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Technical Memorandum

To:	Kathy Arnold	**From:**	Greg Hemmen
Company:	Rosemont Copper Company	**Date:**	January 28, 2010
Re:	Rosemont Dry Stack Tailings Facility Drainage Bench Analysis	**Doc #:**	031/10-320832-5.3
CC:	David Krizek, P.E. (Tetra Tech)		

1.0 Introduction

This technical memorandum discusses the design of stormwater conveyance channels associated with the Dry Stack Tailings Facility at the proposed Rosemont Copper Project (Project) in Pima County, Arizona. Designs are based on the Rosemont Ridge Landform (Landform) shape shown on Figure 1. Should modifications to this Landform shape occur, this stormwater analysis, and corresponding stormwater conveyance channel design, would still be applicable assuming channel lengths are under the maximum analyzed herein.

In general, the channels will route stormwater from the Dry Stack Tailings Facility either to stilling pools/drop structures constructed on the Rosemont Ridge Landform's face, to the Waste Rock Storage Area located at the Landform's southern portion, or directly to the Landform's perimeter into channels cut in natural ground or depressions located at the Landform's base. Two (2) channel designs were explored herein: a v-channel and a trapezoidal channel. Additionally, the conveyance capacity for each channel was analyzed with and without expected sedimentation.

The methodology behind the design of the stormwater conveyance channels was based on the Natural Resources Conservation Service (NRCS) curve number approach for the hydrologic analysis to estimate the peak stormwater runoff. This method, along with the utilization of Manning's open-channel flow equation, was used for the hydraulic analysis to calculate the proper channel size and to design the typical drainage bench cross section.

2.0 Hydrologic Methodology Overview (NRCS Method)

The NRCS method was developed for general hydrologic analysis and allows for various storm distributions and durations to be analyzed. The NRCS approach is applicable to the analysis of large complex watershed systems, such as mining sites, where landscape conditions may change over time. Due to its widespread acceptance, the NRCS method has been incorporated into many hydrologic modeling programs and was performed using HEC-HMS, which is a hydrologic modeling software package developed by the U.S. Army Corps of Engineer's for general applications and allows for the analysis of more complex/integrated systems, i.e., multiple sub-basins, reservoir and channel routing, etc.

The primary input variables for the NRCS method are precipitation, storm distribution, curve number, basin delineation or area, and time of concentration or lag time. The NRCS method utilized by HEC-HMS employs these parameters to develop a specific basin's relationship between runoff versus time, where the apex of this distinctive hydrograph signifies the basin's estimated peak flow rate that is subsequently used for the design of its stormwater conveyance channel. These variables are presented in the following paragraphs and discussed in greater detail in the technical memorandum titled "Rosemont Hydrology Method Justification" (Tetra Tech, 2010).

2.1 Precipitation

Precipitation was acquired from the NOAA Atlas 14 Point Precipitation website. The coordinates used to obtain precipitation data for the Rosemont Site were 31.862 N 110.692 W, at an elevation of 4,429 feet. This point is located northeast of the Dry Stack Tailings Facility. The mean NOAA Atlas 14 precipitation values are typically used with the NRCS analysis. However, both the mean and upper 90% confidence interval precipitation values, which uses the 90% upper confidence interval precipitation values to predict estimates of peak flows for design purposes, were analyzed herein for the stormwater conveyance channels.

2.2 Rainfall Storm Distributions

The NRCS method allows for many precipitation patterns to be applied to the watershed. For the NRCS method, the following return periods were analyzed: 100-year, 500-year, 1000-year. Variations in storm distributions and durations for the NRCS method were analyzed to determine the most appropriate criteria for designing the stormwater conveyance channels at the Dry Stack Tailings Facility. Storms analyzed using the NRCS method were the 24-hour NRCS Type II Distribution, the 1-hour NRCS Type II Distribution, the 1-hour Symmetrically-Centered Thunderstorm, and the 1-hour Compressed Distribution from a 6-hr National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Distribution.

HEC-HMS allows for the application of various storm distributions and durations. The application of a unit hydrograph allows the storm distribution of a desired duration to be applied to the watershed by modeling the watershed as a linear hydrologic system. A runoff versus time distribution relationship (hydrograph) is the end result. Storm precipitation hyetographs, which show the time distribution of rainfall, must be developed in order for the unit hydrograph to yield a runoff hydrograph for the watershed. This process allows for more complex system analysis, such as modeling of multiple sub-basins and routing effects.

The storm-distribution patterns used in the analyses performed herein are briefly presented in the following paragraphs and are discussed in greater detail in the technical memorandum titled "Rosemont Hydrology Method Justification" (Tetra Tech, 2010).

2.2.1 NRCS Rainfall Distributions

The NRCS has developed synthetic hyetographs for the entire U.S., for 6-hour and 24-hour storm events, called "type curves". The U.S. is divided into four (4) regions where specific "type curves" can be applied. Two (2) NRCS synthetic distributions were analyzed for the design of the stormwater conveyance channels and are described below.

2.2.1.1 *24-Hour NRCS Type II Distribution*

Based on the NRCS Type Curve Map, Arizona falls within the Type II region, which is characterized by high-intensity storms. A Type II storm represents one of the more intense storm patterns defined by NRCS. The 24-hour distribution is widely used in hydrologic modeling, and is embedded in HEC-HMS.

2.2.1.2 *One-Hour NRCS Type II Rainfall Distribution*

The 1-hour storm analyzed herein was created from the 24-hour NRCS Type II distribution. It applies to the most intense (steepest) 1-hour portion of the synthetic 24-hour distribution. The 1-hour storm was analyzed to account for an event with the same return frequency, but with a shorter duration. The 1-hour storm is generally more intense and produces greater peak flows than the 24-hour storm.

2.2.2 One-Hour Symmetrically Centered Thunderstorm Distribution

Using the 5-, 10-, 15-, 30-, and 60-minute (i.e., one-hour) precipitation values obtained from NOAA Atlas 14, a symmetrically centered thunderstorm distribution was created. By centering the most intense portion of the storm in the middle of the distribution (30-minute rainfall value), then evenly distributing the incremental change in precipitation outward, a typical thunderstorm pattern was simulated. A one-hour design storm was created in this manner to analyze a storm that is shorter and more intense than the NRCS 24-hour event, and applies to a distribution other than the NRCS Type II curve.

2.2.3 One-hour Compressed Temporal Rainfall Distribution

The one-hour design storm was created from a 6-hour temporal convective storm. The one-hour storm that was selected for analysis is “front end loaded,” in that 52% of the rainfall falls within the first quartile of the storm event. The one-hour storms described previously were symmetrically centered, suggesting that the maximum burst of rainfall occurs exactly at the mid-point the storm duration.

2.2.4 Storm Distribution Summary

Table 1 summarizes the storms that were considered for design purposes. For detailed information regarding the development and analysis of these storms, refer to technical memorandum titled “Rosemont Hydrology Method Justification” (Tetra Tech, 2010).

Table 1 Design Storms

Parameters	NRCS Storms								
Return Period (yrs)	1000	500	100	100	100	100	100	100	100
Duration (hrs)	24	24	24	24	1	1	1	1	1
Precipitation (in)	6.57	6.00	5.35*	4.75	3.56*	3.17	3.56*	3.17	3.17
Distribution	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	Thunder-storm	Thunder-storm	Compressed 6-Hr

*Denotes the upper bound of the 90% confidence interval (from NOAA Atlas 14)

2.3 Rainfall Losses - Curve Number

The Natural Resource Conservation Service (NRCS) has developed a widely used curve number (CN) procedure for estimating runoff from storm events. The NRCS method incorporates this curve number procedure.

Rainfall initial 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 runoff factors (known as runoff curve numbers). Curve numbers represent the runoff potential of a soil type (i.e., the higher the CN, the higher the runoff potential).

For hydrologic calculations, to determine the runoff potential the NRCS classifies soils as “A”, “B”, “C”, or “D”, based on their hydrologic soil group. Type “A” soils, such as sandy soils, have a very low runoff potential. Heavy clay and mucky soils, as well as shallow/rocky soils, are a type “D” soil, and have a very high runoff potential. Soil groups at the Rosemont site were determined from the NRCS Soil Survey Geographic Database (SSURGO) data set.

