TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
WA-RD 408.1		

4. TITLE AND SUBTITLE	5. REPORT DATE
Hot In-Place Recycling, SR-97 West Wapato Road to Lateral A Road (SB)	April 1996
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Linda M. Pierce	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
Washington State Department of Transportation Materials Laboratory PO Box 47365 Tumwater, Washington 98504-7365	11. CONTRACT OR GRANT NO. Contract 4673 Federal Aid No. STPF-0097(066)
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Washington State Department of Transportation Transportation Building Olympia, Washington 98504-7370	Post Construction
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

The construction of the Washington State Department of Transportation's first hot in-place recycling project is documented. The project is located in the eastern portion of the state southwest of Yakima on SR-97. The two southbound lanes for approximately 5.5 miles were recycled using the Pyrotech brand of equipment.

The report also includes a description of the hot in-place recycling process, equipment specifications, a discussion of the limitations and benefits of the process, and a survey of other state DOTs' experience with the process.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
asphalt concrete, recycling, in-place	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	66	

HOT IN-PLACE RECYCLING

SR-97
West Wapato Road to Lateral A Road (SB)
Contract 4673

Post Construction Report
Federal Aid No. STPF-0097(066)

by

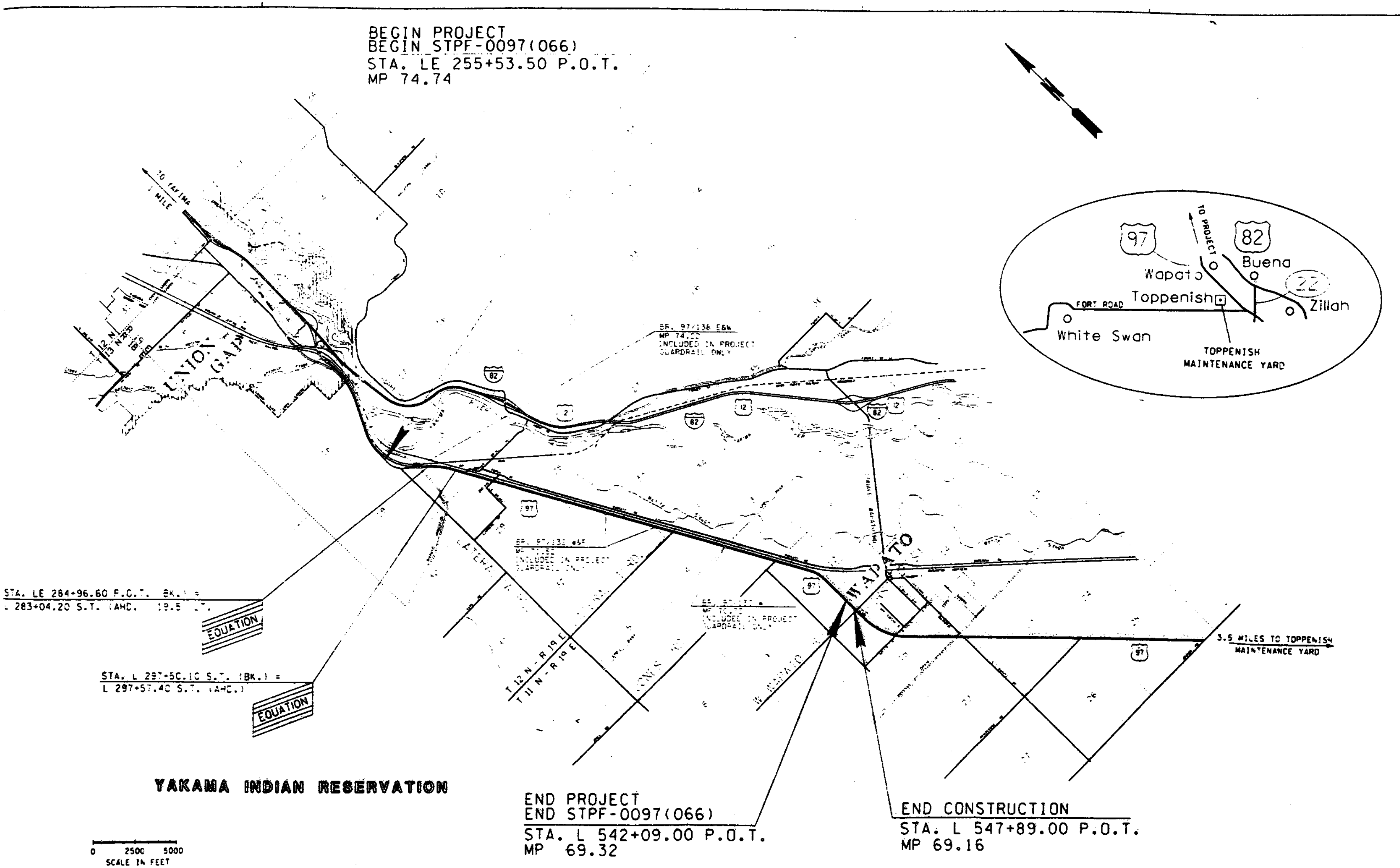
Linda M. Pierce, PE
Pavement Design Engineer

Prepared for
Washington State Department of Transportation
and in cooperation with
US Department of Transportation
Federal Highway Administration
April 1996

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Washington State Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

TABLE OF CONTENTS



DESIGNED BY	GERRY CRAIG			
ENTERED BY	TERI VANASSCHE	NOV. 9:		
CHECKED BY	RON CLIFTON			
PROJ. ENGR.	K.G. LOCKWOOD			
DIST. ADM.	R.L. LARSON			
		DATE	DATE	REVISION	BY

REGION NO.	STATE	FED. AID PROJ. NO.
10	WASH	
JOB NUMBER 95E015		
CONTRACT NO.		

PROGRAM DEVELOPMENT DIVISION

Washington State Department of Transportation

SR 97
WEST WAPATO ROAD TO LATERAL A ROAD - SB

VICINITY MAP

V1

SHEET 2 OF 54 SHEETS

OBJECTIVE

The primary objective of this experimental feature is to evaluate the performance of Hot In-Place Recycling (HIPR) of an existing asphalt concrete pavement. In the past, there has been much controversy over the effectiveness and quality of HIPR projects, a few states have reported good results, while others have had negative experiences. This project will allow the Washington State Department of Transportation (WSDOT) to observe first hand the latest HIPR process as well as to evaluate the short and long term performance of a HIPR pavement. This report will only address the project selection process and project construction. This project will be evaluated on a yearly basis over the next three to five years or until such time that no further useful information can be obtained. At that time a final report will be written to address HIPR performance and life cycle costs.

INTRODUCTION

Currently, the Asphalt Recycling and Reclaiming Association has recognized three methods of recycling: cold in-place, hot in-place and in-plant recycling. Cold in-place recycling is the in place milling of the existing pavement surface followed by the addition of an emulsified asphalt or rejuvenator, mixing the milled material with the asphalt emulsion or rejuvenator, relaying, and compacting the recycled mix. HIPR involves heating and scarification of the existing pavement, mixing the scarified material with additional aggregate, asphalt, and/or rejuvenating agent, as necessary, relaying the recycled mix with a conventional asphalt paving machine, and compacting. In-plant recycling requires milling of the existing pavement surface, transporting the milled material to an asphalt plant where it is heated and mixed with additional asphalt, aggregate, and/or rejuvenator, then transported back to the construction site, and placed using a conventional paving machine, and compacting. This report will concentrate solely on the HIPR process.

HIPR is defined as a process of correcting asphalt pavement surface distresses by softening the existing surface with heat, mechanically removing the pavement surface, mixing it with a recycling agent, possibly adding virgin asphalt or aggregate, and replacing it in the pavement without removing the recycled material from the original pavement site [*1*]. HIPR can be used to address the following pavement distresses: rutting, corrugations, raveling, flushing, loss of friction, and minor thermal cracking. There are three basic HIPR processes: heater-scarification, repaving, and remixing.

Heater-scarification involves removing approximately 1 inch of the existing roadway surface, rejuvenating the recycled mix as necessary, and reshaping it in the final operation. Typically, this process also includes the placement of a conventional wearing course over the recycled layer.

Repaving is similar to heater-scarification with the exception that the repaving includes placement of the overlay and the recycled layer in one pass.

Remixing combines the elements of heater-scarification and repaving and add to it the ability to incorporate virgin asphalt and/or aggregate material. The remixed material is then laid as a wearing course.

The project constructed in Washington state and discussed in this report involved only the remixing process.

HIPR Train

Currently, there are several manufacturers of the HIPR equipment, namely,

- Pyrotech Asphalt Equipment Manufacturing Company, Ltd, North Vancouver, British Columbia,
- Artec, and
- Taisei Road Construction Company, Japan.

Only the Pyrotech equipment, which was used on this project, will be discussed.

The Pyrotech Pyropaver 300E is a two stage system that consists of a preheater, two heating/milling units, a pugmill mixer, followed by a conventional asphalt paving machine and conventional rollers.

- The preheater is pulled by a one ton supply truck (see Figure 1). The preheater removes any excess surface moisture and begins the heating process by the use of infrared heaters. These high air flow burners (propane) are fired horizontally approximately one foot above the pavement surface and are capable of heating the entire lane width. Rubber tire wheels are used for transporting the equipment and are replaced by steel wheels during operation. The truck and preheater have a total length of 56 feet and the width of 13 feet.

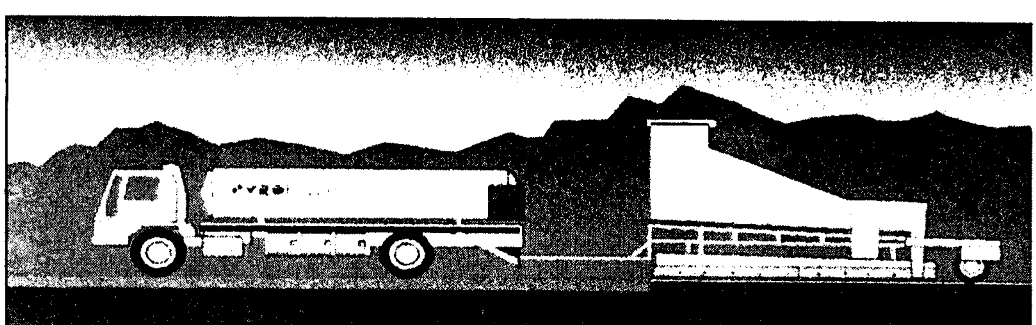


Figure 1. Pyropaver 300E Supply Truck and Preheater.

- The first heater/miller (referred to as Unit "A") is self propelled and also uses propane fired infrared heaters to heat a full lane width of asphalt to a depth of 1 to 1-1/4 inches (see Figure 2). Two parallel five foot wide rotating milling heads remove the upper 1 inch of softened asphalt from each side of the lane and windrows the material into the center of the lane. The rejuvenating tank is also located on Unit A. The total length of the Unit "A" is 59 feet with a width of 12.5 feet.

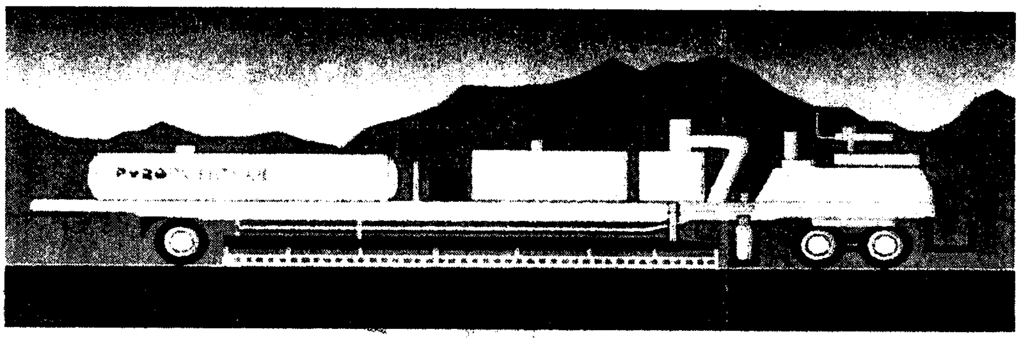


Figure 2. Pyropaver 300E Unit "A".

- The second heater/miller (referred to as Unit B) is pushed by the track paver (see Figure 3). This unit contains a four foot milling head which removes the material in the center of the lane that was not removed by Unit A. The drag-slat conveyor picks up the windrow from Unit A and the material removed by the four foot milling head of Unit B and transports it over the heater banks of Unit B, dropping it in front of the pugmill, which is mounted on the end of Unit B. The infrared heaters of Unit B then heats the newly exposed asphalt to a depth of 1 to 1-1/4 inches and a 12 ft milling head removes the lower layer of asphalt, windrowing it with the material from Unit A. Unit B is also equipped with a front mounted hopper which meters new mix or coated aggregate into the drag-slat conveyor. The pugmill picks up the windrow, which includes the material from Unit A, Unit B and any newly added material, and thoroughly mixes it prior to elevating it into the paver hopper. The length of Unit "B" is 73 feet and a width of 13 feet.

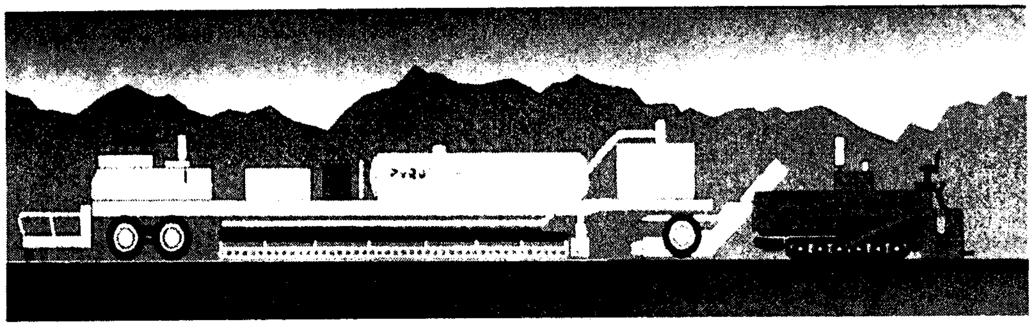


Figure 3. Pyropaver 300E Unit "B".

- Total length of the entire HIPR train is approximately 188 ft.
- The milled and windrowed material is maintained at a temperature of 275°F [5]. The mixed material directly behind the screed is maintained at a temperature range of 220 to 240°F [5]. Table 1 shows additional temperature data obtained from a case study in British Columbia.

Table 1. Case Study Mixture Temperatures (°F).

	Random Locations along Project Length					
	1	2	3	4	5	Avg
Before Preheater	64	91	82	97	72	81
After Preheater	275	248	205	252	226	241
After 1st Stage*	298	302	293	239	295	285
After 2nd Stage**	234	235	225	203	234	226
At Laydown	234	235	225	203	234	226
5 Min. After Laydown	194	174	172	181	176	179

* In windrow
** In hopper

- Manhole covers and other steel materials are easily addressed with this equipment. The operator can stop the milling head and allow it to "walk over" the casting, when the cutting edge falls off the obstruction the miller is restarted. The crew then scoops the softened asphalt around the castings into the windrow.

Equipment Specifics

The Pyropaver 300E has a fuel capacity that will provide for a full day of production without interruption. In addition, the Pyropaver 300E, on the average, can recycle two inches of asphalt at a speed of 20 feet per minute or approximately two lane miles per day [5]. This of course is dependent on road conditions, and ambient and surface temperatures.

All of the axles on the Pyropaver 300E are steering axles which makes this equipment very maneuverable.

The entire system can be transport ready in 30 minutes.

HIPR Limitations

The HIPR process has several limitations, these are as follows:

- Rejuvenates only the upper two inches of asphalt.
- This process will not address any base or subgrade failures.
- This process will not address any structural inadequacies. The structural capacity of the roadway can only be addressed through the addition of a structural overlay over the recycled mix.
- If the original mix is substandard (flushing, stripping, raveling, etc.) some improvements can be made by adding aggregates or asphalt, but major improvements can not be

expected. Obviously, if these problems are not identified during the evaluation of the project, or if identified and not corrected, the problem will appear soon after rehabilitation.

