

Third Quarterly Progress Report

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of

BENTONITE SEALING INVESTIGATIONS

For the Period

of

August 1, 1960 to November 1, 1960

by

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Prepared for the

Southeastern Colorado Water Conservancy District

and the

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Colorado State University Experiment Station Engineering Research

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#### INTRODUCTION

This report contains several condensed but detailed tabulations of information, which at this early stage in the resource-evaluation and application-research-and-development work are of a tentative incomplete nature<sup>1</sup>. Widespread interest in the work and numerous inquiries for information make it desirable to present a fairly detailed summary of work at this time. Common questions include:

- 1. <u>Procedure--what are the best procedures for canal or reservoir</u> sealing work with local clays?
- 2. <u>Quality--what are the specifications for a clay, satisfactory</u> for sealing purposes?
- 3. <u>Results</u>--what results have been produced in the field trials with local clays?

As a partial answer to the above questions, consider the information compiled by the early efforts of the bentonite (or clay) sealing project at CSU, in cooperation with many irrigation organizations, individuals, and clay producers.

#### SAMPLING AND EVALUATION OF SAMPLES

Tables I and II summarize the results of the initial sampling and laboratory testing of bentonites or clays from locations as shown on Map I.

In the laboratory evaluation work, samples of clays are being tested that have been collected both (a) by CSU project people, and (b) by interested individuals or prospectors. We are especially encouraging the latter type of sampling and will be glad to furnish additional details of what to look for to any interested parties. An Extension Service circular, <u>Testing Bentonite for Sealing Purposes</u> (No. 205-A), is available at most County Agent offices in Colorado (and in Wyoming as well--Circular No. 161).

The test procedures used in the laboratory evaluation work have involved existing procedures to the maximum extent possible, but in order to fully characterize and evaluate the clays or bentonites from a canal and reservoir sealing standpoint, the development of new test procedures, including major modification of existing procedures, has been necessary. A brief description of the test procedures used in the evaluations to date is included at the bottom of Table I. More complete details of the test procedures can be obtained, if desired, by writing to us.

<sup>1</sup>Tentative in a sense that the work is in its beginning stages--having been fully funded starting July 1, 1960.



Testing with procedures, in addition to those outlined in Table I, is planned and will be completed as time permits.

### EVALUATION OF FIELD TRIALS

Table III summarizes briefly the results of the evaluations, to date, of field trials at locations as shown on Map 2.

While the table is essentially self-explanatory, it is very brief (perhaps even fragmentary). Detailed records are being compiled on each of the jobs included in the table. Thus, if additional information relating to any particular trial is desired, or if you have additional information to supply for any trial, please write us.

Additional evaluations are planned, both for the trials in the present table and for new trials or other trials not included in this summary.

## DISCUSSION OF RESULTS AND FUTURE PLANS

As mentioned in the two preceding quarterly reports, the objectives of the CSU bentonite project are (a) to inventory the clay resource of Colorado, and (b) to develop methods of utilizing the local clays in sealing canals and reservoirs in Colorado. Thus, the two important justifications for this State-funded work relate to (a) development of new mineral industry, and (b) conservation of water. Thus, while the market potential aspects are not involved directly in many research studies, they are definitely involved in this inventory, research and development project -- organization of the bentonite project work clearly reflects this influence.

Chay inventory--with the valuable assistance of many cooperators (individuals, companies, districts), the initial sampling efforts by the CSU project have revealed a good range of available clay (bentonite?) deposits (See Map I). As a result of this, we are convinced (a) that a significant potential of clay deposits is available for development in Colorado, and (b) that the initial sampling efforts as outlined in this report have covered only a small fraction of the total potential. Because of the magnitude of the clay resource inventory work remaining to be completed, plans are being made for continuing this work by the CSU Geology Department in the next fiscal year--provided funding is available. The field work is planned for the summer and the clay mineral identification (including X-ray and D-T analyses) for the winter. Chemical testing of the better clay samples by the CSU Soils Department is also planned.

# TABLE I: SUMMARY OF TEST RESULTS (PART I) FROM INITIAL LABORATORY EVALUATIONS OF COLORADO CLAY SAMPLES

Sample No.	Name and Location	Collo 0-	oidal '	Yield Over	Gr	Lt Con	tent	Fil	ter Lo (ml/m	ss Test in)2	Fi	lter ( tabil:	Cake ity	Mi	xabil:	ity In	dex		Swell :	Index (;	.)
NO.		45%	45- 65%	65%		10-5%	Under 5%	0-10	10-50	Over 50	Poor	r Fain	r Good	0-25	25-50	50-75	75-100	0-50	50-100	100-150	0ve
\$28-1	Fox-Dilley N. of Canon City	39.5				8.8		5.1					x				77.5		97.8		
528-2	Fox-Dilley	39.6				7.9		4.8					x		34.9				88.0		
S <b>31-1</b>	N. of Canon City Wyble		57.7				1.8	8.6				х			32.8					108.0	
S31A-3	N. of Wellington Wyble	36.2					3.0	5.3					x		32.5				78.0		
S33-1	Near Creede Monroe N. of Ft. Collins			73.3			3.1			189.0	x						82.7		1-34	143.0	
533-2	Monroe	1		78.2			2.0	9.9			-	x			47.1						162.
36-4	N. of Ft. Collins Schrader		52.3				1.7		26.7		x				47.0					132.0	
36-5	N. of Ft. Morgan Schrader		57.6			5.5			44.3		x						77.9		99.0		
37-2	N. of Ft. Morgan Strainland		56.2		12.81				15.5			x		12.3			11-2	30.0	<i>,,,</i>		
8. S.	N. of Golden Marshall				41.4		1.8					~		12.0		68.7		50.0			
\$37-5	N. of Golden		50.0				1.0		23.7		x					00.1		50.0			
542-1	Rump SN of Grand Junction		47.2			9.4		1.5					x	14.7							170.
543-1	Burton-Tuttle	36.0				7.0			17.1			х			46.9				55.0		
544-4	W. of Aspen Butterfield			66.1			1.8	1.2					x	8.5							253.
645-1	S. of Las Animas Wagner		55.6			7.9			10.3			x			38.2					130.0	
547-1	Near Las Animas Moss Near Westcliffe	24.3			12.2 <sup>1</sup> 35.8				40.1		x						78.0	25.0			
548-1	Mumma	30.6			11.1		2.41	4.3					x				89.7			110.0	
549-3	W. of Salida Lamberg	35.6				6.7		2.6				х					77.7		90.0		
552-1	SE of Salida Warren			67.7			3.7			172.0	x				36.4		11:1		60.0		
	N. of Ft. Collins		0	0111						162.2					<i>J</i> 0.14		98.9				
\$52-18	Warren N. of Ft. Collins		56.8				2.2				x						90.9		75.0		
853-1	White Rose Near Carr		47.5				0.9			129.3	x				30.0			30.0			
854-1	Brick Plant S. of Ft. Collins	35.5					0.8		45.9		x			21.4				30.0			
855 <b>-</b> 1	Clover Basin	29.9					0.8			52.0	x			19.4				46.0			
356-1	SW of Longmont Cox	26.4				5.4			31.7		x			13.2				10.0			
660-4	NE of Morrison Welte	37.3					3.5			97.0	x					62.1		30.0			
62-1	N. of Colorado Springs Wisenhunt Near Castle Rock		52.4				2.1		12.3			x		12.6				40.0			
62-2	Wisenhunt	43.1				5.2			10.4			x		10.9		100 C C		20.0			
63-1	Near Castle Rock Last Chance	41.9					1.7		19.7			x		24.3					57.8		
564-1	SW of Akron Harvey	44.4			18.8					304.0	x				38.1			40.0			
67-2	W. of Canon City Bennett		49.5				0.2	6.8					x	16.8	,			40.0			
68-1	N. of Golden Lindsey N. of Golden	33.4					2.8	5.7					x	10.0		66.7		30.0			
71-1	Highway 63	34.3			16.4				42.5		x				25.7			25.0			
72-1	N. of Akron Peach Valley		60.8			7.3			15.1			x			46.1					132	
	E. of Delta	21 7	50.0			09	7.0					~			.0.1		82.4	50.0		-)-	
73-2	Mahan Near (?) Pueblo	31.7					3.2		32.5		x						02.4	50.0			
74-1 and 2	Schrader N. of Ft. Morgan	36.2					1.1			112.3		х			32.7				70.0		
00-5	Wyoming bentonite			86.8			2.8	0.9					x								627

With extra washing

Supplemental Procedure Notes

Sample Preparation--All samples are registered for identification, oven-dried at 100°C, and a test portion crushed to pass a U.S. No. 8  $\,$ sieve.

