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APPENDED MAPS **Located on Thumb Drive**

Functional Classification by Segment
Pavement Condition Index by Segment
Pavement Condition Rating by Segment Using Descriptive Terms
Assembled Projects
Pavement Condition Rating by Project Using Descriptive Terms
$2.25M/year Rehab Plan Budget
$2.25M/year Post Rehab PCI Map

Abbreviation or Acronym	Definition
$k	Dollars in thousands ($,000)
$M	Dollars in millions
%SP	Percent Spreadability - component of deflection analysis
AC	Asphalt Concrete - asphalt streets, flexible pavements, also know n as ACP
ACP	Asphalt Concrete Pavement - asphalt streets, flexible pavements, also know n as AC
ART	Arterial roadw ay functional classification
ASTM	American Society of Testing Methods
Avg	Average
BCI	Base Curvature Index - component of deflection analysis
Brk	Break
CAL	Coarse Aggregate Loss
CDV	Corrected Deduct Value - part of the ASTM D6433 PCI calculation
COL	Collector roadw ay functional classification
Crk	Crack
DeflCON	Deflection Condition - structural load analysis based on traffic loading and deflection
DMD	Dynamic Maximum Deflection - temperature corrected deflection
Dvdd Slab	Divided Slab
DynaCON	Dynamic Condition - structural layer analysis
ft or FT	Foot
ft2 or FT2	Square foot
FunCL	Functional Classification
FWD	Falling w eight deflectometer
GCI	Gravel Condition Index
GFP	Good - Fair - Poor
GIS	Geographic Information System
GISID	GIS segment identification number
H&V	Horizontal and Vertical
IRI	International Roughness Index
Jt	Joint
L&T	Longitudinal and Transverse
LAD	Load associated distress
LOC	Local roadw ay functional classification - same as RES
LOG	Lip of Gutter
m	Metre or meter
M	Moderate
m2	square metre or square meter
MART	Major arterial roadw ay functional classification
Max	Maximum
MaxDV	Maximum Deduct Value
MCOL	Major collector roadw ay functional classification
mi or Mi	Mile
Min	Minimum
MnART	Minor arterial roadw ay functional classification
MnCOL	Minor collector roadw ay functional classification
MOD	Moderate
NLAD	Non-load associated distress
OCI	Overall condition index, also know n as PCI
Olay	Overlay
PART	Primary arterial roadw ay functional classification
Pavetype	Pavement Type
PCC	Portland Cement Concrete - concrete streets
PCI	Pavement Condition Index - generic term for OCI
R&R	Remove and replace
RART	Rural arterial roadw ay functional classification
PWF	Priority Weighting Factor
Recon	Reconstruction
Rehab	Rehabilitation
RES	Local roadw ay functional classification - same as LOC
RI or RCI	Roughness Index
S	Strong
SART	Secondary arterial roadw ay functional classification
SCI	Surface Curvature Index - componenent of deflection analysis
SDI	Surface Distress Index
SI	Structural Index
STA	Station or chainage
Surf Trtmt	Surface Treatment
TDV	Total Deduct Value
W	Weak

1.0 PROJECT DESCRIPTION

1.1 PRINCIPLES OF PAVEMENT MANAGEMENT

Nationwide, billions of dollars have been invested in roadway networks by municipal, state, and federal governments. Locally, Dunwoody has just over 150 centerline miles of roadways, encompassing over 2.5M square yards of concrete and asphalt surfacing. At an average replacement cost for a typical roadway just over $1.0M per mile, not including the value of the land, the City has over $156.1M invested in its paved roadway network.

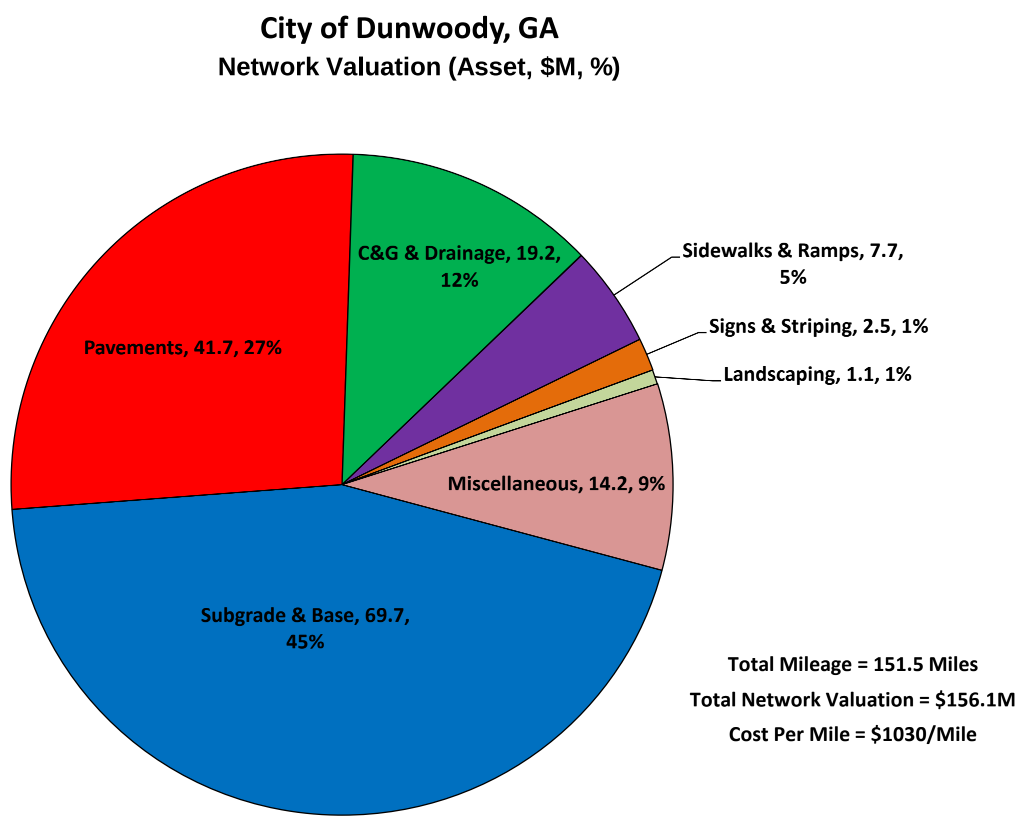

Figure 1 – Replacement Value of Dunwoody Paved Roadway Network

Preservation of existing roads and street systems has become a major activity for all levels of government. There is a shortage of funds to maintain street systems at the state and local government levels. Therefore, funds that have been designated for pavements must be used as effectively as possible. One proven method to obtain the maximum value of available funds is through the use of a pavement management system.

Pavement management is the process of planning, budgeting, funding, designing, constructing, monitoring, evaluating, maintaining, and rehabilitating the pavement network to provide maximum benefits with available funds.

A pavement management system is a set of tools or methods that assist decision makers in finding optimal strategies for providing and maintaining pavements in a serviceable condition over a given time period. The intent is to identify the optimum level of long-term funding to sustain the network at a predetermined level of service while incorporating local conditions and constraints.

As shown in **Figure 2**, streets that are repaired when they are in a good condition will cost less over their lifetime, than streets that are allowed to deteriorate to a poor condition. Without an adequate routine pavement maintenance program, streets require more frequent reconstruction, thereby costing millions of extra dollars. Over time, pavement quality drops until the pavement condition becomes unacceptable. For each street, the shape of the curve, and hence, the rate of deterioration, is dependent on many factors – foremost of which being the strength of the roadway structure and traffic loading. The key to a successful pavement management program is to develop a reasonably accurate performance model of the roadway, and then identify the optimal timing and rehabilitation strategy. The resultant benefit of this exercise is realized by the long term cost savings and increase in pavement quality over time. As illustrated in **Figure 2**, pavements typically deteriorate rapidly once they hit a specific threshold. A $1 investment after 40% lifespan is much more effective than deferring maintenance until heavier overlays or possibly reconstruction are required just a few years later.

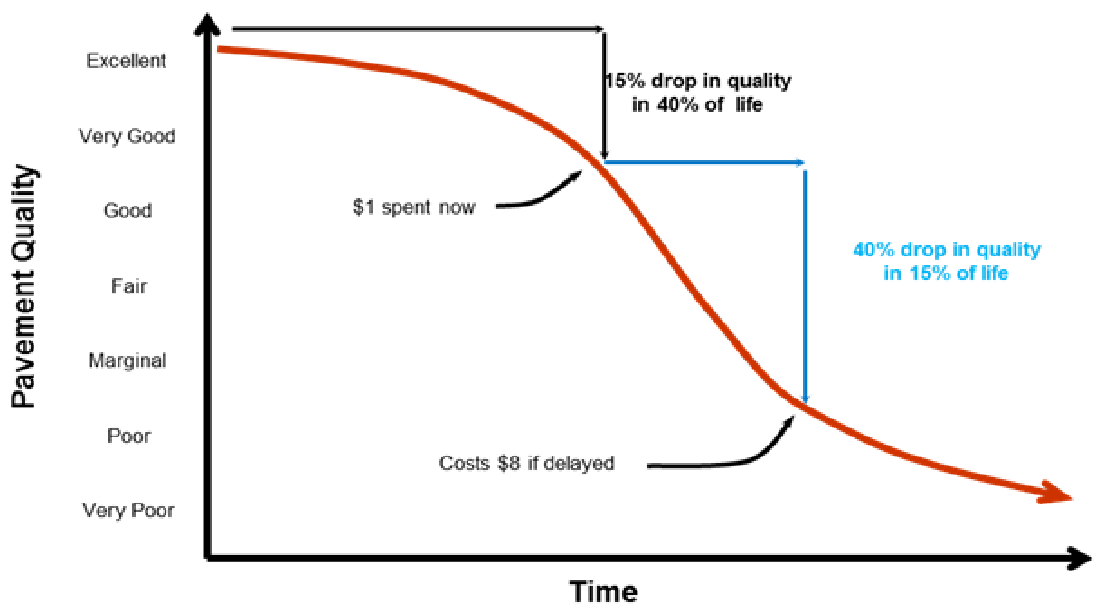

Figure 2 – Pavement Deterioration and Life Cycle Costs

Once implemented, an effective pavement information management system can assist agencies in developing long-term rehabilitation programs and budgets. The key is to develop policies and practices that delay the inevitable total reconstruction for as long as practical, yet still remain within the target zone for cost effective rehabilitation. As each roadway approaches the steepest part of its deterioration curve, apply a remedy that extends the pavement life, at a minimum cost, thereby avoiding costly heavy overlays and reconstruction.

The goal of a pavement management system is to identify the optimal level of funding and timing to create a renewal strategy that agencies should adopt to keep their roadway network at a satisfactory level of service. **Figure 3** illustrates the concept of extending pavement life through the application of timely rehabilitations.

Figure 3 – Pavement Life Cycle Curve

Ideally, the lower limit of the target zone shown in **Figure 3** would have a minimum PCI value in the 60 to 65 range to keep as many streets as possible requiring a thin overlay or less. The upper limit would tend to fall close to the higher end of the Very Good category – that is a pavement condition score approaching 85. Other functions of a pavement management system include assessing the effectiveness of maintenance activities, new technologies, and storing historical data and images.

For Dunwoody, a prioritization methodology based on pavement condition, pavement materials, functional class, and strength rating was used to analyze the network condition and develop the proposed 5 year rehabilitation plan.

The analysis methodologies and data collection technologies were based on the latest version of *ASTM D6433 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys* (hereinafter ASTM D6433) for assessment of pavement surface condition and the International Roughness Index (IRI) for quantification of pavement roughness on all City streets. These measurements of pavement quality are combined to form an overall 0 to 100 Pavement Condition Index (PCI), with 100 being the best.

1.2 THE PAVEMENT MANAGEMENT PROCESS

The actual pavement management process involves three unique, but important steps, and is presented graphically in **Figure 4**. Each activity builds on the previous, until the end result is a prioritized paving and rehabilitation program.

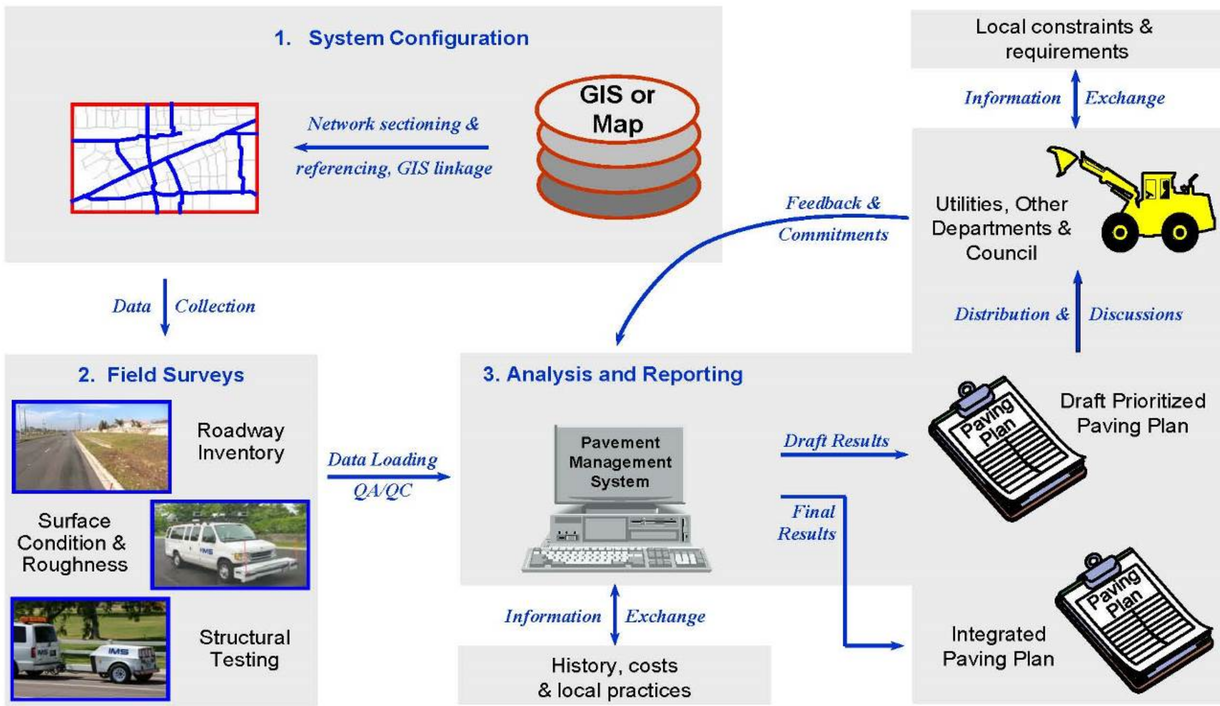

Figure 4 – The Pavement Management Process

Highlights of the pavement management process include:

1. **System Configuration** – This step involves identifying all roadways in the City's network, assigning them a unique identifier, listing their physical characteristics (length, width, etc.) and demographic attributes (pavement type, traffic, functional classification), and linking the network to the City's GIS map.

