RECOMMENDED EMBANKMENT PROTECTION

FOR

EFFLUENT LAKE 27-1

AT

FOUNTAIN HILLS, ARIZONA

December 21, 1994

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Prepared for

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Phoenix, Arizona 85008

Prepared by

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ARIZONA, U.S.A.

RECOMMENDED EMBANKMENT PROTECTION FOR EFFLUENT LAKE 27-1 AT FOUNTAIN HILLS, ARIZONA

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Registered Professional Engineer (Civil) CERTIFICATE NO. 10283 SAMUEL E. KAO Date Signed 12/21/94 ARIZONA, U.S.A.

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RECOMMENDED EMBANKMENT PROTECTION FOR EFFLUENT LAKE 27-1 AT FOUNTAIN HILLS, ARIZONA

A. PURPOSE AND SCOPE

This report is a sequel to the report entitled, *Hydrologic Study for Effluent Lakes Project at Fountain Hills, Arizona*, prepared by AGK Engineers on December 6, 1994 for Anderson-Nelson, Inc. (**Reference 1**). The scope of this report is to perform a hydraulic analysis and recommend necessary protection for the embankment of Lake 27-1 along Cereus Wash.

B. PROJECT LOCATION

The project area is located at the central part of Section 27, Township 3 North, Range 6 East, Gila and Salt River Base and Meridian, Maricopa County, Arizona.

C. DESIGN FLOWS

As summarized in Table 1, the design flows are the 100-year peak discharges in various reaches of Cereus Wash under future development conditions, without any upstream lakes. The derivation of these flows is presented in Appendix D.4 of **Reference 1**.

TABLE 1
DESIGN FLOWS IN VARIOUS REACHES OF CEREUS WASH

Location	Design Flow (cfs)
At downstream end of culvert on Saguaro Blvd	595
Estimated flow through the culvert on Saguaro Blvd	563
Between Saguaro Blvd and Conc. Pt. CER8	2998
Between Conc. Pt. CER8 and Travino Wash Confluence	2961
Between Travino Wash Confluence and Conc. Pt. CER7	2877
Reach along Lake 27-1 Embankment	2860

D. HYDRAULIC ANALYSIS

1. Methodology

Water surface elevations and velocities along the study reach of Cereus Wash were computed by use of the HEC-2 computer program (**Reference 2**). The HEC-2 program was run for the following two conditions:

Condition 1- Existing channel of Cereus Wash without the proposed Lake 27-1

Condition 2- Cereus Wash with the proposed Lake 27-1 in place

The HEC-2 outputs for Conditions 1 and 2 are presented in **Appendices B.1 and B.2**, respectively.

2. Channel Cross Sections

The HEC-2 analysis started at the existing double-barrel 60" CMP culvert under Saguaro Boulevard, even though the proposed Lake 27-1 is much further upstream from this location. Since AGK Engineers is currently performing a floodplain delineation project for the southern part of the Fountain Hills area under contract with the Flood Control District of Maricopa County (District), the same set of channel cross sections was used for the study reach without the proposed Lake 27-1 (Condition 1). These cross sections were digitized by Kenney Aerial Mapping based on their topographic maps prepared in 1991 (**Reference 3**).

Cross sections along the embankment of the proposed lake were modified when the HEC-2 analysis for Condition 2 was performed. Modification was based on the embankment design information as shown on Anderson-Nelson's plans (**Reference 4**). Elevations obtained from Anderson-Nelson's plans were adjusted to conform with the survey datum used by Kenney Aerial Mapping. In addition, three new sections (Sections 371, 376, and 379) were added to the HEC-2 input data in order to have a more complete description of the cross-sectional geometry along the embankment.

3. Manning's Roughness Coefficient

Values of Manning's roughness coefficient were estimated in accordance with the methodology and procedure described in **Reference 5**. Details of the estimation are presented in **Appendix A**. The estimated values of Manning's roughness coefficient have been reviewed and approved by the District.

For the modified cross sections along the embankment of the proposed lake, a Manning's *n* value of 0.025 was used to represent the roughness coefficient on the dam embankment. The NH cards were used for the modification of Manning's *n* values in the HEC-2 input.

4. Coefficients of Contraction and Expansion

The coefficients of contraction and expansion were respectively assumed to be 0.1 and 0.3 for ordinary channel sections. At the downstream of the Travino Wash confluence, the coefficients of contraction and expansion were assumed to be 0.2 and 0.4. Furthermore, at the culvert of Saguaro Boulevard, the coefficients were assumed to be 0.3 and 0.5, respectively.

5. Flow Velocities

Flow velocities obtained from the HEC-2 output (**Appendix B.2**) for the seven cross sections along the lake embankment are summarized in Table 2. The highest velocity along the embankment was estimated to be 12.5 fps, which occurred in the vicinity of Section 374; while the highest channel velocity was 13.4 fps, which occurs near Section 371.

TABLE 2
ESTIMATED FLOW VELOCITIES IN CEREUS WASH

Channel Section	Flow Velocity (fps)		
	Left Overbank	Channel	Right Overbank
369	0	10.6	0
371	9.9	13.4	6.3
374	12.5	12.1	2.4
376	7.2	13.0	5.9
379	3.7	10.3	3.5
382	4.6	9.4	5.2
393	4.0	10.6	6.5

E. PROPOSED EMBANKMENT PROTECTION

1. Riprap Size

Since the flow velocities obtained from the HEC-2 output were far greater than the permissible velocity along an earthen embankment, rock riprap is proposed to be installed on the outer slope of the embankment for erosion protection.

The MAG Standard Specifications (**Reference 8**) calls for a median stone size (D_{50}) equivalent to 12.6 inches for riprap purposes. The size of stone required for this project was separately checked in accordance with the procedures and guidelines developed by the Federal Highway Administration (**References 6** and **7**) and the Army Corps of Engineers (**Reference 10**). Detailed calculations are presented in Appendix C. Based on both methods, the required median stone size appeared to be around 6 inches. Since the median stone size (D_{50}) specified in MAG Standard Specifications would provide a safety factor of 2, we recommend that the materials specified in Sections 703.1 and 703.2 of the MAG Standard Specifications be used for embankment protection of Lake 27-1, provided that the minimum stone size be revised in accordance with the gradation requirements contained in this report.

2. Riprap Gradation

The gradation requirements for stones, as shown in Table 3, were determined based on the criteria developed by the Flood Control District of Maricopa County.

TABLE 3
RECOMMENDED RIPRAP GRADATION

Percent Passing	Stone Size in Terms of D_{50}	Stone Size (inches)
90 to 100	2.0 $_{D50}$	24
70 to 85	1.5 $_{D50}$	18
30 to 50	1.0 $_{D50}$	12
5 to 15	0.67 $_{D50}$	8
0 to 5	0.33 $_{D50}$	4

3. Thickness of Riprap Layer

The minimum thickness of riprap layer was set to be 24 inches, which is equal to the maximum stone size.

4. Riprap Installation

A typical section of the riprap with toe trench is presented in Appendix C. The installation of riprap shall be in accordance with Section 913-3 of Arizona Department of Transportation's (ADOT) Standard Specifications for Road and Bridge Construction (**Reference 9**). The filter fabric material under the riprap layer shall conform to ADOT Standard Specs Section 913-2.05. The toe trench for riprap shall be at least five (5) feet below the streambed.

5. Degradation Potential in Cereus Wash

At the present time, a double-barrel 60" CMP culvert is located in Cereus Wash at Saguaro Boulevard. It was reported that MCO Properties is planning to replace this culvert with a double-barrel reinforced concrete box culvert at the same grade. Since either the present or the future culvert would serve as a grade control structure, significant degradation in the upstream reaches of Cereus Wash would not likely occur in the future.

6. Impact of Riprap on Water Surface Elevations

A HEC-2 run was performed to reflect the impact of riprap on water surface elevations in Cereus Wash. A Manning's *n* value of 0.038 was used for the riprap surface. The HEC-2 output for this run is presented in Appendix B.3. The impact on water surface elevations is shown in Table 4. The top of riprap along the lake embankment is recommended to be extended at least five (5) feet above the "new" water surface elevations.

TABLE 4
CHANGE OF WATER SURFACE ELEVATION DUE TO RIPRAP INSTALLATION

Channel Section	Estimated Water Surface Elevation before Riprap		Estimated Water Surface Elevation after Riprap	
	Anderson-Nelson Survey Datum	Kenney Aerial Survey Datum	Anderson-Nelson Survey Datum	Kenney Aerial Survey Datum
369	1600.00	1598.74	1600.00	1598.74
371	1602.83	1601.57	1602.94	1601.68
374	1604.75	1603.49	1604.85	1603.59
376	1606.96	1605.70	1607.15	1605.89
379	1608.55	1607.29	1608.56	1607.30
382	1611.03	1609.77	1611.04	1609.78
393	1617.40	1616.14	1617.40	1616.14
400	1621.54	1620.28	1621.54	1620.28

REFERENCES

1. AGK Engineers, Inc., *Hydrologic Study for Effluent Lakes Project at Fountain Hills, Arizona*, December 6, 1994.

2. U.S. Department of the Army, Corps of Engineers, Hydrologic Engineering Center, *Generalized Computer Program 723-X6-L202A, HEC-2 Water Surface Profiles,* Davis, California, May 1991.

3. Kenney Aerial Mapping, Inc., *Topographic Maps for the Town of Fountain Hills, Scale 1" = 200', Contour Interval = 2 feet,* 1991.

4. Anderson-Nelson, Inc., *Fountain Hills, Arizona - Effluent Lakes Plan*, September 2, 1994.

5. Thomsen, B.W. and Hjalmarson, H.W., *Manning's Roughness Coefficients for Stream Channels and Flood Plains in Maricopa County, Arizona*, April 1991.

6. Federal Highway Administration, *Use of Riprap for Bank Protection*, Hydraulic Engineering Circular No. 11, June 1967.

7. Richardson, E.V., Simons, D.B. Julien, P.Y., *Highways in the River Environment*, Federal Highway Administration, January 1987.

8. Maricopa Association of Governments (MAG), *Uniform Standard Specifications for Public Works Construction*, 1979.

9. Arizona Department of Transportation (ADOT), *Standard Specifications for Road and Bridge Construction*, 1990

10. U.S. Department of the Army, Corps of Engineers, *Hydraulic Design of Flood Control Channels*, EM 1110-2-1601, July 1970.

11. Flood Control District of Maricopa County, *Drainage Design Manual for Maricopa County, Arizona*, Volume II - Hydraulics, November 1991.

APPENDIX A

ESTIMATION OF MANNING'S *N* VALUE

ESTIMATION OF MANNING'S *n* VALUES

Manning's roughness coefficients were estimated in accordance with the methodology described in *Estimated Manning's Roughness Coefficient for Streams, Channels, and Flood Plains in Maricopa County, Arizona* (USGS, Water Resources Division, April 1991). The method described in this publication selects a base value for the roughness coefficient exclusively on bed material. This base value is then modified by adding adjustments to account for vegetation, irregularities, obstructions and cross section variations. A multiplier applied to the adjusted *n*-values if meandering of the reach is significant.

Vegetation and bed materials were identified with the aid of 1" = 100' aerial photographs and field observations. Channel reaches were photographed during field reconnaissance phase at representative and accessible locations.

