Statewide Sampling Protocol and Management Strategy for Assessing Field Maintenance Activities

Sample Size Analysis for Future Monitoring and Assessment of Maintenance Activities Statewide

Prepared by

John J. Borkowski

Associate Professor of Statistics

Department of Mathematical Sciences

of the

Western Transportation Institute

College of Engineering

Montana State University - Bozeman

Prepared for the

Maintenance Division

Montana Department of Transportation

2701 Prospect Ave.

Helena, MT 59620-1001

May 20, 2003

1 Introduction

This project addresses a structured long-term data collection plan of maintenance activities statewide in Montana. One goal of the project is the formulation of a statewide sampling protocol for maintenance activities requiring field assessment as defined in the AMMO (Accountability for Montana's Maintenance Operations) Field Data Collection Manual.

Statistically-based survey sampling methods were developed based on available information of centerline miles to define natural stratification criteria of roadway miles statewide. The statistical methodology used to generate the stratified sampling plan of roadway sites was summarized in the report *A Report on the Sampling Methodology used for the Summer 2002 Data Collection.* An assessment of the current state of 20 maintenance activities based on analysis of the survey data collected during the summer of 2002 was summarized in the report *Statistical Analysis of the Summer 2002 Survey Data.*

In this report, summary statistics from the summer 2002 survey data will be used to address the goal of formulating a statewide sampling protocol for maintenance activities. All tables are included in the Appendix.

2 Assessing Variability

When designing the 2002 summer survey, a .2 mile roadway segment was selected as the basic sampling unit for four of the five highway systems: National Highway Service (NHS), Official (OFF), Primary (PRI), and Secondary (SEC). A .2 mile segment was chosen because it permitted a reasonably large sample to be collected given the window of time for data collection. There is no claim, however, that a .2 mile roadway segment is an optimal length sampling unit. To be able to address this issue, the data was recorded for each of the two .1 mile segments comprising a .2 mile segment. Thus, a comparison of results based on .1 mile segments and .2 miles segments could be performed based on a single survey. Specifically, the comparison will provide information concerning a future survey sampling protocol. In this section, we will address the issue of sample size efficiency using both .2 mile and .1 mile roadway segments as sampling units.

It is reasonable to expect that the estimates based on .2 mile segments should provide more information than a sample containing the same number or .1 mile segments. Intuitively, it makes sense that collecting more data will provide a more precise estimate. However, having segments that are twice as large does not translate into providing an estimate that is twice as precise. The main reason for this is the presence of spatial correlation. Simply put, two measurements that are taken closer together in space are more likely to be correlated than two measurement that are far apart in space. For example:

- If one .1 mile roadway segment has acceptable (or unacceptable) mowing, than the mowing states on its neighboring .1 mile roadway segments are also likely to be acceptable (or unacceptable).

- However, the mowing states on two .1 mile roadway segments that are miles apart and probably on different corridors are much less likely to be similar. In this case, it may be more efficient to survey more .1 mile segments in lieu of .2 mile segments.

To assess the impact of using .2 mile versus .1 mile segments, we need to study the variability associated with maintenance activity estimates using both length segments. The **standard deviation** is a common measure of variability. When dealing with sample size issues, it is common to use the **variance** which is the squared value of the standard deviation.

Because we only have surveyed a portion of the entire roadway system, we can only provide an estimate for the true variance of our estimators. We will provide two different estimates of the true variance. The first estimate is based on the **standard error** and the second estimate is based on the width of the 95% **bootstrap percentile method confidence interval**. In the report *Statistical Analysis of the Summer 2002 Survey Data*, the methods of calculating standard errors and confidence intervals based on .2 mile segments were described and values were provided. In this report, standard errors and confidence interval widths based on .1 mile segments will also be provided. Then, we will compare the estimated variances from .2 mile segments to the estimated variances using .1 mile segments which in turn will provide information for future sample size recommendations.

3 Statewide Assessment

The survey data can be viewed as three different samples: (i) a sample of .2 mile segments, (ii) a sample of the first .1 mile segments, and (iii) a sample of the second .1 mile segments. The original sample of .2 mile segments in (i) will be denoted sample O. The samples of .1 mile segments in (ii) and (iii) will be denoted samples A and B.

For each of these three samples (O, A, B), the standard errors and 95% confidence interval widths are given in Table 1 for each of the statewide roadside, roadway, and traffic maintenance activities. As stated earlier, we would expect a sample of .2 mile segments to either yield a more precise (i.e., smaller variability) estimator than one associated with a same-size sample of .1 mile segments, or, at worst, an estimator having similar variability. We see this is true when the .2m column values are compared to the values in the two .1m columns in Table 1.

A better way to view these comparisons is to calculate the following ratios:

$$R_1 = \left(\frac{\text{SE}(A)}{\text{SE}(O)}\right)^2 \qquad R_2 = \left(\frac{\text{SE}(B)}{\text{SE}(O)}\right)^2 \qquad R_3 = \left(\frac{\text{CI}(A)}{\text{CI}(O)}\right)^2 \qquad R_4 = \left(\frac{\text{CI}(B)}{\text{CI}(O)}\right)^2$$

where SE(A), SE(B), and SE(O) are the standard errors associated with samples A, B, and O, respectively, and CI(A), CI(B), and CI(O) are the confidence interval widths associated with samples A, B, and O, respectively. Each of these four ratios is an estimate of how many times larger the variance is using .1 mile segments versus .2 mile segments. Each ratio will be referred to as a **sample size inflation factor (SSIF)**. The values of the SSIFs (R_1, R_2, R_3, and R_4) are given in the four columns in Table 2. For example, consider line 1 in Table 2:

$$R_1 = \left(\frac{\text{SE}(A)}{\text{SE}(O)}\right)^2 = \left(\frac{3.12}{2.61}\right)^2 = 1.43 \qquad R_2 = \left(\frac{\text{SE}(B)}{\text{SE}(O)}\right)^2 = \left(\frac{3.18}{2.61}\right)^2 = 1.48$$

$$R_3 = \left(\frac{\text{CI}(A)}{\text{CI}(O)}\right)^2 = \left(\frac{12.22}{10.42}\right)^2 = 1.37 \qquad R_4 = \left(\frac{\text{CI}(B)}{\text{CI}(O)}\right)^2 = \left(\frac{12.09}{10.42}\right)^2 = 1.35$$

Based on the smallest (1.35) and largest (1.48) of these four values, we conclude that the variance of the estimator (assuming equal sample sizes) will be approximately 35% to 48% larger (or inflated) when .1 mile segments are used than when .2 mile segments are used. When looking at the values in Table 2, we can make the following generalizations about statewide maintenance activity estimation:

- Values close to or less than 1 indicate that nothing is gained from using .2 mile segments instead of .1 mile segments when estimating statewide.
- As the values begin to increase, the precision of the estimator using .2 mile segments improves relative to the estimator using .1 mile segments.

4 Highway System Assessment

Because interest may also lie in assessment at the highway system level, tables analogous to Tables 1 and 2 were generated for each of the NHS, OFF, PRI, and SEC highway systems. The standard error and confidence interval width summaries can be found in Tables 3A, 3B, 3C, and 3D for the NHS, OFF, PRI, and SEC highway systems, respectively. The sample size inflation factor summaries can be found in Tables 4A, 4B, 4C, and 4D for the NHS, OFF, PRI, and SEC highway systems, respectively. In several cases, there was little

or no data for certain maintenance activity and highway system combinations. These cases are indicated with periods in these 8 tables.

Because the sample size at the highway system level is approximately one-fourth that of the state level, the estimates should be more variable. The increased variability is, in general, reflected in larger standard errors and wider confidence intervals (which are shown in Tables 3A, 3B, 3C, and 3D). A similar generalization cannot be made for the sample size inflation factors in Tables 4A, 4B, 4C, and 4D because the values in these tables are ratios. For example, if the numerator and denominator of the sample size inflation factor ratio are both increasing, the ratio itself can increase, decrease, or stay about the same. It all depends if the rates of increase in the numerator and denominator differ substantially.

5 Analysis of Sample Size Inflation Factors

To further condense the volume of tabled values for interpretation purposes, the mean and maximum of the four sample size inflation factors contained in each row of Table 2 and Tables 4A through 4D were determined. The means and maximum of the sample size inflation factors statewide and for the four highway systems are contained in Tables 5 and 6, respectively.

The mean values in Table 5 can be treated as estimates of the proportion of observations that would be required in a sample of .1 mile segments to yield the same variance as a sample of .2 mile segments for that maintenance activity and for that highway system or statewide. For example:

- The first row in Table 5 contains the values 1.59, 1.53, 1.54, 1.51, and 1.41. The first four values are the mean of the four NHS, OFF, PRI, and SEC values in the first rows of Tables 4A through 4D, respectively. The 1.41 value is the mean of the four statewide values in the first row of Table 2.

- Based on this survey data, the 1.41 value indicates that we would need to survey approximately 41% more .1 mile roadway segments statewide than we would need if we were to use .2 mile segments to achieve a similar variance. Similar statements of 59%, 53%, 54%, and 51% can be made for surveying the NHS, OFF, PRI, and SEC highway systems with .1 mile versus .2 mile segments.

