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June 30, 2006

BY EMAIL

To: Regional Executive Directors

From: Bill Howard
Director
Revenue Branch

Re: Amendment No. 8 to the *Scaling Manual*

I hereby approve Amendment No. 8 to the *Scaling Manual*, and attach a copy for your use.

This amendment provides an update to the weight scaling chapters and appendices as follows.

- Updated procedures, forms reference, statistical formulas, etc.
- Ensured compliance and consistency with Measurement Canada.
- Simplified reading for users by streamlining and by removing redundancies.

The business process remains the same.

This amendment is effective the date of this memo. Further amendments or revisions to this manual require my approval.



Bill Howard
Director
Revenue Branch

Attachment

pc: Coast Scaling Advisory Committee

Interior Scaling Advisory Committee





**BRITISH
COLUMBIA**

Ministry of
Forests



MANUAL REVISION TRANSMITTAL

<p>FOR FURTHER INFORMATION OR IF YOU HAVE A CHANGE OF ADDRESS, PLEASE CONTACT:</p> <p>Jim Crover Scaling Policy Forester Revenue Branch Ministry of Forests and Range 6th Floor - 727 Fisgard Street Victoria, BC V8W 1R8 Phone: 356-1955 PROFS userid: Jim.Crover@gov.bc.ca FAX: 387-5670</p>	MANUAL TITLE	
	Scaling Manual	
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Judy Laton Manuals Co-ordinator		
AUTHORIZATION (Name, Title)		
W. Howard Director, Revenue Branch		

Please make the following changes to your copy of the above Ministry manual.

ACTION (Remove/Insert)	(VOL.) CHAPTER-SECTION-SUBJECT	PAGE(S)	COMMENTS
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INSERT	Chapter 9	1 - 16	
REMOVE	Appendix 9A	1 - 14	After Chapter 9A Tab
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The Weight Scale System

9

Weight scaling is a sampling method where only a portion of the total production is measured or sampled, unlike piece scaling where all logs are measured for volume and grade. Based on the sample results, an estimate can be made about the total production. This chapter provides an overview of the Weight Scale System and an introduction to the statistical concepts that underlie this system. A more detailed look at how these concepts are applied to satisfy the data needs of industry and government follows in Chapter 10.



Figure 9.1 A loaded logging truck on the platform of a weight scale.

9.1 Weight Scaling - Overview of the System

9.1.1 Background

Weight scaling was introduced in the B.C. Interior in the early 1960s as a cost effective and reliable alternative to measuring every log to be scaled. The introduction of weight scaling corresponded with the rapid growth of the Interior forest industry. The 1960s also saw the introduction of close utilization harvesting practices, which resulted in greatly increased truck piece counts and reduced average piece sizes. Based on HBS data, in 2005, some 97% of the Interior harvest was scaled with the weight scale system.

On the Coast, because of less consistent forest types, more complex grading, sorting and marketing needs and more complex transportation and log handling opportunities, weight scaling plays a much less prominent role. Based on HBS data in 2005, some 31% of the coastal harvest was scaled with the weight scale system.

While the concepts of precision and accuracy will be explored in detail later in this, and the following chapter, it should be understood that the volume produced through weight scaling is an estimate of the actual volume. The actual volume is not known unless every load going over the weight scale is piece scaled. As such, weight scaling is a sampling method and volumes calculated using it are estimates of the actual volumes.

So, unlike piece scaling where all logs are measured, weight scaling is a sampling method where only a portion of the total production is measured or sampled. Based on the sample results, an estimate is made about the total production.

9.1.2 Estimating Volumes Under Weight Scaling

Under weight scaling, all truckloads are weighed and samples are selected at random and scaled for volume and grade. All logs on each truckload must carry the same timber mark. Conceptually, volumes are estimated by summing the total weight or mass of the total production and multiplying this sum by the volume/weight ratio derived from the samples, as shown in the following formula (Figure 9.2).

	Volume	=	$\text{Weight} \frac{\sum \text{Volume}_{\text{samples}}}{\sum \text{Weight}_{\text{samples}}}$
Where:	Volume	=	total volume estimate
	Weight	=	total net weight of all loads
	$\sum \text{Volume}_{\text{samples}}$	=	total volume of all sample loads
	$\sum \text{Weight}_{\text{samples}}$	=	total net weight of all sample loads
	$\frac{\sum \text{Volume}_{\text{samples}}}{\sum \text{Weight}_{\text{samples}}}$	=	the sample ratio or simply the ratio

Figure 9.2 Conceptual formula for estimating volumes.

In practice, this same principle is followed to determine volumes for each timber mark, for each species and for each timber grade.

9.1.3 Objectives of the Weight Scale System

The reliability of the estimate you wish to achieve is known as the "sampling error objective" and is set under the *Scaling Regulation* at 1% for the sampling plan. It requires that 95% of the time, the total estimated volume in one year will be within 1% of the actual volume (which is the same as within 1% of the volume you would determine if you scaled every piece). In addition to this objective, data users, including the Forest Service and Industry, may set other objectives to meet their respective data needs.

To reduce the total number of samples required and to better meet other data needs, weight scale populations may be subdivided into groups of truckloads that have similar qualities (e.g., timber mark, stumpage value, and ownership or quality). These groups are known as strata and the process of identifying and subdividing the population into strata is known as stratification. The term "stratum" is singular for strata. The formation of strata will never cause a bias, and should not cause more samples to be needed. The incorrect assignment of a load to a particular stratum cannot cause a bias (but it will probably increase the sampling error), and once a load has been assigned to a stratum it must not be reassigned based on the scale results. The exception to that would be the incorrect recording of a timber mark.

9.1.4 Elements of Weight Scaling

9.1.4.1 Agreement

Prior to beginning weight scaling, the Forest Service and weight scale operator (usually a licensee), must enter into an agreement to use weight scaling for a given population. The population typically includes the company's own production as well as any purchase or trade volumes delivered to the scale over a 12-month period. This 12-month period is known as the cyclic billing period.

The definition of a population is: The aggregate of all loads of timber scaled at a scale site or a group of scale sites owned by the same holder within a forest region to be sampled in a 12-month period for which you wish to estimate volumes for timber marks, grades and species.

Included under the agreement is provision for the physical weight scale site, the weighing of loads, the selection of samples, spreading and scaling sample loads, staffing, as well as documentation and reporting requirements.

In all cases, the scale and weighing equipment is owned and operated by the scale holder. The population holder is responsible for preparing the sampling plan and the Forest Service is responsible for approving the sampling plan.

The user and the Forest Service are responsible for::

- monitoring the sampling plan,
- ensuring satisfactory data and processing controls are in place, and
- ensuring scaling and processing standards are maintained.

9.1.4.2 The Weight Scale Sample Plan

Central to weight scaling is the sample plan which contains the strategy to sample enough loads to meet the population and other sampling objectives. This plan is prepared largely from the scale holder's production forecast that is comprised of an estimate of the timber to be scaled for the cyclic billing period. Stratum Advisor in HBS has many tools for individual sample plans and must be used to complete this annual plan. Population holders must propose and monitor their sampling plans.

9.1.4.3 Sampling Frequency

The sampling frequency sets the rate of sampling in each stratum required to meet the sampling objectives. Under weight scaling, only those loads selected as samples are physically scaled. Sample selection is a computerized process that is a program function

of the scale holder's weight scale hardware and the scale holder is responsible for ensuring that all sampling is fully random. All loads must have an equal opportunity of being selected. The ability to predict samples must not be possible by the scale site holder, operator, timber weigher or others at any time. Sample selection provided by systems software must conform to the standards set by MOFR.

The MOFR is responsible for programming sampling frequencies into the scale holder's weight scale computer. This is usually done by district staff.

9.1.4.4 Weighing Loads and Processing Samples

The scale holder is responsible for weighing all loads and ensuring loads selected as samples are scaled and reported to the Forest Service for processing.

All weighing and weighing equipment must conform to standards set and regulated by Measurement Canada, an agency of Industry Canada.

9.1.4.5 Compilation and Reporting Requirements

Data is submitted daily or as per the HBS submission requirements to the Harvest Billing System and reports are generated from this data. Sample load details are compiled and reported as they are scaled. Individual reporting and submission requirements are detailed in the Scale Site Authorization document.

See the documenting and reporting section of this manual for a more detailed explanation of these requirements.

9.2 Statistics Underlying the Weight Scale System

Because weight scaling is a sampling approach, its theoretical foundation lies in statistical sampling convention. Statistics provide answers to some basic questions in weight scale sampling:

1. How many samples do we need to take to provide reliable results?
2. How can we conduct sampling to avoid biased results?
3. How can we achieve more efficient sampling (acceptable results at lower cost)?
4. How good are our results?

While the formulae underlying weight scaling are complex for most users, it is most important to concentrate on their significance rather than the details of each calculation. This chapter attempts to provide only a basic introduction to the statistics and statistical conventions relating to weight scaling. The detailed statistical formulae that are used in weight scaling are summarized in Appendix 9A.

9.2.1 Statistical Concepts

9.2.1.1 An Overview of Estimating Using Statistics

In weight scaling the chief objective is to estimate the total volume delivered over the weight scale in a year (cyclic billing year). In determining an estimate, one could simply use historic data, take some samples, or use some other estimating approach. While such an estimate might suffice for some purposes, the importance placed on scale data by government and industry requires that our estimates be reliable and it must be known how reliable they are. This assurance can only be achieved by introducing statistics into the estimates.

As discussed under Section 9.1.2, weight scale estimates are made using a sampling method. To ensure reliable data results are achieved, instead of simply taking a couple of samples, the starting point must be to determine how many samples to take. The required number of samples (n), is dependent upon two things:

1. How much do the estimated volumes vary from truckload to truckload? (this is measured by the standard deviation (SD) which is in cubic metres (m^3)).
2. How good do we wish the results to be? (this is set by regulation at one percent for the sampling plan and is called the sampling error objective (SE)).

If all the individual loads in the population were similar, some very accurate conclusions could be made about the population by taking only a few samples. If, on the other hand, individual truckloads differed greatly from load to load, many more samples would have to be taken to draw the same conclusions.

In the same way, the better we wish our results to be, the more samples we require. And, on the other hand, if we are willing to accept the risk associated with less reliable results, fewer samples will be required. We don't have the option of changing the sampling error for the overall population, but we do have control over the sampling error for subsets of the data ("strata"). This will be discussed in detail later in this chapter and in Chapter 10.

After it is determined how many samples are required, sampling can begin. Under statistical sampling, it is required that all truckloads have an equal opportunity of being selected as a sample (samples must be selected at random). This is done to avoid bias.

At the end of the year, after all the samples have been taken and all loads have been weighed, calculations must be done to determine how successful the sampling was: (how reliable were the volume estimates). To do this, the question must be asked: "Were our sampling objectives achieved?"

Figure 9.3 shows the relationships between the basic questions that must be asked at the start and end of the year as well as their related statistical relationship. Before proceeding, attempt to relate the foregoing discussion to the diagram. This overview is the conceptual essence of weight scale sampling.

The next sections cover each component of sampling in more detail.

A. Start of the Cyclic Billing Year

Basic question: How many samples do we require?

Basic statistical relationship:

$$n = \left(\frac{SD}{\text{one SE}} \right)^2 \quad \text{Where: } n = \text{the total number of samples required.}$$

SD = standard deviation = a measure of how much samples ratios vary from truck to truck.