The base roughness coefficient was selected based on the average particle size observed in the field. The typical average size of the bed materials in the study area ranges from 0.08" to 2.5". For this size of bed material the typical values of the roughness coefficient range from 0.027 to 0.035. Values greater than 0.035 were used for reaches where the average particle size is larger than 2.5 inches.

The base values, adjusting values, and the adjusted values for Manning's roughness coefficient are shown in the following tables.

DETERMINATION OF MANNING'S ROUGHNESS COEFFICIENTS BY FCDMC METHOD

Project: Fountain Hills South Flood Delineation Study
Stream: Cereus Wash - CER2
Location: From downstream from Saguaro Blvd. to Trevino Wash confluence - South west ¼ of section 26
Picture: CER-P2, CER-P3, CER-P4, CER-P5, CER-P6

Channel Conditions		Manning's n Adjustment		Left Overbank	Channel	Right Overbank
Channel Material	Concrete	n_b	.012 - .018			
	Firm soil		.025 - .032			
	Coarse sand		.026 - .035	0.028	0.030	0.028
	Gravel		.028 - .035			
	Cobble		.030 - .050			
	Boulder		.040 - .070			
Degree of Irregularity	Smooth	n_1	.000			
	Minor		.001 - .005			
	Moderate		.006 - .010			
	Severe		.011 - .020			
Effects of Obstruction	Negligible	n_2	.000 - .004			
	Minor		.005 - .015			
	Appreciable		.020 - .030			
	Severe		.040 - .060			
Vegetation	Small	n_3	.002 - .010		0.002	
	Medium		.010 - .025			
	Large		.025 - .050			
	Very Large		.050 - .100	0.05		0.05
Variations in Channel Cross section	Gradual	n_4	.000			
	Occ. Alt.		.001 - .005			
	Freq. Alt.		.010 - .015			
			0.34	0.078	0.032	0.078
Degree of Meandering	Minor	m	1.00	1.00		1.00
	Appreciable		1.15		1.15	
	Sever		1.30			
$n = (n_b+n_1+n_2+n_3+n_4)m$				0.078	0.037	0.078

DETERMINATION OF MANNING'S ROUGHNESS COEFFICIENTS BY FCDMC METHOD

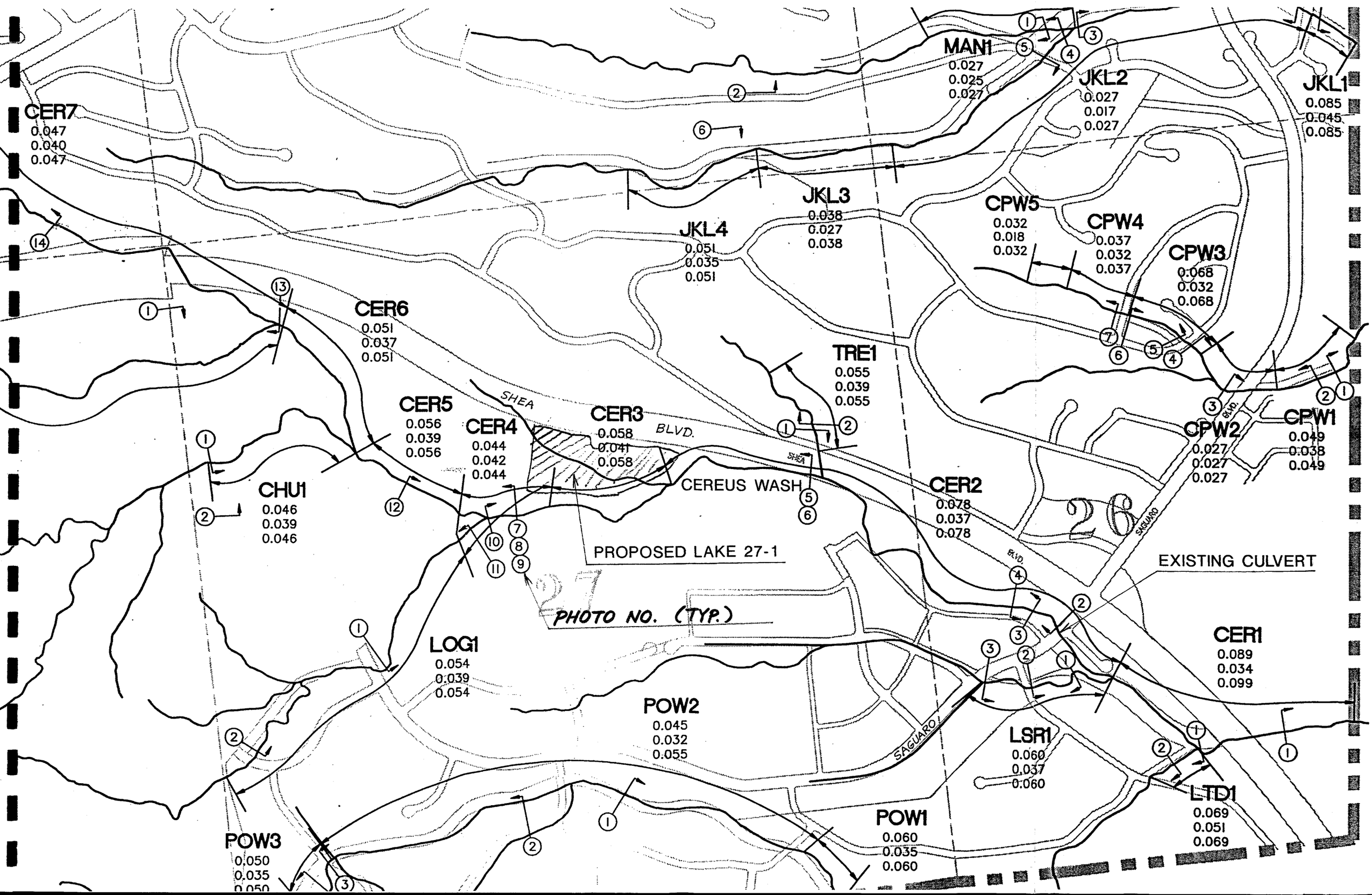
Project: Fountain Hills South Flood Delineation Study
Stream: Cereus Wash - CER3
Location: North east ¼ of section 27
Picture: No picture

Channel Conditions		Manning's n Adjustment		Left Overbank	Channel	Right Overbank
Channel Material	Concrete	n_b	.012 - .018			
	Firm soil		.025 - .032	0.027		0.027
	Coarse sand		.026 - .035		0.027	
	Gravel		.028 - .035			
	Cobble		.030 - .050			
	Boulder		.040 - .070			
Degree of Irregularity	Smooth	n_1	.000			
	Minor		.001 - .005			
	Moderate		.006 - .010			
	Severe		.011 - .020			
Effects of Obstruction	Negligible	n_2	.000 - .004			
	Minor		.005 - .015			
	Appreciable		.020 - .030			
	Severe		.040 - .060			
Vegetation	Small	n_3	.002 - .010		0.008	
	Medium		.010 - .025			
	Large		.025 - .050	0.030		0.030
	Very Large		.050 - .100			
Variations in Channel Cross section	Gradual	n_4	.000			
	Occ. Alt.		.001 - .005	0.001	0.001	0.001
	Freq. Alt.		.010 - .015			
			0.34	0.058	0.036	0.058
Degree of Meandering	Minor	m	1.00	1.00		1.00
	Appreciable		1.15		1.15	
	Sever		1.30			
$n = (n_b+n_1+n_2+n_3+n_4)m$				0.058	0.041	0.058

DETERMINATION OF MANNING'S ROUGHNESS COEFFICIENTS BY FCDMC METHOD

Project: Fountain Hills South Flood Delineation Study
Stream: Cereus Wash - CER4
Location: North west ¼ of section 27
Picture: CER-P7, CER-P8, CER-P9, CER-P10, CER-P11

Channel Conditions		Manning's n Adjustment		Left Overbank	Channel	Right Overbank
Channel Material	Concrete	n_b	.012 - .018			
	Firm soil		.025 - .032	0.029		0.029
	Coarse sand		.026 - .035		0.027	
	Gravel		.028 - .035			
	Cobble		.030 - .050			
	Boulder		.040 - .070			
Degree of Irregularity	Smooth	n_1	.000			
	Minor		.001 - .005			
	Moderate		.006 - .010			
	Severe		.011 - .020			
Effects of Obstruction	Negligible	n_2	.000 - .004			
	Minor		.005 - .015			
	Appreciable		.020 - .030			
	Severe		.040 - .060			
Vegetation	Small	n_3	.002 - .010	0.010	0.010	0.010
	Medium		.010 - .025			
	Large		.025 - .050			
	Very Large		.050 - .100			
Variations in Channel Cross section	Gradual	n_4	.000			
	Occ. Alt.		.001 - .005	0.005	0.005	0.005
	Freq. Alt.		.010 - .015			
			0.34	0.044	0.042	0.044
Degree of Meandering	Minor	m	1.00	1.00	1.00	1.00
	Appreciable		1.15			
	Sever		1.30			
$n = (n_b+n_1+n_2+n_3+n_4)m$				0.044	0.042	0.044


MAN1
0.027
0.025
0.027
JKL2
0.027
0.017
0.027
JKL1
0.085
0.045
0.085
CER7
0.047
0.040
0.047
JKL3
0.038
0.027
0.038
JKL4
0.051
0.035
0.051
CPW5
0.032
0.018
0.032
CPW4
0.037
0.032
0.037
CPW3
0.068
0.032
0.068
CER6
0.051
0.037
0.051
TRE1
0.055
0.039
0.055
CER5
0.056
0.039
0.056
CER4
0.044
0.042
0.044
CER3
0.058
0.041
0.058
SHEA
BLVD.
CEREUS WASH
CPW2
0.027
0.027
0.027
CPW1
0.049
0.038
0.049
CHU1
0.046
0.039
0.046
CER2
0.078
0.037
0.078
26
SAGUARO
BLVD.
PROPOSED LAKE 27-1
EXISTING CULVERT
27
PHOTO NO. (TYP.)
LOG1
0.054
0.039
0.054
CER1
0.089
0.034
0.099
POW2
0.045
0.032
0.055
LSR1
0.060
0.037
0.060
LTD1
0.069
0.051
0.069
POW1
0.060
0.035
0.060
POW3
0.050
0.035
0.050