<u>Colloidal Yield</u>--is the percent of sample that will remain sus-pended or dispersed in water after 24 hours. A high yield normally means a high clay content, and usually a high sealing potential.

Grit Content--is the percent of sample left on a U.S. No. 200 seive after washing. A low percentage of grit is desired for most sealing applications.

Filter Loss--is the loss\* in ml./min when 400 ml. of a 2% mixture of bentonite in water is placed in a pressure cell, subjected to an air pressure (equal to 3<sup>1</sup>/<sub>2</sub> of water), and filtered through a standard filter paper. A low rate of loss is desired.

Compiled by R. W. Hansen and C. C. Smith

Filter Cake Stability--is obtained by subjecting the clay coating left on the filter paper from the <u>Filter Loss</u> test to a small jet of water. This gives an approximate idea of the resistance to erosion of the clay sediment.

Mixability Index--is obtained by dividing the weight of sample lost (after a standard washing test) by the original weight. A high index indicates easy mixing.

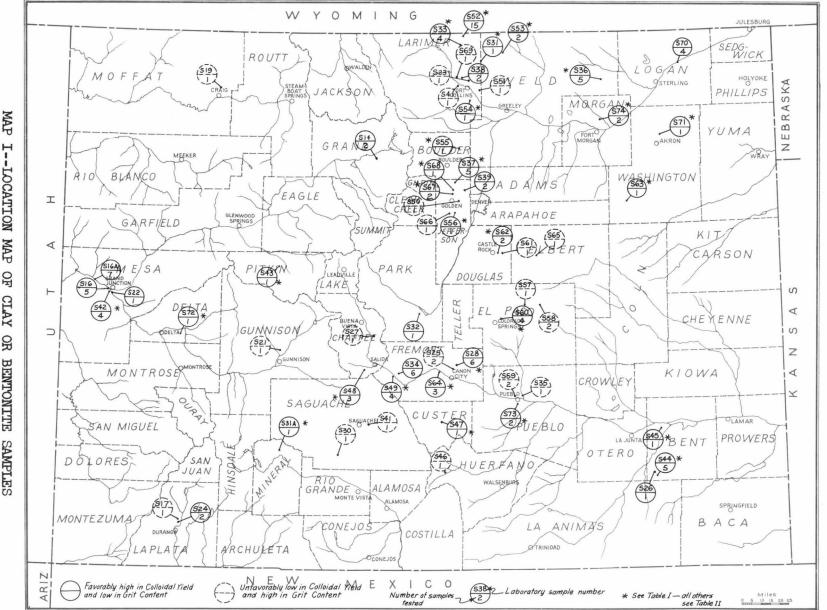
Swell Index--is obtained by measuring the increase in volume when a dry sample of known bulk volume is saturated or completely wetted. Some swell is desirable but not too much.

\*For comparison note that a: 1/8-inch layer of -40 Ottawa sand had a seepage rate equal to 1440 ml./min 1/8-inch layer of local sandy soil had a seepage rate equal to 1005 ml./min Filter paper alone had a seepage rate equal to 651 ml./min