2. **Field Surveys** – Following a set of predefined assessment protocols matching the pavement management software (ASTM D6433), a specialized piece of survey equipment – referred to as a Laser Road Surface Tester (Laser RST, pictured on page 6) – is used to collect observations on the condition of the pavement surface, as well as collect high definition digital imagery and spatial coordinate information. The Laser RST surveys each local street from end to end in a single pass, while all other roadway classifications are completed in two passes.

   Key pavement condition data elements collected by the Laser RST include:

   - Roughness Index – Roughness is measured following the industry standard "International Roughness Index" (IRI), an open-ended score that measures the number of bumps per mile and reports the value as millimeters/meter. The IRI value is converted to a 0 to 100 score and reported as the Roughness Index (RI) as follows:

$$RI = (10.5 – 3.5 \times \ln(IRI)) \times 10$$

where ln(IRI) is the natural logarithm of IRI.

In common terms, a newer street would have a Roughness Index above 85, while one due for an overlay would be in the range 40 to 70. Failed streets typically have roughness values below 40.

- Surface Distress Index – The Laser RST collects surface distress observations based on the extent and severity of distresses encountered along the length of the roadway following ASTM D6433 protocols for asphalt and concrete pavements. The surface distress condition (cracking, potholes, raveling, and the like) is considered by the traveling public to be the most important aspect in assessing the overall pavement condition.

Presented on a 0 to 100 scale, the Surface Distress Index (SDI) is an aggregation of the observed pavement defects. Within the SDI, not all distresses are weighted equally. Certain load associated distresses (caused by traffic loading), such as rutting or alligator cracking on asphalt streets, or divided slab on concrete streets, have a much higher impact on the surface distress index than non-load associated distresses such as raveling or patching. Even at low extents and moderate severity – less than 10% of the total area – load associated distresses can drop the SDI considerably. ASTM D6433 also has algorithms within it to correct for multiple or overlapping distresses within a segment.

For this project, extent and severity observations were collected, processed, and loaded into the pavement management software. Within the software, the following distresses, listed in order from greatest to lowest impact, are presented as a 0 to 10 rating for review and reporting:

Alligator Cracking – Alligator cracking is quantified by the severity of the failure and number of square feet. Even at low extents, this can have a large impact on the condition score as this distress represents a failure of the underlying base materials.

Wheel Path Rutting – Starting at a minimum depth of ¼ inch, wheel path ruts are quantified by their depth and the number of square feet encountered. Like alligator cracking, low densities of rutting can have a large impact on the final condition score.

Longitudinal, Transverse, Block (Map), and Edge Cracks – These are quantified by their length and width. Longitudinal cracks that intertwine are the start of alligator cracking.

Patching – Patching is quantified by the extent and quality of patches. When the majority of a roadway surface is covered by a patch, such as a large utility replacement, the rating of the patch is minimized. All potholes are rated as patches.

Distortions – All uneven pavement surfaces such as depressions, bumps, sags, swells, heaves, and corrugations are included as distortions and are quantified by the severity and extent of the affected area.

Raveling – Raveling is the loss of fine aggregate materials on the pavement surface and is measured by the severity and number of square feet affected.

Bleeding – Bleeding is the presence of free asphalt on the roadway surface caused by too much asphalt in the pavement or insufficient voids in the matrix. The result is a pavement surface with low skid resistance and is measured by the amount and severity of the area.

Similar distresses were collected for concrete streets including divided slab, corner breaks, joint spalling, faulting, polished aggregate, and scaling.

- Structural Index – The network of streets was not tested for structural adequacy, instead, the relationship between the final pavement condition score and amount of load associated distresses was analyzed and each pavement section assigned a Weak, Moderate or Strong strength rating. The assigned structural index (30, 60 or 80 for weak, moderate and strong respectively) was not used in determining the overall pavement condition score, but simply to classify the pavement strength and aid in selecting appropriate rehabilitation strategies.

3. **Analysis and Reporting** – Following the field surveys, the condition data is assembled to create a single score representing the overall condition of the pavement. The Pavement Condition Index (PCI) is calculated as follows:

PCI = 33% Roughness Index + 67% Surface Distress Index

Development of the pavement management plan and budgets was completed using Dunwoody-specific rehabilitation strategies, unit rates, priorities, and pavement performance curves. The process was iterative in its attempt to obtain the greatest efficiency and cost benefit.

Figure 5 – Laser Road Surface Tester (Laser RST)

1.3 FUNCTIONAL CLASS REVIEW

As part of the scope of this assignment, the functional classification designations currently used by Dunwoody were reviewed and updated for their use in the pavement management analysis. There is no uniform standard for functional classification designation used by municipalities in the nation or within any given state. Assignment of functional classifications is left to the individual municipalities. The Federal Highway Administration (FHWA), American Public Works Association (APWA) and Institute of Transportation Engineers (ITE) offer some broad guidelines on how to assign classifications that were followed in this study. The City’s functional classification definitions used in the assessment are as follows:

1. **Minor Arterial (MnART)** – Continuous and discontinuous cross city and inter-district corridors that are 2 to 4 lanes across and generally have a centerline stripe or a designated bus route. The ADT generally falls in the 10,000 to 20,000 vehicle per day range. They are typically spaced on the ½ or ¼ mile section line and on occasion, may have a short non-landscaped median.
2. **Collector (COL)** – continuous and discontinuous cross City and inter-district corridors that are 2 to 4 lanes across and generally have a centerline stripe or a designated bus route. The ADT generally falls in the 1,000 to 10,000 vehicle per day range. They are typically spaced on the ½ or ¼ mile section line and on occasion, may have a short non-landscaped median. Collectors are also assigned to streets segments leading to, or adjacent to, a major traffic generator site such as a regional shopping complex.
3. **Local (LOC)** – are the majority of the street segments consisting of all residential and frontage roads not defined above or as an industrial/commercial.

The following figure (**Figure 6**) highlights the functional classifications used for the Dunwoody roadway network. An electronic version of this map is appended to this report.

Figure 6 – Dunwoody Functional Classification Designation

1.4 ASSEMBLY OF DATA INTO PROJECTS

Dunwoody's Geographic Information System (GIS) was used as the basis for segmenting the roadway network on a block-by-block basis. Each segment was assigned a unique identifier referred to as a GISID, establishing a one-to-one relationship between the GIS and the street inventory. The segments form the basic building block of the pavement management system and are where all attribute and condition data are stored.

The centerline segments were aggregated together within the pavement management system to form logical projects that the analysis and rehabilitation program are developed against.

In general:

- Arterial projects run from major intersection to major intersection.
- Similar to arterials, collector streets within a neighborhood were aggregated together to form a single project where practical.
- Local streets along a homogenous route were aggregated together along with adjacent side streets to form a small neighborhood based approach.

Segments were joined only when the pavement condition and functional classification were homogeneous in nature such that when joined they have a relatively uniform condition that may be rehabilitated using a single strategy.

The following figure (**Figure 7**) highlights the projects IMS used for this report. The electronic database provided allows the city to easily customize projects to meet local conditions and needs.

Figure 7 – Dunwoody Assembled Projects

1.5 UNDERSTANDING THE PAVEMENT CONDITION INDEX SCORE

The following illustration (**Figure 8**) compares the Pavement Condition Index (PCI) to commonly used descriptive terms. The divisions between the terms are not fixed, but are meant to reflect common perceptions of condition.

Figure 8 – Understanding the Pavement Condition Index (PCI) Score

The following table details a general description for each of these condition levels with respect to remaining life and typical rehabilitation actions:

PCI Range	Description	Relative Remaining Life	Definition
85 – 100	Excellent	15 to 25 Years	Like new condition – little to no maintenance required when new; routine maintenance such as crack and joint sealing.
70 – 85	Very Good	12 to 20 Years	Routine maintenance such as patching and crack sealing with surface treatments such as seal coats or slurries.
60 – 70	Good	10 to 15 Years	Heavier surface treatments, chip seals and thin overlays. Localized panel replacements for concrete.
40 – 60	Marginal to Fair	7 to 12 Years	Heavy surface-based inlays or overlays with localized repairs. Moderate to extensive panel replacements.
25 – 40	Poor	5 to 10 Years	Sections will require very thick overlays, surface replacement, base reconstruction, and possible subgrade stabilization.
0 – 25	Very Poor	0 to 5 Years	High percentage of full reconstruction.

The images presented below provide a sampling of the Dunwoody streets that fall into the various condition categories with a discussion of potential rehabilitation strategies.

Very Poor (PCI = 0 to 25) – Complete Reconstruction (not a Dunwoody road)

Mount Vernon Highway from End of Pavement to Mount Vernon Highway (GISID 344, PCI = 24) *– Rated as Very Poor, this street displays extensive base failure as evidenced by the extensive amount of severe fatigue cracking and wheel path rutting. A mill and overlay on this street would not be suitable as the base has failed and would not meet an extended service life of at least 15 years. In addition to age and loading, the drainage and cross slope of the pavement have also contributed to its deteriorated condition.*

Deferral of reconstruction of streets rated as Very Poor will not cause a substantial decrease in pavement quality as the streets have passed the opportunity for overlay-based strategies. Due to the high cost of reconstruction, Very Poor streets are often deferred until full funding is available in favor of completing more streets that can be rehabilitated at lower costs, resulting in a greater net benefit to the City. This strategy however must be sensitive to citizen complaints forcing the street to be selected earlier. In addition, this type of street can pose a safety hazard for motorists, since severe potholes and distortions may develop. It is important to consistently monitor these streets and check for potholes or other structural deficiencies until the street is rebuilt.

Poor (PCI = 25 to 40) – Last Opportunity for Surface Base Rehabilitation

Windhaven Court from South End to Womack Road (GISID 1318, PCI = 34) *– Rated as Poor, this segment still has some remaining life before it becomes a critical reconstruction need. On this street, the base is starting to fail extensively. This is evident by the severe alligator cracking that persists throughout most the street. Some of the other distresses present in this segment include linear and transverse cracking, patching and a fair amount of raveling. If left untreated, within a short period of time, a full reconstruction would be required.*

On arterial roadways, Poor streets often require partial to full reconstruction – that is removal of the pavement surface and base down to the subgrade and rebuilding from there. On local roadways, they require removal of the pavement surface through grinding or excavation, base repairs, restoration of the curb line and drainage, and then placement of a new surface.

In general, the service life of Poor streets is such that if deferred for too long, it would require a more costly reconstruction. Streets rated as Poor are typically selected first for rehabilitation as they provide the greatest cost/benefit to the City – that is the greatest increase in life per rehabilitation dollar spent.

Marginal (PCI = 40 to 50) – Progressively Thicker Overlays

Witham Drive from Roberts Drive to Whitewood Court (GISID 2783, PCI = 41) *– Marginal streets have distresses that tend to be localized and moderate in nature – that is they do not extend the full length of the segment and can be readily dug out and repaired. This street segment highlights this characteristic as the failed area does not quite extend the full length or width of the roadway and is still serviceable. However, it also highlights the relationship between base and pavement quality. Placing an overlay on this street without repairing the base would not achieve a full 15 year life as the failure would continue to occur over time. Structural patching of the failed areas along with localized rehabs would permit a full width grind and inlay on this street segment and return it to full service.*

Similar to streets rated as Very Poor, Marginal streets that display high amounts of load associated distresses are selected as a priority for rehabilitation as they provide the greatest cost/benefit to the City. If left untreated, Marginal streets with high amounts of load associated distresses would deteriorate to become partial reconstruction candidates. Marginal streets that are failing due to materials issues or non-load associated failures may become suitable candidates for thick overlays if deferred, without a significant cost increase.

Fair (PCI = 50 to 60) – Thin to Moderate Overlays

Winters Chapel Road from Charmant Place to Fontainebleau Way (GISID 1647, PCI = 52) *– Rated in the Fair category, these streets require thin to moderate overlays for asphalt when they enter their need year. Several distresses are present, including longitudinal and transverse cracking and wheel-path rutting. On this segment of road, the signs of deterioration are evident along the right side of the street where alligator cracking that runs along the wheel path can be clearly seen. The drainage and curbing appear to be in good condition indicating the base has not yet failed along the entire length of roadway.*

Asphalt streets rated as Fair tend to receive a lower priority when developing a rehabilitation program. The reason for this is the cost to complete an overlay now would be on the order of \$14.25 to \$19.25/yd^2. If deferred, the rehabilitation cost would only increase by about \$3 to \$6/yd^2, again depending on the functional classification, in about 5 to 10 years. This delay represents a 20% difference over the time stated. Thus, the cost of deferral is low when compared to deferring a thick overlay to a reconstruction with a two to threefold increase in cost. Rehabilitation strategies tend to focus on removal and replacement of whole sections and surface grinding to restore the longitudinal profile of the roadway.

Good (PCI = 60 to 70) – Surface Treatments to Thin Overlays

Redstone Terrace from Redstone Lane to North East Lane (GISID 1150, PCI = 61) *– Rated as Good with the primary cause of deterioration as loss of fines on the surface presenting a weathered – oxidized appearance. Obvious wheel path rutting can be seen along the left hand lane. The existing cracks should be sealed and the pavement surface restored, with a heavier surface treatment such as microsurfacing or double slurry to fully waterproof the pavement and cover the crack sealant. The occasional dig out and replacement may be required to correct localized deficiencies. Alternatively, depending on the extent of the distressed areas, base strength and drainage, a thin overlay may be applied.*

*Asphalt streets rated as Good are ideal candidates for thinner surface-based rehabilitations and local repairs. Depending on the amount of localized failures, a thin edge mill and overlay, or possibly a surface treatment, would be a suitable rehabilitation strategy for streets rated as Good. Streets that fall in the high 60 - low 70 PCI range provide the greatest opportunity for extending pavement life at the lowest possible cost, thus applying the principles of the perpetual life cycle approach to pavement maintenance. The adjacent photo is a great example of a street segment (**not a Dunwoody Road**) that displayed low load associated distresses and thus, high structural characteristics, and once the distressed areas were replaced, a slurry seal was applied. The patching accounted for less than 5 to 10% of the total area and resulted in a good looking, watertight final surface at a much lower cost than an overlay with less disruption to the neighborhood and curb line. The patches were paver laid and roller compacted.*

Very Good (PCI = 70 to 85) – Surface Treatments and Localized Rehabilitation

Vermack Road from Vanderlyn Drive to Corners Cove (GISID 1140, PCI = 83) *– Rated as Very Good, this road displays minor amounts of cracking that are localized and in good condition. The surface is non-weathered, and the base is still strong, however the segment displays high amounts of roughness lowering the score slightly. This street is an example of a candidate for preventative maintenance and light weight surface treatments to extend the life of a roadway. Asphalt streets rated as Very Good generally need lightweight surface-based treatments such as surface seals, slurries, chip seals or microsurfacing. Routine maintenance such as crack sealing and localized repairs often precede surface treatments. The concept is to keep the cracks as waterproof as possible through crack sealing and the application of a surface treatment. By keeping water out of the base layers, the pavement life is extended without the need for thicker rehabilitations such as overlays or reconstruction. Surface treatments also tend to increase surface friction and visual appearance of the pavement surface but do not add structure or increase smoothness.*

Surface treatments may include:

- *Double or single application of slurry seals (slurries are a sand and asphalt cement mix).*
- *Microsurfacing – asphalt cement and up to 3/8 sand aggregate.*
- *Chip seals and cape seals (Chip seal followed by a slurry).*

Additional cost benefits of early intervention include:

- *Less use of non-renewable resources through thinner rehabilitation strategies.*
- *Less build-up of crown for the first and possibly second rehabilitation cycle.*
- *Less intrusive rehabilitation and easier to maintain access during construction.*
- *Easier to maintain existing drainage patterns.*

Excellent (PCI = 85 to 100)

Wellshire Place from Mount Vernon Road to Wellshire Lane (GISID 2126, PCI = 95) *– Rated as Excellent, displaying little to no surface distresses. The ride is smooth and the surface is non-weathered and the base is strong. In a couple of years, this street segment would be an ideal candidate for routine maintenance activities such as crack sealant rehabilitation.*

In terms of pavement management efficiency, a program based on worst-first, that is starting at the lowest rated street and working up towards the highest, does not achieve optimal expenditure of money. Generally, under this scenario, agencies can not sufficiently fund pavement rehabilitation and lose ground despite injecting large amounts of capital into the network.