CEREUS WASH

CER-P4

CER-P5

CER-P6

CER-P10

CEREUS WASH

CER-P7 CER-P8 CER-P9

APPENDIX B.1

HEC-2 OUTPUT FOR CEREUS WASH WITHOUT LAKE 27-1

```
*****************************************
* HEC-2 WATER SURFACE PROFILES          *
*                                       *
* Version   4.6.2;  May 1991            *
*                                       *
* RUN DATE    09DEC94    TIME   07:41:17 *
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****************************************
* U.S. ARMY CORPS OF ENGINEERS         *
* HYDROLOGIC ENGINEERING CENTER        *
* 609 SECOND STREET, SUITE D           *
* DAVIS, CALIFORNIA 95616-4687         *
*          (916) 756-1104              *
****************************************
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X     X  XXXXXXX   XXXXX              XXXXX
X     X  X        X     X            X     X
X     X  X        X                        X
XXXXXXX  XXXX     X          XXXXX    XXXXX
X     X  X        X                  X
X     X  X        X     X            X
X     X  XXXXXXX   XXXXX             XXXXXXX
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THIS RUN EXECUTED 09DEC94 07:41:17

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************************************
HEC-2 WATER SURFACE PROFILES

Version   4.6.2;  May 1991
************************************


T1      Fountain Hills Efluent Lake 27-1 Scour Analisys
T1      Prepared for Anderson-Nelson, Inc.
T1      by AGK Engineers, Inc.  (HAA)

T2      Furure Development - No Lakes
T3      Fountain Hills - CEREUS WASH -  Lake 27-1

T1  ICHECK    INQ      NINV     IDIR     STRT     METRIC   HVINS    Q        WSEL     FQ

              2                          -1                                 1550

T2  NPROF     IPLOT    PRFVS    XSECV    XSECH    FN       ALLDC    IBW      CHNIM    ITRACE

                                                           -1

T3  VARIABLE CODES FOR SUMMARY PRINTOUT

    38       10        8       53       54        1       68
    38       43       26        1        2       10        8        3       58      200
    38        8       49       86       46       47


  Culvert Outlet CER2
  Conc. Point *CER11 Flow upstrem from Laser Drain confluence

QT       2      595      595
NC    .078     .037     .078      0.3      0.5
X1     301       20     9995    10005       80       80       80
X3      10                                                  1554.31  1553.78
GR  1563.5   9905.5   1564.4   9943.9   1563.2   9951.4   1556.0   9964.0   1550.6   9979.7
GR  1549.8   9993.0   1546.3     9995   1546.3  10000.0   1546.3    10005   1546.9  10010.3
GR  1550.6  10023.8   1553.2  10038.7   1554.6  10050.3   1556.2  10064.5   1557.8  10078.8
GR  1559.6  10086.7   1561.8  10098.2   1563.7  10107.4   1564.3  10117.4   1564.3  10118.5

  Culvert - CER2 -  2 CMP 60" X 110'  Saguaro Blvd.
  Conc. point SCER9 Flow throught Saguaro Blvd. Culvert
```

```
QT        2       563       563
SC    2.024        .8         3                  5                 110       2.3   1549.75    1546.3

 Culvert inlet CER2
X1      304        19    9993.4   10009.5       120       150       120
X2                          2                1563.6
X3       10                                                        1564.6    1563.6
T        -7   9735.28      1566                9950    1564.6                10000    1564.3
T             10050   1564.07                10082.9    1563.6              10104.9      1564
BT            10164.0      1566
GR     1566   9735.28      1564   9898.72    1563.8    9914.7    1563.4    9949.7    1561.4    9959.6
R    1554.3    9979.9    1552.5    9988.6    1550.6    9993.4    1549.7      9994    1549.7   10000.0
R    1549.7     10006    1550.6   10009.5    1555.9   10024.0    1563.5   10041.0    1561.1   10053.9
R    1562.8   10065.8    1563.6   10082.9      1564   10104.9      1566   10164.0

 Conc. point CER9 Flow upstrem from Saguaro Blvd.

T        2      2998      2998
X1     305        14    9982.7   10020.2        60       100        59
GR     1566   9864.71    1564.0    9915.3    1563.7    9953.0    1562.3    9961.6    1551.8    9982.7
R    1551.4   10000.0    1551.7   10020.2    1552.2   10029.7    1552.2   10033.9    1564.7   10061.4
R    1563.4   10083.6    1563.5   10092.3      1564   10149.8      1566   10184.1

NC                                     .1        .3

1      314        13    9986.3   10020.2       500       420       472
GR   1571.9    9900.0    1569.6    9920.0    1563.3    9946.5    1560.6    9970.5    1557.4    9986.3
GR   1557.1   10000.0    1557.5   10020.2    1558.6   10028.4    1559.1   10044.8    1560.5   10056.1
R    1568.2   10078.3    1569.8   10098.2    1571.6   10113.4

NC                                     .2        .4

1      323        21      9976      10016       460       530       498
R    1578.5    9882.3    1578.3    9900.4    1577.2    9915.8    1576.1    9924.8    1573.6    9932.7
GR   1569.2    9938.3    1565.2    9948.7    1563.5    9959.2    1565.6    9976.0    1563.1    9990.6
GR   1563.1   10000.0    1563.3   10010.1      1565     10016    1567.2   10021.9    1573.3   10037.3
R    1577.6   10049.8    1580.2   10060.0    1581.5   10070.5    1582.1   10082.6    1582.0   10088.7
R    1582.2   10091.2

X1     332        20    9981.8   10015.5       520       420       487
R    1579.6    9847.5    1575.5    9872.6    1577.0    9879.7    1578.2    9904.6    1579.3    9925.9
R    1579.2    9939.9    1578.2    9951.6    1576.4    9961.4    1574.0    9972.0    1573.3    9981.8
GR   1569.0    9994.7    1568.9   10000.0    1568.9   10003.5    1570.7   10015.5    1572.2   10029.6
GR   1571.9   10041.4    1570.8   10050.4    1570.3   10066.7    1577.8   10088.4    1583.1   10111.2
```

```
NC                                  .1        .3

X1     336        17    9986.3   10006.8       130       190       171
GR  1582.1    9773.8    1581.5    9800.5    1582.0    9825.2    1581.0    9845.6    1579.4    9869.5
GR  1579.1    9875.5    1578.7    9897.6    1576.2    9920.0    1574.3    9948.3    1572.4    9961.3
GR  1573.2    9986.3    1572.0   10000.0    1572.0   10006.8    1575.0   10021.0    1580.3   10039.4
GR  1581.7   10073.5    1584.1   10086.8

Conc. point CER8 Flow dowstream from Travino Wash confluence

QT       2       2961       2961
NC                                  .2        .4

X1     342         24    9990.3    10006       260       460       333
GR  1587.7    9922.2    1588.3    9947.7    1588.8    9968.7    1576.7    9990.3    1576.6   10000.0
GR  1577.2   10006.0    1577.2   10017.4    1578.3   10032.3    1579.3   10061.5    1581.0   10106.3
GR  1581.0   10123.1    1581.7   10147.4    1581.8   10165.2    1581.7   10182.8    1582.0   10200.9
GR  1583.1   10213.0    1583.1   10228.9    1580.6   10251.0    1582.9   10266.5    1585.1   10276.8
GR  1586.4   10300.1    1587.2   10327.3    1587.2   10349.5    1588.1   10373.7

NC                                  .1        .3

Trevino Wash confluence
X1     350         23    9979.1   10015.4       440       250       431
GR  1595.2    9947.4    1593.1    9958.3    1581.8    9979.1    1581.0    9989.0    1580.4   10000.0
GR  1580.4   10005.0    1582.6   10015.4    1583.4   10040.0    1584.2   10065.0    1584.8   10087.7
GR  1585.6   10117.3    1585.5   10148.2    1586.0   10165.1    1590.2   10185.0    1590.9   10198.4
GR  1590.5   10223.7    1590.0   10253.7    1590.5   10269.8    1591.6   10285.5    1590.8   10312.3
GR  1590.8   10323.9    1593.1   10352.6    1595.2   10375.1

Conc. Point *CER8 Flow upstream from Travino Wash Confluence

QT       2       2877       2877
NC                                  .1        .3

X1     359         16    9992.5    10004.9       480       420       476
GR  1597.9    9909.7    1597.9    9936.5    1589.3    9959.7    1587.5    9986.1    1585.7    9992.5
GR  1585.5   10000.0    1585.7   10004.9    1588.9   10023.6    1589.3   10028.8    1590.9   10040.8
GR  1593.1   10050.5    1594.8   10066.5    1595.0   10077.1    1600.6   10095.7    1601.3   10102.1
GR  1601.8   10115.9

X1     369         18    9984.5    10014.7       550       410       523
GR  1608.7    9944.7    1599.6    9962.4    1596.7    9976.9    1596.4    9984.5    1594.6    9991.7
GR  1594.0   10000.0    1594.0   10006.5    1596.1   10014.7    1597.5   10058.0    1597.7   10088.4
GR  1601.7   10105.8    1602.5   10116.9    1602.0   10143.4    1602.2   10164.9    1602.4   10192.1
GR  1604.4   10203.6    1610.3   10226.7    1623.1   10277.6
```

```
C     .058      .041      .058
 Basin 120-M confluence
X1     374        15    9993.7   10010.1       250       275       245
R   1627.3    9906.3    1616.7    9928.3    1602.0    9952.3    1599.8    9984.0    1597.4    9993.7
R   1597.0   10000.0    1597.9   10010.1    1603.3   10026.1    1607.7   10047.1    1608.2   10063.6
GR  1608.8   10089.0    1609.0   10110.4    1610.4   10124.3    1614.0   10137.6    1623.1   10167.8

 Conc. point *CER7 Flow upstream from basin 120-M Confluence

T       2      2769      2769

X1     382        26    9991.7   10013.4       525       475       469
R   1620.3    9603.5    1619.0    9628.2    1617.4    9661.2    1617.3    9688.5    1616.4    9731.1
R   1615.4    9745.3    1615.7    9755.1    1614.5    9787.3    1612.9    9813.5    1612.8    9836.4
GR  1612.8    9861.1    1612.4    9880.4    1610.6    9902.6    1609.4    9918.3    1607.6    9927.5
GR  1607.3    9942.8    1605.6    9953.2    1604.1    9963.0    1606.6    9971.1    1606.7    9982.2
R   1604.1    9991.7    1602.5   10000.0    1604.8   10013.4    1603.3   10021.5    1610.4   10035.6
R   1620.1   10052.6

NC    .044      .042      .044

1      393        39    9983.1   10015.4       480       530       534
GR  1632.2    9527.4    1628.2    9548.0    1624.9    9565.5    1624.4    9583.5    1622.4    9607.8
GR  1625.7    9622.6    1627.2    9638.3    1627.4    9653.8    1626.2    9681.7    1625.0    9715.0
R   1624.6    9752.4    1625.0    9777.2    1624.5    9805.5    1624.1    9821.1    1624.4    9851.1
R   1624.6    9869.3    1624.4    9889.0    1625.4    9922.8    1625.9    9947.8    1624.6    9971.5
R   1620.9    9976.8    1612.2    9983.1    1611.0    9987.0    1610.1    9996.6    1610.5   10000.0
GR  1611.5   10004.7    1613.9   10015.4    1613.0   10032.9    1613.0   10050.2    1614.3   10058.5
GR  1614.1   10072.3    1614.9   10088.7    1616.1   10108.5    1617.5   10133.8    1617.9   10149.7
R   1619.7   10165.0    1622.2   10185.1    1624.4   10195.4    1628.3   10205.2

 Logan Wash Confluence

1      400        20    9908.7    10078       480       400       404
R   1639.6    9795.2    1636.6    9815.8    1635.3    9823.2    1634.9    9835.0    1631.4    9855.9
R   1626.4    9876.9    1617.4    9908.7    1617.1    9940.1    1617.2    9976.8    1617.5   10000.0
GR  1617.3   10034.8    1617.6   10038.3    1617.8   10050.9    1617.9   10078.0    1617.9   10102.4
GR  1621.8   10120.3    1627.9   10145.9    1632.8   10170.1    1633.0   10194.3    1639.7   10216.8
```