# TABLE II<sup>1</sup>: SUMMARY OF TEST RESULTS (PART II) FROM INITIAL LABORATORY EVALUATIONS OF COLORADO CLAY SAMPLES

S14-2         Monoscient           S16-1         Ruff           S16-2A         Upp           S16-2B         Lon           S16-3         Lin           S16-3         Lin           S16-4         Smin           S16-5         Smin           S16-5         Smin           S16A-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S16A-6         Weil           S17-1         For           S21-1         Lon           S22-1         Stit           S22-1         Stit           S22-1         Stit           S22-1         For           S22-1         Stit           S22-1         Stit           S22-2         For           S22-3         For           S28-32         For           S28-32         For           S28-4         For           S28-5         For           S32-1         Pac           S30-1         Hor	<pre>PisherNear Granby dorrisNear Grand Junction Grand Junction Jpper Pond'sNear Grand Junction Sower Pond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Mith (lower)Near Grand Junction Vells (25-30)Near Fruita Vells (25)Near Fruita Vells (25)Near Fruita Vells (15)Near Fruita Vells (25)Near Fruita Vells (25)Near Verago Verago Verago Verago Verago Verago Vells (25)-Near Verago Vells (25)-Near Verago Vells (25)-Near Verago Verago Verago Vells (25)-Near Verago Vells (25)-Near Verago Vells (25)-Near Vells (25)-Near Verago Verago Verago Verago Vells (25)-Near Vells (2</pre>	Under 25% 2 22.7 18.3 20.1 18.5	15-115% 143.0 140.7 35.0 33.9 143.2 26.1 38.3 31.9 39.3 35.5 25.7	4 <u>5-65</u> % 56.4 53.8 47.6	0ver 65%	0ver 10% 19.1 26.5	9.2 6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0	Under 5% 2.7 1.1	539-2 S40-1 S41-1 S44-1 S44-2 S44-5 S46-1 S46-1 S48-2 S49-4 S50-1 S51-1	Standley LakeNear Arvada Charman (Mailed) Near Fl Center SmithNear Fort Collins RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden	Under 25% 3.3 16.8 18.4 7.6	25-45% 39.7 34.6	0ver 45-65≸ 65≸ 50.4 53.4 48.0 47.2 49.8	0ver 105 14.3 73.7 27.2 21.4 22.1 34.6	9.3 5.7 7.4	Under 5% 4.6 3.3
S14-2         Monoscience           S16-1         Rur           S16-2A         Upp           S16-2B         Lor           S16-2B         Lor           S16-2B         Lor           S16-3         Lin           S16-4         Smither           S16-5         Smither           S16-6-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S16A-7         Weil           S16A-7         Weil           S16A-7         Weil           S16A-6         Weil           S17-1         Foo           S22-1         Strighther           S22-1         Strighther           S25-1         Difther           S25-2         Difther           S28-32         Foo           S28-4         Foo           S28-5         Foo           S28-5         Foo           S30-1         Hog           S31-2         Weil           S31-2         Weil           S31-	Granby AorrisNear Grand Junction Grand Junction Jpper Pond'sNear Grand Junction Jower Pond'sNear Grand Junction Jime KilnNear Grand Junction Smith (lower)Near Grand Junction Smith (lower)Near Grand Junction Hells (25-30)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (15)Near Fruita Nells (10)Near Fruita Nells (10)Near Fruita Near-Near Craig Jurango Port Collins PloraNear (?) Durango NileyN. of	22.7 18.3 20.1	43.0 40.7 36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5	56.4 53.8		19.1	9.2 6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0	2.7	540-1 541-1 544-1 544-2 544-5 546-1 548-2 549-4 550-1	Arvada Chapman (Mailed) Near Pl Center SmithNear Fort Collins RodgersS. of Las Animas RodgersS. of Las Animas SchoolS. of Las Animas SchoolS. of Las Animas McAlpinNear Redwing MummaW. of Salida LambergNear Howard SkinnerNear Golden	3.3 16.8 18.4	39.7 34.6	50.4 53.4 48.0 47.2	14.3 73.7 27.2 21.4 22.1 34.6	9.3 5.7	4.6
S14-2         Mon           S16-1         Rur           S16-1         Rur           S16-2         Up           S16-2B         Lor           S16-2B         Lor           S16-2B         Lor           S16-2B         Lor           S16-3         Lir           S16-5         Smin           S16A-1         Wei           S16A-2         Wei           S16A-3         Wei           S16A-4         Wei           S16A-5         Wei           S16A-6         Wei           S17-1         For           S21-1         Lor           S22-1         Str           S24-1         Fli           S25-2         Dif           S25-1         Dif           S26-1         Br           S28-32         For           S28-4         For           S28-5         For           S28-5         For           S28-6         For           S30-1         Hor           S31-2         Wei           S32-1         Dav           S34-1         Kei	dorrisNear Granby NumpNear Grand Junction Joyer Pond'sNear Grand Junction Jower Pond'sNear Grand Junction Mith (lower)Near Grand Junction Smith (upper)Near Grand Junction Smith (upper)Near Grand Junction Smith (upper)Near Grand Junction Smith (15)Near Fruita Yells (15)Near Fruita Yells (15)Near Fruita Yells (15)Near Fruita Yells (15)Near Fruita Yells (10)Near Fruita Yells (10)Near Grand Junction StraffordNear (?) Grand-Junction SchraferNear (?) Fort Collins FloraNear (?) Durango	18.3 20.1	40.7 36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5		65+3	26.5	6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0		S41-1 S44-2 S44-2 S44-3 S44-5 S46-1 S48-2 S48-2 S49-4 S50-1	Chapman (Mailed) Mear PI Center SmithNear Fort Collins RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden	16.8		53.4 48.0 47.2	27.2 21.4 22.1 34.6	5.7	
S16-1         Rum           S16-2         Upp           S16-28         Lov           S16-28         Lov           S16-29         Lov           S16-3         Lin           S16-5         Smin           S16-5         Smin           S16-5         Smin           S16A-2         Weil           S16A-2         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S17-1         For           S21-1         Lor           S22-1         Still           S21-1         Lor           S22-1         Still           S22-1         Still           S24-1         Fill           S25-2         Dill           S28-32         For           S28-32         For           S28-32         For           S28-5         For           S28-6         For           S30-1         Hor           S31-2         Weil           S31-2         Weil     <	Granby RumpNear Grand Junction Grand Junction Grand Junction Jover Pond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Jord Junction Vells (25-30)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (15)Near Fruita Kells (16)Near Fruita Kells (16)Near Kells (17)-Near Fruita Kells (17)-Near Fruita Kells (18)-Near Fruita Kells (18)-Near Fruita Kells (18)-Near Fruita Kells (18)-Near Kells (18)-Near	18.3 20.1	40.7 36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5		65.3		6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0		S41-1 S44-2 S44-2 S44-3 S44-5 S46-1 S48-2 S48-2 S49-4 S50-1	Near Pl Center SmithNear Fort Collins RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden	16.8		53.4 48.0 47.2	27.2 21.4 22.1 34.6	5.7	
S16-2A         Up           S16-2B         Low           S16-2B         Low           S16-3         Lin           S16-3         Lin           S16-4         Smith           S16-5         Smith           S16-7         Weith           S16A-1         Weith           S16A-2         Weith           S16A-3         Weith           S16A-4         Weith           S16A-5         Weith           S16A-6         Weith           S17-1         Form           S21-1         Low           S22-1         Sch           S21-1         Low           S22-1         Sch           S22-1         Sch           S22-1         Dift           S22-1         Dift           S22-1         Dift           S22-2         Form           S22-3         Form           S22-4         Form           S22-5         Dift           S22-1         Dift           S28-32         Form           S28-32         Form           S28-5         Form           S30-1         Horm <td>Grand Junction Jpper Pond'sNear Grand Junction Jower Pond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Nith (upper)Near Fruita Vells (25-50)Near Fruita Vells (15)Near Fruita Vells (15)Near Craig Jurango FloraNear (?) Durango VelleyN, of</td> <td>18.3 20.1</td> <td>36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5</td> <td></td> <td>65.3</td> <td></td> <td>6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0</td> <td></td> <td>544-1 544-2 544-3 544-5 546-1 548-2 549-4 550-1</td> <td>Fort Collins RodgersS. of Las Animas RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redwing MummaW. of Salida LambergNear Howard SkinnerNear Golden</td> <td>18.4</td> <td></td> <td>53.4 48.0 47.2</td> <td>21.4 22.1 34.6</td> <td>5.7</td> <td></td>	Grand Junction Jpper Pond'sNear Grand Junction Jower Pond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Nith (upper)Near Fruita Vells (25-50)Near Fruita Vells (15)Near Fruita Vells (15)Near Craig Jurango FloraNear (?) Durango VelleyN, of	18.3 20.1	36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5		65.3		6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0		544-1 544-2 544-3 544-5 546-1 548-2 549-4 550-1	Fort Collins RodgersS. of Las Animas RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redwing MummaW. of Salida LambergNear Howard SkinnerNear Golden	18.4		53.4 48.0 47.2	21.4 22.1 34.6	5.7	
