LTPP Data Analysis

Task Order #03

"Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost"

Quarterly Progress Report

April, May, June 2005

Prepared for:

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Federal Highway Administration
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Detailed Technical Summary of NCE Task Order #03 "Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost"

In this quarter, NCE has continued work on Task 8 and Task 9 of Task Order #03.

Task 8

Conduct detailed analysis of the effects of multiple freeze-thaw cycles verses deep frost penetration on pavement performance

The analysis team continued to work on developing regression models to predict various pavement performance measures this quarter. Multiple regression models have been developed for each performance measure. The team has been working on selecting the best alternative to use in the environmental comparisons.

Two models were considered in the prediction of rut depth in flexible pavements. The first model incorporated a linear relationship between rut depth and pavement age. A scatter plot of predicted vs. observed rut depth values for this model is shown in Figure 1. The overall R-squared value for the model is approximately 0.37. The second model under consideration for use in predicting rut depth incorporated a natural logarithm relationship between rut depth and pavement age. The scatter plot of predicted vs. observed values can be found in Figure 2. This model resulted in an increased R-squared value of 0.45.

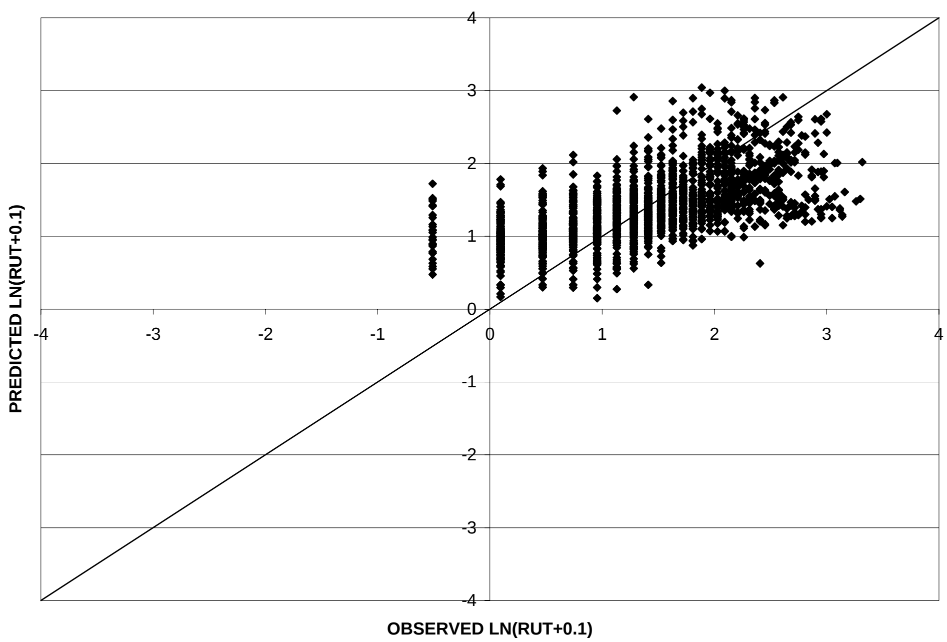

Figure 1. Scatter Plot for Rut Depth Model with Linear Rut – Age Relationship.