SE = One sampling error = a measure of how reliable we wish our year end volume estimates to be (this is our sampling objective, 1% is 2 SE).

B. During the Year

Weigh all loads and scale randomly selected samples.

C. At the End of the Cyclic Billing Year

Basic questions: How reliable are our estimates?

Did we meet our sampling objective?

Basic statistical relationship:

$$SE = \frac{SD}{\sqrt{n}}$$

Where: SE = sampling error = a measure of how reliable our estimates are. Compared with the sampling objective, we can answer the basic questions - Did we meet our sampling objective? How reliable are our estimated volumes?

SD = standard deviation = at the year end, this is a measure of how much the ratios actually varied from truck to truck.

n = the number of samples we actually took.

Figure 9.3 Conceptual overview of weight scale sampling.

9.2.1.2 Accuracy and Precision

When we ask ourselves how accurate our results are we are really asking ourselves how close our estimates calculated from our samples are to the actual quantity or value. For weight scaling, we often refer to the sample means that are the ratios (remember ratio x weight = volume). In discussing accuracy, we ask ourselves "how close is the sample mean to the unknown population mean". In sampling, because we do not measure all units, we never really know the actual mean and, as such, we never really know how accurate our estimate is. We do, however, have some understanding through the standard sampling error of how close our sample ratio is to the unknown population ratio. This estimate (Sampling Error) is referred to as precision. The smaller the sampling error, the better the precision. The sampling error is 0 when all units in the population are measured.

Statisticians often refer to *Bias* of an estimate. Bias is a distortion of results arising from an incorrect method of sampling, or incorrect measurements. Figure 9.4 shows a dartboard example of bias as well as the difference between precision and accuracy. Note that the darts show good precision (the darts are clustered together), but they reflect an inaccurate result, which is biased.

Bias in weight scale sampling is avoided by ensuring sample selection is completely random and by ensuring that scaling is done correctly. This concept will be explained further in the next chapter.

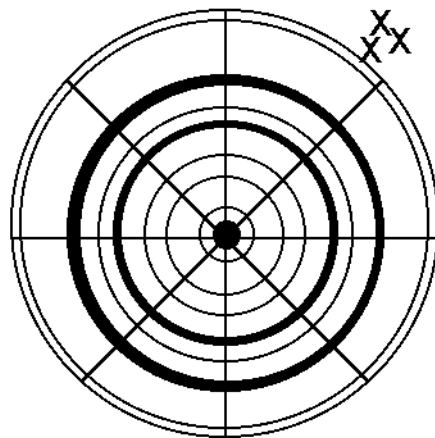


Figure 9.4 In this dartboard example, the 3 darts (x) are precise but inaccurate and biased.

9.2.1.3 Determining the Sample Size

In the previous sections we have discussed the concepts of standard deviation and the sampling error.

The standard deviation is a characteristic of the population that reflects the variation between individual truckload ratios. The sampling error on the other hand, provides us with a measure of how precise our sampling results are at the end of sampling. At the beginning of the sampling year we use the sampling error as the precision (or sampling error objective) we wish to achieve through the sampling. The actual number of samples we require to meet the sampling error objectives is known as the sample size.

While the formula for the sample size is complex, you should understand the relationship between the standard deviation, the sampling error, and the sample size. Functionally it can be presented as the following:

$$n = \left(\frac{SD * 2}{SE} \right)^2$$

Where SE is the sampling error at the 95% or $t = 2$ level (1% for the sampling plan).

You can conclude from this relationship several things:

- the more the truckload ratios vary (the higher the SD) the more samples you require;
- the greater the precision (lower the value of SE) you wish to achieve, the more samples you require;
- similarly, the corollaries of each of these is true, i.e.:
- the less the truckload ratios vary (the lower the SD) the fewer samples you require; and
- the lower the precision (the higher the SE that can be tolerated) the fewer samples you require.

Once the sample size has been established, you must determine the rate of sampling or the sampling frequency. In the case of weight scaling, if a population of 5 000 loads requires 100 samples to meet the sampling objective, the sampling rate is equal to 1 in 50 loads (5 000/100).

In terms of weight scaling, this means that approximately 1 sample out of every 50 loads must be randomly selected as a sample and piece scaled for volume and grade.

9.2.1.4 Stratified Random Sampling

If a population was comprised of a single species, all trees were of equal quality, equal stumpage value, and under a single timber mark (consistent in terms of species, quality, value, and mark holder), sampling of the entire population, as a single unit, would probably provide satisfactory results and sampling costs would be within reason. The normal situation, however, sees weight scale populations as variable in composition. Most weight scale populations are comprised of multiple species and grade combinations, multiple timber marks, small business, major licensee and purchase volumes, salvage timber volumes, along with other variables. Sampling such populations as single units would result in volume estimates of lower precision.

The reasons for low precision and high costs lie in the conceptual relationship between the sampling error, the standard deviation, and the number of samples (sample size).

$$\text{One SE} = \frac{\text{SD}}{\sqrt{n}} \text{ or sample size} = n = \left(\frac{\text{SD}}{\text{SE}} \right)^2$$

If a low SE is required and you are confronted with a high variation among sample units, your only option under this approach would be to increase n (take more samples).

To overcome these deficiencies, Stratified Random Sampling is employed for sampling most forest populations. Under stratified sampling, units of the population can be grouped together on the basis of similarity - usually, the similarity in the ratio caused by the timber having the same weight volume relationship. These groupings are referred to as strata (stratum for singular) or subpopulations. Each stratum is then sampled and stratum estimates (volume/stratum) are combined to give a population estimate (volume for the population).

Stratified random sampling provides several advantages over simple random sampling.

- it provides an estimate of precision and a separate ratio for each stratum,
- population estimates may be more precise with the same number of samples, and
- the required number of samples is often reduced.

Separate answers could be computed from the data without stratification (for instance by timber mark) from the Harvest Billing System data, if better precision was the only objective. Stratification is especially useful when the user wants to shift the sampling into strata with greater value, lower scaling cost, or greater scaling capacity due to physical site characteristics. This reassignment might actually increase the total number of sample loads, but could have other important advantages.

Going back to the basic relationship, it can be deduced that if through stratification we can reduce the variation (SD) among sample units within strata to less than that which occurred if we did not stratify, then our estimates will be more precise (a lower SE). One can also expect an increased precision at the stratum level if we, in fact, did reduce the SD within each stratum.

Stratification can be demonstrated through a graph of sample ratios. Figure 9.5 shows a graph of ratios for Population XYZ. This population was stratified into two strata (1 and 2).

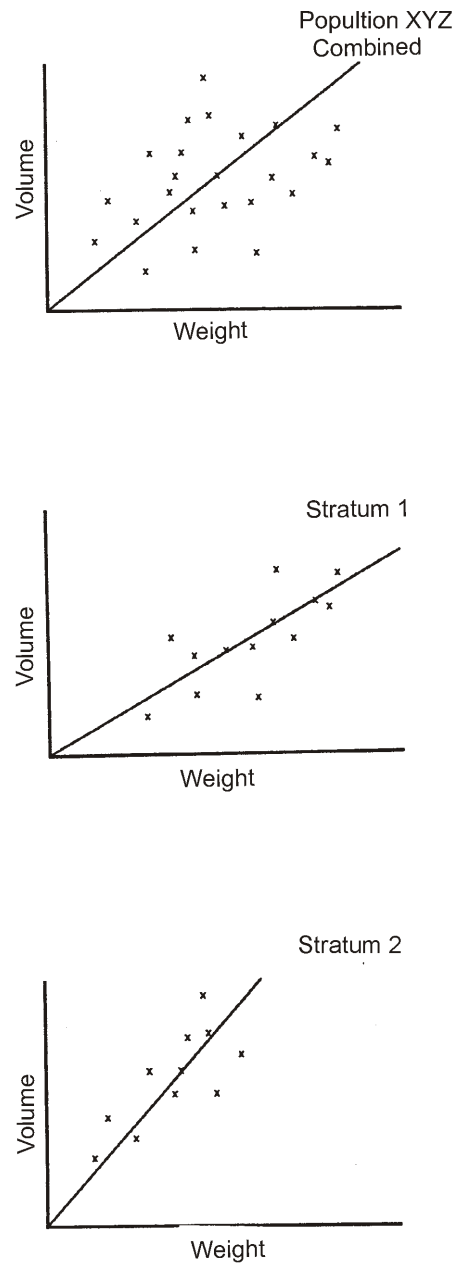


Figure 9.5 *Graphs to show the impact of stratification.*

From this example you can see stratification resulted in better clustering of data around the ratio line in each of the strata.

In other words, the standard deviation for each of the strata is less than the standard deviation for the combined group. This will allow a reduction of the total sample size for the population. Because stratum data are less variable, we can likely expect data for each stratum to be more precise.

For our purposes, stratification is a useful step to achieving more reliable scale results and more operational convenience and will be discussed more thoroughly in the next chapter.

9.2.1.5 The Weight Scale Sampling Plan

The Weight Scale Sampling Plan is a comprehensive plan to sample the weight scale population. It requires a clear definition of data needs and sampling objectives, and requires estimates of production and standard deviations on a stratum and population basis. The sampling plan provides the foundation for sampling. The sampling plans and procedures to monitor sampling plan progress are documented thoroughly in the next chapter. The Stratum Advisor function of the Harvest Billing System calculates necessary values and equations and information on its use can be obtained from the *HBS Reference Guide for Industry* available at:

http://www.for.gov.bc.ca/hva/hbs/HBS_INDUSTRY_GUIDE.pdf

9.2.1.6 Chapter Summary

This chapter has discussed in very general terms the statistics and related relationships behind the weight scale system. To use weight scaling as detailed in the next chapter, all calculations are heavily systematized eliminating the need for long calculations.

While some of this material was covered quite sparingly, it is important to understand some basic relationships and the concepts discussed in this chapter.

You should be equipped to answer some basic questions:

- What is random sampling, and why is it important to weight scale sample selection?
- Given a standard deviation - what does it really mean?
- Given a sampling error - what does it mean in terms of the population and stratum volume estimates?
- What is the relationship between the standard deviation, the sampling error, and the sample size?
- Why do we stratify populations? What are the benefits of stratification?

- How do we allocate the sample size to individual strata?
- What is the relationship between precision, accuracy, and bias?

The next chapter on weight scale sampling assumes a basic understanding of these concepts.

Appendix 9A Summary of Statistical Formulae in Weight Scaling

This Appendix summarizes the statistical formulae that underlie weight scaling. The terminology assumes that readers are familiar with basic statistics.

This appendix is for documentation purposes, and scalers are not expected to comprehend this material. The equations from earlier documentation have not been improved for readability, since it is important that the documentation in this appendix relates to former computer programs and past documentation for the weight scaling method in B.C. Minor changes from earlier manuals have been made for typographical errors and to improve statistical clarity for the benefit of specialists.

For those wishing to compare this material to standard statistical textbooks, the estimation of averages and standard deviations use formulae for the common "ratio-of-means" estimator. Once any strata totals and their total variance are computed, they are combined using the usual stratified sampling formulae found in most textbooks.

