9
6/29/1943	1.2	7/16/1985	1.7
8/11/1944	1.8	10/12/1986	1.2
7/26/1945	0.7	1/16/1987	1.1
5/11/1949	1.1	7/29/1988	1.2
7/7/1950	0.7	7/26/1989	0.8
6/4/1951	0.6	7/13/1990	1.8
6/2/1952	0.6	6/30/1991	1.0
3/8/1953	0.5	5/22/1992	1.5
7/8/1954	1.4	8/30/1993	1.8
8/11/1955	1.7	8/16/1994	1.6

Date	24-hr Max Rainfall (in)
8/24/1995	1.3
10/28/1996	1.2
7/29/1997	1.9
3/16/1998	1.8
7/10/1999	0.9
3/23/2000	1.4
8/4/2001	1.3

Date	24-hr Max Rainfall (in)
9/11/2002	1.5
11/13/2003	1.3
4/5/2004	1.8
9/6/2005	1.3
7/31/2006	1.7
7/20/2008	0.8
8/14/2009	0.5

2.3 Methodology

The National Weather Service (NWS) recommended methodology for rainfall frequency analysis was used for the current study. The NWS is part of the National Oceanic and Atmospheric Administration (NOAA) and is one of the most respected organizations in the world that provides climate and hydrologic forecasts. As stated in Chapter 18, “Selected Statistical Methods”, in the National Engineering Handbook by the Natural Resource Conservation Service (former Soil Conservation Service), the Type I Extremal Distribution (Fisher – Tippett) is used by the NWS in the precipitation frequency analysis. Considering that the NWS is at the leading edge of technology in hydrologic analysis, the rainfall frequency analysis method recommended by them was selected for this Conceptual Hydrological Analysis. The Laguna, Cubero, and Marquez station data were analyzed using this methodology. The probability density of the Type I Extremal Distribution by Fisher & Tippett is described as follows:

$$P(x) = (\exp^{(-(a + x)/c - \exp -(a + x)/c)}) / c$$

Where x is the variable (rainfall), and a and c are parameters. The cumulative probability is

$$P(x) = \exp\ (-(\exp^{-(a+x)/c}))$$

By the method of moments, the parameters have been evaluated as

$$a = 0.5772 * c - \mu$$
$$c = 6^{0.5} * s / 3.14159$$

$$T = 1 / (1 - P),$$

where μ is the mean, s is the standard deviation, P is the probability and T is the return period. The equations are presented in more detail in the Handbook of Applied Hydrology (V. T. Chow, 1988).

The NOAA Atlas 14 Volume 1 has precipitation frequency estimates for the semi-arid southwest with associated confidence limits. The Atlas is intended as the official documentation of precipitation frequency estimates and associated information for the United States. The NOAA Atlas 14 precipitation frequency estimates are more widely available via the Precipitation Frequency Data Server (PFDS) which was created by NWS. The PFDS was used to collect precipitation frequency estimates for the project study area.

Storm precipitation depth-duration-frequency estimates for the site were determined using the NOAA – NWS - Precipitation Frequency Data Server (PFDS) web site at <http://hdsc.nws.noaa.gov/> for point of coordinates, Latitude 35.16 and Longitude -107.29, located in the area of Laguna, New Mexico. These precipitation depths were used for all drainage basins

2.4 Results

The results of the rainfall frequency analysis using data from the Laguna, Cubero, and Marquez data stations, as well as the precipitation frequency estimates from the NOAA Atlas 14 are presented in **Table 2-3**. **Table 2-4** displays the maximum storm events from the NOAA Atlas 14 for shorter storm durations. The relationships between rainfall depths and return periods for the maximum 24-hr rainfalls are shown in **Graph 1**.

