

Implementing a Pavement Management System for Low Volume Roads: Challenges and  
Successes

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## **ABSTRACT**

The United States Federal Lands Highway Program (FLHP) provides engineering services for planning, design, construction, rehabilitation, and preservation of the roads and bridges providing access to federally-owned lands. The Federal Highway Administration (FHWA) administers the FLHP of Fish and Wildlife system roads, Forest Highway system roads, Parkways and Park roads, and other Federal lands roads.

As part of a pilot project under the Asset Management initiative, the Eastern Federal Lands Highway Division (EFLHD) retained Stantec Consulting (Stantec) to investigate the feasibility of implementing a pavement management system for the U.S Fish & Wildlife Services Regions 2 & 6 refuge roads, where the majority of the roads were low volume roads consisting of either gravel or native/primitive surfaces. The project team had previously implemented pavement management systems for other federal land road networks, including the National Park Service and the Forest Service. However, this was their first implementation of a pavement management system for unsurfaced pavement structures.

This paper presents some of the challenges of developing a pavement management system for a large network of low volume roads with unpaved surfaces, including data collection and assembly, development of engineering models, and dissemination of information back to the refuges. The paper also presents successes throughout the project, including the development of short and long-term budget forecasts and awareness of further data collection needs.

A network-level pavement condition survey had previously been conducted on all the road segments. Initial prediction models and decision trees were developed based on engineering experience and input from the project team. Two separate ground truth trips covering 10 refuges in five States was conducted to verify the models and proposed treatment options. It was found that the performance of unpaved roads was dramatically influenced by precipitation and maintenance practices. As such, the team developed maintenance and rehabilitation decision models based on recommended best practices for routine maintenance for different environmental zones based on field observations.

## **Introduction**

The Federal Lands Highway Program (FLHP) provides engineering services for planning, design, construction, rehabilitation, and preservation of the highways and bridges providing access to federally-owned lands. Federal Highway Administration (FHWA) administers the FLHP of Fish and Wildlife system roads, Forest Highway system roads, Parkways and Park roads, Indian Reservation roads, Defense access roads, and other Federal lands roads.

As part of the Asset Management initiative in Federal Lands Highway Division of FHWA, the management systems services assisted the US Fish and Wildlife Services (FWS) in conducting a pavement management system (PMS) pilot project. The FWS PMS Pilot Project Team, herein referred to as the Project Team, was lead by the Eastern Federal Lands Highway Division (EFLHD) and also consisted of representation from Central Federal Lands Highway Division (CFLHD), FWS Regional Coordinators, and Stantec Consulting (Stantec).

FLHP and Stantec have worked together on previous PMS initiatives for other federally-owned lands, including the implementation of Stantec's Highway Pavement Management Application (HPMA) for the National Park Service (NPS) and United States Forest Service (USFS). The HPMA was also used in this pilot project.

One of the unique challenges of working with the FWS road network is that the majority of the roads are low volume roads with either gravel or native/primitive surfaces, and very few roads consist of the traditional "paved" road surfaces such as asphalt and concrete.

This paper presents some of the challenges of developing a pavement management system for a large network of low volume roads with unpaved surfaces, including data collection and assembly, development of engineering models, and dissemination of information back to the refuges. The paper also presents successes throughout the project, including the development of short and long-term budget forecasts and awareness of further data collection needs.

## **PROJECT SCOPE**

The pilot study was limited to refuges with available data in the Southwest Region (Region 2) and Mountain Prairie Region (Region 6) of the FWS network (see FIGURE 1), which included approximately 4,600 miles (7,400 kilometres) of roads. The network is a large discontinuous pavement network of primarily low volume roads. It is spread across the West and Midwest United States, with different climatic conditions, subgrade soil conditions, and traffic levels.

The scope of FWS PMS Pilot Project was divided into two main phases:

- Phase 1
  - Review existing FWS database
  - Develop and populate HPMA database
  - Conduct preliminary analysis for paved roads using models developed through previous FHLP PMS initiatives
  - Develop preliminary analysis models for the gravel and native roads based on input/experience from the FWS

- Phase 2
  - Conduct ground truth trips
  - Finalize analysis models based on feedback from ground truth trips

