pavement surcharge, inspection and permit fees interfere with current federal and state regulation of Southwest Gas Corporation. Southwest Gas Corporation further covenants not to initiate suit against the City of Phoenix with respect to the City's right to assess a pavement surcharge fee, permit fee and inspection fees, nor the manner in which the City calculates the said pavement surcharge, inspection or permit fees assessed against Southwest Gas Corporation between, on the one hand, the Effective Date of this Agreement, and, on the other hand, the termination of the current franchise contract existing between the City of Phoenix and Southwest Gas Corporation or July 8, 1994, whichever occurs earlier, provided that, between, on the one hand, July 1, 1991, and, on the other hand, the termination of the current franchise contract existing between the City of Phoenix or July 8, 1994, whichever occurs earlier, the City has not changed and does not change the manner in which it calculates the franchise, sales tax, pavement surcharge fee, inspection fee or permit fee so as to result in an unreasonable increase in Southwest Gas Corporation's payments to the City of pavement surcharge, inspection or permit fees.

6.0 ATTORNEY FEES AND COSTS. Each party to this Agreement agrees to bear its own attorney fees and costs incurred in Maricopa County Cause No. CV 89-11051.

7.0 NO ADMISSIONS. The parties agree that the provisions of this Agreement shall not constitute and shall not be deemed to constitute an admission of liability on the part of

the City of Phoenix. The parties further agree that the provisions of this Agreement shall not constitute and shall not be deemed to constitute an admission by Southwest Gas Corporation of the propriety or lawfulness of the pavement surcharge, inspection and/or permit fees or of the amounts of those fees.

8.0 NO RES JUDICATA OR COLLATERAL ESTOPPEL EFFECT. The parties further covenant and agree that in any future litigation by or among them, neither party shall assert, either offensively or defensively, that any of the rulings and orders of the Arizona Superior Court in Cause CV 89-11051 is entitled to res judicata or collateral estoppel effect.

9.0 EFFECTIVE DATE. This Agreement shall become effective on the "Effective Date," which date shall be the first day when all of the following events shall have occurred:

9.1 The Phoenix City Council shall have duly approved this Agreement;

9.2 The Phoenix City Council shall have duly authorized an individual to execute this Agreement on behalf of the City of Phoenix;

9.3 The individual duly authorized by the City Council to execute this Agreement on behalf of the City shall have so executed this Agreement;

9.4 The representative of Southwest Gas Corporation authorized to execute this

Agreement on behalf of that company shall have so executed this Agreement;

9.5 The attorneys for the City of Phoenix and Southwest Gas Corporation shall have executed the Stipulation for Dismissal Without Prejudice and to Vacate All Prior Rulings attached hereto as Exhibit A;

9.6 The judge of the Arizona Superior Court shall have executed the Order attached hereto as Exhibit B; and,

9.7 The City of Phoenix shall have paid to Southwest Gas Corporation, by City warrant, the sum of One Hundred Fifty Thousand Dollars ($150,000.00) as provided in Section 1.0 hereof.

10.0 AUTHORITY. The execution, delivery and performance by the City of Phoenix of this Agreement and the consummation by the City of Phoenix of the transactions contemplated hereby have been duly authorized by all necessary corporate action on the part of the City of Phoenix. This Agreement has been duly and validly executed and delivered by the City of Phoenix and constitutes a legal, valid and binding obligation of the City of Phoenix, enforceable against it in accordance with its terms.

11.0 SEVERABILITY. Any term of this Agreement that is illegal or unenforceable at law or in equity shall be deemed to be void and of no force and effect to the extent necessary to

bring such term within the provisions of any such applicable law or laws, and such terms are so modified and the balance of the terms of the Agreement shall be fully enforceable.

12.0 ADDITIONAL DOCUMENTS. The parties agree to cooperate fully and to execute any and all supplementary documents and to take all additional actions which may be necessary or appropriate to give full force and effect to the basic terms and intent of this Agreement.