Here are some practical interpretations of the values in Table 5:

- A value of 2 suggests a survey using .2 mile segments is equivalent (from a variance standpoint) to a survey of twice as many .1 mile segments. Note, however, that both of these samples would survey the same total amount of roadway.

- If a value is less than 2, it is more efficient to sample .1 mile segments. On the other hand, if a value is greater than 2, it is more efficient to sample .2 mile segments.
- If a value is 1 than it is just as efficient to sample .1 mile segments as .2 mile segment. In other words, we can cut the total sampling effort in half.

If we order the sample size inflation factors (SSIFs) in the column for statewide estimation in Table 5, we have the following:

#	Maintenance Activity	SSIF	Precision using .1 mile segments
5.	% paths and sidewalks acceptable	0.84	large gain
18b.	% right striping acceptable (w/ refl)	0.94	↓
20b.	% left striping acceptable (w/ refl)	0.94	↓
19b.	% center striping acceptable (w/ refl)	0.98	↓
18a.	% rt. striping acceptable (w/o refl)	1.04	↓
3.	% mowing acceptable	1.05	↓
9.	% of roadway swept	1.09	↓
6.	% slopes and ditches acceptable	1.10	↓
20a.	% lt. striping acceptable (w/o refl)	1.11	↓
19a.	% cr. striping acceptable (w/o refl)	1.22	↓
12.	% highway lighting acceptable	1.25	↓
17.	% roadside delineators acceptable	1.29	↓
1.	% drainage structures acceptable	1.41	moderate gain
11.	% guide signs acceptable	1.45	↓
14.	% pavement symbols acceptable	1.48	↓
8.	pieces of debris per mile	1.55	↓
4.	% nuisance vegetation acceptable	1.64	↓
13.	% traffic signals acceptable	1.71	small gain
2.	% fencing acceptable	1.72	↓
7.	pieces of litter per mile	1.75	↓
16.	% reg/warning symbols acceptable	1.89	↓
10.	% crash barriers acceptable	2.17	no gain
15.	% protective barriers acceptable	2.25	↓

Because the majority of mean SSIFs are less than 2, we predict there would be a gain in the precision of statewide estimates if .2 mile segments were replaced with twice as many .1 mile segments.

Note that although the mean SSIFs in Table 5 for the NHS, OFF, PRI, and SEC highway systems tend to be larger than the corresponding statewide SSIF, the majority of values are still less than 2. Thus, a statement can be made for the precision of highway system estimates that is similar to the statement made for the statewide estimates. That is, because the majority of the mean SSIFs in Table 5 for the NHS, OFF, PRI, and SEC highway systems are less than 2, we predict there would be a gain in the precision of highway system estimates if .2 mile segments were replaced with twice as many .1 mile segments.

More conservative estimates of the SSIFs are given in Table 6 which contains the maximum SSIFs instead of the mean SSIFs. The maximum SSIFs can be considered the worst-case scenario based on the survey data, or, the more pessimistic view of sampling .1 mile segments instead of .2 mile segments. Note that although there are more values close to or greater than 2 in this worst-case scenario, the majority of values are less than 2.

From a sampling planning standpoint, we have several options for future monitoring of the roadway system. Before presenting these options in Section 7, one important issue needs to be addressed — an acceptable margin of error.

6 An Acceptable Margin of Error for Future Surveys

Many people are familiar with the term "margin of error" in reported results from political polls that use a 95% confidence level. A margin of error is a measure of how close our estimate is to the truth. For example, if a poll's margin of error is plus or minus 4 percentage points, then we have the following interpretation:

- If we could take samples repeatedly using the same sampling method that generated the data, then 95% of the samples would yield an estimate that is within 4 percentage points (plus or minus) of the true value.

Once a survey has been performed, we can use information about variability (e.g., standard errors and confidence interval widths) to assess how large a sample needs to be taken to achieve a desired margin of error in a future survey. Specifically, to determine an appropriate sample size when planning a future roadway survey, we require a prespecified acceptable margin of error (assuming the traditional confidence level of 95%).

In Table 7, multipliers are provided that indicate how many times larger or smaller a future sampling plan should be relative to the size of the summer 2002 sampling plan for a prespecified margin of error for statewide estimates. Three prespecified levels for the margin of error are given: 3, 4, and 5. For example,

- In row 1 of Table 7, consider the two values (3.03 and 4.50) in the ME=3 column.

- The ME=3 column indicates that we want our statewide estimate of the percentage of acceptable drain structures to be within 3% of the true percentage.
- The 3.03 indicates that if we were to use .2 mile segments, we should sample approximately 3 times (triple) the number of .2m segments that were sampled in the summer of 2002 to achieve a 3% margin of error.
- The 4.50 indicates that if we were to use .1 mile segments, we should sample approximately 4.5 times the number of .2m segments that were sampled in the summer of 2002 to achieve a 3% margin of error.
- Note that the .1 mile column value of 4.50 is less than twice the .2 mile column value of 3.03. Thus, the total sampling effort as measured by total roadway miles sampled would be less if .1 mile segments were used.

- In row 1 of Table 7, consider the two values (1.70 and 2.53) in the ME=4 column.
  - The ME=4 column indicates that we want our statewide estimate of the percentage of acceptable drain structures to be within 4% of the true percentage.
  - The 1.70 indicates that if we were to use .2 mile segments, we should sample approximately 70% more or 1.7 times the number of .2m segments that were sampled in the summer of 2002 to achieve a 4% margin of error.
  - The 2.53 indicates that if we were to use .1 mile segments, we should sample approximately 150% more or 2.5 times the number of .2m segments that were sampled in the summer of 2002 to achieve a 4% margin of error.

- In row 1 of Table 7, consider the two values (1.09 and 1.62) in the ME=5 column.
  - The ME=5 column indicates that we want our statewide estimate of the percentage of acceptable drain structures to be within 5% of the true percentage.
  - The 1.09 indicates that if we were to use .2 mile segments, we should sample approximately 10% more or 1.1 times the number of .2m segments that were sampled in the summer of 2002 to achieve a 5% margin of error. Because the value is close to 1, the margin of error for the summer 2002 estimate was close to 5%.
  - The 1.62 indicates that if we were to use .1 mile segments, we should sample approximately 60% more or 1.6 times the number of .2m segments that were sampled in the summer of 2002 to achieve a 5% margin of error.

Once again, it is important to point out that if the value in the .1m column is less than twice the value in the .2m column, the total amount of sampled roadway would be less using .1 mile segments. For completeness, sample size multipliers were calculated also for the four highway types. These values are contained in Tables 8A through 8D.

7 Sampling Plans for Future Monitoring

Sampling plans for future monitoring will be based on the sample size multiplier values in Table 7. In Table 7, the largest sample size multipliers are associated with (i) % crash barriers acceptable, (ii) % pavement symbols acceptable, (iii) % traffic signals acceptable, (iv) % highway lighting acceptable, (v) % drainage structures acceptable, and (vi) % paths and sidewalks acceptable. These will be important maintenance activities to consider when proposing the following monitoring sampling plans. Each of these six activities will be referred to as a **larger sample maintenance activity (LSMA)**.

Note: If a multiplier in the .1m column equals 2 then the new sampling plan would require twice as many .1 mile sampling units as the number of .2 mile sampling units taken in the summer 2002 sampling plan. For this case the total sampling effort would be the same as the summer 2002 sampling plan. The main difference is that the .1 mile segments would be sampled individually at a larger number of sampling locations instead of being sampled as adjacent pairs at fewer locations. Therefore, to achieve a specified ME for any maintenance activity:

- If the multiplier in the .1m column is > 2 then a new sampling plan would require a greater total sampling effort than the summer 2002 sampling plan.
- If the multiplier in the .1m column is < 2 then a new sampling plan would require less total sampling effort than the summer 2002 sampling plan.

As you progress from PLAN I to PLAN V, differing levels of complexity are required.

PLAN I: *Sample the same number of .1 mile segments for all maintenance activities.*

- For a margin of error of 3 (ME=3), eight of the maintenance activities have sample size multipliers > 2 for .1 mile segments. Thus, the summer 2002 sampling plan is sufficient to provide estimates having a ME=3 for the majority (15 of 23) of maintenance activities.
- For a margin of error of 4 (ME=4), all but the six LSMAs have sample size multipliers close to one. Thus, the summer 2002 sampling plan should be sufficient to provide estimates having a ME=4 for all but the six LSMAs.

- For a margin of error of 5 (ME=5), all but the LSMAs have sample size multipliers less than one. Thus, the summer 2002 sampling plan should be sufficient to provide estimates having a ME< 5 for all but the six LSMAs. It would also be possible to reduce the summer 2002 sampling plan by approximately 20% and still achieve a ME=5 for all but the six LSMAs.

IMPLEMENTATION:

For PLAN I, determine the sample size L_I associated with those maintenance activities of interest that require the greatest sampling effort. Then select the L_I sampling segments from the sampling frame. PLAN I limits the number of sites to visit to a total of L_I.

Benefits: This plan is logistically the simplest because all sampling units will be the same size and all maintenance activities will be assessed on each of the L_I units.