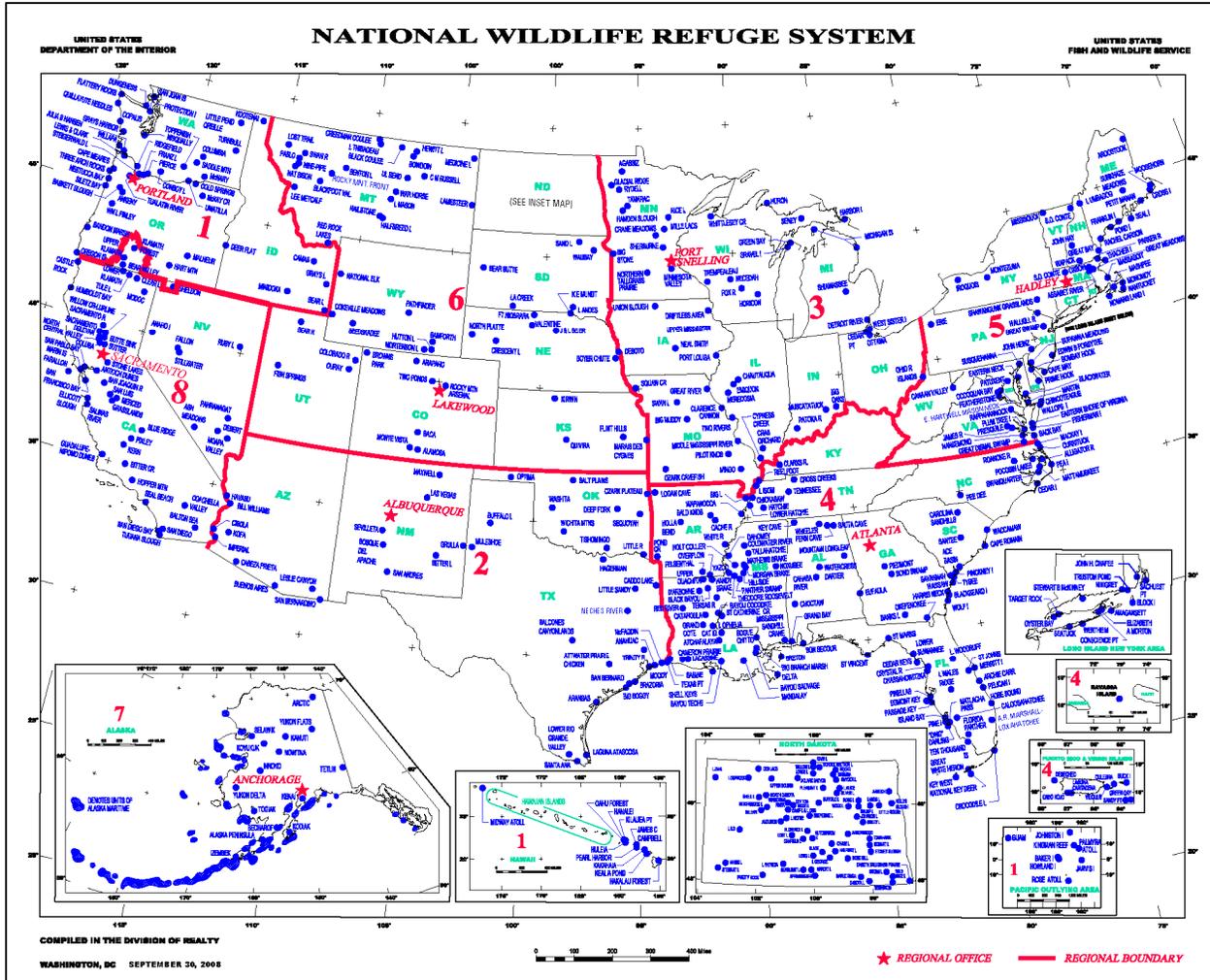
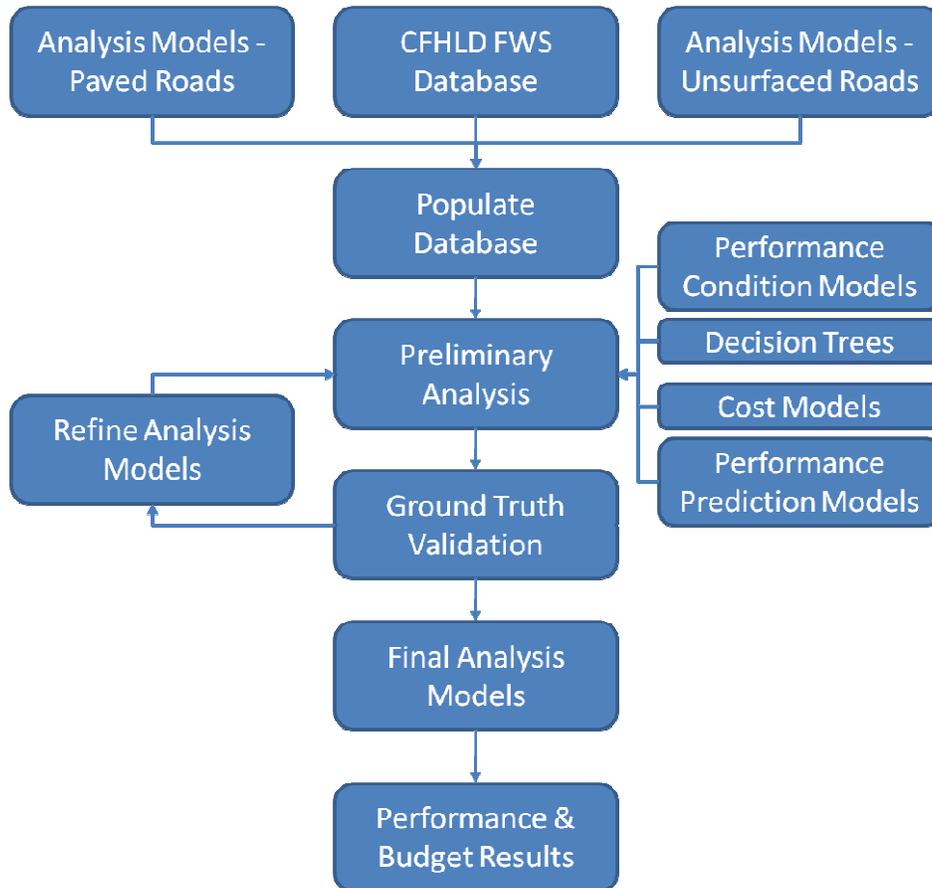