13.0 INTEGRATION. This Agreement contains the entire agreement between the parties hereto concerning the matters addressed herein. Neither this Agreement nor any term or provision hereof may be changed, waived, discharged or terminated in any manner other than by an instrument in writing signed by the party against which the enforcement of the change, waiver, discharge or termination is sought. The parties hereby waive their respective rights to modify or alter this Agreement in any other manner.

14.0 COUNTERPARTS. This Agreement may be executed in one or more counterparts, each of which shall be an original, but all of which together shall constitute one and the same instrument.

15.0 GOVERNING LAW. The parties stipulate and agree that this Agreement shall be governed by the laws of the State of Arizona.

16.0 SUCCESSORS. This Agreement shall be binding upon and inure to the benefit of and be enforceable by the parties hereto and the successors and assigns of the parties.

17.0 NOTICES. All notices and communications pertaining to this Agreement or the transactions contemplated hereby shall be made in writing and shall be deemed sufficiently given if delivered in person to those persons designated below, or their successors, or if mailed by first class mail, addressed as follows:

Mr. Thomas J. Trimble
Senior Vice President and General Counsel
Southwest Gas Corporation
5241 Spring Mountain Road
P. O. Box 98510
Las Vegas, NV 89193

Mr. Roderick G. McDougall
City Attorney
251 W. Washington, Room 800
Phoenix, AZ 85003

DATED this 2nd day of March, 1992.

SOUTHWEST GAS CORPORATION

By _____
James Lowman

APPROVED BY:

_____
Attorneys for Southwest Gas Corporation

CITY OF PHOENIX, a municipal corporation
Frank Fairbanks, City Manager

By _____
Deputy City Manager

APPROVED AS TO FORM:

ACTING City Attorney

ATTEST:

Vicky Miel

City Clerk

STATE OF ARIZONA)
)ss:
County of Maricopa)

The foregoing instrument was acknowledged before me this 2nd day of March, 1992, by James F. Lowman of Southwest Gas Corporation, a California corporation, on behalf of the corporation.

Notary Public

My commission expires:
10/29/92

STATE OF ARIZONA)
) ss:
County of Maricopa)

The foregoing instrument was acknowledged before me this 2nd day of April, 1992, by Patrick Manion, Deputy City Manager of the City of Phoenix, Arizona, who acknowledged that he signed the instrument by proper authority and that he executed the instrument in the capacity and for the purposes therein stated.

Dawnell M. Navarro
Notary Public

My commission expires:
My Commission Expires March 16, 1993

COSTING THE EFFECTS OF UTILITY CUTS IN THE LIFE CYCLE OF ASPHALT PAVEMENTS

by

M. Y. Shahin
Consulting Engineer, Ph.D., P.E.
Champaign, IL.

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September 23, 1986

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of the author and the American Public Works Association.

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ABSTRACT

This paper describes procedures for testing and analyzing pavements containing utility cut patching to determine the effects of the patching on pavement performance and structural adequacy. These procedures were developed based on a testing project conducted in the Northeastern United States. A paired experiment was conducted to determine the effect of utility cut patching on the Pavement Condition Index (PCI) for streets of various ages throughout the city. A nondestructive deflection testing (NDT) program was also conducted at positions in and around patched areas using a falling weight deflectometer (FWD) to measure the effects of patching on the structural adequacy of the pavement. Also included is a cost analysis based on the results of the PCI and NDT surveys showing the extra rehabilitation costs to the city due to utility cut patching.

Key Words: Utility Cut Patching, Pavement Condition Index, Nondestructive Deflection Testing, Rehabilitation Costs.