THIS RUN EXECUTED 09DEC94 07:41:18

****
HEC-2 WATER SURFACE PROFILES

Version 4.6.2; May 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	HV	DEPTH	SSTA	ENDST	CWSEL	FRCH
*	301.000	2.41	4.77	9995.00	10005.00	1551.07	1.01
	304.000	.02	13.98	9993.40	10087.26	1563.68	.05
*	305.000	.23	12.21	9953.53	10105.43	1563.61	.15
	314.000	.59	6.99	9943.18	10066.45	1564.09	.31
	323.000	1.38	5.30	9940.38	10024.93	1568.40	.80
*	332.000	.88	6.48	9965.90	10081.40	1575.38	.37
	336.000	1.31	5.12	9911.77	10028.35	1577.12	.67
*	342.000	.56	5.60	9980.48	10261.79	1582.20	.35
	350.000	.95	5.53	9971.50	10162.64	1585.93	.58
	359.000	1.26	6.72	9951.84	10046.60	1592.22	.50
	369.000	1.17	5.37	9963.52	10095.69	1599.37	.60
	374.000	1.52	6.83	9949.31	10028.64	1603.83	.80
	382.000	.63	7.25	9913.77	10034.30	1609.75	.49
	393.000	1.28	5.88	9980.36	10106.47	1615.98	.87
*	400.000	.38	3.15	9898.62	10113.20	1620.25	.53

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	Q	VCH	CWSEL	CRIWS	HV	DEPTH	EG	KRATIO
*	301.000	595.00	12.46	1551.07	1551.07	2.41	4.77	1553.49	.00
	304.000	563.00	1.00	1563.68	.00	.02	13.98	1563.70	23.44
*	305.000	2998.00	2.89	1563.61	1556.60	.23	12.21	1563.84	1.72
	314.000	2998.00	4.56	1564.09	1561.90	.59	6.99	1564.68	.43
*	323.000	2998.00	9.77	1568.40	1567.93	1.38	5.30	1569.77	.36
	332.000	2998.00	4.86	1575.38	1574.27	.88	6.48	1576.26	2.17
	336.000	2998.00	8.20	1577.12	1576.86	1.31	5.12	1578.44	.56
*	342.000	2961.00	4.63	1582.20	1581.75	.56	5.60	1582.76	1.93
	350.000	2961.00	7.28	1585.93	1585.93	.95	5.53	1586.88	.59
	359.000	2877.00	7.34	1592.22	1591.61	1.26	6.72	1593.48	1.19
	369.000	2877.00	7.40	1599.37	1599.13	1.17	5.37	1600.54	.78
	374.000	2877.00	11.53	1603.83	1603.55	1.52	6.83	1605.35	1.09
	382.000	2769.00	6.94	1609.75	1608.40	.63	7.25	1610.37	1.55
*	393.000	2769.00	10.52	1615.98	1615.98	1.28	5.88	1617.26	.70
	400.000	2769.00	5.03	1620.25	1619.31	.38	3.15	1620.63	1.55

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	DEPTH	CLASS	QCULV	QWEIR	QPR
*	301.000	4.77	.00	.00	.00	.00
	304.000	13.98	16.00	562.08	.43	.00
*	305.000	12.21	.00	.00	.00	.00
	314.000	6.99	.00	.00	.00	.00
*	323.000	5.30	.00	.00	.00	.00
	332.000	6.48	.00	.00	.00	.00
*	336.000	5.12	.00	.00	.00	.00
*	342.000	5.60	.00	.00	.00	.00
	350.000	5.53	.00	.00	.00	.00
	359.000	6.72	.00	.00	.00	.00
	369.000	5.37	.00	.00	.00	.00
	374.000	6.83	.00	.00	.00	.00
	382.000	7.25	.00	.00	.00	.00
*	393.000	5.88	.00	.00	.00	.00
	400.000	3.15	.00	.00	.00	.00

SUMMARY OF ERRORS AND SPECIAL NOTES

```
CAUTION SECNO=    301.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=    304.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    305.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    314.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    323.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    332.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    336.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    342.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=    350.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    350.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=    382.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=    393.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    393.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=    400.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

APPENDIX B.2

HEC-2 OUTPUT FOR CEREUS WASH WITH LAKE 27-1

```
*******************************************
  HEC-2 WATER SURFACE PROFILES            *
                                          *
*  Version   4.6.2;  May 1991             *
*                                         *
  RUN DATE    14DEC94    TIME   11:42:29  *
*******************************************
```

```
****************************************
*  U.S. ARMY CORPS OF ENGINEERS        *
*  HYDROLOGIC ENGINEERING CENTER       *
*  609 SECOND STREET, SUITE D          *
*  DAVIS, CALIFORNIA 95616-4687        *
*          (916) 756-1104              *
****************************************
```

```
X     X  XXXXXXX   XXXXX              XXXXX
X     X  X        X     X            X     X
X     X  X        X                        X
XXXXXXX  XXXX     X          XXXXX    XXXXX
X     X  X        X                  X
X     X  X        X     X            X
X     X  XXXXXXX   XXXXX             XXXXXXX
```

THIS RUN EXECUTED 14DEC94 11:42:29

```
************************************
HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
************************************


T1      Fountain Hills Efluent Lake 27-1 Scour Analisys
T1      Prepared for Anderson-Nelson, Inc.
T1      by AGK Engineers, Inc.  (HAA)

T2      Furure Development - No Lakes
T2      Smooth Embankment n=0.025
T3      Fountain Hills - CEREUS WASH -  Lake 27-1


J1  ICHECK    INQ      NINV     IDIR     STRT     METRIC   HVINS    Q        WSEL     FQ

              2                          -1                                 1550

J2  NPROF     IPLOT    PRFVS    XSECV    XSECH    FN       ALLDC    IBW      CHNIM    ITRACE

                                                            -1


J3  VARIABLE CODES FOR SUMMARY PRINTOUT

    38       10       8        53       54       1        68
    38       43       26       1        2        10       8        3
    38       55       26       56       13       14       15       5

  Culvert Outlet CER2
  Conc. Point *CER11 Flow upstrem from Laser Drain confluence

QT      2       595      595
NC    .078     .037     .078      0.3      0.5
X1    301       20      9995     10005     80       80       80
X3     10                                                    1554.31  1553.78
GR  1563.5    9905.5   1564.4   9943.9   1563.2   9951.4   1556.0   9964.0   1550.6   9979.7
GR  1549.8    9993.0   1546.3     9995   1546.3  10000.0   1546.3    10005   1546.9  10010.3
GR  1550.6   10023.8   1553.2  10038.7   1554.6  10050.3   1556.2  10064.5   1557.8  10078.8
GR  1559.6   10086.7   1561.8  10098.2   1563.7  10107.4   1564.3  10117.4   1564.3  10118.5

  Culvert - CER2 -  2 CMP 60" X 110'  Saguaro Blvd.
  Conc. point SCER9 Flow throught Saguaro Blvd. Culvert
```

```
QT       2       563       563
SC   2.024        .8         3                 5                 110       2.3   1549.75    1546.3

 Culvert inlet CER2
X1     304        19    9993.4   10009.5       120       150       120
X2                          2                1563.6
X3      10                                                       1564.6    1563.6
T       -7   9735.28      1566                9950    1564.6                10000    1564.3
T            10050   1564.07               10082.9    1563.6              10104.9      1564
BT           10164.0     1566
GR    1566   9735.28      1564   9898.72    1563.8    9914.7    1563.4    9949.7    1561.4    9959.6
R   1554.3    9979.9    1552.5    9988.6    1550.6    9993.4    1549.7      9994    1549.7   10000.0
R   1549.7     10006    1550.6   10009.5    1555.9   10024.0    1563.5   10041.0    1561.1   10053.9
R   1562.8   10065.8    1563.6   10082.9      1564   10104.9      1566   10164.0

 Conc. point CER9 Flow upstrem from Saguaro Blvd.

T       2      2998      2998
X1    305        14    9982.7   10020.2        60       100        59
GR   1566   9864.71    1564.0    9915.3    1563.7    9953.0    1562.3    9961.6    1551.8    9982.7
R   1551.4   10000.0    1551.7   10020.2    1552.2   10029.7    1552.2   10033.9    1564.7   10061.4
R   1563.4   10083.6    1563.5   10092.3      1564   10149.8      1566   10184.1

NC                                     .1        .3

1     314        13    9986.3   10020.2       500       420       472
GR   1571.9    9900.0    1569.6    9920.0    1563.3    9946.5    1560.6    9970.5    1557.4    9986.3
GR   1557.1   10000.0    1557.5   10020.2    1558.6   10028.4    1559.1   10044.8    1560.5   10056.1
R   1568.2   10078.3    1569.8   10098.2    1571.6   10113.4

NC                                     .2        .4

1     323        21      9976     10016       460       530       498
R   1578.5    9882.3    1578.3    9900.4    1577.2    9915.8    1576.1    9924.8    1573.6    9932.7
GR   1569.2    9938.3    1565.2    9948.7    1563.5    9959.2    1565.6    9976.0    1563.1    9990.6
GR   1563.1   10000.0    1563.3   10010.1      1565     10016    1567.2   10021.9    1573.3   10037.3
R   1577.6   10049.8    1580.2   10060.0    1581.5   10070.5    1582.1   10082.6    1582.0   10088.7
R   1582.2   10091.2

X1    332        20    9981.8   10015.5       520       420       487
R   1579.6    9847.5    1575.5    9872.6    1577.0    9879.7    1578.2    9904.6    1579.3    9925.9
R   1579.2    9939.9    1578.2    9951.6    1576.4    9961.4    1574.0    9972.0    1573.3    9981.8
GR   1569.0    9994.7    1568.9   10000.0    1568.9   10003.5    1570.7   10015.5    1572.2   10029.6
GR   1571.9   10041.4    1570.8   10050.4    1570.3   10066.7    1577.8   10088.4    1583.1   10111.2
```

```
NC                                  .1        .3

X1     336       17    9986.3   10006.8       130       190       171
GR  1582.1   9773.8    1581.5    9800.5    1582.0    9825.2    1581.0    9845.6    1579.4    9869.5
GR  1579.1   9875.5    1578.7    9897.6    1576.2    9920.0    1574.3    9948.3    1572.4    9961.3
GR  1573.2   9986.3    1572.0   10000.0    1572.0   10006.8    1575.0   10021.0    1580.3   10039.4
GR  1581.7  10073.5    1584.1   10086.8
```

Conc. point CER8 Flow dowstream from Travino Wash confluence

```
QT       2      2961      2961
NC                                  .2        .4

X1     342        24    9990.3    10006       260       460       333
GR  1587.7   9922.2    1588.3    9947.7    1588.8    9968.7    1576.7    9990.3    1576.6   10000.0
GR  1577.2  10006.0    1577.2   10017.4    1578.3   10032.3    1579.3   10061.5    1581.0   10106.3
GR  1581.0  10123.1    1581.7   10147.4    1581.8   10165.2    1581.7   10182.8    1582.0   10200.9
GR  1583.1  10213.0    1583.1   10228.9    1580.6   10251.0    1582.9   10266.5    1585.1   10276.8
GR  1586.4  10300.1    1587.2   10327.3    1587.2   10349.5    1588.1   10373.7

NC                                  .1        .3
```

Trevino Wash confluence

```
X1     350        23    9979.1   10015.4       440       250       431
GR  1595.2   9947.4    1593.1    9958.3    1581.8    9979.1    1581.0    9989.0    1580.4   10000.0
GR  1580.4  10005.0    1582.6   10015.4    1583.4   10040.0    1584.2   10065.0    1584.8   10087.7
GR  1585.6  10117.3    1585.5   10148.2    1586.0   10165.1    1590.2   10185.0    1590.9   10198.4
GR  1590.5  10223.7    1590.0   10253.7    1590.5   10269.8    1591.6   10285.5    1590.8   10312.3
GR  1590.8  10323.9    1593.1   10352.6    1595.2   10375.1
```

Conc. Point *CER8 Flow upstream from Travino Wash Confluence

