IN PLACE PULVERIZATION OF A SOIL CEMENT BASE AND BITUMINOUS CONCRETE OVERLAY

VT RTE. 66 RANDOLPH, VT

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ABSTRACT

This report describes the cold recycling process used to reconstruct a severely distressed portion of Vermont Route 66 in the Town of Randolph, Vermont. The existing 8 inch soil cement base and 3 inch bituminous concrete pavement were scarified, pulverized, reshaped and compacted in May and June, 1981. The 23,458 square yard, 1.5 mile project was completed in 19 working days with a minimum of difficulty.

Production rates averaged 1234 square yards per day or 119 square yards per hour. Based on an average working depth of 15.7 inches, production volume averaged 539 cubic yards per day or 95 tons per hour.

Energy requirements for the recycling process totaled 39,420 BTU per square yard or 49,304 BTU per ton. An alternate method, which would have included removal of the material and replacement with gravel, was estimated at 92,080 BTU per square yard or 134% more than the in-place pulverization process. The cost of the alternate method was also estimated at 24 percent more than the process used.

The elimination of reflective cracking and the conservation of natural resources (gravel) are significant features of the construction method utilized.

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INTRODUCTION

In 1963, a 1 1/2 mile section of Vermont Route 66 between the Village of Randolph and Randolph Center was reconstructed utilizing a soil cement base in lieu of gravel due in part to the lack of availability of the latter. Within the first season, a significant amount of cracks developed in the soil cement and reflected up through the 2 1/2 to 3 inch bituminous concrete pavement surface. The condition resulted in a very poor riding surface which was particularly troublesome in the winter and spring seasons due to frost action caused by moisture penetration. The unsatisfactory conditions led to a decision in 1981 to try in-place pulverization as a means of eliminating the cracked base and bituminous concrete pavement prior to placing a new overlay. This report covers the reconstruction phase of the project.

PROJECT DESCRIPTION AND ROADWAY CONDITION

The reconstruction project consisted of 1.54 miles of Vermont Rte. 66 in the Town of Randolph beginning at Bridge No. 1, MM 0.43 and extending easterly to MM 1.97, a point approximately 0.55 miles west of Interstate 89 interchange No. 4.

The existing roadway was constructed in 1963 featuring a 24 foot wide surface with 10 foot shoulders (Project - Randolph S 0190 (1) SA). The sub-base design consisted of 20 inches of Granular Borrow (Item 102-A), a 7 inch Soil Cement Base Course (Item 214A), and two courses of Bituminous Concrete Pavement (Item 361-B modified) totaling 2 1/2 inches in thickness. The soil cement consisted of granular borrow with nine percent Portland Cement added in place as a means of improving the material's stability. The resulting material produced 7 day compressive strengths in the area of 500 psi. At the time of reconstruction, cores of the soil cement revealed compressive strengths ranging from 1189 to 2145 psi.

Pavement condition surveys made prior to reconstruction revealed an average of 851 lineal feet of cracks per 100 feet of 24 foot wide roadway. Longitudinal cracks made up 65 percent of the total with an average of 4 cracks occurring at 5 foot intervals across the 24 foot roadway. Transverse cracks which made up 35 percent of the total, were noted at an average interval of 30 lineal feet of roadway. In most cases the main transverse cracks were accompanied by adjacent alligator cracks which covered an area 12 to 15 inches in width. No attempt was made to record the numerous miscellaneous cracks.

Pavement Condition Prior To Reconstruction

Differences in the cross section of the pavement surface ranged up to 13/16 of an inch. In general, the variations in grade appeared to be caused more by shifting of the soil cement base rather than by sub-base settlement or wheel path rutting as the latter was recorded at a maximum of 3/8 inch.

Climatological data for the area shows an air freezing index of 2161, an average of 118 freeze-thaw cycles and 77 inches of snowfall.

Traffic volume on the roadway in 1980 averaged 3420 vehicles per day with truck traffic estimated at 10 percent.

PRELIMINARY INVESTIGATION

The possibility of recycling the soil cement base and bituminous concrete surface was first investigated in 1977 and 1978. Laboratory analysis was carried out in accordance with specification Section 310-Bituminous Aggregate Base Course Stabilized in Place. The investigation revealed that the material could be pulverized by the hammermill process; that proper compaction could be obtained; and that the addition of 2 percent asphalt would provide additional stability. Further testing of the bituminous overlay prior to reconstruction disclosed an average asphalt content of 6.2 percent, absolute viscosities ranging from 5800 to 21,600 and an average recovered penetration of 31. Although the laboratory study indicated that the addition of asphalt would be beneficial, none was specified in an effort to keep project costs at a minimum.

CONSTRUCTION OPERATION

The reconstruction work was handled as a Force Account Project through Maintenance District No. 4. The pulverization contract, Randolph RS-SR 0190 (3), was awarded to Bell & Flynn, Inc. of Stratham, New Hampshire with the price for scarifying, pulverizing, regrading, and compacting the material established at $3.50 per square yard.

Construction began on May 18, 1981 and was completed 19 working days later on June 12, 1981. Generally good weather conditions occurred during the construction period. Temperatures ranged from 28° F to 90° F with an average daily temperature of 64° F. (see daily log for detailed information Pages 14-19, Appendix A). Light to moderate rain showers which occurred on two days were generally beneficial in aiding in the attainment of the optimum moisture content for satisfactory compaction of the pulverized material. The one exception was a heavy shower on June 4, 1981 which caused the opened work area to become saturated with moisture. The problem was alleviated the following day by aerating the material with the road graders.

Equipment involved in the construction process included a Caterpillar 16G grader, a Caterpillar 14E grader, an International TD25 bulldozer, two Caterpillar 966C loaders, two Bros Preperator hammermills modified for increased horsepower and larger hammers, two 10 wheeler dump trucks rigged with 2500 gallon water tanks and pumps, a 12-14 ton double axle tandom steel wheeled roller and smaller support equipment.

The construction procedure consisted of preparing areas from 1000 to 2000 feet in length by 4 to 13 feet in width. Treatment of the 27 foot width specified was accomplished best in 3 stages since it provided adequate working space while accommodating controlled one-way traffic. Processing of the full roadway width was generally completed over a 3 day period. Scarification was accomplished with a single spike tooth mounted on the 16G grader.

Due to the thickness and strength of the soil cement base and pavement, pushing assistance was required from the bucket loaders and the bulldozer in order to rip up the material. Generally each scarification pass averaged 2 feet apart. Efforts to scarify smaller widths resulted in the tooth slipping into the previously scarified path. Late in the project it was discovered that making two passes on the same area, one to

Tooth used for scarifing

scarify just the bituminous material and the second the soil cement, was more efficient.

