APPENDIX G
EROSION PROTECTION MATERIAL EVALUATION

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1.0 BACKGROUND

This appendix summarizes the characteristics of erosion protection materials to be used in reclamation of the tailings impoundments at the Cotter Corporation Canon City milling facility. This document has been prepared as an appendix to the 2011 Tailings Reclamation Plan (in progress), associated with Radioactive Materials License 369-01. Durability testing of potential riprap materials (conducted by Cotter Corporation) is summarized in this appendix. This testing was previously presented in the 2005 Decommissioning and Reclamation Plan (MFG, 2005). Additional testing is in progress and will be presented in a future submittal of this appendix.

2.0 EROSION PROTECTION MATERIALS

This section presents the results of evaluation of durability of a potential commercial source of riprap for erosion protection for tailings reclamation. This work was conducted by Cotter in 1998 and 1999, with pertinent documents included in Attachment G.1.

Two riprap materials are planned for tailings reclamation: (1) riprap on regraded embankment slopes, and (2) riprap in diversion channels (where needed based on channel foundation conditions). The design of the riprap size for the regraded embankment slopes is provided in Appendix C of the 2011 Tailings Reclamation Plan. MWH evaluated extreme storm runoff from regraded embankment slopes, and estimated that riprap with a D_{50} (median size) ranging from 1.4 to 4.0 inches would provide acceptable long-term erosional stability under extreme storm events on regraded slopes. MWH is currently in the process of optimizing the final design of the diversion channels and an estimate of the required riprap material sizes will be provided in a future submittal of this appendix. Required material quantities for riprap will be included in the future submittal for the embankment slopes, Primary and Secondary Impoundment surfaces, and for the diversion channels.

Cotter evaluated sources of riprap based on material with a D_{50} of up to nine inches for both slope and channel applications. A commercial source near Canon City, T.H.E. Aggregate Source, was identified in 1998 by Cotter for this material and the material was sampled and tested for durability. Cotter plans to use this same rock source for this riprap. Cotter recently contacted T.H.E. Aggregate Source and they still have the similar material available in sufficient quantities. This appendix discusses the durability test results from 1999 with respect to established durability criteria for uranium tailings reclamation documented by the U.S. Nuclear Regulatory Commission (NRC).

Durability criteria. NRC recommendations for long-term durability of riprap are based on specific tests and scoring summarized in Appendix D of NRC (1990), from literature review in Lindsey and others (1982) and primarily based on work documented in De Puy (1965).

Table D1 (NRC, 1990) contains the scoring criteria for the commonly used durability tests (specific gravity, adsorption, sodium sulfate, L.A. abrasion, Schmidt hammer, and splitting tensile strength). Scoring for the other tests (ultrasonic cavitation, freeze-thaw, scleroscope, coefficient of restitution, compressive strength, and sonic velocity) can be determined from De Puy (1965).

Durability testing. The test results on a rock sample from T.H.E. Aggregate Source conducted by Lincoln DeVore, Inc. in 1997 are attached at the end of this appendix. These results were part of correspondence provided by Cotter to CDPHE in 1999 (Cotter, 1999). The test results are summarized below.

1. L.A. Abrasion (ASTM Method C 535), 21.3 percent loss after 1,000 revolutions.
2. Sodium sulfate soundness (ASTM Method C 88), 0.2 percent loss after 5 cycles.
3. Specific gravity (ASTM C 127); bulk specific gravity (saturated, surface dry): 2.61; apparent specific gravity: 2.63.
4. Absorption (ASTM C 127), 0.3 percent.

In order to be consistent with the scoring criteria in NRC (1990), the L.A. abrasion results were adjusted to a percentage loss after 100 revolutions. A linear adjustment was made, resulting in a percentage loss of 2.1 percent after 100 revolutions. The apparent specific gravity value (from the results above) was used in the scoring criteria. The test results above are summarized in Table G.1. The material was identified as an igneous rock and therefore weighting factors for an igneous rock were used for the scoring.