```
QT       2      2877      2877
NC                                  .1        .3

X1     359        16    9992.5   10004.9       480       420       476
GR  1597.9   9909.7    1597.9    9936.5    1589.3    9959.7    1587.5    9986.1    1585.7    9992.5
GR  1585.5  10000.0    1585.7   10004.9    1588.9   10023.6    1589.3   10028.8    1590.9   10040.8
GR  1593.1  10050.5    1594.8   10066.5    1595.0   10077.1    1600.6   10095.7    1601.3   10102.1
GR  1601.8  10115.9
```

Conc. Point CER7

```
QT       2      2860      2231

XH       3      .025     10016      .041     10092      .058   10277.6
X1     369        25     10016     10092       550       410       523
GR  1622.7      9944   1620.74      9951   1618.74      9957   1616.74      9962   1614.74      9968
GR  1612.7    9973.5   1610.74      9980   1608.74      9986   1606.74      9992   1604.74      9998
GR  1602.7     10004   1600.74     10010   1598.74     10016    1593.1     10053   1592.69     10060
GR  1593.1     10067    1597.7     10092    1601.7     10109    1602.5   10116.9    1602.0   10143.4
GR  1602.2   10164.9    1602.4   10192.1    1604.4   10203.6    1610.3   10226.7    1623.1   10277.6
```

Added X-sec. from 1"=50' construction plans

NH	4	.025	10015.6	.058	10021.8	.041	10043	.058	10106	
1	371	22	10021.8	10043	122	122	122			
R	1622.7	9940	1620.74	9946	1618.74	9952.5	1616.74	9958	1614.74	9964
R	1612.7	9970	1610.74	9975	1608.74	9982	1606.74	9988.5	1604.74	9993.5
GR	1602.7	10000	1600.74	10005	1598.74	10009.5	1597.57	10015.6	1596.4	10021.8
GR	1594.7	10027	1594.3	10034	1594.7	10041	1595.4	10043	1598.4	10052
R	1602.0	10063	1606.7	10106						

Basin 120-M confluence

NH	3	.025	9984	.041	10018.1	.085	10167.8			
1	374	27	9984	10018.1	120	125	122			
R	1622.7	9910.5	1620.74	9917	1618.74	9923	1616.74	9928	1614.74	9933.5
GR	1612.7	9940	1610.74	9946.5	1608.74	9953	1606.74	9958	1604.74	9964.5
GR	1602.7	9970	1600.74	9975	1599.8	9984.0	1597.4	9993.7	1596.1	9997
R	1596.0	10000.0	1596.1	10003	1597.9	10010.1	1600.60	10018.1	1603.3	10026.1
R	1607.7	10047.1	1608.2	10063.6	1608.8	10089.0	1609.0	10110.4	1610.4	10124.3
GR	1614.0	10137.6	1623.1	10167.8						

H	4	.025	9964	.058	10000	.041	10015	.058	10101	
1	376	21	10000	10015	122	122	122			
GR	1624.7	9897	1622.74	9903	1620.74	9909.5	1618.74	9915.5	1616.74	9920.5
GR	1614.7	9926	1612.74	9932	1610.74	9938	1608.74	9944	1606.74	9951
R	1604.7	9956.5	1602.83	9964	1602.74	9966	1600.74	10000	1597.73	10010
R	1600.7	10015	1602.7	10028	1604.74	10041.5	1606.74	10055	1608.74	10067.5
GR	1610.7	10101								

H	4	.025	9931.5	.058	9966	.041	10022	.058	10070	
1	379	20	9966	10022	135	135	135			
GR	1624.7	9877	1622.74	9883.5	1620.74	9890	1618.74	9895.5	1616.74	9901.5
GR	1614.7	9907	1612.74	9913	1610.74	9918	1608.74	9925	1606.74	9931.5
R	1604.7	9966	1602.74	9990	1599.58	10000	1602.74	10010	1604.74	10022
R	1606.7	10034	1608.74	10045	1610.74	10053	1612.74	10060.5	1614.74	10070

H	4	.025	9896.55	.058	9991.7	.041	10013.4	.058	10052.6	
1	382	27	9991.7	10013.4	213	213	213			
GR	1634.7	9823	1632.74	9829	1630.74	9836	1628.74	9842	1626.74	9848
GR	1624.7	9854	1622.74	9859.5	1620.74	9866	1618.74	9873	1616.74	9879
R	1614.7	9885	1612.74	9890.5	1611.67	9896.55	1610.6	9902.6	1609.4	9918.3
R	1607.6	9927.5	1607.3	9942.8	1605.6	9953.2	1604.1	9963.0	1606.6	9971.1
GR	1606.7	9982.2	1604.1	9991.7	1602.5	10000.0	1604.8	10013.4	1603.3	10021.5
GR	1610.4	10035.6	1620.1	10052.6						

Modified to include lake dike

```
NH      4      .025   9960.75     .044   9983.1     .042  10015.4     .044  10205.2
X1    393        27    9983.1  10015.4      480      530      534
GR 1634.7      9918   1634.74   9932.5  1632.74     9938  1630.74   9943.5  1629.74  9946.75
GR 1628.7      9950   1626.65  9960.75   1624.6   9971.5   1620.9   9976.8   1612.2   9983.1
GR 1611.0    9987.0    1610.1   9996.6   1610.5  10000.0   1611.5  10004.7   1613.9  10015.4
GR 1613.0   10032.9    1613.0  10050.2   1614.3  10058.5   1614.1  10072.3   1614.9  10088.7
GR 1616.1   10108.5    1617.5  10133.8   1617.9  10149.7   1619.7  10165.0   1622.2  10185.1
GR 1624.4   10195.4    1628.3  10205.2

NC    .044      .042      .044

 Logan Wash Confluence
X1    400        20    9908.7    10078      480      400      404
GR 1639.6    9795.2   1636.6   9815.8   1635.3   9823.2   1634.9   9835.0   1631.4   9855.9
GR 1626.4    9876.9   1617.4   9908.7   1617.1   9940.1   1617.2   9976.8   1617.5  10000.0
GR 1617.3   10034.8   1617.6  10038.3   1617.8  10050.9   1617.9  10078.0   1617.9  10102.4
GR 1621.8   10120.3   1627.9  10145.9   1632.8  10170.1   1633.0  10194.3   1639.7  10216.8
```

THIS RUN EXECUTED 14DEC94 11:42:31

****
HEC-2 WATER SURFACE PROFILES

Version 4.6.2; May 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	HV	DEPTH	SSTA	ENDST	CWSEL	FRCH
*	301.000	2.41	4.77	9995.00	10005.00	1551.07	1.01
	304.000	.02	13.98	9993.40	10087.26	1563.68	.05
*	305.000	.23	12.21	9953.53	10105.43	1563.61	.15
	314.000	.59	6.99	9943.18	10066.45	1564.09	.31
	323.000	1.38	5.30	9940.38	10024.93	1568.40	.80
	332.000	.88	6.48	9965.90	10081.40	1575.38	.37
	336.000	1.31	5.12	9911.77	10028.35	1577.12	.67
*	342.000	.56	5.60	9980.48	10261.79	1582.20	.35
	350.000	.95	5.53	9971.50	10162.64	1585.93	.58
	359.000	1.26	6.72	9951.84	10046.60	1592.22	.50
	369.000	1.75	6.05	10016.06	10096.38	1598.74	.99
*	371.000	2.26	7.27	10002.88	10061.69	1601.57	.91
	374.000	2.27	7.49	9967.87	10027.00	1603.49	.89
	376.000	1.55	7.97	9953.80	10048.00	1605.70	.90
	379.000	1.51	7.71	9929.70	10037.20	1607.29	.86
	382.000	.81	7.27	9913.46	10034.35	1609.77	.66
*	393.000	1.28	6.04	9980.25	10109.16	1616.14	.86
	400.000	.39	3.18	9898.50	10113.36	1620.28	.53

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	Q	VCH	CWSEL	CRIWS	HV	DEPTH	EG
*	301.000	595.00	12.46	1551.07	1551.07	2.41	4.77	1553.49
	304.000	563.00	1.00	1563.68	.00	.02	13.98	1563.70
*	305.000	2998.00	2.89	1563.61	1556.60	.23	12.21	1563.84
	314.000	2998.00	4.56	1564.09	1561.90	.59	6.99	1564.68
*	323.000	2998.00	9.77	1568.40	1567.93	1.38	5.30	1569.77
	332.000	2998.00	4.86	1575.38	1574.27	.88	6.48	1576.26
	336.000	2998.00	8.20	1577.12	1576.86	1.31	5.12	1578.44
*	342.000	2961.00	4.63	1582.20	1581.75	.56	5.60	1582.76
	350.000	2961.00	7.28	1585.93	1585.93	.95	5.53	1586.88
	359.000	2877.00	7.34	1592.22	1591.61	1.26	6.72	1593.48
	369.000	2860.00	10.62	1598.74	1598.70	1.75	6.05	1600.49
*	371.000	2860.00	13.43	1601.57	1601.57	2.26	7.27	1603.84
	374.000	2860.00	12.09	1603.49	1603.49	2.27	7.49	1605.76
	376.000	2860.00	12.95	1605.70	1605.59	1.55	7.97	1607.25
	379.000	2860.00	10.31	1607.29	1607.18	1.51	7.71	1608.81
	382.000	2860.00	9.42	1609.77	1608.70	.81	7.27	1610.58
*	393.000	2860.00	10.64	1616.14	1616.14	1.28	6.04	1617.41
	400.000	2860.00	5.13	1620.28	1619.35	.39	3.18	1620.67

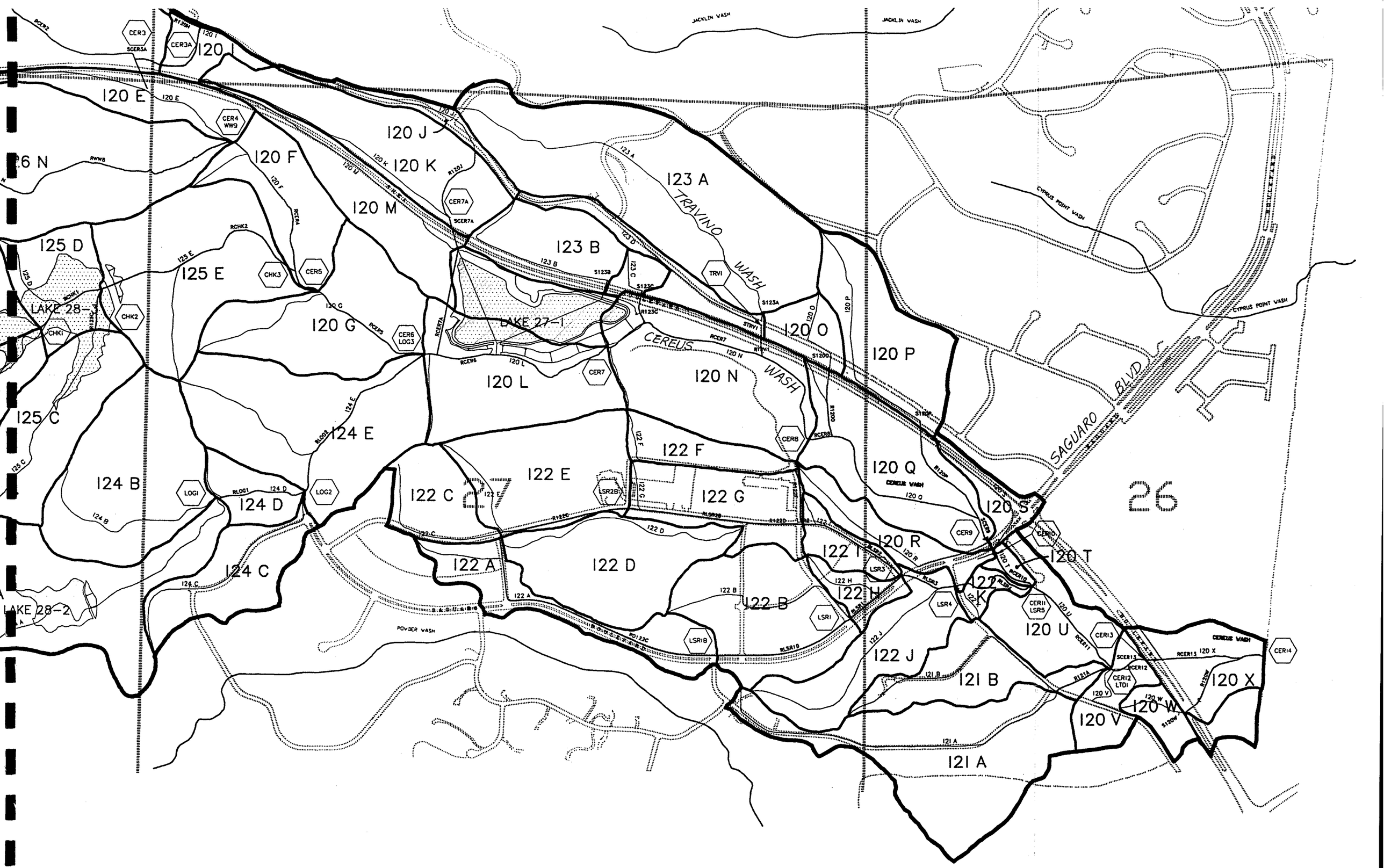
ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	VLOB	VCH	VROB	QLOB	QCH	QROB	10*KS
	301.000	.00	12.46	.00	.00	595.00	.00	532.38
	304.000	.00	1.00	1.28	.00	223.14	339.86	.87
*	305.000	1.74	2.89	4.73	250.43	1305.42	1442.15	8.34
	314.000	3.05	4.56	7.61	406.18	1051.69	1540.13	44.33
*	323.000	8.27	9.77	11.54	997.03	1823.33	177.64	342.66
	332.000	2.12	4.86	8.45	44.95	866.51	2086.54	72.91
*	336.000	6.65	8.20	13.24	1420.91	793.41	783.68	235.17
	342.000	2.68	4.63	6.26	72.46	396.86	2491.68	61.76
	350.000	3.80	7.28	8.36	59.54	1281.33	1620.12	179.77
	359.000	5.21	7.34	10.95	771.86	602.28	1502.86	119.68
	369.000	.00	10.62	2.05	.00	2855.36	4.64	161.34
*	371.000	9.85	13.43	6.26	575.49	1925.13	359.37	110.11
	374.000	12.46	12.09	2.39	481.65	2348.72	29.63	114.50
	376.000	7.15	12.95	5.91	1118.35	1257.82	483.84	117.84
	379.000	3.67	10.31	3.53	200.89	2589.07	70.04	112.61
	382.000	4.63	9.42	5.21	1123.34	1278.83	457.83	59.93
	393.000	4.03	10.64	6.48	22.61	1618.78	1218.60	117.59
	400.000	3.15	5.13	4.41	46.40	2499.27	314.32	56.19

SUMMARY OF ERRORS AND SPECIAL NOTES