INTRODUCTION

This paper describes the testing and analysis results of utility patched pavements in a city in the Northeast United States. The objective of this study was to determine the average life of pavements with and without utility cut patches. This was achieved through consideration of both pavement performance and load carrying capacity. A representative sample of streets was randomly chosen from areas throughout the city. Representative pavement sections from each street were surveyed to assess the condition of the pavement with and without patches using both visual inspection and nondestructive deflection testing (NDT). The results were analyzed to 1) determine the effect of patching on pavement life and 2) to determine what level of rehabilitation is necessary to upgrade the patched areas to levels equivalent to non patched areas.

To the best knowledge of the authors, the material presented in this paper provides for the first time a quantitative assessment of pavement damage due to utility cut patching. It is hoped that the results presented herein will prove beneficial to communities around the United States and abroad. It should be emphasized that even though the procedure developed is not site specific, the results will vary based on conditions in each community including climate, construction history, maintenance activities and traffic.

PAVEMENT PERFORMANCE MEASUREMENTS

Pavement performance is related to several factors including ructural integrity, roughness and maintenance requirements. These ctors can be assessed through visual observation by measuring the amount distress present in the pavement. Data collected from various streets the city indicated that pavement life was shortened by a factor of over .6 as a result of utility cut patches.

I.

vement Condition Index Rating Procedure

The Pavement Condition Index (PCI) survey method was developed by the S. Army Corps of Engineers to provide a systematic method of measuring vement distresses and quantifying their effect on pavement performance. e PCI is a numerical indicator of the pavement condition which ranges 0 to 100 with 100 representing a pavement in excellent condition. The is computed based on the amount and severity level of distress present the pavement. For flexible pavements, nineteen (19) different distress pes have been identified. Curves have been developed to compute the lative amount that each distress affects the quality of the pavement in rms of structural integrity and surface operational conditions. The fects of each distress type/severity combination are called deduct lues. All deduct values computed are summed and adjusted based on tablished rules to determine the final PCI rating of the pavement. The I procedure is summarized in Figure 1. The U.S. Army Corps of Engineers nstruction Engineering Research Laboratory Technical Report M-294 ef.1) details all procedures followed along with all charts necessary to mplete the PCI survey.

Selection of Streets for PCI Survey

The PCI survey was designed to provide a paired experiment of PCI values for patched vs. non-patched pavements. The survey was initiated in the Fall of 1984 (mid November) and completed in the Spring of 1985 (late May). This timing was considered conservative in that seasonal effects on the pavement, i.e. differential frost heave, would not affect the results.

The streets included in this survey were randomly selected from throughout the city to provide a representative cross section in terms of age and functional classification, i.e. residential, collector and arterial. Each selected street was first divided into sample units approximately 100 feet long. Representative sample units were then randomly selected from areas with and without patches present. This provides results that would be favorable to patching as compared to selecting a 100 foot section around patches. For example, in the event that a sample unit boundary fell within the borders of a patch, only the portion of the patch falling within the sample unit was surveyed. In cases where only one sample unit would not provide a true representation of the selected street section, a second sample unit with and without patching was surveyed. In these cases, the final PCI for the patched and non patched sections was obtained by averaging the results of the two sample units. Table 1 summarizes the final PCI values computed for all streets surveyed.

Results of the PCI Survey

The PCI survey results were analyzed to determine the effect of utility cut patching on pavement life. Pavement life is not defined as

the point when the street can no longer safely carry traffic, it is rather e age in years that the street can be economically maintained without the need for major rehabilitation such as an overlay. This was defined as the pavement age at which a PCI value of 70 would be reached. The PCI value of 70 is conservative in terms of minimizing rehabilitation costs. Allowing the pavement to deteriorate beyond this point will result in rapid increases in restoration costs. This concept is also supported by the graph presented in Figure 2, which was published by the American Public Works Association (Ref.2). As this figure shows, it is much more economical to maintain pavements in a relatively good condition and before the rate of deterioration (annual loss in PCI) shows a considerable increase.

Three methods were used to determine the average pavement life before PCI of 70 would be reached. These three methods are described and the results presented.