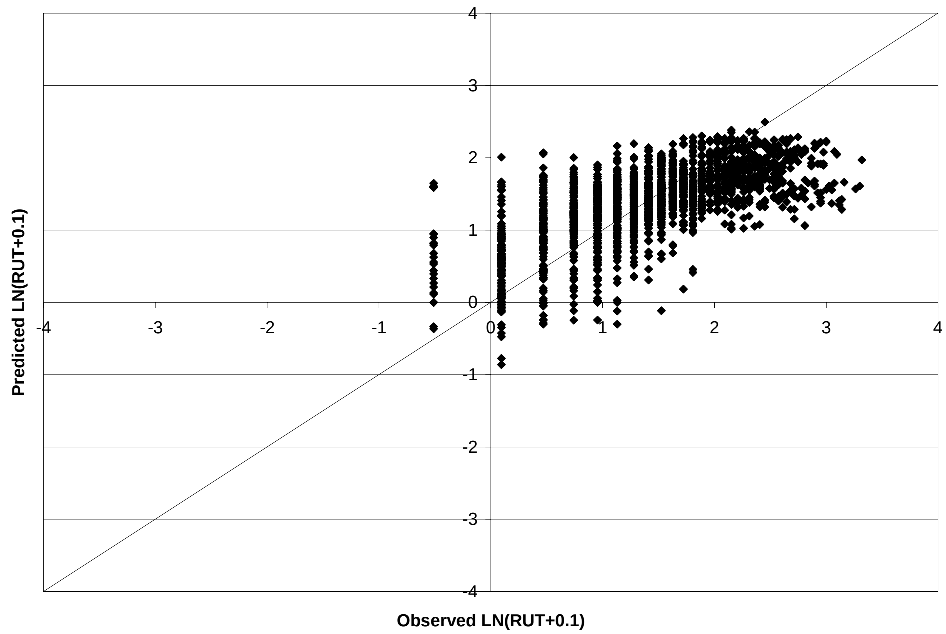

Figure 2. Scatter Plot for Rut Depth Model with Rut – Natural Logarithm Age Relationship.

The second model was selected for use in comparing rut depth performance of pavement in different environmental regions because of the improved fit of the data set. Rutting mechanisms generally result in an increased rate of rutting in the early years of pavement life. As the pavement ages, this rate diminishes and rutting values level off (following a logarithmic relationship). Therefore, applying the logarithmic relationship in the model provides a better representation of the data set, which is evident in the improved R-squared value.

Using the selected model, rutting performance curves for the various environmental regions were plotted for purposes of comparison. Table 1 provides a list of the five climatic scenarios evaluated along with details on the values used in deriving each region.

Table 1. Overview of Climatic Scenarios.

SCENARIOS	ACTHICK	BASE	SG	LESN	EXP	FI	FTC	PRECIP	CI
Deep Freeze Wet Region (low FTC)	6.5	DGAB	FINE	1.02	G1	688	80	1140	205
Moderate Freeze Wet Region (high FTC)	6.5	DGAB	FINE	1.02	G1	137	130	1140	645
No Freeze Wet Region	6.5	DGAB	FINE	1.02	G1	10	10	1140	1300
Deep Freeze Dry Region (low FTC)	6.5	DGAB	FINE	1.02	G1	688	80	380	205
Moderate Freeze Dry Region (high FTC)	6.5	DGAB	FINE	1.02	G1	137	130	380	645

Each of the contributing non-environmental variables (i.e. asphalt concrete thickness, base type, subgrade type, and logarithm of Equivalent Single Axle Loads/Structural Number) was held constant so that the effects of the environment could be studied. For these variables, the 50^{th}

percentile (median) of the entire dataset was selected for use in Table 1. Table 2 provides details on the process used to select the environmental values in each climatic region.

Table 2. Details on selection of Environmental Variables.

Variable	Criteria	Value
Deep Freeze (FI)	50^{th} percentile of deep freeze (>400 FI)	688
Moderate Freeze (FI)	50^{th} percentile of mod freeze (50<FI<400)	137
No Freeze (FI)	50^{th} percentile of no freeze (<50 FI)	10
Low FTC	10^{th} percentile of FTC values in deep freeze (>400 FI)	80
High FTC	90^{th} percentile of FTC values in mod freeze (50<FI<400)	130
No Freeze FTC	50^{th} percentile of FTC values in no freeze (<50 FI)	10
Dry (PRECIP)	50^{th} percentile of dry region (<508mm)	380
Wet (PRECIP)	50^{th} percentile of wet region (>508mm)	1140
Deep Freeze (CI)	50^{th} percentile of deep freeze (>400 FI)	205
Moderate Freeze (CI)	50^{th} percentile of mod freeze (50<FI<400)	645
No Freeze (CI)	50^{th} percentile of no freeze (<50 FI)	1300

Using the criteria set forth in Tables 1 and 2, rutting performance was plotted for each of the scenarios and is provided as Figure 3. The Moderate Freeze Regions are exhibiting the largest accumulation of rutting compared with the other Regions. Error bands are currently unavailable but will be computed and included on the graph to determine if the differences in rutting performance are significant.