- The amount and quality of any present patching material will affect the final product. Cold patches have been shown to be particularly bad for both production rates and mix consistency. It is recommended that patching material be removed prior to HIPR.
- Crack sealing and seal coating materials can also effect the final product. Crack sealing materials can cause excessive emissions problems when exposed to the preheaters. Seal coat and chip seal materials also help to insulate the underlying asphalt pavement, which reduces the depth of cut and/or the equipment productivity. If excess quantities of these materials exist, removal prior to recycling is often recommended.
- The existing pavement should be at least one inch thicker than the depth of recycle.
- Unless traffic can be rerouted, narrow roads are not good candidates for HIPR, due to equipment widths of 10 to 14.5 feet.
- Due to reduced productivity rates, HIPR is not recommended for any roads that have excessive amounts of obstructions (manhole covers, grates, etc.).
- The preferred weather is hot, calm days with no moisture in or on the existing pavement. The warmth and dryness significantly enhances production rates as well as assuring that the specified depth (typically two inches) can be obtained.
- Wearing courses with aggregates larger than one inch may be unsuitable for HIPR.
- Excessive smoke emissions have been a problem. The equipment that is currently being produced has made significant improvements in emission control systems.

- The rejuvenators used must meet health and safety requirements. This of course is not an exclusively characteristic of HIPR, but applies to all asphalt mixtures that use rejuvenators.

HIPR Benefits

Many benefits exists that makes the HIP process desirable, they include:

- Recycling asphalt minimizes the demand on sources of oil and aggregate.
- Minimal motorist inconvenience due to the fact that the material is recycled and replaced all in one pass, which results in minimal lane closures to the traveling public.
- High productivity rates (on the average two lane miles per day).
- Ability to recycle main lanes only.
- Considering all factors, a cost savings of 10 to 50 percent can be achieved when a one inch HIPR layer is compared with a new one inch overlay [*1*]. This is based on initial costs only since long term performance data for HIPR is very limited.

Mix Design

When determining the appropriate paving mixture, the intent is to develop a recycled mixture with properties that are nearly similar to that of a new hot mix asphalt. Though a mix design procedure has not been developed specifically for HIPR, the following minimum steps should be taken when considering the appropriate mix design [*1*].

1. Evaluate the existing asphalt material (see Table 2).
2. Select the type and amount of rejuvenating agent.
3. Determine the need for additional aggregate and/or asphalt.

4. Prepare and test the paving mixtures.

5. Select the optimum combination of new aggregate, asphalt and rejuvenator.

Field Sampling

Representative, random field samples and visual evaluations should be made from the pavement to be recycled. This information, along with construction, performance, and maintenance records, should be used to determine if significant material differences exist within the project limits. Due to difficulties with uniformity and predictability, separate mix designs should be conducted when significantly different materials exist within the projects length.

Binder Properties

Asphalt content and binder properties (penetration and viscosity) will help to estimate the type and quantity of the required recycling agent as well as the uniformity of the pavement to be recycled. The percentage of recycling agent to be added to the reclaimed recycled asphalt pavement binder is determined by initially establishing a target viscosity value. Trial blends are then prepared to be within the limits (ASTM D 3381) of the target viscosity value.

Epps et al [*3*] indicated that because some recycling agents may not be compatible with the salvaged asphalt, a thin-film oven test should be performed on the recovered asphalt-rejuvenator blend selected. A ratio of the aged viscosity to original viscosity of less than 3 indicates that the recycled agent is likely compatible with the recovered asphalt.

Table 2. Information Required from Preliminary Pavement Structure Evaluation [*2*]

ITEM	DETAILS	REASON
Pavement Inventory Information	• class of pavement • pavement structure[a]	• work schedule • applicability of HIPR

	• pavement history • traffic volume	• supplement detailed evaluation • work schedule
Pavement Structure	• structural defects[a] • non-structural defects • localized structural defects	• applicability of HIPR • selection of HIPR option • need for preliminary localized repairs
Prior Treatments	• any special treatments or materials (surface treatment, rubberized asphalt, road markings, fabrics, epoxy patching, etc.)	• need for removal (cold milling for instance), if possible, before HIPR process
Geometry and Profile	• width, alignment and gradient • surface profile (rutting and wear)[b]	• applicability of HIPR • need for preliminary treatment (cold milling for instance) before HIPR process
Miscellaneous	• manholes, catch-basins, utility covers, etc. • adjacent (close) plants, trees, flammables, etc.	• work schedule, protection, and potential flammable gas counter-measures • work schedule and protective action as necessary

a. In general, a pavement with structural defects (i.e., lack of structural capacity and/or inadequate base, beyond localized defects that can be readily repaired) will not be a suitable candidate for HIPR. Pavements with non-structural surface defects (rutting, wearing, cracking, aging, poor frictional characteristics, etc.) are suitable candidates for HIPR.

b. Pavement width, alignment and/or gradient improvement requirements, or excessive rutting and wear (greater than about 2 inches), may preclude HIPR.

Aggregate Properties

Large quantities of material should be obtained from the pavement to be recycled. This material should be heated to simulate the hot milling process and then crushed by hand. "Mechanical crushing may significantly alter the aggregate gradation. Hot milling reportedly has little effect on aggregate gradation, neither should laboratory crushing of the samples used in mixture design [*1*]." Aggregates should be tested for uniformity within the projects length, gradation, durability, and skid resistance if the recycled mix is to be used in the wearing course.

Mixture Properties

Samples should be fabricated which vary the type and quantity of the recycled and virgin materials. These samples should then be tested and compared to agency specifications. The mixture which posses the optimum properties and the most economical result should be the mix design selected.

Project Selection Process

To determine if HIPR is a viable rehabilitation alternative, for any given project, the evaluation procedure shown in Figure 4 should be followed. Each of the steps will be discussed in detail [*4*].

Preliminary Investigation

The existing pavement structure needs to be thoroughly investigated early in the HIPR process. This involves reviewing the design, the construction records, and the pavement condition data for a given project. This review may indicate the need for adding virgin aggregate or asphalt, indicate the need for overlaying the HIPR material, or determining that HIPR is not appropriate for this project. Information that would assist in the decision process includes: adequate width for HIPR train, adequate turning radius, existing pavement distress (rutting, patching, excessive number of sealed cracks, fatigue cracks which would indicate base and subgrade failures or structural inadequacy of the existing pavement, stripping, delaminations, and flushing), layer thickness of existing pavement, and any other problems over the pavement's history.

As a secondary issue, the construction environment and season should also be reviewed. The ambient air temperature and pavement temperature are important issues to ensure that the specified depth and production rate for the HIPR process can be achieved. Therefore, environmental considerations, such as wind, rain, excessive shady areas and time of construction (month and time of day) must be addressed.

Detailed Pavement Evaluation

If the preliminary investigation indicates that HIPR is still viable, then a detailed pavement condition must be conducted to determine the extent and severity of any pavement distress. If any of these distresses are extensive, HIPR production rates may be significantly reduced such that HIPR may not be appropriate. The following distresses must be identified and quantified:

1. Patching - Due to differences in material properties from plant mix and that used for patching, excessive amounts of patching will not only reduce the production rates (patching material may require additional heat to soften), but will also affect the mix design if not considered properly.

2. Delaminations - If a pavement layer is delaminated below the depth of recycle (1 - 2 inches), there is a high probability that the delaminated material will be picked up during the scarification process. These pieces may get stuck in the augers or may be passed through to the finished mat. Delaminated areas will affect the mix design as well as production rates.

3. Stripping - Rejuvenating agents do not serve as an aggregate binder; they act to rejuvenate the asphalt in the recycled mix. The stripped material does not have enough asphalt for the rejuvenating agent to be effective. If stripping is found, HIPR is strongly discouraged.

4. Rutting - Rutting may be a problem due to uneven heat penetration which will affect HIPR production. If rutting is due to excessive asphalt in the existing pavement, this must be addressed in the mix design process. If the addition of virgin aggregate, during the mix design process, still results in a rut susceptible mix, HIPR is not recommended. In addition, careful considerations must be made when adding additional material due to the potential problems of volume differences between adjacent lanes.

5. Alligator Cracking - The presence of alligator cracks indicates either base or subgrade failures, or structurally inadequate pavement. If base or subgrade failure is present, the underlying problem must be corrected. If the pavement is structurally inadequate a combination of HIPR and a structural overlay will be necessary to ensure adequate performance.

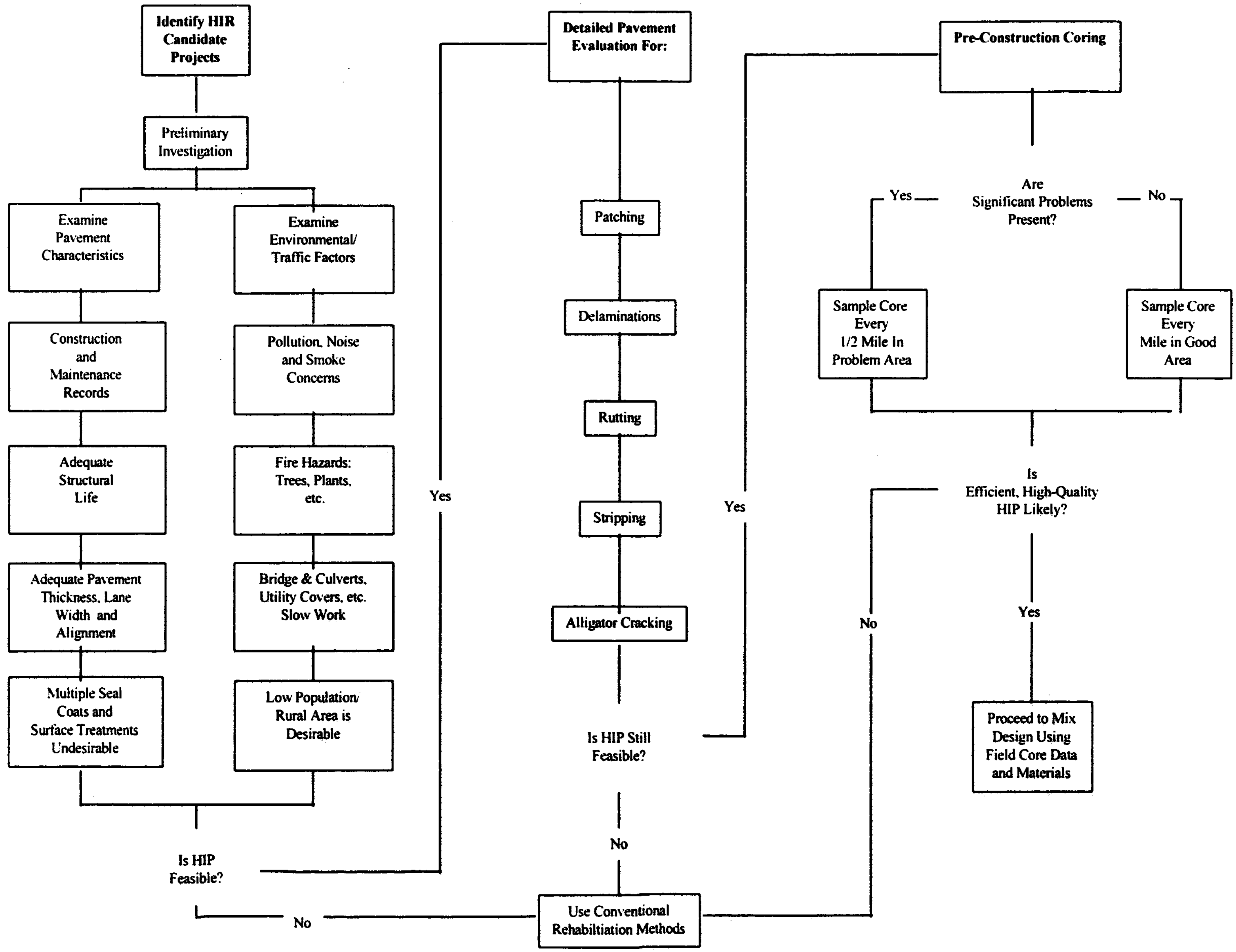


Figure 4. HIPR Project Selection Process [*4*]

Pre-Construction Core Sampling

Core sampling should be conducted on a random basis to verify that there are no hidden layer delaminations or stripping problems. In addition, this material will be needed for determining the mix design.

Survey of States

In 1994 several states (Oregon, Idaho, Nevada, Montana, Arizona, and California) were contacted to determine if there were any concerns with the construction and performance of the HIPR process. The following is a summary of their comments:

- All states had concerns with ambient air temperatures. The production rates of the HIPR process is highly dependent on air temperatures at the time of construction. The cooler the air temperature, the slower the machine must operate to obtain a full two inch depth of recycle. Conversely, warmer temperature assist in the production rates.
- All states expressed concerns with the speed of the HIP operation. Fast production rates are undesirable since it may result in mix segregation and the inability to obtain the full two inch recycle depth.
- Several states noted that cracks in the existing pavement reflected through the recycled material within six months. This is due in part to the inability to repair any underlying distressed pavement or the inability to obtain proper compaction of the recycled mix.
- The presence of excessive rubberized material (crack sealing) is likely to create a smoke cloud during the HIPR process.

- Patched and oxidized pavement are potential difficulties for the HIPR process. The non-uniformity and nature of this material causes difficulty in uniform heating and is therefore difficult to remove by the HIPR operation.
- Any areas of stripping are a problem if undetected.
- The best performance, based on a maximum of two years of service, has been when the HIPR material was overlaid with two inches of asphalt. Therefore, performance of this HIPR project is based more on the performance of the overlay and not the recycled layer.
- This process is susceptible to reduced levels of performance if not placed under stringent quality control.

In addition to the survey of the above states, the British Columbia Ministry of Transportation has had substantial experience with the HIPR process. British Columbia has been using the HIPR process, described in this report, since 1987. In 1993 the ministry conducted a study to determine the performance and economics of HIPR [7]. The results of this study is briefly described below:

- HIPR is an effective rehabilitation method for specific projects.
- The HIPR process conserves aggregate, asphalt and energy.
- In general, the HIPR process is considered less disruptive to traffic than the conventional overlay alternatives.
- Visible emissions are reduced to acceptable levels.
- Due to the short time of use and the rapidly evolving technology, there is insufficient data on HIPR mix properties and performance to quantify a relationship.

- South Coast Region uses HIPR with an overlay due to short life and poor durability of HIPR surfaces under extremely heavy traffic loading.
- Vancouver Island Region uses HIPR without an overlay due to mild climate (wet no freeze) in conjunction with lighter and less frequent traffic loadings.
- It is difficult and undesirable to prepare generic recommendations for HIPR. HIPR with and without an overlay is dependent on Region, climate and levels of traffic.
- Considered to be a suitable rehabilitation tool based on specific project requirements.
- The average expected life of HIPR with no overlay and no mix design is approximately 2.8 years. The average expected life of HIPR with no overlay and a mix design is approximately 5.8 years.

STUDY SITE

Several projects were evaluated to determine the most appropriate project for HIPR. Characteristics which made this project an ideal candidate was sufficient lane and shoulder widths, minimal number of curves (relatively straight roadway section), uniform surfacing depth over the entire project length, minimal number of cracks and patching, no stripping, minimal aging, and warm to hot ambient air temperature during the construction period.

Project Details

This project is located in Yakima County approximately 5 miles south of the city of Yakima in the southbound direction on SR-97. This roadway has an average daily traffic (ADT) of approximately 9,000 vehicles, approximately 13 percent trucks, and 15 year equivalent single axle loads (ESAL's) ranging from 1,500,000 to 3,600,000. This roadway section is classified as a rural minor arterial.