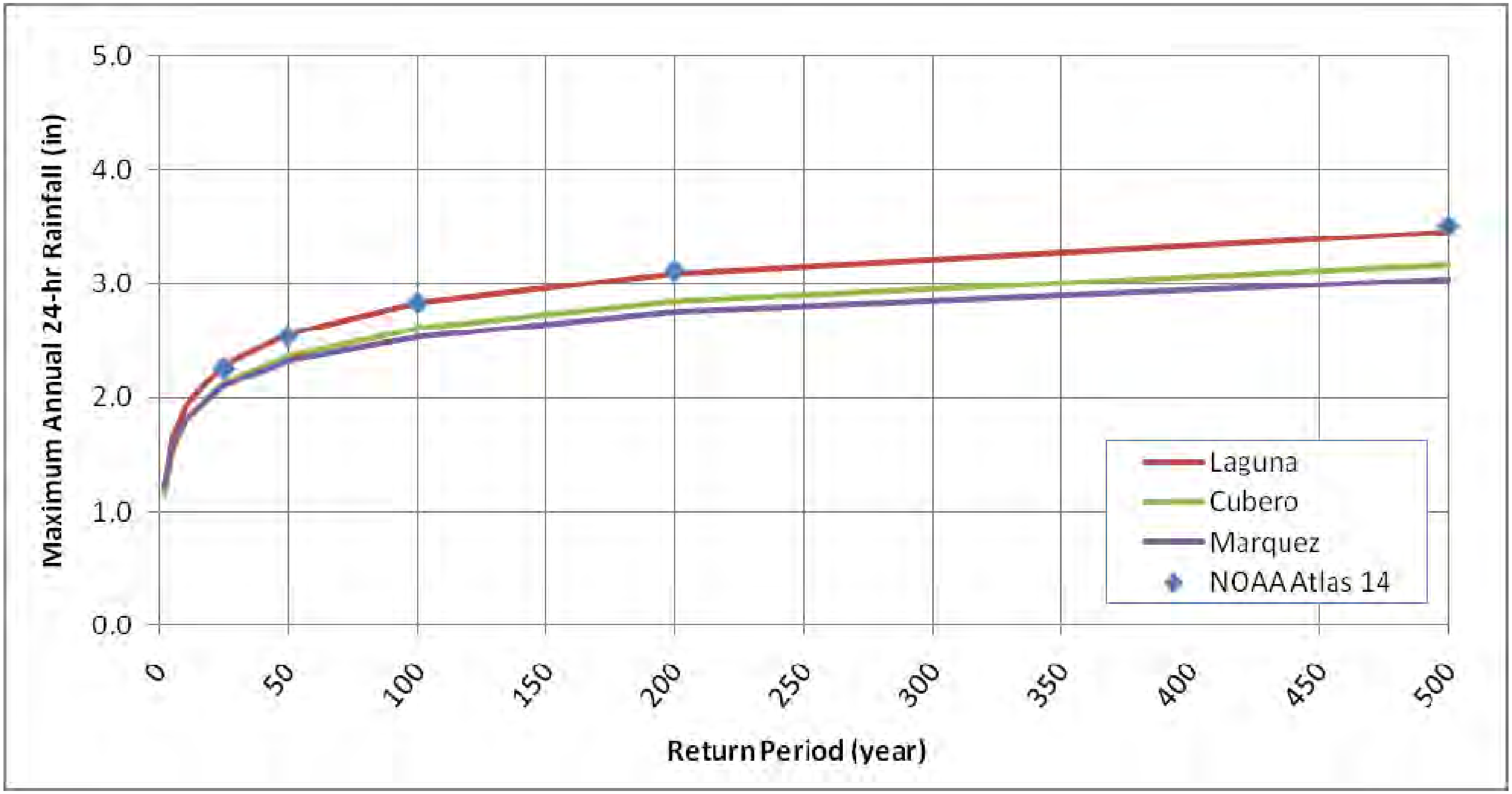
TABLE 2-3
MAXIMUM 24-HR STORM DEPTHS AT VARIOUS RETURN PERIODS

Return Period	Laguna (in)	Cubero (in)	Marquez (in)	NOAA Atlas 14 (in)
25 - yr	2.3	2.1	2.1	2.3
100 - yr	**2.8**	**2.6**	**2.5**	**2.8**
500 - yr	3.5	3.2	3.0	3.5

TABLE 2-4
NOAA ATLAS 14 – MAXIMUM STORM EVENTS AT VARIOUS RETURN PERIODS

Return Period	15-min (in)	30-min (in)	60-min (in)	3-hr (in)	6-hr (in)	12-hr (in)	24-hr (in)
25 - yr	0.9	1.2	1.5	1.8	1.9	2.1	2.3
100 - yr	**1.2**	**1.6**	**1.9**	**2.3**	**2.5**	**2.6**	**2.8**
500 - yr	1.5	2.0	2.5	3.0	3.1	3.3	3.5

The 100-year 24-hour storm is initially selected to estimate the flows to be used for the future stormwater management plan since a decision has not been made regarding the final design criteria to be used for design.