9A.1 Ratio of a Stratum

$$r_k = \left(\frac{\sum_{i=1}^{n_k} y_i}{\sum_{i=1}^{n_k} m_i} \right) = \left(\frac{n_k \cdot \bar{y}_k}{n_k \cdot \bar{m}_k} \right) = \left(\frac{\bar{y}_k}{\bar{m}_k} \right) = \frac{\text{average stratum load volume}}{\text{average stratum load weight}}$$

where:

- y_i denotes the volume of the i-th sampled load from stratum k,
- m_i denotes the weight of the i-th sampled load from stratum k,
- n_k denotes the number of samples in stratum k, and
- r_k denotes the ratio (cubic metres per tonne) for stratum k, and is the same whether you use the totals or averages to calculate the ratio.

The ratio, r_k , is used to estimate the total volume harvested from a stratum when you multiply it times the total weight of all loads for that stratum.

9A.2 Estimate of Total Volume in a Stratum (From a Sample)

$$\hat{Y}_k = r_k \cdot \left(\sum_{i=1}^{N_k} m_i \right) = r_k N_k \bar{M}_k$$

where: m_i denotes the weight of the i-th load from stratum k,
 N_k denotes the number of loads in stratum k,
 $\bar{M}_k$ denotes the average weight of a load in stratum k,
 r_k denotes the ratio of stratum k, and
 $\hat{Y}_k$ denotes the estimated total volume of stratum k.

9A.3 Estimate of Variance of Total Volume in a Stratum (From a Sample)

$$\text{var}(\hat{Y}_k) = \left(\frac{N_k^2 (1 - f_k)}{n_k} \right) \cdot \left\{ \frac{\sum_{i=1}^{n_k} (y_i - r_k m_i)^2}{n_k - 1} - \left(\frac{\sum_{i=1}^{n_k} [(y_i - r_k m_i)^2 \cdot (m_i - \bar{m}_k)]}{\sum_{i=1}^{n_k} (m_i - \bar{m}_k)^2} \right) \cdot (\bar{m}_k - \bar{M}_k) \right\}$$

where: n_k denotes the number of samples in stratum k,
 N_k denotes the number of loads in stratum k,
 $f_k = \left(\frac{n_k}{N_k} \right)$ denotes the sampling fraction of stratum k,
 y_i denotes the volume of the i-th sampled load from stratum k,
 m_i denotes the weight of the i-th sampled load from stratum k,
 $\bar{m}_k$ denotes the average weight of sampled loads in stratum k,
 $\bar{M}_k$ denotes the average weight of all loads in stratum k,
 r_k denotes the ratio of stratum k, and
 $\text{var}(\hat{Y}_k)$ denotes the estimated variance of estimated total volume of stratum k.

The Estimate/Variance calculated above is used later in calculating the precision achieved in a stratum.

9A.4 Estimate of Variance for Load Volumes in a Stratum (From a Sample)

$$s_k^2 = \left(\frac{1}{\bar{M}_k^2} \right) \cdot \left\{ \frac{\sum_{i=1}^{n_k} (y_i - r_k m_i)^2}{n_k - 1} - \left(\frac{\sum_{i=1}^{n_k} [(y_i - r_k m_i)^2 \cdot (m_i - \bar{m}_k)]}{\sum_{i=1}^{n_k} (m_i - \bar{m}_k)^2} \right) \cdot (\bar{m}_k - \bar{M}_k) \right\}$$

where: n_k denotes the number of samples in stratum k,
 y_i denotes the volume of the i-th sampled load from stratum k,
 m_i denotes the weight of the i-th sampled load from stratum k,
 $\bar{m}_k$ denotes the average weight of sampled loads in stratum k,
 $\bar{M}_k$ denotes the average weight of all loads in stratum k,
 r_k denotes the ratio of stratum k, and
 s_k^2 denotes the estimated variance of the load ratios of stratum k.

This figure estimates the inherent variability of the load ratios within a stratum. It differs from the previously calculated variance 9A.3 in the following manner: 9A.3 estimates the variance of the estimated total volume, while this formulae estimates the variance of the individual load predictions. Thus, if additional samples were drawn, the variance in 9A.3 (variance of the average or total) would decrease while the variance above (for the individual loads) would not - except, of course, for random variation due to new samples. This can be seen from the presence of n_k in the denominator of the first term of 9A.3 and from its absence above. As sample size increases, the variance of a mean or total decreases, but the variance of the objects themselves is not expected to change.

9A.5 Precision of the Estimated Volume of a Stratum (From a Sample)

$$\hat{E}_k = \left(\frac{\sqrt{\text{var}(\hat{Y}_k)} \cdot t_{.95, n_k - 1}}{\hat{Y}_k} \right) \cdot 100\% \text{ [K15]}$$

where: $\text{var}(\hat{Y}_k)$ denotes the estimated variance of estimated total volume of stratum k,

$\hat{Y}_k$	denotes the estimated total volume of stratum k,
n_k	denotes the number of samples in stratum k,
$t_{.95, n-1}$	denotes the two-sided, 95 th percentile of the Student's t distribution with $(n_k - 1)$ degrees of freedom, and
$\hat{E}_k$	denotes the (estimated) precision achieved for stratum k.

The above figure is the precision of a stratum, not the population. Though scaling regulations require that precision of a sampling plan (population) must be at least 1%, 19 times out of 20, they do not specify a target precision for a stratum. In practice, the precision of a stratum will often vary from about 1 to 5%.

9A.6 Estimate of Total Volume in a Population (Combining Strata)

$$\hat{Y} = \sum_{j=1}^m (\hat{Y}_j)$$

where: $\hat{Y}_j$ denotes the estimated total volume of the j-th stratum, and
 m denotes the total number of strata in the population.

9A.7 Estimate of Variance of Total Volume in a Population (Combining Strata)

$$\text{var}(\hat{Y}) = \sum_{j=1}^m [\text{var}(\hat{Y}_j)]$$

where: $\text{var}(\hat{Y}_j)$ denotes the estimated variance of total volume in the j-th stratum
 m denotes the total number of strata in the population, and
 $\text{var}(\hat{Y})$ denotes the estimated variance of the estimated total volume in the population.

9A.8 Precision of the Estimated Total Volume in a Population (From a Sample)

$$\hat{E} = \left(\frac{\sqrt{\text{var}(\hat{Y})} \cdot t_{.95, n-m}}{\hat{Y}} \right) \cdot 100\%$$

where: $\text{var}(\hat{Y})$ denotes the estimated variance of total volume in the population,

m denotes the total number of strata in the population,

$\hat{Y}$ denotes the estimated total volume in the population,

$t_{.95, n-m}$ denotes the two-sided, 95th percentile of the Student's t distribution with approximately $\left[\left(\sum_{j=1}^m n_j \right) - m \right]$ degrees of freedom, and

$\hat{E}$ denotes the precision achieved in the population.

Scaling regulation requires that the above precision be estimated to at least 1%, at a confidence level of 95%.

To estimate volumes and precisions for sub-groups such as species and grades within a stratum, the preceding formulae can still be employed. However, in such instances, the ratios from sampled loads will need to be re-defined as follows: the numerator is defined as the volume of the species and grade of interest, while the denominator remains as the total weight of the sampled load.

9A.9 Sample Size (for Planning)

9A.9.1 Required for the Population

$$\tilde{n} = \left\lceil \frac{\left(\sum_{j=1}^m w_j s_j \right) \cdot \left(\sum_{j=1}^m \left(\frac{s_j N_j^2}{w_j} \right) \right)}{\left(\frac{E^2 Y^2}{t_{.95, d}^2} \right) + \left(\sum_{j=1}^m N_j s_j^2 \right)} \right\rceil$$

- where: m denotes the number of strata in the population,
- $w_j = \left(\frac{N_j}{N}\right)$ denotes the proportion of total loads in stratum j ,
- N_j denotes the total number of loads in stratum j ,
- N denotes the total number of loads in the population,
- s_j denotes the standard deviation of load ratios from stratum j ,
- E denotes the desired precision (usually set at 0.01),
- Y denotes the anticipated total volume in the population,
- $t_{.95,d}$ denotes the two-sided, 95th percentile from the Student's t distribution with $\left[\left(\sum_{j=1}^m n_j\right) - m\right] = (\tilde{n} - m) = d$ degrees of freedom.
- Since the SD is estimated for planning, you can assume it is correct (in which degrees of freedom (d) is infinite) or use the degrees of freedom (sample size minus one) for the historical data that provided your SD estimate for each strata.
- $\tilde{n}$ denotes the number of samples required from the entire population.

9A.9.2 A Stratum Containing a Pre-specified Target Precision (for Planning)

If a stratum contains a target precision, use the following formula to estimate sample sizes for that stratum. In this instance, the number of strata in the population will be one, and the formula reduces to the following:

$$\tilde{n} = \left\{ \frac{(s_j^2 \cdot N_j^2)}{\left(\frac{E^2 Y^2}{t_{.95,9}^2} \right) + (N_j s_j^2)} \right\}$$

where: N_j denotes the number of loads in the stratum of interest,
 s_j denotes the standard deviation of load ratios in the stratum,
 E denotes the desired precision for that stratum,
 Y denotes the anticipated total volume in that stratum,

Here again, you can assume the SD for planning (s_j in this equation is correct, so that degrees of freedom for the stratum (d_j) is infinite) or use the degrees of freedom (sample size minus one) for the historical data that provided that SD estimate.

$t_{.95,9}$ denotes the two-sided, 95th percentile from the Student's t distribution with a (d_j) degrees of freedom, and
 $\tilde{n}$ denotes the number of samples required from that stratum.

9A.9.3 Sample Size for a Population Containing Some Pre-specified Strata (for Planning)

If some strata contain precision targets while others do not, use the following formula to estimate the sample sizes for the strata without precision targets:

$$\tilde{n} = \left\{ \frac{\left(\sum_{j=1}^{\tilde{m}} w_j s_j \right) \cdot \left(\sum_{j=1}^{\tilde{m}} \left(\frac{s_j N_j^2}{w_j} \right) \right)}{\left(\frac{E^2 Y^2}{t_{.95,d}^2} \right) - \text{var}(\hat{Y}_P) + \left(\sum_{j=1}^{\tilde{m}} N_j s_j^2 \right)} \right\}$$

where: $\tilde{m}$ denotes the number of free strata in the population ("free" refers to strata without precision targets; summation is over the free strata),
 m denotes the number of strata in the entire population,
 $w_j = \left(\frac{N_j}{\tilde{N}} \right)$ denotes the proportion of total loads in stratum j ,
 N_j denotes the number of loads in stratum j ,
 $\tilde{N}$ denotes the total number of loads in the free strata,
 s_j denotes the standard deviation of load ratios from stratum j ,

E	denotes the desired precision of the entire population (usually set at 0.01),
Y	denotes the anticipated total volume in the entire population,
$\text{var}(\hat{Y}_p)$	denotes the variance of the estimated total volume in the non-free (that is, the pre-specified) strata,
$t_{.95,d}$	denotes the two-sided, 95 th percentile from the Student's t distribution with "d" as an infinite number of degrees of freedom, or $\left[\left(\sum_{j=1}^m n_j \right) - m \right] = (\tilde{n} - m) = d$ where the sample sizes (n_j) are from the data that estimate that SD.
$\tilde{n}$	denotes the number of samples required from the free strata.