Method 1: Rate of Deterioration

The rate of deterioration is defined herein as the average loss in PCI per year since the last overlay/construction at which time a PCI of 100 is assumed. For example, a pavement that has a PCI of 80 and is 10 years old has a deterioration rate of (100 - 80) / 10 = 2.0 PCI points per year.

All of the pavement sections surveyed were categorized into five groups based on their non-patched PCI as follows: 100-90, 100-80, 100-70, 100-50, and 100-25. The average rates of deterioration for both patched and non-patched pavements were then determined as presented in Figures 3 thru 7. The results are summarized in the bar chart graph shown in Figure

8. This figure clearly illustrates the dramatic effect that patching has on the pavement's rate of deterioration. For a terminal PCI of 70, the average lives of patched and non-patched pavements were determined from Figure 5 to be 11.6 and 20.1 years respectively. This translates to a life reduction factor of 20.1/11.6 or 1.73.

Method 2: Best Line fit Through PCI vs. Age Data

This method fits a straight line through the PCI vs. Age data points so that the sum of errors are minimized (least-square error method). The results are shown in Figure 9. From this figure, the average lives at a PCI of 70 for the patched and non-patched pavements were determined to be 12.1 and 19.8 years respectively. This translates into a life reduction factor of 1.64.

Figure 9 also showed that the two lines for patched and non-patched pavements approach each other at low PCI values. Therefore, the data were further analyzed by comparing the average values of patched and non-patched pavements based on non-patched PCI ranges of 100-90, 89-80, 79-70, 69-50, and Under 40. The results are shown in the bar chart in Figure 10. Even though there were only four pavements where the non-patched PCI was less than 40, the figure clearly shows that patching may have no negative impacts on the PCI of pavements in this category. In other words, pavements with a PCI less than 40 are already in poor condition and patching could be beneficial (in terms of PCI) for the short run.

Based on this conclusion, the analysis shown in Figure 9 was repeated after eliminating the three pavements where the non-patched PCI values were less than 40. The results of this analysis are shown in Figure 11. The average lives for patched and non-patched pavements were determined from this figure to be 11.9 and 30.0 years respectively. This translates to a life reduction factor of 2.52.

Method 3: Best Curve fit through PCI vs. Age Data

This method is similar to Method 2 except that a third degree curve was used to fit the data rather than a straight line. The results are shown in Figure 12 for all pavements surveyed and in Figure 13 for only those pavements with non-patched PCI values greater than 40. These figures are used in a fashion similar to Figures 9 and 11 respectively. The life reduction factors due to utility cut patching were determined from Figures 12 and 13 as follows:

Figure 12:	Average Life of Patched Pavement	= 8.5 years
	Average Life of Non-Patched Pavement	= 25.9 years
	Life Reduction Factor = 25.9/8.5	= 3.05
Figure 13:	Average Life of Patched Pavement	= 7.8 years
	Average Life of Non-Patched Pavement	= 28.9 years
	Life Reduction Factor	= 3.71

Discussion of Results from PCI Analysis Methods

The three methods of analysis are quite different yet they show the same conclusion; patched pavements have a much shorter life than non-patched pavements. Table 2 presents a summary of the results obtained

from the three analysis methods. As can be seen from this table, the life duction factor varies from 1.64 to 3.71. For the purposes of follow up analysis in this paper, the results of analysis Method 2a will be used as they offer the most conservative assessment of the damage caused as a result of utility cut patching.

STRUCTURAL TESTING

Based on extensive deflection testing of the streets in the city, it was determined that areas in and around patches are considerably weaker than the original pavement. The patches are a major source of discontinuity and non-uniformity which detrimentally affects future pavement performance. Additional structural overlay thicknesses averaging 0.75 to 1.5 inches are required to compensate for the structural weakness in and around the patched areas. This, however, will not compensate for the discontinuity effects on future pavement performance after the overlay.