Drawbacks: If precise estimation of any of the six LSMAs is a high priority, then the sample size L_I will have to be increased (relative to the summer 2002 sampling plan). The improved estimation for the LSMAs, however, may be offset by the additional time and cost required to complete the sample. We would also be collecting more information than is required for the maintenance activities that have multipliers < 2.

PLAN II: *Sample .1 mile segments for all maintenance activities, but sample a different number of segments for different maintenance activities.*

Before providing details for PLAN II, it is important to review results for the three margin of error cases.

1. For a margin of error of 3 (ME=3):

   (a) Ten of the maintenance activities have sample size multipliers < 1 for .1 mile segments. For these activities we could reasonably cut the total sampling effort in half and still achieve a ME=3.

   (b) Seven of the maintenance activities have sample size multipliers between 1 and 2 for .1 mile segments. Thus, the summer 2002 sampling plan is sufficient to provide estimates having a ME=3 for these maintenance activities.

   (c) Eight of the maintenance activities have sample size multipliers > 2 for .1 mile segments. Thus, the summer 2002 sampling plan is insufficient to provide estimates having a ME=3 for these maintenance activities.

2. For a margin of error of 4 (ME=4):

   (a) Fifteen of the maintenance activities have sample size multipliers < 1.1 for .1 mile segments. For these activities we could reasonably cut the total sampling effort in half and still achieve a ME=4.

   (b) Three of the maintenance activities have sample size multipliers between 1.1 and 1.9 for .1 mile segments. Thus, the summer 2002 sampling plan is sufficient to provide estimates having a ME=4 for these maintenance activities.

   (c) Five of the maintenance activities have sample size multipliers > 2 for .1 mile segments. Thus, the summer 2002 sampling plan is insufficient to provide estimates having a ME=4 for these maintenance activities.

3. For a margin of error of 5 (ME=5):

   (a) Seventeen of the maintenance activities have sample size multipliers < 1 for .1 mile segments. For these activities we could reasonably cut the total sampling effort in half and still achieve a ME=5.

   (b) Two of the maintenance activities have sample size multipliers between 1.2 and 1.6 for .1 mile segments. Thus, the summer 2002 sampling plan is sufficient to provide estimates having a ME=5 for these maintenance activities.

   (c) Four of the maintenance activities have sample size multipliers > 2 for .1 mile segments. Thus, the summer 2002 sampling plan is insufficient to provide estimates having a ME=4 for these maintenance activities.

There are several sampling plans with varying sample sizes to achieve an acceptable ME for each maintenance activity. Here are two that should be considered:

PLAN II(A):

1. Choose an acceptable ME for each maintenance activity.

2. Decrease the sampling effort for those maintenance activities that have multiplier values < 1 for the specified ME. I would recommend a reduction of at most 50%, preferably closer to 25% to be conservative.

3. Leave the sampling effort unchanged for those maintenance activities that have multiplier values between 1 and 2 for the specified ME.

4. Increase the sampling effort for those maintenance activities that have multiplier values > 2 for the specified ME. Because the multipliers for the six LSMAs are very large

(in the > 5 to the > 15 range depending on the ME level), the sample size would be impractically large to achieve a ME ≤ 5 for these activities. Thus, I would increase the sampling effort for these maintenance activities by as much as resources allow.

PLAN II(B):

1. Choose an acceptable ME for each maintenance activity.
2. Leave the sampling effort unchanged for those maintenance activities that have multiplier values < 2 for the specified ME.
3. Increase the sampling effort for those maintenance activities that have multiplier values > 2 for the specified ME (following the suggestions given in PLAN II(A)).

IMPLEMENTATION:

For PLAN II(A) and PLAN II(B), you would

1. Determine L_{II}, the largest sample size associated with those maintenance activities requiring increased sampling effort.
2. Select a sample of size L_{II} from the sampling frame.
3. For maintenance activities requiring fewer than L_{II} sampling segments, take subsamples from the L_{II} segments to determine which segments to sample. This limits the total number of sites to visit to be L_{II}. Note: L_I from PLAN I and L_{II} from PLAN II should be similar.

   Benefits: Both plans are flexible to allow for varying amounts of sampling across maintenance activities and both plans avoid over-sampling maintenance activities having more precise estimates than the LSMA estimates. It is more economical to sample only a subset of maintenance activities then to sample all maintenance activities for all .1 mile units (as in PLAN I).

   Drawbacks: Logistically it is slightly more complicated and would require reliable accounting for the differences in sampling effort.

PLAN III: *Sample .1 mile segments for maintenance activities having low sample size multipliers and .2 mile segments for maintenance activities having high sample size multipliers.*

- For a margin of error of 3 (ME=3), eight of the maintenance activities have sample size multipliers > 2 for .1 mile segments. Thus, the summer 2002 sampling plan is sufficient to provide estimates having a ME=3 for the majority (15 of 23) of maintenance activities.

- For a margin of error of 4 (ME=4), all but the six LSMAs have sample size multipliers close to one. Thus, the summer 2002 sampling plan should be sufficient to provide estimates having a ME=4 for all but the six LSMAs.

- For a margin of error of 5 (ME=5), all but the LSMAs have sample size multipliers less than one. Thus, the summer 2002 sampling plan should be sufficient to provide estimates having a $ME < 5$ for all but the six LSMAs. It would also be possible to reduce the summer 2002 sampling plan by approximately 20% and still achieve a ME=5 for all but the six LSMAs.

IMPLEMENTATION:

1. Choose an acceptable ME for each maintenance activity.

2. For ME=3 or ME=4, leave the sampling effort of .1 mile segments unchanged for those maintenance activities that have multiplier values less than 2. For ME=5, either leave the sampling effort unchanged, or, reduce sampling effort by at most 25%. Let L_{III} be the number of .1 mile segments associated with these maintenance activities.

3. Increase the sampling effort by sampling .2 mile segments instead of .1 mile segments for those maintenance activities that have multiplier values > 2 for the specified ME.

4. When sampling .2 mile segments, first sample the .1 mile starting segment. Then sample the prior .1 mile segment if the sampling unit number (from the sampling frame) is even and sample the next .1 mile segment if the sampling unit number is odd.

   Benefits: This plan is logistically simple because all maintenance activities will be assessed at each sampling location for either a .1 mile or .2 mile segment.

   Drawbacks: If precise estimation of any of the six LSMAs is a high priority, then the number of sampling locations will have to be increased. The improved estimation for the LSMAs may be offset by the additional time and cost required to complete the sample. We would be collecting more information than is required for the maintenance activities that have multipliers < 2.

PLAN IV: *Incorporate elements from both PLAN II and PLAN III.*

There are several sampling plans with varying sample sizes to achieve an acceptable ME for each maintenance activity. Here are two that should be considered.

IMPLEMENTATION:

PLAN IV(A):

1. Choose an acceptable ME for each maintenance activity.

2. Decrease the sampling effort of .1 mile segments for those maintenance activities that have multiplier values < 1 for the specified ME. I would recommend a reduction of at most 50%, preferably a reduction closer to 25% to be conservative.

3. Leave the sampling effort of .1 mile segments unchanged for those maintenance activities that have multiplier values between 1 and 2 for the specified ME.

4. Increase the sampling effort by sampling .2 mile segments for those maintenance activities that have multiplier values > 2 for the specified ME. Because the multipliers for the six LSMAs are very large (in the > 5 to the > 15 range depending on the ME level), the sample size would be impractically large to achieve a ME ≤ 5 for these activities. Thus, I would increase the sample size of .2 mile segments by as much as resources allow.

PLAN IV(B):

1. Choose an acceptable ME for each maintenance activity.

2. Leave the sampling effort of .1 mile segments unchanged for those maintenance activities that have multiplier values < 2 for the specified ME.

3. Increase the sampling effort by sampling .2 mile segments for those maintenance activities that have multiplier values > 2 for the specified ME (following the suggestions given in PLAN IV(A)).

For PLAN IV(A) and PLAN IV(B), you would select a sample from the sampling frame. When sampling .2 mile segments, first sample the .1 mile starting segment. Then sample the prior .1 mile segment if the sampling unit number (from the sampling frame) is even and sample the next .1 mile segment if the sampling unit number is odd.

Benefits: Both plans are flexible to allow for varying amounts of sampling effort and both plans avoid over-sampling maintenance activities having more precise estimates

than the LSMA estimates. Thus, it is more economical than sampling all maintenance activities for all .1 mile units (as in PLAN I). It will also require having to visit fewer locations than PLAN II and PLAN III.

Drawbacks: Logistically it is slightly more complicated than PLAN II and PLAN III because we would be using varying levels of sampling effort and two different length sampling segments across the maintenance activities. This would require reliable accounting for the differences in sampling effort and unit length.