```
CAUTION SECNO=    301.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=    304.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    305.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    314.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    323.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    332.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    336.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    342.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=    350.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    350.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    371.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    371.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    374.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    374.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    393.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    393.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=    400.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```


JACKLIN WASH
JACKLIN WASH
CER3
SCER3A
CER3A
120 I
120 E
CER4
WW9
120 J
120 F
120 K
120 M
CER7A
SCER7A
123 A
TRAVINO
WASH
CYPRUS POINT WASH
CYPRUS POINT WASH
125 D
125 E
CHK3
CER5
123 B
LAKE 28-3
CHK2
CHK1
120 G
CER6
LOG3
LAKE 27-1
TRV1
120 O
CEREUS
WASH
120 P
120 L
CER7
120 N
125 C
124 E
122 F
CER8
SAGUARO
BLVD
120 Q
124 B
LOG1
LOG2
124 D
122 C
27
122 E
LSR2B
122 G
120 S
26
CER9
CER10
120 R
122 I
120 T
124 C
122 A
122 D
LSR3
122 H
LSR4
122 K
CER11
LSR5
LAKE 28-2
122 B
LSR1
120 U
CER13
CER14
POWDER WASH
LSR1B
122 J
121 B
CER12
LTD1
120 X
120 V
120 W
121 A

EARTHWORK

CUT: 184,396 C.Y.
FILL: 77,337 C.Y.

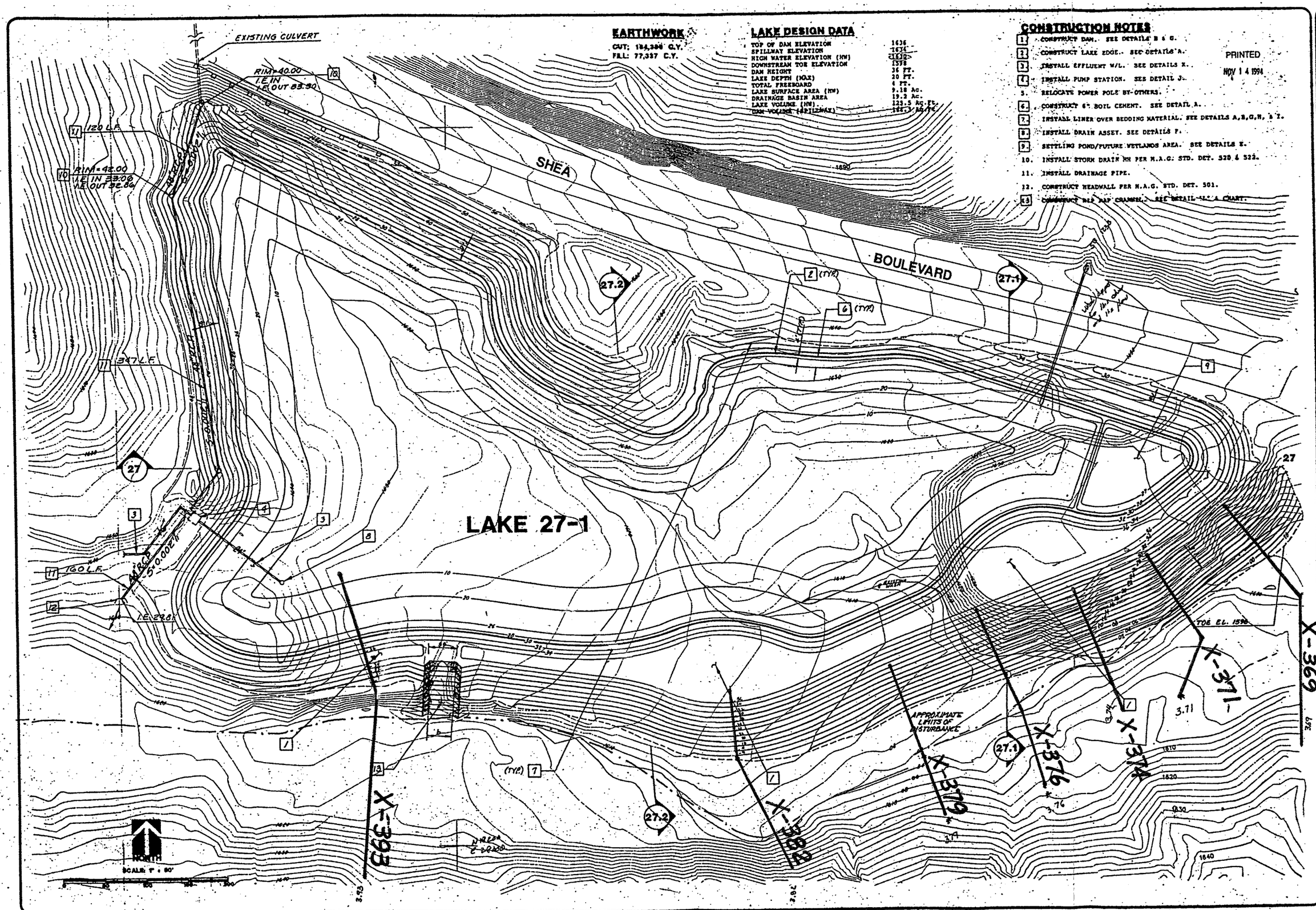
LAKE DESIGN DATA

TOP OF DAM ELEVATION	1636
SPILLWAY ELEVATION	1634
HIGH WATER ELEVATION (HW)	1630
DOWNSTREAM TOE ELEVATION	1598
DAM HEIGHT	36 FT.
LAKE DEPTH (MAX)	20 FT.
TOTAL FREEBOARD	4 FT.
LAKE SURFACE AREA (HW)	9.18 Ac.
DRAINAGE BASIN AREA	19.2 Ac.
LAKE VOLUME (HW)	123.5 Ac.Ft.
DAM VOLUME (SPILLWAY)	164.7 Ac.Ft.

CONSTRUCTION NOTES

1. CONSTRUCT DAM. SEE DETAILS B & G.
2. CONSTRUCT LAKE EDGE. SEE DETAILS A.
3. INSTALL EFFLUENT W/L. SEE DETAILS X.
4. INSTALL PUMP STATION. SEE DETAIL J.
5. RELOCATE POWER POLE BY OTHERS.
6. CONSTRUCT 6" SOIL CEMENT. SEE DETAIL A.
7. INSTALL LINER OVER BEDDING MATERIAL. SEE DETAILS A,B,G,H, & I.
8. INSTALL DRAIN ASSEY. SEE DETAILS F.
9. SETTLING POND/FUTURE WETLANDS AREA. SEE DETAILS E.
10. INSTALL STORM DRAIN MH PER M.A.G. STD. DET. 520 & 522.
11. INSTALL DRAINAGE PIPE.
12. CONSTRUCT HEADWALL PER M.A.G. STD. DET. 501.
13. CONSTRUCT BLP RAP CHANNEL. SEE DETAIL "L" & CHART.

PRINTED
NOV 14 1994



F.H., AZ - EFFLUENT LAKES PLAN

Anderson - Nelson, Inc.