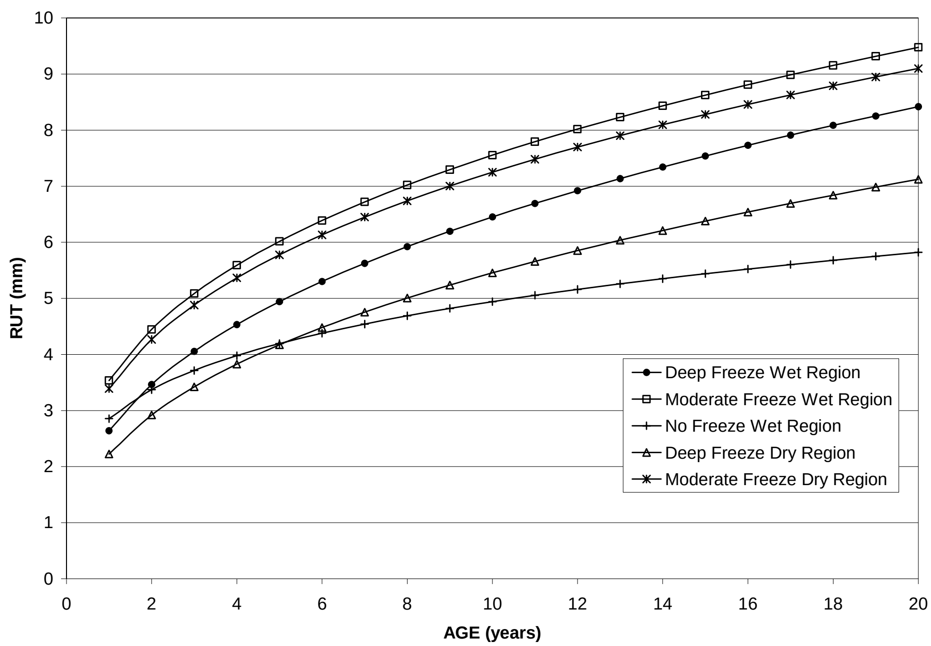

Figure 3. Predicted Rutting Accumulation for each Climatic Scenario.

A similar evaluation was performed for the roughness performance measure. Two models were investigated. The first model utilized a linear relationship between IRI and pavement age. Figure 4 provides a scatter plot of the predicted IRI values (normalized) vs. the observed IRI values. The R-squared value for this model is approximately 0.76. An additional model was generated using an exponential relationship between IRI and pavement age. The scatter plot that resulted from this model is shown in Figure 5. The corresponding R-squared value is 0.70.

Using a linear relationship between IRI and age results in a model that is less biased than the exponential relationship. This is evident when comparing Figures 4 and 5. In Figure 4, the cluster of data points is more centered on the equality line as compared with Figure 5 where the majority of the cluster falls below the line. This indicates a model that is generally predicting values less than the observed values. Considering the reduction in bias as well as the improved R-squared value, the linear relationship model was selected for use in making performance comparisons.