PLAN V: *Modify PLAN I or PLAN II by incorporating adaptive cluster sampling (ACS) for those maintenance activities that are rare and tend to cluster spatially.*

Maintenance activities that are rare and tend to cluster spatially would include protective barriers, fencing, paths and sidewalks, crash barriers, and highway lighting. For example, only 19.1 miles of fencing were observed in over 200 miles of roadside sampled. Fencing, however, clusters spatially. That is, when fencing is observed in a .1 mile sampling segment, it is also likely to be present in the neighboring .1 mile segments. ACS will permit the surveyor to collect fencing data in neighboring segments when fencing is present in the initially selected sampling segment. With ACS, more fencing will be surveyed than using the current (nonadaptive) sampling procedures. The ACS procedure involves the following:

- If the rare/clustered maintenance activity is present in the initial sampling segment, then also sample its two neighboring .1 mile segments. Otherwise, sampling is completed for that initial sampling segment.
- If the rare/clustered maintenance activity is also present in a neighboring .1 mile segment, then continue by sampling its neighboring .1 mile segment. Otherwise, discontinue sampling in that direction.
- Continue adaptively sampling in both directions until you hit .1 mile segments in both directions that do not contain the rare/clustered maintenance activity.

For example, consider the following figure where each row represents ten .1 mile segments.

	.1m	.1m	.1m	.1m	.1m	.1m	.1m	.1m	.1m	.1m
Row 1	?	?	?	?	?	?	Yes	?	?	?
Row 2	?	?	?	?	?	Yes	Yes	Yes	?	?
Row 3	?	?	?	?	Yes	Yes	Yes	Yes	No	?
Row 4	?	?	?	No	Yes	Yes	Yes	Yes	No	?

Suppose that 'Yes' in Row 1 indicates a .1 mile segment that is sampled and fencing was present. You would then sample the adjacent segments shown in Row 2. Suppose fencing is present in these segment also. Sampling continues to the next two adjacent segments shown in Row 3. Suppose that fencing is present in the left segment but is not present ('No') in the right segment. We would stop sampling to the right but would continue sampling to the left. Suppose that fencing is not present in the next segment to the left and depicted in Row 4. At this point ACS would stop. Thus, the initial presence of fencing led to sampling a total of .4 miles of fencing instead of just .1 mile.

IMPLEMENTATION:

PLAN V(A): *Sample the same number of .1 mile segments for all maintenance activities, but apply ACS only for maintenance activities that are classified as rare and/or clustered.*

- Follow the steps in PLAN I. Apply ACS for the subset of maintenance activities that are classified as rare and/or clustered.

PLAN V(B): *Sample .1 mile segments for all maintenance activities, but sample a different number of sampling segments for different maintenance activities. Then apply ACS for maintenance activities that are classified as rare and/or clustered.*

- Follow the steps in PLAN II. Apply ACS for the subset of maintenance activities that are classified as rare and/or clustered.

  Benefits: Both plans are flexible to allow for varying amounts of sampling. It is economical to adaptively sample for those rare/cluster maintenance activities once observed than having to increase the number of sampling locations in hope of detecting additional cases.

Drawbacks: Logistically, the ACS aspect adds one more level of complexity. This would require reliable accounting and some preliminary training of surveyors in the adaptive sampling method.

8 Final Comments

In this report, summary statistics from the summer 2002 survey data were used to provide various options for a statewide sampling protocol for monitoring maintenance activities. Selection of an option will depend on

- Determining the margin of error to assign to each maintenance activity.
- Assessing the 23 maintenance activities in terms of relative importance.
- Determine whether or not using two different length sampling segments is reasonable.
- Estimate the amount of sampling resources that can be committed to data collection in the future.

My personal recommendation (if feasible to MDT) would be to use PLAN V(A) or PLAN V(B). This would require the same sampling effort as the summer 2002 survey for the majority of maintenance activities, and a slight increase in sampling effort for those rare and/or clustered maintenance activities. Once a second year's data is collected, the sampling plan can be updated and modified if desired.

APPENDIX

TABLE 1:

STATEWIDE MAINTENANCE ACTIVITY VARIABILITY

		Standard Error			CI Width		
	ROADSIDE Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
1.	% drainage structures acceptable	2.61	3.12	3.18	10.42	12.22	12.09
2.	% fencing acceptable	0.40	0.30	0.68	1.51	1.13	2.53
3.	% mowing acceptable	2.03	2.05	2.07	7.64	7.68	8.10
4.	% nuisance vegetation acceptable	0.19	0.23	0.26	0.75	0.91	1.00
5.	% paths and sidewalks acceptable	3.00	2.74	2.68	10.65	9.94	9.78
6.	% slopes and ditches acceptable	0.66	0.64	0.73	2.62	2.60	2.85
7.	pieces of litter per mile	1.57	2.14	2.09	6.14	8.06	7.80

		Standard Error			CI Width		
	ROADWAY Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
8.	pieces of debris per mile	0.98	1.17	1.22	3.69	4.46	4.89
9.	% of roadway swept	0.93	0.95	0.99	3.60	3.62	3.90

		Standard Error			CI Width		
	TRAFFIC Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
10.	% crash barriers acceptable	5.45	8.73	6.94	21.13	35.81	27.05
11.	% guide signs acceptable	1.78	1.91	2.27	6.70	7.43	8.90
12.	% highway lighting acceptable	4.30	5.79	3.53	17.22	23.88	13.42
13.	% traffic signals acceptable	4.25	6.02	5.68	16.95	21.91	19.95
14.	% pavement symbols acceptable	4.30	3.36	6.49	16.47	13.15	25.60
15.	% protective barriers acceptable	0.54	0.96	0.66	2.18	3.77	2.55
16.	% reg/warning symbols acceptable	1.52	2.06	2.03	5.84	8.08	8.26
17.	% roadside delineators acceptable	1.38	1.40	1.74	5.45	5.45	6.79
18a.	% rt. striping acceptable (w/o refl)	1.12	1.17	1.13	4.47	4.58	4.51
19a.	% cr. striping acceptable (w/o refl)	1.47	1.57	1.61	5.49	5.97	6.43
20a.	% lt. striping acceptable (w/o refl)	1.16	1.22	1.20	4.60	4.94	4.76
18b.	% right striping acceptable (w/ refl)	1.89	1.84	1.84	7.57	7.27	7.39
19b.	% center striping acceptable (w/ refl)	1.70	1.65	1.59	6.21	6.42	6.29
20b.	% left striping acceptable (w/ refl)	1.88	1.81	1.79	7.26	7.18	7.07

The .2m .1m .1m column labels represent the
.2 mile unit samples and the two .1 mile unit samples, respectively.

TABLE 2:

STATEWIDE MAINTENANCE ACTIVITY
SAMPLE SIZE INFLATION FACTORS

		Std Error		95% CI	
	ROADSIDE Maintenance Activities	(A)	(B)	(A)	(B)
1.	% drainage structures acceptable	1.43	1.48	1.37	1.35
2.	% fencing acceptable	0.57	2.95	0.56	2.80
3.	% mowing acceptable	1.01	1.04	1.01	1.12
4.	% nuisance vegetation acceptable	1.47	1.87	1.46	1.78
5.	% paths and sidewalks acceptable	0.84	0.80	0.87	0.84
6.	% slopes and ditches acceptable	0.96	1.25	0.98	1.18
7.	pieces of litter per mile	1.85	1.77	1.72	1.61

		Std Error		95% CI	
	ROADWAY Maintenance Activities	(A)	(B)	(A)	(B)
8.	pieces of debris per mile	1.44	1.56	1.46	1.75
9.	% of roadway swept	1.04	1.13	1.01	1.18

		Std Error		95% CI	
	TRAFFIC Maintenance Activities	(A)	(B)	(A)	(B)
10.	% crash barriers acceptable	2.57	1.62	2.87	1.64
11.	% guide signs acceptable	1.16	1.63	1.23	1.77
12.	% highway lighting acceptable	1.81	0.67	1.92	0.61
13.	% traffic signals acceptable	2.01	1.79	1.67	1.38
14.	% pavement symbols acceptable	0.61	2.28	0.64	2.42
15.	% protective barriers acceptable	3.17	1.46	2.99	1.37
16.	% reg/warning symbols acceptable	1.84	1.79	1.92	2.00
17.	% roadside delineators acceptable	1.03	1.58	1.00	1.56
18a.	% rt. striping acceptable (w/o refl)	1.09	1.02	1.05	1.02
19a.	% cr. striping acceptable (w/o refl)	1.14	1.20	1.18	1.37
20a.	% lt. striping acceptable (w/o refl)	1.12	1.08	1.16	1.07
18b.	% right striping acceptable (w/ refl)	0.95	0.95	0.92	0.95
19b.	% center striping acceptable (w/ refl)	0.95	0.88	1.07	1.03
20b.	% left striping acceptable (w/ refl)	0.93	0.91	0.98	0.95

(A) and (B) indicate the first and second .1 mile unit samples, respectively.