Construction History

The past construction history for this roadway was taken from the Washington State Pavement Management System and is shown in Table 3

Table 3. Construction History

MP Limits	Year	Contract	Construction	Thickness (ft)	Surface Type
69.19 - 69.21	1991	3910	Resurfacing	0.20	ACP Class B
	1991	3910	Grinding	0.12	Grinding
	1979	1047	Resurfacing	0.22	ACP Class B
	1958	5719	New Construction	0.20	ACP Class B
	1958	5719	New Construction	0.92	Base
69.21 - 69.28	1979	1047	Resurfacing	0.22	ACP Class B
	1958	5719	New Construction	0.20	ACP Class B
	1958	5719	New Construction	0.92	Base
69.28 - 74.72	1985	2891	Resurfacing	0.25	ACP Class B
	1958	5719	New Construction	0.20	ACP Class B
	1958	5719	New Construction	0.92	ACP Class B

Pavement Condition

The pavement of the southbound lanes are distressed as follows (as described in the Region Rehabilitation Report):

MP 74.72 to MP 69.28

The major pavement deficiency on this section of roadway is transverse and longitudinal cracking. The transverse cracks, which generally are full width, occur frequently and have minor edge raveling and rarely exceed 1/8 inch in width. The longitudinal cracks are most often found in the inside wheel path of the outside lane. The longitudinal cracks occur erratically, are unraveled at the surface, and are low severity (<1/4" wide). Wheel path rutting is minimal, and bleeding, stripping and raveling is not existent.

MP 69.28 to MP 69.19

This area is subjected to braking or stopping traffic. This segment has deep wheel path rutting, bleeding, shoving, and surface raveling. This occurs in both lanes, though it is most severe in the outside lane. The outside lane has received a maintenance patch and this patch has wheel path rutting of up to 1/2 inch in depth. The inside lane and left turn lane both have severe transverse and longitudinal cracks. This entire section needs to be replaced with a more stable asphalt concrete mix.

The left and right shoulders, for the entire length of the project, are distressed with transverse cracks and slight washboarding.

The proposed rehabilitation of this project involved removing and replacing the top 0.15 ft of rutted ACP from MP 69.28 to MP 69.19 and then overlaying the entire project, including shoulders, with 0.08 ft ACP Class D. This project was to be originally constructed during the 1991 paving season, but the actual contract advertising date was delayed until April 1995 (construction in July 1995).

Due to this delay, the recommended rehabilitation was reviewed and the following changes were made by the Region Materials Engineer. Upon completion of the HIPR process (recycle to a depth of 0.18 ft), the entire roadway will be overlaid with 0.11 ft ACP Class D (open graded friction course). A short section of the recycled material will not be overlaid such that monitoring of the recycled material with and without an overlay can be conducted. The non overlaid section is approximately 500 ft north of the Lateral A Road Intersection.

CONSTRUCTION SUMMARY

The prime contractor for this project was Superior Paving Co., the HIPR process was subcontracted to Pacific Pavement Recycle. Construction of this project began in July 1995. Since this was the first HIPR project in Washington state, the Field Construction office (Rick Gifford), South Central Region Materials Lab, FOSSC Materials Lab (Tumwater), and Pacific Pavement Recycle personnel worked hand in hand to ensure the success of this project. It was initially believed that the contractor would have a difficult time in monitoring the quantities of the recycling agent and precoated aggregate, but during construction it was determined that the contractor was able to accurately monitor the additives [*6*]. A second concern was the ability of the contractor to meet the required density specifications. Compaction of the recycled mix was easily achieved and any compaction difficulties were attributed to improper roller operation.

The following table contains project details concerning air and pavement temperatures, quantity of material recycled and quantity of added materials.

Table 4. Temperature, Recycled Quantities, and Quantity of Added Materials.

Day	Pavement Temperature Min. (°F)	Pavement Temperature Max. (°F)	Air Temperature Min. (°F)	Air Temperature Max. (°F)	HIPR (SY)	Coated Aggregate (Ton)	Recycling Agent (Ton)
Thursday, July 13, 1995	*	*	65	85	5,506	92.81	3.11
Friday, July 14, 1995	Equipment breakdown						
Monday, July 17, 1995	110	150	*	98	10,792	218.67	6.06
Tuesday, July 18, 1995	90	150	80	100	7,949	144.86	4.34
Wednesday, July 19, 1995	80	150	80	120	5,947	116.76	3.25
Thursday, July 20, 1995	*	*	*	*	9,953	168.56	5.55
Friday, July 21, 1995	*	139	75	100	7,009	137.87	3.97
Monday, July 24, 1995	*	139	70	85	9,101	183.38	5.08
Tuesday, July 25, 1995	*	*	70	85	10,728	186.66	5.92
Wednesday, July 26, 1995	*	*	65	85	3,860	60.68	2.22
Thursday, July 27, 1995	80	150	75	96	6,287	120.50	3.52
Total Quantities					77,132	1430.75	43.02

* no data

As shown in Table 4, the pavement temperature ranged from a low of 80°F to a high of 150°F. This high pavement temperature significantly contributed to the production rate of the HIPR process. Obviously, the warmer the pavement structure, the less energy required to heat the pavement structure to the full two inch depth. In addition, the warmer pavement and air temperatures contributed to the ability of the contractor to obtain compaction. The warmer temperatures minimized the rate of cooling on the recycled material which allowed the contractor more time to complete the rolling process before the pavement was to cool to compact.

The HIPR portion of this project was completed in 10 working days. The average production rate for this project was approximately 1.1 lane miles per day (approximately 12 feet per minute).

Several problems were encountered on this project. The first difficulty was the volume difference of the recycled mix between the right lane and the left lane. Since the right lane had approximately 1/4" to 1/2" ruts (automobile wheel path raveling due to studded tires and shoving at the intersections due to stopping motion) and the left lane had essentially no wear, the volume of material recycled from the right lane was less then the volume of material recycled from the left lane (recycle depths were the same for both lanes). The amount of additives (recycling agent and precoated aggregate) was the same for both lanes. This resulted in difficulties in maintaining an acceptable height difference along the longitudinal joint between the two lanes. Obviously, this could be corrected in future projects by adjusting the amount of added material to compensate for volume differences in the recycled mix between adjacent lanes. A second difficulty was in maintaining a constant depth at the final milling head. To correct this problem it was suggested that an automatic control like the joint matcher on a paving machine be required. The third difficulty was in maintaining a constant milling/scarifying depth, pavement temperature, etc. at speeds greater than 16 feet per minute. As stated previously, strict control of machine speeds significantly enhances the properties of the recycled mix. Though not found to be a problem, it was recommended that a "heated box" pugmill be added to the recycling train to improve the mixing process. It was also noted that uneven heating of the asphalt mat occurred when there was a 15 mph or higher cross wind. Temperature differences between the up and down wind sides were observed to be up to 30°F. Though it is impossible to control the wind direction and speed, consideration of this problem could be addressed during the project selection process.

Several advantages were also noted from the Region construction office. These include:

1. The cost to rotomill and replace ($4.00/sy) as compared to HIPR ($2.60/sy), which resulted in an initial cost difference of 35 percent.

2. Traffic control costs were less for the HIPR process due to removing and replacing the asphalt in one pass rather than the two pass operation that generally occurs with conventional rotomilling and replacing.
3. It was noted that less disruption to traffic occurs since the HIPR process requires only one truck, every 30 to 40 minutes, to deliver the coated aggregate.
4. It was felt that the HIPR process would help in lowering the bid prices due to competition.

In conclusion, the construction office stated that if a pavement was consistent, evaluated and re-designed to meet the required specifications and if HIPR is shown to have an equivalent performance life to conventional overlays, then HIPR could be a viable rehabilitation option.

COST COMPARISON

Total project costs was $671,220.20. The cost related to HIPR is shown in Table 5.

Table 5. Summary of Construction Costs (taken from Contract Bid Item Sheets)

Item	Total Quantity	Unit Cost	Total Cost
HIPR	75,660 SY	$2.05/SY	$155,103
Recycling Agent	45 Ton	$420/Ton	$18,900
Precoated Mineral Aggregate	1,513 Ton	$25.00/Ton	$37,825
TOTAL COST			**$211,828**

Since long term performance data is not available for the HIPR process, a cost comparison to conventional rehabilitation alternatives can not be conducted. A complete life cycle cost analysis will be conducted on this project at the end of the evaluation period (three to five years or until such time that no further useful information can be obtained).

CONCLUSION

Based on the experience obtained from other states, the British Columbia Ministry of Transportation and the experience WSDOT has obtained from the construction of a HIPR project, the success of the HIPR process is extremely dependent on the existing conditions of the pavement to be recycled. The HIPR process is not applicable to any given project, detailed pavement condition and mix design is required for each project to be rehabilitated using the HIPR process.

Based on the results of in service pavements, an expected service life of the HIPR process, without an overlay, is three to six years. If the HIPR material is overlaid and assuming that the recycled material is a quality product, the performance of the pavement section will be dependent on the performance of the overlay.

RECOMMENDATIONS

Based on the experience obtained on this project and those in other states, the following recommendations can be made:

1. Existing asphalt depths should be at least one inch thicker than the depth of recycle.
2. A pugmill should be used to ensure complete and uniform mixing of the recycled asphalt pavement, rejuvenator and virgin materials. On this project, the recommendation was to use a "heated box" pugmill to improve the mixing process.
3. Specifications should require indirect or radiant heating by preheaters. Radiant heat should be defined as that which does not permit direct contact of flame with the pavement surface [*1*].

4. The same quality control test for hot mix asphalt plant production should be performed for HIPR production, which includes aggregate gradation, asphalt content and compacted density. Quality control test should also include recovering of binder from the recycled mixture and measuring absolute viscosity and penetration [*1*].

Table 6. Recommendations for HIPR

HIPR Not Recommended:	**HIP Recommended:**
Thin Pavements	Existing Pavement is Rutted (not severely)
Base/Subgrade Failures	Existing Pavement is Aged (not severely)
Drainage Improvements are Required	Existing Pavement is Stripped (not severely)
Irregular or Frequent Patching	Minor Thermal Cracking
Narrow Roads	Ideal Candidate is a pavement that is not too old and not excessively oxidized
Numerous Obstructions	
Multiple Surface Treatments are Present	
Open-Graded Friction Courses	
Severely Stripped or Delaminated	

REFERENCES

1. Button, J. W., Little, D. N., Estakhri, C. K., "Hot In-Place Recycling of Asphalt Concrete, A Synthesis of Highway Practice," NCHRP Synthesis 193, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D. C., 1994.

2. Emery, J. J., Gurowka, J. A., Hiramine, T., "Asphalt Technology for In-Place Surface Recycling Using the Heat Reforming Process," Proc., The 34th Annual Conference of Canadian Technical Asphalt Association, Vol. XXXIV, 1989.

3. Epps, J. A., Little, D. N., Holmgreen, R. J., and Terrel, R. L., "Guidelines for Recycling Pavement Materials," NCHRP Report 224, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., September 1980.

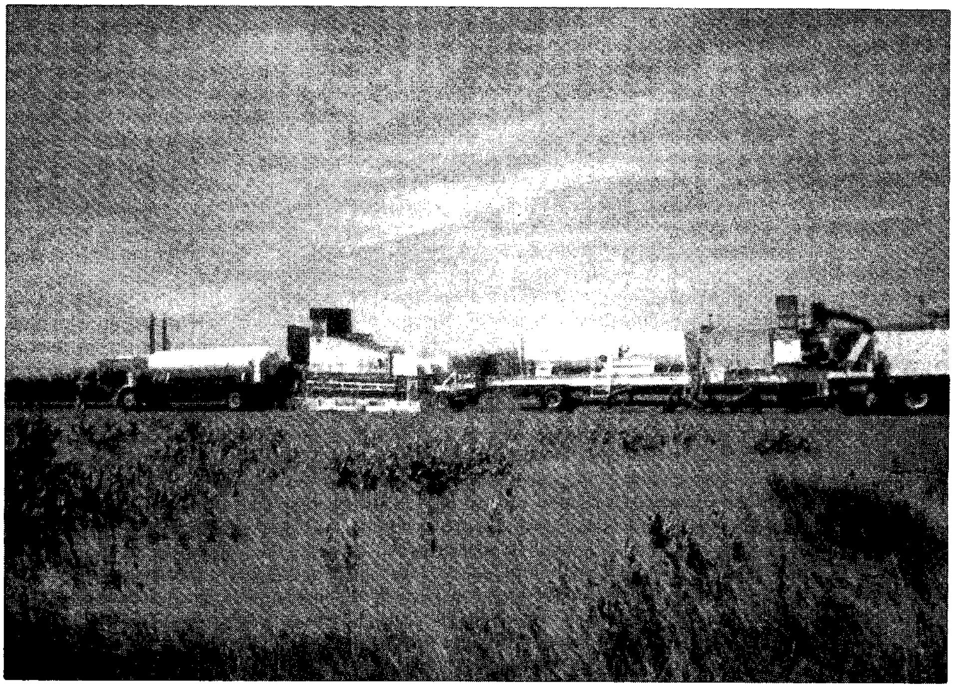
4. Rogge, D. F., Hislop, W. P., Dominick, D., "Exploratory Study of Hot In-Place Recycling of Asphalt Pavements, Volume 1," FHWA-OR-RD-95-07A, Oregon Department of Transportation, Salem, Oregon, November 1994.

5. Conference notes, Hot In-Place Asphalt Recycling Conference, Vancouver, B. C., Canada, August, 1991.

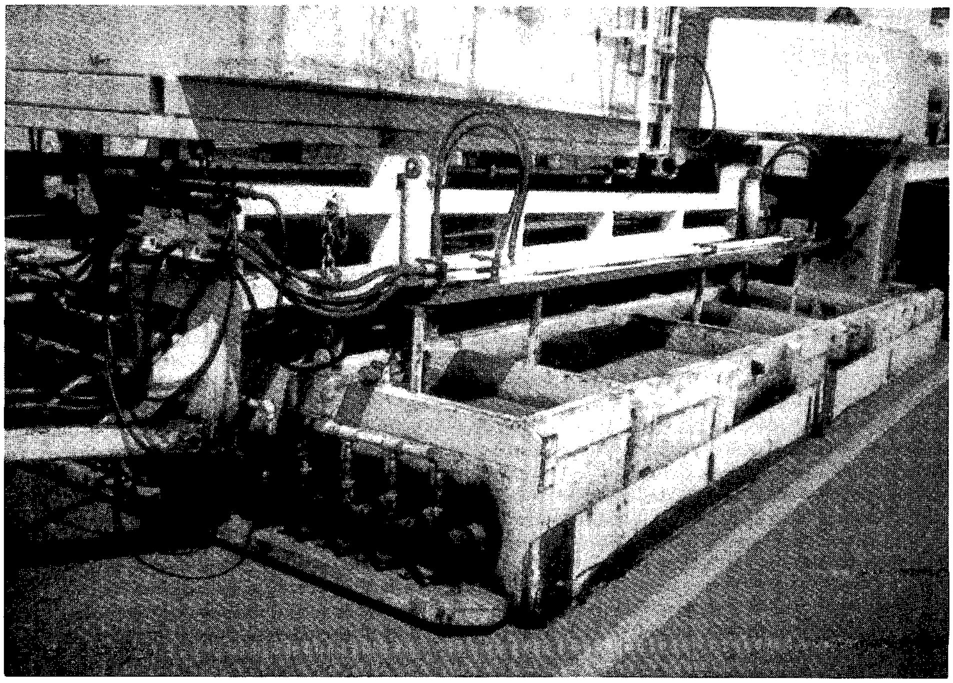
6. Cichowski, J. T., "Construction Field Office Evaluation of Contract 4673 Hot In-Place Recycling," January, 1996.