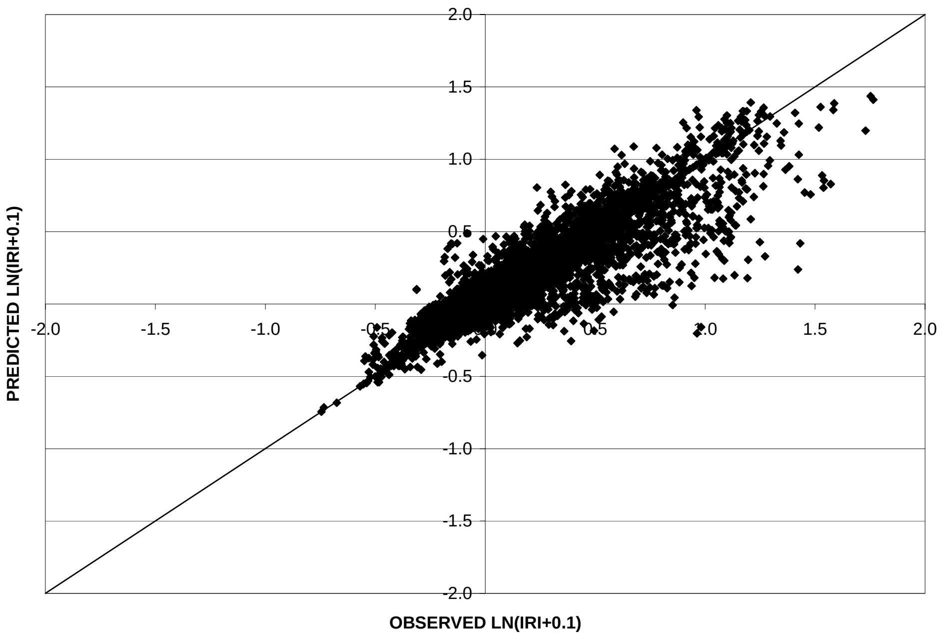

Figure 4. Scatter Plot for Rut Depth Model with Linear Rut – Age Relationship.

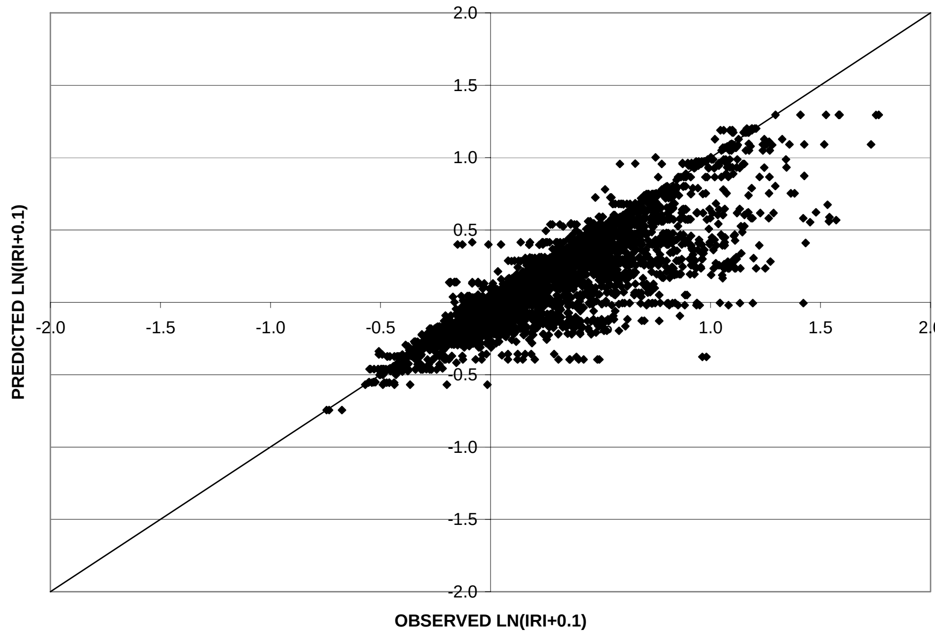

Figure 5. Scatter Plot for Rut Depth Model with Rut – Exponential Age Relationship.

Figure 6 provides a plot of predicted IRI accumulation with age for each of the climatic regions (using the linear relationship model). The values listed in Table 1 and 2 define each of the climatic regions provided in Figure 6. These curves were normalized assuming an initial IRI value of 1.0 m/km at a pavement age of 1 year. The plot indicates that pavements in the Deep Freeze Regions (Wet and Dry) accumulate roughness at a higher rate than the other regions (Moderate and No Freeze). As with the rutting models, error bands are not currently available to evaluate if the differences are significant.