The curve number selected as appropriate and applied to all the basins for the TSF is 85, which is considered conservative for the buttress areas associated with the Dry Stack Tailings Facility whose proposed soils are anticipated to be type “C”.

2.4 Drainage Basin Delineations

A total of 31 separate drainage basins were analyzed along the outer sloped areas on the waste rock buttress of the proposed Dry Stack Tailings Facility as shown on Figure 1. Each basin’s contributing hydrologic watershed was uniquely delineated with its corresponding drainage bench that is designed to appropriately convey stormwater.

2.5 Time of Concentration / Lag Time

The time of concentration (Tc) used in the NRCS method was determined by considering the most hydraulically distant flow path for each basin and was calculated using the sum of the travel times for each flow segment within the basin. The travel time is the ratio of flow length to flow velocity and defined by the following relationship:

$$Tc = \sum_{i=1}^{n} \frac{L_i}{v_i}$$

Where:

- Tc = the time of concentration, in minutes;
- n = the number of flow segments;
- L_i = the length of the flow path, in feet, for the i^{th} segment; and
- V_i = the estimated velocity, in feet per second, for the i^{th} segment (ft/s).

The basins within the Dry Stack Tailings Facility’s buttress comprise two (2) flow segments as shown on Figure 1: an overland flow path down the side-slope flowing into an anticipated longitudinal v-channel with 3:1 (Horizontal to Vertical) side-slopes. The velocity of the overland segment was estimated by the following equation:

$$V = a*S^{0.5}$$

Where:

V = the estimated velocity, in feet/second;

a = the overland flow coefficient, conservatively estimated at 15.2 ft/s; and

S = the slope of the flow path, in feet per foot (ft/ft).

The velocity of the channel segment was estimated utilizing an iterative approach between the applied HEC-HMS and Manning's equation for open-channel flow. An initial time of concentration was generated from an assumed velocity for the channel segment to obtain an estimate of the peak flow rate. This value was then used in Manning's formula presented in the following section to refine the assumed velocity. The overland flow velocity and channel velocity were summed to give the total time of concentration for each basin. This time of concentration was then converted into a lag time, which is equal to 0.6*Tc, and input into HEC-HMS.

3.0 Hydraulic Methodology Overview (Manning's Formula)

The hydraulic analysis entailed utilizing Manning's open-channel flow equation, together with the basin that yielded the largest (in magnitude) peak flow rates from the hydrologic analysis, in order to appropriately size a representative stormwater channel. This channel size was applied to all drainage benches. The geometry of a typical drainage bench includes a stormwater channel in addition to an access road and an outer berm.

Furthermore, different geometries of the drainage channel were examined during the design process. These different geometries addressed the probability of a decrease in the channel's stormwater capacity due to sedimentation and also considered an increase in its capacity by steepening the channel's side-slope adjacent to the access road.

Manning's formula for open-channel flow is as follows:

$$Q = \frac{1.486 A \cdot R^{2/3} \cdot S^{1/2}}{n}$$

Where:

Q = the channel flow rate, in cubic feet per second (cfs);

A = the cross sectional area of flow, in square feet (ft^2);

R = the hydraulic radius of flow, in feet;

S = the longitudinal slope of the flow path for the channel, universally 2% or 0.02 ft/ft; and

n = Manning's roughness coefficient for the channel, conservatively estimated at 0.045 (unitless). A roughness coefficient of 0.045 assumes a large earthen drainage ditch.

The following equations for the area and the hydraulic radius of the flow were obtained from the properties of triangles, whereas the depth of flow was calculated using these relationships and thus the necessary depth of channel was obtained after considering allowances for safety:

$$A = \frac{1}{2}(m_1 y^2 + m_2 y^2)$$

$$R = \frac{\frac{1}{2}(m_1 y^2 + m_2 y^2)}{\sqrt{m_1^2 y^2 + y^2} + \sqrt{m_2^2 y^2 + y^2}}$$

Where:

- A = the cross sectional area of flow, in square feet (ft^2);
- R = the hydraulic radius of flow, in feet;
- m_1 = the side slope of the channel;
- m_2 = the side slope of the channel; and
- y = the depth of flow, in feet.

After obtaining the depth and consequently the top width of the v-channel necessary for stormwater conveyance, the drainage bench was designed with the adjacent access road proposed to be 12 feet wide and a safety berm at 3.5 feet tall and approximately 10.5 feet wide.

4.0 Hydrologic and Hydraulic Analysis Results

In the technical memorandum titled “Rosemont Hydrology Method Justification” (Tetra Tech, 2010), it was concluded that the minimum event used to calculate peak flows for permanent conveyance structures shall generally be the 500-year, 24-hour storm. In addition to this design storm and for comparison purposes, the 1,000-year, 24-hour event was also used in this analysis. Table 2 summarizes the results of the peak runoff analysis and the resultant flow depth for the proposed longitudinal v-channel with 3:1 (Horizontal to Vertical) side-slopes corresponding to the 31 unique drainage basins featured in Figure 1:

Table 2 Summary of V-Channel Analysis

Basin Name	1,000-year, 24-hour NRCS Type II Storm		500-year, 24-hour NRCS Type II Storm	
	Peak Flow Rate (cfs)	Flow Depth (ft)	Peak Flow Rate (cfs)	Flow Depth (ft)
SE Tailings Bench 1	156.4	2.98	139.2	2.85
SE Tailings Bench 2	220.0	3.38	195.3	3.24
SE Tailings Bench 3	214.3	3.35	189.8	3.20
SE Tailings Bench 4	185.3	3.17	164.2	3.03
SE Tailings Bench 5	183.6	3.16	163.6	3.03
SE Tailings Bench 6	51.5	1.96	45.6	1.88
SE Tailings Bench 7	160.2	3.00	142.7	2.88
SE Tailings Bench 8	142.8	2.88	127.0	2.75
SE Tailings Bench 9	72.7	2.23	64.7	2.14
NE Tailings Bench 1	163.5	3.03	145.1	2.90
NE Tailings Bench 2	***270.0***	***3.65***	***239.4***	***3.49***
NE Tailings Bench 3	216.5	3.36	192.8	3.22
NE Tailings Bench 4	232.9	3.46	206.5	3.30
NE Tailings Bench 5	207.8	3.31	183.9	3.16
NE Tailings Bench 6	83.0	2.35	73.9	2.25
NE Tailings Bench 7	103.8	2.55	92.6	2.45
NW Tailings Bench 1	68.2	2.18	61.0	2.09
NW Tailings Bench 2	97.2	2.49	86.7	2.39
NW Tailings Bench 3	86.8	2.39	77.2	2.29
NW Tailings Bench 4	115.8	2.66	103.2	2.55
W Tailings Bench 1	129.3	2.77	114.5	2.65
W Tailings Bench 2	107.3	2.59	95.6	2.48
W Tailings Bench 3	41.5	1.81	37.1	1.74
W Tailings Bench 4	60.2	2.08	53.6	1.99
W Tailings Bench 5	72.4	2.23	64.6	2.14
W Tailings Bench 6	69.8	2.20	62.1	2.11
SW Tailings Bench 1	75.8	2.27	67.5	2.17
SW Tailings Bench 2	89.9	2.42	80.1	2.32
SW Tailings Bench 3	128.5	2.77	114.5	2.65
SW Tailings Bench 4	109.1	2.60	97.2	2.49
SW Tailings Bench 5	88.4	2.40	78.7	2.30

Note: NE Tailings Bench 2 produced the largest peak flow rates that were used as the basis for the channel's design.

According to the results indicated in Table 2, together with Figure 1, the controlling basin for the design of the v-channel with 3:1 side-slopes required for adequate stormwater conveyance is NE Tailings Bench 2. This basin yielded the greatest flow magnitude. The corresponding flow depth for the 500-year, 24-hour storm event emanating from this basin into the v-channel is approximately 3.5 feet. By accounting for an additional 12 inches for freeboard, the total design flow depth is 4.5 feet and the resultant top width of the proposed v-channel with 3:1 side-slopes is 27 feet.