4441 East McDowell Road
Phoenix, Arizona 85008
(602) 273-1850
Bullhead City, AZ (602) 754-7272
Parker, AZ (602) 667-9202

DESIGNED	R.A.F.		BY
DRAWN	J.K.S.	Add Spillway	9/30/94 R.R.
APPROVED	D.N.A.		
DATE	7-25-94		

LAKE 27-1

263-1100

SHEET 13 OF 16

FILE BOX PC8442 TUBE

APPENDIX B.3

HEC-2 OUTPUT FOR CEREUS WASH WITH RIPRAP IN PLACE

```
*********************************************
*  HEC-2 WATER SURFACE PROFILES             *
*                                           *
*  Version   4.6.2;  May 1991               *
*                                           *
*  RUN DATE    14DEC94    TIME   11:44:28   *
*********************************************
```

```
****************************************
*  U.S. ARMY CORPS OF ENGINEERS        *
*  HYDROLOGIC ENGINEERING CENTER       *
*  609 SECOND STREET, SUITE D          *
*  DAVIS, CALIFORNIA 95616-4687        *
*          (916) 756-1104              *
****************************************
```

```
X     X  XXXXXXX   XXXXX              XXXXX
X     X  X        X     X            X     X
X     X  X        X                        X
XXXXXXX  XXXX     X          XXXXX    XXXXX
X     X  X        X                  X
X     X  X        X     X            X
X     X  XXXXXXX   XXXXX             XXXXXXX
```

THIS RUN EXECUTED 14DEC94 11:44:28

```
************************************
HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
************************************

T1      Fountain Hills Efluent Lake 27-1 Scour Analisys
T1      Prepared for Anderson-Nelson, Inc.
T1      by AGK Engineers, Inc.  (HAA)

T2      Furure Development - No Lakes
T2         Riprap Embankment n=0.038
T3      Fountain Hills - CEREUS WASH -  Lake 27-1

J1  ICHECK    INQ      NINV     IDIR     STRT     METRIC   HVINS    Q        WSEL     FQ

              2                          -1                                 1550

J2  NPROF     IPLOT    PRFVS    XSECV    XSECH    FN       ALLDC    IBW      CHNIM    ITRACE

                                                            -1

J3  VARIABLE CODES FOR SUMMARY PRINTOUT

    38       10       8        53       54       1        68
    38       43       26       1        2        10       8        3
    38       55       26       56       13       14       15       5

 Culvert Outlet CER2
 Conc. Point *CER11 Flow upstrem from Laser Drain confluence

QT      2       595      595
NC    .078     .037     .078      0.3      0.5
X1    301       20      9995     10005     80       80       80
X3     10                                                    1554.31  1553.78
GR   1563.5   9905.5   1564.4   9943.9   1563.2   9951.4   1556.0   9964.0   1550.6   9979.7
GR   1549.8   9993.0   1546.3     9995   1546.3  10000.0   1546.3    10005   1546.9  10010.3
GR   1550.6  10023.8   1553.2  10038.7   1554.6  10050.3   1556.2  10064.5   1557.8  10078.8
GR   1559.6  10086.7   1561.8  10098.2   1563.7  10107.4   1564.3  10117.4   1564.3  10118.5

 Culvert - CER2 -  2 CMP 60" X 110'  Saguaro Blvd.
 Conc. point SCER9 Flow throught Saguaro Blvd. Culvert
```

THIS RUN EXECUTED 14DEC94 11:44:30

****
HEC-2 WATER SURFACE PROFILES

Version 4.6.2; May 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	HV	DEPTH	SSTA	ENDST	CWSEL	FRCH
*	301.000	2.41	4.77	9995.00	10005.00	1551.07	1.01
	304.000	.02	13.98	9993.40	10087.26	1563.68	.05
*	305.000	.23	12.21	9953.53	10105.43	1563.61	.15
	314.000	.59	6.99	9943.18	10066.45	1564.09	.31
*	323.000	1.38	5.30	9940.38	10024.93	1568.40	.80
	332.000	.88	6.48	9965.90	10081.40	1575.38	.37
	336.000	1.31	5.12	9911.77	10028.35	1577.12	.67
*	342.000	.56	5.60	9980.48	10261.79	1582.20	.35
	350.000	.95	5.53	9971.50	10162.64	1585.93	.58
	359.000	1.26	6.72	9951.84	10046.60	1592.22	.50
	369.000	1.75	6.05	10016.06	10096.38	1598.74	.99
*	371.000	2.29	7.38	10002.60	10062.03	1601.68	.92
	374.000	2.26	7.59	9967.61	10027.47	1603.59	.92
	376.000	1.42	8.16	9953.29	10049.26	1605.89	.85
	379.000	1.52	7.72	9929.72	10037.17	1607.30	.86
	382.000	.81	7.28	9913.30	10034.37	1609.78	.66
*	393.000	1.27	6.04	9980.25	10109.21	1616.14	.86
	400.000	.39	3.18	9898.50	10113.35	1620.28	.53

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	Q	VCH	CWSEL	CRIWS	HV	DEPTH	EG
*	301.000	595.00	12.46	1551.07	1551.07	2.41	4.77	1553.49
	304.000	563.00	1.00	1563.68	.00	.02	13.98	1563.70
*	305.000	2998.00	2.89	1563.61	1556.60	.23	12.21	1563.84
	314.000	2998.00	4.56	1564.09	1561.90	.59	6.99	1564.68
*	323.000	2998.00	9.77	1568.40	1567.93	1.38	5.30	1569.77
	332.000	2998.00	4.86	1575.38	1574.27	.88	6.48	1576.26
	336.000	2998.00	8.20	1577.12	1576.86	1.31	5.12	1578.44
*	342.000	2961.00	4.63	1582.20	1581.75	.56	5.60	1582.76
	350.000	2961.00	7.28	1585.93	1585.93	.95	5.53	1586.88
	359.000	2877.00	7.34	1592.22	1591.61	1.26	6.72	1593.48
	369.000	2860.00	10.62	1598.74	1598.70	1.75	6.05	1600.49
*	371.000	2860.00	13.73	1601.68	1601.68	2.29	7.38	1603.98
	374.000	2860.00	12.55	1603.59	1603.59	2.26	7.59	1605.85
	376.000	2860.00	12.51	1605.89	1605.61	1.42	8.16	1607.31
	379.000	2860.00	10.33	1607.30	1607.25	1.52	7.72	1608.82
	382.000	2860.00	9.39	1609.78	1608.70	.81	7.28	1610.59
*	393.000	2860.00	10.63	1616.14	1616.14	1.27	6.04	1617.41
	400.000	2860.00	5.13	1620.28	1619.35	.39	3.18	1620.67

ountain Hills - CEREUS

SUMMARY PRINTOUT

	SECNO	VLOB	VCH	'VROB	QLOB	QCH	QROB	10*KS
*	301.000	.00	12.46	.00	.00	595.00	.00	532.38
	304.000	.00	1.00	1.28	.00	223.14	339.86	.87
*	305.000	1.74	2.89	4.73	250.43	1305.42	1442.15	8.34
	314.000	3.05	4.56	7.61	406.18	1051.69	1540.13	44.33
*	323.000	8.27	9.77	11.54	997.03	1823.33	177.64	342.66
	332.000	2.12	4.86	8.45	44.95	866.51	2086.54	72.91
	336.000	6.65	8.20	13.24	1420.91	793.41	783.68	235.17
*	342.000	2.68	4.63	6.26	72.46	396.86	2491.68	61.76
	350.000	3.80	7.28	8.36	59.54	1281.33	1620.12	179.77
	359.000	5.21	7.34	10.95	771.86	602.28	1502.86	119.68
	369.000	.00	10.62	2.05	.00	2855.36	4.64	161.34
*	371.000	7.93	13.73	6.40	479.60	1999.66	380.74	112.64
	374.000	8.57	12.55	2.54	344.92	2481.25	33.83	120.72
	376.000	6.68	12.51	5.74	1103.19	1250.04	506.77	105.80
	379.000	3.66	10.33	3.53	199.76	2590.45	69.78	113.21
	382.000	4.62	9.39	5.19	1124.89	1277.40	457.70	59.40
*	393.000	4.03	10.63	6.47	22.62	1618.15	1219.23	117.29
	400.000	3.15	5.13	4.41	46.39	2499.35	314.27	56.27