The structural strength of selected pavements in the city was examined using information gathered from a nondestructive deflection testing (NDT) program. The strength of pavement sections with and without patching was measured by recording the magnitude which the surface of the pavement deflected under a load impulse similar in magnitude and duration to a moving truck wheel load. The lower the surface deflection under a given load, the stronger the pavement and the greater the remaining number of allowable axle loads to "failure".

Uniformity of deflections is also important to insure a uniform foundation for any future pavement strengthening by overlays.

Testing Equipment

The structural testing was done using a Falling Weight Deflectometer (FWD) capable of applying an impulse load up to 25,000 pounds-force. The FWD, shown schematically in Figure 14, accurately simulates loads similar in magnitude and duration to that of a moving wheel load. The surface deflections are measured using seven velocity transducers, one of which is located in the center of the loading plate. The other sensors are spaced at 12 inch intervals. The data obtained from the sensors is stored on both paper and magnetic medium for further analysis. The entire operation of the FWD is controlled and monitored with an onboard Hewlett Packard 85B micro computer.

Structural Indicators

The maximum deflection of a pavement under a given load is an indicator of its load carrying capacity. Field studies have shown that the higher the surface deflection, the fewer the number of applications to structural failure. A second indicator of the pavements structural adequacy is the Dynamic Stiffness Modulus, DSM. The DSM was developed by the Corps of Engineers (ref.3) and is a measurement of the rigidity of the total pavement system. The DSM is computed using the maximum measured deflection (in mils) under various load levels (in pounds) using the formula:

$$DSM = \frac{\text{Load X} - \text{Load Y}}{\text{Deflection at Load X} - \text{Deflection at Load Y}}$$

Where: Load X is greater than Load Y

Selection of Streets for NDT

A representative sample of streets was chosen to reflect conditions present throughout the city. A total of 28 street sections were selected containing utility patches prior to the start of testing.

Testing Procedures

Each street was tested at numerous locations to determine the deflection response due to loads in patched and non-patched pavement areas.

Testing locations in non-patched pavement areas were chosen to produce standard base values for each street. Random test locations in this category were chosen at various distances from existing patch boundaries ranging from 3 to over 50 ft. Testing locations inside the boundaries of any existing patches were randomly chosen to provide measurements of patch deflections. Testing was also conducted adjacent to each patch boundary both inside and outside the patch. Each test consisted of three load levels; 7,000, 9,000 and 17,000 pounds-force.

Two measures of significance, namely the DSM and maximum deflection, were analyzed at each test location. DSM values ranging from 87 to 1250 were calculated. For comparative purposes, test locations were grouped into 4 separate categories relating the proximity of the test location to a patched area. Test locations away from patches are denoted as PVT. Test locations adjacent to patches (less than 3 feet away) are denoted as PVT-E. The effects of subsurface disturbance as a result of patching operations is of significance in these areas. Locations inside patch boundaries adjacent to the pavement are designated PAT-E. All other test

points inside patch boundaries are designated as PAT. These test locations are shown in Figure 15.

The bar chart shown in Figure 16 illustrates the range of DSM values calculated at the four locations. In non-patched pavement areas (PVT) the average DSM value calculated (AVE) was 509.2 with values ranging from 136 to 1250. Near patch boundaries (PVT-E), the average DSM value dropped to 381.5 with a range from 99 to 690. The average DSM value calculated at PAT-E locations was 360.7 with a range from 155 to 714. Central patch values (PAT) were found to average 400.5 with a range from 135 to 909. Figure 17 compares the average DSM from each street in and around patched areas (PAT, PAT-E and PVT-E) with the average value from non-patched (PVT) areas. Values below the line of equality indicate a structural weakness in the pavement in and around patched areas.

The second measure of structural adequacy obtained from FWD records is the maximum surface deflection, Do. The maximum deflection provides an indication of the strength of the pavement and the service life remaining. As pavement deflection increases, critical stresses and strains in the pavement increase resulting in accelerated fatigue damage. Overlays are commonly applied to the pavement to reduce deflections and thereby increase the pavements service life.