The preferred basis of rehabilitation candidate selection is to examine the cost of deferral of a street, against increased life expectancy.

2.0 ROADWAY NETWORK CONDITION AND FINDINGS

2.1 ROADWAY NETWORK SIZE

The paved roadway network consists of three functional classes, covering approximately 152 miles of pavement. The average pavement condition index (PCI) of the roadway network at the time of the survey is a 67. The network's primary pavement type is asphalt. The following table and **Figure 9** summarize the functional classification splits within the system.

City of Dunwoody, GA
Network Summary by Functional Class

	Pavetype	Network	Major Arterial	Minor Arterial	Collector	Local
Segment (Block) Count	All Streets	1546	0	209	223	1114
	Asphalt	1546	0	209	223	1114
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Network Length (ft):	All Streets	799,995	0	111,063	99,713	589,219
	Asphalt	799,995	0	111,063	99,713	589,219
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Network Length (mi):	All Streets	151.5	0.0	21.0	18.9	111.6
	Asphalt	151.5	0.0	21.0	18.9	111.6
	Concrete	0.0	0.0	0.0	0.0	0.0
	Composite	0.0	0.0	0.0	0.0	0.0
Average Width (ft):	All Streets	28.1	0.0	34.2	33.2	26.0
	Asphalt	28.1	0.0	34.2	33.2	26.0
	Concrete	0.0	0.0	0.0	0.0	0.0
	Composite	0.0	0.0	0.0	0.0	0.0
Network Area (yd2):	All Streets	2,493,783	0	421,978	367,899	1,703,906
	Asphalt	2,493,783	0	421,978	367,899	1,703,906
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Current Pavement Condition	All Streets	67	0	73	73	64
Index (CPCI)	Asphalt	67	0	73	73	64
7/15/19	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Pavement Condition Index	All Streets	67	0	75	71	64
(Surveyed PCI)	Asphalt	67	0	75	71	64
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Current Backlog (%)	All Streets	19	Percentage of Network with a PCI < 40			
Current Network Index	All Streets	54	Minimum Acceptable Network Index			
Surface Distress Index (SDI)	All Streets	67	0	71	68	65
7/15/19	Asphalt	67	0	71	68	65
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0
Roughness Index (RI)	All Streets	66	0	76	71	62
7/15/19	Asphalt	66	0	76	71	62
	Concrete	0	0	0	0	0
	Composite	0	0	0	0	0

Typically, 12% to 18% of a network falls in the collector category with 62% to 75% of the segments being categorized as locals. Dunwoody streets conform to these standards.

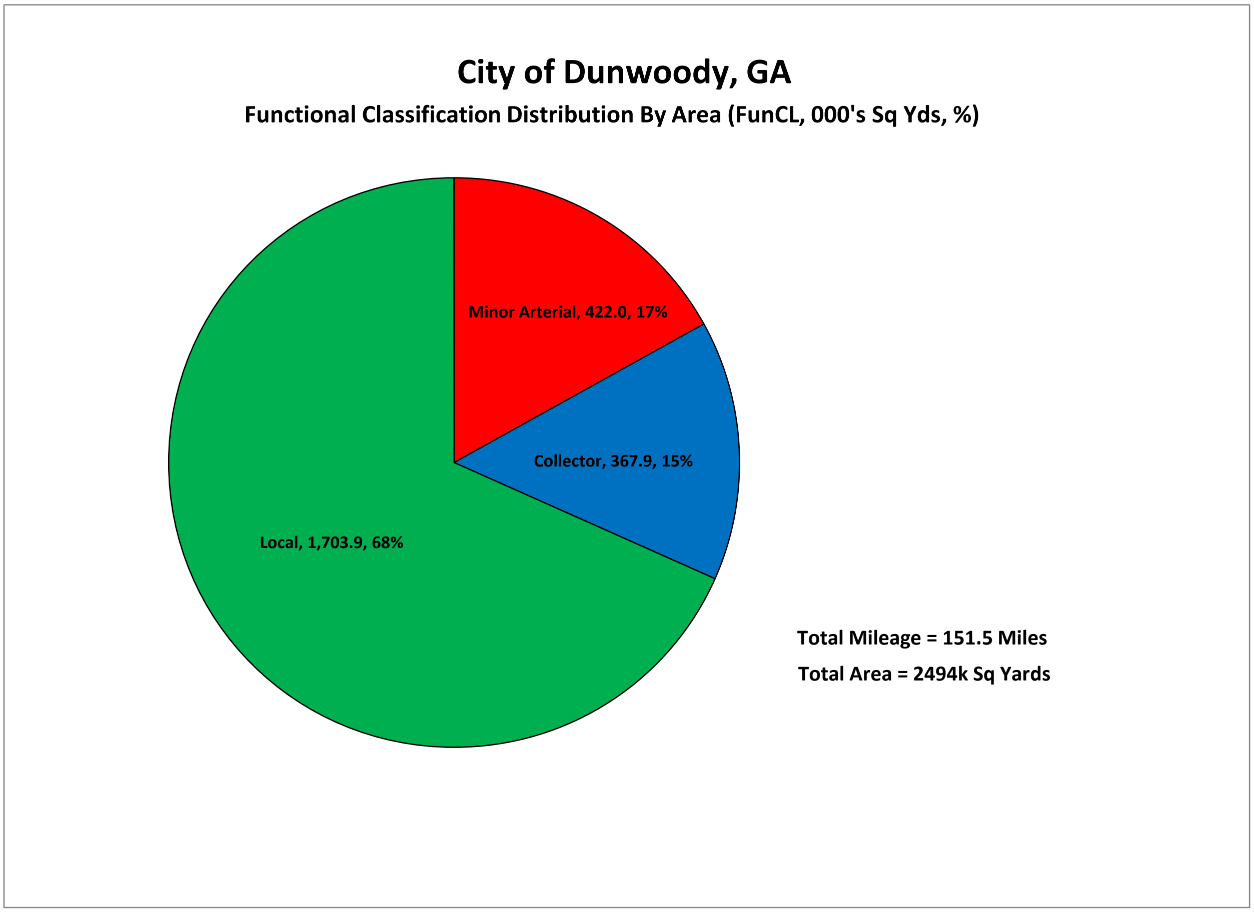

Figure 9 – Functional Classification Distribution by Mileage

2.2 NETWORK PRESENT CONDITION

Figure 10 presented below shows the distribution of pavement condition for the roadway network in Dunwoody on a 0 to 100 scale, 0 is the worst condition and 100 is the best condition. The average PCI for the network at time of survey was 67. While direct comparisons to other agencies is difficult due to variances in ratings systems, overall, Dunwoody falls slightly above the average of other agencies recently surveyed by IMS, which typically fall in the 60 to 65 range.

Figure 10 – Roadway Network Present Status

This is reflective of an aged network that has had some roadway renewal effort. Simultaneously, the City has only a small sample of streets that are approaching the end of their life where surface based rehabilitations, such as overlays, can be effective. Traditionally we expect to see a bell curve that is skewed to the right and centered between a PCI of 60 and 70. The Dunwoody network does not fit this typical pattern. Indirectly the network has likely experienced less investment than needed to maintain equity and average PCI in the system. The lack of poor and very poor rated streets is indicative of a "worst-first" pavement rehabilitation strategy which may not achieve the optimal budget expenditure.

The following graph **(Figure 11)** plots the same pavement condition information, but instead of using the actual Pavement Condition Index (PCI) value, descriptive terms are used to classify the roadways. From the chart, fifteen percent (15.1%) of the network can be considered in Excellent condition with a PCI score greater than 85. These streets are in like new condition and require only routine maintenance. The target value for the amount of roadways falling into the Excellent category is a minimum of fifteen percent (15%) representing sufficient ongoing – annual investment in the roadway network. About thirty-four percent (34.3%) of the network falls into the Very Good classification. These are roads that benefit most from preventative maintenance techniques such as microsurfacing, slurry seals and localized panel repairs. If left untreated, these roadways will drop in quality to become heavy surface treatment, overlay candidates, or panel replacements candidates. About eleven percent (11%) of the streets are rated as Good and are candidates for lighter surface-based rehabilitations such as thin overlays or slight panel replacements. Thirty-eight percent (37%) of network can be considered Fair to Marginal condition representing candidates for progressively thicker overlay-based rehabilitation or panel replacements. If left untreated, they will decline rapidly into reconstruction candidates. The remaining two percent (2.3%) of the network is rated as Poor or Very Poor, meaning these roadways have failed or are past their optimal due point for overlay or surface-based rehabilitation and may require progressively heavier or thicker forms of rehabilitation (such as extensive panel replacement, surface reconstruction or deep patch and paving) or total reconstruction.

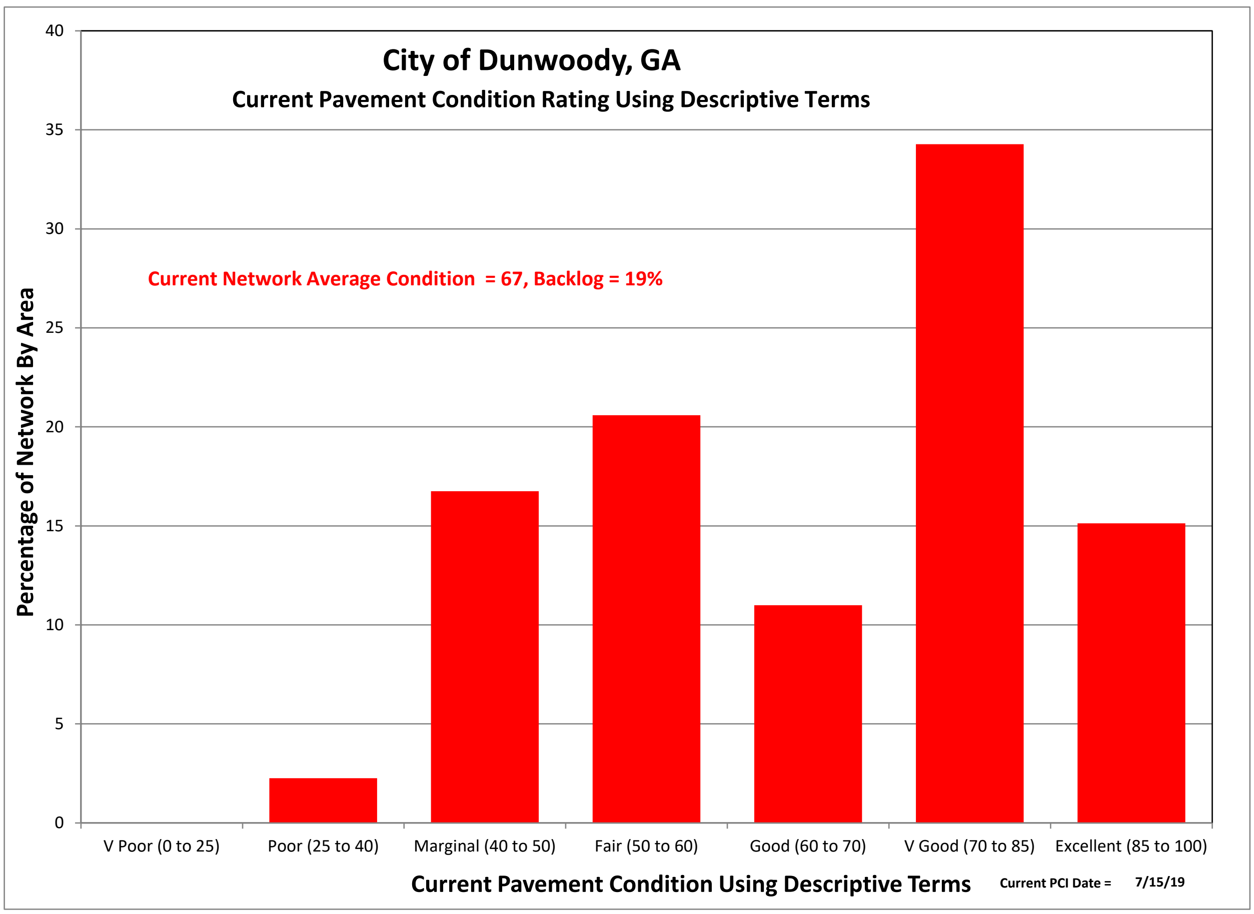

Figure 11 – Roadway Network Present Status Using Descriptive Terms by Centerline Mileage

Figures 12 and 13 present the surveyed condition of the streets using PCI and Good-Fair-Poor descriptive terms, respectively. Electronic versions of these maps are appended to this report.

