Performance Audit Report

FRAMES Reconciliation

Issue

The Auditor General's Performance Audit "Sustaining Native Forest Operations: Forests NSW" of April 2009 included an action item (Recommendation 5), requiring Forests NSW to "compare harvest results against its yield estimates over five year periods as a means of testing the accuracy of estimates" and "report the results annually starting June 2010".

This is the first report addressing this requirement and covers the reconciliation of actual harvested volumes versus harvestable volumes predicted by FRAMES (the Forests NSW Forest Resource And Management Evaluation System) for the period July 2005 to June 2010 for Forests NSW North East and Central Regions plus the Southern Regional Forest Agreement (RFA) region. The remaining part of the Forests NSW Southern Region, comprising Eden RFA region, was excluded from this study because FRAMES is not used in that area for prediction of current and future harvestable volumes.

Background

FRAMES is the set of tools used to predict the strategic level harvestable volume within areas of native forest in Forests NSW North East, Central and Southern Regions. Volumes of high quality large (HQL), high quality small (HQS) and low quality (LQ) sawlogs as well as pulpwood (Pulp) are estimated on a per hectare basis for specified harvesting regimes (silvicultural treatment) and applied to the area of forest potentially available for harvesting. HQL, HQS, LQ and Pulp are collectively referred to in this report as log classes. HQL and in some cases HQS volumes are the basis for the majority of Forests NSW contracted log supply commitments.

Strategic versus operational estimates of harvestable volume

FRAMES is a strategic level harvestable volume simulator. It is not designed to be an accurate predictor of harvestable volume by log class at compartment level (typically 100-200 ha); rather, it is intended to predict harvestable volume by log class over an aggregation of many compartments. For reasons that are set out below, compartments in this study have been amalgamated into Analysis Groups based on: Region; coastal versus tableland forests; Blackbutt-rich forests; and primary silviculture applied in harvesting operation. There are 4 Analysis Groups in North East Region, 6 in Central Region and 4 in Southern RFA region (see Table 1).

FRAMES does not calculate the potential harvestable volume by log class at compartment level. While this approach is desirable as it would align operational and strategic harvest volume estimates, it is not practical. A minimum of 15 inventory plots per compartment would be needed to achieve reasonable accuracy of volume estimates at compartment level in the absence of spatial stratification. This number of plots would be expensive to establish and measure.

Technologies such as LiDAR offer the prospect of cost-effective improvement in accuracy at operational level, through increased efficiency of inventory based on stratification. This process is currently being tested by Forests NSW. To produce reasonably accurate predictions at operational level, such strata would need to be spatially accurate and correlated with both current and future harvestable volumes, such that the variation in harvestable volumes within a stratum was significantly less than variation between strata. This is a core requirement for increasing the efficiency of forest inventory. However, as there is currently no stratification available that achieves this outcome, there is no basis for assigning the predicted current and future harvestable volumes from inventory plots to geographically specific areas at the operational scale.

Project Design

The FRAMES Reconciliation project compares FRAMES-predicted volumes by log class with actual harvested volumes by log class for areas harvested during the period July 2005 to June 2010.

Dataset for actual harvested volume by log class

In 2011, Forests NSW implemented an Event Management (EM) system to record the spatial extent and timing of harvesting events. This is a GIS-based system for recording, among other things, harvest plans and the results of harvesting operations at the compartment level, thereby providing a spatially explicit compartment history. The EM system has also been linked to the Forests NSW sales system (Scion), so that volumes actually harvested can be matched to the spatial location of the harvesting event. Population of the EM system was accelerated to assist with this project, primarily to ensure consistency in data records used to conduct the reconciliation.

The EM system, linked with the Scion sales system, was used to identify all compartments harvested between July 2005 and June 2010. A range of filters was applied to this compartment list by Region. A compartment was removed from the list if:

(i) The harvesting operation was unusual, such as road-line clearing.
(ii) The actual harvesting start date, where this occurred prior to July 2005, could not readily be identified.
(iii) The harvest completion date was beyond June 2010.
(iv) The forest type was not native forest.
(v) The area harvested was leasehold or plantation.
(vi) Data for GIS boundaries, harvested area boundaries, size and type characteristics and/or harvest volumes could not be reconciled.