S16-2B         Low           S16-2B         Low           S16-3         Lin           S16-5         Smin           S16-5         Smin           S16-7         Wei           S16A-2         Wei           S16A-3         Wei           S16A-4         Wei           S16A-5         Wei           S16A-6         Wei           S17-1         For           S17-1         For           S21-1         Lor           S22-1         Str           S25-1         Dii           S25-2         Dii           S27-1         Joi           S28-32         For           S28-34         For           S28-5         For           S28-5         For           S28-5         For           S29-1         Pate           S30-1         Hor           S31-2         Wyt           S32-1         Dav           S34-1         Kei	Grand Junction Jower Pond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Dith (upper)Near Grand Junction bells (25)Near Fruita lells (15)Near Fruita lells (15)Near Fruita lells (15)Near Fruita lells (15)Near Fruita lells (10)Near Fruita NosterNear Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango PileyN. of	18.3 20.1	36.0 33.9 43.2 26.1 38.3 31.9 39.3 35.5	47.6	65.3		6.7 7.7 9.7 5.6 8.3 6.7 6.1 8.0	1.1	544-2 544-3 544-5 546-1 548-2 549-4 550-1	Las Animas RodgersS. of Las Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden			53.4 48.0 47.2	21.4 22.1 34.6		
S16-2B         Lot           S16-3         Lit           S16-5         Smither           S16-5         Smither           S16-5         Smither           S16-7         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S16A-6         Weil           S16A-6         Weil           S16A-6         Weil           S17-1         Porther           S21-1         Lot           S22-1         Stit           S22-1         Stit           S22-1         Stit           S22-1         Stit           S22-1         Stit           S22-1         Stit           S22-2         Stit           S22-3         For           S28-32         For           S28-32         For           S28-5         For           S28-6         For           S30-1         Hor           S31-2         Wat           S32-1         Dax           S34-1         Kein	Lower Fond'sNear Grand Junction Jime KilnNear Grand Junction Mith (lower)Near Grand Junction Mith (lower)Near Grand Junction Vells (25-30)Near Fruita Vells (25)Near Fruita Vells (25)Near (?) Grand Junction SchraderNear (?) Durango VelleyN, of	18.3 20.1	33.9 43.2 26.1 38.3 31.9 39.3 35.5	47.6	65+3		7.7 9.7 5.6 8.3 6.7 6.1 8.0	1.1	544-3 544-5 546-1 548-2 549-4 550-1	RodgersS. of Les Animas StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden			48.0 47.2	21.4 22.1 34.6	7.4	
S16-3         Lin           S16-3         Lin           S16-4         Smither           S16-5         Smither           S16-7         Smither           S16A-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S16A-7         Weil           S16A-6         Weil           S17-1         For           S21-1         Lon           S22-1         Sct           S21-1         Lon           S22-1         Sct           S22-1         Sct           S24-1         Flin           S25-2         Dil           S25-2         Dil           S26-1         Brother           S28-32         For           S28-32         For           S28-34         For           S28-5         For           S30-1         Hor           S31-2         Wat           S32-1         Dax           S34-1         Keil	Jime KilnNear Grand Junction Smith (lower)Near Grand Junction Mith (upper)Near Fruita [c]16 (25-50)Near Fruita [c]16 (25)Near Fruita [c]16 (25)Near Fruita [c]16 (25)Near Fruita [c]16 (15)Near Fruita [c]16 (15)Near Fruita [c]16 (15)Near Fruita [c]16 (15)Near Fruita [c]16 (15)Near Fruita [c]16 (15)Near [c]16] [c]16Near Craig Durango [c]16-Near (?) Fort Collins FloraNear (?) Durango StleyN. of	18.3 20.1	33.9 43.2 26.1 38.3 31.9 39.3 35.5		65.3		9.7 5.6 8.3 6.7 6.1 8.0	1.1	544-5 546-1 548-2 549-4 550-1	StoughS. of Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden			47.2	21.4 22.1 34.6	7.4	3.3
S16-4         Smith           S16-5         Smith           S16A-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-5         Weil           S16A-6         Weil           S16A-6         Weil           S17-1         For           S21-1         Loc           S22-1         Str           S22-1         Str           S25-1         Dil           S25-2         Dil           S25-2         Dil           S26-3         For           S28-32         For           S28-32         For           S28-4         For           S28-5         For           S28-5         For           S28-6         For           S30-1         Hog           S31-2         Weil           S31-2         Keil	Grand Junction mith (lower)Near Grand Junction Mith (upper)Near Grand Junction tells (25-30)Near Fruita T	18.3 20.1	33.9 43.2 26.1 38.3 31.9 39.3 35.5		65.3		9.7 5.6 8.3 6.7 6.1 8.0	1.1	544-5 546-1 548-2 549-4 550-1	Las Animas SchoolS. of Las Animas McAlpinNear Redving MummaW. of Salida LambergNear Howard SkinnerNear Golden			47.2	21.4 22.1 34.6		3.3
S16-5         Smith           S16A-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-4         Weil           S16A-5         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S17-1         For           S17-1         For           S21-1         Lor           S22-1         Setting           S22-1         Setting           S25-2         Diil           S25-2         Diil           S25-2         Diil           S25-1         Deil           S25-2         Diil           S25-3         For           S28-3         For           S28-3         For           S28-4         For           S28-5         For           S28-6         For           S31-2         Writ           S31-2         Writ           S31-2         Ket           S34-1         Ket	Grand Junction Smith (upper)Near Grand Junction Vells (25-30)Near Fruita Vells (25)Near Fruita Vells (25)Near Fruita Vells (25)Near Fruita Vells (25)Near Fruita Vells (15)Near Fruita Vells (15)Near Fruita Vells (15)Near Fruita Vells (15)Near Vells (15)Near Fruita Vells (15)Near Fruita Vells (15)Near Fruita Vells (15)Near (15)Near (15)-Near Fruita Vells (15)Near (15)-Near (1	18.3 20.1	43.2 26.1 38.3 31.9 39.3 35.5		65.3		5.6 8.3 6.7 6.1 8.0	1.1	546-1 548-2 549-4 550-1	Las Animas McAlpinNear Redwing MummaW. of Salida LambergNear Howard SkinnerNear Golden				21.4 22.1 34.6		3.3
S16A-1         Weil           S16A-2         Weil           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-5         Weil           S16A-5         Weil           S16A-6         Weil           S16A-6         Weil           S16A-6         Weil           S17-1         For           S217-1         Lor           S22-1         Sch           S21-1         Lor           S22-1         Sch           S21-2         Fli           S25-2         Dil           S25-2         Dil           S26-1         Bro           S28-32         For           S28-32         For           S28-34         For           S28-5         For           S28-5         For           S30-1         Hor           S32-1         Paa           S32-1         Paa           S32-1         Daa           S34-1         Keil	Grand Junction kells (25-30)Near Fruita kells (15)Near Fruita kells (15)Near Fruita kells (15)Near Fruita kells (15)Near Fruita kells (10)Near Fruita VosterNear Craig Lost CanyonNear Gunnison StraffordNear (?) Fort Collins FloraNear (?) Durango FloraNear (?) Durango FloraNear (?) Durango	18.3 20.1	26.1 38.3 31.9 39.3 35.5		65+3		8.3 6.7 6.1 8.0	1,1	548-2 549-4 550-1	Redwing MummaW. of Salida LambergNear Howard SkinnerNear Golden			49.8	21.4 22.1 34.6		
S16A-1         Wei           S16A-2         I           S16A-3         Wei           S16A-3         Wei           S16A-5         Wei           S16A-5         Wei           S16A-5         Wei           S16A-6         Wei           S16A-5         Wei           S16A-6         Wei           S17-1         For           S21-1         Loc           S22-1         Str           S22-1         Str           S25-1         Di           S25-2         Di           S25-2         Di           S27-1         Jot           S28-32         For           S28-32         For           S28-4         For           S28-5         For           S28-5         For           S28-6         For           S29-1         Pac           S30-1         Hog           S31-2         Wr           S32-1         Dav           S34-1         Ket	<pre>kells (25-30)Near Fruita fells (1)Near Fruita fells (15)Near Fruita kells (25)Near Fruita fells (15)Near Fruita fosterNear Craig costerNear Gunnison SchraderNear (?) Grand Junetion SchraderNear (?) Fort Collins FloraNear (?) Durango StlagNear (?) Durango StlagNear (?) Durango StlagNear (?) Durango StlagNear (?)</pre>	18.3 20.1	26.1 38.3 31.9 39.3 35.5				8.3 6.7 6.1 8.0		549-4 550-1	MummaW. of Salida LambergNear Howard SkinnerNear Golden			49.8	22.1 34.6		