The initial size of the scarified soil cement and pavement pieces varied greatly depending upon the width of the pass, the amount of cracks in the pavement and the thickness of the soil cement. The larger slabs, which separated along crack lines, ranged up to 3 feet in width by 8 to 12 feet in length, with the thickness of the soil cement up to 14 inches. Following the ripping process, the 16G grader and bucket loaders worked the larger slabs to the surface where the bull-dozer could travel over the material breaking it down into smaller pieces.


Scarified Material

Four to 8 passes of the equipment reduced the size of the slabs to a dimension of 2 feet or less. Once the equipment had completed this process, the graders bladed a portion of the material onto the adjacent road surface making a windrow approximately 4 feet wide by 1 1/2 feet high. The bucket loaders then drew the hammermills over the windrow reducing the size of the material to 10 inches or less. The grader then releveled the material and bladed another windrow of material from the work area. This resulted in a mixture of pulverized material from the previous pass and new material which was then processed with the hammer-mills. The process continued until all material was pulled out of the scarified area and pulverized once. The material was returned to its original location using the same procedure, except this time, windrowing, pulverizing and releveling took place within the work area. Once all the material was back in its original place all pieces were 1 1/2" or less. For gradation and asphalt content of finished product, refer to Appendix B page 20.

Windrowing Material

Although the hammermill made only one pass over each windrow, the grading operation exposed any remaining chunks of material and included them in the next windrow to be processed. Throughout the scarification and pulverization process, the water trucks continually sprayed the work area to bring the moisture content within the desired range for proper compaction and dust control. Once back in place the equipment traveled back and forth over the surface which compacted the material enough so traffic could be put back on.

Production rates varied widely ranging from 700 to 2300 square yards per day with an overall project average of 1235 square yards per day or 119 square yards per hour. The wide range of production rates was due to the varied depths of material encountered from day to day. For daily average depths encountered, see Appendix C,page 21. Based on an average working depth of 15.7 inches, production volume averaged 539 cubic yards per day or 95 tons per hour (See production data in Appendix D, pages 22-32).

The hammermills were able to travel at rates up to 50 feet per minute pulverizing from 4 to 16 tons per minute of operation. Wear on the teeth (hammers) was less than expected resulting in 6.5 to 15.1 working hours between replacement periods. The average work hours for a set of hammers was 9.3 hours (See Appendix E, page 33). Overall mechanical down time was low for all of the equipment on the project.

The fine grading and compaction of the road surface began on June 5 and was completed on June 12 following completion of the pulverization process. The 14E grader was used to fine grade the surface and was followed closely by a 14 ton double axle tandom steel wheeled roller. The reconstructed base was overlaid with a 1 1/4 inch binder course of Type III Bituminous Concrete Pavement (Item 406) on June 25 and 26 and the project was completed with a 3/4 inch surface course of Type IV mix on July 23, 1981.

Finished Roadway

PROJECT TESTING AND OBSERVATIONS

On project testing and record keeping included sampling of the pulverized material for gradation, asphalt content, and moisture and density requirements. Course thickness, areas treated, equipment production rates, fuel consumption, mechanical down time and weather conditions were also documented.

The density requirement for the project was specified to be a minimum of 95 percent of the maximum density obtained on a test strip constructed within the project limits. Determination of the maximum obtainable control density was checked with a nuclear gauge with the values compared with maximum dry density of 124.5 to 130.5 obtained using the Standard Proctor Test AASHTO T180.

Due to the fineness of the pulverized material, it was possible to complement nuclear gauge readings with the standard sand cone density test. Both tests were also taken at a level 6 to 8 inches below the surface where the results indicated the process was able to obtain the necessary compaction even though the material was being placed in a single lift ranging from 14 to 18 inches in depth. In most cases, acceptable densities were obtained prior to using the 12 to 14 ton static steel wheeled roller.

ENERGY AND COST ANALYSIS

Records were kept of the amount of fuel required to carry out the pulverization process. A total of 5038.2 gallons of diesel fuel were used to pulverize 23458 square yards or 18,755 tons of roadway material. See Appendix F, page 33 for daily breakdown of fuel consumption. This averaged out to 0.215 gallons of fuel per square yard or 0.269 gallons per ton. Converting fuel to units of energy, and adding the energy units for production of the steel hammers, energy consumption totaled 39,420 BTU per square yard or 49,304 BTU per ton.

Energy consumption was estimated for an alternate process which would have insured the elimination of reflective cracking. The method included the removal and disposal of the pavement and soil cement base followed by replacement with a 12 inch course of gravel. This process would have required approximately 92,080 BTU per square yard or 134 percent more than the in-place pulverization process used. Energy consumption data can be seen in Appendix G, page 35.

The cost for removal, disposal, and replacement of the existing material was estimated at $4.35 per square yard or 24 percent more than the $3.50 per square yard cost of in-place pulverization. Cost data can be seen in Appendix H, page 36.

SUMMARY

A 1.54 mile section of Vermont Route 66 in the Town of Randolph was selected for reconstruction primarily due to a poor riding surface and extensive cracking averaging 851 lineal feet of cracks per 100 feet of roadway.

An in-place pulverization process was selected as the reconstruction method primarily to eliminate reflection cracking in the proposed new bituminous pavement.

The reconstruction contract was handled as a Force Account Project with the price for scarifying, pulverizing, regrading, and compacting the material established at $3.50 per square yard. Equipment involved in the construction process included 2 graders, 1 bulldozer, 2 loaders, 2 Bros Preperator hammermills, water wagons and smaller support equipment.

The construction procedure consisted of preparing the 27 foot roadway width in 3 stages since it provided adequate working space while accommodating controlled one-way traffic. Initial scarification was accomplished with a single spike tooth mounted on a grader with pushing assistance provided by the bucket loaders and bulldozer. The initial breakdown of the soil cement and pavement pieces was accomplished by making 4 to 8 passes over the material with the bulldozer and bucket loaders. Following that process, the graders made a 4 foot wide by 1 1/2 foot high windrow of the material. The bucket loaders then drew the hammermills over the windrow reducing the size of the material to 10 inches or less. Although the hammermill made only one pass over each windrow, the grading operation exposed any remaining chunks of material and included them in the next windrow to be processed.

The 23,458 square yard, 1.5 mile project was completed in 19 working days with a minimum of breakdowns or other difficulties. Production rates

averaged 1235 square yards per day or 119 square yards per hour. Based on an average working depth of 15.7 inches, production volume averaged 539 cubic yards per day or 95 tons per hour.