Table G.1 Riprap Sample Durability Scoring Summary

Durability Test	Test Result	Score	Weighting Factors (Igneous Rock)[a]	Score x Weighting Factor[b]
L.A. abrasion (%)	2.1	9	1	9
Sodium sulfate soundness (%)	0.2	10	11	110
Specific gravity (units)	2.63	8	9	72
Absorption (%)	0.3	9	2	18
TOTAL SCORE	----	----	----	209
MAXIMUM SCORE[c]	----	10	23	230
ROCK QUALITY SCORE[d]	----	----	----	91

a From Table D1 of NRC (1990)
b Product of actual score and weighting factor
c Product of maximum score and weighting factor
d Sum of products of actual score and weighting factor divided by sum of products of maximum score and weighting factor.

Discussion of test results. The test results in Table G.1 were converted to the nearest whole number score value, as outlined in Appendix D of NRC (1990). The corresponding score is listed in the Table G.1 along with the weighting factors used. Results from durability tests are used to determine a total rock quality rating. Durability testing results are given a score which is multiplied by a weighting factor. The weighting factor varies with each durability test and general rock type (igneous, sandstone, limestone). The rock quality rating is the sum of the weighted scores divided by the maximum possible score for the specific rock type tested and number of tests conducted. The rock quality rating calculations for the tested sample are summarized in Table G.1.

Since the type of rock for the riprap borrow material source is an igneous rock, the rock quality score was calculated for this rock type. The rock quality score is above 80, which indicates that this rock is of sufficient durability for use as riprap in both critical and non-critical areas, with no oversizing. Rock quality scores are used to determine acceptance of a rock sample for use as riprap and oversizing requirements. Riprap areas are designated as critical and non-critical areas. Critical areas include frequently saturated areas, all channels, poorly-drained toes and aprons, control structures, and energy dissipation areas (NRC, 1990). For critical areas, scores of 80 to 100 indicate riprap that is of acceptable quality and does not require oversizing, scores

of 65 to 80 indicate riprap that is of acceptable quality but requires oversizing, and scores less than 65 indicates riprap of not acceptable quality. Non-Critical areas include occasionally-saturated areas, top slopes, side slopes, and well-drained toes and aprons (NRC, 1990). For non-critical areas, scores of 80 to 100 do not require oversizing, scores of 50 to 80 require oversizing, and scores of less than 50 are rejected. Oversizing is referred to as a percent increase in rock diameter based on the difference between a score of 80 and the actual score. For example, a sample with a score of 65 would require oversizing of 15 percent. This oversizing percentage is applied directly to the diameter of the riprap.

NRC (1990) suggests initially performing several types of rock durability tests on a selected rock sample to get an indication of rock quality (as has been done for the source near Canon City). Final testing consists of the six tests listed by the NRC: specific gravity, adsorption, sodium sulfate, L.A. abrasion, Schmidt hammer, and splitting tensile strength. Other tests which can be used to determine rock quality are ultrasonic cavitation, freeze-thaw, scleroscope, coefficient of restitution, compressive strength, and sonic velocity. In addition to conducting durability tests, a petrographic examination of the rock sample should be performed by a geologist to determine the qualitative condition of the rock (NRC, 1990).

Based on the preliminary evaluation by Cotter and the testing described above, the commercial rock source near Canon City can provide the particle size and quantity of riprap under the updated plan for tailings impoundment reclamation. The test results and scoring calculations described above indicate that this material is of acceptable long-term durability. As recommended in NRC (1990), confirmation of the durability of this material should include a petrographic analysis as well as durability testing using the six tests listed above. Additional durability testing and a petrographic analysis are currently in process for samples recently collected from the riprap source. The additional durability tests include the Schmidt hammer and splitting tensile strength tests. Results of the additional testing and analysis will be provided in a future update to this appendix. Riprap durability scoring will updated based on the additional testing and included in the updated appendix.

3.0 REFERENCES

Cotter Corporation (Cotter), 1999. Letter to Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (Philip Stoffey) from David Munger concerning rock borrow source material, February 22.

De Puy, G.W., 1965. "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," Engineering Geology, Vol. 2, No. 2, July.

Lindsey, C.G., L.W. Long, and C.W. Begei, 1982. "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," NUREG/CR-2642, prepared for U.S. Nuclear Regulatory Commission, June.

MFG, Inc., 2005. 2005 Update of the Mill Decommissioning and Tailings Reclamation Plan for the Cotter Corporation Canon City Milling Facility. Prepared for Cotter Corporation. August.

U.S. Nuclear Regulatory Commission (NRC), 1990. “Final Staff Technical Position, Design of Erosion Protective Covers for Stabilization of Uranium Mill Tailings Sites.” August.