S16A-2         Wei           S16A-3         Mei           S16A-4         Mei           S16A-5         Wei           S16A-6         Mei           S16A-6         Wei           S16A-6         Wei           S17-1         For           S17-1         For           S17-1         For           S21-1         Lor           S22-1         Sch           S23-1         Sch           S25-1         Sch           S25-2         Di           S25-2         Di           S25-2         Di           S25-2         Di           S25-2         Di           S25-2         Di           S28-32         For           S28-34         For           S28-5         For           S28-5         For           S29-1         Pac           S30-1         Hog           S31-2         Wy           S32-1         Dav           S34-1         Ket	<pre>kells (h)Near Fruita Fruita fells (15)Near Fruita kells (25)Near Fruita kells (15)Near Fruita Kells (10)Near Fruita CosterNear Craig Jost CanyonNear Gunnison SchaderNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango FloraNear (?) Durango SchleyN. of</pre>	18.3 20.1	38.3 31.9 39.3 35.5				6.7 6.1 8.0		S50-1	LambergNear Howard SkinnerNear Golden	7.6		49.8	34.6		
I           S16A-3         Weil           S16A-4         Weil           S16A-5         Weil           S16A-6         Weil           S16A-6         Weil           S17-1         Formation           S19-1         Wind           S21-1         Loc           S22-1         Sci           S24-1         File           S25-2         Dif           S25-2         Dif           S26-1         Dif           S27-1         Jot           S28-32         Formation           S28-32         Formation           S28-4         Formation           S28-5         Formation           S28-5         Formation           S28-6         Formation           S30-1         Hord           S31-2         Weil           S31-2         Keil           S31-2         Keil	Fruita fells (15)Near Fruita fruita (25)Near Fruita fruita (15)Near Fruita fulcerNear Durango finderNear Craig Lost CanyonNear Gunnison StraffordNear (?) Fort Collins floraNear (?) Durango floraNear (?) Durango floraNear (?) Durango	18.3 20.1	38.3 31.9 39.3 35.5				6.7 6.1 8.0			Howard SkinnerNear Golden	7.6					
1           S16A-1         We           S16A-5         We           S16A-6         We           S17-1         For           S19-1         Wi           S17-1         For           S21-1         Lor           S22-1         Str           S22-1         Scr           S24-1         Fic           S25-2         Di           S25-2         Di           S26-1         Br           S27-1         Jot           S28-32         For           S28-4         For           S28-5         For           S28-6         For           S29-1         Pac           S30-1         Hor           S31-2         Wr           S34-1         Ke           S34-1         Ke           S34-2         Ke	Fruita fells (25)Near Fruita fruita (15)Near Fruita folls (10)Near Fruita Trutta Truta Durango (inderNear Craig Lost CanyonNear Gundison SchraderNear (?) Fort Collins FloraNear (?) Durango SileyN. of	18.3 20.1	31.9 39.3 35.5				6.1 8.0			Golden	1.6					
1           S16A-5         Wei           S17-1         For           S17-1         For           S19-1         Win           S21-1         Loo           S22-1         Sch           S24-1         Fic           S25-2         Fic           S25-2         Dif           S26-1         Bro           S28-32         For           S28-5         For           S28-5         For           S29-1         Pac           S30-1         Hog           S31-2         Wy           S32-1         Dav           S34-1         Kee           S34-2         Kee	Fruita Vells (15)Near Fruita VosterNear Durango VinderNear Craig Jost CanyonNear Gunnison StraffordNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango PloraNear (?) Durango NilleyN. of	18.3 20.1	39•3 35•5				8.0		S51-1							
S16A-5         We:           S16A-6         We:           S17-1         Formation           S19-1         Win           S21-1         Lot           S22-1         Sch           S24-1         Flo           S25-1         Sch           S25-2         Dit           S25-2         Dit           S26-1         Bring           S27-1         John           S25-2         Dit           S26-1         Bring           S28-32         Formation           S28-32         Formation           S28-4         Formation           S28-5         Formation           S28-6         Formation           S29-1         Paster Signon           S30-1         Hormation           S31-2         Weit           S32-1         Data           S34-1         Keit	<pre>Wells (15)Near Fruita Vells (10)Near Fruita VosterNear Durango VinderNear Craig Lost CanyonNear Gunnison SchraderNear (?) Fort Collins PloraNear (?) Durango VileyN. of</pre>	18.3 20.1	35.5						~/	SmithE. of Fort Collins		25.6		31.4		
S16A-6         Weil           S17-1         For           S17-1         For           S19-1         Min           S21-1         Loc           S22-1         Str           S25-1         Str           S25-1         File           S25-1         File           S25-2         Dil           S25-2         Dil           S26-3         For           S28-32         For           S28-5         For           S28-5         For           S30-1         Hor           S32-1         Dav           S32-1         Dav           S31-2         Wy           S32-1         Lor           S34-1         Kee           S34-1         Kee	<pre>/ells (10)Near Fruita FosterNear Durango (raig cost CanyonNear Gunnison SchraderNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango Schrader (?) Durango SileyN. of</pre>	18.3 20.1							S52-2	GreenacreN. of	20.7					1.6
1     For       S17-1     For       S19-1     With       S21-1     Lor       S22-1     Sch       S25-1     Sch       S24-1     File       S25-2     Di       S25-2     Di       S25-2     Di       S25-2     Di       S25-2     Di       S26-1     Br       S28-32     Foo       S28-32     Foo       S28-5     Foo       S28-5     Foo       S28-6     Foo       S30-1     Hor       S32-1     Dav       S32-1     Dav       S32-1     Co       S32-1     Co       S32-1     Co       S34-1     Ket       S34-1     Ket	Fruita FosterNear Durango YinderNear Craig Jost CanyonNear StraffordNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango FloraNear (?) Durango JileyN. of	18.3 20.1				1	5.9		S52-3	Fort Collins WarrenN. of	18.0				7.0	
I           S19-1         With           S21-1         Lot           S21-1         Lot           S22-1         Str           S25-1         Sch           S21-2         File           S25-1         Dit           S25-2         Dit           S25-2         Dit           S26-1         Brc           S26-1         Jot           S27-1         Jot           S28-32         Foo           S28-5         Foo           S28-5         Foo           S29-1         Pas           S30-1         Hop           S31-2         Wyt           S32-1         Dav           S34-1         Kee           S34-2         Kee	Durango VinderNear Craig Jost CanyonNear StraffordNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango Jurango JuleyN. of	18.3 20.1	25.7			22.8			S52-4	Fort Collins WarrenN. of		35.0		16.3		
S21-1         Lot           S22-1         Str           S25-1         Set           S25-1         Set           S25-1         Fit           S25-1         Fit           S25-2         Dit           S25-2         Dit           S26-1         Br           S27-1         Jot           S28-32         For           S28-4         For           S28-5         For           S28-6         For           S29-1         Pac           S30-1         Hor           S32-1         Dav           S31-2         Ker           S34-1         Ker           S34-2         Ker	Craig Lost CanyonNear Gunnison StraffordNear (?) Fort Collins FloraNear (?) Furanço FloraNear (?) Duranço JulayN, of	20.1	25.7							Fort Collins		)).0		10.0		
S21-1         Lot           S22-1         Sti           S23-1         Sci           S24-1         Fi           S24-1         Fi           S24-1         Fi           S24-1         Fi           S24-1         Fi           S25-2         Di           S25-2         Di           S26-1         Brc           S28-32         Foo           S28-34         Foo           S28-5         Foo           S28-6         Foo           S29-1         Pa           S30-1         Ho           S32-1         Dav           S32-1         Dav           S34-1         Ke	Jost CanyonNear Gunnison StraffordNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Durango Durango MilleyN. of		25.7			14.8			S52-5	WarrenN. of Fort Collins	20.9					4.6
S22-1         Sti           S25-1         Sci           S25-1         Sci           S24-1         File           S24-2         File           S25-2         Di           S25-2         Di           S25-2         Di           S26-1         Br           S27-1         Joi           S28-32         Foo           S28-34         Foo           S28-5         Foo           S28-5         Foo           S28-6         Foo           S29-1         Pac           S30-1         Hop           S32-1         Dax           S32-1         Co           S34-1         Kee           S34-2         Kee	StraffordNear (?) Grand Junction SchraderNear (?) Fort Collins FloraNear (?) Eurango Durango Durango DulayN. of	18.5	25.7			34.2			s52-6	WarrenN. of Fort Collins		31.8		38.7		