9A.10 Sample Size Required for Stratum (for Planning)

$$n_j = \tilde{n} \left(\frac{W_j s_j}{\sum_{j=1}^m (W_j s_j)} \right) \quad 10$$

where: m	denotes the number of strata in the population (or the number of free strata in a constrained population),
$W_j = \left(\frac{N_j}{N} \right)$	denotes the proportion of total loads in stratum j,
s_j	denotes the standard deviation of the ratio in stratum j,
$\tilde{n}$	denotes the number of samples required from the entire population (or the free strata), and
n_j	denotes the number of samples required from stratum j.

In our notation, $\tilde{n}$ represents the estimated sample size to be drawn from a population, while the actual sample size to be drawn is $n = \sum_{j=1}^m n_j$. In other words, n may be larger than $\tilde{n}$ because some strata may have their sample sizes increased to a minimum number of 5 samples per stratum, while in other cases a sample size will be rounded-up to a whole number.

9A.11 Relative Variance of a Stratum (from a Sample)

$$C_k = \frac{\left(\frac{S_k^2}{N_k} \right)}{\left(\frac{\hat{Y}_k}{N_k} \right)^2} = \left(\frac{N_k^2 \cdot s_k^2}{\hat{Y}_k^2} \right)$$

where: s_k^2 denotes the variance of the load ratios of stratum k(formulae A9.4),

$\hat{Y}_k$ denotes the estimated total volume in stratum k,

N_k denotes the total number of loads harvested from stratum k, and

C_k denotes the relative variance of stratum k.

The relative variance relates the inherent dispersion of a stratum to its average volume, so it is not affected by the number of samples.

One could argue that the relative variance should be based on ratios and not, as is the case here, on volumes. However, differences between the two are likely to be negligible.

9A.12 Relative Variance of a Population (From a Sample)

$$C = \left(\frac{n}{N^2(1-f)} \cdot \frac{1}{\bar{M}^2} \cdot \text{var}(\hat{Y}) \right) \cdot \left(\frac{\hat{Y}}{N} \right)^{-2} = \left(\frac{n \cdot \text{var}(\hat{Y})}{(1-f) \cdot \bar{M}^2 \cdot \hat{Y}^2} \right)$$

where: n denotes the total number of samples from the population,

$f = \left(\frac{n}{N} \right)$ denotes the sampling ratio of the population,

$\text{var}(\hat{Y})$ denotes the variance of the estimated total volume harvested from the population,

$\hat{Y}$ denotes the estimated total volume in the population,

N denotes the total number of loads harvested from the population,

$\bar{M}$ denotes the average weight of all loads in the population, and

C denotes the relative variance of the population.

9A.13 Combining Strata

It might be decided to combine strata when it is observed that they had the same ratio in the past. They might also combine them if they have similar definitions and there were operational reasons to do so. In general, it will not reduce the total number of samples needed, or the sampling ratio by combining strata. Therefore, combining data would usually be done for operational simplicity.

If the strata are combined part way through a billing cycle, the strata must have had the same sampling rate and have a similar definition and ratio. If it is decided that strata with different rates should be combined then they should both be closed off and a new combined strata should be created with a new required sample size and sampling rate to be used from that point forward.

9A.14 Dividing Strata (also Referred to as Splitting of Strata)

It might be decided to split strata for operational purposes or for other reasons, such as using a larger sample ratio in some of the delivered loads to satisfy a contractor, even when they have exactly the same ratio.

It might also be found that a stratum seems to have two distinct ratios, and therefore it is more efficient (requires a smaller total sample size) when they are divided into two different strata. Whether to do this is a question of examining the data, with the Harvest Billing System information.

Midway in the billing cycle, dividing old un-sampled loads into several different strata would usually be difficult, and while not necessarily biased it would at least be time cumbersome. In general, the best procedure would be to close the strata at that point and begin several new ones, with different descriptions and quite possibly different sampling rates.

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Weight Scale Sampling

10

This chapter applies some of the statistical principles and procedures discussed in the previous chapter to the Weight Scale Program. Sampling under weight scaling is divided into four main functions:

1. Setting up the sampling plan,
2. Monitoring sampling plan progress,
3. Managing the sampling plan, and
4. Maintaining the integrity of weight scaling and the sampling plan.

10.1 Setting Up the Sampling Plan

The Weight Scale Sampling Plan is a comprehensive plan to ensure the weight scale population and data needs are defined and sampling is undertaken to meet some predetermined precision requirements. As such, the sampling plan provides the foundation for weight scale sampling. Its basic components are:

1. Defining the weight scale population - the Production Estimate.
2. Setting the sampling objectives.
3. Stratification to help meet the sampling objectives.
4. Finalizing the Sampling Plan.
5. Selecting and processing samples.

A discussion of each component follows:

10.1.1 Defining the Weight Scale Population

In the earlier days of weight scaling, the population was simply viewed as the timber cut from an operation in a one-year period. The evolution of the forest industry and the growth of small operators, harvesting on private land, log trading, and other developments now see the population more correctly defined as follows:

The aggregate of all loads of timber scaled at a scale site or a group of scale sites owned by the same holder within a forest region to be sampled in a 12-month period for which you wish to estimate volumes for timber marks, grades and species.

Under this definition, the population may consist of a licensee's own production as well as any purchase or trade volumes. It may include any volumes scaled on another party's behalf within a limited distance of 20 km between the weight scale and the other party's processing facility.

Under weight scaling, the population is sampled over a 12-month period referred to as the Cyclic Billing Period. The cyclic billing period places a time parameter on the definition. Under some circumstances the cyclic billing period may be less than or exceed 12 months. While there are no limiting policies, the Interior cyclic billing period is usually from break-up to break-up or May 1 - April 30. Coastal cyclic billing periods traditionally follow the calendar year.

Weight Scaling or Piece Scaling for Small Population:

While the merits of each situation vary, it is generally considered that acceptable scaling costs under weight scaling for most timber profiles will not be realized unless the annual production going over a weight scale exceeds 500 truckloads. Similarly, the specific data needs of data users may not be met if the annual production is insufficient. On this basis, the Forest Service may direct that all loads be piece scaled if there are insufficient loads in the plan.

10.1.1.1 The Sampling Plan

The sampling plan, which is prepared and submitted to HBS by the weight scale holder is an estimate of all loads to be weighed under the population for the specified cyclic billing period. This estimate is based on the company's forecast of log deliveries from all sources. It requires:

- company's proposed stratification along with definition of proposed strata (composition by species/grade, stumpage level, others),
- number of loads under each stratum,
- estimated volume for each stratum, and
- estimated standard deviation for each stratum (based on historical or similar stratum).

The sampling plan must be approved by the ministry. In finalizing the sampling plan, the ministry may request the scale holder to re-submit the sampling plan with additional information to HBS prior to approval. The population holder should notify the ministry contact once they have proposed a plan in HBS.

Responsibility for Reliable Production Forecasts:

The weight scale holder has sole responsibility for a reliable sampling plan and is also responsible for ensuring the ministry is advised, as soon as possible, of any changes to the forecast during the year.

10.1.2 PSY

Each population and stratum must carry a unique eight digit identity called the PSY.

POPULATION	STRATUM	YEAR
4 digits	2 digits	2 digits

The population field is linked to a region and district. This identity is an essential part of all data collected under the weight scale system.

10.1.3 Setting the Sampling Objectives

10.1.3.1 Sampling Objectives

The primary objective of sampling is to satisfy the data needs of the ministry. Secondary to these needs are those of the weight scale holders. General ministry data needs include:

- volumes by species, grade, and timber mark for stumpage and royalty billing, and stumpage appraisals, and
- volumes by grade for cut control.

The scale holder's data needs may vary from ministry requirements but both can be accommodated through judicious stratification.

10.1.3.2 Precision Requirements

Currently, the only precision requirement for weight scaling is set under the *Scaling Regulation*.

Precision is set at the sampling plan level as $\pm 1\%$ at the 95% confidence interval.

What does this mean?

This requires that we must sample the population to ensure there is a 95% probability the total volume we estimate for the population will be within $\pm 1\%$ of the actual volume.

While there are no precision requirements set on a stratum basis by regulation, they may be required at the discretion of the ministry. Working within the confines of the 1% population objective and defining some stratum objectives enables sampling to be focused on strata where greater precision may be desirable. Similarly, it enables sampling to be relaxed where data needs can be fulfilled with lower precision such as strata comprised of salvage timber appraised at minimum stumpage rates, or private timber.

10.1.4 Stratification to Meet the Sampling Objectives

10.1.4.1 Why We Stratify

As defined in the preceding chapter, stratification is the grouping of components of the population on the basis of similarity of one or more characteristics (species, similar value, grade, timber mark, volume to weight ratio, utilization level).

Under weight scaling, stratification serves two objectives:

1. Reduces sampling costs by reducing the overall sample size.
2. Specifies the sample size in a particular stratum in order to achieve better efficiency.

In the earlier days of weight scaling with low stumpage rates, little grading in the Interior and little differences between stumpage rates, the first objective of reducing the sampling requirement prevailed. With higher stumpage rates, an Interior grading system introduced in the late 1980s, more complex log marketing arrangements, and growth of the small business sector, stratification is expected to serve both objectives. This is the challenge of stratification.

Objectives of Weight Scale Stratification

Group units into strata that provide better precision at the population level or to provide efficiency, operational, or special data requirements at an acceptable sampling cost.

10.1.4.2 How are the Objectives of Stratification Met

10.1.4.2.1 Reducing the Sample Size

The simple relationship between the sample size, the standard deviation, and the sampling error provide some insight into why we stratify and also what happens to the sample size (n) with changes in the standard deviation (SD) and the sampling error (SE).

Note: This is a shortened functional equation suitable only for conceptual purposes.

$$SE = \frac{SD}{\sqrt{n}} \text{ or } n = \left(\frac{SD}{SE} \right)^2$$

From this simple relationship, one can see:

1. n (the sample size) increases with a larger standard deviation and decreases with a smaller standard deviation. If the standard deviation doubles, it requires four times the sample size for the same quality result, so it is very important that the number here be realistic.
2. SE (the sampling error) rises with a larger standard deviation and lowers as more samples are taken.

Following these relationships, one can appreciate how the objectives of stratification can be realized (grouping of components of the population with similar traits may reduce the variance between units within that group and thereby reduce the standard deviation. This may in turn reduce the SE or require fewer samples to meet the same SE objective).

Weight scale statistics revolve around the relationship between the scaled volume and the weight (the ratio). As such, the standard deviation is reduced only where you stratify the population into strata that have similar ratios.

To minimize the standard deviations requires an understanding of factors that impact the ratios. These factors may vary considerably from population to population, and are best understood through experience. Common factors include:

1. Species: wood density varies by species, with red cedar wood significantly lighter and hemlock wood significantly heavier than average.
2. Growth rate: fast grown coniferous trees on good sites (lower elevation, fertile, moist, warm) are heavier than slower grown trees of the same species on poorer sites (higher elevation, infertile, dry or water logged, cold).
3. Age: young trees with a high proportion of sapwood are heavier than older trees with a smaller proportion of sapwood. Similarly, wood density varies by location in each tree.

4. Moisture content: a tree stem starts to lose moisture after it is dead and such moisture loss decreases the mass. The rate of loss is greater in dry weather than in wet weather. Logs from fire, or insect killed trees are usually light, as are logs left decked for any length of time.
5. Defect: defect volumes are excluded from the scale and defect in a log will decrease the volume/weight ratio.
6. Foreign matter: dirt, ice and snow are often weighed with the load and decrease the volume/mass ratio.
7. Utilization level: different utilization levels in the same stand will yield a different grade profile arriving at the scale and as such will result in different ratios.