Energy requirements for the recycling process totaled 39,420 BTU per square yard or 49,304 BTU per ton. Requirements for an alternate method which included removal and disposal of the soil cement base and pavement were estimated at 92,080 BTU per square yard or 134% more than the in-place pulverization process. The cost of the alternate method was also estimated at 24 percent more than the process used.

RECOMMENDATION

Although the cost of in-place pulverization is significant, the process is recommended for roadways in very poor condition since problems with the existing pavement surface will quickly reflect up through a new bituminous overlay. It is believed that the process would be especially beneficial when used to blend all existing courses of distressed bituminous material with the underlying gravel subbase for the improvement of the load carrying capacity of the subbase and the elimination of reflective cracking.

APPENDIX A

DAILY WEATHER, LOCATION, AND PRODUCTION DATA

EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
1 - Water truck 1 - Hammermill 1 - 16G Grader 1 - Loader 5 Men	5/18	Sunny - Windy 30° F in morning to 50° F in afternoon	Sta. 0+00 thru 10+00 Eastbound lane	8.5' wide x 1000' long x average of 15" deep.	944	408
1 - Water truck 1 - Hammermill 1 - 16G Grader 1 - Loader 5 Men	5/19	Sunny - Windy 34° F in morning to 65° F in afternoon	Sta. 0+00 thru 10+00 Centerline	7' wide x 1000' long x average of 16" deep.	778	346
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	5/20	Sunny - Calm 40° F in morning to 72° F in afternoon	Sta. 0+00 thru 10+00 Westbound lane	10.5' wide x 1000' long x avg. of 16" deep.	1167	525
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	5/21	Morning-Partly Cloudy 40° F Afternoon calm & sunny 75° F	Sta. 10+00 thru 31+00 Westbound lane	12.5' wide x 2100' long x avg. of 18" deep	2917	1458

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EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	5/22	Morning - Clear & Sunny 45^{o} F Afternoon partly cloudy 75^{o} F	Sta. 10+00 thru 31+00 Westbound land	Reworked Area Done on 5/21/81		
2 - Water trucks 2 - Hammermills 2 - Loaders 1 - 16G Grader 1 - 14E Grader 9 Men	5/25	Partly Cloudy all day. Frequent Sunny periods 60^{o}F in morning to 90^{o} in afternoon	Sta. 10+00 thru 31+00 centerline	4' wide x 2100' long x Avg. 15" deep	933	389
2 - Water trucks 2 - Hammermills 2 - Loaders 1 - 16G Grader 1 - 14E Grader 9 Men	5/26	Sunny and humid occasional cloudiness 65^{o} in morning to 90^{o} in afternoon	Sta. 10+00 thru 21+00 Eastbound land	9.5' wide x 2100' long x Avg. 16" deep	2217	985
2 - Water trucks 2 - Hammermills 2 - Loaders 1 - 16G Grader 1 - 14E Grader 9 Men	5/27	Cloudy and humid Mid-day showers 59^{o}F to 88^{o}F	Sta. 31+00 thru 45+00 Westbound	9' wide x 1400' long x Avg. of 15" deep	1400	583

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EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
2 - Water trucks 2 - Hammermills 2 - Loaders 1 - 16G Graders 1 - 14E Grader 9 Men	5/28	Cloudy and humid 59^{O}F	Sta. 31+00 thru 45+00 centerline Westbound lane	2.5' wide x 1400' long x avg. 15" deep	389	162
2 - Water trucks 2 - Hammermills 2 - Loaders 1 - 16G Grader 1 - 14E Grader 9 Men	6/1	Sunny & Calm 50^{O}F in morning to 75^{O}F in after- noon	Sta. 31+00 thru 45+00 centerline	4.5 x 1400' long x avg. 16" deep	700	311
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	6/2	Sunny & Calm morn- ing; partly couldy afternoon; 40^{O}F in morning to 68^{O}F in afternoon	Sta. 31+00 thru 45+00 eastbound lane	1400' long x 10' wide x 16.5" deep	1555	713
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	6/3	Cloudy all day; Slight breeze in morning, 52^{O}F in morning to 65^{O}F in afternoon	Sta. 45+00 thru 61+00 eastbound lane	1600' long x 13' side x 16" deep	2311	1027

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EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
2 - Water trucks 2 Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	6/4	Partly couldy all day-Heavy rain storm late in day Temp. 60°F - 78°F	Sta. 45+00 thru 61+00 centerline	1600' long x 7.5' wide x 16" deep	1333	556
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	6/5	Coudy in morning clearing in after-noon; 59°F-75°F	Sta. 45+00 thru 61+00 westbound lane	1600' long x 5.5' wide x 15" deep	978	407
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 10 Men	6/8	Clear & dry, 50° in morning to 78° in afternoon	Reworked area 45+00 thru 61+00 to improve material	Reworked Areas Done on 6/4/81 and 6/5/81		

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EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 Loaders 1 - Bulldozer 1 - Roller 10 Men	6/9	Rain in morning, heavy at times-68° clearing to partly cloudy in afternoon 75°F	Sta. 61+00 thru 81+20 eastbound lane	2020'long x 10.5' wide x 14" deep	2357	916
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 1 - Roller 10 Men	6/10	Sunny & Calm 65°F morning to 79°F in afternoon	Sta. 61+00 thru 81+20 centerline	2020' long x 8.5' wide x 15" deep	1908	848
2 - Water trucks 2 - Hammermills 1 - 16G Grader 1 - 14E Grader 2 - Loaders 1 - Bulldozer 1 - Roller 10 - Men	6/11	Sunny, light showers in afternoon 65°F-80°F in afternoon	Sta 61+00 thru 81+20 westbound lane	2020' long x 7' wide x 17" deep	1571	742

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EQUIPMENT	DATE 1981	WEATHER	WORK LOCATION	DIMENSIONS	AREA (SY)	VOLUME (CY)
1 - Water truck 1 - Hammermill 1 - 16G Grader 1 - 14E Grader 1 - Loader 1 - Roller 8 Men	6/12	Sunny-Fog in morning - 60°F to 75°F	Reworked westbound lane Sta. 61+00 thru 81+20	Reworked Area Done on 6/11/81		

APPENDIX B

GRADATION AND ASPHALT CONTENT OF PULVERIZED MATERIAL

GRADATION (% PASSING)