Graph 1. Rainfall frequency analysis results.

3.0 RAINFALL AND RUNOFF MODELING

3.1 Drainage Basins

The drainage basin for the St. Anthony Mine extends north of the mine site approximately 13 miles. The main drainage pathway for this flow is the Arroyo del Valle, which flows into the north end of the mine and through the mine area. The Arroyo del Valle has been known as Myer Draw where if flows through the site. A smaller drainage called Bohart Creek meets up with the Arroyo del Valle shortly before it exits the south end of the mine. The drainage basin primarily consists of arid and semiarid range land.

The drainage basins for the site were delineated using aerial site wide topography in conjunction with United States Geological Survey (USGS) Digital Elevation Model (DEM) data for off the site. The site description data was collected using ArcGIS and information provided by the Natural Resources Conservation Service (NRCS).

The basin and sub-basin characteristics considered, including route length, elevation difference, average slope, and lag time, are summarized in **Table 3-1**. Watershed basins are shown on **Figure 3** and **Figure 4**.

The lag time for the watershed was estimated based on the curve number method developed by the NRCS. This method is described as follows:

$$L = (\boldsymbol{l}^{0.8} * (S + 1)^{0.7}) / (1900 * Y^{0.5})$$

Where,

L = lag time in hours
l = hydraulic length of watershed in feet
S = (1000/CN) – 10
CN = soil group curve number
Y = average watershed slope in percent

The CN value used in this analysis was based on soil and land use information from the site and calculated as a weighted value for each subbasin. The hydrologic condition for each sub-basin was determined based on the amount of ground cover visible from aerial photographs and were classified as either fair (30% to 70% cover) or poor (less than 30%). A CN was then determined within these classifications based on the hydrologic soil group(s) assigned to the sub-basin using soils information provided by the NRCS.

Table 3-1 summarizes the water course length, elevation difference, weighted average slope, and lag time for each route.

TABLE 3-1
WATERSHED CHARACTERISTICS

Basin	Area (mile^2)	CN	Water Course Length (ft)	Elevation Difference (ft)	Average Slope (%)	Lag Time (min)
1	7.10	81.1	35,387	1,850	5.23	139.8
2	1.45	82.3	18,788	1,350	7.19	69.1
3	6.99	84.4	38,094	1,850	4.86	138.0
4	4.38	87.1	21,595	1,650	7.64	63.3
5	6.17	83.7	21,566	400	1.68	152.4
6	1.45	81.3	11,365	1,040	9.15	42.3
A	0.13	85.0	3,967	N/A	19.19	11.1
B	0.19	81.3	4,821	N/A	10.81	19.6
C	0.03	85.0	1,545	N/A	24.82	4.6
D	0.08	85.0	3,096	N/A	18.46	9.3
E	0.07	85.0	2,939	N/A	18.08	9.0
F	0.02	85.0	200	N/A	16.93	1.1
G	0.53	85.0	4,000	N/A	42.05	7.6
H	0.20	85.0	5,386	N/A	21.90	13.3
I	0.16	85.0	2,250	N/A	27.72	5.9
J	0.04	85.0	500	N/A	36.69	1.5
K	0.21	85.0	3,285	N/A	33.76	7.2
L	0.07	85.0	520	N/A	35.94	1.6
M	0.26	86.5	5,651	N/A	16.86	14.9
N	0.14	73.0	550	N/A	27.37	2.8
O	0.10	80.8	1,600	163	10.98	8.4

3.2 HEC HMS Hydrologic Modeling

The Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) model developed by the U.S. Army Corps of Engineers (USACE) was used to compute the surface runoff during the 100-year 24-hour storm. HEC-HMS is a computer model developed by the USACE used to simulate the precipitation-runoff processes of dendritic watershed systems. Rainfall depths for specified storm durations were input into the HEC-HMS model for generation of the peak flows due to the storm events.