TABLE 3A: MAINTENANCE ACTIVITY VARIABILITY

NATIONAL HIGHWAY SYSTEM (NHS)

		Standard Error			CI Width		
	ROADSIDE Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
1.	% drainage structures acceptable	3.91	4.85	5.01	15.28	19.11	19.27
2.	% fencing acceptable	0.40	0.30	0.68	1.51	1.13	2.53
3.	% mowing acceptable	3.10	3.15	3.15	12.29	12.67	12.43
4.	% nuisance vegetation acceptable	0.26	0.20	0.47	1.05	0.76	1.75
5.	% paths and sidewalks acceptable	.	.	.	.	.	.
6.	% slopes and ditches acceptable	0.99	0.99	1.06	3.90	3.85	4.12
7.	pieces of litter per mile	2.94	3.05	3.00	11.29	11.43	11.73

		Standard Error			CI Width		
	ROADWAY Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
8.	pieces of debris per mile	0.77	0.91	1.25	2.92	3.48	4.74
9.	% of roadway swept	1.82	1.89	1.78	7.03	7.25	6.99

		Standard Error			CI Width		
	TRAFFIC Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
10.	% crash barriers acceptable	7.19	12.16	8.68	27.83	43.38	31.58
11.	% guide signs acceptable	1.41	2.37	1.68	5.33	9.42	6.65
12.	% highway lighting acceptable	14.58	18.73	13.44	51.09	64.43	48.50
13.	% traffic signals acceptable	1.87	.	.	4.35	.	.
14.	% pavement symbols acceptable	7.35	8.31	8.69	30.26	34.09	34.27
15.	% protective barriers acceptable	0.45	0.67	0.54	1.77	2.68	2.10
16.	% reg/warning symbols acceptable	1.34	2.01	1.77	5.39	7.53	6.68
17.	% roadside delineators acceptable	2.07	2.06	2.82	7.73	8.01	10.81
18a.	% rt. striping acceptable (w/o refl)	1.49	1.51	1.52	5.93	5.82	5.95
19a.	% cr. striping acceptable (w/o refl)	2.47	2.43	2.59	10.08	9.54	10.46
20a.	% lt. striping acceptable (w/o refl)	1.53	1.55	1.60	5.96	6.05	6.35
18b.	% right striping acceptable (w/ refl)	2.62	2.57	2.53	11.92	12.35	11.93
19b.	% center striping acceptable (w/ refl)	3.05	3.12	3.08	9.91	10.29	9.71
20b.	% left striping acceptable (w/ refl)	2.92	2.86	2.85	11.56	11.06	11.08

The .2m .1m .1m column labels represent the
.2 mile unit samples and the two .1 mile unit samples, respectively.

TABLE 3B: MAINTENANCE ACTIVITY VARIABILITY

OFFICIAL (OFF) ROUTE SYSTEM

		Standard Error			CI Width		
	ROADSIDE Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
1.	% drainage structures acceptable	9.46	12.92	10.01	36.54	51.58	39.29
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	6.59	6.80	6.59	25.17	26.39	25.08
4.	% nuisance vegetation acceptable	0.88	1.44	0.74	3.48	5.64	2.95
5.	% paths and sidewalks acceptable	3.56	7.59	1.93	9.17	20.31	4.85
6.	% slopes and ditches acceptable	2.81	2.87	2.86	10.59	11.20	10.53
7.	pieces of litter per mile	0.80	1.08	1.11	3.14	4.01	4.41

		Standard Error			CI Width		
	ROADWAY Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
8.	pieces of debris per mile	0.21	0.24	0.45	0.80	0.90	1.71
9.	% of roadway swept	3.17	2.72	4.20	12.63	10.71	16.03

		Standard Error			CI Width		
	TRAFFIC Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
10.	% crash barriers acceptable	.	.	.	.	.	.
11.	% guide signs acceptable	10.21	9.95	16.59	38.53	37.23	66.90
12.	% highway lighting acceptable	.	.	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.	.	.
14.	% pavement symbols acceptable	20.28	18.98	22.77	100.0	50.00	100.0
15.	% protective barriers acceptable	0.88	1.46	.	2.28	4.02	.
16.	% reg/warning symbols acceptable	11.32	10.63	15.54	44.18	41.59	59.02
17.	% roadside delineators acceptable	6.69	6.63	7.79	25.50	26.83	30.46
18a.	% rt. striping acceptable (w/o refl)	3.46	3.81	4.01	13.44	15.05	14.93
19a.	% cr. striping acceptable (w/o refl)	3.52	3.49	3.64	13.54	13.39	13.92
20a.	% lt. striping acceptable (w/o refl)	3.30	3.99	3.29	12.43	15.78	12.53
18b.	% right striping acceptable (w/ refl)	4.98	4.99	4.07	23.32	23.32	23.32
19b.	% center striping acceptable (w/ refl)	5.97	5.97	5.97	19.96	19.38	15.96
20b.	% left striping acceptable (w/ refl)	5.60	4.07	5.35	22.06	16.30	21.26

The .2m .1m .1m column labels represent the
.2 mile unit samples and the two .1 mile unit samples, respectively.

TABLE 3C: MAINTENANCE ACTIVITY VARIABILITY

PRIMARY (PRI) ROUTE SYSTEM

		Standard Error			CI Width		
	ROADSIDE Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
1.	% drainage structures acceptable	4.69	5.98	5.58	18.25	23.12	22.46
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	3.99	3.98	4.12	15.47	15.47	15.78
4.	% nuisance vegetation acceptable	0.50	0.66	0.62	1.92	2.65	2.37
5.	% paths and sidewalks acceptable	3.62	2.01	5.82	11.93	7.50	18.16
6.	% slopes and ditches acceptable	1.56	1.36	2.06	6.10	5.39	8.00
7.	pieces of litter per mile	1.39	1.85	1.25	5.46	7.11	4.79

		Standard Error			CI Width		
	ROADWAY Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
8.	pieces of debris per mile	3.85	3.60	4.55	14.50	13.75	18.11
9.	% of roadway swept	1.84	2.11	1.82	7.14	8.20	7.14

		Standard Error			CI Width		
	TRAFFIC Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
10.	% crash barriers acceptable	16.98	26.05	17.74	60.00	100.0	50.94
11.	% guide signs acceptable	3.02	3.54	4.52	11.74	13.56	17.81
12.	% highway lighting acceptable	5.62	12.12	.	19.54	43.15	.
13.	% traffic signals acceptable	8.09	10.50	11.17	34.17	50.00	40.00
14.	% pavement symbols acceptable	8.14	3.75	15.73	31.97	14.47	65.37
15.	% protective barriers acceptable	2.25	4.71	0.95	8.21	15.71	3.55
16.	% reg/warning symbols acceptable	2.11	3.56	2.08	7.79	13.23	8.27
17.	% roadside delineators acceptable	2.10	2.50	2.62	8.22	9.85	10.59
18a.	% rt. striping acceptable (w/o refl)	2.53	2.76	2.77	9.87	10.88	10.79
19a.	% cr. striping acceptable (w/o refl)	3.28	3.28	3.43	12.21	12.57	13.05
20a.	% lt. striping acceptable (w/o refl)	2.56	2.80	2.67	10.15	11.02	10.60
18b.	% right striping acceptable (w/ refl)	3.67	3.42	3.44	12.72	11.86	13.01
19b.	% center striping acceptable (w/ refl)	3.23	3.05	3.30	14.56	13.71	13.79
20b.	% left striping acceptable (w/ refl)	3.68	3.71	3.58	14.14	14.02	13.64

The .2m .1m .1m column labels represent the
.2 mile unit samples and the two .1 mile unit samples, respectively.

TABLE 3D: MAINTENANCE ACTIVITY VARIABILITY

SECONDARY (SEC) ROUTE SYSTEM

		Standard Error			CI Width		
	ROADSIDE Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
1.	% drainage structures acceptable	5.68	6.89	6.87	21.56	28.49	25.36
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	4.32	4.33	4.43	16.97	16.68	17.34
4.	% nuisance vegetation acceptable	0.26	0.30	0.28	0.97	1.17	1.07
5.	% paths and sidewalks acceptable	.	.	.	.	.	.
6.	% slopes and ditches acceptable	0.89	1.11	0.84	3.46	4.28	3.30
7.	pieces of litter per mile	2.27	2.30	2.41	8.77	8.82	9.28

		Standard Error			CI Width		
	ROADWAY Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
8.	pieces of debris per mile	1.45	2.87	0.89	5.79	11.30	3.52
9.	% of roadway swept	0.18	.	0.38	0.71	.	1.42

		Standard Error			CI Width		
	TRAFFIC Maintenance Activities	.2m	.1m	.1m	.2m	.1m	.1m
10.	% crash barriers acceptable	.	.	.	.	.	.
11.	% guide signs acceptable	3.13	2.04	4.85	12.96	6.98	19.40
12.	% highway lighting acceptable	.	.	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.	.	.
14.	% pavement symbols acceptable	16.03	.	22.04	65.78	.	100.0
15.	% protective barriers acceptable	.	.	.	.	.	.
16.	% reg/warning symbols acceptable	2.44	4.67	3.52	10.42	18.35	14.16
17.	% roadside delineators acceptable	2.62	2.65	3.66	10.18	9.95	14.02
18a.	% rt. striping acceptable (w/o refl)	2.46	2.62	2.40	9.72	10.24	9.44
19a.	% cr. striping acceptable (w/o refl)	2.62	3.71	2.23	10.21	14.61	8.80
20a.	% lt. striping acceptable (w/o refl)	2.64	2.81	2.71	10.60	11.13	10.69
18b.	% right striping acceptable (w/ refl)	3.38	3.22	3.15	14.70	15.22	15.55
19b.	% center striping acceptable (w/ refl)	3.86	3.92	3.89	13.19	12.39	12.20
20b.	% left striping acceptable (w/ refl)	4.05	3.60	4.01	15.44	14.23	15.53

The .2m .1m .1m column labels represent the
.2 mile unit samples and the two .1 mile unit samples, respectively.