\$25-1         Sch           \$24-1         FL           \$24-1         FL           \$25-2         FL           \$25-2         FL           \$25-2         FL           \$25-2         FL           \$25-2         FL           \$25-2         FL           \$26-1         Br           \$27-1         JC           \$28-32         FOO           \$28-34         FOO           \$28-5         FOO           \$28-5         FOO           \$29-1         Pa           \$330-1         HOT           \$31-2         Wyt           \$32-1         Dax           \$34-1         Ket           \$34-2         Ket	SchraderNear (?) Fort Collins FloraNear (?) Durango FloraNear (?) Durango DilleyN. of	18.5						0.5	S52-7	WarrenN. of	13.6			56.7		
\$24-1         Flo           \$25-2         Flo           \$25-1         Di           \$25-1         Di           \$25-1         Di           \$25-2         Di           \$26-1         Br           \$27-1         Joi           \$28-32         Foo           \$28-32         Foo           \$28-34         Foo           \$28-5         Foo           \$29-1         Pac           \$330-1         Hop           \$31-2         Wy           \$32-1         Dav           \$334-1         Ker	FloraNear (?) Durango FloraNear (?) Durango DilleyN. of							2.6	S52-8	Fort Collins WarrenN. of	8.7			77.7		
S2%-2         Fit           S25-1         Di           S25-2         Di           S25-2         Di           S26-1         Br           S26-1         Jo           S26-1         Jo           S26-1         Jo           S28-32         Foo           S28-34         Foo           S28-5         Foo           S28-6         Foo           S29-1         Pac           S30-1         Ho           S31-2         Wyt           S32-1         Dav           S34-1         Ket           S34-2         Ket	Durango FloraNear (?) Durango DilleyN. of		32.6				6.6			Fort Collins WarrenN. of		33.0		17.5		
1           \$225-1         Dil           \$225-2         Dil           \$225-2         Dil           \$225-2         Dil           \$226-1         Bro           \$227-1         Joh           \$228-32         Foo           \$228-34         Foo           \$228-35         Foo           \$228-46         Foo           \$229-1         Pas           \$330-1         Hop           \$330-1         Hop           \$32-1         Data           \$334-1         Ket           \$34-2         Ket	Durango DilleyN. of		52.0				0.0		\$52-9	Fort Collins						
\$25-1         Difference           \$25-2         Difference           \$26-1         Br           \$28-32         Foo           \$28-32         Foo           \$28-34         Foo           \$28-5         Foo           \$28-5         Foo           \$28-6         Foo           \$29-1         Pac           \$30-1         Hop           \$31-2         Wyt           \$32-1         Dave           \$34-1         Ket           \$34-2         Ket	DilleyN. of			59.4				0.7	\$52-10	WarrenN. of Fort Collins		31.1		24.6		
\$25-2         Diamon State           \$26-1         Breen State           \$26-1         Jot           \$27-1         Jot           \$28-32         Foo           \$28-32         Foo           \$28-32         Foo           \$28-34         Foo           \$28-5         Foo           \$28-6         Foo           \$29-1         Pac           \$30-1         Hop           \$31-2         Wyt           \$32-1         Dave           \$33+1         Ket           \$34-2         Ket		17.8					8.9		S52-11	WarrenN. of			63.2	15.6		
S26-1         Brc           S27-1         Job           S28-32         Foo           S28-4         Foo           S28-5         Foo           S28-6         Foo           S29-1         Pac           S30-1         Hog           S31-2         Wyt           S32-1         Dave           S34-1         Kee           F34-2         Kee           F         F	Canon City DilleyN. of		30.0				5.0		S52-12	Fort Collins WarrenN. of			60.1		8.3	
1           S27-1         Join           S28-32         For           S28-34         For           S28-4         For           S28-5         For           S28-6         For           S29-1         Pac           S30-1         Hor           S31-2         Wyt           S32-1         Dav           S34-1         Ket           F34-2         Ket           F34-2         Ket	Canon City		2010		81.8		· · · ·			Fort Collins WarrenN. of			48.3		7.4	
I           \$28-32         Fox           \$28-34         Fox           \$28-5         Fox           \$28-5         Fox           \$28-5         Fox           \$29-1         Pac           \$30-1         Hoy           \$31-2         Wyt           \$32-1         Dav           \$34-1         Kes           \$34-2         Kes	BrownS. of Las Animas				01.0			3.2	\$52-13	Fort Collins			40.)			
\$28-32         For           \$28-4         For           \$28-4         For           \$28-5         For           \$28-6         For           \$28-7         Pac           \$29-1         Pac           \$370-1         Hor           \$38-1         Ket           \$34-2         Ket           \$1         For	JohnsonNear	8.8				very	high		\$52-14	WarrenN. of Fort Collins		32.0			8.6	
S28-h         Fox           S28-5         Fox           S28-6         Fox           S28-7         Fox           S28-6         Fox           S29-1         Pac           S30-1         Hoy           S31-2         Wyt           S32-1         Dav           S34-1         Ket           S34-2         Ket           I         S34-2	Nathrop Fox-DilleyN.		37.0				9.1		S52-15	WarrenN. of	9.8			46.9		
S28-5         Fox           S28-6         Fox           S29-1         Pac           S30-1         Hoy           S31-2         Wyt           S32-1         Dax           S34-1         Ket           S34-2         Ket           S34-2         Ket	of Canon City Fox-DilleyN. of			49.3				2.0	S52-16	Fort Collins WarrenN. of			55.4		9.7	
S28-6         Fox           S29-1         Pace           S30-1         Hop           S31-2         Wyt           S32-1         Data           S34-1         Kee           S34-2         Kee           F         F	Canon City		70.0				5.8			Fort Collins			51.6		9.3	
529-1 Pace 530-1 Hoy 531-2 Wyt 532-1 Dav 534-1 Kes 534-2 Kes 534-2 Kes	Fox-DilleyN. of Canon City		30.2				- 		S52-17	WarrenN. of Fort Collins			51.0			
529-1 Pad 530-1 Hor 531-2 Wyt 532-1 Dav 534-1 Kes 534-2 Kes 1	Fox-DilleyN. of Canon City		43.8				6.0		S53-2	Lone Tree Creek Near Carr		36.0			8.7	
530-1 Hoy 531-2 Wyt 532-1 Dav 534-1 Kes 534-2 Kes 1 534-2 Kes	PachekNear	24.7						1.8	S57-1	RobinsonNear Payton	10.8			22.4		
531-2 Wyt 532-1 Dav 534-1 Kes 534-2 Kes 1	Salida HopkinsNear	24.9				39.33			S58-1	RobinsonNear		29.8		25.1		
532-1 Dav 534-1 Kes 534-2 Kes 1	Center Nyble (Ash ?)	Floce	ulated				8.2		S58-2	Calhan RobinsonNear		35.8		25.3		
834-1 Kes 834-2 Kes 834-2 Kes							8.7			Calhan	11.7			67.2		
S34-2 Kes	DavidsonN. of Canon City		34.3				0.1	7	S59-1	WandsNear Pueblo	11.3	101		2 2 2		
S34-2 Kes	Kessler (Red)Near Howard		26.1					0.93	S59-2	WandsNear Pueblo		27.6		27.0		
1	(essler (Pink)Near	22.9						0.83	S60-1	WelteN. of Colorado Springs		26.3			9.4	
\$34-3 Kes	Howard Kessler (White)	20.2				28.43			s60-2	WelteN. of		33.2		+		5.0
1	Near Howard Kessler (Green)	14.2				51.13			s60-3	Colorado Springs WelteN. of		31.3			6.5	
1	Near Howard		07.7			2.14		- 3		Colorado Springs	01.7	1-12		30.3		
	Kessler (Mailed) Near Howard		27.7					2.63	S61-1	HarrisNear Castle Rock	21.3					
534-6 Kes	Cessler (Mailed) Near Howard	22.5						1.43	s64-2	HarveyNear Parkdale		28.7		18.0		
535-1 Emt	LmbryNear (?)	7.0				49.9			s64-3	HarveyNear	23.9				8.4	
	Pueblo Schrader (Pawnee)			48.9				2.6	S65-1	Parkdale HarrisNear		26.6		18.9		
1			17 7							Kiowa	010			41.7		
1	N. of Ft. Morgan		43.7	and a				2.6	S66-1	PallaoroNear Morrison	24.2					
	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan			54.5				2.5	S67-1	BennettsN. of Golden	6.4			82.1		
537-1 Roc	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee)	15.7				49.7			s69-1	HarrisNear	9.3			65.h		
	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Rocky FlatsN. of	15.0					5.6		S70-1	Laporte YahnNear	9.2			43.4		
	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Rocky FlatsN. of Golden		-0./			10 5				Iliff				05.0		
(	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Nocky FlatsN. of Golden PlainviewN. of Golden		28.6			12.5			\$70-2	YahnNear Iliff	14.8			25.8		
538-1 Nor	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Rocky FlatsN. of Golden PlainviewN. of			62.2				0.2	S70-3	YahnNear Iliff	10.6			57.9		
\$38-2 Not	N. of Ft. Morgan Schrader (Pavnee) N. of Ft. Morgan Schrader (Pavnee) N. of Ft. Morgan locky FlatsN. of Golden Socky FlatsN. of Golden JortonNear			46.7				1.4	S70-4	BauerNear		28.9		12.7		
	N. of Ft. Morgan Bchrader (Pavnee) N. of Ft. Morgan Bchrader (Pavnee) N. of Ft. Morgan Rocky FlatsN. of Golden PlainviewN. of Golden NortonNear LaPorte JortonNear					17 0			11	Iliff				1		
	N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Schrader (Pawnee) N. of Ft. Morgan Ocky FlatsN. of Golden Nocky FlatsN. of Golden Socky FlatsN. of Golden Socky FlatsN. of Golden Socky FlatsN. of Golden		25.4			17.8			S73-1	BauerNear	12.9			65.3		