Exclusive recognition of only these factors in preparation of the sampling plan coupled with local knowledge will likely optimize sampling costs but may not satisfy other important data needs.

10.1.4.2.2 Providing More Meaningful Answers

The most important role played by stratification is in providing more meaningful information for data users. This includes ensuring the data needs for billing stumpage and royalty, cut control, and stumpage reappraisals are satisfied.

These objectives are partially met through stratification by:

- Clear and restrictive definition of loads going into each stratum, and
- Assigning precision levels for certain strata.
- Designing stratum to take advantage of the Harvest Billing System reporting structure (rather than processing the data by hand or with another computing system).

10.1.4.2.3 Stratum Definition

The principal means of ensuring data are meaningful and reflect user needs is through clearly defining each stratum. The Stratum Definition prescribes the makeup of loads that may be included under a given stratum. Through this definition, one is able to ensure loads within a stratum have similar traits. The specific definition is predicated by the traits that the stratum should reflect. For example, the definition for a No. 1 Sawlog stratum would likely prescribe a mandatory percent of No. 1 sawlogs in each load, such as a 90% requirement (stratum 1 = all loads having greater than a 90% No. 1 sawlog content). For data processing conventions, strata are identified by a 2-digit numeric field and a 16-digit descriptive field.



10.1.4.2.4 Factors Limiting the Stratum Definition

Stratum definitions may be limited and influenced by a number of considerations:

The ability to sort logs prior to transport,

Sorting of logs on the cutblock prior to loading provides the ability to control the content of each truckload being weighed. It minimizes the variation of the ratio between loads in each stratum and enables more correct stratification of loads. Logs can be sorted on the basis of traits the loader operator can readily observe and physically handle. Usual traits include: species content, log size and to a more limited extent, log condition with the latter confined to differentiating dry from green logs, pulp from sawlogs, or sorting out low grade salvage logs.

While sorting is beneficial from a weight scaling perspective, it is not always feasible from operational or forest site management perspectives.

Where timber is not sorted or sorting is restricted, a few guidelines should be followed:

- stratification plans where strata are assigned according to timber mark are the most reliable in terms of ensuring loads are assigned to the correct stratum,
- where strata definitions refer to species content, the percent requirements should facilitate the stratum decision and avoid overlap,
- that sorting may be difficult in the bush but dry timber should not ordinarily be mixed with green timber.

The ability of the loader operator or timber weigher to classify loads according to desired stratum definitions, and

Classifying loads where logs are not sorted prior to transport means the ability to control the content of each truckload is impaired. The correct classification is dependent upon the knowledge and good judgement of the loader operator and the timber weigher. While the loader operator, if adequately trained, may have knowledge of the content of each load, the timber weigher is confronted with a limited view of the external log sides and ends. As such, it is unreasonable to expect the timber weigher to know what is inside the load.

The production forecast.

To include any stratum under the sampling plan requires an estimate of the total number of loads in that stratum along with an average load size and a standard deviation for the stratum. While standard deviations can usually be approximated from previous sampling experience, to be meaningful, the production forecast relies on the ability to differentiate the population into the qualities reflected by the stratification. For example, if you wish to stratify on the basis of timber mark, you will require an estimate of truckloads expected

for each mark. Other approaches, such as stratifying by grade profile or species composition may require more difficult estimates. If reliable forecasts cannot be made about a stratum, the stratum should be avoided and that material considered for inclusion in another stratum or strata.

Poor production forecasts are the chief cause of under or over sampling.

Small strata are particularly dependent upon reliable production forecasts. Because the statistics underlying the calculation of sample size require at least 10 samples to be reliable, over estimated strata volumes will result in poor precision, and in unreliable statistics about that precision.

Similarly, while the minimum number of samples for the purposes of calculating the standard deviation is 10, highly variable strata will require more than 10 samples to achieve acceptable precision. As such, if the anticipated number of loads is small, the benefit of better information may be outweighed by the costs of sampling and the risk of unsatisfactory results.

The exception is for a small stratum of 200 loads or less, where the sample floor can be set at 5 or 5% of the estimated number of loads for the stratum, whichever is greater. If the number of samples required is greater than 9 then the stratum is treated as if requiring at least 10 samples.

10.1.4.2.5 Assigning Precision Levels for Certain Strata

For some strata such as those containing high value species, high value marks, salvage material, or other traits, it may be in the interest of the user to know that the volume within that stratum was sampled to a given precision.

The objective of sampling for any given stratum may therefore be: to estimate volumes for loads of timber with predefined traits to a set level of precision. At the end of sampling a statement can be made that the total volume of loads of predefined traits was sampled to a given precision (e.g., the volume under Stratum 1 comprised of Douglas-fir and lodgepole pine loads, all grades were sampled to a 2.5% precision).

10.1.4.3 Common Stratification Methods

To meet the varying objectives of data users, the sampling plan may include one or more stratification methods. The following are examples of stratification but are not restricted to:

10.1.4.3.1 Stratification by Species

Under this approach, stratum definitions may include single species where timber is sorted, a specified minimum species content by load or groupings of species, which exhibit similar densities, stumpage value, or other characteristics.

Stratum 01	-	SP/LO	-	SP, LO with maximum 10% other species,
Stratum 02	-	SP	-	minimum 90% SP by volume.

10.1.4.3.2 Stratification by Stumpage Value

Several approaches are available:

1. grouping timber from marks with similar stumpage value under the same stratum:

Stratum 03 - High Value - A099, YK02, 32/9.

2. specifying strata by species and/or grade composition. If the objective is to better account for high value sawlogs, the stratum definition could include a minimal level of sawlog content or a maximum tolerance of lower grades. Similarly, low value timber can be handled in the same way:

Stratum 04 - CY S/L - minimum 90% X & better.

10.1.4.3.3 Stratification by Season

Where the ratio for a given stratum varies significantly from season to season (e.g., $\geq 20\%$) it may be beneficial to divide the stratum into two parts (i.e., 07 = Season A, 08 = Season B).

10.1.4.3.4 Stratification by Timber Mark

It may be feasible to assign separate strata to single timber marks where the timber profile is not similar in other strata or it is desirable to assign precision against a single timber mark. The forecasted production for the stratum may be a limiting factor:

Stratum 05 - 39/2.

10.1.4.3.5 Stratification by Tenure Type

If an objective is to account for the total volume of all marks under a class of tenure to a pre-set precision, all marks under that tenure can be included under a single stratum:

Stratum 09 - Purchase Strata - all purchase marks.

10.1.4.3.6 Stratification by Quality of Timber

Under this approach, timber of similar quality, such as sawlogs, insect damaged or fire killed timber, salvaged volumes, or low grade timber can be included under a single stratum:

Stratum 10 - Fire Kill - 100% dry,

Stratum 11 - Fir S/L - 90% fir, no more than 5% non No. 1 and 2 grades.

The keys to effective stratification are a meaningful and reasonable production forecast and experience. Experience is gained mostly through monitoring sampling results.

Because sampling is in place to serve different objectives, the final sampling plan may provide for several methods of stratification. It should also be clearly understood by all weight scale users that the final stratification strategy will not likely satisfy all objectives for all data users. The section about monitoring sampling results will discuss this aspect in further detail.

10.1.5 Determining and Allocating the Sample Size

This is the final stage of preparing the sampling plan and consists of merging the production forecast with the stratification proposal, finalizing sampling objectives, determining sampling frequencies and entering the plan on the Harvest Billing System (HBS). Most of these functions are carried out by the planner segment of the Stratum Advisor Program on HBS.

Stratum Advisor is a tool used by industry and ministry personnel to create and monitor sampling plans. Sample Plan Administrators will use Stratum Advisor to determine optimum precision and sampling objectives for a population by:

- creating a sampling plan using estimated production levels,
- monitoring the sampling plan, and
- adjusting the sampling plan as required and adjusting the sampling plan to statistical data.

While only a Sample Plan Administrator can create or modify a sampling plan, all users (including the public) can use Stratum Advisor to view sampling plans.

The program is interactive, enabling the user to make different assumptions, set varying precision objectives, and adjust the sample size before finalizing the sampling plan.

Basic functions of Stratum Advisor include:

- entry of data from the production forecast, and statistical data,
- calculating optimum or unconstrained sample sizes and precisions,
- setting sample size and/or precision constraints, and
- calculating the final precision and sample size targets.

For a description of the data fields and instructions on how to use the program refer to the *HBS Reference Guide for Industry* at:

http://www.for.gov.bc.ca/hva/hbs/HBS_INDUSTRY_GUIDE.pdf

Following entry of the data, the Stratum Advisor calculates the optimum or unrestricted sample sizes and precision for each stratum. This calculation always supports a 1% precision requirement at the population level.

Because the Sampling Plan (Population) Precision Standard is set by regulation at 1%, all calculations in the planner support a 1% precision level for the plan. However, to assist in evaluating the impact of different sampling models, the precision for the population can be adjusted to values that are greater than or less than 1%.

The allocation of samples is based on the standard deviation of each stratum relative to all other strata. As such, those strata with the highest standard deviation will demand the most intensive sampling.

The optimum allocation represents a calculation based strictly on the production estimates.

Because data users may wish to achieve better sampling results in some strata (high value timber) or be willing to accept poorer results in other strata (perhaps low value salvage timber) the planner enables the user to constrain the calculations. Two options are available:

1. constrain precision, and
2. constrain the sample size.

Constraining precision enables the user to set the precision objective for one or more strata. Where precision on a stratum is set, the program re-allocates sampling effort to all other strata, while at the same time ensuring the 1% sampling error objective for the population is maintained.

Similarly, constraining the sample size enables the user to increase or decrease the sample size for one or more strata. As in the event of setting precision levels, setting the sample size sees a reallocation of samples to ensure the 1% population objective is met.

To calculate the required number of samples (the sample size) and expected precision for any stratum requires estimates of the total number of loads, the average load size (m3) and an estimate of the standard deviation. While the volume estimate (total loads times average load size) is taken directly from the production forecast, the standard deviation requires more judgement to estimate. If the same stratum was sampled in the previous year, the experienced standard deviation may simply be inserted in the new plan. If there is no sampling history in the stratum you may wish to borrow one from similar strata in the same or a different population. Failing any similar strata, you will have to use your best judgement in estimating a representative standard deviation. After setting any precision and/or sample size constraints, the final precision and sample size targets are calculated. These are reviewed and further modifications to the production estimates or constraints may be made before finalizing the sample plan.

It should, similarly, be noted that weight scale calculations revolve around the ratio and reflect statistics about stratum and population volumes. In realizing its sampling objectives, they may require additional samples to better account for other characteristics such as timber mark, species, and grade. In all cases, approval of the final sampling plan rests with the ministry.

10.1.5.1 Subsampling

The incentive for subsampling lies in the logistics of measuring and recording every piece where there are large numbers of pieces. This applies to full bunks on logging trucks carrying short logs. Under controlled circumstances subsampling is a statistically valid sampling approach. Under some conditions it may be authorized for scaling by the Ministry of Forests and Range.