Sieve Size	Location / Date Sampled 9+00 5/17/81	9+00 5/17/81	45+00 5/27/81	45+00 5/27/81	79+00 6/11/81	79+00 6/11/81	Average Of All Samples
1 1/2"	100	100	100	100	100	100	100
1"	98.5	95.3	97.3	100	100	97.7	98.1
3/4"	96.6	93.8	94.6	96.5	98.8	95.7	96.0
1/2"	88.0	86.4	87.8	93.0	97.5	91.9	90.8
3/8"	79.2	76.5	79.4	89.1	92.8	87.6	84.1
#4	66.2	63.4	65.9	78.2	83.3	75.8	72.1
#8	55.0	52.1	54.1	66.8	73.3	63.4	60.8
#16	44.2	41.6	43.3	54.2	62.4	49.6	49.2
#30	30.9	28.7	29.9	38.9	45.8	32.1	34.4
#50	19.7	18.4	19.0	25.2	28.4	19.9	21.8
#200	5.9	5.8	5.8	9.5	8.7	6.8	7.1
ASPHALT CONTENT %	1.6	0.2	1.0	1.0	0.4	0.9	0.9

APPENDIX C
AVERAGE DAILY MATERIAL DEPTH

DATE	DAILY AVERAGE SOIL CEMENT (Inches)	DAILY AVERAGE BITUMINOUS (Inches)	DAILY AVERAGE TOTAL WORKING DEPTH (Inches)
May 18	10	3"	15
May 19	10	3	16
May 20	11	3	16
May 21	9	3 1/2	18
May 25	7 1/2	3 3/4	15
May 26	7 1/4	3 1/2	16
May 27	8	2 3/4	15
May 28	8 1/2	2 3/4	15
June 1	7 3/4	2 3/4	16
June 2	8	2 3/4	16
June 3	7 3/4	2 1/2	16
June 4	10 1/2	2 3/4	15
June 5	5 1/2	3 1/4	15
June 9	5 1/2	3 1/4	14
June 10	7 3/4	2 3/4	16
June 11	7 1/2	2 3/4	17
Project Avg.	7.7"	3"	*15.7"

*This figure includes an average of the top 5 inches of the existing 20 inch granular borrow sub-base which was blended into the pulverized soil cement and bituminous pavement. When this recycling method is used on badly cracked bituminous pavements, the common practice is to scarify a thickness of gravel base equal to the overlay depth and blend the two materials into a homogenous mass which acts as a new stabilized base.

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Grader #2	5/18	8	7.5	0	944	406	744	125.9	54.1	99.2
Loader 1	5/18	8	7.5	.5	944	406	744	78.7	33.8	62.0
Loader 2	5/18	8	5.0	0						
Hammermill 1	5/18	8	5.5	0	944	406	744	171.6	73.8	99.2
Water Wagon 1	5/18	8	5.5	0	944	406	744	171.6	73.8	135.3
Grader #1 -16G	5/19	11	11	0	778	346	634	70.7	31.5	57.6
Grader #2 -14E	-	-	-	-	-	-	-	-	-	-
Bulldozer	-	-	-	-	-	-	-	-	-	-
Loader 1	5/19	11	10.5	0	778	346	634	70.7	31.4	57.6
Loader 2	5/19	11	0.5	0						
Hammermill #1	5/19	11	7.5	.5	778	346	634	97.3	43.2	79.3
Hammermill #2	5/19	11	0.5	0						
Water Wagon #1	5/19	11	11.0	0	778	346	634	70.7	31.5	57.6
Water Wagon #2	-	-	-	-	-	-	-	-	-	-
Grader #1 -16G	5/20	10	10.5		1111	525	962	105.8	50.0	91.6
Grader #2 -14E	-	-	-	-	-	-	-	-	-	-
Bulldozer	5/20	10	3		1111	525	962	370.3	175.0	320.7

- Not Used

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EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Loader 1	5/20	10	8	0	1111	525	962.5	74.1	35.0	64.2
Loader 2	5/20	10	7.0	0						
Hammermill #1	5/20	10	6.0	0	1111	525	962.5	79.4	37.5	68.7
Hammermill #2	5/20	10	8.0	0						
Water Wagon #1	5/20	10	9.0	0	1111	525	962.5	60.0	28.4	52.0
Water Wagon #2	5/20	10	9.5	0						
Grader #1 -16G	5/21	12	12	0	2917*	1458*	2673*	149.6**	74.8**	137.1**
Grader #2 -14E	5/21	12	7	0	2917*	1458*	2673*	201.2**	100.6**	184.3**
Bulldozer	5/21	12	4.5	0	2917*	1458*	2673*	648.2	324.0	594.0
Loader 1	5/21	12	11	0	2917*	1458*	2673*	78.8**	39.4**	72.2**
Loader 2	5/21	12	12	0						
Hammermill #1	5/21	12	8.5	0.5	2917*	1458*	2673	114.4**	57.2**	104.8**
Hammermill #2	5/21	12	8.0	0						
Water Wagon #1	5/21	12	9.0	0	2917*	1458*	2673	88.4**	44.2**	81.0**
Water Wagon #2	5/21	12	9.0	0						
Grader #1 - 16G	5/22	7.5	7.5	0	Completed Area Started on 5/21					

*Not completed in single day **For two days work

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Grader #2	5/22	7.5	7.5	0	Completed Area Started on 5/21					
Bulldozer	5/22	7.5	0	0	" " " " "					
Loader #1	5/22	7.5	6.5	0	" " " " "					
Loader #2	5/22	7.5	7.5	0	" " " " "					
Hammermill #1	5/22	7.5	6.0	0	" " " " "					
Hammermill #2	5/22	7.5	4.5	1.0	" " " " "					
Water Wagon #1	5/22	7.5	7.5	0	" " " " "					
Water Wagon #2	5/22	7.5	7.5	0	" " " " "					
Grader #1	5/25	10.0	9.5	0	933	389	713.2	98.2	40.9	75.1
Grader #2	5/25	10.0	4	0	933	389	713.2	233.2	97.2	178.3
Bulldozer	-	-	-	-	-	-	-	-	-	-
Loader #1	5/25	10.0	8.5	0	933	389	713.2	54.9	22.9	42.0
Loader #2	5/25	10.0	8.5	0						
Hammer #1	5/25	10.0	6.5	1.0	933	389	713.2	71.8	29.9	54.9
Hammer #2	5/25	10.0	6.5	0						
Water Wagon 1&2	5/25	10.0	8.5 each	0	933	389	713.2	54.9	22.9	42.0