See Table I for remaining test results in this same series.
 Samples S14-1 through S27-1 tested prior to July 1960--S28-3 to S73-1 tested after July 1960
 Required extra washing.



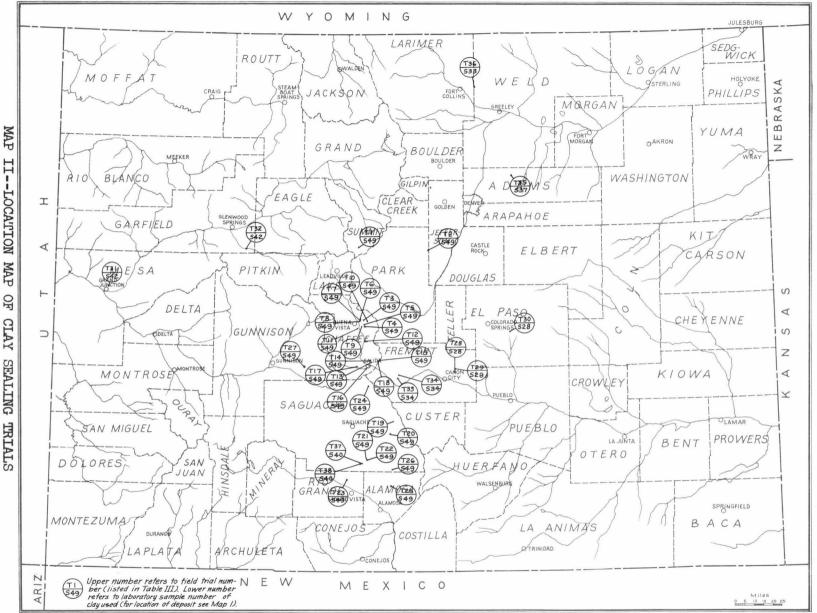
I--LOCATION MAP Ŗ CLAY 0R BENTONITE SAMPLES

5-

## SUMMARY OF PRELIMINARY RESULTS FROM FIELD TRIALS WITH COLORADO CLAYS

No.	Job Title Location	Capacity Grade	WP1 L2	Bed Material	Before <sup>3</sup> Losses	Install. Date Amt. of Bent.	Method of Application and Costs	Results
<b>Ť</b> 1	Climax Canal No. 1 NE of Climax	100-20 cfs medium	9 ft 5700 ft	Rocky	*	* 91 ton (S-49)	¥	*
T2	Wellington Lake Canal SE of Bailey	40-10 cfs medium	13 ft 3000 ft	Decomposed granite	20%-June (measured)	July 1960 36 ton (S-49)	Multiple dam - dump truck backed up ditch - 15 dams - \$17.50/ton	Apparently very good - evaluation to be made in spring
T3	Cottonwood Creek Buena Vista	60 cfs-July steep	22 ft 16,000 ft	Cobbles and sand	(est.) 15%	July 1960 100 ton (S-49)	30-40-30 ton dams in upper part of creek - mix/crawler tractor	Bentonite dispersed and carried thru well - (est.) 5% loss now
T4	Kelly Ditches S. of Buena Vista	2-8 cfs steep	4 ft 13,000 ft	Rocky	(est.) 25	June 1960 28 ton (S-49)	12-multiple dams placed and mixed/crawler tractor	Good - (est.) 5-10% loss after treatment - follow up in spring
<b>T</b> 5	Saylor Seep Ditch S. of Buena Vista	2 cfs steep	4 ft 4000 ft	Rocky	100% Aug.	Sep. 1960 24 ton (S-49)	5-multiple damsnear upper end, placed and mix/front loader	Good, Sept., 1/4 cfs out of 1/3 cfs now getting thru to end of ditch
<b>T</b> 6	Twin Silos Ditch W. of Buena Vista	4 cfs steep	3 ft 8000 ft	Rocky	(est.) 95%	June 1960 26 ton (S-49)	4-multiple damsupper half, 1 load at head gate, \$9/ton	Good, (est.) loss 5-10% after treatment
<b>T</b> 7	Tegler Ditch W. of Buena Vista	10 cfs steep	4 ft 4000 ft	Rocky	(est.) 20%	Apr. 1960 4 ton (S-49)	Material placed in dams over upper half of ditch, \$9/ton	Good, (est.) 5% loss after treat- ment
т8	Irwin Ditch W. of Buena Vista	10 cfs steep	4 ft 5000 ft	Rocky	(est.) 20%	Apr. 1960 6 ton (S-49)	Material placed in dams over upper half of ditch, \$9/ton	Good, (est.) 0-5% loss after treatment
T9	Lee Diversion Ditch W. of Buena Vista	4 cfs steep	3 ft 3000 ft	Rocky	(est.) 50%	Apr. 1960 25 ton (S-49)	Bentonite sluiced in at 4 points over upper half	Good, (est.) 10% loss after treat- ment
T10	Esgar Ditch Buena Vista	2 cfs medium	3 ft 2600 ft	Rocky- gravel	(est.) 40%	June 1960 4 ton (S-49)	Majority sluiced into flow at upper end or upper half	Good, 10-15% loss (est.) after treatment
<b>T</b> 11	Dry Creek Diversion SW of Buena Vista	2 cfs very steep	2 ft 8000 ft	Rocky	100%	July 1960 20 ton (S-49)	Bentonite dumped into flow at at upper end, \$9/ton	Fair, 80% loss after treatment, additional bentoniting planned
T12	Pioneer Ditch	9 cfs	4 ft 4000 ft	Rocky	(est.) 40%	May 1960 42 ton (S-49)	Sluiced in at upper end and dams near mid-point of ditch	Good, (est.) 5-10% loss after treatment
T13	SW of Nathrop Branch of Post Ditch NW of Salida	steep 5 cfs medium	8 ft 1300 ft	Rocky	(est.) 30%	June 1960 5 ton (S-49)	10-multiple dams, dispersion ponded with rock dams, \$9/ton	(Est.) 5-10% loss after treatment, seep areas dried up below ditch
T14	Missouri Park Ditch NW of Salida	70-10 cfs medium	10 ft 34,000 ft	Rocky- gravel	100% loss of 10 cfs	Aug. 1959 203 ton (S-49)	27 multiple dams, upper 1-1/2 miles received 100 tons, \$7/ton	Excellent installation, 1-1/2 cfs will carry thru 7 mile stretch
<b>T</b> 15	Sunnyside Ditch N. of Salida	40-15 cfs medium	10 ft 3000 ft	Gravel- sandy	5-10 cfs (est.)	Apr. 1960 69 ton (S-49)	30 ton in multiple dams, 40 ton sluiced-head end, \$9/ton	(Est.) stopped 75/2 of total seepage loss
<b>T</b> 16	Pass Creek Diversion W. of Poncha Springs	6 cfs medium	4 ft 21,000 ft	Loose-rock shale	4 cfs in 1/2 mile	1948 24 ton (S-49)	Placed near head end, added where concentration decreases	14, loss of 4 cfs over 4 miles (measured)
T17	John Boyce Pond Maysville	1/2 AF		Loose-sand gravel	(est.) 50% in 12 hrs	1957 1/4 ton (S-49)	Distributed and spread manually with shovel	Practically no seepage loss after treatment
T18	Everett Stock Pond N. of Salida	Stockwater pond		Peat- gravel	100%	1959 1 ton (S-49)	Spread manually with shovel	Bentoniting developed enough water for 50 head of cattle
T19	O'Brien Diversion Ditch Nd of Crestone	9 cfs steep	6 ft 19,000 ft	Rocky-sand gravel	4 cfs in 3/4 mile	Nov. 1959 136 ton (S-49)	35 multiple dams, 81 ton, 55 ton, head end \$12/ton	Good results, 1 cfs out of 4 cfs will carry 3-1/2 miles now
T20	Shellabarger Ditch No. 1 NE of Moffat	10 cfs steep	6 ft 11,000 ft	Gravelly-	(est.) 305	1959-1960 50 ton (S-49)	Multiple dams placed upper part of ditch (est.) \$12/ton	Good results, 5-10% loss after treatment
T21	Coors Farm Lateral NE of Center	8 cfs 4 ft/mi	7 ft 3000 ft	Gravel	(est.) $10^{4}_{P}$	July 1959 * (S-49)	6 multiple dams and part sluiced in at head end	Good (est.) 3-4% loss after treat- ment
T22	Coors Farm Lateral NE of Center	7 cfs 4 ft/mi	7 ft 1300 ft	Gravel sand	Similar to T21 site	Aug. 1959 16 ton (S-49)	8 multiple dams; V-ditcher run thru several times to mix, spread	Good, extensive seep areas along ditch bank - dried up
T23	Arthur Benson Ditch NE of Del Norte	3 cfs medium	4 ft 1500 ft	Cobbles	(est.) 50%	Aug. 1960 13 ton (S-49)	Multiple dams, greatest amount near high loss area,\$14.50/ton	Very good, (est.) 5-10% loss after treatment
T21	Shewalter Pond S. of Poncha Pass	6-1/2 AF		Shaley- gravel	(est.) 50% per day	1959-1960 117 ton (S-49)	2 lbs per sq ft, leveled with tractor and blade, \$9/ton	Majority of seepage loss stopped
T25	Sangre De Cristo Pond Mosca	1/2 AF		Sandy- loam	100% in 24 hrs	Oct. 1959 18 ton (S-49)	Spread, leveled manually compac- ted, rubber tire roller, \$14.75/ton	Fair, 100% loss in approximately 1-month
<b>T</b> 26	Sangre De Cristo Pond Hooper	1/3 AF		Sandy- loam	100% in 10 hrs	Nov. 1959 15 ton (S-49)	Spread and leveled manually, no compaction	Poor, 100% loss in approx. 2-wks. re-treatment planned/compaction
T27	Parlin-Quartz Ditch N. of Parlin	32 cfs medium	9 ft 3000 ft	Sandy	*	Oct. 1959 37 ton (S-49)	8 multiple dams, additional mixing with crawler tractor	Seepage areas below ditch dried up or reduced
T28	Garden Park Ditch N. of Canyon City	9 cfs steep	4 ft 4000 ft	Rocky- sandy	(est.) 30%	May 1960 32 ton (S-28)	Majority of material dumped in near head of ditch	Good, (est.) 5-10% loss after, seep areas dried up below ditch
T29	Nelson-Culifer Ditch N. of Canyon City	2 cfs medium	3 ft 3000 ft	Rocky- sandy	(est.) 50 <sub>7</sub>	May 1960 16 ton (S-28)	Multiple dams, mix manually with shovels	Good, (est.) 5-10% loss after treatment
T30	Fountain Mutual Ditch NE of Fountain	5 cfs medium	4 ft 6500 ft	Sandy	(est.) 20%	July 1960 ± 20 ton (S-28)	Bentonite added with front loader tractor near head end of ditch	Material dispersed into water readilyafter losses not avail.
T31	Redlands 2nd Lift Ditch W. of Grand Junction	13 cfs flat	11 ft 2600 ft	Sandy- clay	17/2 for system	Mar. 1960 40 ton (S-42)	Material distributed 1/2" thick with truck and chute set-up	Fair, seepage reduced initially, some seepage beginning again
T32	East Mesa Ditch S. of Carbondale	28 cfs medium	15 ft 500 ft	Rocky	(est.) 3 cfs	Apr. 1960 60 ton (S-42)	Spread on bottom and bank, back- hoe mulched $6-8"$ , compacted	Good, extensive seepage area below elevated section dried up
T33	Goodman Storage Pond SE of Howard	8 AF		Rocky- gravel	2 ft drop in 24 hrs	Apr. 1960 160 ton (S-34)	Spread on bottom with tractor and blade	Loss reduced to 4-inch drop in 24 hrs
T311	Adamson Storage Pond SE of Howard	5 AF		Cobbles- rocky	New pond	Apr. 1960 80 ton (S-34)	Spread on bottom with tractor and blade	Loss reduced to 4-inch drop in 24 hrs
T35	Mest Burlington Ext-Canal SW of Hudson	40-10 cfs flat	12 ft 50,000 ft	Sandy	35-70%	Sept. 1960 52 ton (S-37)	40 ton, head end; 6 ton below mid-point; 6 ton, near end	*
<b>T</b> 36	Smith Farm Pond E. of Fort Collins	8 AF		Clay- sand	l ft drop in 24 hrs	Oct. 1960 120 ton (S-33)	Spread with front loader tractor, manually on bottom and sides $\pm 1/2$ "	Installation not complete*
<b>T</b> 37	Brace Pond No. 1 NJ of Center	10 AF		Gravelly	*	Jan. 1960 120 ton (S-40)	Material leveled with land leveler mulched with renovator - releveled	Fair. water surface drops approxi- mately 1 ft in 10 days
T38	Brace Pond No. 2 NW of Center	12 AF		Rocky	*	Jan. 1957 300 ton (S-40)	Material leveled with land leveler mulched with renovator, releveled	Fair, water surface drops approxi- mately, 1 ft in 10 days