TABLE 4A: SAMPLE SIZE INFLATION FACTORS

NATIONAL HIGHWAY SYSTEM (NHS)
MAINTENANCE ACTIVITY

		Std Error		95% CI	
	ROADSIDE Maintenance Activities	(A)	(B)	(A)	(B)
1.	% drainage structures acceptable	1.54	1.64	1.56	1.59
2.	% fencing acceptable	0.57	2.95	0.56	2.80
3.	% mowing acceptable	1.03	1.03	1.06	1.02
4.	% nuisance vegetation acceptable	0.59	3.27	0.52	2.75
5.	% paths and sidewalks acceptable	.	.	.	.
6.	% slopes and ditches acceptable	0.99	1.13	0.97	1.12
7.	pieces of litter per mile	1.07	1.04	1.03	1.08

		Std Error		95% CI	
	ROADWAY Maintenance Activities	(A)	(B)	(A)	(B)
8.	pieces of debris per mile	1.39	2.65	1.42	2.63
9.	% of roadway swept	1.08	0.96	1.06	0.99

		Std Error		95% CI	
	TRAFFIC Maintenance Activities	(A)	(B)	(A)	(B)
10.	% crash barriers acceptable	2.86	1.46	2.43	1.29
11.	% guide signs acceptable	2.83	1.42	3.12	1.56
12.	% highway lighting acceptable	1.65	0.85	1.59	0.90
13.	% traffic signals acceptable	.	.	.	.
14.	% pavement symbols acceptable	1.28	1.40	1.27	1.28
15.	% protective barriers acceptable	2.22	1.44	2.29	1.41
16.	% reg/warning symbols acceptable	2.25	1.74	1.95	1.54
17.	% roadside delineators acceptable	0.99	1.86	1.07	1.96
18a.	% rt. striping acceptable (w/o refl)	1.03	1.04	0.96	1.01
19a.	% cr. striping acceptable (w/o refl)	0.97	1.10	0.90	1.08
20a.	% lt. striping acceptable (w/o refl)	1.03	1.09	1.03	1.14
18b.	% right striping acceptable (w/ refl)	0.96	0.93	1.07	1.00
19b.	% center striping acceptable (w/ refl)	1.05	1.02	1.08	0.96
20b.	% left striping acceptable (w/ refl)	0.96	0.95	0.92	0.92

(A) and (B) indicate the first and second .1 mile unit samples, respectively.

TABLE 4B: SAMPLE SIZE INFLATION FACTORS

OFFICIAL (OFF) ROUTE MAINTENANCE ACTIVITY

		Std Error		95% CI	
	ROADSIDE Maintenance Activities	(A)	(B)	(A)	(B)
1.	% drainage structures acceptable	1.86	1.12	1.99	1.16
2.	% fencing acceptable	.	.	.	.
3.	% mowing acceptable	1.07	1.00	1.10	0.99
4.	% nuisance vegetation acceptable	2.68	0.71	2.62	0.72
5.	% paths and sidewalks acceptable	4.55	0.29	4.91	0.28
6.	% slopes and ditches acceptable	1.04	1.04	1.12	0.99
7.	pieces of litter per mile	1.82	1.92	1.63	1.96

		Std Error		95% CI	
	ROADWAY Maintenance Activities	(A)	(B)	(A)	(B)
8.	pieces of debris per mile	1.38	4.89	1.27	4.55
9.	% of roadway swept	0.73	1.75	0.72	1.61

		Std Error		95% CI	
	TRAFFIC Maintenance Activities	(A)	(B)	(A)	(B)
10.	% crash barriers acceptable	.	.	.	.
11.	% guide signs acceptable	0.95	2.64	0.93	3.01
12.	% highway lighting acceptable	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.
14.	% pavement symbols acceptable	0.88	1.26	0.25	1.00
15.	% protective barriers acceptable	2.75	.	3.11	.
16.	% reg/warning symbols acceptable	0.88	1.88	0.89	1.78
17.	% roadside delineators acceptable	0.98	1.36	1.11	1.43
18a.	% rt. striping acceptable (w/o refl)	1.21	1.34	1.25	1.23
19a.	% cr. striping acceptable (w/o refl)	0.98	1.07	0.98	1.06
20a.	% lt. striping acceptable (w/o refl)	1.46	0.99	1.61	1.02
18b.	% right striping acceptable (w/ refl)	1.00	0.67	1.00	1.00
19b.	% center striping acceptable (w/ refl)	1.00	1.00	0.94	0.64
20b.	% left striping acceptable (w/ refl)	0.53	0.91	0.55	0.93

(A) and (B) indicate the first and second .1 mile unit samples, respectively.

TABLE 4C: SAMPLE SIZE INFLATION FACTORS

PRIMARY (PRI) ROUTE
MAINTENANCE ACTIVITY

		Std Error		95% CI	
	ROADSIDE Maintenance Activities	(A)	(B)	(A)	(B)
1.	% drainage structures acceptable	1.63	1.42	1.60	1.52
2.	% fencing acceptable	.	.	.	.
3.	% mowing acceptable	1.00	1.07	1.00	1.04
4.	% nuisance vegetation acceptable	1.70	1.50	1.91	1.53
5.	% paths and sidewalks acceptable	0.31	2.59	0.40	2.32
6.	% slopes and ditches acceptable	0.76	1.75	0.78	1.72
7.	pieces of litter per mile	1.76	0.80	1.70	0.77

		Std Error		95% CI	
	ROADWAY Maintenance Activities	(A)	(B)	(A)	(B)
8.	pieces of debris per mile	0.87	1.40	0.90	1.56
9.	% of roadway swept	1.31	0.98	1.32	1.00

		Std Error		95% CI	
	TRAFFIC Maintenance Activities	(A)	(B)	(A)	(B)
10.	% crash barriers acceptable	2.35	1.09	2.78	0.72
11.	% guide signs acceptable	1.37	2.24	1.33	2.30
12.	% highway lighting acceptable	4.65	.	4.88	.
13.	% traffic signals acceptable	1.68	1.91	2.14	1.37
14.	% pavement symbols acceptable	0.21	3.73	0.20	4.18
15.	% protective barriers acceptable	4.38	0.18	3.66	0.19
16.	% reg/warning symbols acceptable	2.85	0.97	2.88	1.13
17.	% roadside delineators acceptable	1.42	1.56	1.44	1.66
18a.	% rt. striping acceptable (w/o refl)	1.19	1.20	1.22	1.20
19a.	% cr. striping acceptable (w/o refl)	1.00	1.09	1.06	1.14
20a.	% lt. striping acceptable (w/o refl)	1.20	1.09	1.18	1.09
18b.	% right striping acceptable (w/ refl)	0.87	0.88	0.87	1.05
19b.	% center striping acceptable (w/ refl)	0.89	1.04	0.89	0.90
20b.	% left striping acceptable (w/ refl)	1.02	0.95	0.98	0.93

(A) and (B) indicate the first and second .1 mile unit samples, respectively.

TABLE 4D: SAMPLE SIZE INFLATION FACTORS

SECONDARY (SEC) ROUTE MAINTENANCE ACTIVITY

		Std Error		95% CI	
	ROADSIDE Maintenance Activities	(A)	(B)	(A)	(B)
1.	% drainage structures acceptable	1.47	1.46	1.75	1.38
2.	% fencing acceptable	.	.	.	.
3.	% mowing acceptable	1.00	1.05	0.97	1.04
4.	% nuisance vegetation acceptable	1.36	1.22	1.45	1.21
5.	% paths and sidewalks acceptable	.	.	.	.
6.	% slopes and ditches acceptable	1.56	0.89	1.53	0.91
7.	pieces of litter per mile	1.03	1.12	1.01	1.12

		Std Error		95% CI	
	ROADWAY Maintenance Activities	(A)	(B)	(A)	(B)
8.	pieces of debris per mile	3.88	0.37	3.82	0.37
9.	% of roadway swept	.	4.18	.	3.98

		Std Error		95% CI	
	TRAFFIC Maintenance Activities	(A)	(B)	(A)	(B)
10.	% crash barriers acceptable	.	.	.	.
11.	% guide signs acceptable	0.42	2.40	0.29	2.24
12.	% highway lighting acceptable	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.
14.	% pavement symbols acceptable	.	1.89	.	2.31
15.	% protective barriers acceptable	.	.	.	.
16.	% reg/warning symbols acceptable	3.66	2.08	3.10	1.85
17.	% roadside delineators acceptable	1.02	1.95	0.96	1.90
18a.	% rt. striping acceptable (w/o refl)	1.13	0.95	1.11	0.94
19a.	% cr. striping acceptable (w/o refl)	2.01	0.72	2.05	0.74
20a.	% lt. striping acceptable (w/o refl)	1.13	1.05	1.10	1.02
18b.	% right striping acceptable (w/ refl)	0.91	0.87	1.07	1.12
19b.	% center striping acceptable (w/ refl)	1.03	1.02	0.88	0.86
20b.	% left striping acceptable (w/ refl)	0.79	0.98	0.85	1.01

(A) and (B) indicate the first and second .1 mile unit samples, respectively.