The physical representation of a watershed is accomplished with a basin model. Hydrologic elements (subbasin, reach, junction, reservoir, and sink) are connected in a network to simulate runoff processes based on the physical layout of the subbasins. The main elements of the hydrologic network (Junctions) are shown on **Figure 3**. The HEC-HMS routing diagrams are presented in **Attachment A.**

The HEC-HMS model was simulated for 24-hours using 5-minute and 15-minute time steps. The HEC-HMS output is located in **Attachment A**.

3.2.1 Storm Depth and Distribution

Hydrologic modeling using the SCS methodology requires the input of storm precipitation depth along with a precipitation distribution in time. A graph of the precipitation distribution with time is called a hyetograph, that is part of the model input.

Typical approaches were used for rainfall distribution determination to assess the most critical condition for peak flow estimates. Two of the available alternative standards-based storms provided by the HEC-HMS model were used:

1. A balanced frequency-based storm: The objective of the frequency-based hypothetical storm is to define an event for which the precipitation depths for various durations within the storm have a consistent exceedance probability. The NOAA Atlas 14 precipitation frequency estimates for the 100-yr, 24-hr storm were used.

2. The Soil Conservation Storm (SCS): Based on observation data, SCS has developed four types of rainfall distributions for the United States: Type I, Type IA, Type II, and Type III. The corresponding distribution for New Mexico is Type II. The SCS type II storm in 5-minute time intervals for the 100-yr, 24-hrs storm duration was used within HEC-HMS.

The 100-yr, 24-hr storm may be used either with the balanced frequency-based storm or the SCS Type II distribution. Therefore, the two alternatives were used and modeled. Final results that yield the most critical flow values should be used when considering stormwater alternatives.

3.2.2 Subbasin Inputs

The drainage area, CN and lag time vaues listed in **Table 3-1** were incorporated as model inputs. No lag times less than 5 minutes were entered.

In the HEC-HMS model, it was assumed that all areas were pervious, and that baseflow occurring during the design storm was negligible. The initial abstraction (Ia) variable was calculated by the program using the equation Ia = 0.2S, where S = (1000/CN) - 10.

Inputs for a typical reach routing model using the muskingum-cunge method include a typical cross-section geometry. Eight different cross-sections were produced from the available topographic data to correspond with HEC-HMS reaches. This was entered into HEC-HMS using the 8-point method, which consisted of creating tables with eight distances across the channel and their corresponding elevations. Also included in the reach calculations were the distances of each reach and their average slopes, both determined from the available topographic data. A Manning's n of 0.030 was used for all reaches. These inputs are listed in **Attachment A**.