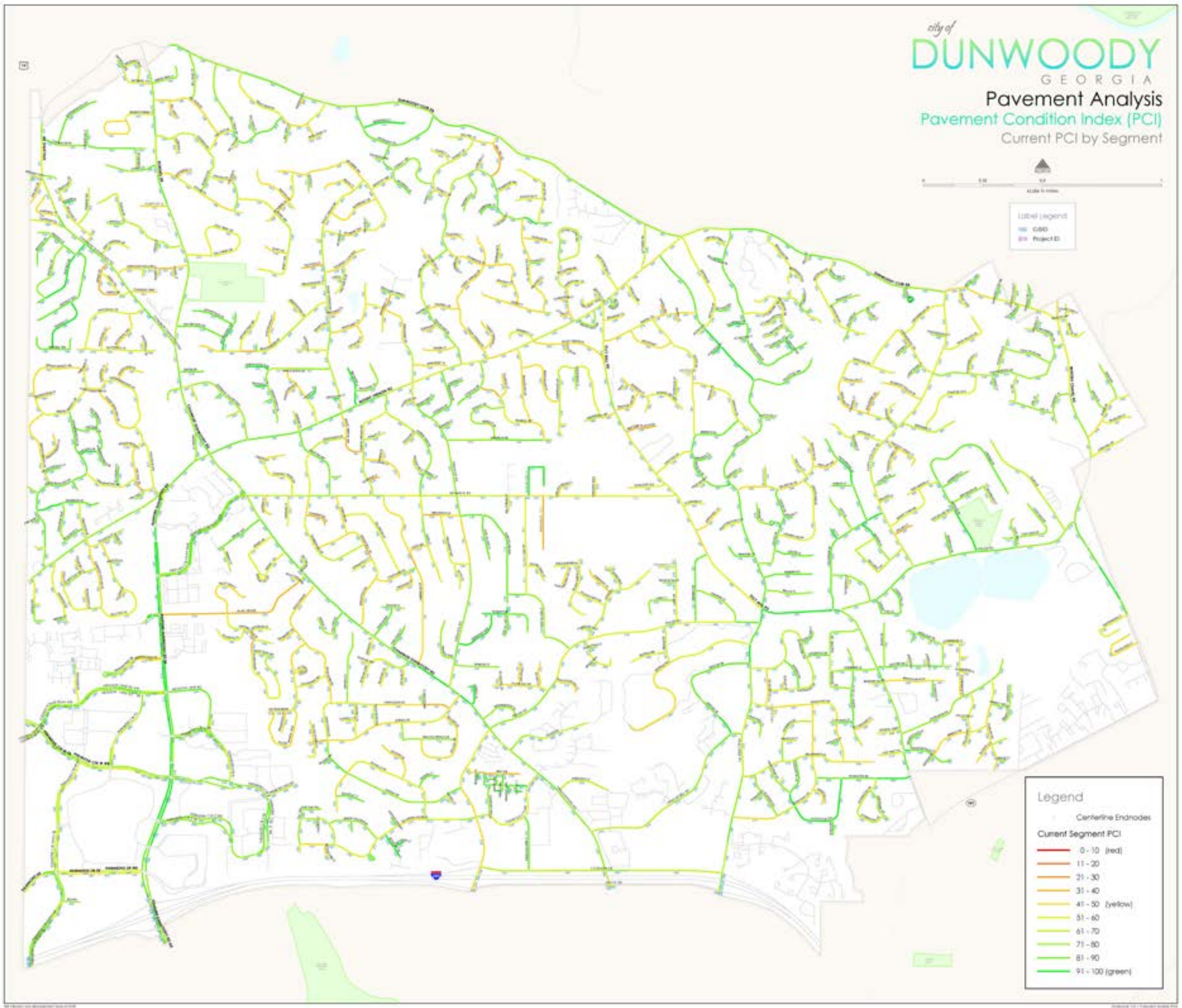

Figure 12 – Dunwoody by Segment Using Pavement Condition Index (PCI)

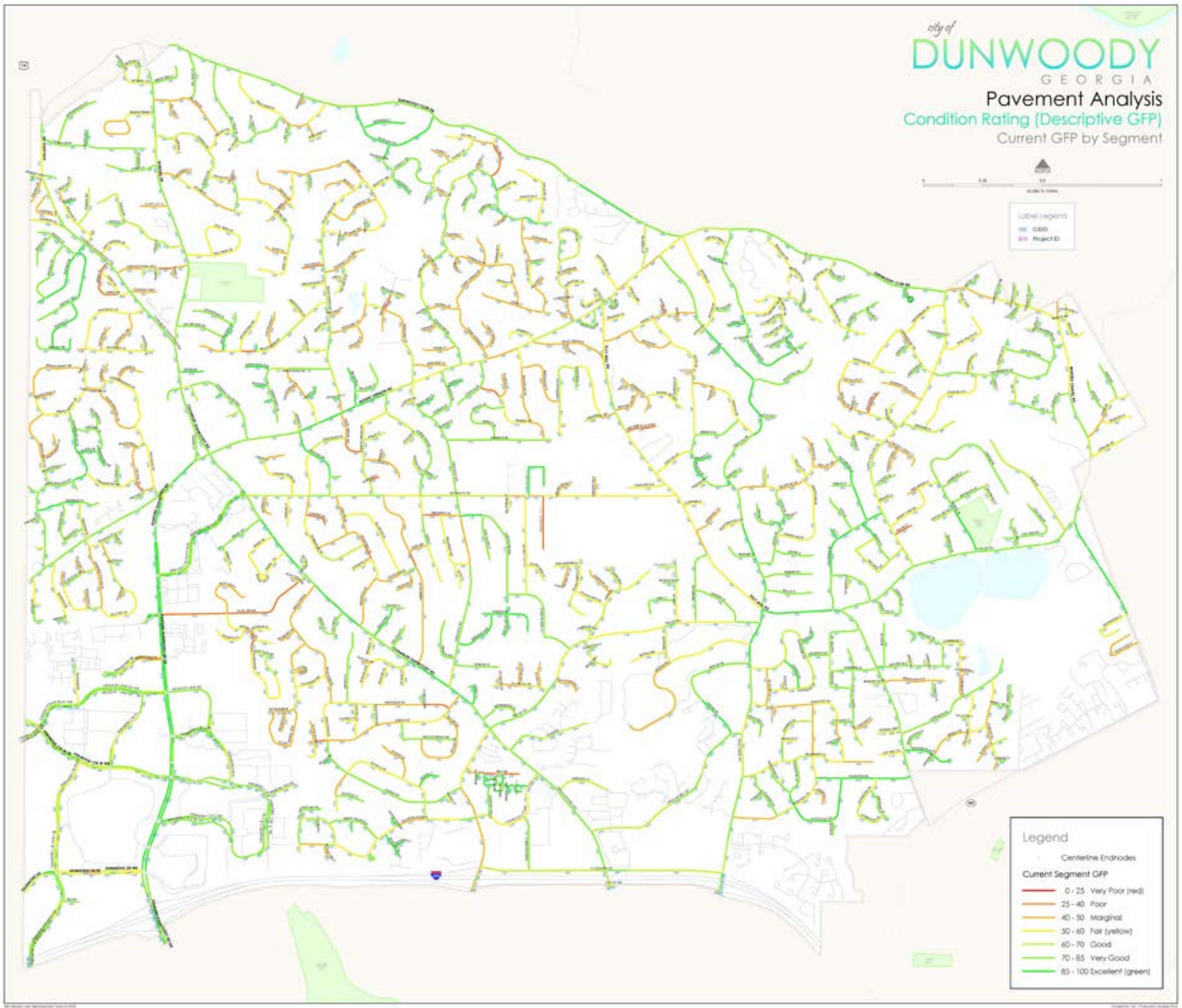

Figure 13 – Dunwoody Pavement Condition by Segment Using Descriptive Terms

2.3 CONDITION BY FUNCTIONAL CLASSIFICATION

Figure 14 highlights the pavement condition distribution for the arterial, collector, and local streets. From the plot, arterial roadways (shown in red) have an average PCI of 75. Arterial roadways, the streets that have the majority of traffic use and link various parts of the city together, may be considered the thoroughfares of the city and during the budget development process, should receive the highest priority when selecting rehabilitation candidates.

The collector network has an average PCI of 71. The local network forms the majority of the city's street system and has an average PCI of 64. Local roadways are the streets that people live on or are used for driving within the community.

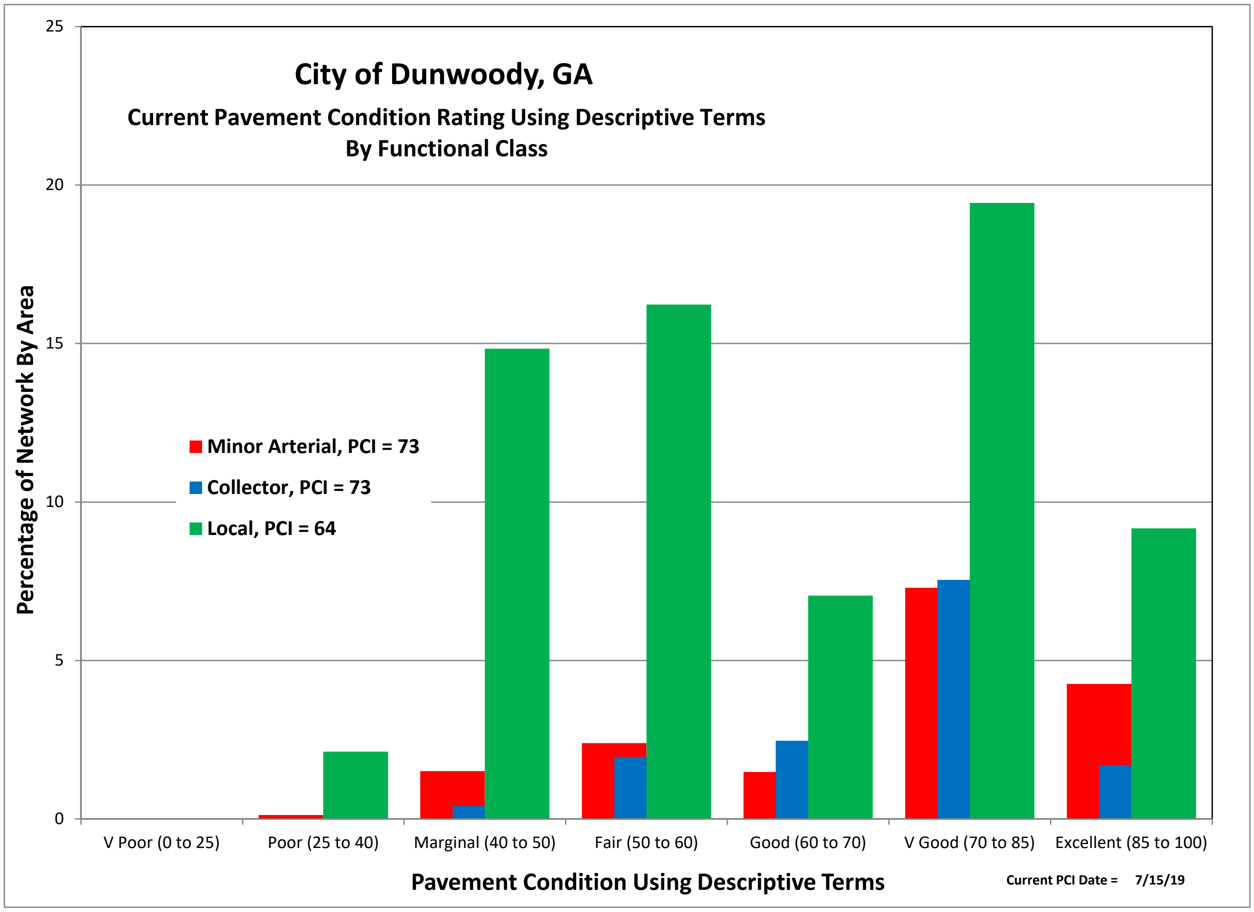

Figure 14 – Condition Rating by Functional Classification

2.4 LOAD ASSOCIATED DISTRESS ANALYSIS

Structural testing and analysis was not performed for the City of Dunwoody. Instead, analysis of the cause of pavement failure for these street segments was completed by examining the types of distresses that have caused the PCI score to drop.

Surface distresses may be categorized into two classifications – load associated distresses (LADD) and non-load associated distresses (NLAD). Load associated distresses are those that are directly related to traffic loading and structural capacity. Non-load associated distresses are those that result from materials or environmental issues including shrinkage (transverse) cracking, bleeding and raveling. Generally, load associated distresses affect the overall condition score more than non-load associated distresses – as is the case in Dunwoody. For asphalt streets, roadways were classified as Weak, Moderate, or Strong.

The purpose of the structural analysis is twofold:

- The structural analysis provides input into which performance curve each segment is to use – performance curves are used to predict pavement deterioration over time.
- Structural analysis assists in rehabilitation selection by constraining inadequate pavement sections from receiving too light of a rehabilitation and conversely, identifying segments suitable for lighter weight treatment.

Figure 16 plots the relationship of the load associated distresses (shown in red) against pavement condition. As can be seen from the plot, at higher PCI scores, it is the non-load associated distresses that have a higher concentration of deducts over the load associated distresses. As the PCI score drops, the load associated distresses typically affect the PCI score to a higher degree. This is indicative of a network that has good pavement performance for the first half of a street's life, and then suffers from progressive structural or base failures over time. High PCI score (above 65) rehab selections should focus on pavement preservation activities such as surface treatments or thin overlays, possibly with some localized pavement repairs and crack sealing.

The upper black diagonal line identifies segments that have a high ratio of load associated distresses compared to their PCI score and are defined as weak. The lower black diagonal line identifies segments that have a low ratio of load associated distresses compared to their PCI score and are defined as strong. In between the two lines, and all segments with a PCI > 80 are assigned a moderate pavement strength.

The sum of the Load-Associated Distress deducts (LADD) is also used to qualify the appropriate rehabilitation strategy selection in addition to the overall pavement condition score. For example, a street that has a good PCI score (that is between 60 and 70) and is displaying relatively low load associated distress deducts would be a suitable candidate for a surface treatment in place of a thin overlay in that the PCI score is more influenced by materials issues such as transverse cracking or raveling.

Figure 16 – Pavement Condition Index versus Sum of Distress Deducts

2.5 EVALUATING QUALITY OF THE NETWORK AND RECONSTRUCTION BACKLOG

The concept of the Pavement Condition Index (PCI) score, backlog percentage and number of streets rated as Excellent must be fully understood in order to understand and develop an effective pavement management program. These three metrics should fall into certain ranges in order to measure the quality and long term viability of a network.

The PCI score indicates the overall pavement condition and represents the amount of equity in the system; it is the value most commonly considered when gauging the overall quality of a roadway network. It may also be used to define a desired level of service: that is, an agency may wish to develop a pavement management program such that in five years the overall network score meets a set minimum value. Obviously, the higher the PCI score the better off the overall network condition is. Agencies with an average PCI score above 80 (when considering surface distress, roughness and possibly strength) are rare and found only in a few select communities. Less than 1 in 20 communities surveyed by IMS have that high of a condition average. Averages between 65 and 80 are indicative of either newer networks, or ones that have an ongoing pavement rehabilitation program and tend to be fully funded. Scores between 60 and 65 are common and represent a reasonable average providing a satisfactory balance between levels of service and funding, and when taken with the other two metrics may represent a well-managed and funded network. A minimum score of 60 means that overall the network falls at the lower end of the range where light weight surface treatments and thin overlays are the standard rehabilitation practice. Below a 60 means an agency has to rely on more costly rehabilitations and reconstructions to address condition issues.

At the upper end of the condition scale, a minimum of 15% of the network should be rated as Excellent. Generally, at or above 15%, means that a noticeable percentage of the roadway network is in like new condition, requiring only routine maintenance. While higher percentages of streets rated as Excellent are certainly desirable, the annual cost to maintain rates at higher multiples is often cost prohibitive. Below 15% means the agency is struggling to effectively rehabilitate their network on an annual basis. The 15% marker represents a cost effective balance between annual investment and satisfactory level of service.