Moreover, the basin for NE Tailings Bench 2 governs the configuration of the typical drainage bench that is proposed throughout the Dry Stack Tailings Facility area. Consequently, a bench width of 50 feet is needed to accommodate a 4.5 feet deep, 27 feet wide v-channel with consideration for a 3.5 foot tall, 10.5 foot wide safety berm together with a minimum 12 foot wide access road. This typical bench cross section with the various channel geometries analyzed herein and discussed below is depicted on Figure 2.

In addition to the proposed v-channel, different trapezoidal geometries of the drainage channel were examined together with various storm events in anticipation of a decrease in the channel's stormwater capacity due to sedimentation and to consider an increase in its capacity by steepening the channel's side-slope adjacent to the access road. This analysis was made possible by basically manipulating the hydraulic equations discussed in the previous section to accommodate a bottom channel width characterized by trapezoidal channel geometry.

Table 3 summarizes the storms and channels that were analyzed, and Figures 3 and 4 illustrate the drainage bench scenarios examined for this exercise.

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Table 3 Summary of NE Tailings Bench 2 Analysis

Parameters	NRCS Storms								
Return Period (years)	1000	500	100	100	100	100	100	100	100
Duration (hours)	24	24	24	24	1	1	1	1	1
Precipitation (inches)	6.57	6.00	5.35*	4.75	3.56*	3.17	3.56*	3.17	3.17
Distribution	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	NRCS Type II	Thunder -storm	Thunder -storm	Compressed 6-hour
Calculations	**V-Channel with 3:1 Side-Slopes**								
Channel Velocity (ft/s)	6.74	6.54	6.29	6.03	6.75	6.42	6.54	6.22	6.13
Peak Flow Rate (cfs)	270.0	239.4	204.6	172.7	271.0	221.8	239.2	196.1	184.9
Flow Depth (ft)	3.65	3.49	3.29	3.09	3.66	3.39	3.49	3.24	3.17
Calculations	**V-Channel with 3:1 Side-Slopes and 30% Capacity Decrease due to Sedimentation**								
Channel Velocity (ft/s)	6.21	5.98	-	-	6.19	-	5.96	-	-
Peak Flow Rate (cfs)	264.0	232.8	-	-	261.3	-	230.2	-	-
Flow Depth (ft)	2.03	1.89	-	-	2.02	-	1.88	-	-
Calculations	**Trapezoidal Channel with 2:1 & 3:1 Side-Slopes**								
Channel Velocity (ft/s)	6.95	6.74	-	-	6.97		6.74	-	-
Peak Flow Rate (cfs)	272.4	232.8	-	-	274.8	-	241.4	-	-
Flow Depth (ft)	3.16	2.99	-	-	3.17	-	2.99	-	-
Calculations	**Trapezoidal Channel with 2:1 & 3:1 Side-Slopes and 30% Capacity Decrease due to Sedimentation**								
Channel Velocity (ft/s)	6.35	6.11	-	-	6.34	-	6.10	-	-
Peak Flow Rate (cfs)	266.0	234.9	-	-	264.2	-	233.0	-	-

*Denotes the upper bound of the 90% confidence interval (from NOAA Atlas 14)

As Table 3 indicates, the proposed v-channel with 3:1 side-slopes was analyzed with all NRCS storm events considered for the largest NE Tailings Bench 2 basin, whereas the remaining trapezoidal channels were simply investigated with the most conservative storm events.

The proposed 4.5 foot deep v-channel with 3:1 side-slopes is sufficient to contain all NRCS storms studied. As indicated above, the 500-year, 24-hour design storm with a calculated depth of approximately 3.5 feet leaves 12 inches for freeboard in the v-channel. Additionally, the v-channel design is capable of withstanding the 1,000-year, 24-hour event with about 10 inches of freeboard remaining as shown on Figure 3. If this v-channel's capacity to convey stormwater is reduced by 30% due to the bottom being filled by projected sedimentation, then the channel's geometry becomes trapezoidal with a depth of about 2 feet and a bottom width of just less than 15 feet as represented on Figure 3. The v-channel with 30% sedimentation is still able to withhold the most intense storm events for the largest basin analyzed, albeit without any freeboard for the 1,000-year, 24-hour event and only a couple inches for the 500-year, 24-hour design storm event as Table 3 suggests. However, in addition to providing safety, the outside berm is intended to provide redundancy in terms of stormwater control, affording an additional 3.5 feet of channel depth for the 50 feet wide bench beyond the proposed v-channel as illustrated on Figure 3.

The starting v-channel geometry was also modified in favor of handling more stormwater by steepening the side-slope adjacent to the access road to 2:1 (Horizontal to Vertical) while maintaining the opposite side-slope consistent with the buttress slope at approximately 3:1 and the top width of the channel at 27 feet. This gives a trapezoidal configuration for the channel having a bottom width of 4.5 feet as shown on Figure 4. Since the cross sectional area, and thus the capacity, for this trapezoidal channel is larger when compared to the v-channel design without sedimentation, the calculated depth of 3.0 feet required to pass the 500-year, 24-hour design event is approximately 0.5 feet lower than the equivalent storm depth of 3.5 feet for the v-channel as represented in Table 3. This results in a freeboard of 18 inches seen on Figure 4 versus 12 inches depicted on Figure 3 for the same 500-year, 24-hour design storm. Similarly, the calculated water surface for the 1,000-year, 24-hour storm event is about 0.5 feet lower than the equivalent for the v-channel, resulting in a freeboard of 16 inches versus 10 inches.

Comparable to the v-channel and as represented on Figure 4, if the trapezoidal channel capacity is reduced 30% by sedimentation, the trapezoidal channel's cross sectional area becomes smaller with a depth of about 2.3 feet and a bottom width of just over 15 feet. Table 3 and Figure 4 also reveals that the trapezoidal channel with 30% sedimentation will pass the largest storms but with minimal channel freeboard remaining. However, the outer safety berm can also provide redundancy with regard to stormwater control as indicated before and illustrated on Figure 4.

The drainage bench designs shown on Figures 2 through 4 all assume a starting bench width of 50 feet. The v-channel design along with the 3.5 foot high safety berm and the 12 foot wide access road requires the bench elevation to be raised approximately 10 inches to 11 inches in a balanced cut-to-fill scenario. Also excess fill material would be generated with the trapezoidal channel design in order to maintain the 12 foot wide access road.

Attachment 1 contains the output results together with the data and calculations developed for this study.

5.0 Conclusion

Based on the analysis and the results discussed herein, a 50 foot wide typical starting bench width is capable of accommodating the proposed v-channel, an adjacent 12 foot wide access road, and a 3.5 foot high safety berm while adequately conveying the estimated stormwater runoff generated from an NRCS Type II design storm with a 500-year return period and a 24-hour duration. Furthermore, if sedimentation occurs within the drainage channels, the proposed bench cross section is designed with sufficient redundancy to safely transmit stormwater runoff.

The design basis for the drainage benches of the proposed Dry Stack Tailings Facility is the 500-year, 24-hour design storm with one (1) foot of freeboard. The typical channel design was based on the maximum peak flow from NE Tailings Bench 2, which is the largest of the 31 distinct drainage basins shown on Figure 1. Using this maximum channel design for the remaining basins and their respective drainage benches provides additional redundancy to the stormwater conveyance system associated with the Dry Stack Tailings Facility.