FIGURE 1: FWS Refuge Location Map [FWS, 2008]

## METHODOLOGY

The methodology used in this FWS PMS Pilot project is represented graphically in FIGURE 2. Initially the PMS database was populated based on data available in the Central Federal Highway Land Division (CFHLD) FWS database, including performance condition data (visual inspections) collected as part of the FHWA Data Collection Cycle 4. Analysis models for the paved roads (asphalt and concrete) were developed based on previous FHWA PMS initiatives. Analysis models for the unsurfaced (gravel and native) roads were developed based on input and experience from the FWS and the Project Team. Engineering models developed as part of this exercise include performance condition models, decision tree models, cost models, and

performance prediction models. Once the preliminary models were developed, two separate ground truth trips were conducted at 10 refuges across Regions 2 and 6 to validate the analysis models. After each ground truth trip, the models were refined based on field observations. Once the Project Team was satisfied with the analysis models, performance and budget results were developed.



**FIGURE 2: FWS PMS Pilot Project Methodology**

### Challenges & Successes

The Project Team experienced both challenges and successes throughout the various stages of the project. While a great deal of work went into the development of the engineering models for the PMS and the results of the analysis, the following sections focus primarily on some of the lessons learned at various stages of the pilot project. These lessons learned are intended to provide assistance to other agencies that may be considering embarking on a non-traditional approach to pavement (or maintenance) management. It should be noted that despite the various challenges, the Project Team were able to work together and persevere in order to develop a useful analytical budgeting/planning tool.

## **CHALLENGE/SUCCESS 1: DATABASE**

The core of any management system, whether it is for pavements, or assets, or finances, is the accuracy and relevancy of the data. As a result, the outputs are directly related to the quality of the data input into the database (i.e., garbage in, garbage out).

In this case, the CFHLD maintains an existing database for the FWS Refuge roads, which contains a variety of data (jurisdictional, geometric, etc) for a very large network of roads (more than 7,000 miles or 11,000 km) across a vast geographical area (the entire United States).

Since the HPMA allows for dynamic segmentation, the key to the database is the referencing system as all of the data is linked to that referencing system. There were some initial challenges regarding which fields in the database should be used as the base referencing system since there were missing fields in the database (as is often the case with large data sets). Some of these missing fields were highlighted through this pilot project because the Project Team was attempting to use the data in the database in a way that it had not been used before.