\- Not Used

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Grader #1	5/26	13.5	13.5	0	2217	985	1805.8	164.2	73.0	133.8
Grader #2	5/26	13.5	7.0	0	2217	985	1805.8	316.7	140.7	258.0
Bulldozer	5/26	13.5	-	-	-	-	-	-	-	-
Loader #1	5/26	13.5	11.0	0	2217	985	1805.8	94.3	41.9	76.8
Loader #2	5/26	13.5	12.5	0						
Hammermill #1	5/26	13.5	10.0	1.0	2217	985	1805.8	134.4	59.7	109.4
Hammermill #2	5/26	13.5	8.5	1.0						
Water Wagon #1	5/26	13.5	11.0	0	2217	985	1805.8	100.8	44.8	82.1
Water Wagon #2	5/26	13.5	11.0	0						
Grader #1	5/27	10.5	8	3.0	1400	583	1068.8	275.0	72.9	133.6
Grader #2	5/27	10.5	8	0	1400	583	1068.8	175.0	72.9	133.6
Bulldozer	5/27	10.5	-	-	-	-	-	-	-	-
Loader #1	5/27	10.5	8.5	1.0	1400	583	1068.8	87.5	36.4	66.8
Loader #2	5/27	10.5	8.5	0						
Hammermill #1	5/27	10.5	6.0	0	1400	583	1068.8	102.2	42.6	78.0
Hammermill #2	5/27	10.5	6.7	0						

\- Not Used

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Water Wagon #1	5/27	10.5	7.0	0	1400	583	1068.8	200.0	83.3	152.7
Water Wagon #2	5/27	10.5	1.5	0	1400	583	1068.8	933.3	388.7	712.5
Grader #1	5/28	5.0	5.0	0	389	162	297.0	77.8	32.4	59.4
Grader #2	5/28	5.0	1.0	0	389	162	297.0	389.0	162.0	297.0
Bulldozer	5/28	5.0	-	-	-	-	-	-	-	-
Loader #1	5/28	5.0	5.0	0	389	162	297.0	38.9	16.2	29.7
Loader #2	5/28	5.0	5.0	0						
Hammermill #1	5/28	5.0	3.5	0	389	162	297.0	51.9	21.6	39.6
Hammermill #2	5/28	5.0	3.5	0						
Water Truck #1	5/28	5.0	5.0	0	389	162	297.0	36.1	20.2	37.1
Water Truck #2	5/28	5.0	3.0	0						
Grader #1	6/1	8	8.0	0	700	311	570.2	87.5	38.9	71.3
Grader #2	6/1	8	3.0	0	700	311	570.2	233.3	103.7	190.1
Bulldozer	6/1	8	0	0	-	-	-	-	-	-
Loader #1	6/1	8	7.0	0	700	311	570.2	46.7	20.7	38.0
Loader #2	6/1	8	8.0	0						

\- Not Used

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Hammermill #1	6/1	8	6.0	0	700	311	570.2	66.7	29.6	54.3
Hammermill #2	6/1	8	5.5	1.0						
Water Truck #1	6/1	8	6/5	0	700	311	570.2	51.9	23.0	42.2
Water Truck #2	6/1	8	7.0	0						
Grader #1	6/2	13	12.5	0.5	1555	713	1307.1	124.4	57.0	104.6
Grader #2	6/2	13	8.0	0	1555	713	1307.1	194.4	89.1	163.4
Bulldozer	6/2	13	5.0	0	1555	713	1307.1	311.0	142.6	261.4
Loader #1	6/2	13	12.0	0	1555	713	1307.1	69.9	32.0	58.7
Loader #2	6/2	13	10.25	0						
Hammermill #1	6/2	13	7.25	0.5	1555	713	1307.1	113.1	51.9	95.1
Hammermill #2	6/2	13	8.0	1.0						
Water Truck #1	6/2	13	10.0	0	1555	713	1307.1	86.4	39.6	72.6
Water Truck #2	6/2	13	8.0	0						
Grader #1	6/3	11.0	10.5	0.5	2311	1027	1882.8	231.1	102.7	188.3
Grader #2	6/3	11.0	9.0	0	2311	1027	1882.8	256.8	114.1	209.2
Bulldozer	6/3	11.0	5.0	0	2311	1027	1882.8	462.2	205.4	376.6

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Loader #1	6/3	11.0	10.0	0	2311	1027	1882.8	112.7	50.1	91.8
Loader #2	6/3	11.0	10.5	0						
Hammermill #1	6/3	11.0	6.5	0	2311	1027	1882.8	159.4	70.8	129.8
Hammermill #2	6/3	11.0	8.0	0						
Water Truck #1	6/3	11.0	8.0	0	2311	1027	1882.8	144.4	64.2	117.7
Water Truck #2	6/3	11.0	8.0	0						
Grader #1	6/4	13.5	13.0	0	1333	556	1019.3	102.5	42.8	78.4
Grader #2	6/4	13.5	5.5	0	1333	556	1019.3	242.4	101.1	185.3
Bulldozer	6/4	13.5	3.5	0	1333	556	1019.3	380.9	158.9	291.2
Loader #1	6/4	13.5	12.0	0	1333	556	1019.3	53.3	22.2	40.8
Loader #2	6/4	13.5	13.0	0						
Hammermill #1	6/4	13.5	7.0	0	1333	556	1019.3	96.9	40.4	74.1
Hammermill #2	6/4	13.5	6.75	0.5						
Water Truck #1	6/4	13.5	6.0	0	1333	556	1019.3	133.3	55.6	101.9
Water Truck #2	6/4	13.5	4.0	0						

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Grader #1	6/5	8.0	8.0	0	978	407	746.2	59.3**	24.7**	45.2**
Grader #2	6/5	8.0	8-0	0	978	407	746.2	67.4**	28.1**	51.5**
Bulldozer	6/5	8.0	3.0	0	978	407	746.2	326.0	135.7	248.7
Loader #1	6/5	8.0	5.5	0.5	978	407	746.2	40.8**	17.0**	31.1**
Loader #2	6/5	8.0	6.0	0						
Hammermill #1	6/5	8.0	5.5	0	978	407	746.2	51.5**	21.4**	39.3**
Hammermill #2	6/5	8.0	5.0	0						
Water Truck #1	6/5	8.0	1.0	0	978	407	746.2	55.9**	23.3**	42.6**
Water Truck #2	6/5	8.0	2.5	0						
Roller	6/5	8.0	6.5	0				Rolled 0+00 thru 20+00		
16-G Grader #1	6/8	8.5	8.5	0	Reworked Sta. 45+00 thru 61+00 - Area done on 6/8					
14-E Grader #2	6/8	8.5	6.5	0	"	"	"	"	"	"
Bulldozer	6/8	8.5	0	0	"	"	"	"	"	"
Loader #1	6/8	8.5	5.0	0	"	"	"	"	"	"
Loader #2	6/8	8.5	8.0	0	"	"	"	"	"	"
Hammermill #1	6/8	8.5	5.0		"	"	"	"	"	"
Hammermill #2	6/8	8.5	3.5		"	"	"	"	"	"