7. Haughton, D. R., "Performance and Economics of Hot In-Place Recycling in British Columbia," March 1993.

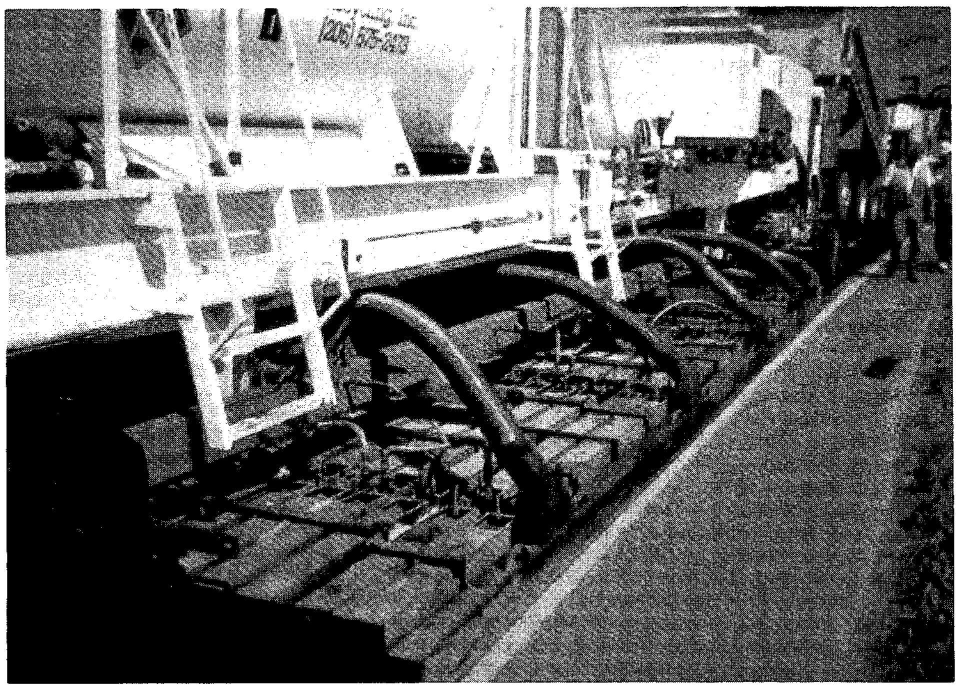
APPENDIX A - PHOTOGRAPHS



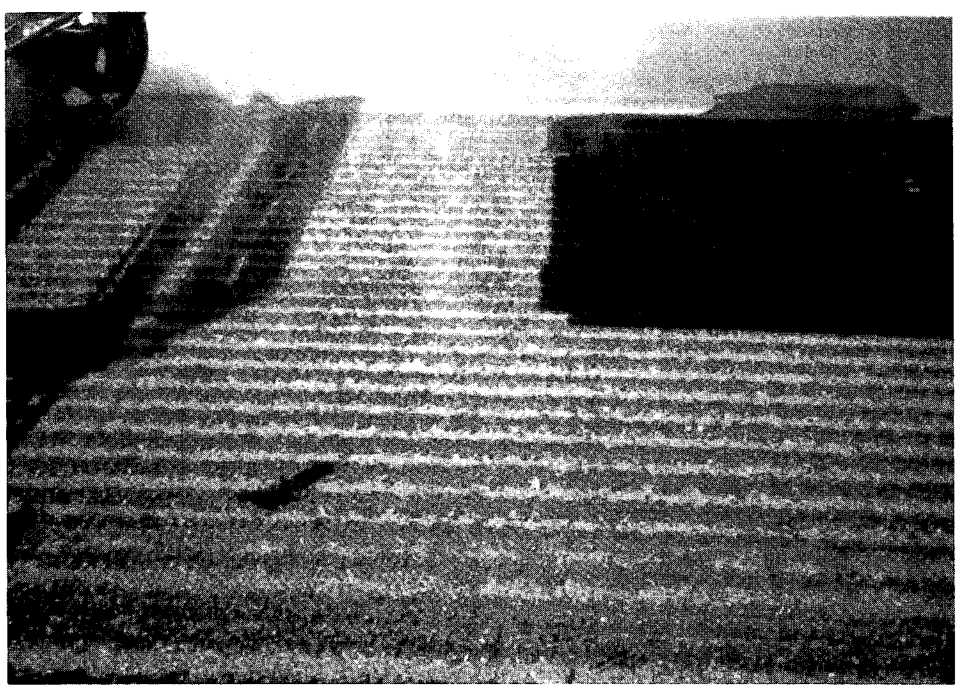
Picture 1. Pyropaver Preheater and "Unit A".



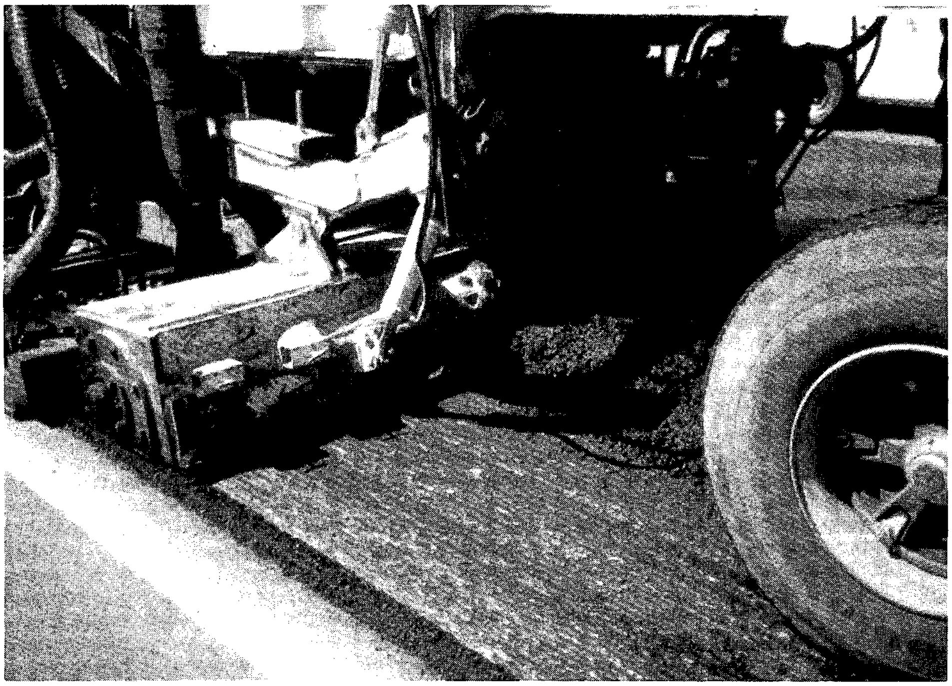
Picture 2. Infra Red Heaters of the Preheater. Removes any excess surface moisture and begins the heating process. Heats entire lane width (12 feet).



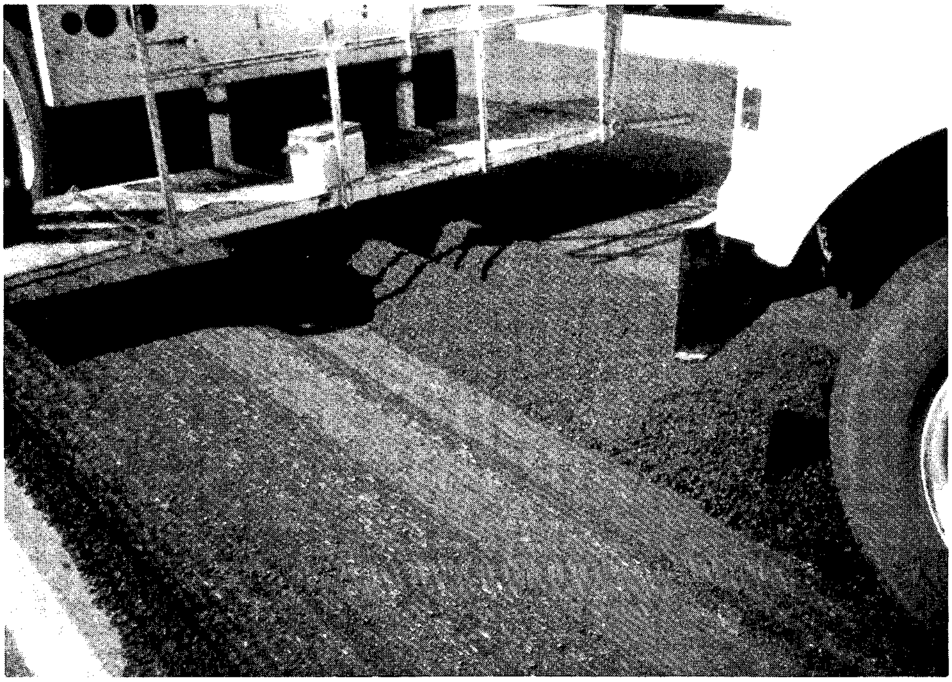
Picture 3. Infra Red Heaters of "Unit A". Continues heating process of upper 1 inch of existing pavement, heats full width (12 feet).



Picture 4. Pavement surface after "Unit A" heaters and before "Unit A" milling heads.

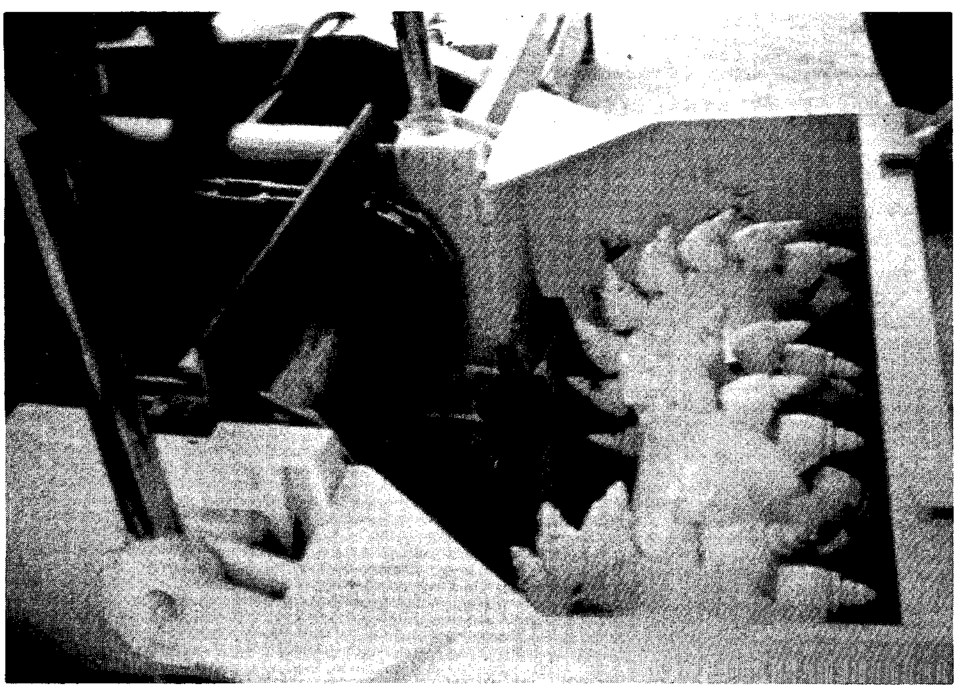


Picture 5. Milling heads of "Unit A". Removes the top inch of heated material. Milling heads remove the outside 5 feet from each side of the travel lane.



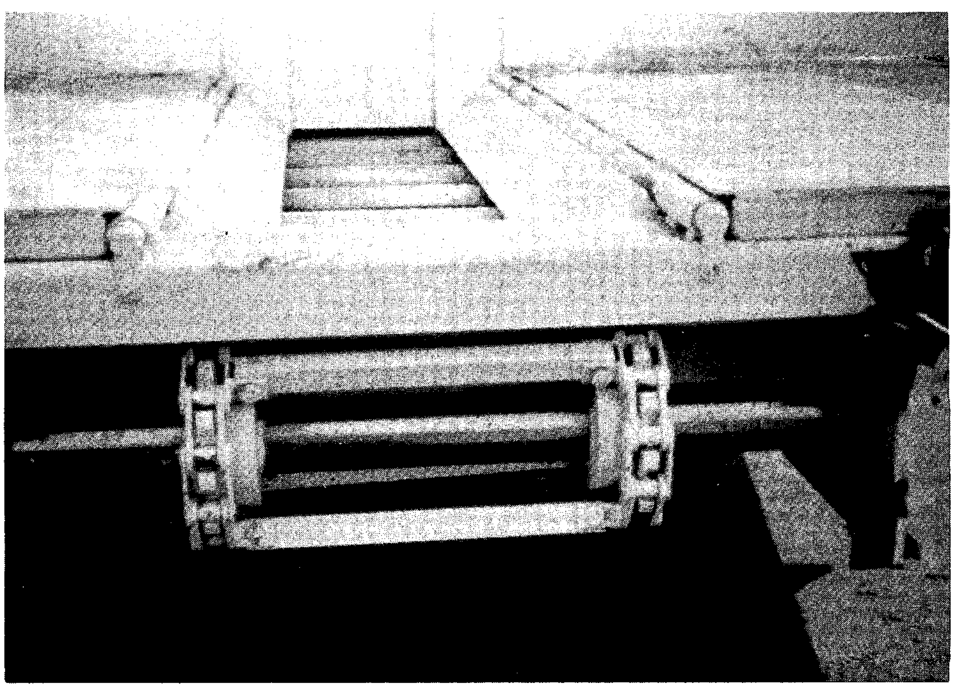
Picture 6. Milled and windrowed material after "Unit A".

Picture 7. Truck delivering precoated aggregate, "Unit B", and conventional paving machine.

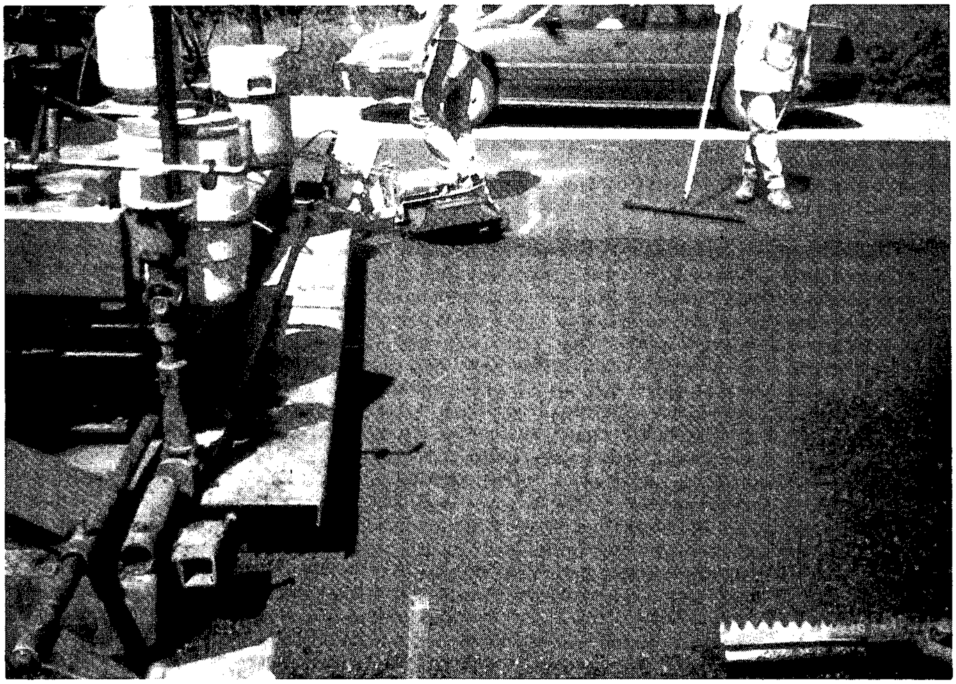


Picture 8. Milling head of "Unit B". Removes the material from the center portion of the lane that was not removed by "Unit A" (photo courtesy of Pacific Pavement Recycling, Inc.).