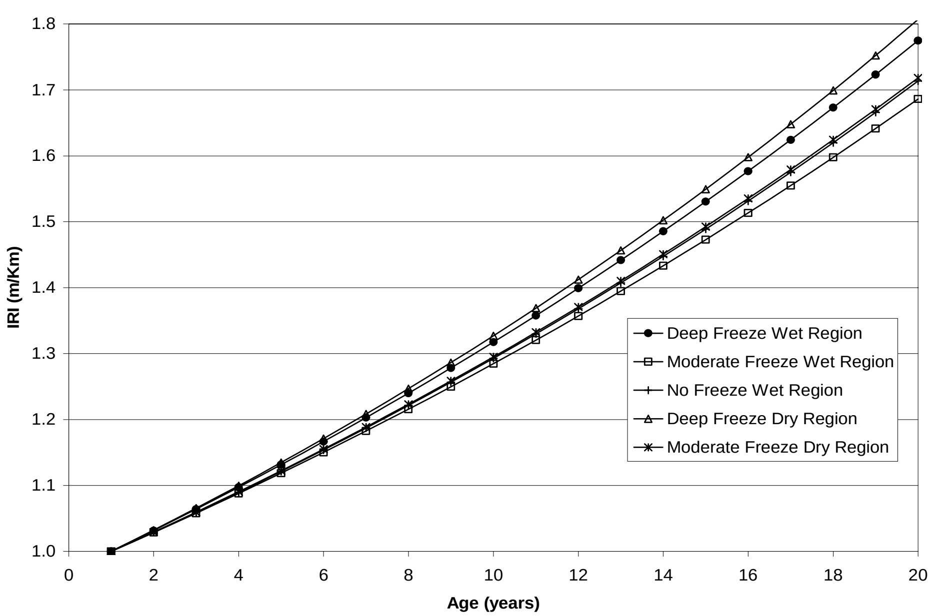

Figure 6. Predicted Roughness Accumulation for each Climatic Scenario.

The analysis team continues to work on the selecting the models to be used to make performance comparisons between the various climatic regions. Additionally, error bands will be computed and added to the comparisons to quantify the performance differences in terms of confidence intervals.

Task 9

Conduct detailed analysis of the extent to which local adaptations of materials standards and empirical pavement design practices have been effective at reducing the rate of pavement deterioration

NCE received all of the states' responses to the questionnaire sent out in March, 2004. A summary of the data from the states was presented at the Pooled Fund Panel meeting at the Annual TRB Meeting. The summary indicates a large variation in the typical pavement sections provided by the different states to the design criteria stated in the questionnaire. The variation is not necessarily consistent with trends in frost depth or freeze-thaw cycles. This information was returned to the Pooled Fund Panel members for review and comments as well as a request to provide any known information on bordering states' unique approaches to mitigate frost effects and possible contacts. To date, four of the eight states have responded to that request. NCE is also compiling the information on materials and specifications that was submitted in response to the questionnaire. Most of the responses regarding material and standard specifications directed NCE to each department's website.

NCE has been downloading and compiling all of the relevant materials and construction specification, whenever that information was not directly supplied by the state. NCE has not fully analyzed the data or made any conclusions at this time. However, it has been observed that the nationwide adoption of Superpave binder specifications more specifically address environmental issues such as rutting and thermal cracking but the performance information available in the LTPP database is only related to the earlier binder specifications. In addition, the adoption of the Superpave mix design procedures tends to treat all environmental areas the same whereas state specifications in place before the adoption of Superpave may have more specifically addressed the environment in which they were used. The performance data will only indicate the trends based on the prior material and construction specifications. NCE will also make an attempt to collect the material properties and specifications that were in place before adoption of the Superpave as part of this task.

Resources Used

Figure C.1 in Appendix C shows the current work schedule for Task Order #03 through June 2005.

This task order remains several months behind schedule compared to the planned timeline. This is a carryover from the delay in starting on Phase 2 from the previously intended schedule and the added work of developing the additional databases that were used in the trend analysis for Task 3 as well as the delay in the return of the state questionnaires. While NCE will continue to concentrate on getting back on schedule, a no-cost time extension request will be submitted this next quarter. The current schedule and several options were discussed at the Pooled Fund Panel meeting in January. There was a consensus among the panel members that an extension should be requested and that the timing should be scheduled such that the final panel meeting could take place during the 2006 Annual TRB Meeting in Washington, DC. A six month time extension request will be submitted next quarter to provide for the panel meeting in January 2006 and final edit time after comments at the panel meeting.

The expenditures have continued to be about 30 percent below planned expenditures as a carryover from the earlier delay. Figure C.2 in Appendix C shows the planned costs versus actual costs for Task Order #03 through June 2005. However, with a six month extension, the current expenditure rate appears to be in line with future spending through the time extension.