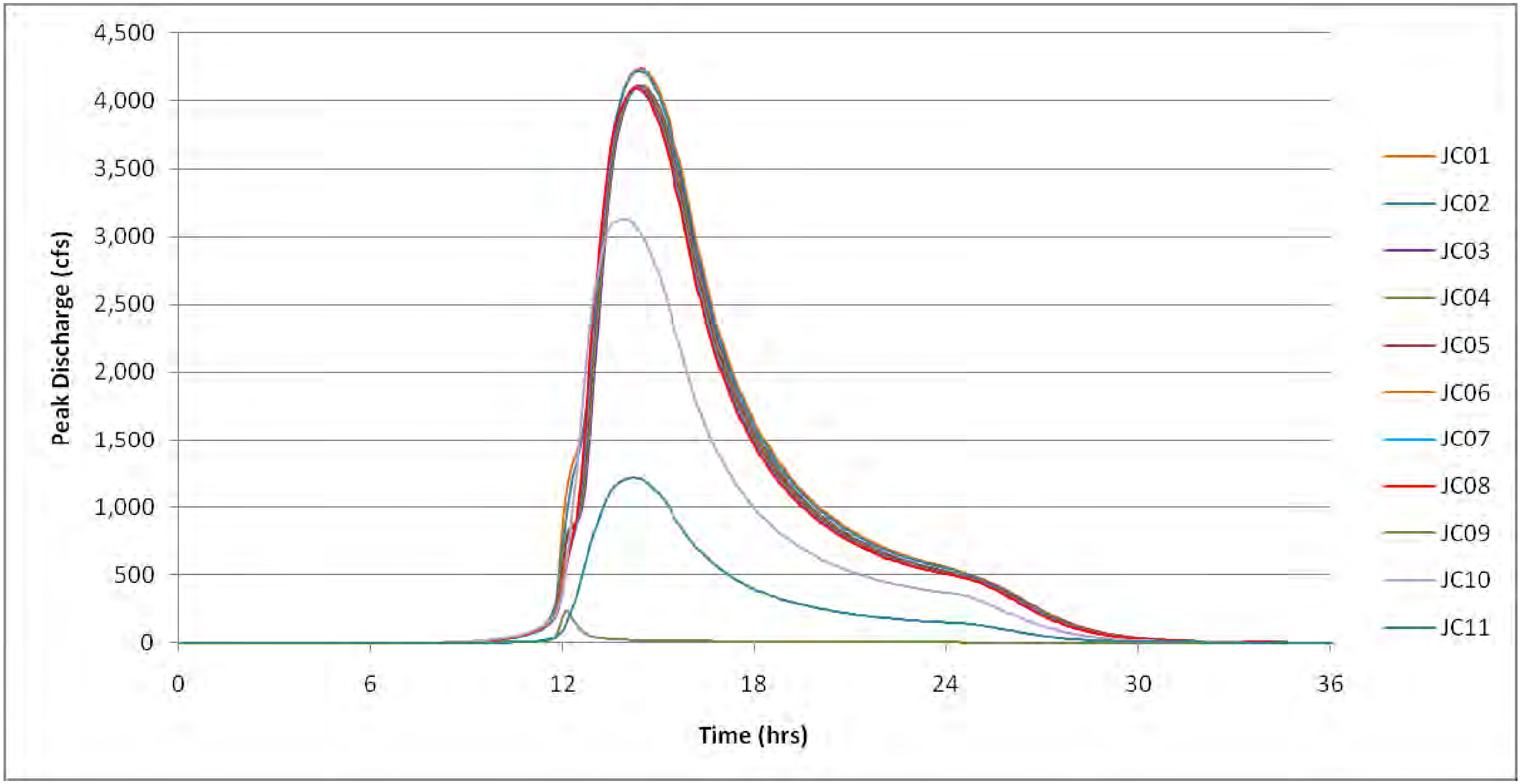
3.3 Results

Based on our analysis using the 100-year 24-hour storm event and the HEC-HMS model, the peak flows estimates are presented in **Table 3-2**.