REFERENCES

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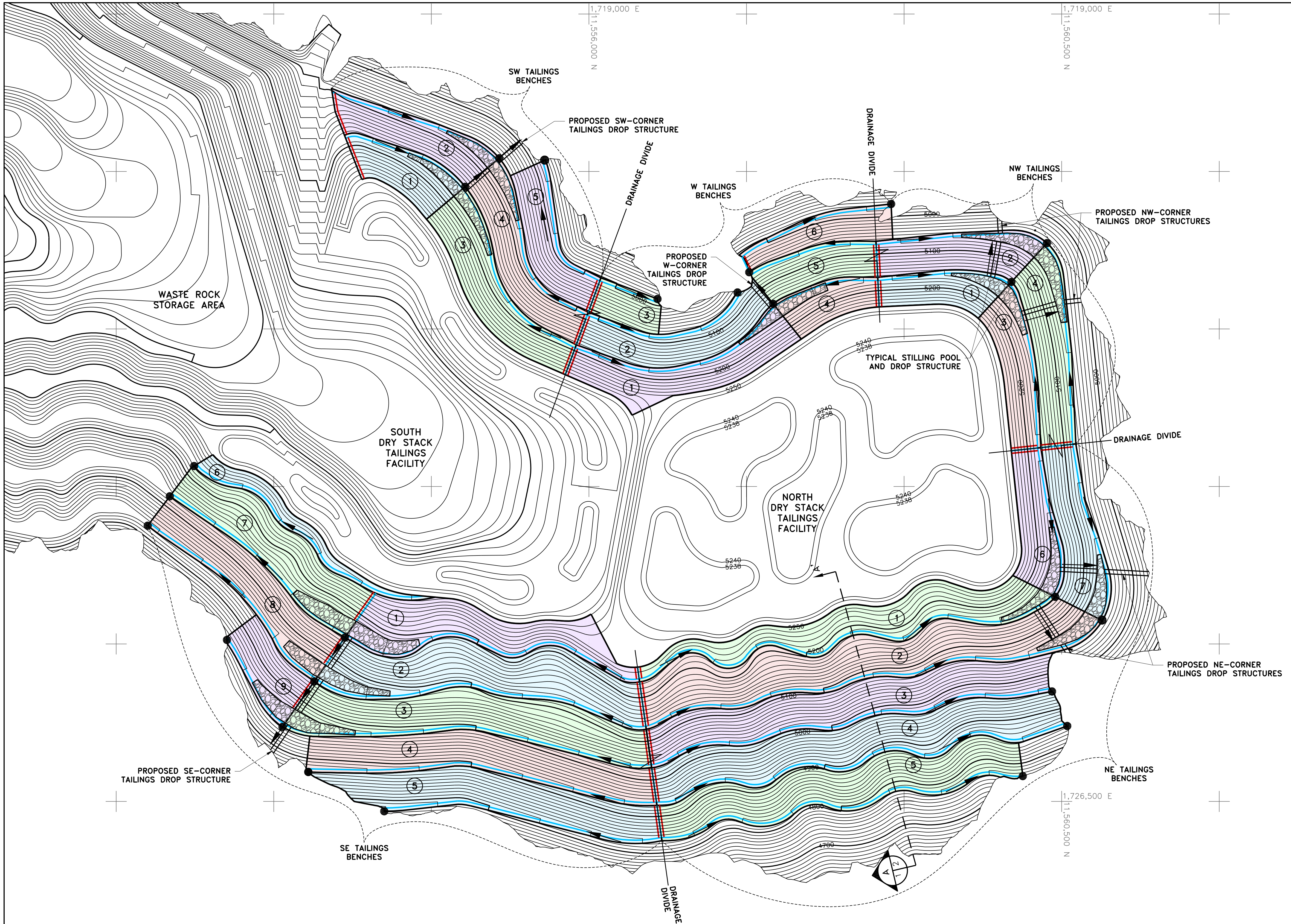
http://websoilsurvey.nrcs.usda.gov/app/ (2009) Natural Resource Conservation Service (NRCS) Soil Survey Website. Viewed August 25, 2009.

http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Tools_Models/other/TR55.html (2009) Natural Resource Conservation Service (NRCS) Web Soil Survey Website. Viewed August 25, 2009.

Tetra Tech. (2010). Rosemont Copper Project Hydrology Method Justification. Technical Memorandum from Ronson Chee and Greg Hemmen (Tetra Tech) to Kathy Arnold (Rosemont Copper). Dated January 27, 2010.

FIGURES



N

SCALE

500' 0 500' 1000'

CONTOUR INTERVAL = 10'

LEGEND

(1) TAILINGS BENCH BASIN DELINEATION (COLOR VARIES AND NUMBER CORRESPONDS TO BASIN NAME IN TABLE BELOW)

CHANNEL FLOW

OVERLAND FLOW

STORMWATER FLOW

BASIN CONCENTRATION POINT

NOTES:

1. THE FINAL YEAR OF RECLAMATION AND CLOSURE IS SHOWN. THE VERSION SHOWN IS WITHOUT NORTHWEST HAUL ROAD.
2. THE DRY STACK TAILINGS FACILITY BENCHES ARE SLOPED AT 2%.

TAILINGS BENCH DRAINAGE BASINS

BASIN NAME	AREA (AC)	1,000-YR 24-HR FLOWRATE (CFS)	1,000-YR 24-HR DEPTH (FT)	500-YR 24-HR FLOWRATE (CFS)	500-YR 24-HR DEPTH (FT)
SE TAILINGS BENCH 1	22.1	156.4	3.0	139.2	2.9
SE TAILINGS BENCH 2	31.5	220.0	3.4	195.3	3.2
SE TAILINGS BENCH 3	31.1	214.3	3.4	189.8	3.2
SE TAILINGS BENCH 4	26.8	185.3	3.2	164.2	3.0
SE TAILINGS BENCH 5	25.5	183.6	3.2	163.6	3.0
SE TAILINGS BENCH 6	7.5	51.5	2.0	45.6	1.9
SE TAILINGS BENCH 7	21.5	160.2	3.0	142.7	2.9
SE TAILINGS BENCH 8	19.4	142.8	2.9	127.0	2.8
SE TAILINGS BENCH 9	9.2	72.7	2.2	64.7	2.1
NE TAILINGS BENCH 1	25.3	163.5	3.0	145.1	2.9
NE TAILINGS BENCH 2	41.4	270.0	3.7	239.4	3.5
NE TAILINGS BENCH 3	32.2	216.5	3.4	192.8	3.2
NE TAILINGS BENCH 4	34.9	232.9	3.5	206.5	3.3
NE TAILINGS BENCH 5	30.3	207.8	3.3	183.9	3.2
NE TAILINGS BENCH 6	10.8	83.0	2.4	73.9	2.3
NE TAILINGS BENCH 7	13.8	103.8	2.6	92.6	2.5
NW TAILINGS BENCH 1	8.8	68.2	2.2	61.0	2.1
NW TAILINGS BENCH 2	12.9	97.2	2.5	86.7	2.4
NW TAILINGS BENCH 3	11.4	86.8	2.4	77.2	2.3
NW TAILINGS BENCH 4	15.5	115.8	2.7	103.2	2.6
W TAILINGS BENCH 1	17.5	129.3	2.8	114.5	2.7
W TAILINGS BENCH 2	14.2	107.3	2.6	95.6	2.5
W TAILINGS BENCH 3	5.2	41.5	1.8	37.1	1.7
W TAILINGS BENCH 4	7.7	60.2	2.1	53.6	2.0
W TAILINGS BENCH 5	9.4	72.4	2.2	64.6	2.1
W TAILINGS BENCH 6	9.2	69.8	2.2	62.1	2.1
SW TAILINGS BENCH 1	9.9	75.8	2.3	67.5	2.2
SW TAILINGS BENCH 2	12.1	89.9	2.4	80.1	2.3
SW TAILINGS BENCH 3	17.2	128.5	2.8	114.5	2.7
SW TAILINGS BENCH 4	14.5	109.1	2.6	97.2	2.5
SW TAILINGS BENCH 5	11.5	88.4	2.4	78.7	2.3

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Title:

DRY STACK TAILINGS FACILITY DRAINAGE BENCH ANALYSIS BASIN DELINEATION MAP

A REVISION

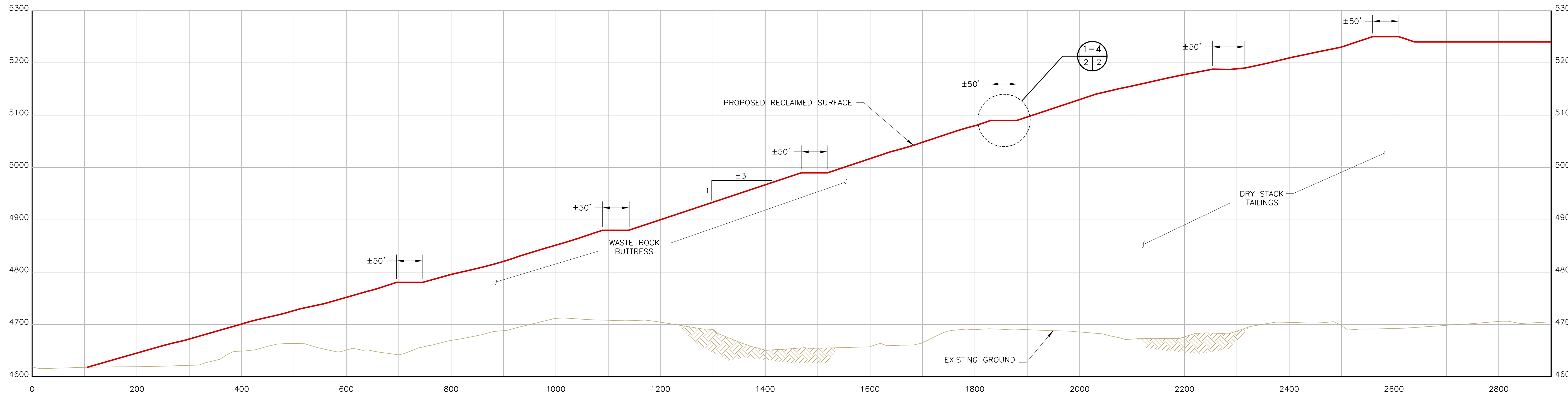
Project: ROSEMONT COPPER PROJECT

Project no.: 320832

Figure no.: 1

Location: PIMA COUNTY, ARIZONA

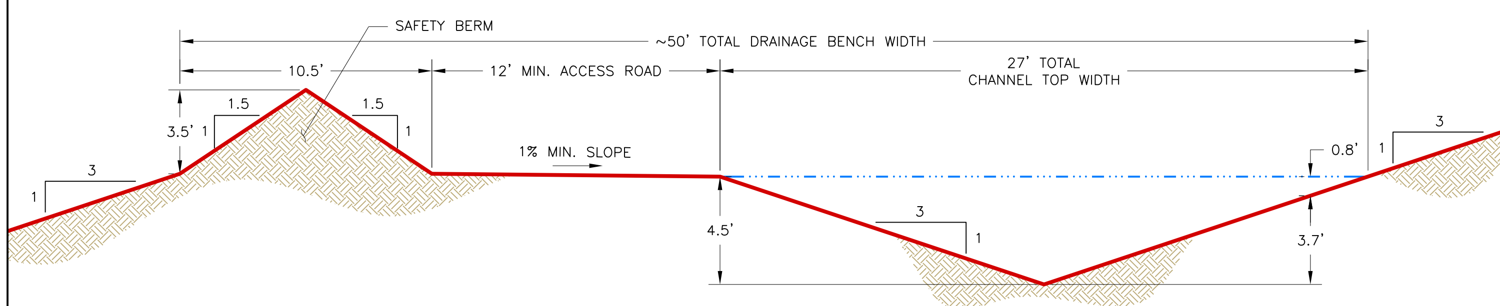
Date: 01/10



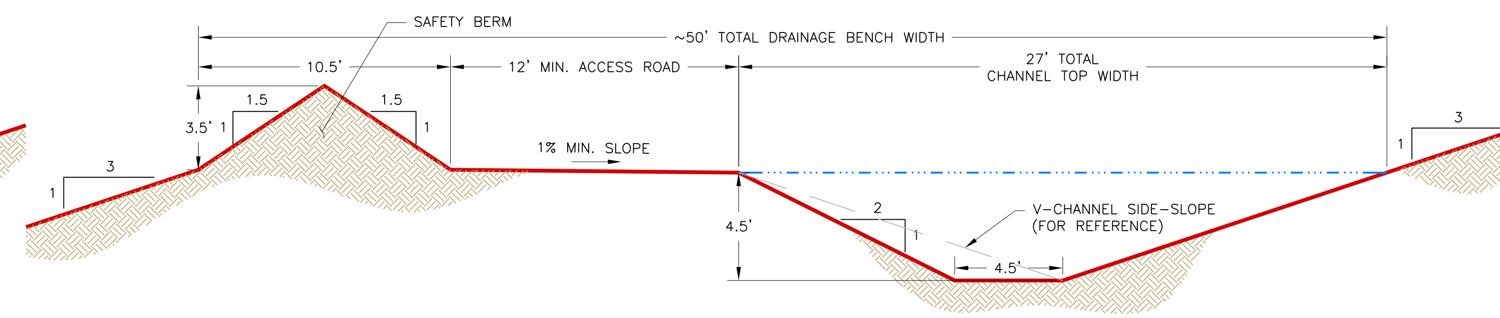
NOTES:

1. THE RED SURFACE IS THE PROPOSED RECLAIMED SURFACE OF THE ROSEMONT RIDGE LANDFORM. THE BUTTRESS STACKING AND ACCESS REQUIREMENTS MAY VARY THE FINAL LANDFORM SHAPE.
2. THE WASTE ROCK BUTTRESS IS NOT SHOWN FOR CLARITY.

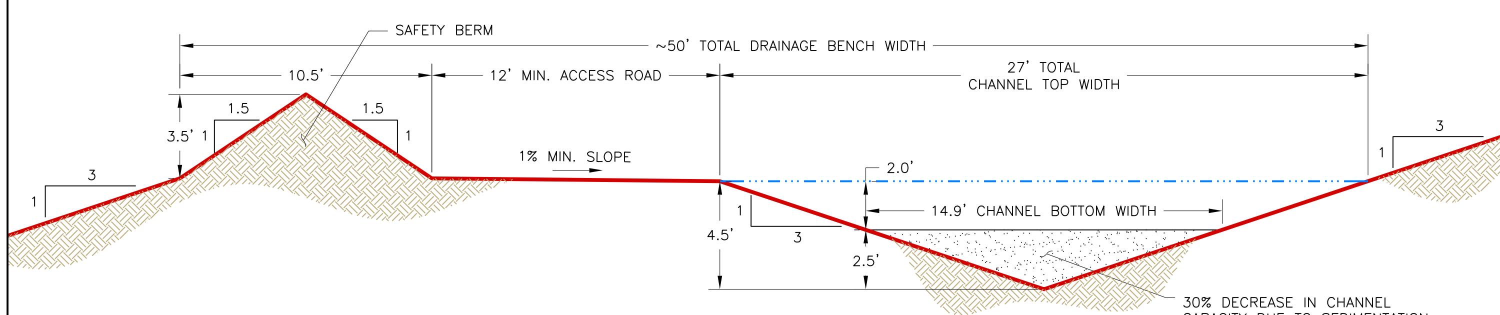
A / 1 | 2 TYPICAL DRY STACK TAILINGS FACILITY CROSS SECTION



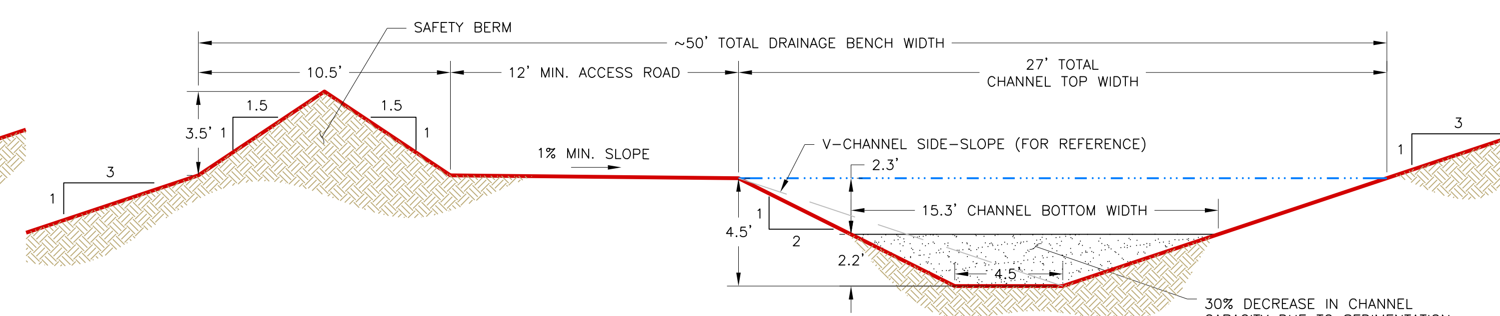
1 / 2 | 3 TYPICAL DRAINAGE BENCH CROSS SECTION WITH V–CHANNEL CONFIGURATION
N.T.S.