Instead of getting hung up on the missing data, the Project Team moved forward with the available data. In order to make full use of the system and develop more realistic budget work programs, additional data is required and the following suggestion for consideration have been developed:

- It is recommended that FWS work together in fiscal Year 2011 with EFLHD to expand the pilot and draft up work plans.
- In order to make use of the work orders generated in SAMMS, the FWS should consider working with EFLHD to develop a mechanism for adding new pavement projects by SAMMS to the PMS database.
- In addition, including some sort of traffic or visitation data (traffic counts or even ranges of low, medium, high traffic categories) may also add value to the PMS.

## **CHALLENGE/SUCCESS 2: CHANGE IN DATA COLLECTION METHODOLOGY**

Based on field observations from the ground truth trips and literature review, it is apparent that different data collection process for the paved and gravel or natives roads may be useful to FWS. [Eaton, 1988]

The behavior of asphalt and concrete roads differ significantly than the behavior of native and gravel roads. The current FWS distress rating system is different than the current NPS distress rating system. In recent years, a great deal of work has been put into the development and refinement of the NPS distress rating system to ensure that the distress results reflect field observations. [Stantec, 2006] For consistency between federal agencies, especially when comparing condition, consideration should be given for adding FWS asphalt and concrete roads to the NPS road survey.

During Data Collection Cycle 4, a visual inspection was conducted on all refuge roads that rated the extent and severity of multiple distress types and assigned each distress a rating score from 0 to 9 or 0 to 3 depending on the distress type. The basis for the scoring was primarily based on the Remaining Service Life (RSL) of the pavement structure. The data collection methodology used in previous projects included the extent (% area or length) at various severity levels for a given section of road. [Stantec, 2006]

To overcome this obstacle, the distress rating scores were converted to extent and severity and loaded into the FWS PMS. The severity was determined based on the distress rating score itself and the extent was developed based on nominal extents for low, medium, and high extents. An example is provided below to illustrate the process.

**TABLE 1: Distress Rating – Corrugation (Gravel and Native Roads)**

		Extent (Length)		
		No Defects	Low < 10%	Med 10-30%
Severity	Low <2”	1	2	3
	Med 2-4”	4	5	6
	High >4”	7	8	9

**TABLE 2: Nominal Extent – Corrugation (Gravel and Native Roads)**

		Extent (Length)		
		No Defects	Low < 10%	Med 10-30%
Severity	Low <2”	5%	20%	65%
	Med 2-4”	5%	20%	65%
	High >4”	5%	20%	65%

Therefore, a road segment with a corrugation distress rating of 4 would be loaded into the FWS HPMA system as 5% extent with low severity. Samples of photos illustrating different performance category ranges is provided in Appendix A.

### **CHALLENGE/SUCCESS 3: DATA COLLECTION SURVEYS**

Another observation noted during the ground truth trips was that the survey did not appear to pick up or distinguish between varying types of crown and/or drainage distresses. These two particular distresses tend to drive the decisions in terms of the scale of treatments to apply (routine maintenance vs. heavy rehabilitation). Since the Project Team was not confident in these two distress types, they were excluded from the decision trees. Instead, the decision trees were developed based on best practices observed at the FWS Refuges.

To further complicate the issue, the current data collection cycle is approximately four to five years, which means that a refuge is surveyed only once every four to five years. The majority of the refuge road system consists of gravel or native and the condition of these roads can change

dramatically in a short period of time (sometimes daily). Decreasing the duration of the data collection cycle to one to two years may not be feasible from a cost perspective. As such, consideration should be given for more aggressive (i.e., more frequent) survey for sample refuges. The sample refuges should be representative samples of the different climate, road class, and visitation (traffic). This would allow for more data points to further refine the analysis models.

In order to assist with future data collection surveys, the Project Team has developed the following suggestions for consideration:

- As part of the Cycle 4 data collection effort, all refuge roads were included in the survey. In an attempt to save on costs and reduce the data collection cycle, consideration should be given to only survey roads that will require some form of rehabilitation or treatment, i.e., public access roads or restricted roads with higher priority.
- One of the recurring observations from the ground truth trips was that some distress, particularly cross-section crown and roadside drainage appeared to not be evaluated consistently, e.g. in some instances, no distress noted when inverted crown present or road below grade. Unlike paved roads where the list treatment options can be exhaustive and heavily dependent on the specific surface distresses, gravel and native roads have limited treatment options based on surface conditions (distresses). To expedite the survey process and reduce the amount of data collected, it might be more useful for FWS to use a condition category for gravel and native roads based on descriptions rather than measured distresses.