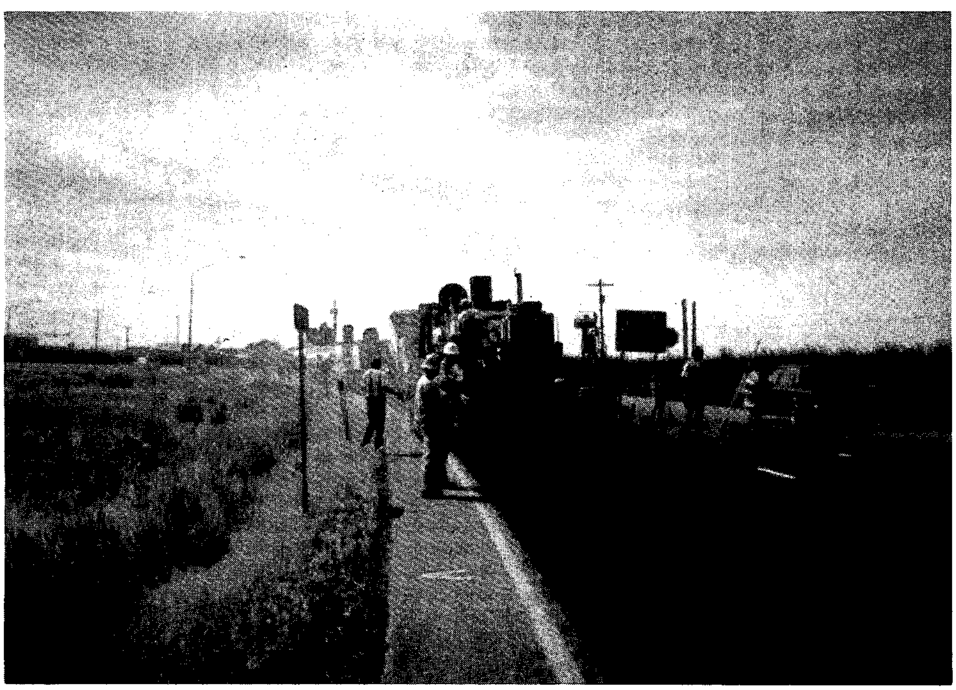
Picture 9. Addition of precoated material into hopper of "Unit B"..



Picture 10. Drag slat conveyor - measures the amount of material being added (photo courtesy of Pacific Pavement Recycling, Inc.).

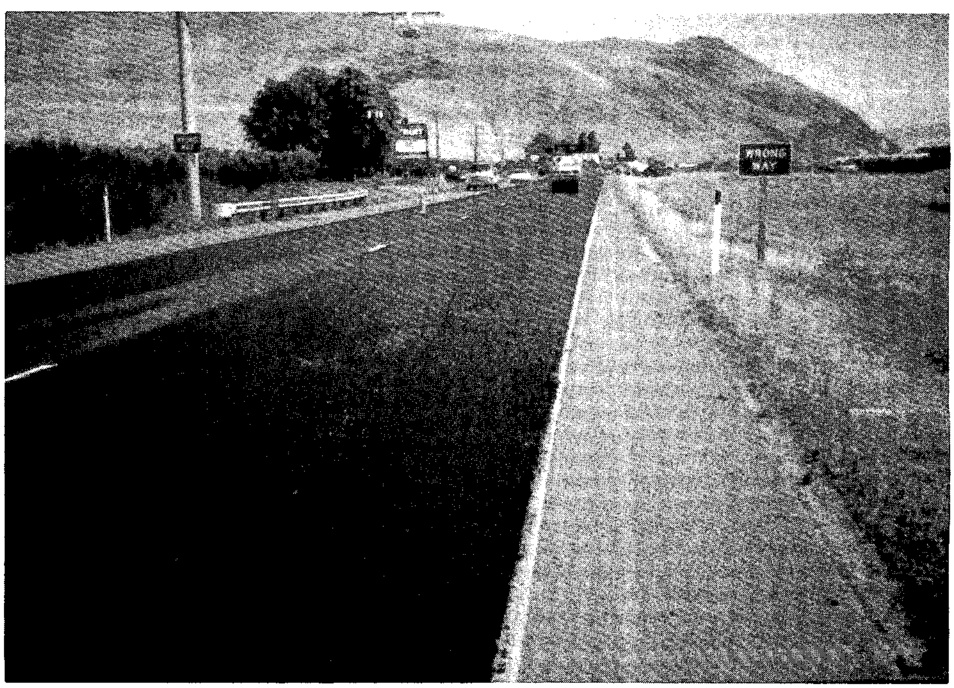


Picture 11. HIPR material directly after the conventional paver.



Picture 12. HIPR prior to rolling operation.

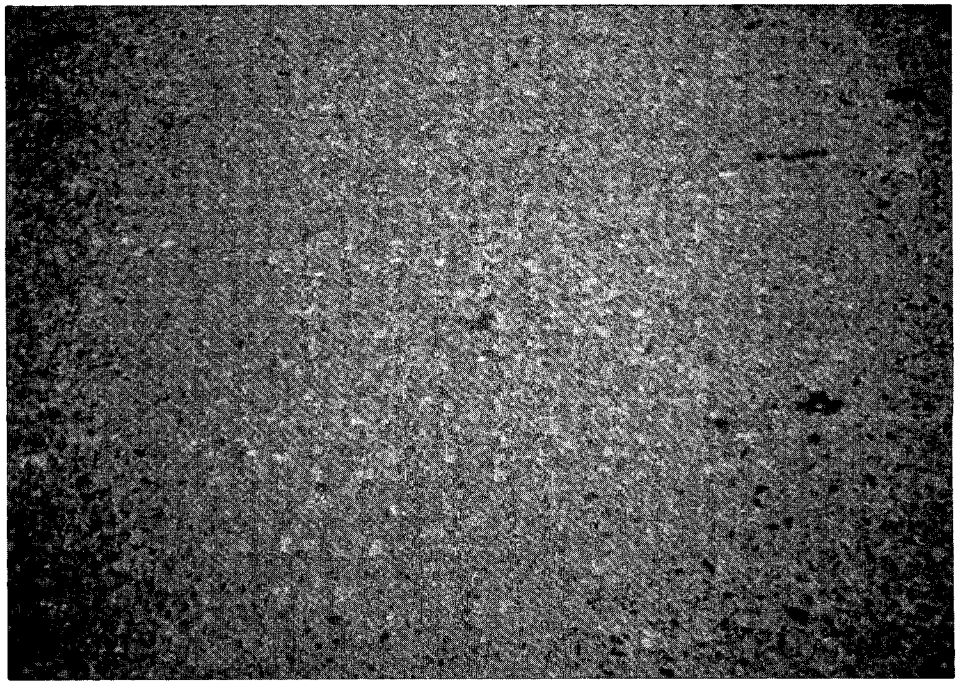
Picture 13. HIPR train and rollers.



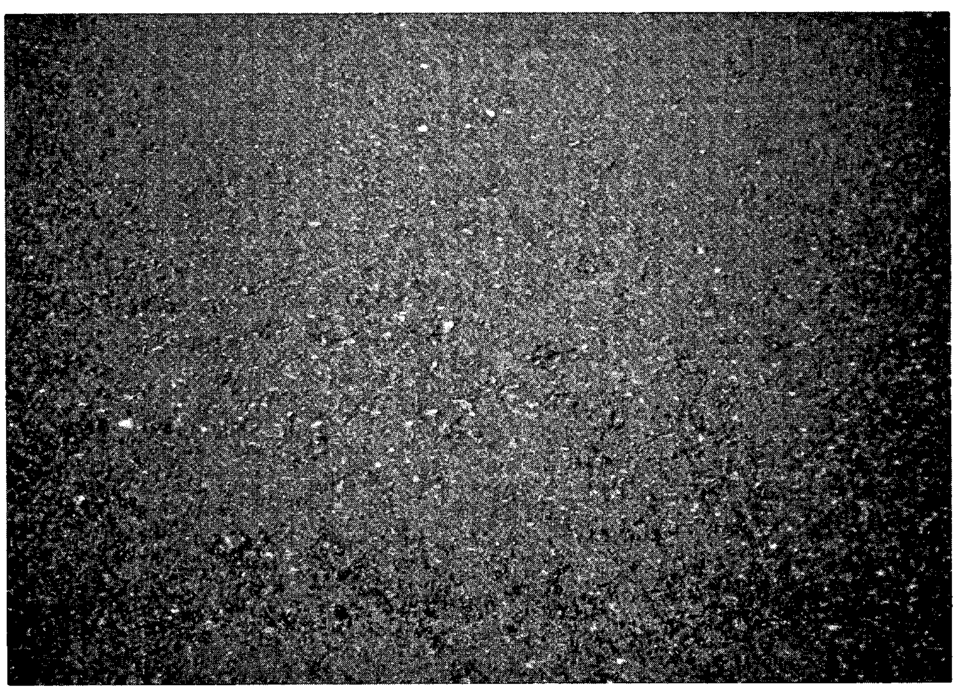
Picture 14. HIPR material showing yellow painted rock from the edge stripe that was not coated during the remixing process.

Picture 15. Close up of uncoated aggregate in HIPR material.

Picture 16. Non coated aggregate that was easily pulled from the recycled material.



Picture 17. Existing roadway prior to HIPR. Pavement distress in this area is mainly due to the effects of aging.



Picture 18. Recycled material after compaction (note uneven texture of finished material).

APPENDIX B - MATERIAL SPECIFICATIONS

SPECIAL PROVISION

Description

This work shall consist of softening the existing asphalt pavement with heat, milling/scarifying the top 0.15 ft and thoroughly remixing, leveling and compacting the milled/scarified material. The work items shall include the addition and mixing of recycling agents and the addition and mixing of precoated mineral aggregate. The work shall be accomplished by a single pass of an equipment train which is capable of cleaning, heating, milling/scarifying, mixing, re-leveling, and compacting.

Materials

Recycling Agent

The recycling agent used shall be RA-5 and applied at a rate of 0.14 gallons per square yard.

Aggregate

Mineral aggregate used shall meet the following gradation, be heated and precoated with 1% AR 4000W asphalt and added at a rate of 40 pounds per square yard. Gradation shall be per Standard Specification Section 9-03.4(2) Crushed Screenings 5/8" - 1/4".

Existing Asphalt Concrete Pavement

The existing asphalt concrete pavement has been sampled and tested for gradation, the results will be available to the Project Engineer's office.

Mixture Design

If the Contractor proposes an alternate mix design, a minimum of 15 working days shall be allowed after the job mix design proposed, aggregate samples, and asphalt have been received in the Headquarters Materials Laboratory in Tumwater. Only one change in the mix design will be considered.

Mix design and samples shall be as follows:

1. Type and amount of recycling agent to be used, with adequate sample of material to perform testing.

2. Type and gradation of mineral aggregate to be used with adequate sample of material to perform testing.

3. Sample of asphalt to be used for mineral aggregate precoating.

4. Sample of RAP material removed from the traveled roadway and adequate in amount to perform testing.

Equipment

General

The Contractor should indicate at the pre-construction conference the type of equipment intended for use. The equipment shall be on the project in general operating condition in sufficient time for evaluation by the Engineer.

Heating Unit(s)

One or more heating units, consisting of clusters of radiant heaters, shall be used. These units shall impart thermal energy to the asphalt pavement without charring the asphalt binder and without producing

- unacceptable health risks to the Contractor's workforce and citizenry,
- unacceptable air quality,
- direct flames on the pavement surface and,
- breaking of aggregate particles.

The heating unit shall be so equipped that heat application shall be under an enclosed or shielded hood. Each heating unit shall contain safety equipment to minimize workforce injury.

Milling/Scarification Unit(s)

One or more pavement removal units capable of removing the pavement to the desired depth shall be used. These units shall contain a rotating drum with cutting teeth and/or an acceptable scarifier which uniformly loosens the heated asphalt pavement to the depth specified. Automatic grade and cross slope controls are required on the final pavement removal unit in the equipment train. The equipment shall be capable of height adjustments in order to clear utility hardware and other obstructions in the pavement surface.

Distribution and Blending Unit(s)

Units capable of uniformly distributing recycling agents and mixing hot mix asphalt shall be integral components of the equipment. This mixing equipment shall be capable of uniformly mixing recycling agent, precoated mineral aggregate, and ACP RAP. This equipment shall be capable of providing the following:

1. Positive feed and shut-off of the recycling agent linked to the movement of the machine.

2. Control of the quantity of the recycling agent to ± 0.05 gallons per square yard of surface treated with a recycling agent application range of 0.1 to 0.2 percent recycling agent by weight of recycled mixture.

3. Proportional interlinking of the recycling agent application rate to the machine's processing rate.

4. Heating the recycling agent to within ± 25 °F of the temperature of the recycled material.

5. Measurement of the amount of recycling agent by means of a device capable of recording accumulated gallons to an accuracy of ± 2 percent.

6. Uniform mixing of recycled pavement and mineral aggregate pugmill, continuous mixing chamber such that the specified proportion of mineral aggregate can be accommodated.

Spreading and Leveling Unit

A unit capable of spreading and leveling the blended and mixed recycled material uniformly over the width being processed and to the finished grade and cross slope as specified on the Plans shall be provided. This unit shall have characteristics equivalent to those associated with conventional hot mix asphalt laydown machines and shall contain automated grade and cross slope controls.

Compaction

Compaction equipment shall be supplied in accordance with Standard Specification 5-04.3(4).

Construction

General

The hot in-place recycling shall be performed with self-propelled equipment that is capable of:

- softening the existing asphalt concrete surface by applying heat,
- milling/scarifying the surface to the depth shown in the Plans,
- blending and mixing recycling agent and precoated mineral aggregate,
- spreading and leveling the heated material and,
- compacting the resulting mixture.

This operation shall be accomplished with a single pass of the equipment train.

Cleaning of Existing Surface

The existing paved surface to be recycled shall be cleaned of all dirt, fabric, thermoplastic markers, rubberized materials, oils and other objectionable materials by blading, brooming, flushing with water or other approved methods prior to beginning hot in-place recycling.

Heating and Milling/Scarifying

The pavement surface shall be evenly heated, milled/scarified and reworked to the widths and depths shown on the Plans. There shall be no burning or scorching of trees, shrubs or other items near the recycled pavement. It shall be the responsibility of the Contractor to protect the adjacent landscape from damage by shielding and/or water spray or other methods approved by the Engineer. The heated and milled/scarified materials shall have a temperature in the range of 230 °F to 290 °F as measured immediately behind the laydown machine. The temperature shall be selected within this range to provide for adequate compaction. This selected temperature shall not vary by more than $\pm$ 20 °F from this target value and shall always be above the lower limit of 230 °F.

Blending, Mixing, Spreading, and Leveling

The recycled pavement materials, recycling agent, and mineral aggregate shall be fed into a mixing unit and thoroughly precoated. The resulting mixture shall be fed into a spreading and leveling unit.

Joints

The heating unit shall supply heat a minimum of 4 inches beyond the width of the area to be recycled. When a pass is adjacent to a previously placed mat, the heating shall extend 6 inches into the adjacent mat and the joint shall be located a minimum of 4 inches into the previously placed mat.

Compaction

The compaction operation shall meet the requirements of Standard Specification Section 5-04.3(10)

Regulation

The Contractor shall be required to meet all local, county, regional, state, and federal air quality standards and all workforce health and safety standards.

Test Strip

At the beginning of the hot in-place recycling operation, the Contractor shall construct a test strip on the project a minimum of 0.1 miles but no more than 0.2 miles in length using the equipment and methods to be used for the remainder of the project. No further work shall be performed until the test strip is evaluated and the process approved by the Engineer.

Acceptance

Temperature

The temperature behind the laydown machine shall be selected to achieve the specified density/air voids and shall be between 230 °F and 290 °F. This selected temperature shall not vary by more than ± 20 °F from this target value and shall always be above the lower limit of 230 °F.

Depth

The depth of recycled ACP shall be controlled by an average of 4 depth measurements per compaction lot and shall be equal to or greater than the specified value with no single value less than 0.05 ft below the specified value of 0.18 ft.

Compaction of the recycled asphalt pavement shall be per Standard Specification Section 5-04.3(10).

Smoothness

The smoothness shall meet the tolerances as specified in Standard Specification Section 5-04.3(3).

Measurement

Hot In-Place Recycling

Hot in-place recycling shall be measured by the square yard of surface area of completed and accepted work to a width of 24 ft and a depth as specified.

Recycling Agent

Recycling agents shall be measured by the ton.

Aggregate

Precoated mineral aggregate shall be measured by the ton.

Payment

Hot In-Place Recycling

Recycling shall be paid by the unit price (square yard) bid for hot in-place recycling. This price shall be full compensation for cleaning existing pavement, all heating, milling/scarifying, mixing, relaying, compaction, labor, tools, and incidentals necessary to complete the work.