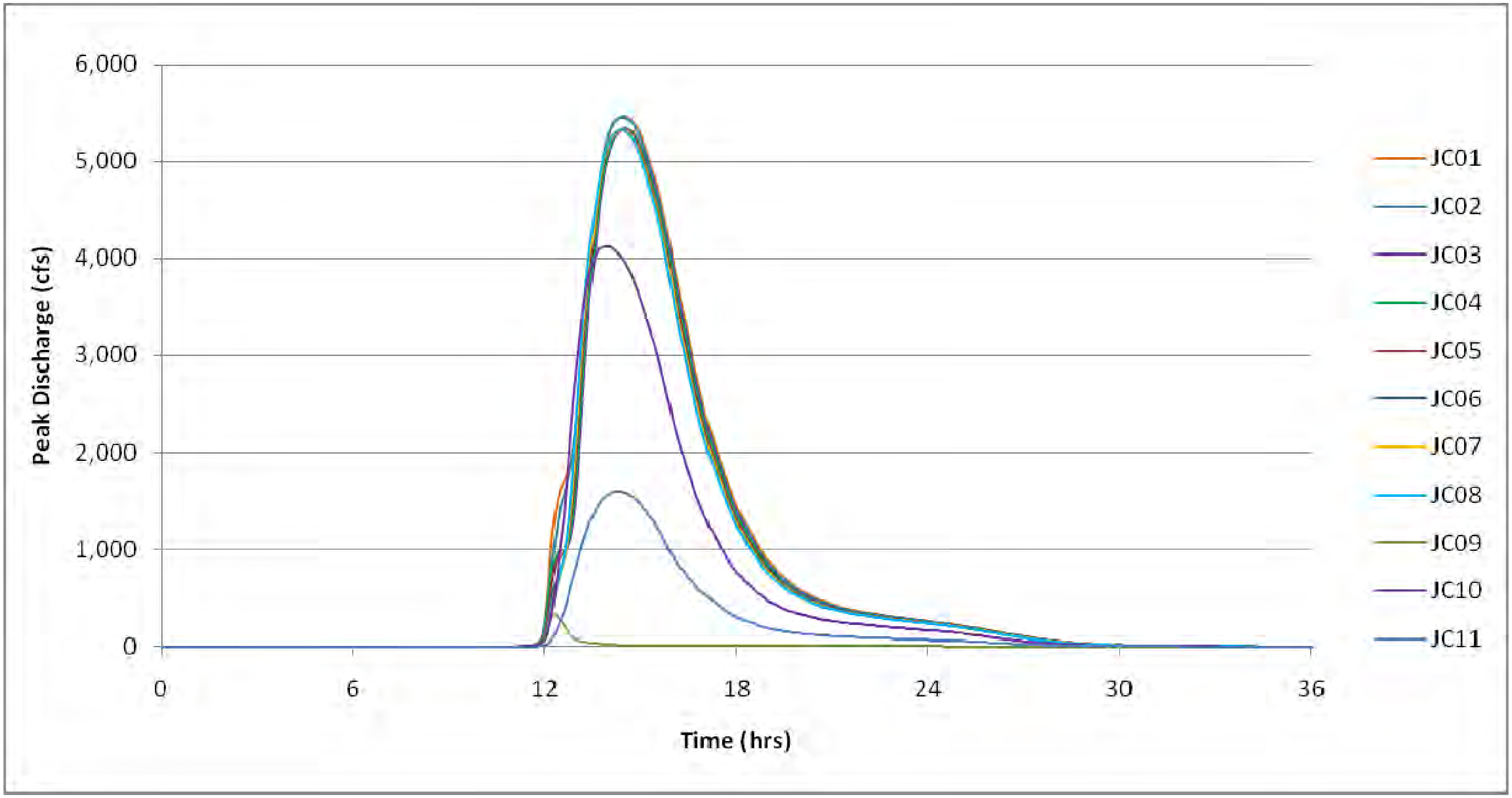
TABLE 3-2
PEAK FLOW RESULTS – 100-YEAR 24-HOUR SCS TYPE II STORM AND BALANCED STORM

	100-year 24-hour SCS Type II Storm		100-year 24-hour Balanced Storm	
Junction	Runoff Volume (10^6 ft^3)	Peak Inflow (cfs)	Runoff Volume (10^6 ft^3)	Peak Inflow (cfs)
1	89.61	4238.8	89.42	5467.0
2	88.45	4221.2	88.27	5454.5
3	84.24	4114.7	84.06	5338.9
4	84.09	4114.1	83.92	5340.0
5	83.55	4106.6	83.38	5335.0
6	82.80	4096.4	82.63	5329.8
7	82.53	4092.2	82.36	5327.5
8	82.31	4089.1	82.14	5325.9
9	1.05	236.5	1.05	337.7
10	61.89	3133.3	61.76	5454.5
11	23.44	1213.7	23.39	1595.8

Graph 2 and **Graph 3** show the hydrographs for the 100-yr 24-hr SCS Type II storm event and the 100-yr 24-hr balanced storm event respectively, at the different junctions considered in the network modeled with the HEC-HMS model.



Graph 2. 100-yr 24-hr SCS Type II Storm Hydrograph.



Graph 3. 100-yr 24-hr SCS Balanced Storm Hydrograph.

5.0 SUMMARY AND CONCLUSIONS

The 24 hr, 100 yr storm using the blance storm method was selected for purpose of developing prelimanary estimate of stormwater flows through the site. These preliminary estimates indicate that large flows can be expected through the site.

The philosophy of the Conceptual Hydrologic Analysis as presented in this Technical Memorandum is based on the determination of storm runoff flows for future stormwater solutions for existing conditions in the project area. It is understood that reclamation design will be performed in the future during the closure design phase for post-closure planned conditions and it is expected that changes will need to be performed to update and perform the design of structures needed for stormwater management alternatives for the reclaimed site.

6.0 REFERENCES

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