#### **CHALLENGE/SUCCESS 4: NEW CONDITION MODELS FOR UNSURFACED ROADS**

Once the distress data were converted to severity and extent, similar models used in previous projects were able to be used for the asphalt and concrete roads. However, new models needed to be developed for the unsurfaced roads.

Initially, the individual distress index models for gravel and native roads were developed in the same manner as the paved roads. However, during the first ground truth trip to Region 2, it was discovered that the individual distress index models were too high compared to field observations. As a result, it was decided that the distress index values for the gravel and native roads should correlate to the RSL as noted in the equation below:

$$Index Model_{Distress} = 10 * RSL$$

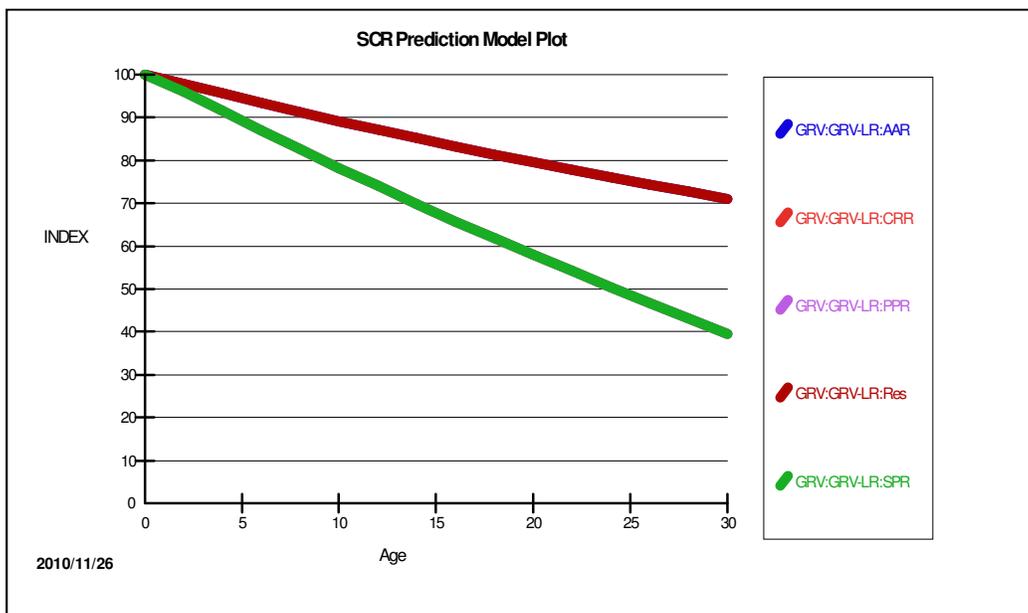
After the ground truth trip to Region 6, it was found that this correlation was more representative of what was actually observed in the field.

#### **CHALLENGE/SUCCESS 5: PREDICTING THE UNPREDICTABLE**

As with the performance rating models, prediction models developed as part of previous projects were employed for the asphalt and concrete roads. [Stantec, 2006] However, new prediction models had to be developed for the unsurfaced roads.

Initially models were developed such that a performance curve would reach the trigger level (60) by year 10, to be consistent with the maximum RSL for the gravel and native roads. However, after the first ground truth trip to Region 2, it was noted that the rate of deterioration was too conservative and the estimated rate of deterioration was far too high. It was also noted that the condition of the gravel and native roads can change dramatically upon weather events (e.g. significant rainfall) or after routine maintenance (e.g. grading). As such, it is quite difficult to predict the future condition of the road as it will depend greatly on the environment and the maintenance practices. To resolve this issue, it was decided that the prediction models would deteriorate based on a straight line deterioration model and the decision trees would reflect the maintenance practices for different environmental zones.

Based on discussions with FWS Refuge staff, it was evident that in most cases, there were different maintenance practices for the different road classifications. The Principal Refuge Roads, Connector Refuge Roads, Special Purpose Roads and Administrative Access Roads were assumed to deteriorate at an average rate of two points per year; whereas, the Restricted Roads were assumed to deteriorate at an average rate of one point per year. The road classification will be further discussed in the next challenge/success case.