Backlog roadways are those that have dropped sufficiently in quality to the point where surface based rehabilitation efforts would no longer prove to be cost effective. These roadways will require either partial or total reconstruction. Backlog is expressed as the percentage of roads requiring reconstruction as compared to the network totals.

It is the backlog, however, that defines the amount of legacy work an agency is facing and is willing to accept in the future. It is the combination of the three metrics that presents the true picture of the condition of a roadway network, and conversely defines improvement goals.

Generally, a backlog of 10% to 15% of the overall network is considered manageable from a funding point of view with 12% being a realistic target. Fifteen percent (15%) is used as a control limit to indicate the maximum amount of backlog that can be readily managed. Backlog rates below 10%, again are certainly desirable, but financially unachievable for a large percentage of agencies. Backlogs approaching 20% or more tend to become unmanageable, unless aggressively checked through larger rehabilitation programs, and will grow at an alarming rate. At about 20% backlog, the rate of decrease in average condition, and hence growth in backlog, exceeds most agencies ability to arrest the decline and address the large volumes of streets in need of rehabilitation. Basically, at 20% a tipping point has been met and the backlog tends to increase faster than an agency's ability to reconstruct their streets.

Dunwoody met one out of three of the metrics for evaluating the quality of its roadway network. Dunwoody's average pavement condition score is above the average zone of 60 to 65 with an average score of 67. The number of streets rated as Excellent was below the minimum recommended target of 15% at 12.3%. The backlog amount was above the target value 12% at 17.3%.

The role of the street network as a factor in the City's well-being cannot be overstated. In the simplest of terms, roadways form the economic backbone of a community. They provide the means for goods to be exchanged, commerce to flourish, and commercial enterprises to generate revenue. As such, they are an investment to be maintained.

The overall condition of an agency's infrastructure and transportation network is a key indicator of economic prosperity. Roadway networks in general are one of the most important and dynamic sectors in the global economy, having a strong influence on not only the economic well-being of a community, but a strong impact on quality of life. Well-maintained road networks experience multiple socioeconomic benefits through greater labor market opportunities and decreasing income gap. As a crucial link between producers and their markets, quality road networks ensure straightforward access to goods and drive global and local economies. Likewise, higher network quality has a strong correlation to improvements in household consumption and income. Roads also act as a key element to social cohesion by acting as a median for integration of bordering regions (Gertler). This social integration promotes a decreased gap in income along with diversity and a greater sense of community that can play a large role in decreasing rates of poverty (Amparo).

Conversely, deterioration of roads can have adverse effects on a community and may bring about important and unanticipated welfare effects that the governments should be aware of when cutting transportation budgets (Gertler). Poor road conditions increase fuel and tire consumption while shortening intervals between vehicle repair and maintenance. In turn, these roads result in delayed or more expensive deliveries for businesses and consumers (Economic Dependence on Good Roads). Economic effects of poor road networks, such as time consuming and costly rehabilitation, can be reduced if a proactive maintenance approach is successfully implemented.

The majority of the Dunwoody road network falls under Good to Very Good categories, while the amount of Very Poor streets is minimal. Dunwoody has a centerline mileage to population ratio that is average when compared to other agencies recently surveyed by IMS. When the centerline mileage is out of proportion to the population, an increased burden is placed on rate payers to maintain the network. The following plot (**Figure 17**) presents a comparison of population versus centerline mileage of several recent surveys. As can be seen, Dunwoody is slightly above the trend line for centerline mileage.

Figure 17 – Agency Population versus Centerline Mileage

One other aspect of the City's network that should be noted is the average width of the pavements. While the center line length to population ratio fits along the expected norms, the average width falls below the range of other agencies recently surveyed by IMS at 27.7 feet. Typical average widths fall in the 34 to 37 foot range, so Dunwoody is below this range. While not directly related to pavement condition, road width does contribute to actual rehabilitation cost for the road network as it relates to minimum standard widths and drainage repairs.

The primary concern for the long term health of Dunwoody's roadway network from a pavement management perspective is to control the growth of backlog and prevent any further PCI slide. By controlling the growth of the backlog and minimizing PCI slide, the city can save itself several thousands of dollars by preventing roadway failure.

3.0 REHABILITATION PLAN AND BUDGET DEVELOPMENT

3.1 KEY ANALYSIS SET POINTS

Pavement management analysis requires user inputs in order to complete its condition forecasting and prioritization. A series of operating parameters were developed in order to develop an efficient program that is tailored to the City's needs.

Some of the highlights include:

- The pavement performance curves that are used to predict future pavement condition. Asphalt streets are classified as weak, moderate, or strong, and then assigned the appropriate pavement performance curve based on their functional classification to use in the analysis. The concept of load associated distresses does not apply to concrete streets.
- The shape of performance curves reflect the concept of deferred maintenance and salvage life. Instead of dropping to an absolute PCI value of 0 after 40 years of service, the curves are designed to become asymptotic to the age axis and have a whole life of approximately 50 to 60 years depending on pavement type. This indicates the concept that once a street deteriorates past a specific threshold – about a PCI of 20, age becomes less important in rehab selection.
- Priority ranking analysis uses prioritization for rehabilitation candidate selection. It is designed to capture as many segments in their need year based on the incremental cost of deferral. The higher the functional classification of a street, the higher priority a segment is given.

Pavement Performance Curves

The basic shape of the curves follows traditional sigmoidal performance models such as those contained in MicroPAVER and other commonly used pavement management applications. These curves were eventually loaded to the City of Dunwoody's ESA pavement management program. Curves were created for asphalt and concrete street segments. The deterioration curves are designed to integrate the pavement condition distribution performance curves for the network, with the applied rehabilitation strategies and their expected life cycle. The curves do not drop to a PCI score of 0 and have been designed to recognize the salvage value of even the worst pavements.

It is important to recognize that even though all streets fall into specific rating categories (as highlighted by the horizontal black dotted lines **in Figure 18**) and their respective rehabilitation strategies, it is not until a street falls to within a few points of the lower end of the range that it will become a critical need selected for rehabilitation. A similar set of curves that are flatter and extended to a longer life were developed for concrete streets and are contained in the City's pavement management system.

Figure 18 – Asphalt (ACP) Performance Curves

Rehabilitation Strategies and Unit Rates

The rehab strategies and unit rates used in the pavement analysis can be found on the following page. Some important parameters include:

- **Rehab Code and Activity** – The assigned identifier and name to each rehabilitation strategy. The term "Strctrl Ptch" refers to structural patching. When this term is present, additional funds have been assigned to the strategy to allow for an increased amount of preparation work and patching. The relative terms of thin, moderate and thick are used to describe the overlay thickness. This is to facilitate consistency in the naming convention, but does not imply the same material thickness has to be used for each functional classification.
- The recommended rehab activities for any given PCI range may vary due to pavement strength and functional classification. For example, an arterial between a PCI of 50 to 60 may receive a thin to moderate overlay, while a local access road may only receive a chip seal or thin overlay.
- **Unit Rates** – The rehab costs are presented on a per square yard basis for each pavement type, functional class, and rehabilitation activity combination. The rates were developed using typical national averages for similar activities and adjusted for Dunwoody's location and unique conditions. An additional burden to all costs was also added to cover City overheads, design and engineering and inspection. Costs for peripheral concrete rehab (valley gutters, inlets, approaches, etc.) have also been included.

The unit rates are based on prevailing wage costs associated with doing work in Dunwoody and thus may be higher than like agencies in different jurisdictions. The rates also assume the work is completed by contract forces. The higher unit rates are reflected in the network value and final budgets and average cost/mile for doing work in Dunwoody.

City of Dunwoody, GA
Rehabilitation Strategies and Unit Rates

Pavetype	Rehab Code	Rehab Activity	Min PCI	Critical PCI (Need Year)	Max PCI	Base Unit Rate ($/yd2)	Major Arterial Unit Rate ($/yd2)	Minor Arterial Unit Rate ($/yd2)	Collector Unit Rate ($/yd2)	Local Unit Rate ($/yd2)	Construction Activities Burden Included in Unit Rates (%)	Agency Overheads Included in Unit Rates (%)	Reset PCI	Steady State Life Cycle (Yrs)	CBA Rehab Priority (Info Only)
All	5	Routine Maintenance	85	87	100	0.00	0.00	0.00	0.00	0.00	0	0		1	
Asphalt	10	Slurry Seal / Prvnttve Mntnnce	85	87	85	3.10	3.60	3.40	3.30	3.10	30	12	85	3	1
Asphalt	20	Surface Treatment	70	73	85	5.75	6.50	6.25	6.00	5.75	30	12	88	9	2
Asphalt	23	Surface Treatment + Strctrl Ptch	70	73	85		7.25	7.00	6.50	6.25	30	12	88	9	3
Asphalt	26	Surface Treatment + Strctrl Ptch	60	63	70		7.75	7.50	7.00	6.75	30	12	88	9	4
Asphalt	30	Edge Mill + Thin Overlay (1.5 - 2.0)	60	63	70	19.75	22.75	21.75	20.75	19.75	30	12	92	17	5
Asphalt	33	Edge Mill + Thin Overlay (1.5 - 2.0) + Strctrl Ptch	60	63	70		23.75	22.75	21.75	20.75	30	12	92	17	6
Asphalt	36	Edge Mill + Thin Overlay (1.5 - 2.0) + Strctrl Ptch	50	54	60		25.00	24.00	22.75	21.75	30	12	92	17	7
Asphalt	40	EM/FWM + Moderate Overlay (2.0 - 3.0)	50	54	60	23.00	27.50	26.00	24.50	23.00	30	12	94	22	8
Asphalt	43	EM/FWM + Moderate Overlay (2.0 - 3.0) + Strctrl Ptch	50	54	60		29.25	27.50	26.00	24.50	30	12	94	22	9
Asphalt	46	EM/FWM + Moderate Overlay (2.0 - 3.0) + Strctrl Ptch	40	44	50		31.00	29.25	27.75	26.00	30	12	94	22	10
Asphalt	50	FWM + Thick Overlay (> 2.0 - 3.0)	40	44	50	26.00	32.00	30.00	28.00	26.00	30	12	96	27	11
Asphalt	53	FWM + Thick Overlay (> 2.0 - 3.0) + Strctrl Ptch	40	44	50		34.50	32.50	30.00	28.00	30	12	96	27	12
Asphalt	56	FWM + Thick Overlay (> 2.0 - 3.0) + Strctrl Ptch	25	30	40		37.00	34.50	32.50	30.00	30	12	96	27	13
Asphalt	60	Surf Recon + FWM + Strctrl Ptch + Olay	25	30	40	44.50	59.00	54.00	49.00	44.50	30	12	98	34	14
Composite	65	Surf Recon + PCC to Base + Strctrl Ptch + Olay	25	30	40	48.50	64.00	58.50	53.50	48.50	30	12	96	33	14
Asphalt	70	ACP Full Depth Reconstruction	0	15	25	64.00	73.50	70.50	67.00	64.00	30	12	100	42	15
Composite	75	Full Depth Recon + PCC to Base	0	15	25	72.00	83.00	79.00	75.50	72.00	30	12	100	42	15
Concrete	510	PCC Jnt Rehab & Crk Seal	85	87	85	7.25	8.25	8.00	7.50	7.25	30	12	83	2	1
Concrete	520	PCC Localized Rehab	70	73	85	15.50	18.50	17.50	16.50	15.50	30	12	80	6	2
Concrete	523	PCC Localized Rehab + Grind	0	0	0		21.50	20.25	19.25	18.00	30	12	80	10	0
Concrete	530	PCC Slight Pnl Rplcmnt (<10%)	60	63	70	31.00	37.00	35.00	33.00	31.00	30	12	88	30	3
Concrete	533	PCC Slight Pnl Rplcmnt (<10%) + Grind	60	63	70		41.50	39.50	37.00	35.00	30	12	88	30	4
Concrete	540	PCC Moderate Pnl Rplcmnt (< 20%)	50	54	60	48.00	59.00	55.50	51.50	48.00	30	12	90	40	5
Concrete	543	PCC Moderate Pnl Rplcmnt (< 20%) + Grind	50	54	60		65.50	61.00	57.00	53.00	30	12	90	40	6
Concrete	550	PCC Extensive Pnl Rplcmnt (<33%)	40	44	50	67.50	89.50	81.50	74.50	67.50	30	12	94	53	8
Concrete	553	PCC Extensive Pnl Rplcmnt (<33%) + Grind	40	44	50		99.00	91.00	82.50	75.00	30	12	94	53	9
Concrete	560	PCC Partial Reconstruction	25	30	40	103.00	146.00	131.00	116.00	103.00	30	12	96	66	10
Concrete	570	PCC Full Depth Reconstruction	0	15	25	184.00	280.00	245.00	213.00	184.00	30	12	100	84	11

Unit rates increase slightly between functional classes to reflect increased costs in pavement thickness, traffic control, and striping, etc. Structural patching adds a nominal amount to the base cost to provide sufficient funds to complete localized repairs to the street segment in order to remove failed areas.

- **Min PCI, Critical PCI, and Max PCI –** These define the Pavement Condition Index (PCI) and Structural Index range applicable to the rehab selection. The Critical PCI defines when a segment is in its need year and is deemed to be critical, otherwise if deferred, the street declines in PCI past the point which the rehabilitation is no longer appropriate. Generally the Critical PCI falls 2 to 4 points higher than the minimum PCI applicable for each rehab activity.

Figures 19 graphically present the application of pavement rehabilitations for asphalt streets by PCI. The Rehab numbers are simply placeholders that separate each rehabilitation project. For example, Rehab 46 is a Moderate Olay (>2.0 - 3.0). The DEFINITIONS tab of the analysis results contains a full list of acronyms used.

Unit rates increase slightly between functional classes to reflect increase costs in pavement thickness, traffic control, and striping.

Figure 19 – Asphalt (ACP) Rehabilitation Strategies

Selection and Prioritization of Rehab Candidates

The City's pavement management program incorporates a series of user defined values to prioritize and select the street segments for rehabilitation. The rehab selection order is not worst first, but rather designed to capture as many segments in their need year based on the incremental cost of rehab deferral. A Street is considered to be in its need year when it has reached its maximum service life and any further deferral would require a heavier, and hence, costlier rehabilitation. The rehab program has been designed to maximize the increased service life for each rehabilitation dollar spent on a segment.

Other factors included in the prioritization process focus on:

- **Need Year** – streets are only selected when they have expended their service life and are optimal for rehab selection.
- **Functional Classification** – generally priority is given to higher functional classifications as they provide greater benefits to a larger group of users. For Dunwoody, preference was given to the local access roads as they have the lowest average PCI score, followed by arterials then collectors.
- **Pavement Strength** – weaker streets are prioritized higher than stronger ones as they deteriorate faster.
- **Pavement Type** – asphalt streets are given preference over concrete as they deteriorate faster.
- **Area** – a very slight increase in priority is given to larger projects over smaller ones.