Forest Information & Planning staff held extensive discussions with the Regions to verify classification of the harvesting records when they were loaded into the EM system. This ensured that the records were current and correct and that the appropriate silvicultural treatment was applied to the strategic inventory plots used by FRAMES to predict volumes. Further discussions identified which log products were dominant in the harvesting operation. HQL was identified as the most important log class; hence HQL volume production was used to drive the FRAMES models and as the primary focus for discussion of results. HQS volumes contribute to contracted timber supply volumes in specific areas but were not the driver for harvesting decisions; hence it was inappropriate to use HQS production for modelling silvicultural treatments. Production of LQ and Pulpwood logs was not used as a driver in the analysis as

market commitments for these products were significantly less than available supply. Incidental production of HQS, LQ and Pulp volumes from the FRAMES models is reported.

All eligible compartments in a Region were then grouped into Analysis Groups. Actual harvest volume and area figures in the EM system were linked to and summarised in a spreadsheet for analysis.

Dataset for FRAMES predicted harvested volume by log class

The methodology used for generating estimates of harvestable volume by log class for the five-year period July 2005 to June 2010 is set out below.

(i) Harvesting tracts based on actual harvest area (as recorded in the EM system) were intersected with strategic inventory plot locations. Only strategic inventory plots that fell within the harvesting tracts were used to generate FRAMES predictions for this project. This comprised 162 plots in North East Region, 163 in Central Region and 111 plots in Southern RFA region (of which 17 were in Tumut sub-region).

(ii) Where strategic inventory plot measurements comprised records from more than one point in time, the measurement record most immediately prior to the completion of harvesting was selected. Plots with a most recent measurement record prior to 2007 (the mid-point of the 5-year study period) were grown forward to 2007.

(iii) Multiple silvicultural treatments cannot be modelled within compartments because sales data are amalgamated to the compartment level in Scion. Three silvicultural treatments were relevant to this study: Single Tree Selection (STS), Australian Group Selection (AGS) and regeneration-enhancing STS (STSRegen). For the purpose of this reconciliation, strategic inventory plots located in areas tagged as predominantly AGS were classified as STS. This was because AGS as practised during the study period typically comprised a combination of traditional (although small) AGS gap creation and some STS between gaps. For FRAMES modelling purposes, this is closer to STS than AGS; further, AGS as currently specified is unlikely to be used as a silvicultural treatment in the foreseeable future. Thinning is the other type of silvicultural treatment that occurred in a small number of compartments harvested from July 2005 to June 2010, but these compartments were excluded as the area treated was small.

(iv) The resulting data set of eligible strategic inventory plots was analysed within Analysis Groups. FRAMES normally models at Price Zone level but modelling at that level was impractical for this study due to the small number of plots in most Price Zones. The definition of Analysis Groups was based on:

- Region
- Management Zone within a Region when the management zone was large and/or distinct in terms of species/management
- Separation of coastal and tableland forests (typically quite different in terms of species, structure and growth rates)
- Separate identification of Blackbutt-rich forests (Blackbutt is a key species in several timber supply contracts)
- Primary silvicultural treatment.

Analysis Group definition was also influenced by the number of strategic inventory plots that fell within each Analysis Group. Where possible, Analysis Groups contained at least 20 plots to increase

the likelihood that confidence limits around predicted volumes per hectare were reasonable, but four significant Analysis Groups were retained even though they contained less than 20 plots. Analysis Groups and plot numbers are shown in Table 1.