AAR=Administrative Access Roads CRR=Connector Refuge Roads GRV=Gravel Road LR=Light Rehabilitation  
 PPR=Principal Refuge Roads Res=Restricted Roads SPR=Special Purpose Roads

**FIGURE 3: Distress Index Prediction Model for Gravel Roads**

## CHALLENGE/SUCCESS 6: ROAD CLASSIFICATION

In a typical PMS for highways or municipal roads, the functional class is generally related to traffic and/or service level, where higher functional classes (higher volume roads) are often prioritized or have a higher level of service as compared to lower functional classes. Within the FWS road network, the functional classes are developed primarily based on the intended use or function of that route:

- Class I – Principal Refuge Road (Public Roads): Routes that constitute the main access route, main auto tour route, or thoroughfare for refuge visitors. These routes are accessible by two-wheel-drive (2WD) vehicles.
- Class II – Connector Refuge Road (Public Roads): Routes that provide circulation within the refuge. These routes can also provide access to areas of scenic, scientific, recreational or cultural interest, such as overlooks, campgrounds, education centers, etc. These routes are accessible by 2WD vehicles.
- Class III – Special Purpose Refuge Road (Public Roads): Roads that provide circulation within special use areas such as campgrounds or public concessionaire facilities or access to remote areas of the refuge. These routes may not be 2WD accessible.
- Class IV – Administrative Access Road (Administrative Roads): Routes intended for access to administrative developments or structures such as maintenance offices, employee quarters, or utility areas. These routes are accessible by 2WD vehicles.
- Class V – Restricted Road (Administrative Roads): Routes normally closed to the public, such as maintenance roads, service roads, patrol roads, and fire breaks. These routes may be open to the public for a short period of time for a special use, such as hunting access. These routes may not be 2WD accessible.

While one may expect that priority should be given to the public roads, there are instances where the traffic volumes on the restricted and administrative roads are higher due to a large number of refuge staff, researchers, etc. accessing the various parts of the refuge.

One of the main goals of the FWS was developing a prioritization program for their road network (i.e., which roads should they fix first, which ones can wait). As evidenced through the ground truth trips and discussions with FWS Refuge staff, another type of road classification is required to assist in the prioritization of roads. Two examples of best practices noted during the ground truth trips were Sevilleta National Wildlife Refuge (NWR) and Valentine NWR.

- Sevilleta NWR has a road prioritization (primary, secondary, 2-track) based on road use and includes increase priority for restricted roads used for researchers.
- Valentine NWR has an internal road type classification (Road Type I – gravel with shoulders; Road Type II – native with gravel fill in wheel tracks; Road Type III – native road (no gravel)) where each section is assigned to a road type and the goal is to achieve that level of service.

The idea of prioritization and end users is further discussed in Challenge/Success #11.

## **CHALLENGE/SUCCESS 7: MAINTENANCE AND REHABILITATION ACTIVITIES FOR UNSURFACED ROADS**

Initially, the EFLHD provided a list of M&R activities for each pavement type. However, after the ground truth trips, it was apparent that maintenance practices for gravel and native roads vary

dramatically between regions, environmental zones, and refuges. Furthermore, based on discussion with refuge staff, work orders for maintenance activities on gravel and native roads tend to be general and do not necessarily specify specific treatments (as the ones previously provided by the EFLHD). As such, it was decided that M&R activities for gravel and native roads would be grouped into three categories:

- Routine Maintenance (RM) – used to bring road from good to excellent condition. Examples include re-grading, blade and maintain crown, and shoulder maintenance.
- Heavy Preventive Maintenance/Light Rehabilitation (LR) – used to bring road from fair to excellent condition. Examples include gravel spot replacement (gravel only), spot crown reestablishment, pull ditches (native only)
- Heavy Rehabilitation (HR) – used to bring road from poor to excellent condition. Examples include re-gravel (gravel only), reshape roadway (native only), drainage improvements (native only)

In addition, it was noted during the ground truth trips that maintenance activities increased as the climate condition become harsher (i.e., colder, wetter). In general, it was noted that typically one routine maintenance activity was performed on roads in the dry no freeze environment; whereas refuges in the dry freeze would perform at least two routine maintenance activities on the same road. In the extreme dry super freeze environment, it was determined that in general four routine maintenance activities would be performed on the same road over the course of the year. As such, maintenance activities and associated costs were created to reflect these observations.