TABLE 5: MEAN OF THE SAMPLE SIZE INFLATION FACTORS

	ROADSIDE Maintenance Activities	NHS	OFF	PRI	SEC	State
1.	% drainage structures acceptable	1.59	1.53	1.54	1.51	1.41
2.	% fencing acceptable	1.72	.	.	.	1.72
3.	% mowing acceptable	1.04	1.04	1.03	1.02	1.05
4.	% nuisance vegetation acceptable	1.79	1.68	1.66	1.31	1.64
5.	% paths and sidewalks acceptable	.	2.51	1.40	.	0.84
6.	% slopes and ditches acceptable	1.05	1.05	1.25	1.22	1.10
7.	pieces of litter per mile	1.06	1.83	1.26	1.07	1.74

	ROADWAY Maintenance Activities	NHS	OFF	PRI	SEC	State
8.	pieces of debris per mile	2.02	3.02	1.18	2.11	1.55
9.	% of roadway swept	1.02	1.20	1.15	2.04	1.09

	TRAFFIC Maintenance Activities	NHS	OFF	PRI	SEC	State
10.	% crash barriers acceptable	2.01	.	1.74	.	2.17
11.	% guide signs acceptable	2.23	1.88	1.81	1.34	1.45
12.	% highway lighting acceptable	1.25	.	2.38	.	1.25
13.	% traffic signals acceptable	.	.	1.78	.	1.71
14.	% pavement symbols acceptable	1.31	0.85	2.08	1.05	1.48
15.	% protective barriers acceptable	1.84	1.47	2.10	.	2.25
16.	% reg/warning symbols acceptable	1.87	1.36	1.96	2.67	1.89
17.	% roadside delineators acceptable	1.47	1.22	1.52	1.46	1.29
18a.	% rt. striping acceptable (w/o refl)	1.01	1.26	1.20	1.03	1.04
19a.	% cr. striping acceptable (w/o refl)	1.01	1.02	1.07	1.38	1.22
20a.	% lt. striping acceptable (w/o refl)	1.07	1.27	1.14	1.08	1.11
18b.	% right striping acceptable (w/ refl)	0.99	0.92	0.92	0.99	0.94
19b.	% center striping acceptable (w/ refl)	1.03	0.90	0.93	0.95	0.98
20b.	% left striping acceptable (w/ refl)	0.94	0.73	0.97	0.91	0.94

TABLE 6: MAXIMUM OF THE SAMPLE SIZE INFLATION FACTORS

	ROADSIDE Maintenance Activities	NHS	OFF	PRI	SEC	State
1.	% drainage structures acceptable	1.64	1.99	1.63	1.75	1.48
2.	% fencing acceptable	2.95	.	.	.	2.95
3.	% mowing acceptable	1.06	1.10	1.07	1.05	1.12
4.	% nuisance vegetation acceptable	3.27	2.68	1.91	1.45	1.87
5.	% paths and sidewalks acceptable	.	4.91	2.59	.	0.87
6.	% slopes and ditches acceptable	1.13	1.12	1.75	1.56	1.25
7.	pieces of litter per mile	1.08	1.96	1.76	1.12	1.85

	ROADWAY Maintenance Activities	NHS	OFF	PRI	SEC	State
8.	pieces of debris per mile	2.65	4.89	1.56	3.88	1.75
9.	% of roadway swept	1.08	1.75	1.32	4.18	1.18

	TRAFFIC Maintenance Activities	NHS	OFF	PRI	SEC	State
10.	% crash barriers acceptable	2.86	.	2.78	.	2.87
11.	% guide signs acceptable	3.12	3.01	2.30	2.40	1.77
12.	% highway lighting acceptable	1.65	.	4.88	.	1.92
13.	% traffic signals acceptable	.	.	2.14	.	2.01
14.	% pavement symbols acceptable	1.40	1.26	4.18	2.31	2.42
15.	% protective barriers acceptable	2.29	3.11	4.38	.	3.17
16.	% reg/warning symbols acceptable	2.25	1.88	2.88	3.66	2.00
17.	% roadside delineators acceptable	1.96	1.43	1.66	1.95	1.58
18a.	% rt. striping acceptable (w/o refl)	1.04	1.34	1.22	1.13	1.09
19a.	% cr. striping acceptable (w/o refl)	1.10	1.07	1.14	2.05	1.37
20a.	% lt. striping acceptable (w/o refl)	1.14	1.61	1.20	1.13	1.16
18b.	% right striping acceptable (w/ refl)	1.07	1.00	1.05	1.12	0.95
19b.	% center striping acceptable (w/ refl)	1.08	1.00	1.04	1.03	1.07
20b.	% left striping acceptable (w/ refl)	0.96	0.93	1.02	1.01	0.98

TABLE 7:

STATEWIDE SAMPLE SIZE MULTIPLIERS NEEDED TO ACHIEVE A SPECIFIED MARGIN OF ERROR (ME)

		ME=3		ME=4		ME=5	
	ROADSIDE Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
1.	% drainage structures acceptable	3.03	4.50	1.70	2.53	1.09	1.62
2.	% fencing acceptable	0.07	0.21	0.04	0.12	0.03	0.07
3.	% mowing acceptable	1.84	1.91	1.04	1.07	0.66	0.69
4.	% nuisance vegetation acceptable	0.02	0.03	0.01	0.02	0.01	0.01
5.	% paths and sidewalks acceptable	4.00	3.34	2.25	1.88	1.44	1.20
6.	% slopes and ditches acceptable	0.19	0.24	0.11	0.13	0.07	0.09
7.	pieces of litter per mile	1.10	2.04	0.62	1.15	0.40	0.73

		ME=3		ME=4		ME=5	
	ROADWAY Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
8.	pieces of debris per mile	0.42	0.66	0.24	0.37	0.15	0.24
9.	% of roadway swept	0.39	0.44	0.22	0.24	0.14	0.16

		ME=3		ME=4		ME=5	
	TRAFFIC Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
10.	% crash barriers acceptable	13.21	33.90	7.43	19.07	4.75	12.20
11.	% guide signs acceptable	1.40	2.28	0.79	1.28	0.50	0.82
12.	% highway lighting acceptable	8.24	14.91	4.63	8.39	2.96	5.37
13.	% traffic signals acceptable	8.02	16.10	4.51	9.05	2.89	5.79
14.	% pavement symbols acceptable	8.23	18.75	4.63	10.55	2.96	6.75
15.	% protective barriers acceptable	0.13	0.41	0.07	0.23	0.05	0.15
16.	% reg/warning symbols acceptable	1.02	1.88	0.58	1.06	0.37	0.68
17.	% roadside delineators acceptable	0.85	1.34	0.48	0.75	0.30	0.48
18a.	% rt. striping acceptable (w/o refl)	0.56	0.61	0.31	0.34	0.20	0.22
19a.	% cr. striping acceptable (w/o refl)	0.96	1.15	0.54	0.64	0.34	0.41
20a.	% lt. striping acceptable (w/o refl)	0.59	0.67	0.33	0.37	0.21	0.24
18b.	% right striping acceptable (w/ refl)	1.59	1.50	0.90	0.84	0.57	0.54
19b.	% center striping acceptable (w/ refl)	1.28	1.22	0.72	0.68	0.46	0.44
20b.	% left striping acceptable (w/ refl)	1.57	1.45	0.88	0.82	0.56	0.52

The .2m and .1m column labels represent the
.2 mile unit samples and the .1 mile unit samples, respectively.

TABLE 8A:

SAMPLE SIZE MULTIPLIERS NEEDED TO ACHIEVE A SPECIFIED MARGIN OF ERROR (ME) — NATIONAL HIGHWAY SYSTEM (NHS) —

		ME=3		ME=4		ME=5	
	ROADSIDE Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
1.	% drainage structures acceptable	6.78	11.14	3.81	6.27	2.44	4.01
2.	% fencing acceptable	0.07	0.21	0.04	0.12	0.03	0.07
3.	% mowing acceptable	4.26	4.40	2.40	2.48	1.54	1.59
4.	% nuisance vegetation acceptable	0.03	0.10	0.02	0.06	0.01	0.04
5.	% paths and sidewalks acceptable	.	.	.	.	.	.
6.	% slopes and ditches acceptable	0.44	0.50	0.25	0.28	0.16	0.18
7.	pieces of litter per mile	3.84	4.12	2.16	2.32	1.38	1.48

		ME=3		ME=4		ME=5	
	ROADWAY Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
8.	pieces of debris per mile	0.26	0.69	0.15	0.39	0.09	0.25
9.	% of roadway swept	1.47	1.59	0.83	0.89	0.53	0.57

		ME=3		ME=4		ME=5	
	TRAFFIC Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
10.	% crash barriers acceptable	22.98	65.72	12.92	36.97	8.27	23.66
11.	% guide signs acceptable	0.88	2.50	0.50	1.40	0.32	0.90
12.	% highway lighting acceptable	94.48	155.9	53.14	87.70	34.01	56.13
13.	% traffic signals acceptable	1.55	.	0.87	.	0.56	.
14.	% pavement symbols acceptable	25.44	33.56	14.31	18.88	9.16	12.08
15.	% protective barriers acceptable	0.09	0.20	0.05	0.11	0.03	0.07
16.	% reg/warning symbols acceptable	0.81	1.80	0.45	1.01	0.29	0.65
17.	% roadside delineators acceptable	1.90	3.53	1.07	1.99	0.69	1.27
18a.	% rt. striping acceptable (w/o refl)	0.99	1.03	0.56	0.58	0.36	0.37
19a.	% cr. striping acceptable (w/o refl)	2.82	2.98	1.59	1.68	1.02	1.07
20a.	% lt. striping acceptable (w/o refl)	1.04	1.14	0.59	0.64	0.37	0.41
18b.	% right striping acceptable (w/ refl)	3.95	2.94	2.22	1.65	1.42	1.06
19b.	% center striping acceptable (w/ refl)	4.13	4.33	2.33	2.43	1.49	1.56
20b.	% left striping acceptable (w/ refl)	3.79	3.64	2.13	2.04	1.36	1.31

The .2m and .1m column labels represent the
.2 mile unit samples and the .1 mile unit samples, respectively.