3 / 2 | 4 TYPICAL DRAINAGE BENCH CROSS SECTION WITH TRAPEZOIDAL CHANNEL CONFIGURATION
N.T.S.

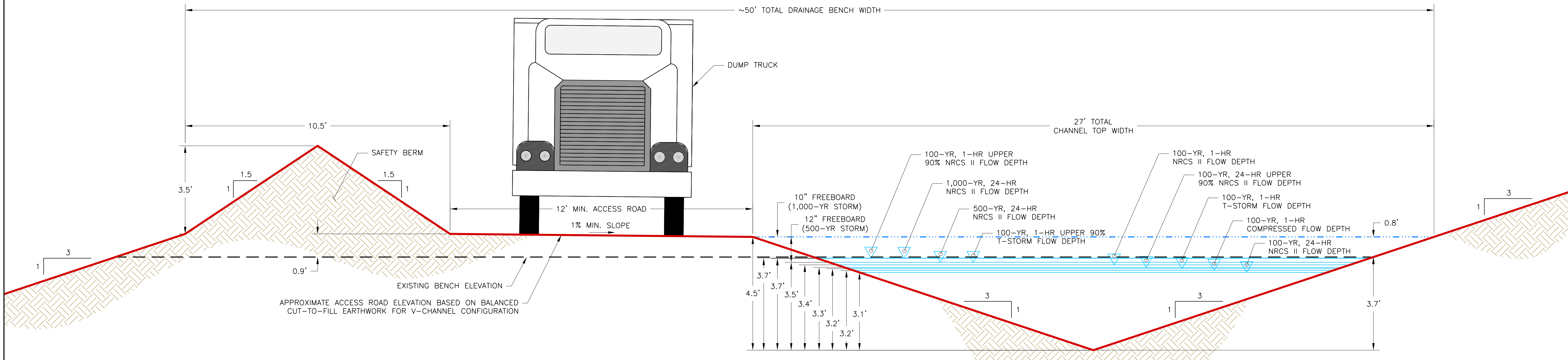


2 / 2 | 3 TYPICAL DRAINAGE BENCH CROSS SECTION WITH V–CHANNEL CONFIGURATION REDUCED BY SEDIMENTATION
N.T.S.

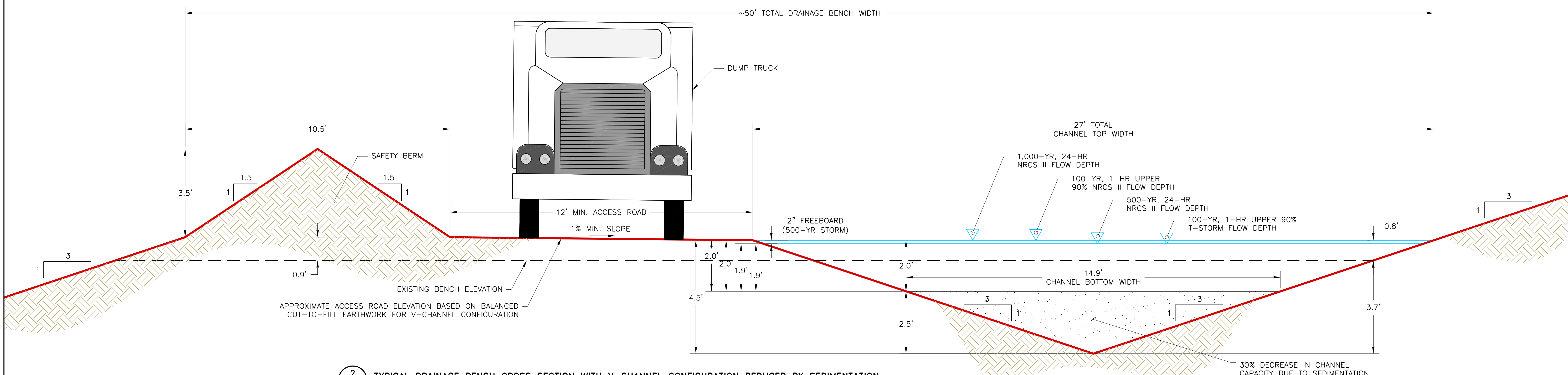


4 / 2 | 4 TYPICAL DRAINAGE BENCH CROSS SECTION WITH TRAPEZOIDAL CHANNEL CONFIGURATION REDUCED BY SEDIMENTATION
N.T.S.

Issued by:	Title:	
TETRA TECH 3031 West Ina Road Tucson, Arizona 85741 (520) 297-7723 (520) 297-7724 fax	DRY STACK TAILINGS FACILITY DRAINAGE BENCH ANALYSIS CROSS SECTION AND DETAILS	A REVISION
	Project: ROSEMONT COPPER PROJECT	Project no.: 320832
	Location: PIMA COUNTY, ARIZONA	Date: 01/10
	Figure no.: 2	



1/2|3 TYPICAL DRAINAGE BENCH CROSS SECTION WITH V-CHANNEL CONFIGURATION
N.T.S.



2/2|3 TYPICAL DRAINAGE BENCH CROSS SECTION WITH V-CHANNEL CONFIGURATION REDUCED BY SEDIMENTATION
N.T.S.

NOTE:

RECLAIMED SLOPES VARY FROM 3H:1V TO APPROXIMATELY 4H:1V.

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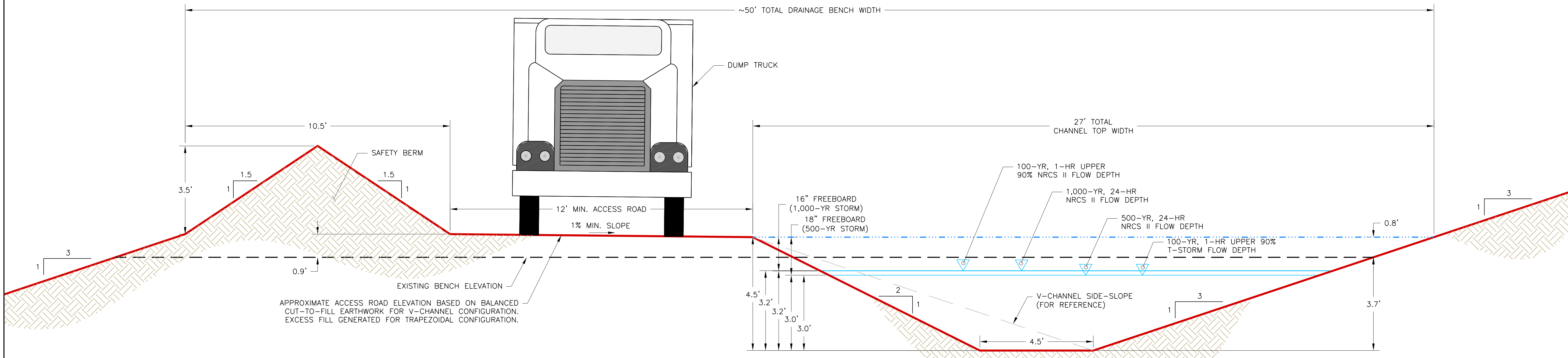
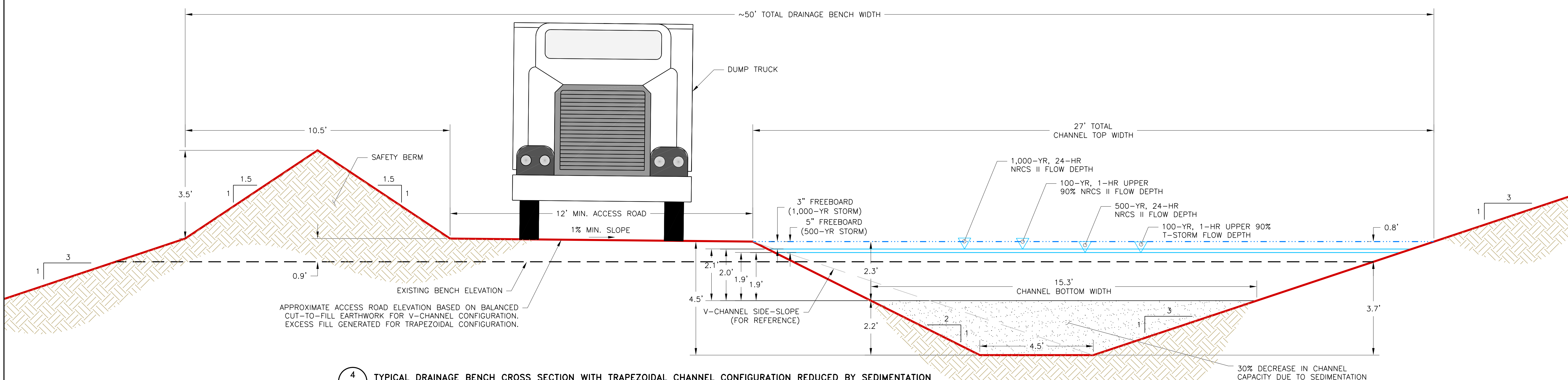
Title:
DRY STACK TAILINGS FACILITY
DRAINAGE BENCH ANALYSIS
V-CHANNEL SECTIONS