ATTACHMENT G.1

Durability Testing

DHM Chrono

Cotter Corporation
General Office

12596 West Bayaud Avenue, Suite 350 Lakewood, CO 80228
Phone (303) 980-1292 FAX (303) 980-1296

February 22, 1999

Mr. Philip S. Stoffey
Colorado Dept. of Public Health & Environment
Hazardous Materials & Waste Management Div.
4300 Cherry Creek Drive South
Denver, CO 80222-1530

Re: PMRF SH-5, Rock Borrow Source Material

Dear Mr. Stoffey:

In response to your letter dated December 15, 1998, regarding the suitability of the rip-rap material at The Aggregate Source, Cotter submits the following supplemental information.

The Aggregate Source was requested to provide Cotter with additional information regarding the quality and quantity of their rip-rap material as detailed on the attached RFQ. The Aggregate Source responded to Cotter's RFQ on January 8, 1999 (see attached correspondence) and addressed the issues of material quality, quantity and cost. In addition, The Aggregate Source provided a copy of laboratory testing resting performed by Lincoln DeVore, Inc., on a plant sample of rip-rap material (see attached correspondence).

Should you have any further questions regarding this matter, please do not hesitate to contact me.

Sincerely,

David H. Munger
Senior Environmental Engineer

DHM:dd
DHM432.DHM

cc: Don Simpson, CDPHE
Ken Weaver, CDPHE
Jeff Hynes, CGS

Cotter Corporation

Lakewood Distribution:

R. Ziegler _____
S. Landau _____
P. Niesen _____
10-01-01 _____

Canon City Distribution:

J. Rothfleisch _____
J. Cain _____
P. Dremel _____

Cotter Corporation
General Office

12596 West Bayaud Avenue, Suite 350 Lakewood, CO 80228
Phone (303) 980-1292 FAX (303) 980-1296

January 5, 1999

T.H.E. Aggregate Source, Inc.
201 Tunnel Drive Rd.
Canon City, CO 81212

Attn: Bev Caligaris

Please respond by January 15, 1999

Fax: 719-275-8196

RFQ

Cotter Corporation is requesting a written quotation for 87,300 c.y. of 9" D_{50} riprap material delivered to Cotter's Canon City Mill Site. Please separate the cost for purchasing the material from the cost for transportation. This quotation is for planning purposes only. The actual purchase and delivery of the rip material will not occur until Cotter commences final site reclamation activities sometime in the future. In accordance with Cotter's Final Reclamation Plan, approved by the State of Colorado, the riprap material specification must meet the NRC Scoring Criteria (see attached). Cotter Corporation is requesting that you provide copies of all laboratory test results, and method of testing used, that confirms your material meets the NRC Scoring Criteria for rock quality and durability. In addition please confirm that the estimated quantity, 87,300 c.y., is available at this time and, if possible, how long this material will be available in the future. Upon receipt of your quotation, Cotter may request a site inspection, along with State personnel, to inspect the suitability of the riprap material sources.

T.H.E. AGGREGATE SOURCE, Inc.

QUARRY OFFICE:
201 TUNNEL DRIVE ROAD • CAÑON CITY, COLORADO 81212 • 719/275-6746
MAIN OFFICE:
~~904 STATE HIGHWAY 115 - PENROSE, COLORADO 81240 - 719-372-3173 - FAX 719/3180~~

RECEIVED
JAN 12 1999

January 8, 1999

Cotter Corporation
LAKEWOOD, CO

Attention: Alice

Re: RFQ dated January 5, 1999

87,300 CY 9" D50 Rip Rap x 1.5= 130,950 Tons

130,950 Tons @ 7.00 Per Ton - FOB Quarry

130,950 Tons @ 2.10 Per Ton Delivery - Canon City Mill

I circled the scoring chart to show the quality of our rip rap.

We normally stockpile 10,000 - 20,000 tons of this material (D50 9"). We have unlimited reserves and can produce 2,000 - 3,000 tons per day of this size.

Please call me if you would like to request a site visit.
The prices quoted above are good for one (1) year.

Ed Tezak, Jr.