SUMMARY OF ERRORS AND SPECIAL NOTES

```
CAUTION SECNO=    301.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=    304.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    305.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    314.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    323.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    332.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    336.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    342.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=    350.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    350.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    371.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    371.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    374.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    374.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    393.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    393.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=    400.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

APPENDIX C

RIPRAP DESIGN FOR LAKE EMBANKMENT

RIPRAP DESIGN FOR OUTER EMBANKMENT

1. Standard Stone Size

According to MAG Std. Spec. 703.2, at least 50% of stone shall weigh not less than 100 pounds and the minimum weigh shall be 10 pounds. Thus,

$$W_{50} = 100 \text{ lbs.}$$

and $$W_{min} = 10 \text{ lbs.}$$

Relation between stone size and weight:

$$D_s = \left(\frac{6W}{\pi \gamma_s}\right)^{1/3} = 1.24\left(\frac{W}{\gamma_s}\right)^{1/3}$$

Where D_s = Stone diameter in ft

W = Stone weight in lbs

γ_s = Specific weight of ston in pcf

Assuming $\gamma_s = 165$ pcf

$$D_{50} = 1.24\left(\frac{100}{165}\right)^{1/3} = 1.05' = 12.6''$$

$$D_{min} = 1.24\left(\frac{10}{165}\right)^{1/3} = 0.49' \cong 6''$$

Therefore, according to MAG Std. Spec. 703.2, $D_{50} = 12.6''$

2. Sizing Riprap according to FHWA Method

Source of Reference :

- Federal Highway Administration. *Use of Riprap for Bank Protection,* Hydraulic Engineering Circular No. 11, June 1967.
- Richardson, E.V., Simons, D.B. Julien, P.Y., *Highways in the River Environment,* Federal Highway Administration, January 1987.

Based on results from HEC-2 analysis, the highest velocity within the study reach (along the proposed embankment of Lake 27-1) of Cereus Wash is 13.4 fps. The suitability of stone size as specified by MAG Std. Specs. Sec. 703.2 is checked by the following steps:

a. Assuming $D_{50} = 12.6'' = 1.05'$ (MAG Std.)

b. $V = 13.4$ fps

c. Flow Depth $y = 7.3'$ } From HEC-2 Output

d. $D_{50}/y = 1.05'/7.3' = 0.144$

e. From Fig. A on the following page,
Velocity against Stone $= 0.56\ V = 0.56 \times 13.4$
$= 7.5$ fps

f. From Fig. B on the following page, the required size of $D_{50} \cong 0.5'$ or $6''$ which is much less than $12.6''$

Source of Reference :

"Use of Riprap for Bank Protection," Hydraulic Engr. Circular No. 11, by FHWA, June 1967.

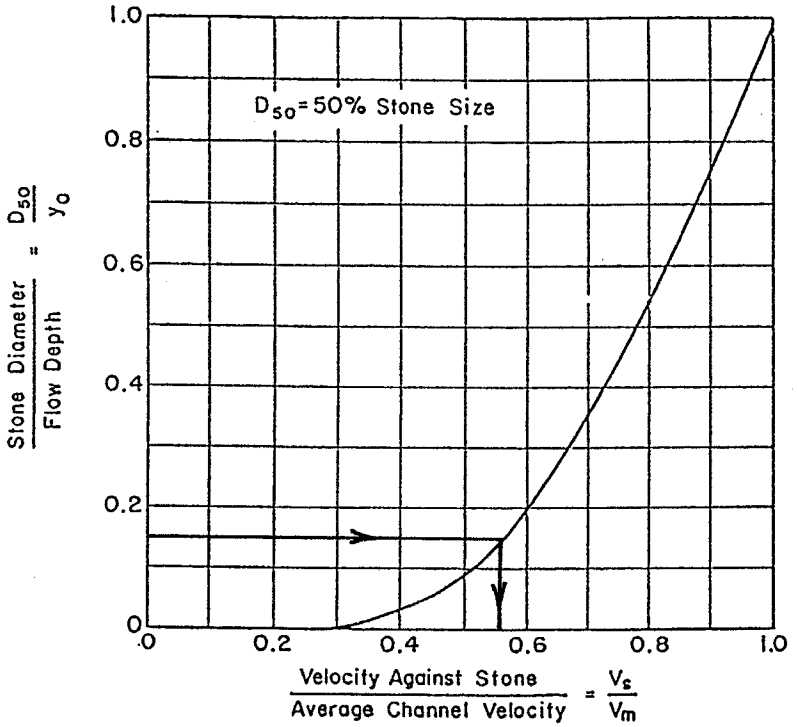


Figure 5.2.3 Velocity against stone on channel bottom (From HEC 11, U. S. DOT, 1967).

(FIGURE A)

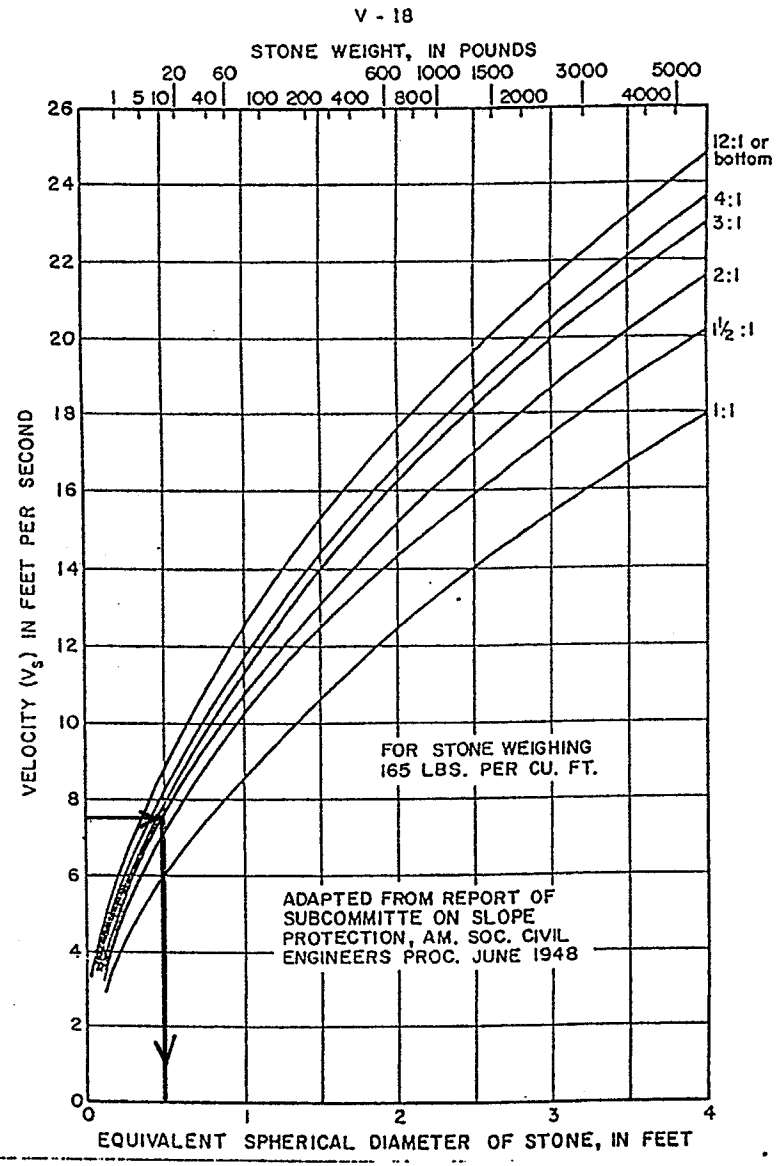


Figure 5.2.4 Size of stone that will resist displacement for various velocities and side slopes. (From Hec 11, 1967).

(FIGURE B)

Sheet 3 of 7
Fig. 11

3. Verification of Riprap Size by Corps of Engineers Method

Source of Reference :

- U.S. Army Corps of Engineers, "Hydraulic Design of Flood Control Channels," EM 1110-2-1601, July 1970

With the construction of the lake embankment, the X-section of Cereus Wash can be approximated by a trapezoidal channel. As shown in the above Source of Reference, the boundary shear for a trapezoidal channel along the wetted perimeter can be determined by the following equation :

$$T_o = \frac{\gamma V^2}{\left[32.6 \log_{10}\left(\frac{12.2\, y}{D_{50}}\right)\right]^2}$$

where T_o = boundary shear in psf
γ = unit weight of water = 62.4 pcf
y = flow depth in ft
D_{50} = average stone size in ft
V = flow velocity in fps

Trial 1 : Assuming $D_{50} = 6'' = 0.5'$

$V = 13.4$ fps

$y = 7.3'$

$$T_o = \frac{62.4 \times 13.4^2}{\left[32.6 \log_{10}\left(\frac{12.2 \times 7.3}{0.5}\right)\right]^2} = \frac{11204.5}{\left[32.6 \log_{10}(178.1)\right]^2}$$

$$= \frac{11204.5}{[32.6 \times 2.25]^2} = \frac{11204.5}{5383.6} = 2.08 \text{ lb/ft}^2$$

On the other hand, from the same Source of Reference, the riprap design shear is equal to :

$$T = a(\gamma_s - \gamma) D_{50} \qquad \text{where Coeff. } a = 0.040$$

$$\text{or } D_{50} = \frac{T}{a(\gamma_s - \gamma)}$$

$$= \frac{T}{0.04(165 - 62.4)} = 0.244\, T$$

When $T = T_o$, $D_{50} = 0.244\, T_o = 0.244 \times 2.08$

$= 0.507' \approx 6''$ Checked !

The computed D_{50} is equal to the assumed D_{50}

4. Factor of Safety

Both FHWA and Corps of Engineers methods suggested that the minimum riprap size required for this project is about 6" in diameter. The MAG Std. Specs requires a $D_{50} = 12.6"$. Thus, the factor of safety for riprap design is:

$$\text{Factor of Safety} = \frac{12.6"}{6"} \cong 2$$

5. Riprap Gradation

According to "Drainage Design Manual, Vol. II – Hydraulics," published by the Flood Control of Maricopa County, the riprap gradation should be as follows:

Table 5.4
Design Gradation for Specified Classes of Riprap

Percent Passing	Size	D_{50} Class, Inches						
		6	8	12	18	24	30	36
100 to 90	2.0 D_{50}	12	16	24	36	48	60	72
85 to 70	1.5 D_{50}	9	12	18	27	36	45	54
50 to 30	1.0 D_{50}	6	8	12	18	24	30	36
15 to 5	0.67 D_{50}	4	5	8	12	16	20	24
5 to 0	0.33 D_{50}	2	3	4	6	8	10	12

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100 to 90	2.0 D_{50}	12	16	24	36	48	60	72
85 to 70	1.5 D_{50}	9	12	18	27	36	45	54
50 to 30	1.0 D_{50}	6	8	12	18	24	30	36
15 to 5	0.67 D_{50}	4	5	8	12	16	20	24
5 to 0	0.33 D_{50}	2	3	4	6	8	10	12

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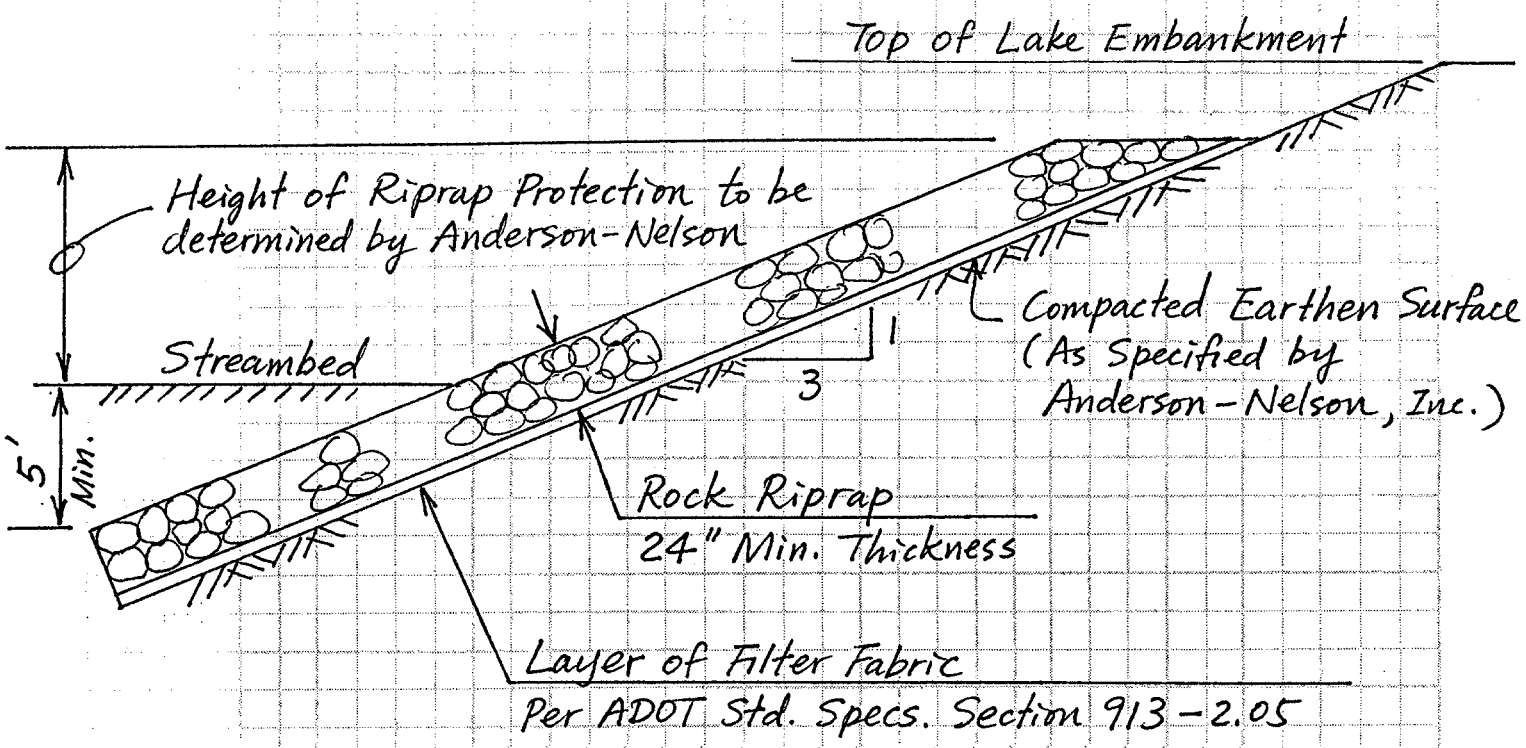
SHEET 7 OF 7
BY SEK DATE 12-20-94
CHECK _____ DATE _____

CLIENT Anderson - Nelson, Inc.
JOB Embankment Protection for Lake 27-1
JOB NO. _____



NOTE: Riprap shall be placed on the entire length of Embankment along Cereus Wash.

RECOMMEND TYPICAL SECTION
FOR OUTER EMBANKMENT PROTECTION
ALONG CEREUS WASH

(NOT TO SCALE)