** Rate for Two Days Work

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Water Truck #1	6/8	8.5	7.0	0		Reworked Sta. 45+00 thru 61+00			Area Done on 6/8	
Water Truck #2	6/8	8.5	7.0							
Roller	6.8	8.5	4.0	0		Rolled 20+00 thru 40+00				
16-G Grader #1	6/9	12.5	9.5	2.5	2304	896	1642.6	242.5	94.3	172.9
14-E Grader #2		12.5	9.0	0	2304	896	1642.6	256.0	99.6	182.5
Bulldozer	6/9	12.5	3.0	0	2304	896	1642.6	768.0	278.7	547.5
Loader #1	6/9	12.5	8.75	0	2304	896	1642.6	129.8	50.5	92.5
Loader #2	6/9	12.5	9.0	0						
Hammermill #1	6/9	12.5	5.5	0	2304	896	1642.6	219.4	85.3	156.4
Hammermill #2	6/9	12.5	5.5	0.5						
Water Truck #1	6/9	12.5	1.0	0	2304	896	1642.6	460.8	179.2	328.5
Water Truck #2	6/9	12.5	4.0	0						
Roller	6/9	12.5	5.0	0	Rolled 40+00 thru 61+00					
16-G Grader #1	6/10	12.0	12.0	0	1865	829	1519.8	155.4	69.1	126.7
14-E Grader #2	6/10	12.0	11.5	0	1865	829	1519.8	162.2	72.1	132.2
Bulldozer	6/10	12.0	4.0	0	1865	829	1519.8	466.2	207.2	380.0

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Loader #1	6/10	12.0	12.0	0	1865	829	1519.8	79.4	35.3	64.7
Loader #2	6/10	12.0	11.5	0						
Hammermill #1	6/10	12.0	9.5	0.5	1865	829	1519.8	193.6	46.0	84.4
Hammermill #2	6/10	12.0	9.0	0						
Water Truck #1	6/10	12.0	7.0	0	1865	829	1519.8	124.3	55.3	101.3
Water Truck #2	6/10	12.0	8.0	0						
Roller	6/10	12.0	7.0	0		Rolled 61+00 thru 71+00				
16-G Grader #1	6/11	14.0	13.5	0	1571	742	1360.3	78.6	37.1	68.0
14-E Grader #2	6/11	14.0	14.0	0	1571	742	1360.3	69.8	33.0	60.5
Bulldozer	6/11	14.0	4.0	0	1571	742	1360.3	392.8	185.5	340.1
Loader #1	6/11	14.0	10.0	0	1571	742	1360.3	48.3	22.8	41.9
Loader #2	6/11	14.0	14.0	0						
Hammermill #1	6/11	14.0	11.0	0.5	1571	742	1360.3	74.1	34.5	63.3
Hammermill #2	6/11	14.0	7.0	0.5						
Water Truck #1	6/11	14.0	7.0	0	1571	742	1360.3	58.1	27.0	49.5
Water Truck #2	6/11	14.0	10.5	0						
Roller	6/11	14.0	3.0	0		Rolled 71+00 thru 75+00				

APPENDIX D

DAILY EQUIPMENT PRODUCTION RATES

EQUIPMENT	DATE 1981	TOTAL LENGTH OF WORK DAY (HRS)	TOTAL OPERATING TIME (HRS)	TIME EQUIPMENT DOWN (HRS)	AREA RECYCLED (YD^2)	VOL. RECYCLED (YD^3)	WEIGHT RECYCLED (TONS)	RATE OF RECYCLING (YD^2/HR)	RATE OF RECYCLING (YD^3/HR)	RATE OF RECYCLING (TONS/HR)
Grader #1	6/12	9	6.5	0	. . . . . .	. . . . . .	Same as day before	. . . . .	. . . .	. . .
Grader #2	6/12	9	8.5	0			" " "	"		
Loader #2	6/12	9	8.5	0			" " "	"		
Hammermill #1	6/12	9	4.5	0			" " "	"		
Water Wagon #1	6/12	9	4.0	0			" " "	"		
Water Wagon #2	6/12	9	6.0	0			" " "	"		
Roller	6/12	9	4.0	0		Rolled 75+00 to end of job.				

APPENDIX E
RATE OF HAMMER WEAR

SET #	DATE CHANGED	NUMBER OF MINUTES OF OPERATION	COMMENTS
	HAMMERMILL 1 #605		
1	May 19, 1981	476	Partially used set when arrived @ project
2	May 21, 1981	567	Broke a hammer, changed set early
3	May 26, 1981	677	
4	May 27, 1981	529	
5	June 2, 1981	484	
6	June 3, 1981	447	
7	June 5, 1981	392	
8	June 10, 1981	506	
9	June 11, 1981	401	
10	June 12, 1981	527	
	Avg.	501 mins. or 8.3 hrs.	
	HAMMERMILL 2 #607		
1	May 25, 1981	908	
2	May 26, 1981	590	
3	May 28, 1981	639	
4	June 2, 1981	610	
5	June 4, 1981 n	559	
6	June 9, 1981	570	
7	June 11, 1981	467	
8	June 11, 1981	362	Did not use entire set before equip. left project
	Avg.	588 mins. or 9.8 hrs.	