Scaling conditions where subsampling may be considered for authorization include:

- each bunk is treated as a load or unit to be sampled,
- and where every bunk has an equal opportunity of being selected as a sample.

Where these conditions cannot be assured, subsampling will not be considered.

Regional and District Staff will authorize and set conditions.

10.1.6 Selecting and Processing Samples

Subsequent to approving the sampling plan and in advance of weight scale production, the Ministry of Forests and Range is responsible for programming the initial sampling frequencies into the sampling selection portion of the scale holder's weight scale computer. Weight scale computers and sample selection routines must conform to standards set by the Ministry of Forests and Range.

Loads selected as samples must be scaled by the scale holder in accordance with the scale site authorization issued for the scale site. The scale details for each sample scaled must be submitted to the ministry in the approved electronic format or on an FS 1217 scaling form.

Population	Year	Plan Abv	Plan Name	Plan Status	Effective	Expiry	Client	Location
5001	2006	V1	update stratum 43	Active	2005-Apr-01	2006-Mar-31	00002468	02

PRECEDING

Precision Limit	Sample Floor
1.00%	10

Stratum		Estimated					Optimum			Constraint		Target		
No.	Name	Segs	Volume	Loads	Size	St Dev	Samp	Prec	Freq	Samp	Prec	Samp	Prec	Freq
01	60%+HE, G4&Z	16	37300.000	1000	37.30	5.44	21	6.17%	47	30	5.14%	30	5.14%	33
04	60%+WH SL	10	4000.000	100	40.00	4.89	10	7.19%	10	15	5.70%	15	5.70%	6
08	60%+CE SL	8	48600.000	1000	48.60	3.55	14	3.80%	71	20	3.17%	20	3.17%	50
12	60%+SP SL	26	76800.000	1600	48.00	4.45	28	3.40%	57	35	3.04%	35	3.04%	45
14	60%+LO SL	13	154000.000	3500	44.00	4.46	60	2.54%	58	58	2.59%	58	2.59%	60
15	60%+LO SL, >40%dry	18	60000.000	1200	50.00	4.35	20	3.78%	60	24	3.45%	24	3.45%	50
16	60%+Gr Fir Green SL	18	10500.000	300	35.00	3.70	10	6.44%	30	17	4.88%	17	4.88%	17
18	60%+FI/LA SL CG	14	24990.000	700	35.70	2.16	10	3.72%	70	16	2.93%	16	2.93%	43
20	60%+FI/LA SL	14	157760.000	3400	46.40	2.92	38	1.99%	89	42	1.89%	42	1.89%	80
22	60%+HE SL	17	215050.000	5500	39.10	4.08	86	2.19%	63	87	2.18%	87	2.18%	63

Figure 10.1 An approved and active sampling plan as shown in HBS Stratum Advisor.

10.2 Monitoring Sampling Plan Progress and Weight Scale Results

With cyclic billing, sampling results are not finalized until the year end and therefore, ongoing monitoring is required to achieve satisfactory year end results. Monitoring involves periodic review of data reports and assessment of the sampling plan. Monitoring may result in periodic changes to the sampling frequency, the estimates contained in the sampling plan and/or the stratification itself.

Monitoring during the year is a periodic function and not to be confused with sample data checks, which are routine. It should always be remembered, some data may not have an adequate sample size until several months into the sampling year. Effective monitoring of the sample plan requires that some basic questions be answered on an ongoing basis during the sampling year and at year-end. Some of the questions which may be answered by the data include:

10.2.1 During the Sampling Year

- are sample loads being correctly stratified? For example, stratum 31 calls for at least 80% lodge pole pine, it is currently 80.4%.
- how frequently are sample loads being deleted? The importance of this question lies in the principle that true random sampling is satisfied only when all loads have an equal opportunity of being selected as samples. Cancellation interferes with this principle.
- Are there any trends in the data?
- How much do the sampling results compare with those assumed in the sample plan? (compare standard deviations if you have enough samples, compare load averages), and
- If current trends continue, will you be meeting your sampling objectives, will you get enough samples in each stratum, and will your production estimates be met?

10.2.2 At Year-end

In addition to the above, at year-end, you can also answer some very basic questions:

- did you meet your sampling objectives?
- could you have achieved the same results with fewer samples?
- what were your actual standard deviations in each stratum?

- how good were the production estimates?
- and how effective was your stratification scheme?

Year end results provide the most accurate data about the population and provide the best information available for the next sampling plan if you conclude the wood profile for any given stratum will be the same in the next year.

Data usually taken from the year end report and used for entry into the next sampling plan include:

1. Strata standard deviations, and
2. Average load size.

Because the final year end calculation is not available until after commencement of the new cyclic billing period, it is necessary to borrow year end data from the most recent available report for use in the new sampling. This does not represent a problem unless there are inadequate samples (less than 10) in a stratum to calculate a reliable standard deviation. Ultimately, good judgement tempered with experience must be used.

HBS Stratum Advisor data is an effective tool for monitoring sampling progress. Drawing any conclusions from it, however, requires a clear understanding of what data is included in the report and what is the significance of each data field.

In reviewing this data, the following should be observed:

- Precision at the stratum level means: there is a 95% probability (or 95% of the time) the total volume calculated for the stratum will be within the precision percent of the actual volume.
- The standard deviation for the stratum: this is a measure of how much truck to truck ratios vary within each stratum. It is reported in cubic metres so strata can be compared. If Stratum A has a standard deviation of 1.5 m³ compared to 6.5 m³ for stratum B, we can conclude stratum B is much more variable than A. One of the underlying objectives of stratification is to minimize the variation between loads in the same stratum and thereby meet sampling objectives with fewer samples. In this case, if strata A and B had the same number of truckloads in them, the more variable situation (Stratum B) would require much more intensive sampling than stratum A to achieve the same sampling objective. This standard deviation is used in calculation precision at the stratum level as well as being used in the next year's sampling plan to calculate the sample size.

- Sampled Loads - This is the number of samples taken to date for each stratum.
- Precision Within a Stratum - This precision percent means there is a 95% probability the volume estimated for the species grade combination is within some percent of the actual volume for that species grade combination.

It must be understood by all users that the basis for calculating precisions at the species grade level is not accurate and the resultant precision is an approximation only. The approximation may be reasonable for species grade combinations comprising a high percentage of the stratum volume. The reliability of the approximation however, erodes very quickly as the species-volume declines. Precision percent calculated for species-grade combinations comprising less than 10% of the total stratum volumes must be viewed as unreliable.

Ratio detail should also be reviewed to pinpoint possible data problems. Generally, ratios varying by more than 25% from the average ratio for the stratum should be reviewed very closely for errors.

10.3 Managing the Sampling Plan

An accurate, well balanced sample plan is critical to obtaining efficient weight scale data. As per the Scaling Regulation a precision of $\pm 1.0\%$ @ 2 SE is required for every sampling plan for which a weighing and sampling method of scaling is agreed to between the ministry, the population holder and the scale site operator. That means the sampling plan must be sampled intensively enough to generate a volume estimate within $\pm 1.0\%$, 19 times out of 20, of the *actual* volume that would have resulted had every piece of timber in the population been individually scaled. Very large amounts of direct revenue are generated by even a relatively small population and care must be taken to ensure that the calculation of the timber volumes is as fair and equitable as possible to both the Crown and the industry. In addition, the scale volumes generated by a sample plan may be used as the basis of trade between buyers and vendors. The methodology of arriving at those volumes must be unbiased and statistically defensible.

10.3.1 Management Responsibility

Maintenance of accurate data and a defensible sampling plan is the responsibility of both the ministry and the population holder. The initial responsibility rests with the population holder, who must ensure the best possible estimate is made of the coming year's production and that a well-planned stratification strategy is prepared. Consultation with company woodland's managers and log buyers, reviews of previous year's sampling results, and ongoing consultation with the ministry's scaling staff will go a long way toward achieving this goal. The ministry's scaling staff is responsible for ensuring that sampling plans are carefully evaluated, compared with the operator's previous year's results, *before* a plan is approved for implementation. The ministry may reject the plan if objectives are not met.

Once the plan is in place, it becomes the responsibility of both parties to continuously monitor the interim results. It is the duty of the population holder to make the best possible estimate of timber production and profile for the coming year. During the course of the sample year, should unforeseen problems, arising from weather, markets, or other constraints beyond the control of the holder, create significant changes in the projected population size or the strata profile, the holder must inform the ministry scaling staff. A joint review of the changes can then be carried out and a decision reached on how (or if) the sample plan will be revised to reflect the changes. Guidelines for evaluating the effect of production changes and how to proceed, are covered in the following sections.

10.3.2 Revising the Sampling Plan

Where it becomes very clear the production forecast and other assumptions underlying the sampling plan are not being realized it may be necessary to revise the sampling plan during the year. While changes to the sampling plan are the subject of frequent debate,

the decision to change or not change a plan must be made in strict compliance with two basic statistical principles.

1. Random Sampling - as discussed in the previous section on statistics underlying the weight scaling, samples must be drawn at random. A random sample is a sample drawn in such a way that all loads in the stratum (every truckload) have an equal chance of being selected as a sample. If random sampling is not satisfied, biased results may occur.
2. Representative Sampling - samples must be representative of the population (in this instance, the stratum) from which they are drawn. A representative sample is one in which the sampled loads fairly reflect the stratum. For example, if the stratum definition calls for 95% sawlog grade and up to 5% other grades, then a representative sample is one which contains at least 95% sawlogs and the balance in other grades. Random Sampling somewhat ensures samples are representative. There are, however, unavoidable instances where sampling may not be strictly random. In this case, ensuring that samples are representative should be sufficient to maintain integrity of the Weight Scale results.

To ensure representative sampling, you must ensure loads are correctly accounted for under the stratum definition.

Changes to the sampling plan should be made only where you are satisfied that the above basic statistical principles will be complied with.

10.3.3 Sample Plan Revisions

How (or whether) one amends a sample plan will depend on how severe the production changes are going to be and whether they are consistent across all strata, much greater in some strata than others, involve decreases, increases, introduction of entirely new species, grades or mixes, or even new strata. The impact of changes can also hinge on the time period over which the timber involved is expected to be delivered.

For example, wood tends to be heavier in spring than in autumn, because there is more sap present. This is especially true of younger trees and can result in noticeably different volume/weight ratios, depending on when the timber was cut. The change is not so dramatic for mature or over-mature timber. Winter-cut timber, on the other hand, can also generate lower ratios; not because of the wood itself, but because large amounts of mud, ice and snow can stick to the load and add to the gross weight of the truck, while contributing nothing to payload volume. Where harvesting will take place across two or more seasons, changing sample frequencies can cause disproportional sampling and should be avoided.

10.3.4 Options

When production estimate amendments are large enough to warrant revisions to the sample plan, there are several possible approaches, and numerous combinations of those approaches, that can be used:

1. close off existing strata and start new ones,
2. combine strata (if the sampling frequency was the same in each stratum),
3. make no changes.

In order to give some general guidance on what approach to take, a simplified, hypothetical example of a sample plan, descriptions of some changes that can occur and possible remedies for each situation follows.