\*Information not available at date of compilation  $WP^{\perp}$  (average wetted perimeter) x  $L^2$  (length of treated section) x A (application for bentonite = total amount of bentonite required. <sup>3</sup>Losses considered over length (L)



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Photo 1--Potential clay deposit (S-52) north of Fort Collins, Colorado. Badland topography with little or no vegetation cover, typical of better bentonite outcrops.



Photo 2--Developed clay deposit (S-49) near Howard, Colorado. Clay deposit has been stripped of overburden so that air-drying of clay can take place. In-place moisture content of clay or bentonite deposits has ranged as high as 50 percent; by air-drying in the pit this can be reduced to 15 to 30 percent.



Photo 3--Most common method of application consists of placing dams of bentonite in dry canal, then running in small head of water and washing bentonite down canal.

Photo 4--The bentonite can be shovelled into the water as the dam is washed out, but in some cases, as above, a small bulldozer has been used.





Photo 5--Several high loss natural channels have also been sealed by washing bentonite downstream with the water.



Photo 6--In several instances, the dams of bentonite have been spaced along a canal and then spread with a V-ditcher rather than with water.

Photo 7--Bentonite has been used for sealing small ponds or reservoirs. It is spread in a layer 1/2 to 2-inches thick over the pond area, worked into the sub-soil, and compacted, if possible.





Photo 8--In the evaluations carried out by the bentonite project, inflowoutflow measurements have been obtained when possible. Laboratory evaluations--In addition to the laboratory identification work mentioned above, the clay samples are also being tested to determine their sealing potential (See Tables I and II). While general agreement has been noted between the laboratory test results and the field trial results (See Table III), some descrepancies have been found. Excellent materials from a lab test angle have produced poor sealing results in field trials. Conversely, clay materials rated poor in the laboratory have produced excellent field trial results. Undoubtedly, part of the problem is related to the need for better test procedures; thus, new and modified procedures are being developed. The general objective of the work is to develop simple economical lab test procedures that can be used for clay specification purposes. However, it is also obvious that the correlation problem between lab and field also reflects a need for improved field trial procedures.

Procedure development trials -- As may be seen in Table III and Map II, the field trial phase of the procedure development work is well advanced for a relatively few clays in several restricted areas of the State. For example, consider the canal (multiple-dam) and reservoir (blanketing) work with the S49 clay in the area surrounding Salida. As time and funds become available, work in new areas of the State will be initiated. However, since the trial work is funded and organized at local level, it is important to realize that the presence or absence of trials in any particular area of the State depends largely on the local interest in initiating such work--from the standpoint of either or both (a) the owners of canals, and (b) the producers of clays. Past project experience indicates that finding contractors or irrigation districts willing to invest their ingenuity and funds in field trials is not normally a problem; nevertheless, the local interest is necessary before the trial work will materialize. For a general idea of the installation procedures utilized in development work to date, see Photos 1 through 8. Detailed procedure write-ups are planned and will be prepared when the results and evaluations for any particular method warrant such publications. Several publications, subject to change as additional evaluations are completed, are available now upon request.

Quality of clay--Another important part of the development work is concerned with the clay itself. Producing a suitably uniform clay product of acceptable quality for sealing purposes is a tougher problem than commonly appreciated. While it is true that the sealing quality and consequently also the reputation of good local clays have been damaged by careless mining and production methods, in fairness to the clay producers, it should be pointed out that they are faced with several important unresolved problems. For example, many clay deposits are extremely variable--in quality, in thickness, and in lateral extent. Perhaps the most pressing problem, however, is the absence, at present, of suitable specifications for canal and reservoir sealing clays. Of the various problems, the specification problem is probably the most important: removing that problem would remove the major uncertainty of the present quality control procedures. Actually, however, sufficient experience information for a State-wide specification is not now available, but as a helpful interim arrangement, tentative specifications for areas with an ample experience background with local clays could be prepared. The CSU project will gladly assist in such local determinations (by County ACP committees, etc.) of specifications for the clay quality, and installation procedures as well.

Skilled applicators--The development of people skilled in the use of local clays for sealing of canals and reservoirs is being accomplished in several different ways. For example, in some areas, the clay producer will also haul and install the bentonite or clay. Actually, the bulk of the favorable work has been installed on this basis. In some areas, the larger irrigation districts prefer to do their own mining, hauling, and installation work. In other areas, especially where the irrigation group has limited equipment, local dirt-moving contractors are assisting in the development work. In any case, continuity of effort from the mining to the installation process is important.

The market potential--In summary, the major market potential of interest to this project relates to water conservation--specifically, to the sealing of leaky canals and reservoirs.<sup>1</sup> As a result of the initial sampling efforts, we believe that ample quantities of suitable clays can be found and developed within a 100-mile radius of every major irrigated area in Colorado. However, to development, this market and its water conservation potential will require coordinated efforts of mining, procedure development, installation, and evaluation. Major problems that must be overcome, more or less concurrently, include (a) development of installation procedures to fit the local clays to the local canal and reservoir conditions, (b) development of local contractors or irrigation districts with men skilled in the sealing applications of the local clays, (c) development of clay deposits so as to insure porduction of clays of resonably uniform and known characteristics for sealing purposes, and (d) acceptance of methods and materials (as developed) for USDA-ACP cost sharing program.

<sup>&</sup>lt;sup>1</sup>Other important potential markets beyond the scope of this project include (a) foundry sand additive, (b) brick and tile clay, (c) desiccator (moisture control) materials, (d) filter (decolorizer) materials, and (e) drilling mud (oil well) use.