APPENDIX F
FUEL USAGE CHART

\- Not Used *Not Fueled

Equipment #		May 18	May 19	May 20	May 21	May 22	May 25	May 26	May 27	May 28	June 1	June 2	June 3	June 4	June 5	June 8	June 9	June 10	June 11	June 12	Gallons/ Hour Equipment
Water Truck 214	Gals.	-	-	16.5	*	28.5	*	20	17.5	*	*	46	*	17.5	*	*	22.1	*	27.5	28.9	1.97
	Hrs.	-	-	9	9	7.5	8.5	11	1.5	3	7	8	8	4	2.5	7	4	8	10	6	
Water Truck 215	Gals.	*	33.3	*	*	*	*	35.6	31.3	20.1	*	17.2	*	14.6	*	*	21.6	*	19.2	16.4	1.58
	Hrs.	5.5	11	9.5	9	7.5	8.5	11	7	5	6.5	10	8	6	1	7	1	8	7	4	
Loader 329	Gals.	28.4	11.1	23.2	19.6	18.9	23.9	39.3	34.5	22	*	30.1	32	35.4	38	17.1	27	23.5	27.5	59.3	3.09
	Hrs.	5	0.5	7	12	7.5	8.5	12.5	8.5	5	8	10.3	10.5	13	6	8	9	11.5	14	8.5	
Loader 344	Gals.	39.1	22	20.3	17.2	18	17.1	28.1	24.7	26.6	*	30.2	36.3	27.7	33.7	12.1	26.6	24.1	27.8	-	2.72
	Hrs.	7.5	10.5	8	11	6.5	8.5	11	8.5	5	7	12	10	12	5.5	5	8.75	12	10	-	
Grader 430	Gals.	88.3	39.3	54.5	46.0	51.1	33.6	55.1	48.6	53.8	*	53.2	49	57.8	49.1	38.7	44.7	43.3	42.8	92.4	5.05
	Hrs.	7.5	11	10.5	12	7.5	9.5	13.5	8	5	8	12.5	10.5	13	8	8.5	9.5	12	13.5	6.5	
Grader 453	Gals.	-	-	-	*	26.1	*	22.2	19.7	9	*	*	31.6	19.3	20.5	34	27.4	27.5	*	46.5	2.47
	Hrs.	-	-	-	7	5	4	7.0	8	1	3	8	9	5.5	8	6.5	9	11.5	14	8.5	
Roller 596	Gals.	-	-	-	-										*	12.3	*	17.4	*	*	1.01
	Hrs.	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	4	5	7	3	4	
Hammer-mill 605	Gals.	50.2	67.5	37.2	31.5	50.3	36.8	60.5	53.2	64.1	*	60.3	70	60.4	65	30.2	40.7	44	63.4	128	7.93
	Hrs.	5.5	7.5	6	8.5	6.0	6.5	10	6	4	6	7.25	6.5	7	5.5	5	5.5	9.5	11	4.5	
Hammer-mill 607	Gals.	-	15.6	49.3	41.7	94.3	47.6	78.1	68.5	78.8	*	66.4	80.6	67.3	62	30.5	29.7	57.4	84.6	-	9.11
	Hrs.	-	0.5	8	8	4.5	6.5	8.5	6.7	3.5	5.5	8	8	6.75	5	3.5	5.5	9	7	-	
Bull-Dozer 225	Gals.	-	-	57.2	54.8	-	-	-	-	-	-	58	62	42	36	-	36	48	48	-	12.60
	Hrs.	-	-	3	4.5	-	-	-	-	-	-	5	5	3.5	3	-	3	4	4	-	
Avg. Gallons Per Hour Per Day		6.6	4.6	4.2	2.6	5.5	2.6	4.0	5.5	8.7	*	2.7	4.8	4.8	5.0	3.2	4.6	3.1	3.6	8.6	Avg. Gal/Hr 4.76

APPENDIX G
ENERGY REQUIREMENTS

BELL & FLYNN RECYCLING

*Gals. of diesel fuel used for entire project per daily records 5038.2 Gals. @ 139,000 Btu/Gal. =	700,309,800 Btu
Energy to produce hammers 17 sets (22/set) (50 lb/hammer) (12000 Btu/lb.) =	224,400,000 Btu
Total	924,709,800 Btu
or	39,420 Btu/s.y.

IF SOIL CEMENT & BITUMINOUS REMOVED AND REPLACED WITH SUB-BASE MATERIAL

Removal and Loading Soil Cement & Bituminous (12" Depth) 30,000 Btu/t (7820 c.y.) (1.89 ton/c.y.) =	443,394,000 Btu
Hauling Material to Dump Site 5 miles (2) (7820 c.y.) (1.92 on/c.y.) (3800 Btu/TM) =	570,547,200 Btu
Loading and Moving Sub-base Material 15,000 Btu/Ton (7820 c.y.) (1.69 ton/c.y.)=	198,237,000 Btu
Hauling Sub-base Material (2) 7.2 miles (3800 Btu/TM) (7820 c.y.) (1.69 ton/c.y.)=	723,168,560 Btu
Placing & Compacting 17,000 Btu/Ton (7820 c.y.) (1.69 ton/c.y.) =	224,668,600 Btu
	2,160,015,360 Btu
or	92,080 Btu/s.y.

*See Appendix F for detailed break-down of fuel useage.

APPENDIX H

COST COMPARISON

BELL & FLYNN RECYCLING

(\$3.50/s.y. per contract) x 23,458 s.y.	\$82,103

REMOVE AND REPLACE WITH GRAVEL (Estimated)

Cost to remove and haul to dump site (Includes, breaking up and loading) \$2.50/c.y. (23,458 s.y.) =	58,645
Cost to purchase, haul, and place 7820 c.y. of sub-base of gravel from nearest source. \$5.00/c.y. (7,820 c.y.) =	39,100
Haul rate 5.4 mile (.10/c.y. mile) (7820 c.y.) =	4,223
Total =	101,968
or \$4.35/s.y.	

APPENDIX I

UNIT WEIGHT OF MATERIALS

Station	LB/CF Soil Cement	LB/CF Bituminous
10+00	141.4	153.2
50+00	138.7	144.9
52+50	142.7	148.7
55+00	138.5	145.2
55+00	143.5	146.0
57+50	136.3	145.2
60+00	136.3	149.7
72+50	139.3	145.9
Avg.	139.6 lb/cf	147.4 lb/cf

(AVG. OVERALL DEPTH 15.7")

Bituminous (3" Avg) 3/15.7 (147.4 lb/cf) = 28.2 lbs.
Soil Cement (7.7" Avg) 7.7/15.7 (139.6 lb/cf) = 68.5 lbs.
Sub-Base (5" Avg) 5/15.7 (122.8 lb/cf) = 39.1 lbs.

TOTAL 135.8 lbs./cf

(135.8 LBS/CF 27 CF = 3666.6 LBS/CY = 1.83 ton/cy

Removal of Material (12" Depth)
Soil Cement (7.7" Avg.) 7.7/12 (139.6) = 89.6 lbs.
Bituminous (3" Avg) 3/12 (147.4) = 36.8 lbs.
Sub-base 1.3/12 (122.8) = 13.3 lbs.

TOTAL 139.7 lbs.