TABLE D1

Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
				10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
	Limestone	Sandstone	Igneous											
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

Lincoln DeVore, Inc.
Geotechnical Consultants
602 East 8th St.
Pueblo, CO 81001
TEL: (719) 546-1150
FAX: (719) 546-1152

September 23, 1997

Tezak Heavy Equipment Co.
840 South 1st Street
Canon City, CO 81212

Re: Plant Sample
Rip Rap
T.H.E. Aggregate Source
LD Job No. 97-1710-P

Gentlemen:

Personnel of Lincoln-DeVore, Inc. have completed the requested testing on the sample referenced above, delivered September 2, 1997. The sample was not obtained in the field by personnel of Lincoln-DeVore, Inc.. As a result, this laboratory cannot verify the field location from which the sample was obtained or the method of sampling. Results are as follow:

ASTM C 535 - Los Angeles Abrasion, Grading No.1

% loss after 1,000 revolutions - 21.3

ASTM C 88 - Soundness of Aggregate by use of Sodium Sulfate 5 cycles

% loss - 0.2

ASTM C 127 - Specific Gravity and Absorption of Coarse Aggregate

Bulk Specific Gravity, SSD - 2.61

Apparent Specific Gravity - 2.63

Absorption - % 0.3

We hope this has provided you with the information that you requested. If you have any questions, or desire additional information, please feel free to contact this office at anytime.

Respectfully submitted,

LINCOLN-DEVORE, INC.

By Larry J. Frank

c: Lincoln-DeVore, Inc., Colorado Springs, CO

C+0,00

Cotter Corporation
General Office

12596 West Bayaud Avenue, Suite 350 Lakewood, CO 80228
Phone (303) 980-1292 FAX (303) 980-1296

December 7, 1998

Mr. Philip S. Stoffey
Colorado Dept. of Public Health & Environment
Hazardous Materials & Waste Management Div.
4300 Cherry Creek Drive South
Denver, CO 80222-1530

Dear Mr. Stoffey:

As a follow up to the recommended future actions contained in PMRF SH-5, develop a preliminary rock borrow source sampling program, Cotter submits the following report.

In summary, SH-5 concluded that of the six potential rock borrow sites located on or near Cotter controlled property only two sites warranted further investigation. Each of the six sites, five on Cotter controlled property and one approximately 2-3 miles south of the mill site (see attached map), were inspected on August 26, 1994 by performing a general lithologic evaluation and a visual inspection to (1) estimate the amount of plus 6-inch rock material available on surface and (2) assess durability. The four sites which were judged unsuitable and thus did not warrant any additional field investigation were dropped due to the high clay content of the potential source material. The remaining two sites (see Locations 1 and 6 on the attached map) were investigated on February 20, 1995.

At Location No. 1 a trench, using a dozer, was excavated on the hillside to a maximum depth of 14 feet (hanging wall). The near surface material ranged in size from 2-7 inches suggesting frost action weathering on larger fragments. Grain size and quantity did not improve with depth. The vast majority (85%) of the material found at depth was less than 3 inches. Based upon this field investigation at Location No. 1 the site was classified as unsuitable due to limited quantity, small size and excessive fines of the material discovered.

Location No. 6, located south of the mill site above the junction of Chandler and Oak Creek Grade (see attached map), was visually inspected on February 20, 1995. This inspection noted the following: (1) approximately 30 percent of the alluvium could be classified as boulders (size greater than 2 foot) and cobbles (size greater than 3-4 inches); (2) the near surface material was much harder than the older alluvium and not as weathered; and (3) the rock material did not break when pounded with a rock hammer. A portion of this site is located on private property while the remaining portion is located on property controlled by the U.S. Forest Service. No subsurface exploration using a dozer was performed during this field inspection. Since this

site is located on private and government-held lands, an access agreement would be required prior to performing any trenching activities. Subsequent to this field inspection, preliminary work on securing an access agreement with the private landowner was initiated. However, pursuit of an access agreement was terminated in August 1995 when an investigation of an offsite commercial aggregate source near Canon City (The Aggregate Source held by Tezak) determined that a suitable quality and quantity of rip-rap material was available.