### **CHALLENGE/SUCCESS 8: COST MODELS**

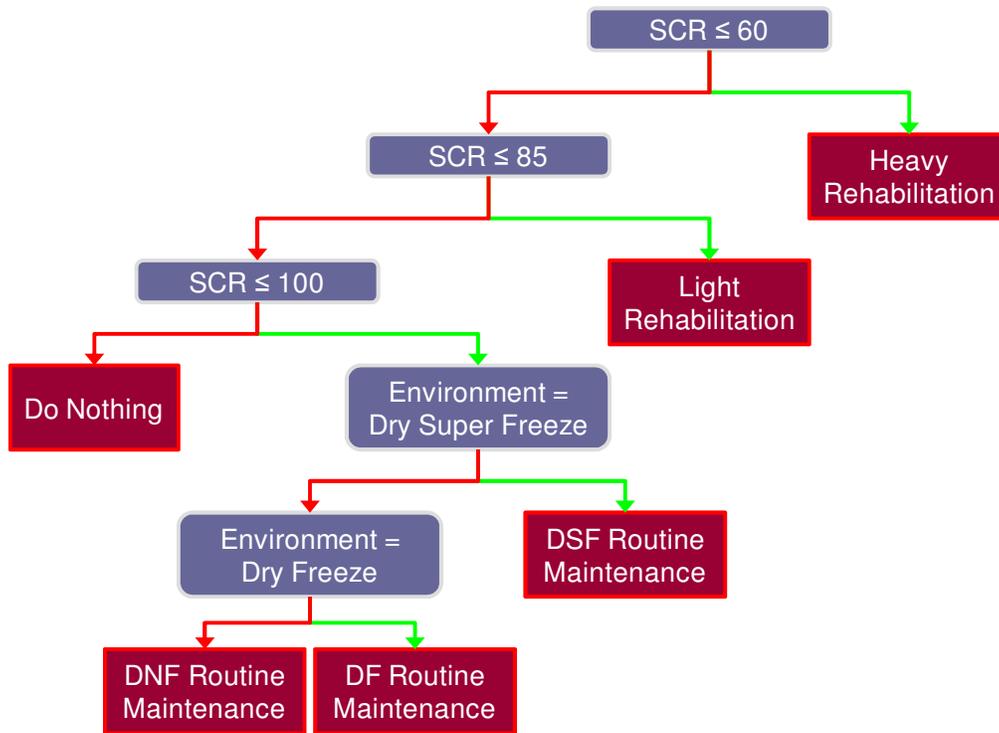
As the reader can appreciate, the unit cost for maintenance and rehabilitation activities can vary significantly across regions, especially a region as large as the United States. As such, the unit costs for gravel and native roads were developed based on nationwide average costs. In addition, cost factors were applied to each refuge location in Regions 2&6 to account for cost variations between locations. In addition, cost factors by State have been entered into the HPMA system as well should the FWS or ELFHD decide to use other unit rates and assign costs based on State incidental cost factors. For the FWS analysis, nationwide unit costs and incidental cost factors by Refuge location were used.

### **CHALLENGE/SUCCESS 9: DEVELOPING DECISION TREES**

As the name implies, decision trees incorporate a set of criteria for identifying a particular M&R activity through the use of “Nodes.” Each node represents a specific set of conditions that ultimately leads to the identification of a particular treatment. The general types of data that could be considered in the development of these tools in the FLH PMS include such variables as the pavement type, construction history, functional classification, traffic level, pavement condition, section geometrics, environmental conditions, etc. However, due to the limited amount of data initially loaded in the FWS HPMA, it was decided that the decision trees would be based on distress data and environment type.

The concept of using decision trees for the M&R analysis is that they should reflect the decision processes normally used by FWS. Initially, preliminary decision trees were developed based on

the FWS recommended treatments by distress rating. However, as previously noted, the maintenance activities for gravel and native roads were modified to reflect field observations noted during the ground truth trips. A sample decision tree for the gravel roads is illustrated in FIGURE 4.



SCR=Surface Condition Rating DF=Dry Freeze Environment  
 DNF=Dry No Freeze Environment DSF=Dry Super Freeze Environment

**FIGURE 4: Sample Decision Tree – Gravel Roads**

It should be noted that these were developed based on limited data and should be updated once additional data becomes available.

### CHALLENGE/SUCCESS 10: ACHIEVING “LONG TERM” OBJECTIVES

The performance of gravel and native road sections can vary significantly from day-to-day depending on precipitation, traffic and maintenance practices. As such, 5-year analysis periods were used in the analysis. In order to assist the ELFHD and FWS develop long-term forecasting, a 10-year budget/optimization was developed (see TABLE 3). As the PMS does not currently contain data regarding the precipitation and traffic data, these estimates are subject to change as more data is added to the system and the models are refined.