Table 1: Analysis group definition and plot numbers

Analysis group	Description	Number of plots
CAS_STS	Casino Management Zone, STS	74
NER_BBT_STS	North East Region, Blackbutt-rich forests, STS	39
NER_COASTAL_STS	North East Region, Coastal forests, STS	14
NER_TABLELAND_STS	North East Region, Tableland forests, STS	35
HUN_STS	Hunter Management Zone, STS	19
CEN_BBT_STS	Central Region, Blackbutt-rich forests, STS	54
CEN_COASTAL_STS	Central Region, Coastal forests, STS	31
CEN_TABLELAND_STS	Central Region, Tableland forests, STS	27
CEN_BBT_STSRegen	Central Region, Blackbutt-rich forests, STSRegen	20
CEN_COASTAL_STSRegen	Central Region, Coastal forests, STSRegen	12
SOU_STS	South Coast sub-region including Queanbeyan, STS	94
TU_STS	Tumut sub-region, STS	17
TOTAL		**436**

Note: Analysis Groups designated as North East Region exclude areas within Casino Management Zone.
Analysis Groups designated as Central Region exclude areas within Hunter Management Zone.
South Coast and Tumut sub-regions are part of the Southern RFA region.

(v) The standard approach adopted in FRAMES modelling is to preclude a silvicultural treatment from generating a harvesting event for an inventory plot until specific economic harvesting thresholds are met. However, in this study, a harvesting operation was known to have occurred in the selected compartments - regardless of whether an individual plot had reached the economic harvesting thresholds, the harvested areas represented by that plot were actually harvested. The most appropriate way to model this situation was to force the plot to be harvested in the FRAMES model by ignoring the economic harvesting thresholds.

(vi) The silvicultural treatment modelled in FRAMES was either STS or STSRegen, specified as per the name of the Analysis Group. Neither AGS nor Thinning were used as a silvicultural treatment, for reasons noted earlier.

(vii) The specific rules applying to the FRAMES-modelled harvesting operations were those specified by Regions as actually applying to the specified silvicultural treatment in the specified Analysis Group (noting that minimum economic harvesting thresholds did not apply). Particular attention was given to any restrictions applying to harvesting of potential HQL stems.

(viii) The FRAMES models were restricted to focus harvesting rules on HQL volumes only, due to the overwhelming importance of HQL in timber supply contracts, the variability in demand for HQS and market conditions limiting the volume of LQ and Pulp referred to earlier.

(ix) FRAMES-modelled harvest volumes were calculated for each individual plot within an Analysis Group, using a single silvicultural treatment. All plots within an Analysis Group were then averaged

to produce a single modelled volume per hectare by log class. FRAMES normally models in this way, but at Price Zone level rather than Analysis Group level.

(x) By forcing the plots to be harvested, the average volume by log class across the set of plots in an Analysis Group will be higher than if plots are harvested only when economic harvesting thresholds are met. For typical strategic level modelling of growth and yield over time, FRAMES applies the economically constrained harvest volumes per hectare to the modelled available area for harvesting (i.e. the modelled Net Mapped Area reduced by area modifiers) to predict harvestable volumes by log class. However, applying this modelled area in this study (FRAMES predictions based on plots with forced harvesting) would over-estimate FRAMES-predicted volumes. For this reason, FRAMES-predicted average volumes per hectare for each Analysis Group were applied to the estimated harvested area, as defined in step (xi), rather than the modelled area. Further, it is appropriate that a comparison of actual versus predicted harvest volumes is driven by the area actually harvested.

(xi) In the EM system, maps are included showing the spatial extent of harvesting. However, these are generally not of sufficiently fine resolution to accurately map the actual harvest area, due to the time and practical field limitations of preparing an accurate post-harvest map. These maps are typically based on planned rather than actual harvest areas (areas available for harvesting after allowing for mapped, and in some cases unmapped, exclusions), together with larger potentially available areas that were not harvested due to restrictions encountered during the harvesting operation. Hence some areas shown as harvested in the EM system were actually excluded from harvesting. As part of the related Net Harvest Area Modifier (NHAM) project, a number of recently harvested areas have been accurately mapped using aerial photography. These NHAM mapped areas were compared to harvested areas for the same compartments as represented in the EM system and the results are shown in Table 2. This comparison provided a basis for calculating adjustment ratios to be applied to the post-harvest areas as recorded in the EM system, to produce the "estimated harvested area" for each compartment for this study.