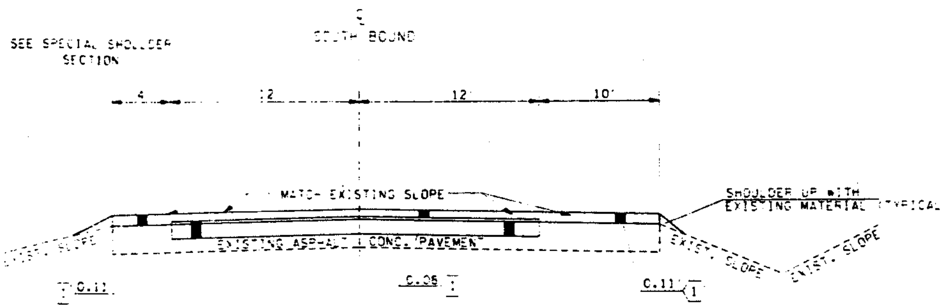
Recycling Agent

Recycling agent shall be paid for at the unit price (ton) bid for recycling agents of the type and grade specified. This price shall be full compensation for furnishing, hauling, dispersing, labor, tools, equipment, and incidentals necessary to complete the work.

Aggregate

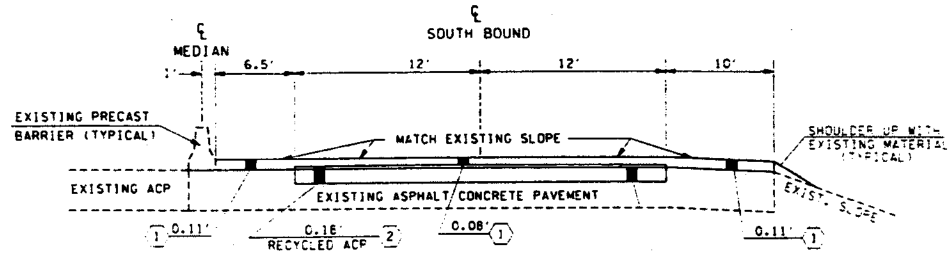
Precoated mineral aggregate shall be paid for at the unit price (ton) bid for precoated mineral aggregate. This price shall be full compensation for producing, heating, precoating, precoating asphalt, blending, mixing, hauling, placement, labor, tools, equipment, and incidentals necessary to complete the work.

APPENDIX C - ROADWAY SECTIONS



ROADWAY SECTION A

LE 255+53.50 TO LE 283+23.78
LE 284+77.00 TO L 283+65.60



ROADWAY SECTION B

L 283+65.60 TO L 424+85.00
L 425+56.64 TO L 466+60.96
L 467+30.76 TO L 542+09.00

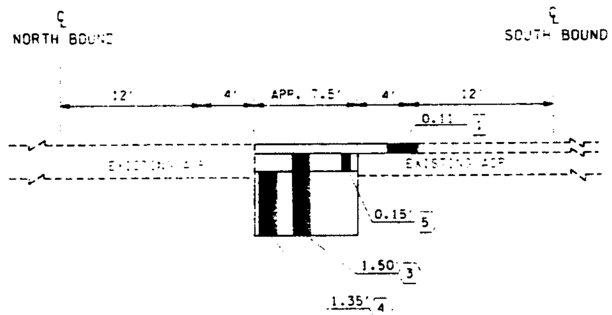
LEGEND

1. ASPHALT CONC. PAVEMENT CL. D
2. HOT IN-PLACE RECYCLING (SEE SPECIAL PROVISION)
3. STRUCTURE EXCAVATION CLASS B INCL. HAUL
4. CRUSHED SURFACING BASE COURSE
5. ASPHALT CONC. PAVEMENT CL. B

NOTE: SEE INTERSECTION PAVING PLANS FOR DETAILS NOT SHOWN
ALL DEPTHS SHOWN ARE COMPACTED DEPTHS

EQUATIONS

LE 284+96.60 (BK.) = L 283+04.20 (AHD.) 19.5' LT.
L 297+50.10 (BK.) = L 297+57.40 (AHD.)



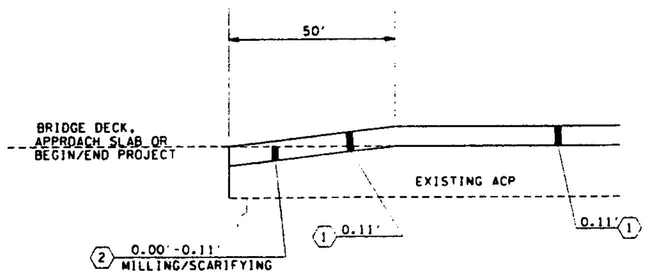
SPECIAL SHOULDER SECTION

LE 284+40.00 TO L 283+38.00

NOTE: STRUCTURE EXCAVATION CLASS B INCL. HAUL=38 C.Y.
FOR ADDITIONAL QUANTITIES SEE SHEET A1

BRIDGES INCLUDED IN PROJECT

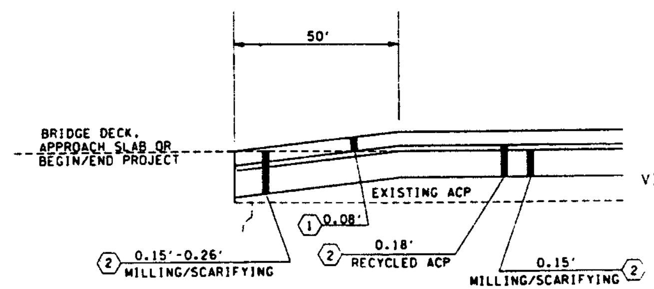
BR.#97/138E	GUARDRAIL WORK ONLY
BR.#97/138W	GUARDRAIL WORK ONLY
BR.#97/132W	GUARDRAIL WORK ONLY
BR.#97/132E	GUARDRAIL WORK ONLY
BR.#97/130W	GUARDRAIL WORK ONLY



SHOULDER INSET DETAIL

(SEE SPECIAL PROVISION)

LE 255+53.50 TO LE 256+03.50
LE 282+73.78 TO LE 283+23.78
LE 284+77.00 TO L 283+34.60
L 424+35.00 TO L 424+85.00
L 425+56.64 TO L 426+06.64
L 466+10.96 TO L 466+60.96
L 467+30.76 TO L 467+80.76



TRAVEL LANE INSET DETAIL

LE 255+53.50 TO LE 256+03.50
LE 282+73.78 TO LE 283+23.78
LE 284+77.00 TO L 283+34.60
L 424+35.00 TO L 424+85.00
L 425+56.64 TO L 426+06.64
L 466+10.96 TO L 466+60.96
L 467+30.76 TO L 467+80.76

DESIGNED BY	RANDY MELOY	
ENTERED BY	JEWELL MOREHEAD	OCT 91
CHECKED BY	JIM BORLEY	
PROJ. ENGR.	K.C. LOCKWOOD	
DIST. ADM.	R.L. LARSON	
		DATE

DATE | REVISION | BY

REGION NO.	STATE	FED. AID PROJ. NO.
10	WASH	

JOB NUMBER 95E015
CONTRACT NO.

PROGRAM DEVELOPMENT DIVISION

Washington State Department of Transportation

/plans2/mck/e95015a.dgn

SR 97
WEST WAPATO ROAD TO LATERAL A ROAD - SB

ROADWAY SECTIONS

R1

SHEET 4 OF 54 SHEETS

APPENDIX D - TEST REPORTS

In order to determine the properties of the existing asphalt pavement on this project, a sampling of the existing wearing course was removed from the project and sent to the FOSSC Materials Laboratory for analysis. The testing of this material included extraction's (gradation, asphalt content and recovered viscosity), stability, percent air voids, rice density, and Lottman stripping. As shown in Table D-1, the percent of recycled asphalt pavement (RAP) and the percent of virgin aggregate was varied and the resulting densities, percent voids and stability's were determined.

Table D-1. Laboratory Analysis for Mix Design.

	Std.	Mixture Samples						
	Spec.	1	2	3	4	5	6	7
% Rap	NA	100	100	95	90	85	80	75
% Aggregate	NA	0	0	5	10	15	20	25
%RA-5*	NA	0	12.5	12.5	12.5	12.5	12.5	12.5
Bulk Density	NA	153.6	155.3	154.7	155.2	154.4	153.6	153.2
Rice Density	NA	157.8	155.9	156.2	156.8	157.6	158.7	158.4
% Voids	2.0-4.5	2.7	0.4	0.9	1.0	2.0	3.2	3.3
Stability	>35	41	28	34	36	36	35	37

*By weight of mix

Based on the results of the above mix design process, it was determined that 20 percent (40 pounds per square yard for a depth of 0.15 ft) of 5/8" to 1/4" aggregate and 0.14 gallons of RA-5 per square yard would be added to the existing mix. This combination of materials would result in a mixture with a stability of 35, voids of 3.2 percent, and a viscosity of 4000 poise. The virgin aggregate gradation was selected in order to "open up" the gradation of the recycled material. At the time of construction, the contractor elected to precoat the aggregate using 1 percent of AR4000W.

Table D-2. Mix Design Gradations.

Sieve Size	Class B Spec.	Samples 1	2	3	4	Average	Added Aggregate	Combined
5/8"	-	100	100	100	100	100	100	100
1/2"	90-100	99	100	98	97	99	86	96
3/8"	75-90	91	88	88	91	90	49	82
1/4"	55-75	79	72	74	79	76	0	61
#10	30-42	45	38	41	41	41	0	32
#40	11-24	20	18	18	18	19	0	15
#200	3.0-7.0	8.2	8.0	7.8	7.9	8.0	0	6.4
% AC	-	5.0	3.8	4.4	4.7	4.5	-	-

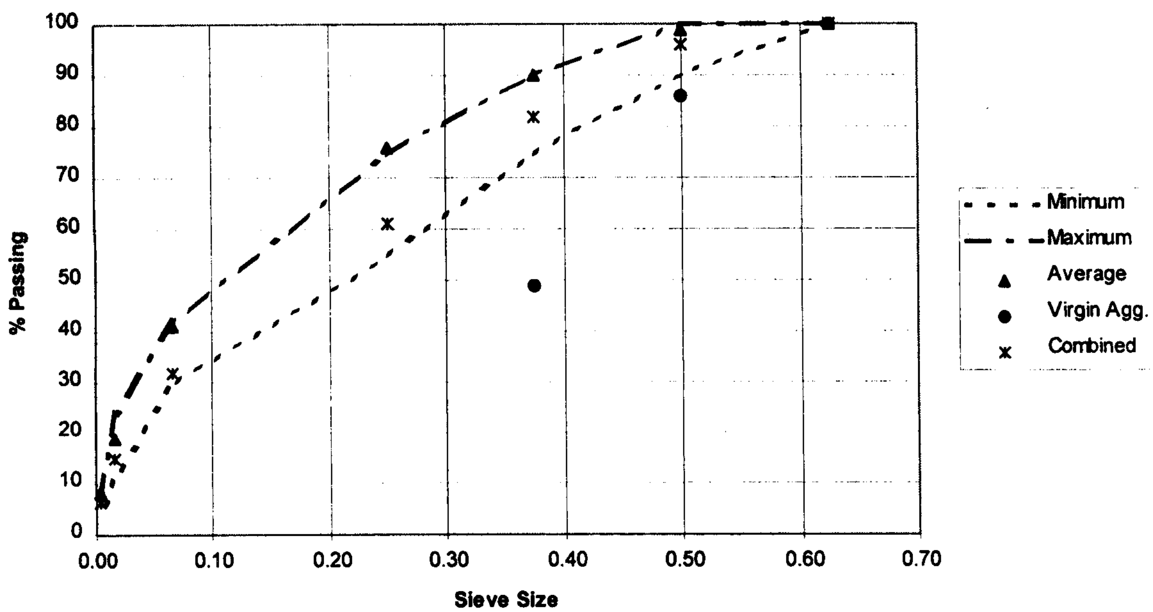


Figure D-1. Mix Design Gradations

During project construction, samples were taken and sent to the FOSSC Materials Lab for Hveem testing, which includes: gradation, percent asphalt, percent voids, rice density, stability and viscosity. The following tables and figures illustrate the results of these tests.

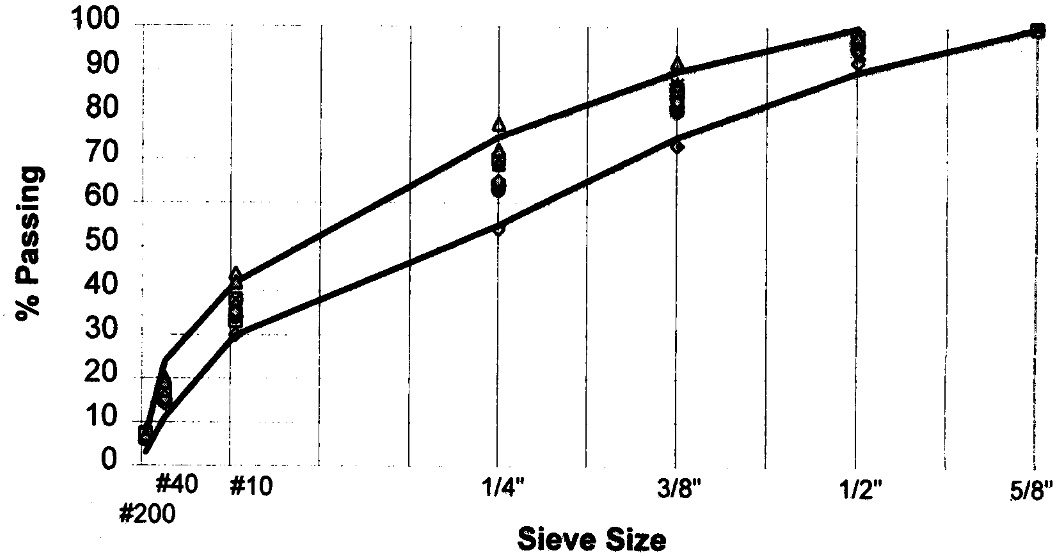


Figure D-2. Field Sample Gradations.

Table D-3. Field Mix Results

	WSDOT Class B	7/13	7/13	7/17	7/18	7/19	7/19	7/20	7/21	7/24	7/25	7/27
5/8"	-	100	100	100	100	100	100	100	100	100	100	100
1/2"	90-100	96	98	92	95	98	93	96	95	97	98	96
3/8"	75-90	85	85	73	81	92	73	82	83	86	87	87
1/4"	55-75	69	64	54	63	78	55	64	65	70	72	70
# 10	30-42	37	33	30	34	44	30	34	35	38	42	38
#40	11-24	16	15	14	15	20	14	15	15	17	19	17
#200	3.0-7.0	6.7	6.3	5.9	6.0	8.0	5.9	6.0	6.2	7.2	7.0	7.5
% Asphalt.		5.8	5.5	5.3	5.3	6.1	5.0	5.2	5.4	5.7	5.9	5.6
% Voids	2.0 - 4.5	1.9	2.2	2.3	2.6	0.9	3.1	2.8	2.4	1.4	1.7	1.7
Rice Density		157.7	157.8	158.0	158.1	156.8	158.4	158.0	157.9	157.8	156.8	158.0
Stability	> 35	37	38	36	38	25	35	41	35	35	27	39
Viscosity		5303	3216	3033	9354	6817	4579	11539	4730	8096	6528	9703

As shown in Table D-3 and Figure D-2, the field samples, in general, are within the required gradation specifications for ACP Class B. Only a handful of samples have a sieve or two that is out of specification.

The actual gradation of the virgin aggregate used in the field is shown below:

Sieve Size	Gradation
3/4"	100
5/8"	100
1/2"	79
3/8"	27
1/4"	1.7
#10	0.5
#40	0.3
#200	0.2

As shown in Table D-3 and Figure D-3, of the 11 field samples taken, two do not meet the ACP Class B specification for stability, while five field samples do not meet the requirements for air voids (all samples are less than two percent). Due to low stability and low air voids these pavements may have the tendency to rut.