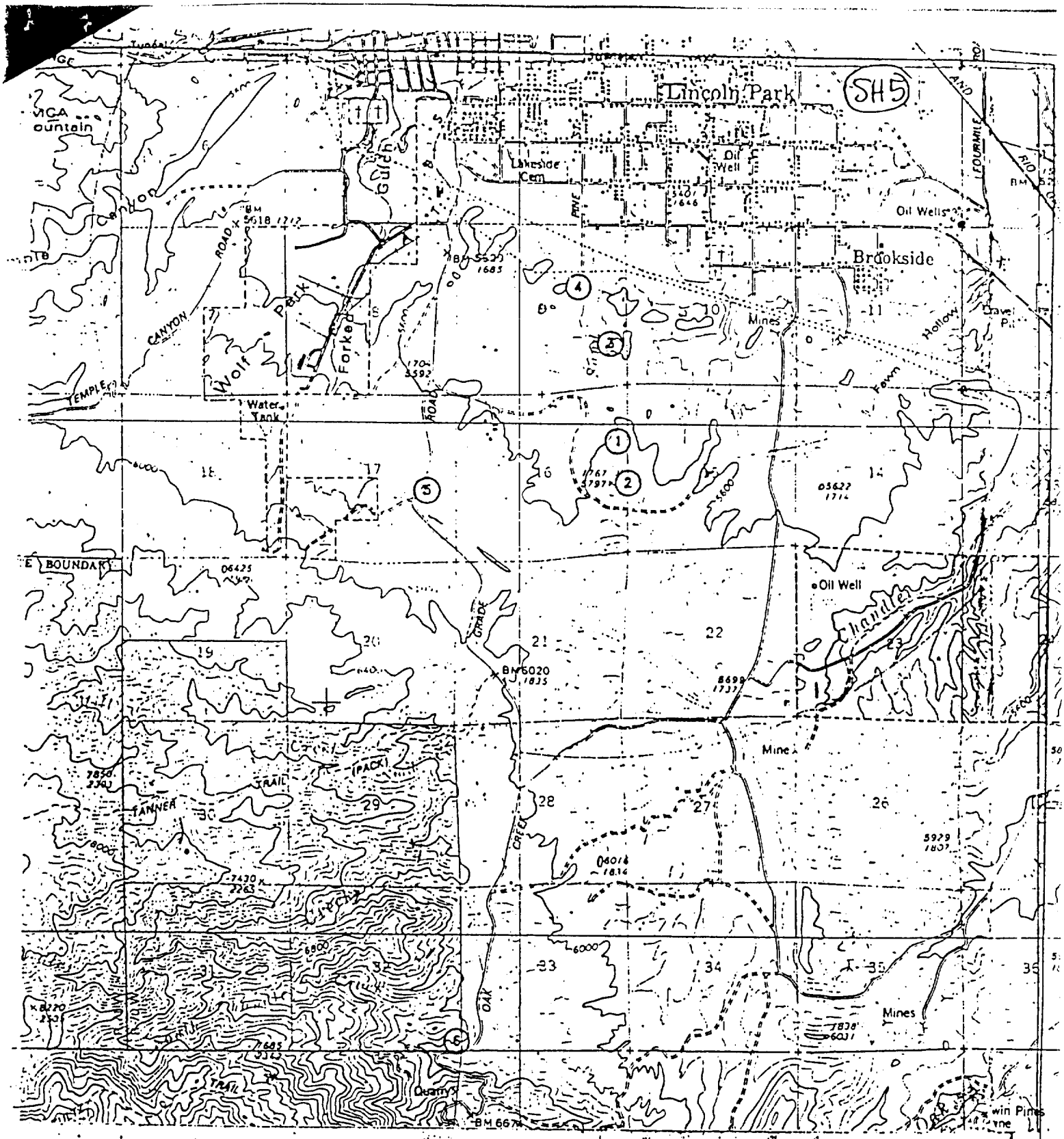
In conclusion, the future actions required by SH-5 which state: (1) the Cotter site will be sampled in the spring/summer 1995; and (2) if the Cotter site material is unsuitable, other possible sites including quarries will be investigated, have been met. Please confirm in writing the State's receipt and acceptance of this report at your earliest convenience.

Should you have any questions regarding this matter please contact me.

Sincerely,

David H. Munger
Senior Environmental Engineer

DHM:dd
DHM425.DHM



POTENTIAL ROCK BORROW SOURCE LOCATIONS

Cotter Corporation

Canon City Distribution:

Jack Rothfleisch _____
Jim Cain _____
Pat Dremel _____

Lakewood Distribution:

Rich Ziegler _____
Steve Landau _____
Preston Niesen _____
File 10-01-01 _____