Example of a Hypothetical Sample Plan

Stratum	Prod. Estimate	Samples Required	Sample Frequency
01	5 000 loads	100	1/50
02	1 000 loads	50	1/20
03	<u>200 loads</u>	<u>10</u>	1/20
Totals:	6 200 loads	160	

Halfway through the sample year, circumstances force a major change to production by stratum. Projected volume in stratum 01 drops to 2 500 loads, increases to 2 500 loads in stratum 02, and in stratum 03 drops to only 50 loads. With *no change* to sample frequency, the revised production estimate will now generate the following:

Stratum	New Prod. Est.	Sample Frequency	Potential Samples
01	2 500 loads	1/50	50
02	2 500 loads	1/20	125
03	50 loads	1/20	2 (or 3)
Totals:	5 050 loads		177

This is a good time to try some "what-if" recalculations of the sample plan, based on the revised volumes and the best statistical data available. The Sample Planner/Advisor software is ideally suited to this application. You may want to try several scenarios before settling on one, bearing in mind that at least $\pm 1.0\%$ @ 2 S. E. precision for the population is still the objective. Species/grade profiles and overall ratio values of each stratum can also be analyzed, especially if one is considering strata amalgamation. As well, consider how significantly seasonal variations in ratios may affect sampling. Let us assume that revised production estimates, current standard deviations, and average load sizes are such that when you calculate a revised sample plan, the number of samples needed for the population remains at "160", and the new distribution of samples by stratum for the scenario you select is:

(Revised Plan)

Stratum	Samples Required	Current Potential Samples
01	75	50
02	75	123
03	10	2 (or 3)
Totals:	160	177

Proportional distribution now requires that stratum 01 and 02 have 75 samples each. The minor stratum, 03, we decide to leave at 10 samples. If the sampling plan does not change, revised production will generate 17 more samples than needed, even though overall production has dropped by almost 20%. At the same time, sampling by stratum has become unbalanced. Though strata 01 and 02 are now the same size, 01 will only generate 50 samples, while 02 will generate 125. Stratum 03, on the other hand, will only have 2 (or maybe 3) samples, well short of the minimum of 10. Some possible remedies are as follows.

10.3.4.1 Stratum 01

1. Depending on production to date, one possibility may be to close the current stratum 01 and start an entirely new stratum with a tighter sampling frequency. If, for example, 750 loads had already been received in stratum 01 and 15 samples generated, and a recalculation of the plan indicated 15 samples were sufficient for the 750 loads received to date, it would be in order to shut the stratum down and start an entirely new one to receive the remaining 1 750 loads expected.
2. Another option *may* be to simply accept the sampling shortfall. However, this should only be considered if the quality/value of the timber going into stratum 01 is very low. If purchase timber is put through this stratum, deliberate under-sampling is not a recommended option.

10.3.4.2 Stratum 02

1. As with stratum 01, closing the stratum off and starting a new one could be an acceptable option if production and sampling to date would make it a viable "stand-alone" stratum. Sampling frequency in the new stratum could then be reduced to where a more reasonable quantity of samples would be generated.
2. If this option is not viable, the most favourable approach would be to simply accept the over-sampling. It is not a perfect solution as it will cause some additional sampling cost and will not result in the best-balanced sampling plan, but it will at least ensure defensible sampling for the stratum. This is especially important if the stratum will be used for scaling purchase timber.

10.3.4.3 Stratum 03

1. The stratum is too small to consider closing it off and starting a new one with a reduced sampling frequency.
2. Though it should not be done without first running the data through the HBS Stratum Advisor program, amalgamating stratum 03 with strata 01 or 02 may be an acceptable solution, providing the species/grade profiles are reasonably similar. This would involve combining the past data from strata 02 and 03, and changing the definition of stratum 02 (which had the same sampling frequency as stratum 03) to allow loads from both types to go into stratum 02 in the future.
3. If none of the above options seem advisable, you can consider leaving the stratum as it is. However, unless it is a very low value stratum, which will *only* be used by the population holder, this is not a recommended option.

If neither options 2 or 3 seem viable, then the best remaining solution will be to accept the higher sampling error in that stratum.

10.3.5 Sampling Plan Amendments

One possible production change that has not yet been discussed is the new stratum, or strata added onto a sampling plan that is already in place. Usually, these are not major strata, do not often require more than the minimum number of samples (10), and will not likely have a significant impact on the rest of the sampling plan. However, if an "added-in" stratum should be large enough to upset the proportional distribution of samples throughout the rest of the population's strata, the possible remedies remain the same as those presented under 'options'.

10.3.6 Standard Deviations

Standard deviations (SD) are one variable that can have a profound effect on sampling requirements without any change to production estimates. These are the mathematical expressions of how widely volume/weight ratios vary from sample to sample. For example, if the variance of ratios in even one stratum (especially a major one) begins to significantly increase, it will not only affect that stratum, but can effect the entire population and thereby require additional samples be taken for *all* strata. Equally, if the SD of a major stratum should drop, the reverse will occur.

Any number of conditions can contribute to variances between the SDs used to initially calculate a sampling plan, and those actually generated as samples are collected. Seasonal variations and mixing of dry and green timber in the same stratum are the two most common ones, but ratios can also be affected by errors in scaling, data recording and key punching. The best place to check for unusual changes to SDs is in sample summaries. If you encounter one or more samples with ratios that significantly deviate

from historical or anticipated ratios, those samples should be carefully examined and any errors that are found corrected.

Whether or not to amend a sampling plan because of unexpected changes to SDs, will depend on how dramatically they alter sampling requirements. As a general rule, if sampling requirements drop because SDs are lower than expected, it is probably best to leave the plan as it is. If SDs increase to the point where one or more strata, or the entire population will fall short of the sampling target, a careful review of potential changes, as discussed under 'Options', will need to be made.

The options of "*closing off existing strata and starting new ones*", "*amending sampling frequencies*", or "*making no changes*", are the most likely ones to consider. It is doubtful that "*amalgamating strata*", would be of much benefit in such a case.

Your best sampling results will be achieved if you comply with basic statistical principles, if you learn from previous sampling results and if you use your best judgement!

10.4 Operational Procedures to Ensure Sampling Plan Integrity

All timber weighers, sample scalers, and site owners/operators are responsible for conducting operations in accordance with all the conditions of the scale site authorization letter. Timber weighers and scalers must also be fully conversant with, and abide by, all the conditions stated in their scaler/weigher authorization letters. If any matters need clarifying, the District Scaling Supervisor or Check Scaler will be pleased to discuss them with you.

10.4.1 Inspecting Loads Before Weighing

Timber weighers are responsible for inspecting every load of timber arriving at their weigh scale. As each load arrives, the weigher must personally examine it to ensure that:

- all wheels of the truck are fully on the platform,
- the timber marks or brands have been applied in the manner required by the Forest Service, and
- the trucker has presented the necessary load documentation (FS 649 or equivalent) to indicate whether the load is unscaled or previously scaled.

During the inspection, take note of the species and grade make-up of the load so it can be assigned to the correct stratum. Depending on the conditions in the scale site authorization letter, it may also be a requirement to affix identifying tags at this time. If unsure, discuss with the local District Scaling Staff.

Where problems are found with either timber marking or load documentation, immediately contact the District Scaling Supervisor and ask for direction on how to deal with the matter. If the scale operates outside normal working hours or on weekends, ministry staff will not always be available. In those cases, arrangements to deal with such matters should be made ahead of time between the Scaling Supervisor and the timber weigher.

10.4.2 Processing the Load

Depending on the status of the timber to be processed, there are a number of different procedures that will be required. An explanation of each follow.

10.4.2.1 Previously Scaled Timber

When timber has been scaled previously, it must be appropriately entered: either into the weigh scale computer, or onto a FS 1217 (weigh slip) if records are being manually kept.

Previously scaled timber may be weighed and/or otherwise recorded as directed by the scale site owner/operator.

10.4.2.2 Unscaled Timber

For unscaled timber, load information is entered into the computer (or onto the FS 1217 and FS 523, if keeping manual records). Minimum required data that will be automatically generated by weigh scale computers are date and time of weighing (in and out) and gross, tare, and net weights. The use of rolling tare is not permitted. Measurement Canada demands an accurate net weight:

Timber weighers must add the balance of information:

- a. the timber mark (ensure mark is valid and approved for scaling at your site),
- b. the stratum and species,
- c. the contractor/trucker name or code, and
- d. other information as may be required by the scale site owner/operator.

Ensure that a stable reading can be obtained before recording the gross weight of the truck. If the load has been selected as a sample, refer to the next section for more information. If the species/grade profile of the load is such that it is not suitable for inclusion in any stratum in the sample plan, refer to the section on "Loads not Suitable for the Sample Plan." The vehicle may then proceed to the off-load area.

When the truck has unloaded and picked up its trailer, it must return directly to the scale to obtain a tare weight. To ensure an accurate net weight can be calculated, the vehicle must not take on fuel or water or make any other significant changes to its tare (dropping off tire chains, for example) before the weighing out procedure is completed.

Unless formally agreed to in the scale site authorization letter, round trip distances from point of weighing to the off-load area must not exceed ten kilometres.

Once the weighing process is completed and recorded on the weigh slip and safety sheet. The timber weigher and the truck driver sign the weigh slip. One copy is given to the trucker. The others are retained at the scale for distribution later to the Forest Service, the logging contractor, and the weigh scale owner/operator. The safety sheet, daily audit report, weigh slips and other specified documents must be available for auditing by the Forest Service. The data is submitted to the HBS data base according to HBS and Scale Site Authorization requirements.

10.4.3 Managing Sample Loads

If a load has been selected as a sample, the timber weigher must enter it into the sample ledger and it must be noted on the weigh slip and the daily load inventory. Computerized systems usually perform the last two tasks automatically. It must then be visually identified as sample. This may be done with specially coloured tags and ribbon, or other methods as approved by the District Scaling Supervisor. Once the load has been tagged, direct the truck driver to take it to the sampling area. Samples are usually either immediately spread in the sample yard for scaling or secured with a wrapper before being off-loaded, as it is absolutely critical that no pieces be lost from or added to a sample before it is scaled.

Conditions of scale for sample loads are normally spelled out in the scale site authorization letter and may vary from one location to another. As a general rule, they will cover matters relating to spreading, security, and integrity of sample loads, methods of recording, such as using a ministry approved hand-held scaling computer or FS 1210 form, or equivalent. Other requirements will focus on leaving the last load scaled for check scale, timely scale, and submission of sample tallies, and other conditions that may be included in the scale authorization letter.

10.4.4 Loads Not Suitable for the Sample Plan

Occasionally a truckload of timber will arrive at a weight scale that is not suitable for inclusion in any of the regular strata in the sample plan, because the specie content, grade, timber mark or other characteristic does not conform to any of the strata criteria.

Depending on the requirements of the scale site authorization, the load will either be weighed through a special stratum specifically set up for the purpose, or more likely will undergo a process called "red-tagging". Red-tag loads are specially flagged as directed by the District Scaling Supervisor, to distinguish them from sample loads. As with a sample, each red tag load is to be identified as such on its weigh slips and in the daily load inventory and entered into a ledger. *Only the gross weight should appear on the daily load inventory* and care must be taken to ensure no net weights from red tag loads are not added in to daily or month-end summaries. Red-tag loads are processed as piece scale loads as per instructions from the District Scaling Supervisor. Red-tag loads should never be entered on any weight scale summaries, as double billing will result.