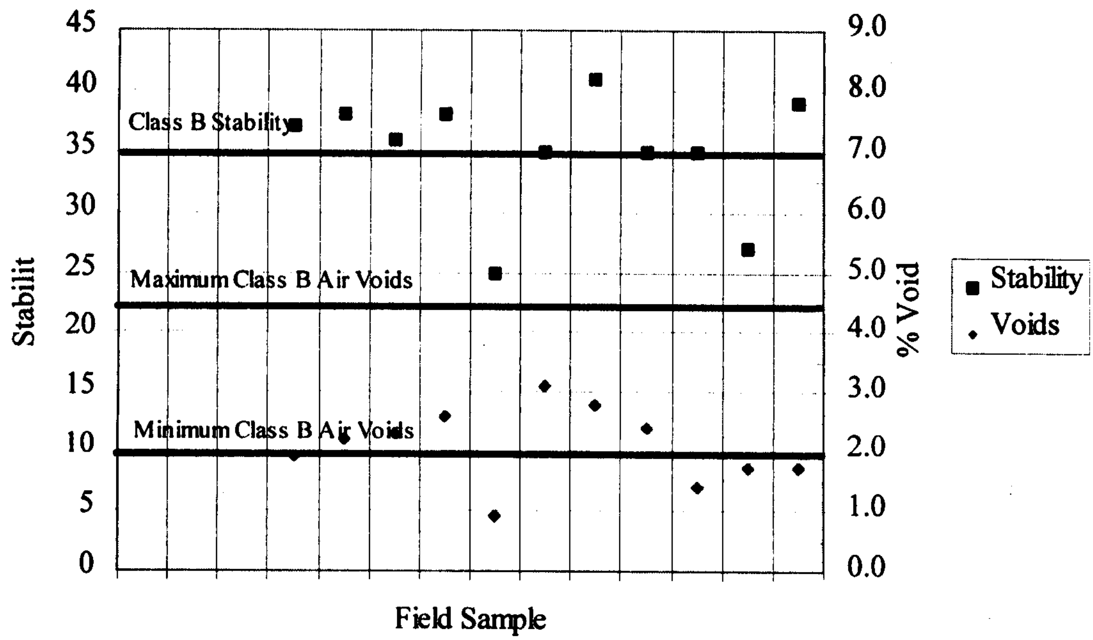


Figure D-3. Field Sample Stability and Voids.

In addition to the above testing, the HIPR material was also evaluated using the gyratory compactor. The gyratory compactor is used to simulate roadway compaction of the laboratory asphalt mixture. The gyratory compacted sample can then be processed through a series of tests to determine or estimate asphalt mixture performance (rutting, fatigue cracking and thermal cracking). At this time only the results of the gyratory compactor, shown in Table D-4, are available. As the FOSSC Materials Laboratory obtains the additional SHRP equipment (namely the Superpave Tester which is essential for predicting rutting and fatigue cracking) additional tests and mix performance will be evaluated.

Table D-4. Gyratory Compactor Field Test Results.

Date Sampled	%Gmm @N_{intial}	%Gmm @$N_{maximum}$	% Voids	%VMA	Rice Density
7/13*	88.9	**99.4**	**1.9**	8.5	157.7
7/13*	88.1	**99.2**	**2.2**	8.6	157.8
7/17	88.6	**99.3**	**2.1**	8.6	157.6
7/17	88.6	**99.3**	**2.0**	8.3	158.1
7/17	**89.2**	**99.9**	**1.3**	8.3	157.2
7/17*	87.9	**99.1**	**2.3**	8.6	157.0
7/18	88.8	**99.5**	**2.2**	8.7	157.2
7/18	88.8	**99.3**	**1.9**	8.5	157.9
7/18*	88.2	**98.8**	**2.6**	8.8	158.1
7/18	**89.9**	**99.8**	**0.9**	8.3	157.4
7/19*	**90.5**	**99.7**	**0.9**	8.8	156.8
7/19*	87.3	**98.3**	3.1	9.1	158.4
7/19	87.9	**98.7**	**2.7**	9.3	157.4
7/19	88.4	**98.9**	**2.3**	8.8	157.9
7/19	87.5	**98.3**	3.1	9.5	157.8
7/20*	88.9	**99.6**	**1.6**	8.4	157.5
7/20	88.7	**99.5**	**1.8**	8.6	157.3
7/20	88.5	**99.1**	**2.0**	8.5	158.0
7/20	87.8	**98.5**	**2.8**	9.1	158.0
7/20	88.6	**99.2**	**2.0**	8.5	157.9
7/21*	88.3	**98.9**	**2.4**	8.8	157.9
7/21	88.7	**99.3**	**1.9**	8.5	157.8
7/24*	89.0	**98.9**	**2.1**	8.7	158.1
7/25*	**90.4**	**99.5**	**1.1**	8.7	157.1
7/27*	88.9	**99.0**	**2.1**	8.4	158.5

* Samples also tested for Hveem at the FOSSC Materials Lab
Bold numbers indicate values that are not within tolerance

%Gmm@N_{intial} = percent gravity mix maximum at $N_{initial}$ (maximum rice density at $N_{initial}$). This value represents the mix compaction during construction. Mixes that compact to quickly in the gyratory compactor may have tenderness problems during construction. This value should be less than 89 percent.

%Gmm@$N_{maximum}$= percent gravity mix maximum at $N_{maximum}$ (maximum rice density at $N_{maximum}$). Mixes that commonly rut have been compacted below 2 percent voids under traffic. Mixes that compact below 2 percent voids in the gyratory compactor may have rutting problems. This value should be less than 98 percent.

$N_{initial}$ = Initial number of gyrations. For this project, $N_{initial} = 8$.

$$\text{Log } N_{initial} = 0.45 \text{ Log } N_{design}$$

$N_{maximum}$ = Maximum number of gyrations. For this project, $N_{maximum} = 152$.

$$\text{Log } N_{maximum} = 1.10 \text{ Log } N_{design}$$

N_{design} = Number of gyrations for design compactive effort. Compactive effort (# of gyrations) is a function of climate and traffic level. For this project, $N_{design} = 96$.

% Voids = percent voids. This value represents the percent voids in the mixture after construction and traffic compaction. The design value for percent voids is 4 percent. A range of 3.0 to 5.0 is used during construction.

% VMA = percent voids in mineral aggregate. Voids in mineral aggregate is defined as the sum of the volume of air voids and effective (unabsorbed) binder in a compacted sample. Represents the void space between the aggregate particles. The allowable %VMA is based on the nominal maximum aggregate size. For this project, the minimum %VMA would be 14.0 percent.

Nominal Maximum Aggregate Size	Minimum %VMA
9.5 mm	15.0
12.5 mm	14.0
19.0 mm	13.0
25.0 mm	12.0
37.5 mm	11.0

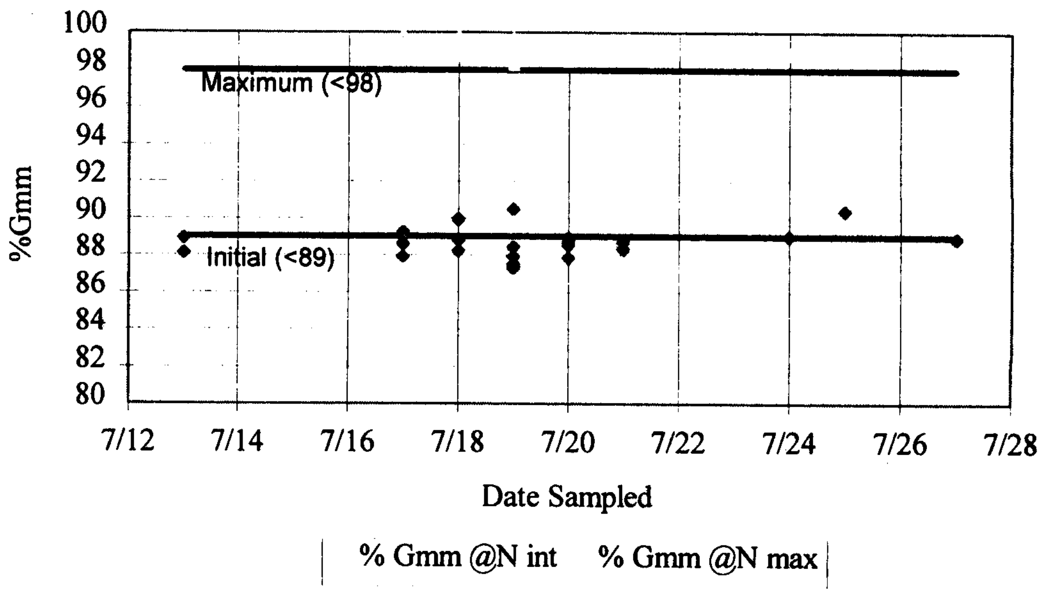


Figure D-4. Gyratory Test Data - % Gmm.

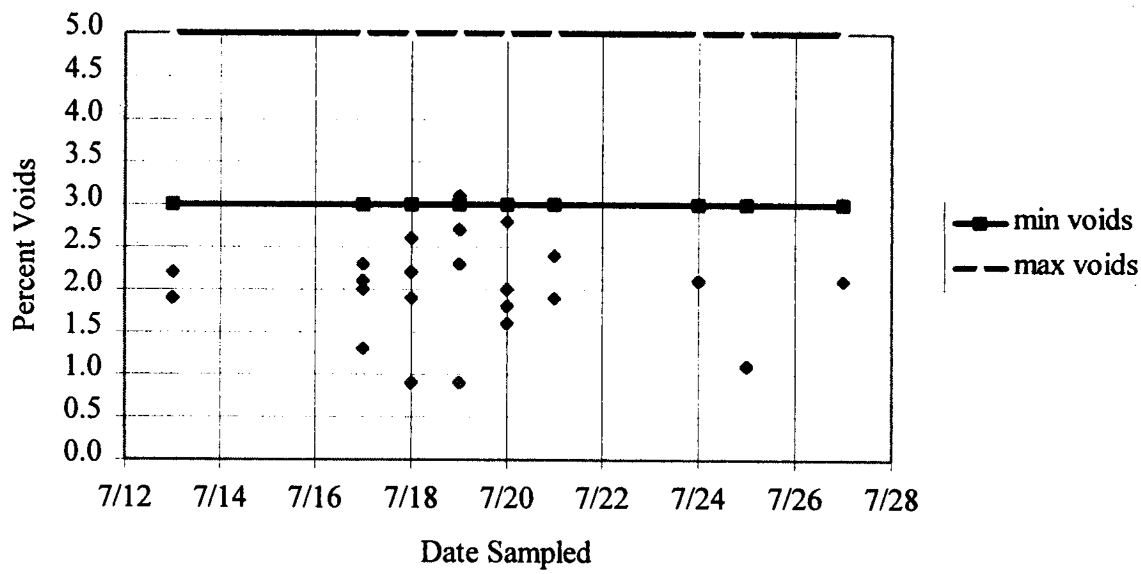


Figure D-5. Gyratory Test Data - % Voids.

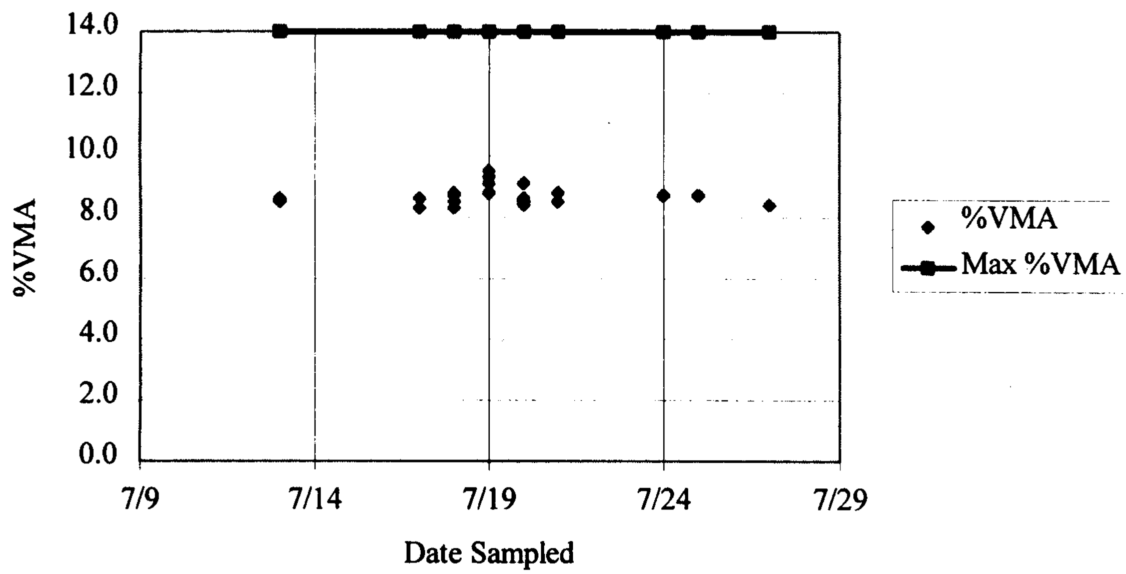


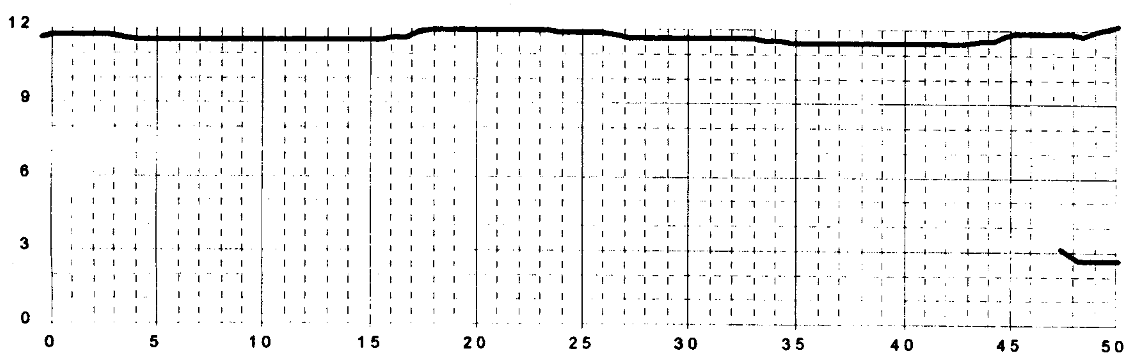
Figure D-6. Gyratory Test Data - %VMA

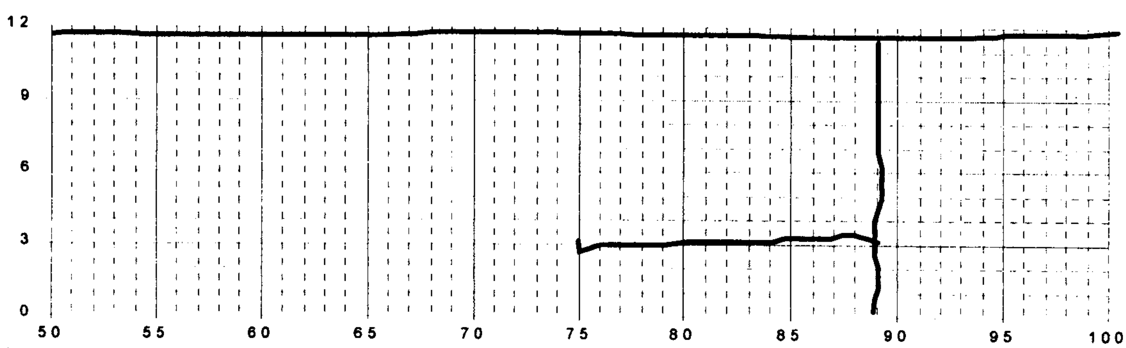
The data contained in Table D-4 and Figures D-4 to D-6 indicates that the majority of the HIPR mixes were below the required value for %Gmm @$N_{initial}$ and all the mixtures were greater than the required value for %Gmm @$N_{maximum}$. The results of the gyratory compactor would imply that there may be a rutting problem with this asphalt mixture.