**TABLE 3: Long-Term Cost and Performance Summary for Regions 2 & 6**

Budget	10-year Costs	SCR Average	
		2011	2020
Do Nothing	\$0	64	51
Achieve/maintain SCR 75	\$134 M	75	75
Achieve/maintain SCR 80	\$237 M	80	80
Unlimited Funding	\$238 M	80	80

The do nothing scenario illustrates that if no funding were available for the next ten years, the network average performance would drop more than 13 points. To attain and maintain a network average of 75 for 10 years would cost approximately \$134 million and to increase the network average to 80 would require an additional \$103 million or nearly \$10 million annually. The unlimited funding optimization, which does not consider any budget or performance constraints, illustrates the impact of implementing the practice outlined in the decision trees. While the annual funding streams for the Achieve/maintain SCR 80 and the unlimited funding scenarios are slightly different, the costs and the resulting performance after 10 years are very similar. In other words, achieving a network average greater than 80 would require a change in the decision tree, i.e., the decision making process. The current funding level for Regions 2 and 6 combined is approximately \$6.8 million annually. Therefore, in order to improve the network average from its current 64 to 75 would require a doubling of the current funding level.

### **CHALLENGE/SUCCESS 11: UNDERSTANDING THE END USER**

The mission of the FWS Refuge staff is to “manage lands and waters for the conservation, management, and where appropriate, restoration of fish, wildlife and plant resources and their habitat”. [FWS 2009] In other words, the maintenance of refuge roads is a low priority. In fact, maintenance is typically performed on as-needed basis with priority given to safety concerns.

The concept of level of service is also unique at some of the Refuges. One Refuge staff member, who works at a Refuge with a significant visitation rate during the winter (hundreds of visitors/day for ice fishing), indicated that they receive complaints from local/regular visitors if roads are “too good” because it “attracts too many people”.

Therefore, in order to develop a prioritization list, the PMS needs to account for some of these unique levels of service concepts. This is a rather large challenge given that very few refuges actually have maintenance plans/goals.

To overcome these challenges, Project Team has developed the following suggestions for consideration.

- Develop an internal classification based on level of service
- Work with FWS Refuge staff to develop maintenance goals/objectives for their roads
- There is also an Asset Priority Index (API) that is used as part of the SAMMS system and is calculated based on the Mission Dependency (80%) and Asset Substitutability (20%) to determine work project. Currently, only the FWS functional class is stored in the PMS. As part of the next phase of the project, it may be worth revisiting these classes and prioritization methods to determine which one(s) should be included in the PMS as a way for prioritizing the work projects.

### **Summary**

The data was successfully loaded into the PMS from source data provided by EFLHD. The data included both attribute data and performance data. The performance data was collected as part of the Data Collection Cycle 4, which ran from 2005 to 2009. The attribute data included the highway definitions, geometric, jurisdiction, and administrative data. Performance data included the distress data for paved (asphalt and concrete), gravel and native roads. The total length of

the roadways defined in the system is in excess of 7,000 miles; however, approximately 4,600 miles are contained within Regions 2&6 and were included in the analysis.

The analysis models for paved roads used in the system were similar to the analysis models used for the NPS analysis. However, new analysis models were developed for gravel and native roads, as well as new decision trees and cost models for all pavement types. These models were developed based on information provided by the FWS and supplemented through the field observations noted during the ground truth trips. While these models are a good starting point for the PMS analysis, additional data is required to further enhance these models.

The most recent performance provides a summary of the most recent data collection (e.g., Data Collection Cycle 4). All of the distress rating scores were translated into individual distress index scores and then combined to create a single Surface Condition Rating (SCR). Due to the fact that there is no roughness data associated with these sections, the Pavement Condition Rating (PCR) is equivalent to the SCR.

In summary, this paper has attempted to demonstrate the challenges and successes of implementing a pavement management system for a large network of low volume roads. The Project team was able to develop 5- and 10-year budget plans for the network and has developed a number of recommendations to improve the level of detailed data to be added to the system to refine the models.

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**APPENDIX A: PERFORMANCE CATEGORY PHOTOS**



**FIGURE A.1: SAMPLE PHOTO –EXCELLENT ROAD**



**FIGURE A.2: SAMPLE PHOTO –GOOD ROAD**



**FIGURE A.3: SAMPLE PHOTO –FAIR ROAD**



**FIGURE A.4: SAMPLE PHOTO –POOR ROAD**