A
REVISION

Project:	Project no.:	Figure no.:
ROSEMONT COPPER PROJECT	320832	3
Location: PIMA COUNTY, ARIZONA	Date: 01/10	



3 (2 | 4) TYPICAL DRAINAGE BENCH CROSS SECTION WITH TRAPEZOIDAL CHANNEL CONFIGURATION
N.T.S.



4 (2 | 4) TYPICAL DRAINAGE BENCH CROSS SECTION WITH TRAPEZOIDAL CHANNEL CONFIGURATION REDUCED BY SEDIMENTATION
N.T.S.

NOTE:

RECLAIMED SLOPES VARY FROM 3H:1V TO APPROXIMATELY 4H:1V.

Issued by:	Title:	
TETRA TECH 3031 West Ina Road Tucson, Arizona 85741 (520) 297-7723 (520) 297-7724 fax	DRY STACK TAILINGS FACILITY DRAINAGE BENCH ANALYSIS TRAPEZOIDAL CHANNEL SECTIONS	A REVISION
Project: ROSEMONT COPPER PROJECT	Project no.: 320832	Figure no.: 4
Location: PIMA COUNTY, ARIZONA	Date: 01/10	

ATTACHMENT 1
OUTPUT RESULTS

TETRA TECH

Summary of V-Channel Hydrologic and Hydraulic Analysis Calculations and Results

	CAD Data and Calculations											1,000-year 24-hour NRCS Type II Storm							500-year 24-hour NRCS Type II Storm						
Basin Name	A (ft2)	A (ac)	A (mi2)	L1 (ft)	H1 (ft)	S1 (ft/ft)	L2 (ft)	H2 (ft)	S2 (ft/ft)	V1-sht (ft/s)	T1-sht (min)	V2-ch (ft/s)	T2-ch (min)	Tc (min)	Tlag (min)	Qpeak (cfs)	Vol. (ac-ft)	D-3:1 V-ch (ft)	V2-ch (ft/s)	T2-ch (min)	Tc (min)	Tlag (min)	Qpeak (cfs)	Vol. (ac-ft)	D-3:1 V-ch (ft)
SE Tailings Bench 1	964,713	22.15	0.0346	111	28	0.25	3,027	61	0.02	7.60	0.24	5.88	8.6	8.8	5.3	156.4	8.9	2.98	5.71	8.8	9.1	5.4	139.2	7.9	2.85
SE Tailings Bench 2	1,371,673	31.49	0.0492	425	106	0.25	3,254	65	0.02	7.60	0.93	6.40	8.5	9.4	5.6	220.0	12.7	3.38	6.21	8.7	9.7	5.8	195.3	11.3	3.24
SE Tailings Bench 3	1,356,619	31.14	0.0487	340	105	0.31	3,555	71	0.02	8.46	0.67	6.36	9.3	10.0	6.0	214.3	12.6	3.35	6.17	9.6	10.3	6.2	189.8	11.2	3.20
SE Tailings Bench 4	1,168,293	26.82	0.0419	329	107	0.33	3,384	68	0.02	8.67	0.63	6.13	9.2	9.8	5.9	185.3	10.8	3.17	5.95	9.5	10.1	6.1	164.2	9.6	3.03
SE Tailings Bench 5	1,109,082	25.46	0.0398	308	103	0.33	2,702	54	0.02	8.78	0.58	6.12	7.4	7.9	4.8	183.6	10.3	3.16	5.95	7.6	8.2	4.9	163.6	9.1	3.03
SE Tailings Bench 6	324,529	7.45	0.0116	0	0	0.00	2,615	52	0.02	0.00	0.00	4.45	9.8	9.8	5.9	51.5	3.0	1.96	4.32	10.1	10.1	6.1	45.6	2.7	1.88
SE Tailings Bench 7	938,603	21.55	0.0337	330	102	0.31	2,156	43	0.02	8.46	0.65	5.91	6.1	6.7	4.0	160.2	8.7	3.00	5.75	6.2	6.9	4.1	142.7	7.7	2.88
SE Tailings Bench 8	843,537	19.36	0.0303	313	104	0.33	2,198	44	0.02	8.78	0.59	5.75	6.4	7.0	4.2	142.8	7.8	2.88	5.58	6.6	7.2	4.3	127.0	6.9	2.75
SE Tailings Bench 9	402,516	9.24	0.0144	328	109	0.33	1,007	20	0.02	8.78	0.62	4.85	3.5	4.1	2.4	72.7	3.7	2.23	4.72	3.6	4.2	2.5	64.7	3.3	2.14
SE Drop (Benches 1-3)	**3,693,005**	**84.78**	**0.1325**													**590.7**	**34.2**						**524.3**	**30.4**	
NE Tailings Bench 1	1,100,000	25.25	0.0395	111	28	0.25	4,365	87	0.02	7.60	0.24	5.94	12.2	12.5	7.5	163.5	10.2	3.03	5.77	12.6	12.9	7.7	145.1	9.1	2.90
NE Tailings Bench 2	1,802,016	41.37	0.0646	425	106	0.25	4,553	91	0.02	7.60	0.93	6.74	11.3	12.2	7.3	270.0	16.7	3.65	6.54	11.6	12.5	7.5	239.4	14.8	3.49
NE Tailings Bench 3	1,404,061	32.23	0.0504	340	105	0.31	3,929	79	0.02	8.46	0.67	6.38	10.3	10.9	6.6	216.5	13.0	3.36	6.19	10.6	11.2	6.7	192.8	11.6	3.22
NE Tailings Bench 4	1,521,678	34.93	0.0546	329	107	0.33	4,157	83	0.02	8.67	0.63	6.49	10.7	11.3	6.8	232.9	14.1	3.46	6.30	11.0	11.6	7.0	206.5	12.5	3.30
NE Tailings Bench 5	1,320,696	30.32	0.0474	308	103	0.33	3,657	73	0.02	8.78	0.58	6.31	9.7	10.2	6.1	207.8	12.2	3.31	6.12	10.0	10.5	6.3	183.9	10.9	3.16
NE Tailings Bench 6	472,077	10.84	0.0169	251	84	0.33	1,448	29	0.02	8.78	0.48	5.02	4.8	5.3	3.2	83.0	4.4	2.35	4.87	5.0	5.4	3.3	73.9	3.9	2.25
NE Tailings Bench 7	600,841	13.79	0.0216	304	101	0.33	1,726	35	0.02	8.78	0.58	5.31	5.4	6.0	3.6	103.8	5.6	2.55	5.16	5.6	6.2	3.7	92.6	4.9	2.45
NE Drop (Benches 1-2)	**2,902,017**	**66.62**	**0.1041**													**433.5**	**26.9**						**384.5**	**23.9**	
NE Drop (Benches 6-7)	**1,072,918**	**24.63**	**0.0385**													**186.8**	**10.0**						**166.5**	**8.8**	
NW Tailings Bench 1	385,315	8.85	0.0138	250	83	0.33	1,274	25	0.02	8.78	0.48	4.78	4.4	4.9	3.0	68.2	3.6	2.18	4.65	4.6	5.0	3.0	61.0	3.2	2.09
NW Tailings Bench 2	560,589	12.87	0.0201	313	104	0.33	1,638	33	0.02	8.78	0.59	5.22	5.2	5.8	3.5	97.2	5.2	2.49	5.07	5.4	6.0	3.6	86.7	4.6	2.39
NW Tailings Bench 3	498,194	11.44	0.0179	251	84	0.33	1,600	32	0.02	8.78	0.48	5.07	5.3	5.7	3.4	86.8	4.6	2.39	4.93	5.4	5.9	3.5	77.2	4.1	2.29
NW Tailings Bench 4	676,204	15.52	0.0243	304	101	0.33	1,941	39	0.02	8.78	0.58	5.45	5.9	6.5	3.9	115.8	6.3	2.66	5.30	6.1	6.7	4.0	103.2	5.6	2.55
NW Drop (Benches 1-2)	**945,904**	**21.71**	**0.0339**													**165.4**	**8.8**						**147.7**	**7.8**	
NW Drop (Benches 3-4)	**1,174,398**	**26.96**	**0.0421**													**202.6**	**10.9**						**180.4**	**9.7**	
W Tailings Bench 1	760,473	17.46	0.0273	272	91	0.33	2,154	43	0.02	8.78	0.52	5.61	6.4	6.9	4.1	129.3	7.0	2.77	5.45	6.6	7.1	4.3	114.5	6.3	2.65
W Tailings Bench 2	618,671	14.20	0.0222	299	100	0.33	1,669	33	0.02	8.78	0.57	5.35	5.2	5.8	3.5	107.3	5.7	2.59	5.20	5.4	5.9	3.6	95.6	5.1	2.48
W Tailings Bench 3	226,019	5.19	0.0081	318	106	0.33	595	12	0.02	8.78	0.60	4.22	2.4	3.0	1.8	41.5	2.1	1.81	4.10	2.4	3.0	1.8	37.1	1.9	1.74
W Tailings Bench 4	334,728	7.68	0.0120	250	83	0.33	1,028	21	0.02	8.78	0.48	4.63	3.7	4.2	2.5	60.2	3.1	2.08	4.50	3.8	4.3	2.6	53.6	2.8	1.99
W Tailings Bench 5	407,895	9.36	0.0146	313	104	0.33	1,245	25	0.02	8.78	0.59	4.85	4.3	4.9	2.9	72.4	3.8	2.23	4.71	4.4	5.0	3.0	64.6	3.4	2.14
W Tailings Bench 6	398,769	9.15	0.0143	161	54	0.33	1,522	30	0.02	8.78	0.31	4.81	5.3	5.6	3.3	69.8	3.7	2.20	4.67	5.4	5.7	3.4	62.1	3.3	2.11
W Drop (Benches 1 & 4)	**1,095,201**	**25.14**	**0.0393**													**189.5**	**10.1**						**168.1**	**9.1**	
SW Tailings Bench 1	429,307	9.86	0.0154	421	105	0.25	1,255	25	0.02	7.60	0.92	4.91	4.3	5.2	3.1	75.8	4.0	2.27	4.77	4.4	5.3	3.2	67.5	3.5	2.17
SW Tailings Bench 2	526,906	12.10	0.0189	430	86	0.20	1,712	34	0.02	6.80	1.05	5.12	5.6	6.6	4.0	89.9	4.9	2.42	4.97	5.7	6.8	4.1	80.1	4.3	2.32
SW Tailings Bench 3	747,751	17.17	0.0268	272	91	0.33	1,953	39	0.02	8.78	0.52	5.60	5.8	6.3	3.8	128.5	6.9	2.77	5.44	6.0	6.5	3.9	114.5	6.2	2.65
SW Tailings Bench 4	632,720	14.53	0.0227	299	100	0.33	1,823	36	0.02	8.78	0.57	5.37	5.7	6.2	3.7	109.1	5.9	2.60	5.22	5.8	6.4	3.8	97.2	5.2	2.49
SW Tailings Bench 5	501,059	11.50	0.0180	318	106	0.33	1,385	28	0.02	8.78	0.60	5.10	4.5	5.1	3.1	88.4	4.6	2.40	4.95	4.7	5.3	3.2	78.7	4.1	2.30
SW Drop (Benches 1-4)	**2,336,683**	**53.64**	**0.0838**													**403.3**	**21.7**						**359.3**	**19.2**	