APPENDIX E - PAVEMENT DISTRESS SURVEY

In the spring of 1995 a detailed crack survey was conducted to document the severity and extent of any pavement distress. The result of this crack survey is shown on the following pages. In general, the pavement is in relatively good condition showing signs of aging, longitudinal and transverse cracking, a few areas of localized alligator cracking, wheel path rutting in the right lane, and shoving at the intersection at the West Wapato Road intersection.

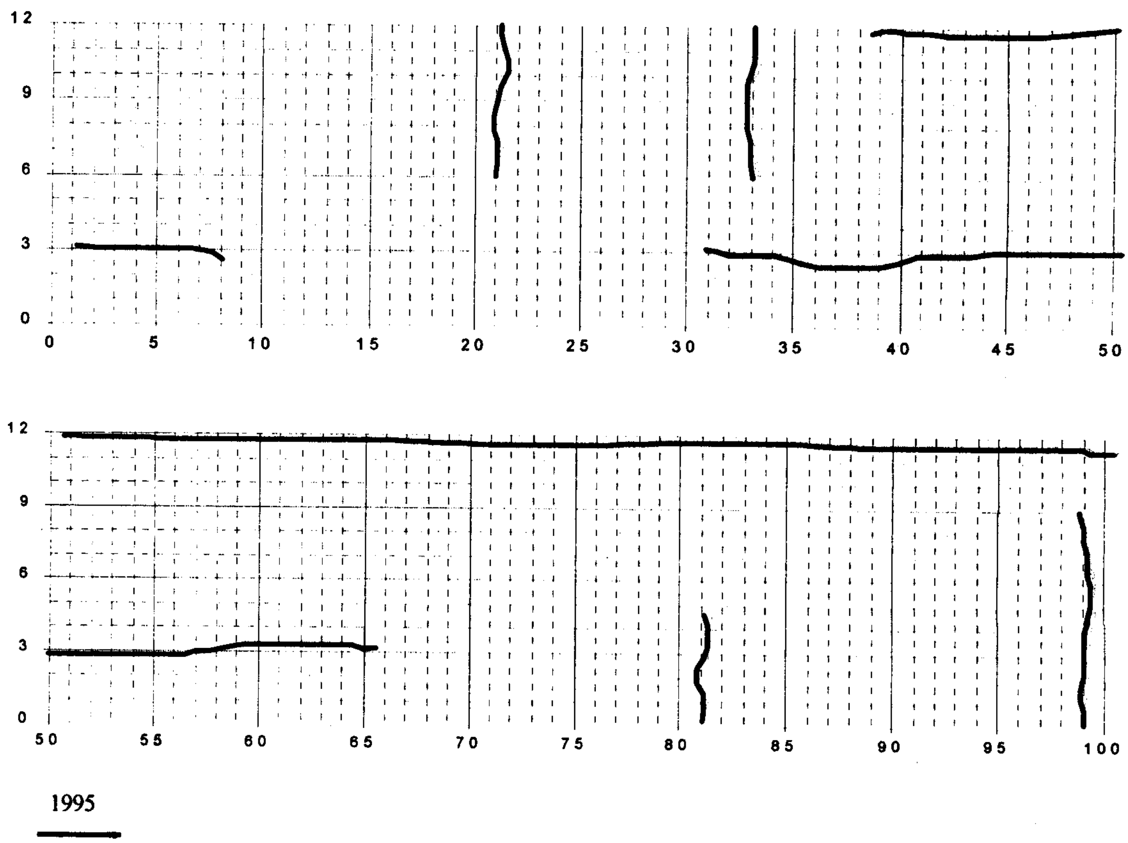
MP 74.08



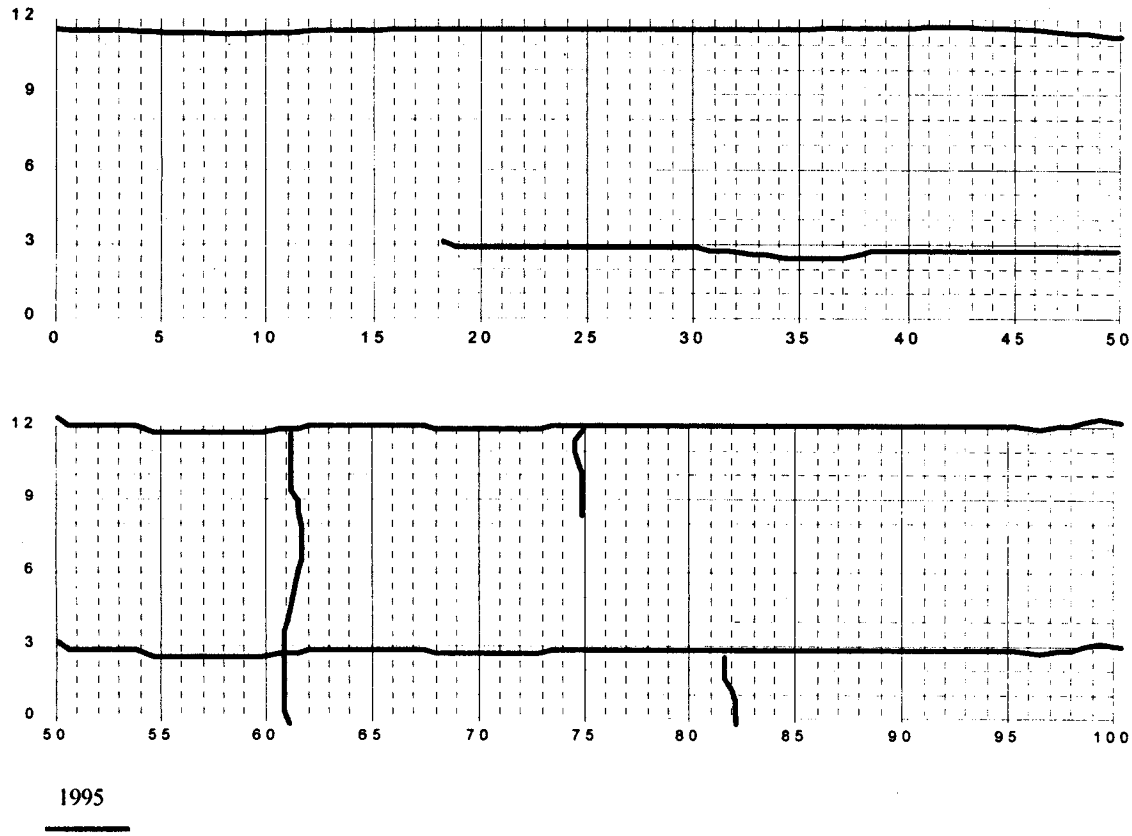


1995

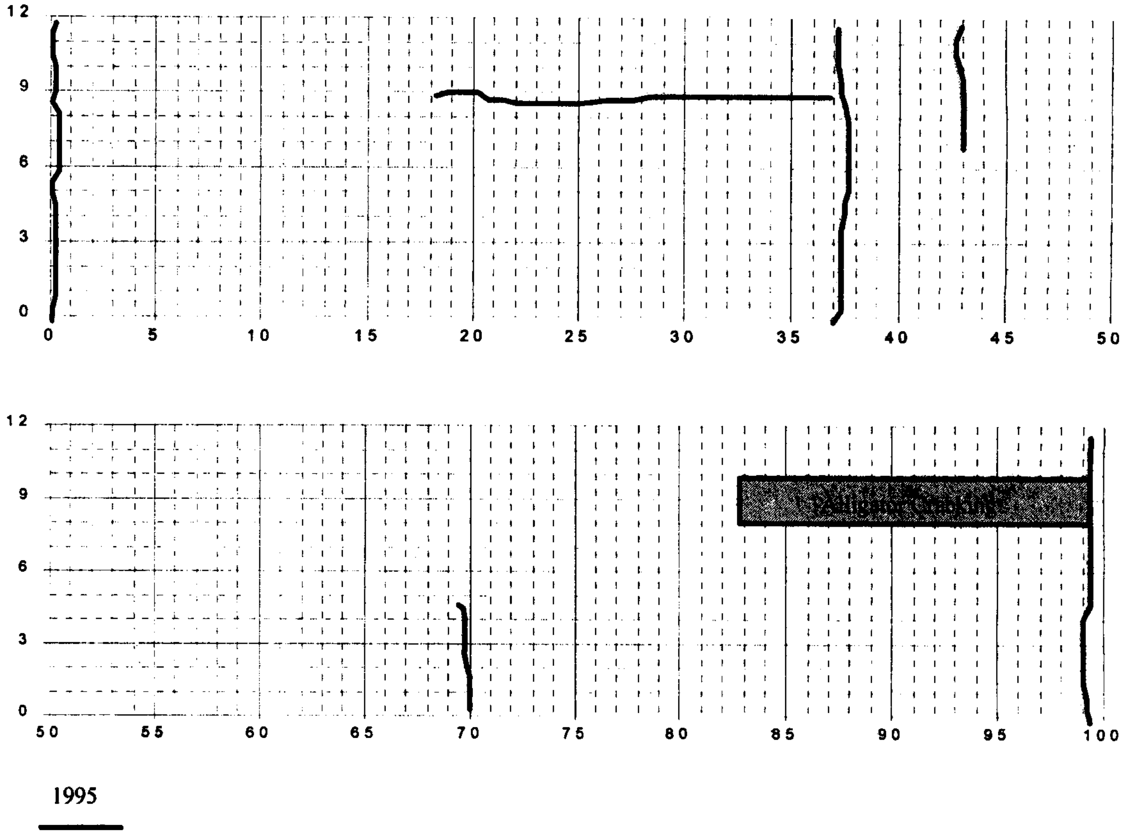
MP 73.08


12
9
6
3
0
0
5
10
15
20
25
30
35
40
45
50
12
9
6
3
0
50
55
60
65
70
75
80
85
90
95
100
1995

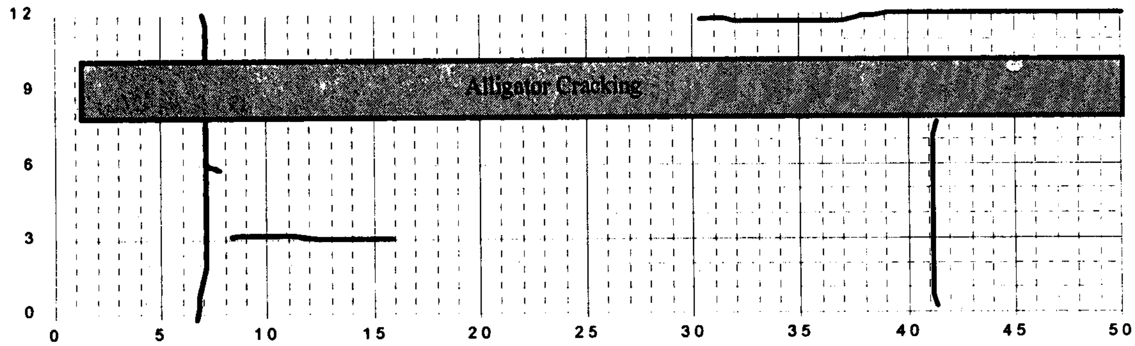
MP 72.08

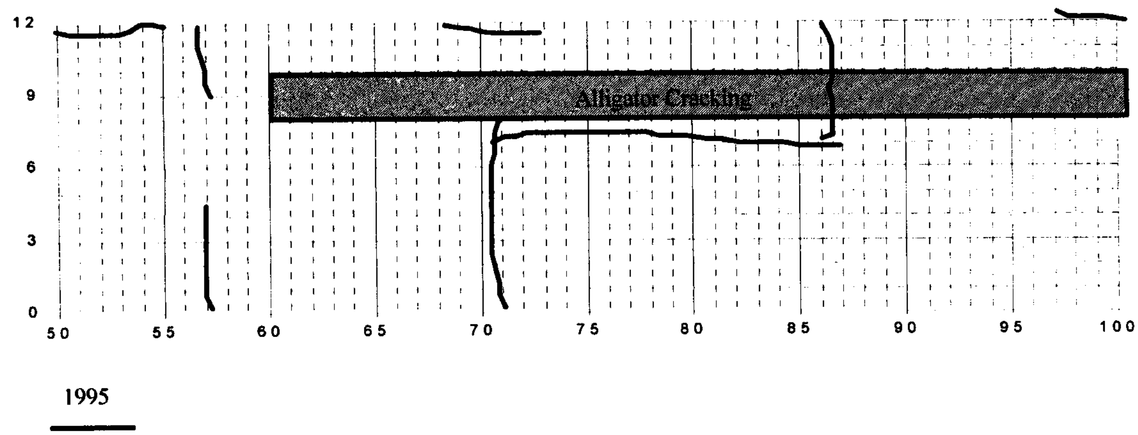

12
9
6
3
0
0
5
10
15
20
25
30
35
40
45
50
12
9
6
3
0
50
55
60
65
70
75
80
85
90
95
100
1995

MP 71.08

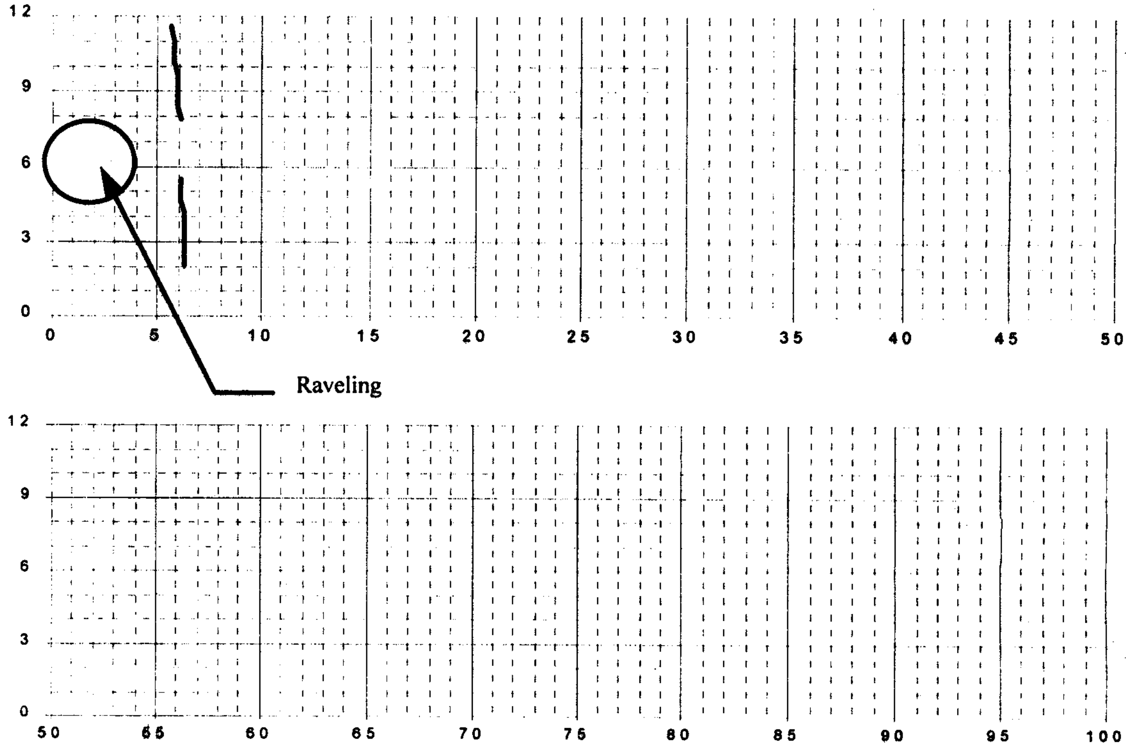

12
9
6
3
0
0
5
10
15
20
25
30
35
40
45
50
12
9
6
3
0
50
55
60
65
70
75
80
85
90
95
100
Alligator Cracking
1995

MP 70.08


12
9
6
3
0
0
5
10
15
20
25
30
35
40
45
50
Alligator Cracking


12
9
6
3
0
50
55
60
65
70
75
80
85
90
95
100
Alligator Cracking
1995

MP 69.08


12
9
6
3
0
0
5
10
15
20
25
30
35
40
45
50
Raveling
12
9
6
3
0
50
55
60
65
70
75
80
85
90
95
100

1995