(139.7 lbs/CF 27 CF = 3771.9 lbs/cy = 1.89 tons/cy

APPENDIX J

PHOTOGRAPHS OF CONSTRUCTION PROJECT

SCARIFYING

MATERIAL AFTER SCARIFYING

WORKING LARGE CHUNKS TO THE SURFACE

BREAKING DOWN LARGE PIECES WITH DOZER

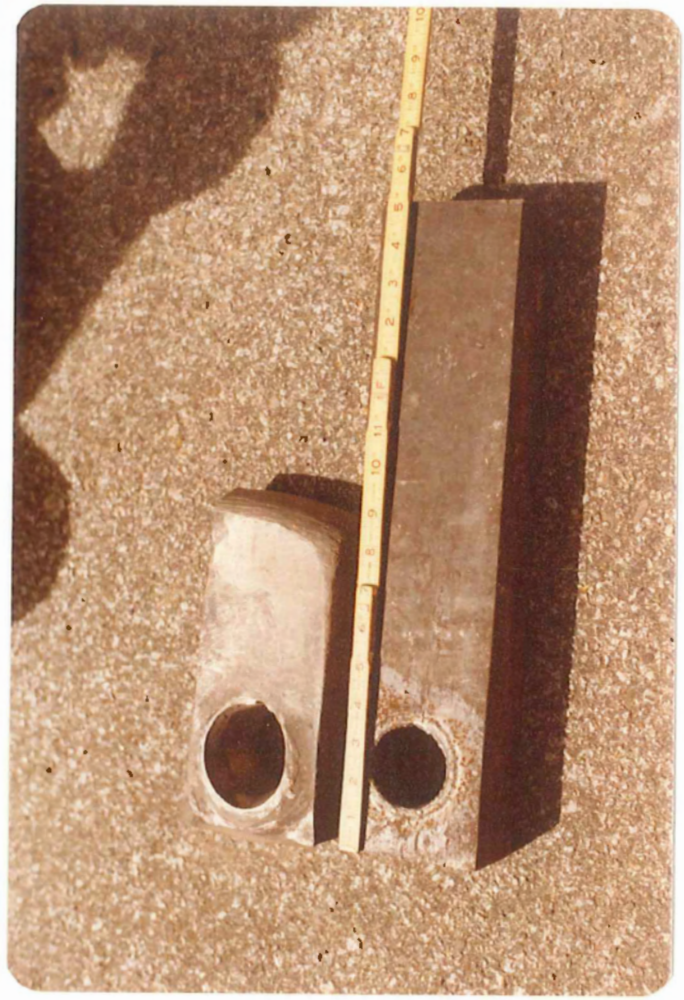
WINDROWING MATERIAL FOR PULVERIZATION

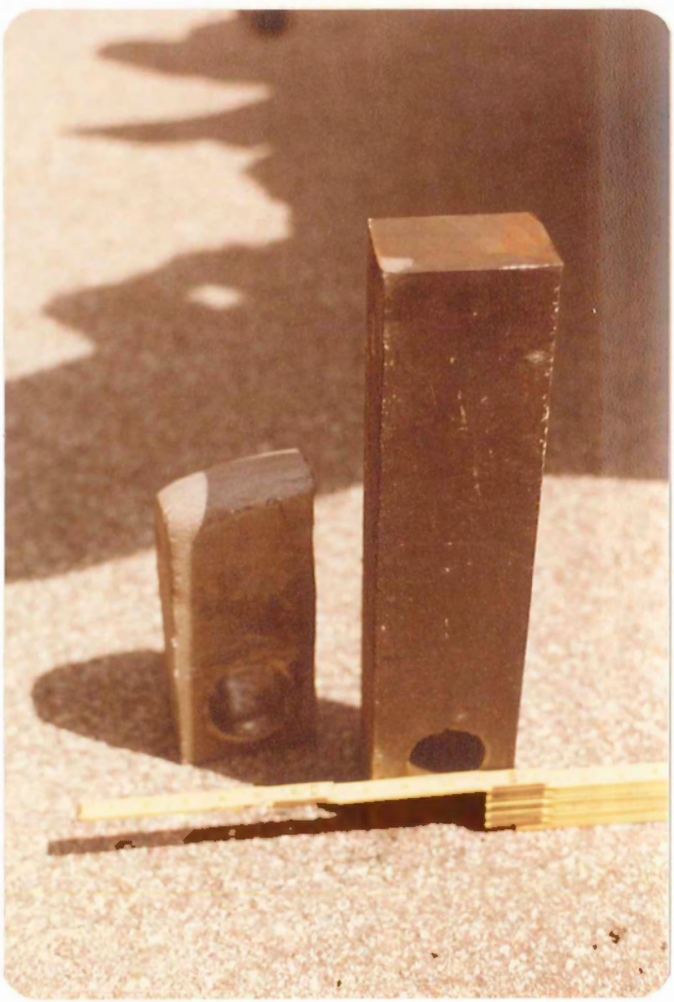
WETTING THE MATERIAL

PULVERIZING

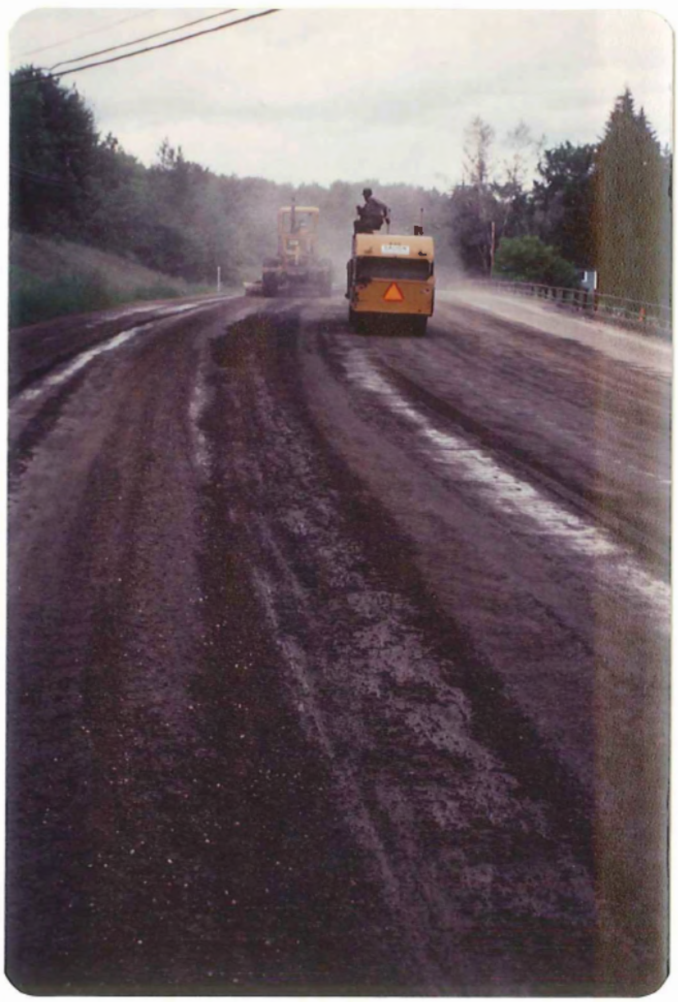
MORE WINDROWING
AND PULVERIZING

WEAR ON HAMMERS & RODS





LEVELING
ROLLING



FINISHED ROADWAY