The net result is a program that favors thick overlays, followed by partial reconstruction projects then full reconstruction projects (more for safety reasons than cost-benefit). These are then followed by surface treatments and lastly by moderate to thin overlays.

3.2 FIX ALL AND ANNUAL ESTIMATES

Three different approaches may be taken to identify and confirm the amount of funds the city needs to set aside each year to maintain the roadway network at its current condition. All three are completed externally to the pavement management system and are simply used to validate the final results.

Option 1 – Estimated Life Cycle Cost Based on Network Value

A ballpark value for the annual street maintenance budget may be quickly determined by taking the total value of Dunwoody's roadway network, estimated at $119M, and dividing that by the ultimate life of a roadway – approximated to be 50 years for asphalt and 100 years for concrete. By this method, the annual budget is estimated at $2,384,000.

Rehabilitation Estimate Based on Network Valuation

Pavement Type	Network Valuation ($)	Ultimate Life Span (yrs)	Life Cycle Cost ($/Yr)
Asphalt Network	119,163,000	50	2,383,000
Concrete Network	111,000	100	1,000
City of Dunwoody, GA Network Totals:	**119,274,000**		**2,384,000**

Option 2 – Estimated Life Cycle Cost Based on Current Condition

A second method to validate the annual budget is to identify the average network PCI and associated rehabilitation requirements, and then estimate the number of miles required to be rehabilitated each year based on a typical life cycle for that rehabilitation activity. For Dunwoody, the average PCI for asphalt roads respectively is 67, which places the Dunwoody in the Edge Mill + Thin Overlay range, at an average cost of $9.49/yd^2$. Based on this estimate the city needs to spend approximately $1,395,269/year to maintain the current condition average.

Rehabilitation Estimate Based on Network Average Condition

Pavement Type	Pavement Condition Index (PCI)	Rehab Activity	Average Rehab Life Cycle (Yrs)	Miles to do Each Year	Blended Unit Rate ($/yd2)	Average Cost/Mile	Life Cycle Cost ($/Yr)
Asphalt Network	67	Edge Mill + Thin Overlay (1.5 - 2.0)	17	9.0	9.49	154,500	1,392,195
Concrete Network	80	PCC Localized Rehab	6	0.0	14.25	234,000	3,073
City of Dunwoody, GA Network Totals:							**1,395,269**

Option 3 – Estimated Life Cycle Cost Based on Network Deficiency

The third methodology to confirm the required amount of annual funding is to identify the current network deficiency, that is the amount required to rehabilitate all streets in the network assuming unlimited funding, and then divide by the typical life cycle of each rehabilitation activity. This is referred to as the

Fix All Estimate and Life Cycle Cost. The rehab strategies listed in the table are generic in nature and not necessarily the final set that was applied to Dunwoody. For Dunwoody, the Fix All Estimate for the network deficiency is approximately $25M and the Life Cycle Cost is $1.36M/year, broken down as follows:

City of Dunwoody, GA

Rehabilitation Estimate Based on Current Network Deficiency and Life Cycle Cost

Rehab Code	Rehab Activity	Network Total ($)	% of Total	Major Arterial	Minor Arterial	Collector	Life Cycle (Yrs)	Life Cycle Cost ($/Yr)
10	Slurry Seal / Prvnttve Mntnnce	0	0.0	0	0	0	1	0
20	Surface Treatment	3,497,200	13.9	0	765,490	774,560	9	388,600
23	Surface Treatment + Strctrl Ptch	177,200	0.7	0	30,620	146,570	9	19,700
26	Surface Treatment + Strctrl Ptch	14,700	0.1	0	0	0	9	1,600
30	Edge Mill + Thin Overlay (1.5 - 2.0)	2,822,800	11.2	0	491,210	869,900	17	166,000
33	Edge Mill + Thin Overlay (1.5 - 2.0) + Strctrl Ptch	160,600	0.6	0	89,570	0	17	9,400
36	Edge Mill + Thin Overlay (1.5 - 2.0) + Strctrl Ptch	127,500	0.5	0	0	25,640	17	7,500
40	EM/FWM + Moderate Overlay (2.0 - 3.0)	9,828,300	39.1	0	1,164,480	904,490	22	446,700
43	EM/FWM + Moderate Overlay (2.0 - 3.0) + Strctrl Ptch	245,500	1.0	0	0	135,290	22	11,200
46	EM/FWM + Moderate Overlay (2.0 - 3.0) + Strctrl Ptch	0	0.0	0	0	0	22	0
50	FWM + Thick Overlay (> 2.0 - 3.0)	7,426,600	29.6	0	426,820	0	27	275,100
53	FWM + Thick Overlay (> 2.0 - 3.0) + Strctrl Ptch	189,600	0.8	0	0	67,720	27	7,000
56	FWM + Thick Overlay (> 2.0 - 3.0) + Strctrl Ptch	617,300	2.5	0	0	0	27	22,900
60	Surf Recon + FWM + Strctrl Ptch + Olay	0	0.0	0	0	0	34	0
65	Surf Recon + PCC to Base + Strctrl Ptch + Olay	0	0.0	0	0	0	33	0
70	ACP Full Depth Reconstruction	0	0.0	0	0	0	42	0
75	Full Depth Recon + PCC to Base	0	0.0	0	0	0	42	0
	Total Asphalt and Composite Network:	**25,107,300**	**100.0**	**0**	**2,968,190**	**2,924,170**		**1,355,700**
510	PCC Jnt Rehab & Crk Seal	0	0.0	0	0	0	1	0
520	PCC Localized Rehab	0	0.0	0	0	0	6	0
523	PCC Localized Rehab + Grind	0	0.0	0	0	0	10	0
530	PCC Slight Pnl Rplcmnt (<10%)	0	0.0	0	0	0	30	0
533	PCC Slight Pnl Rplcmnt (<10%) + Grind	0	0.0	0	0	0	30	0
540	PCC Moderate Pnl Rplcmnt (< 20%)	0	0.0	0	0	0	40	0
543	PCC Moderate Pnl Rplcmnt (< 20%) + Grind	0	0.0	0	0	0	40	0
550	PCC Extensive Pnl Rplcmnt (<33%)	0	0.0	0	0	0	53	0
553	PCC Extensive Pnl Rplcmnt (<33%) + Grind	0	0.0	0	0	0	53	0
560	PCC Partial Reconstruction	0	0.0	0	0	0	66	0
570	PCC Full Depth Reconstruction	0	0.0	0	0	0	84	0
	Total Concrete Network:	**0**	**0.0**	**0**	**0**	**0**		**0**
	City of Dunwoody, GA Network Totals:	**25,107,300**		**0**	**2,968,190**	**2,924,170**		**1,355,700**

3.3 NETWORK BUDGET ANALYSIS MODELS

An analysis containing a total of 11 profile budget runs ($500K through $5.0M per year) plus Unlimited and Do Nothing options was prepared for Dunwoody.

The analysis results are summarized below:

- **Unlimited –** The Unlimited (or Fix All) budget assumes each street is rehabilitated with unlimited funds available. The idea is to identify the upper limit of spending the City would require without any constraints on budgets.
- **Do Nothing –** This option identifies the effect of spending no capital for 5 years.
- **Recommended Budget –** The recommended budget for Dunwoody is 3.52M/yr and results in a PCI increase to 73 while reducing the backlog to 15%
- **Backlog Control Budget –** This identifies a budget of $3.52M designed to increase the PCI to 73 while maintaining a backlog of 15%.
- **Dunwoody Budget –** This budget of $3.1M will increase the PCI to 72 while holding the backlog at a maximum of 15%.
- **Maintain Current Backlog –** The budget required to maintain the City's existing backlog of 19% is on the order of $2.78M.
- **Steady State PCI -** The Steady State PCI budget is the minimum funds required to maintain the City's current PCI average of 67. This can be accomplished with as little as $1.9M, however the City will experience an increase in backlog to 24%.
- **PCI Control Budget –** This budget is the minimum requirement for the City to maintain PCI conditions above a minimum agreed upon service level of 65. This budget is $1.4M but will dramatically inflate the existing backlog to an unmanageable 28%.

The results of the analysis are also summarized in **Figure 20** below. The X-axis highlights the annual budget, while the Y-axis plots the 5 Year Post Rehab Network Average PCI value. The diagonal blue line is the results of the pavement analysis (the Dunwoody Profile). As can be seen from the plot, the Dunwoody budget of $3.1M per year with (shown in solid green) would increase the network PCI to 72 and reduce the backlog to 15%. A PCI control budget of $1.4M per year would slightly lower the network PCI to 65, and the backlog would increase to an unmanageable 28%. A steady state budget of $1.98M per year would maintain the network PCI at 67, with a 24% backlog. In order to lower the backlog to 15%, a minimum annual budget $3.52M would be required.

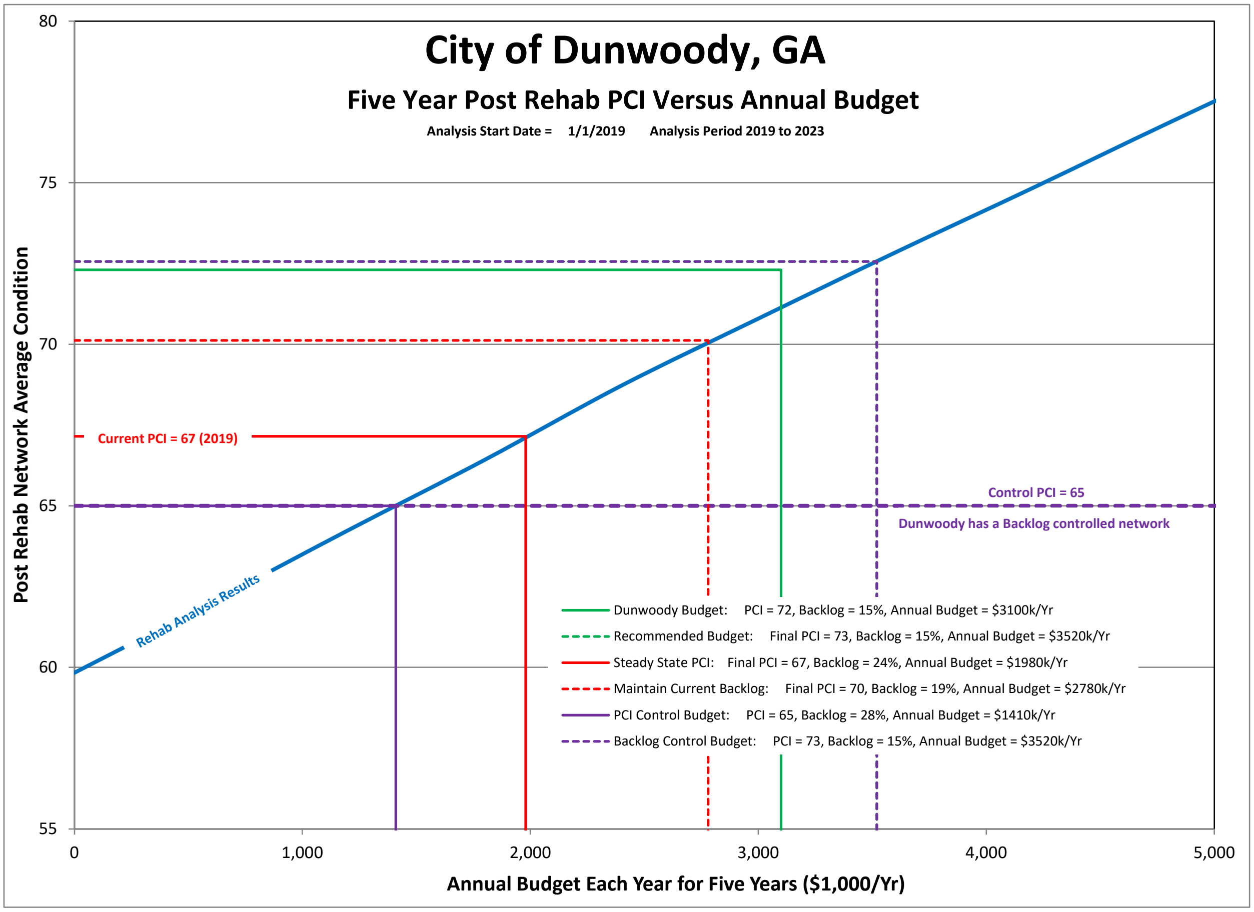

Figure 20 – 5 Year Post Rehab Network PCI Analysis Results

Figure 21 presents the resultant network backlog against annual budget. Similar to Figure 20, but instead of plotting the average PCI score, the blue diagonal line represents the total backlog after 5 years (the lower the backlog the better, with a maximum of 12% recommended). A backlog control budget of $3.52M per year would reduce the backlog to 15% and increase the PCI to 73. The steady state budget of $1.98M per year would increase the backlog to 24% and maintain the PCI at 67. The City of Dunwoody budget of $3.1M per year (shown in the solid green) would maintain the backlog at 15% and would increase the PCI to 72.

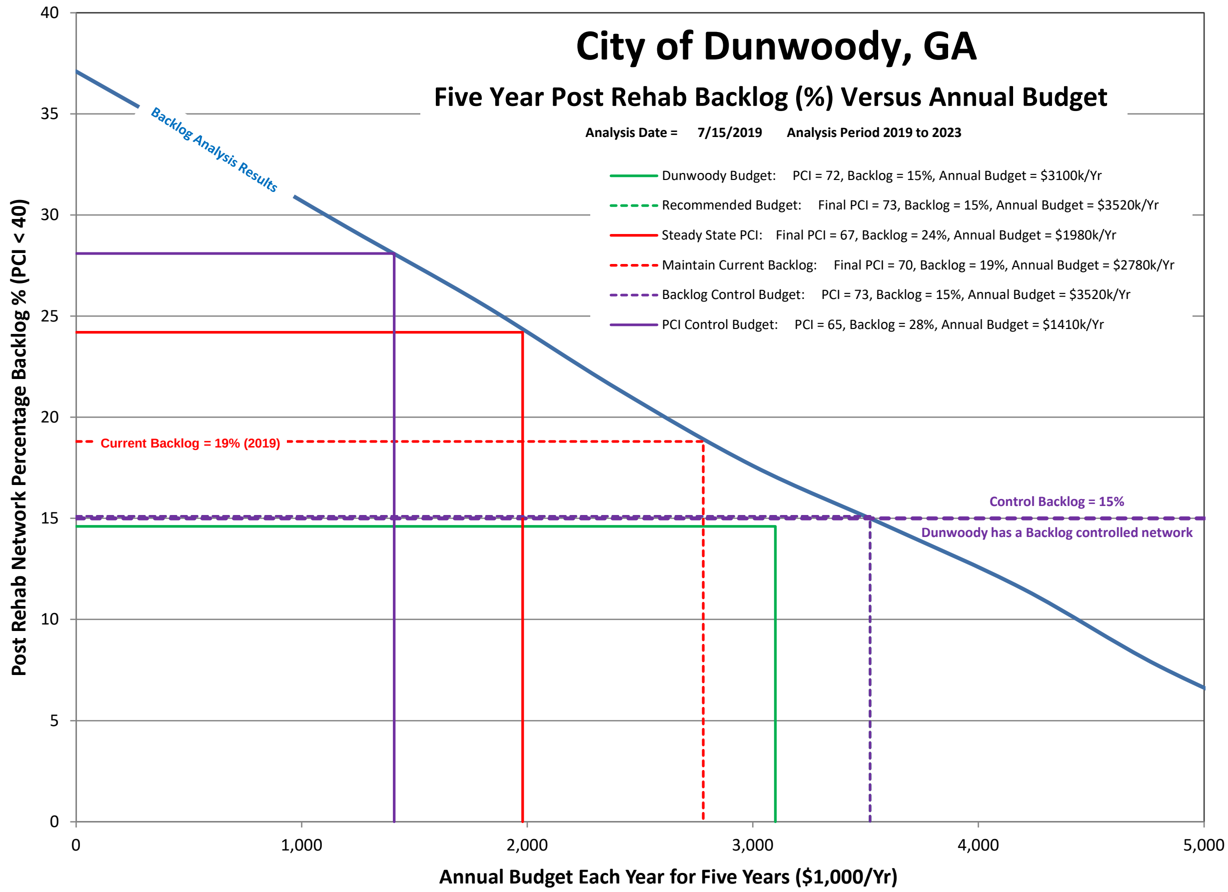

Figure 21 – 5 Year Post Rehab Network Backlog Results

Figure 22 presents the analysis results on an annual basis. This shows that if the budget falls below $1.98M/year, over time the overall condition of the roads will deteriorate.