Summary of NE Tailings Bench 2 Hydrologic and Hydraulic Analysis Calculations and Results

NE Tailings Bench 2		3:1 V-Channel									3:1 V-Channel w/ 30% Decrease				2:1 & 3:1 Trapezoidal Channel				2:1 & 3:1 Trapez. Channel w/ 30% Decr.			
Storm	Return (yrs)	1000	500	100	100	100	100	100	100	100	1000	500	100	100	1000	500	100	100	1000	500	100	100
	Duration (hrs)	24	24	24	24	1	1	1	1	1	24	24	1	1	24	24	1	1	24	24	1	1
	Precip. (in)	6.57	6.00	5.35*	4.75	3.56*	3.17	3.56*	3.17	3.17	6.57	6.00	3.56*	3.56*	6.57	6.00	3.56*	3.56*	6.57	6.00	3.56*	3.56*
	Distrib. Type	NRCS II	NRCS II	NRCS II	NRCS II	NRCS II	NRCS II	T-storm	T-storm	Compr'd	NRCS II	NRCS II	NRCS II	T-storm	NRCS II	NRCS II	NRCS II	T-storm	NRCS II	NRCS II	NRCS II	T-storm
CAD Data	A (ft2)	1,802,016									1,802,016				1,802,016				1,802,016			
	A (ac)	41.37									41.37				41.37				41.37			
	A (mi2)	0.0646									0.0646				0.0646				0.0646			
	L1 (ft)	425									425				425				425			
	H1 (ft)	106									106				106				106			
	S1 (ft/ft)	0.25									0.25				0.25				0.25			
	L2 (ft)	4,553									4,553				4,553				4,553			
	H2 (ft)	91									91				91				91			
	S2 (ft/ft)	0.02									0.02				0.02				0.02			
	Width-ch bot (ft)	0.00									14.85				4.52				15.32			
	CN	85									85				85				85			
Calculations	S-NRCS (in)	1.76									1.76				1.76				1.76			
	Ia (in)	0.35									0.35				0.35				0.35			
	a	15.2									15.2				15.2				15.2			
	Manning's n-ch	0.045									0.045				0.045				0.045			
	V1-sheet (ft/s)	7.60									7.60				7.60				7.60			
	T1-sheet (min)	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	V2-ch (ft/s)	6.74	6.54	6.29	6.03	6.75	6.42	6.54	6.22	6.13	6.21	5.98	6.19	5.96	6.95	6.74	6.97	6.74	6.35	6.11	6.34	6.10
	T2-ch (min)	11.3	11.6	12.1	12.6	11.2	11.8	11.6	12.2	12.4	12.2	12.7	12.3	12.7	10.9	11.3	10.9	11.3	12.0	12.4	12.0	12.4
	Tc (min)	12.2	12.5	13.0	13.5	12.2	12.8	12.5	13.1	13.3	13.2	13.6	13.2	13.7	11.9	12.2	11.8	12.2	12.9	13.4	12.9	13.4
	Tlag (min)	7.3	7.5	7.8	8.1	7.3	7.7	7.5	7.9	8.0	7.9	8.2	7.9	8.2	7.1	7.3	7.1	7.3	7.7	8.0	7.7	8.0
	HEC Qp (cfs)	270.0	239.4	204.6	172.7	271.0	221.8	239.2	196.1	184.9	264.0	232.8	261.3	230.2	272.4	232.8	274.8	241.4	266.0	234.9	264.2	233.0
	HEC Vol. (ac-ft)	16.7	14.8	12.7	10.8	7.1	6.0	7.1	6.0	6.0	16.7	14.8	7.1	7.1	16.7	14.8	7.1	7.1	16.7	14.8	7.1	7.1
	Depth-ch (ft)	3.65	3.49	3.29	3.09	3.66	3.39	3.49	3.24	3.17	2.03	1.89	2.02	1.88	3.16	2.99	3.17	2.99	2.05	1.91	2.04	1.90

*Denotes the upper bound of the 90% confidence interval (from NOAA Atlas 14)