Measured Do data were grouped into four categories based on test locations similar to those presented in the DSM analysis. The values obtained are presented in the bar chart in Figure 18. In sound pavement areas (PVT) the average measured Do was 20.43 mils. Actual values varied from 9.4 to 50.5 mils. In PVT-E areas an average value of 29.07 mils was calculated with a range from 13 to 73.9 mils. In PAT-E areas, an average

value of 27.68 mils was calculated with a range from 13.6 to 54.3 mils. In central patch areas (PAT) the average value was 25.21 mils with a range from 12.6 to 54.8 mils. Figure 19 compares the average Do from each in and around patched areas (PAT, PAT-E and PVT-E) with the average value from non-patched (PVT) areas. Data points plotted above the line of equality represent streets on which overlay requirements would be greater.

Overlay Design Requirements

To compute overlay design requirements for the various portions of the streets tested during the NDT program, the Asphalt Institute's deflection based method was used.

For comparative purposes, overlay design requirements were calculated for pavements with and without patches. Pavements with patching are those locations PVT-E, PAT-E, and PAT. Pavements without patches are those at test locations PVT. Inputs to the design calculations include the average maximum measured deflection, Do, at 9,000 pounds-force loading, the standard deviation of the measured Do values, a seasonal adjustment factor, and a temperature adjustment factor. The seasonal adjustment is the ratio of deflection taken during the most critical time of year (typically springtime) to the time of year that the deflections were measured. A factor of 1.5 was determined to be appropriate for this analysis as deflections were taken during November. The temperature adjustment factor is used to standardize deflections to a pavement temperature of 70°F. A factor of 1.5 was also chosen as appropriate for this analysis.

The design deflection used for analysis is then computed using the equation:

$$\text{Design Deflection} = (X + S) * C * F$$

Where: X = mean pavement deflection, in inches.

S = standard deviation of deflection

C = seasonal adjustment factor

F = temperature adjustment factor

For the two pavement areas analyzed, these calculations result in the following:

	NON PATCHED AREAS	PATCHED AREAS
Average Do	.02043	.02654
Stand. Dev.	.00975	.01087
Seas. Adj.	1.50	1.50
Temp. Adj.	1.50	1.50
Design Def.	.06791	.08417

The required overlay thickness is then computed using the chart shown in Figure 20. By entering Figure 20 with the design deflection for non patched areas of .06791 inches, it can be seen that the pavement is capable of handling 2 ESAL/day without overlay. Using the design deflection for patched areas of .08417 inches, it can be seen that an overlay thickness of 1.5 inches would be required for this same traffic level. The required overlay thicknesses for each area at various traffic levels are shown in the table below.

TRAFFIC	OVERLAY REQUIREMENTS NON PATCHED AREAS	PATCHED AREAS
2 ESAL/day	0.0"	1.5"
10 ESAL/day	2.25"	3.0"
20 ESAL/day	3.0"	3.75"

EXTRA REHABILITATION COSTS DUE TO UTILITY CUT PATCHING

To compute the extra rehabilitation costs associated with utility cut patching, the results obtained from both the PCI and deflection analyses were utilized. The minimum accelerated deterioration rate in patched areas of 1.64, as determined from the PCI analysis, and the overlay thickness requirements for 10 ESAL/day, as determined from the overlay requirement analysis, were used to compute the overlay costs.

All of the costs associated with an overlay, both direct and indirect, are included. These costs include manhole and sewer alignments and curb replacement. This type of overlay will be used as an optimum least cost approach assuming no reconstruction will be necessary by keeping the PCI above 70. It will be assumed that the curb reveal is 6 inches and that the curbing will be replaced only after future overlay thicknesses exceed this value. Manhole and sewer alignment will be completed prior to each overlay. All of the cost figures presented herein are in 1984 dollars. To simplify this analysis, inflation and interest rate adjustments were not included. The cost figures and assumptions used in this analysis are summarized as follows:

1. Asphalt patch material costs are $38.00 / ton, in place, as supplied from recent bids obtained by the city street superintendant.