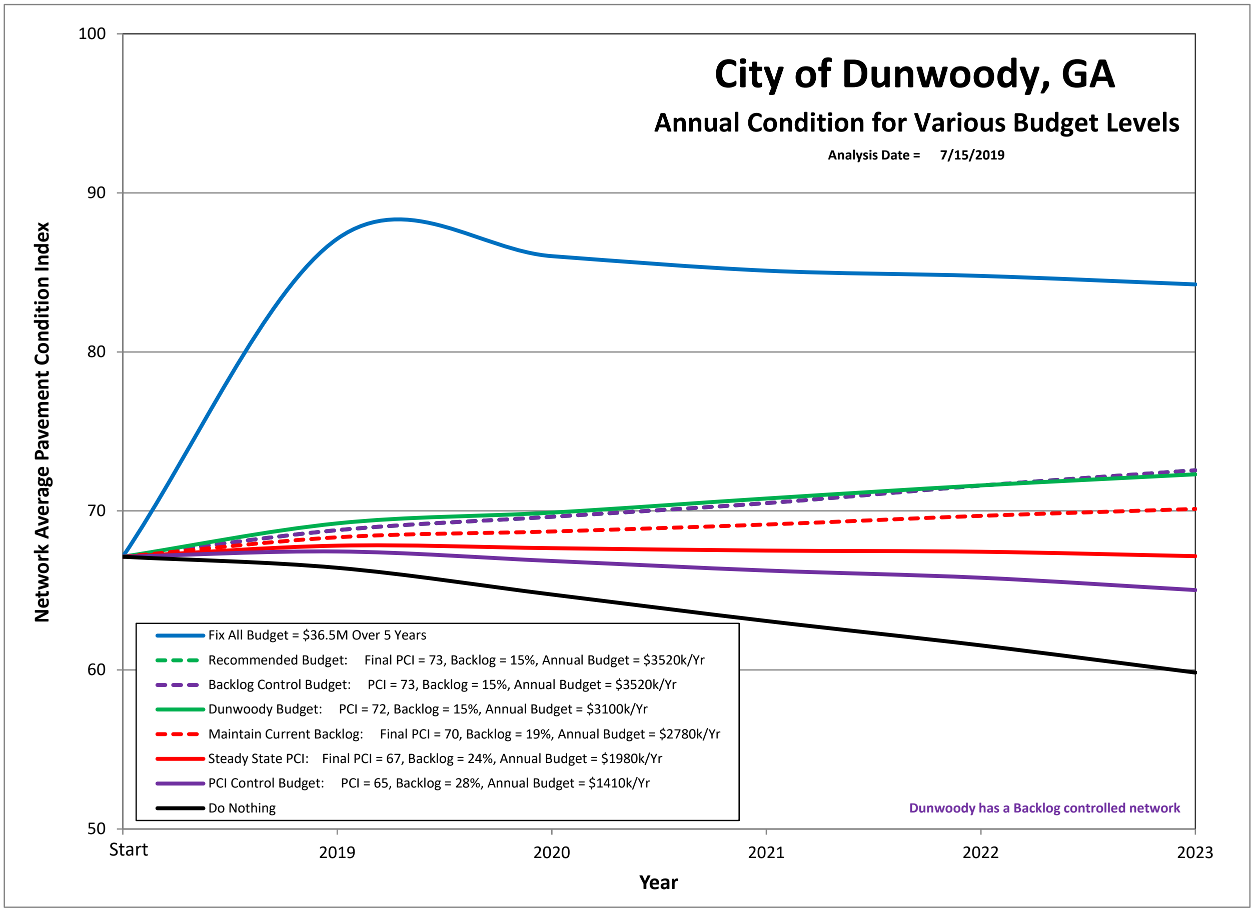

Figure 22 – 5 Year Annual PCI

3.4 DUNWOODY COMPARISONS TO OTHER AGENCIES

The following table presents the steady state versus actual funding levels of various agencies that use similar reporting and analysis software. The list is by no means representing all agencies that use a pavement management system, but rather is a sampling of what other agencies are doing.

Agency Comparison

Agency	State	Year	Mileage (mi)	PCI	Backlog	Controlling Budget ($M/yr)	Controlling Budget Rate ($/mi)	Actual Funding ($M/yr)	Actual Funding Rate ($/mi)	Funding Ratio %	Network Index	Comments
Agency FM	TX	2016	315	81	1.5%	3.50	11,000	2.88	9,000	82	80	Excellent PCI and backlog
Agency CB	CA	2016	315	79	1.0%	3.50	11,000	3.50	11,000	100	78	Excellent PCI and backlog
Agency BH	CA	2016	107	78	2%	1.25	12,000	2.60	24,000	200	76	Excellent PCI and backlog
Agency TC	TX	2018	167	77	1%	3.73	22,000	2.85	17,000	77	76	Very Good PCI, excellent backlog
Agency E	TX	2018	137	76	1%	1.27	9,000	0.96	7,000	78	76	Very Good PCI and Excellent backlog
Agency B	OR	2017	220	76	1%	3.40	15,000	3.20	15,000	100	75	Excellent backlog
Agency MI	WA	2016	118	75	1%	1.75	15,000	0.78	7,000	47	74	Good PCI and low backlog
Agency GI	NE	2016	347	74	0%	2.70	8,000	2.50	7,000	88	74	Very Good PCI, no backlog
Agency C	CA	2018	141	74	2%	2.40	17,000	2.00	14,000	82	73	Excellent Backlog
Agency K	TX	2016	196	76	5%	1.35	7,000	1.50	8,000	114	72	Low Backlog, solid PCI
Agency P	AZ	2017	626	72	1%	6.80	11,000	5.70	9,000	84	71	Newer Network, solid PCI and backlog
Agency BR	MO	2016	87	72	1%	0.88	10,000	1.34	15,000	115	71	Well funded, solid PCI, excellent backlog
Agency PL	TX	2018	391	72	2%	4.60	12,000	2.00	5,000	42	71	Solid PCI, excellent backlog
Agency GP	TX	2016	216	73	4%	1.35	6,000	3.50	16,000	267	70	Well funded, excellent PCI and low backlog
Agency ST	WA	2017	75	70	1%	1.16	15,500	0.92	12,300	79	69	solid PCI, Excellent backlog
Agency CC	MO	2016	82	71	4%	0.90	11,000	1.45	18,000	164	68	Good PCI and Excellent Backlog
Agency AC	CO	2017	504	71	4%	5.91	12,000	7.00	14,000	117	68	Excellent backlog and very solid OCI
Agency H	TX	2017	138	69	2%	1.42	10,000	1.40	10,000	100	68	Excellent backlog and PCI
Agency BA	OK	2016	509	70	4%	4.40	9,000	6.75	13,000	144	67	Fully funded, excellent backlog
Agency LY	CO	2016	114	69	3%	1.30	11,000	0.65	6,000	55	67	Underfunded, but solid backlog and PCI
Agency DM	WA	2016	91	69	3%	1.20	13,000	1.10	12,000	92	67	Under funded,Solid PCI, excellent backlog
Agency PO	WA	2016	66	71	6%	1.40	21,000	0.50	8,000	38	67	Good PCI and Backlog, funding levels under review
Agency SV	WA	2017	449	71	6%	6.30	14,000	3.20	7,000	50	67	Good PCI ,Excellent Backlog, Underfunded
Agency SF	MO	2018	792	68	2%	2.60	3,000	3.80	5,000	167	67	Good PCI & Excellent backlog
Agency SS	GA	2018	312	71	7%	4.00	13,000	3.50	11,000	85	66	Very Good PCI and Excellent backlog
Agency B	WA	2016	302	70	6%	3.50	12,000	3.45	11,000	92	66	Solid backlog and PCI
Agency PO	WA	2016	59	70	6%	1.42	24,000	0.50	8,000	33	66	underfunded and very solid backlog
Agency BH	WA	2016	302	70	6%	2.75	9,000	2.75	9,000	100	66	Solid backlog and PCI, funding under review
Agency LAC	NM	2016	102	69	5%	1.70	17,000	3.95	39,000	229	66	Fully Funded
Agency FW	TX	2018	175	67	3%	1.80	10,000	0.40	2,000	20	65	Solid PCI and Excellent Backlog but underfunded
Agency PW	CO	2018	95	66	6%	1.10	12,000	0.50	5,000	42	62	Above Average PCI and Good backlog
Agency DAC	NM	2018	534	66	7%	4.72	9,000	3.50	7,000	78	61	Above Average PCI and Good backlog
Agency FG	OR	2018	71	67	9%	1.49	21,000	0.45	6,000	29	61	Solid backlog and PCI, underfunded
Agency B	MO	2018	59	66	8%	0.72	12,000	0.98	16,000	133	61	Solid PCI and backlog
Agency SV	AZ	2018	188	64	7%	3.29	18,000	1.00	5,000	28	60	Average PCI and Good Backlog
Agency T	CA	2018	326	65	9%	7.38	23,000	8.20	25,000	109	59	Average PCI and Good Backlog
Agency B	WA	2018	137	63	8%	3.47	25,000	1.00	7,000	28	58	Average PCI, Good backlog, low funding
Agency LO	CO	2016	105	64	11%	1.85	18,000	1.35	13,000	72	57	Well Funded, working to increase PCI and decrease backlog
Agency FH	AZ	2018	163	60	5%	3.60	22,000	2.00	12,000	55	57	Underfunded, Average PCI, Very Good Backlog
Agency Y	CA	2018	197	64	12%	2.12	11,000	1.50	8,000	73	56	Average PCI, Underfunded, Solid Backlog
Agency LC	NM	2016	468	65	14%	2.85	6,000	4.00	9,000	150	56	increasing backlog,
Agency DW	GA	2018	153	67	17%	2.80	18,000	2.25	15,000	83	55	Critical backlog, above average PCI
Agency BH	GA	2016	120	66	16%	1.25	10,000	1.40	12,000	120	55	Working to control Backlog
Agency PC	GA	2018	193	61	10%	2.80	15,000	5.00	26,000	173	55	Average PCI, Well Funded
Agency Y	AZ	2018	409	61	10%	8.00	20,000	3.70	9,000	45	55	underfunded, average PCI
Agency PC	OK	2018	241	64	16%	3.09	13,000	3.09	13,000	100	54	Average PCI, Backlog Concerns
Agency S	CA	2017	122	62	14%	2.48	13,000	1.58	13,000	100	53	underfunded, solid PCI
Agency R	CA	2017	746	61	13%	24.00	32,000	13.50	18,000	56	53	underfunded, sharp B/L Increase expected
Agency DN	TX	2016	426	65	20%	10.50	25,000	6.67	16,000	64	52	Backlog a concern, Underfunded
Agency K	MO	2016	100	59	15%	1.80	18,000	1.00	10,000	56	50	Backlog concern
Agency R	NH	2016	150	58	16%	2.77	18,000	2.00	13,000	72	49	Backlog a concern
Agency LBC	CA	2017	1000	58	21%	53.50	54,000	36.40	36,000	67	46	Backlog concern and average PCI
Agency L	CA	2018	634	55	21%	10.00	16,000	9.00	14,000	88	43	Backlog concern and average PCI
						Average:	**17,100**					

In comparison to other agencies, Dunwoody's controlling budget requirement of approximately $2.8M/year or $18,000/mile is above the sample average of $17,100.

Figure 23 illustrates the overall network health of various agencies by developing a relative scoring system (Network Index) that compares the Network average PCI and the agency's Backlog (Very Poor and Poor roadways). An agency with a PCI of 100 and no backlog would score a perfect Network Index of 100. A very well managed network would score above 71, while one in healthy condition would fall between 58 and 71, representing a PCI score of 65 with no more than 10% backlog up to a PCI of 75 with only 5% backlog. The minimum long-term sustainable Network Index is 51 representing a PCI of 60 with 15% backlog.

Dunwoody's current Network Index is a 66, placing it in the Minimum Network Index Zone (shown as the blue square).

Figure 23 – Network Index

3.5 SELECTION SUMMARY AND POST REHABILITATION CONDITION

The following figure (**Figure 24**) compares the current network condition distribution (red) against what the 5-year post rehabilitation distribution would be at with a budget of $3.1M/year (blue). As can be seen in the plot, the Dunwoody budget meets all three metrics of qualitative assessment.