Appendix C

Task Order #03

Work Summaries

Through June 2005

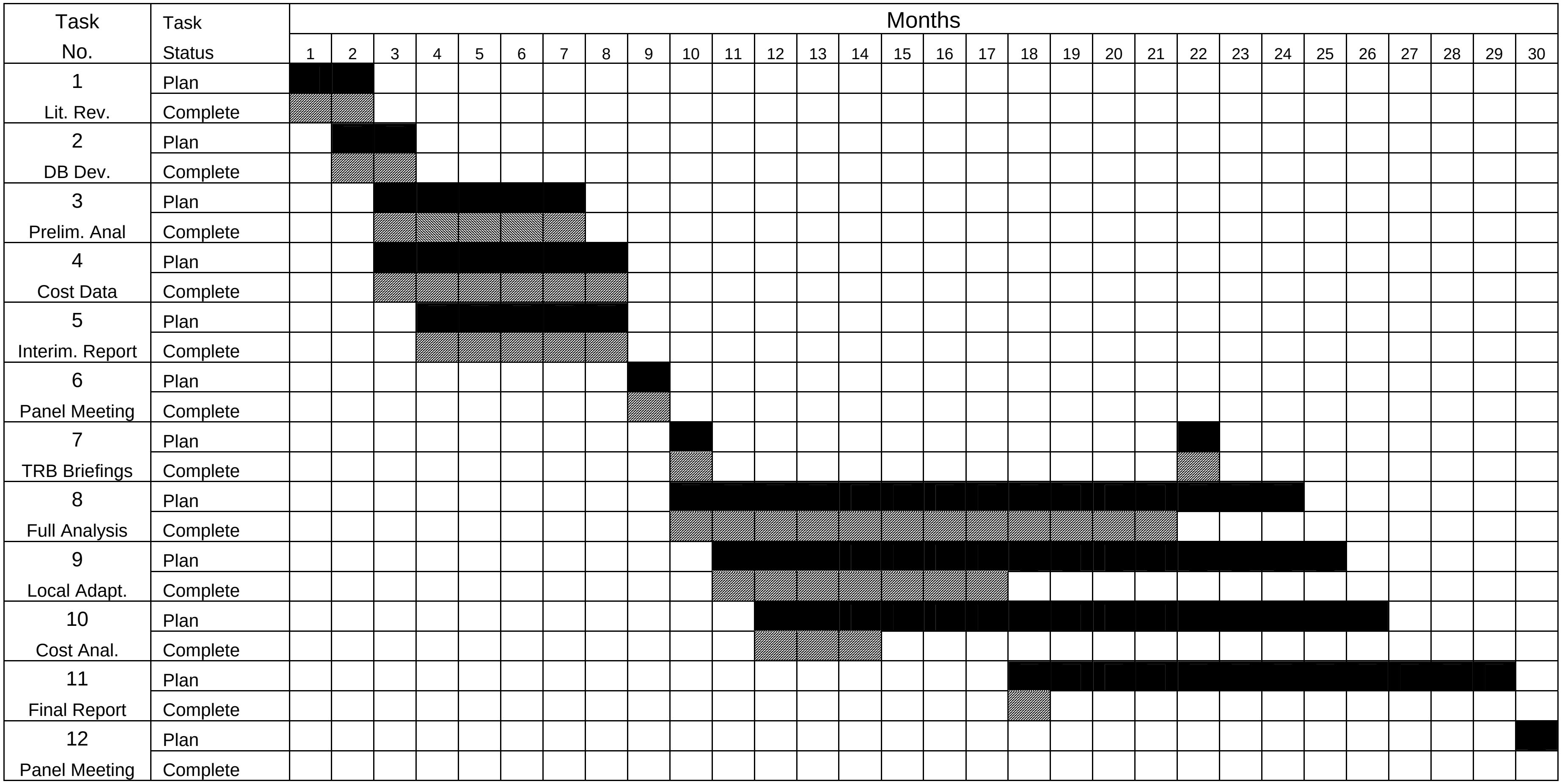

Figure D.1 Work Schedule for Task Order #03 through March, 2005