2. Asphalt patch material weight is 150 lbs / ft^3.

3. Curbing costs are $14.00/lin.ft. ($147,840 / mile), in place, as supplied by the city.

4. Manhole and sewer alignment costs are $2,500.00 / mile as obtained from average costs from the city.

5. The total network of streets in the city contains 87 miles of pavement with an average width of 30 feet. At present, 88% of this mileage contains utility cut patching.

As presented in the overlay design requirements for non patched areas, an overlay thickness of 2.25" would be required to handle 10 ESAL/day during a 20 year design period. Based on the results of the PCI survey, the actual service life of this overlay (PCI = 70) will be assumed to be 19.8 years. Therefore, all yearly costs will be calculated using this value. The average yearly overlay cost per mile of pavement (average of 30 ft. wide) could then be computed as the summation of overlay, curbing and manhole alignment costs as follows:

Overlay Cost = Material Quantity * Material Cost

Where: Material Quantity = {(2.25/12)*5,280*30} cu.ft. per mile

= 29,700 cu.ft. per mile

= 29,700 cu.ft. per mile * 0.075 tons per cu.ft.

= 2,227.5 tons per mile

Material Costs = $38.00 / ton

Therefore: Overlay Costs = ($38/ton) * 2,227.5 tons per mile

= $84,645.00 per mile * 87 miles

= $7,364,115.00 per complete overlay

Average Yearly Overlay Cost = Overlay Cost / Service Life

= $7,364,115 / 19.8 years

= <u>$371,925 per year</u>

Manhole and Sewer Alignment = $2,500.00 per mile

= $2,500 per mile * 87 miles

= $217,500.00 per complete overlay

Average Yearly Manhole Cost = $217,500 / 19.8 years

= <u>$10,985 per year</u>

The final cost associated with the overlaying of streets is the cost of replacing curbing which has been rendered ineffective as a result of the increased pavement thickness. Assuming a maximum curb reveal of 6 inches will be present after the initial overlay, the curbing will require replacement after every third overlay. As each overlay will have a service life of 19.8 years, the service life of the curbing can be expected to be 59.4 years (3*19.8). Therefore, the yearly costs associated with curb replacement would be:

Total Curb Replacement Cost = $147,840.00 per mile * 87 miles

= $12,862,080.00 per 3 complete overlays

Average Yearly Curb Costs = $12,862,080 / 59.4 years

= <u>$216,533.00 per year</u>

Therefore, the total average yearly costs associated with overlaying non-patched pavements would be:

Total Average Yearly Costs = Overlay + Manhole & Sewer + Curbing Costs

= $371,925 + 10,985 + 216,533

= <u>$599,443 per year.</u>

The above cost figure of $599,443 per year represents the average cost to the city to maintain the streets in a PCI condition of 70 or better assuming that no utility cut patching were allowed.

For comparative purposes, the average yearly costs associated with maintaining the city streets in the same condition (PCI greater than 70) while allowing utility cut patching was computed. The costs were computed using procedures identical to those already presented. As presented earlier, an overlay thickness of 3 inches with a service life of 12.1 years was computed for patched pavements.

The average yearly costs associated with an overlay of the street system, with 88% of the streets containing utility cut patches is computed as follows:

Overlay Costs (Patched) = ((3/12)*5280*30) cu.ft. per mile

= 39,600 cu.ft. per mile

= 39,600 cu.ft. per mile * .075 tons/cu.ft.

= 2,970 tons per mile

= 2,970 tons per mile * $38/ton

= $112,860.00 per mile * 76.56 miles

= $8,640,562 per complete overlay

Overlay Costs (Non-Patched) = $84,645.00 per mile * 10.44 miles

= $883,694 per complete overlay