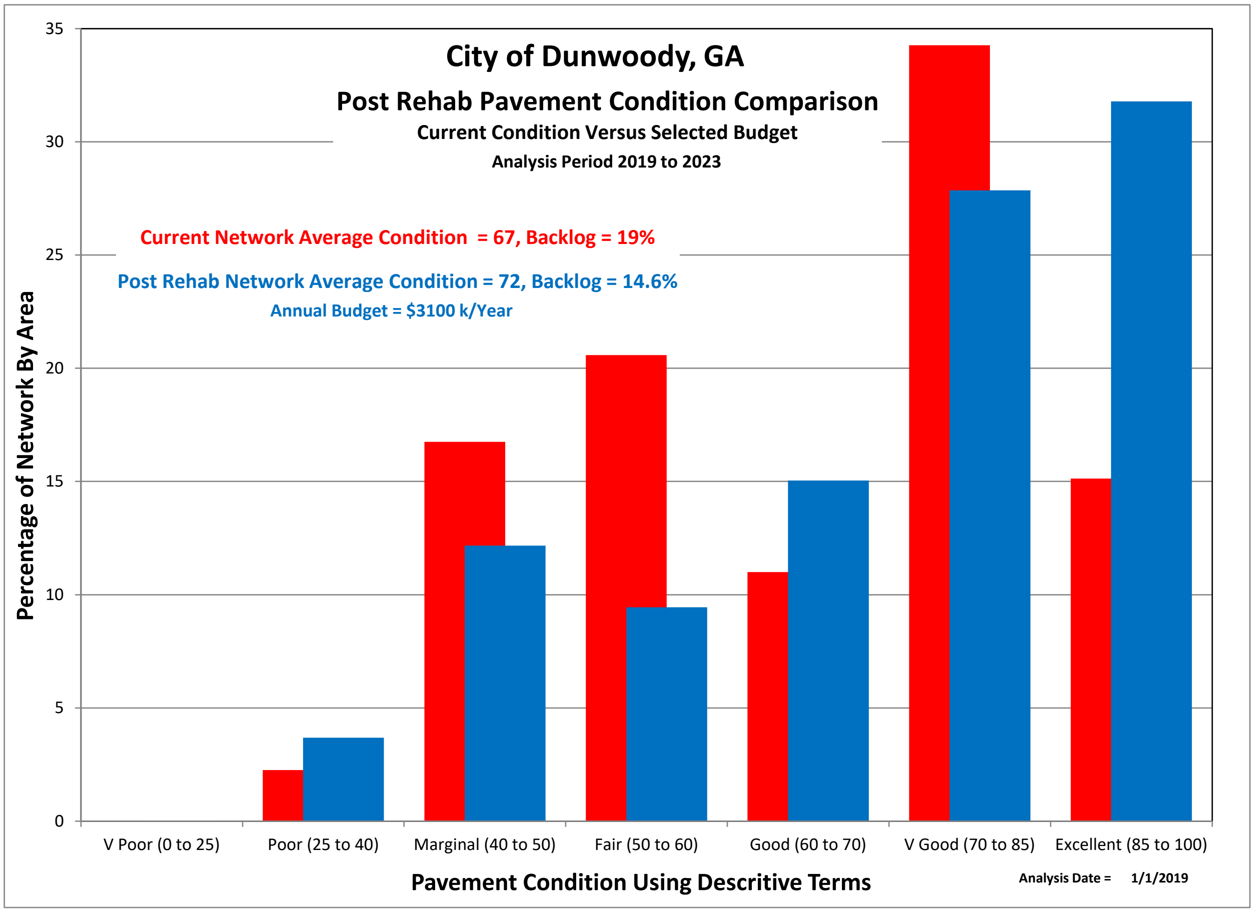

Figure 24 – Five-Year Post Rehabilitation Condition Distribution

Three metrics are used to evaluate the quality of a roadway network, they are:
Average Condition – should be between 60 and 65 at a minimum
Percentage of Backlog – target 12%, should be less than 15%, must be less than 20%
Percentage of Streets Rated as Excellent – should be greater than 15%

Figures 25 through 30 present the current Dunwoody, recommended budget and backlog control budget network rehabilitation plan by year and activity. Electronic versions of these maps are appended to this report.

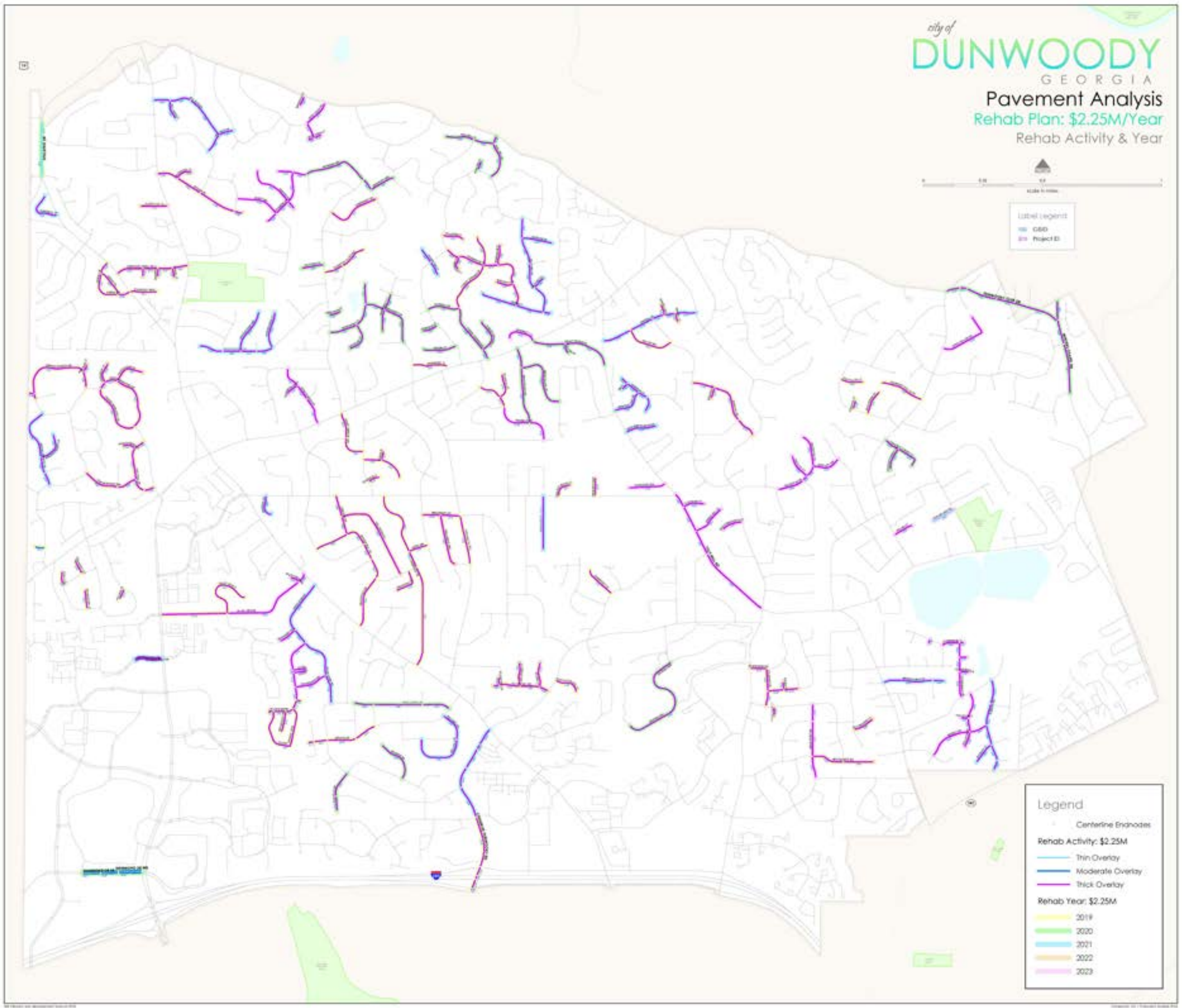

Figure 25 – $3.1M/Year Rehabilitation Plan by Activity and Year

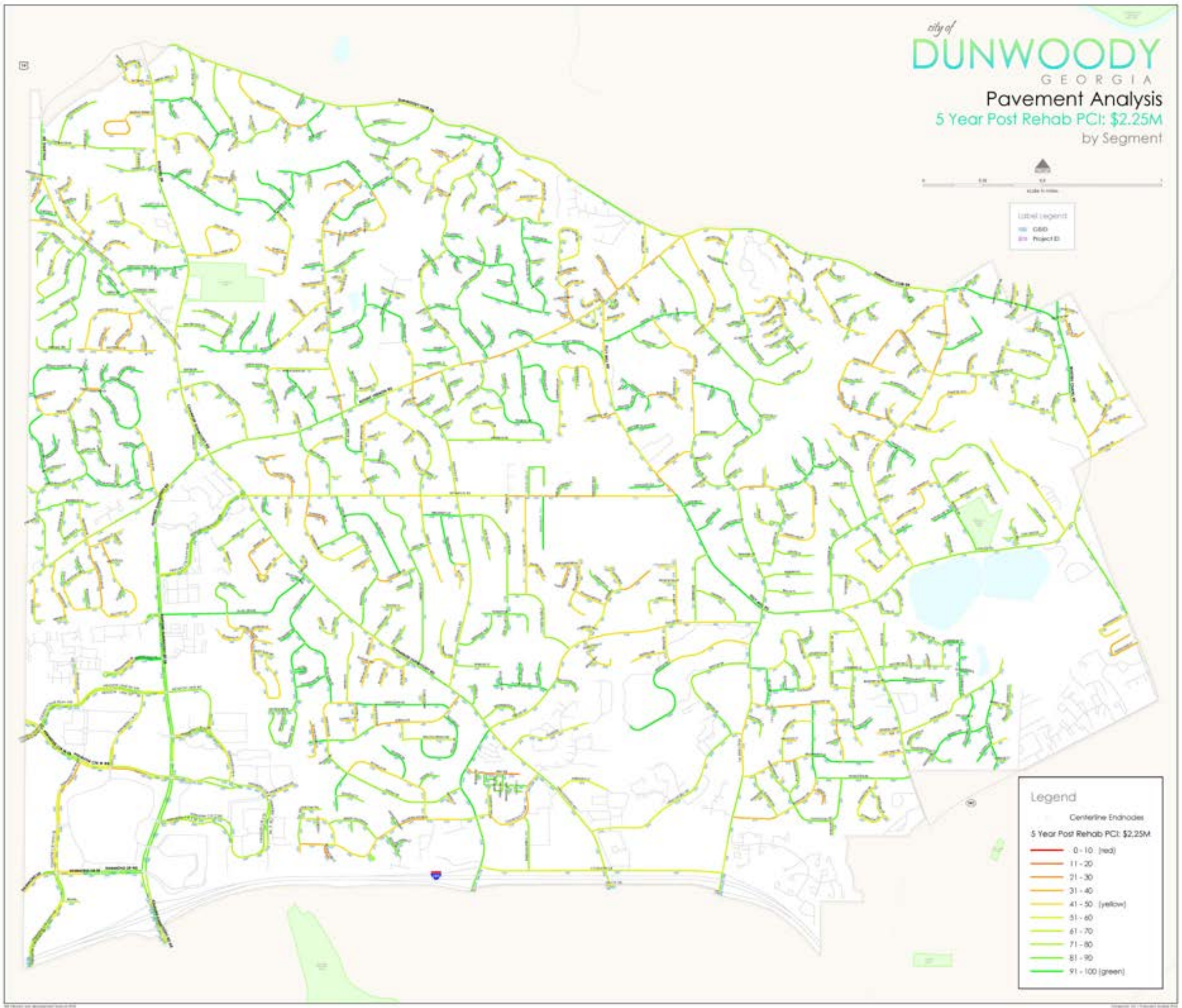

Figure 26 – $3.1M/Year Post Rehabilitation PCI by Segment

3.6 TRUE COST OF UNDERFUNDING OF A ROADWAY NETWORK

Funding of roadway rehabilitation is an exercise in identifying the balance between available funding and the desired level of service that is right for each agency. There are no hard rules for what is the definitive level of funding as this is a decision for local elected officials, based on their priorities and practices.

However, the true costs of over and underfunding must be presented in order to provide decision makers with all the information available to base the decisions upon. Dunwoody has a considerable investment in their paved roadway network with a combined replacement value (just for the streets, not right of way) exceeding $119M. Spreading this cost over a 50 to 100 year period (the expected ultimate life of a roadway) means that an annual investment on the order of $1.39M per year would be required – not including the cost of maintenance, deterioration ,repair curbing, drainage, tree roots, sidewalks or ADA ramps.

Government Accounting Standards Board Statement 34 requires that agencies who collect taxes (local, business, property or gas taxes) for the purpose of maintaining long term infrastructure assets (such as roads) be good stewards of those assets by either accounting for them financially on the City's balance sheet, or implement a methodology to manage and fund them to a locally defined level of service.

The condition of a roadway network may be equated to equity in a depreciating asset. Regular payments to that asset must be made in order to maintain the equity at a constant level. Should those payments fall short, the equity must eventually be replaced through a large influx of capital in order to make the investment whole again. Roadway networks are no different. Long term underfunding of rehabilitation and maintenance is the direct equivalent of removing equity from an asset – eventually it must be repaid through total reconstruction. The following table compares the real cost of the various budgets against the Do Nothing and Steady State options.

City of Dunwoody, GA
Equity Removal Summary

Starting PCI:	67				
Five Year Post Rehab Fix All PCI:	84				
Fix All PCI Increase:	17				
Five Year Fix All Total Cost ($):	36,470,000				
Cost Per PCI Point (Total Cost / PCI Increase, $/pt)	2,130,000				
Equity Removal Based On PCI Restoration					**For PCI Controlled Agencies**
Model:	**Do Nothing**	**$600k Annual**	**$1200k Annual**	**$1800k Annual**	**Steady State**
Annual Budget ($k/Year):	0	600	1200	1800	1980
Starting PCI	67	67	67	67	67
Final PCI	60	62	64	66	67
PCI Drop:	7	5	3	1	0
Cost to Replace Equity (PCI Drop X $/Pt, $):	15,513,000	10,880,000	6,127,000	1,478,000	0
5 Year Budget Expenditure ($):	0	3,000,000	6,000,000	9,000,000	9,900,000
Total 5 Year Cost ($):	15,513,000	13,880,000	12,127,000	10,478,000	9,900,000
Cost Over Steady State Budget ($):	5,613,000	3,980,000	2,227,000	578,000	0
Additional Annual Cost Over Steady State ($/year):	**1,122,600**	**796,000**	**445,400**	**115,600**	**0**

The five-year cost to fix all the streets in the network is approximately $36.47M and would boost the network average to an 84. It will never hit 100 as there are numerous segments in the 85 to 100 range that do not need rehabilitating. This equates to approximately $2.13M required to raise the network average a single point and may be considered the rate to replace equity that is removed through underfunding.

The recommended budget is $3.52M/Year.

3.7 NETWORK RECOMMENDATIONS AND COMMENTS

The following recommendations are presented to Dunwoody as an output from the pavement analysis, and must be read in conjunction with the attached reports.

1. **Dunwoody should adopt the recommended budget of 3.52M/Year increasing the PCI to 73 while keeping the backlog at or below 15%.**

   The backlog control budget is the recommended budget.

2. The full suite of proposed rehabilitation strategies and unit rates should be reviewed annually as these can have considerable effects on the final program.
3. Budget analysis includes 2% inflation of cost of doing business. Any deviations from that amount will need to be reflected in budget adjustments by the City.
4. No allowance has been made for network growth. As the City expands or increases the amount of paved roads, increased budgets will be required.
5. No allowance has been made for routine maintenance activities such as asphalt crack sealing, pothole filling, sweeping, striping or patching within the budget runs and analysis. These costs are assumed to be outside the pavement management costs.
6. The City should resurvey their streets every few years to update the condition data and rehabilitation program.

Appendix A

Street Inventory and Condition Summary

Appendix B

Street Inventory and Condition Summary sorted by Supersegment

Appendix C

$3.1M/Year Rehabilitation Plans by Segment

Appendix D

$3.1M/Year Rehabilitation Plans by Year