TABLE 8B:

SAMPLE SIZE MULTIPLIERS NEEDED TO ACHIEVE A SPECIFIED MARGIN OF ERROR (ME) — OFFICIAL (OFF) ROUTE SYSTEM —

		ME=3		ME=4		ME=5	
	ROADSIDE Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
1.	% drainage structures acceptable	39.80	74.17	22.38	41.72	14.33	26.70
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	19.29	20.58	10.85	11.58	6.95	7.41
4.	% nuisance vegetation acceptable	0.35	0.93	0.19	0.52	0.12	0.33
5.	% paths and sidewalks acceptable	5.63	25.60	3.17	14.40	2.03	9.22
6.	% slopes and ditches acceptable	3.51	3.66	1.98	2.06	1.26	1.32
7.	pieces of litter per mile	0.29	0.55	0.16	0.31	0.10	0.20

		ME=3		ME=4		ME=5	
	ROADWAY Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
8.	pieces of debris per mile	0.02	0.09	0.01	0.05	0.01	0.03
9.	% of roadway swept	4.48	7.85	2.52	4.42	1.61	2.83

		ME=3		ME=4		ME=5	
	TRAFFIC Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
10.	% crash barriers acceptable	.	.	.	.	.	.
11.	% guide signs acceptable	46.33	122.3	26.06	68.81	16.68	44.04
12.	% highway lighting acceptable	.	.	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.	.	.
14.	% pavement symbols acceptable	277.8	230.4	156.3	129.6	100.0	82.96
15.	% protective barriers acceptable	0.34	0.95	0.19	0.53	0.12	0.34
16.	% reg/warning symbols acceptable	56.95	107.3	32.04	60.37	20.50	38.64
17.	% roadside delineators acceptable	19.89	26.97	11.19	15.17	7.16	9.71
18a.	% rt. striping acceptable (w/o refl)	5.32	7.15	2.99	4.02	1.92	2.57
19a.	% cr. striping acceptable (w/o refl)	5.51	5.89	3.10	3.31	1.98	2.12
20a.	% lt. striping acceptable (w/o refl)	4.84	7.08	2.72	3.98	1.74	2.55
18b.	% right striping acceptable (w/ refl)	15.11	11.07	8.50	6.23	5.44	3.98
19b.	% center striping acceptable (w/ refl)	15.84	15.84	8.91	8.91	5.70	5.70
20b.	% left striping acceptable (w/ refl)	13.94	12.72	7.84	7.16	5.02	4.58

The .2m and .1m column labels represent the
.2 mile unit samples and the .1 mile unit samples, respectively.

TABLE 8C:

SAMPLE SIZE MULTIPLIERS NEEDED TO ACHIEVE A SPECIFIED MARGIN OF ERROR (ME) — PRIMARY (PRI) ROUTE SYSTEM —

		ME=3		ME=4		ME=5	
	ROADSIDE Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
1.	% drainage structures acceptable	9.76	15.90	5.49	8.94	3.51	5.72
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	7.07	7.53	3.98	4.24	2.54	2.71
4.	% nuisance vegetation acceptable	0.11	0.19	0.06	0.11	0.04	0.07
5.	% paths and sidewalks acceptable	5.81	15.06	3.27	8.47	2.09	5.42
6.	% slopes and ditches acceptable	1.08	1.89	0.61	1.06	0.39	0.68
7.	pieces of litter per mile	0.86	1.52	0.48	0.85	0.31	0.55

		ME=3		ME=4		ME=5	
	ROADWAY Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
8.	pieces of debris per mile	6.59	9.22	3.71	5.19	2.37	3.32
9.	% of roadway swept	1.51	1.98	0.85	1.11	0.54	0.71

		ME=3		ME=4		ME=5	
	TRAFFIC Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
10.	% crash barriers acceptable	128.1	301.6	72.08	169.7	46.13	108.6
11.	% guide signs acceptable	4.05	9.08	2.28	5.11	1.46	3.27
12.	% highway lighting acceptable	14.04	65.29	7.90	36.72	5.05	23.50
13.	% traffic signals acceptable	32.43	55.45	18.24	31.19	11.68	19.96
14.	% pavement symbols acceptable	29.45	110.0	16.56	61.86	10.60	39.59
15.	% protective barriers acceptable	2.25	9.86	1.27	5.55	0.81	3.55
16.	% reg/warning symbols acceptable	1.98	5.63	1.11	3.17	0.71	2.03
17.	% roadside delineators acceptable	1.96	3.05	1.10	1.72	0.71	1.10
18a.	% rt. striping acceptable (w/o refl)	2.84	3.41	1.60	1.92	1.02	1.23
19a.	% cr. striping acceptable (w/o refl)	4.78	5.23	2.69	2.94	1.72	1.88
20a.	% lt. striping acceptable (w/o refl)	2.91	3.48	1.64	1.96	1.05	1.25
18b.	% right striping acceptable (w/ refl)	5.99	5.26	3.37	2.96	2.16	1.89
19b.	% center striping acceptable (w/ refl)	5.89	4.84	3.31	2.72	2.12	1.74
20b.	% left striping acceptable (w/ refl)	6.02	6.12	3.39	3.44	2.17	2.20

The .2m and .1m column labels represent the
.2 mile unit samples and the .1 mile unit samples, respectively.

TABLE 8D:

SAMPLE SIZE MULTIPLIERS NEEDED TO ACHIEVE A SPECIFIED MARGIN OF ERROR (ME) — SECONDARY (SEC) ROUTE SYSTEM —

		ME=3		ME=4		ME=5	
	ROADSIDE Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
1.	% drainage structures acceptable	14.36	21.10	8.08	11.87	5.17	7.60
2.	% fencing acceptable	.	.	.	.	.	.
3.	% mowing acceptable	8.31	8.74	4.68	4.91	2.99	3.15
4.	% nuisance vegetation acceptable	0.03	0.04	0.02	0.02	0.01	0.01
5.	% paths and sidewalks acceptable	.	.	.	.	.	.
6.	% slopes and ditches acceptable	0.35	0.55	0.20	0.31	0.13	0.20
7.	pieces of litter per mile	2.29	2.58	1.29	1.45	0.83	0.93

		ME=3		ME=4		ME=5	
	ROADWAY Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
8.	pieces of debris per mile	0.94	3.65	0.53	2.05	0.34	1.31
9.	% of roadway swept	0.02	0.06	0.01	0.04	0.01	0.02

		ME=3		ME=4		ME=5	
	TRAFFIC Maintenance Activities	.2m	.1m	.2m	.1m	.2m	.1m
10.	% crash barriers acceptable	.	.	.	.	.	.
11.	% guide signs acceptable	4.67	10.45	2.62	5.88	1.68	3.76
12.	% highway lighting acceptable	.	.	.	.	.	.
13.	% traffic signals acceptable	.	.	.	.	.	.
14.	% pavement symbols acceptable	120.2	215.9	67.61	121.4	43.27	77.72
15.	% protective barriers acceptable	.	.	.	.	.	.
16.	% reg/warning symbols acceptable	3.02	9.69	1.70	5.45	1.09	3.49
17.	% roadside delineators acceptable	3.05	5.95	1.72	3.35	1.10	2.14
18a.	% rt. striping acceptable (w/o refl)	2.69	3.05	1.51	1.72	0.97	1.10
19a.	% cr. striping acceptable (w/o refl)	3.05	6.12	1.72	3.44	1.10	2.20
20a.	% lt. striping acceptable (w/o refl)	3.12	3.51	1.76	1.97	1.12	1.26
18b.	% right striping acceptable (w/ refl)	6.00	4.61	3.38	2.59	2.16	1.66
19b.	% center striping acceptable (w/ refl)	6.62	6.83	3.72	3.84	2.38	2.46
20b.	% left striping acceptable (w/ refl)	7.29	7.15	4.10	4.02	2.62	2.57

The .2m and .1m column labels represent the
.2 mile unit samples and the .1 mile unit samples, respectively.