Once a red-tag load has been properly documented, the trucker can proceed to the off-load area, where the timber will be secured, spread, scaled, and otherwise dealt with in the same manner as a regular sample load. The only real difference is that it will be scaled for billing rather than sampling purposes, and therefore must be recorded on a piece scale tally form such as the FS 1211, or approved electronic equivalent.

A word of caution: should a timber weigher or scaler observe that red-tag loads seem to be occurring more than a few times a month; it can be an indication that the existing sample plan is not adequately accommodating the profile of the timber being delivered.

The matter should be brought to the attention of the company and the District Scaling Supervisor, as an amendment to the sample plan may be needed.

10.4.5 Importance of Accurate Stratification

Timber bush-sorted to a single species or stratified by timber mark only, is relatively easy to classify. Often, however, that is not the case and possibly the most challenging task a timber weigher faces is the accurate stratification of timber as it arrives at the weigh scale. Light and weather conditions, mud or snow on loads, mixes of species, and/or grades in a truckload only add to the difficulty of evaluating timber for inclusion in the appropriate stratum.

Should subsequent scaling of samples or a check scale indicate they have been assigned to wrong strata, it is the responsibility of both timber weigher and scalers to immediately bring the matter to the attention of the District Scaling Supervisor. Scaling staff will then investigate.

Some stratification criteria depend heavily on the timber weigher's skill and ability to judge species-mix percentages and/or grade composition of a truckload. Should a sample be drawn of such a load and its subsequent hand-scale prove that the weigher mis-called the stratum's species/grade criteria, the load must nonetheless remain in the stratum to which it was originally assigned. Be it rightly or wrongly identified, every sample *must* be considered representative of the non-sampled portion of the stratum for which it was drawn. To second guess and move one to some other apparently more appropriate stratum, can introduce a severe sampling bias and is to be avoided.

On the other hand, any loads that have the wrong information simply as the result of a data entry error or incorrect timber mark, must be noted and corrected except the stratum, whenever they are discovered.

Mis-stratification should not occur very often. If it does, it will have been for one or both of the following reasons:

1. The weigher either lacks sufficient skill and experience to accurately assess species and/or grades, or is not taking enough care in viewing and evaluating loads, and/or
2. The stratum definition is too vague or complex to be practicably applied to the timber being sampled.

In this first situation, the problem may be remedied through additional training or supervisory direction, if required. In the second, either the bush sorts or the stratum's definition criteria may need to undergo some adjustment.

10.4.6 Testing of Weight Scales for Accuracy (Eccentricity Test)

Weight scales must conform to the legislation and regulations set by Measurement Canada, a division of Industry Canada.

Regular section tests must be conducted on platform weigh scales. If at all possible, regular tests should also be done on hoist-type scales. Unfortunately, this is not always feasible, as known weights of stable and sufficient mass to do a meaningful test and equipment powerful enough to move the weights in and out of position, are often not available. In those cases, the only testing that can be done is by technicians when load cells are sent away for regular maintenance and calibration.

The requirements are:

1. The weight scale should be inspected each work day before any loaded trucks are processed, for dirt, debris or ice build-up under and around the platform ends. Arrangements are to be made for the removal of any matter that would inhibit the free movement of the scale deck,
2. Sections tests will be conducted at least once each work day, and a second time if the number of loads exceed 150,
3. The device must be zeroed before conducting the test,
4. The heaviest, shortest wheel-base vehicle available (usually a loader) should be used as a test weight. A test weight of 20% to a maximum of 50% of the scale capacity is recommended,
5. Empty logging trucks must not be used as they are too long. Pick-up trucks should not be used,
6. Each section of the scales will be tested in both directions (sections can be marked for the scale operator),
7. Each weight scale must maintain a ledger in which the results of every section tests are recorded by time, date, signed off by the timber weigher. It must be retained at the scale site for 3 months or as per the site authorization, and available for inspection by a forest officer,
8. A test standards (Weights and Measures Canada Reg. Sec 56) shall be used to calibrate and inspect the scale at least once a year,
9. The scale owner/operator is responsible to arrange for immediate repairs,
10. If the prescribed in-service limits of error is outside the range, the Timber weigher is personally responsible to immediately inform both the District Scaling Supervisor and the weight scale owner/operator (as per the tables below),

Using the charts below, determine the type of weighing device and the interval that is used (2, 5, 10 or 20 kg.). Determine the test weight that will be used. The number on the left side of the chart tells you how much tolerance is allowed.

11. If the variation exceeds 3 times the tolerance then the scale shall be shut down until it is repaired (as per the tables below).

Table 10-1 Class III HD Weighing Device, In-Service Limits of Error .

In-service LOE in terms of the number of verification scale intervals	Verification scale interval			
	2 kg	5 kg	10 kg	20 kg
	Load in kg	Load in Kg	Load in Kg	Load in kg
1	0-1 000	0-2 500	0-5 000	0-10 000
2	> 1 000 – 2 600	> 2 500-6 500	> 5 000 -13 000	> 10 000-26 000
3	> 2 600 – 4 200	> 6500 – 10500	> 13 000 – 21 000	> 26 000 – 42 000
4	> 4 200 – 5 800	> 10 500 – 14 500	> 21 000 – 29 000	> 42 000 – 58 000
For heavier weights $LOE = [(L/e) - 500/800] + 1$ L: the load or standards used to determine the LOE e: the value of the verification scale interval Source: Measurement Canada, Field Inspection Manual, Non-automatic weighing devices part 4 appendix B				

Table 10-2 Other Classes Weighing Device, In-Service Limits of Error

Column I Limits of Error	Column II			
	Class I	Class II	Class III	Class IIII
+ 1 e (2, 5, 10, 20 kg)	0 -50 000	0 – 5 000	0-500	0 - 50
+ 2 e (4, 10, 20, 40 kg)	50 000 – 200 000	5 000 – 20 000	500 – 2 000	50 - 200
+ 3 e (6, 15, 30, 60 kg)	> 200 000	20 000 – 100 000	2 000 – 4 000	200 – 400
+ 5 e (10, 25, 50, 100 kg)	-----	-----	4 000 – 10 000	400 – 1 200
Source: Measurement Canada, Field Inspection Manual, Non-automatic weighing devices, order establishing specifications relating to non-automatic weighing devices part 3 Appendix B.				

An example of using the charts to determine the limit of tolerance:

A class IIIHD weighing device has 10 kg intervals. Using a test weight of 25 000 kg. The chart shows that four intervals are allowed or 40 kg. If the variation is more than 120 kg, or three times that tolerance, the device must be shut down and the emergency procedures initiated.

10.4.7 Records Management at a Weight Scale

Scale Return Electronic Submission

As per the requirements of Section 97 (1) (f) of the *Forest Act*, Weight Slip and Log Tally data shall be transmitted as specified by the Ministry of Forests and Range Harvest Billing System.

Document Submission

Load Description Slips shall be stapled in chronological order to the associated Daily Audit Report. The original Daily Audit Reports shall be submitted in chronological order to the Ministry of Forests and Range at mid-month and at month end as directed in the scale site authorization.

Document Retention

- 1. Daily Audit Report:** print daily, immediately after all weight scale load slips have been digitally signed, and retain a copy for 3 months.
- 2. Safety Sheet or Substitute:** to be retained for 3 months, or, the gross truck weight shall be recorded on the Load Description Slip at the time of gross weighing.
- 3. Weight Scale Submitted Load Slips Backup (or Backup Report):** retain for 2 years in paper or electronic format.
- 4. Submitted Log Tally Backup:** retain for 2 years in paper or electronic format.
- 5. Species/Grade Summary Report:** retain for 3 months.
- 6. Section Tests:** retain for 3 months.

The detailed procedures describing the completion, retention, and submission of all weight scale forms are documented in the documenting and reporting scale results section of this manual.

10.4.8 Changes to Scale Data

Changes may be made to any scale data by the scaler whose license number appears on the document or by an approved company representative who is authorized to make such a change.

10.4.9 Emergency Procedures

Weight scales are subject to breakdown. If this occurs, responsibilities are as follows:

- weight person - immediately inform the district scaling supervisor and the weight scale owner/operator,
- weight scale owner/operator - ensure the scale is repaired as soon as possible, and
- District Scaling Supervisor - provide direction in initiating procedures to ensure all production is correctly accounted for during the breakdown.

Appendix 10A outlines emergency procedures to be followed in the event of a breakdown.

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Appendix 10A Emergency Procedures in the Event of a Weight Scale Breakdown

Trade as defined in the Federal Weights and Measures Act is: "the selling, purchasing, exchanging, consigning, leasing or providing of any commodity, right, facility or service on the basis of measure and includes the business of providing facilities for measuring,"

10A.1 Breakdown of the Weighing Device (Weight Indicator is Unavailable or Inaccurate)

There is no provision in the Act for breakdowns and any weights estimated or taken from not legal for trade devices would not comply with the *Weights and Measures Act*.

Section 24(b) of the *Weights and Measures Act* says: "Every trader is guilty of an offence who uses, or has in his possession for use, in trade, any device that

- (a) is not installed in accordance with the requirements of the regulations; or
- (b) does not measure units of measurement within the limits of error prescribed."

Under this section it is clear that as soon as the weight scale weighs outside of the limits of tolerance it must be shut down. See Chapter 10, Table 10-1 and 10-2 for more information on the limits of tolerance.

10A.1.1 Alternatives to Weight Scaling

Weight scale operators are permitted to continue processing loads of timber in the event of scale breakdown, subject to the following conditions:

1. The District Scaling Supervisor must be notified immediately following the breakdown of the scale.
2. All loads may be piece scaled at the discretion of the District Scaling Supervisor.
3. All scale data collected through the emergency procedures must be submitted to the Forest Service along with the regular submission of scale data.
4. If another weight scale is located within 20 km of the malfunctioning scale, it may be authorized for weighing during the breakdown period subject to approval by the District Scaling Supervisor.
5. Loads may be wrapped to protect their integrity, set aside and weighed after the weighing device is repaired.

10A.1.2 Responsibilities

10A.1.2.1 Company (Population Holder)

1. To ensure that the District Scaling Supervisor is notified immediately following the breakdown of the scale.
2. To ensure that loads are not weighed using an inaccurate weighing device after it has been identified as inaccurate.
3. To ensure that all data is accurate, all forms are completed correctly and that this scale data is submitted to the Ministry of Forests and Range by the deadline as stated in the site authorization.
4. To circulate copies of this appendix to all timber weighers and other company personnel who will be involved in the completion of any of the forms and/or the submission of data.

10A.1.2.2 District Scaling Supervisor

1. To ensure that all scale data is completed as required before submission for billing.
2. To ensure that all scalers are aware of this procedure and instruct them if necessary.

10A.3 Breakdown of the Weight Scale Computer or Sample Selector

In the event the sample selector breaks down, the following procedure is in place:

1. Immediately contact the District Scaling Supervisor for direction, and
2. Where the selector cannot be fixed within one day, the District Scaling Supervisor may implement a manual sample selection procedure using a table of random numbers.
3. Contact the District Scaling Supervisor for instructions on the selection of samples during the breakdown period.

10A.2.1 Procedures

1. An FS 1217/Weight Scale Load Slip will be generated with all the required information for every load during the breakdown. Refer to Chapter 7, Section 7A.1 and Figure 7A.1 for details on using this form.

2. Once the weight slips have been entered a summary will be generated for use by the MOFR and the company. Any data used to calculate the weight, as well as the load information is to be submitted to the MOFR.

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