Table 2: Comparison of accurately mapped (NHAM) harvest area with Event Management system

Locality	No. of Matching Compartments	NHAM Total Harvested Area	Event Management Total Harvested Area	Actual harvest area ratio (NHAM/EM)
Central	15	1,219.6	1,418.5	86%
North East	19	1,350.3	1,632.2	83%
Southern	18	1,851.1	2,184.3	85%
Tumbarumba	10	811.0	772.5	105%
Grand Total	**62**	**5,232.0**	**6,007.4**	**87%**

At the completion of the process outlined above, FRAMES-predicted volumes per hectare of HQL, HQS, LQ and Pulpwood were calculated by multiplying the volume per hectare averages calculated at step (ix) by the estimated harvested area calculated at step (xi), for all compartments within an Analysis Group.

Results

Analysis results have been summarised by each Analysis Group, Region and overall, showing Actual versus Predicted yields (Table 3) and Actual versus Predicted yields per hectare and associated Probable Limits of Error (PLE), for both HQL and HQ (HQL + HQS) volumes (Table 4). PLEs are determined by calculating the confidence interval around a measure (in this case, an actual yield per hectare or a predicted yield per hectare) at the 95% probability level and expressing the confidence interval as a ± percentage of the measure. Hence, a PLE of ±30% for a predicted yield of 20 m^3 per hectare means that, 95% of the time, the predicted yield can be expected to lie within the range of 20 m^3 per hectare -30% to 20 m^3 per hectare +30%, i.e. 14 to 26 m^3 per hectare.

Actual yields of HQL were 1% above, 18% above and 23% above predicted volumes for North East Region, Southern RFA region and Central Region respectively. Across all regions studied, the amount of HQL volume harvested was 9% higher than predicted. While there are clearly differences between actual and predicted volumes and volumes per hectare, the calculated PLEs show that there is no statistical difference between the mean actual and mean predicted volumes per hectare of HQL volumes for any of the Analysis Groups. The nature of the analysis precluded calculation of PLEs for predicted HQL volumes, but since both actual and predicted volumes use the same area for calculation, the relationship between actual and predicted volumes and volumes per hectare can be assumed to be the same.

Table 3: Actual versus Predicted Yields by Analysis Group

Analysis Group	Estimated Harvested Area (ha)	Actual HQL	Predicted HQL	Actual/Predicted	
				HQL	HQ
CAS_STS	13,115	122,780	97,920	125%	132%
NER_BBT_STS	8,506	161,425	166,549	97%	91%
NER_COASTAL_STS	3,398	28,751	27,308	105%	107%
NER_TABLELAND_STS	7,071	56,973	72,772	78%	72%
All NER STS Total	32,090	369,929	364,550	101%	100%
HUN_STS	3,902	31,457	30,152	104%	88%
CEN_BBT_STS	7,235	180,501	170,536	106%	90%
CEN_COASTAL_STS	5,403	72,262	67,845	107%	96%
CEN_TABLELAND_STS	4,802	83,288	88,067	95%	85%
All CEN STS Total	21,342	367,508	356,600	103%	90%
CEN_BBT_STSRegen	2,582	79,835	50,385	158%	131%
CEN_COASTAL_STSRegen	1,618	19,110	18,338	104%	84%
All CEN STSRegen Total	4,200	98,945	68,724	144%	118%
SOU_STS	10,222	199,577	153,868	130%	117%
TU_STS	2,863	95,395	95,162	100%	97%
All SOU STS Total	13,085	294,972	249,031	118%	110%
Combined Total	**70,718**	**1,131,354**	**1,038,904**	**109%**	**100%**

Table 4: Actual versus Predicted Yields per hectare by Analysis Group

Analysis Group	Actual/hectare			Predicted/hectare		
	HQL	HQL PLE	HQ	HQL	HQL PLE	HQ
CAS_STS	9.4	± 16%	15.5	7.5	± 28%	11.7
NER_BBT_STS	19.0	± 22%	26.0	19.6	± 35%	28.5
NER_COASTAL_STS	8.5	± 30%	13.1	8.0	± 65%	12.2
NER_TABLELAND_STS	8.1	± 34%	11.2	10.3	± 32%	15.6
All NER STS Total	11.5	± 14%	17.0	11.4	± 19%	17.1
HUN_STS	8.1	± 25%	11.1	7.7	± 69%	12.6
CEN_BBT_STS	24.9	± 20%	32.5	23.6	± 25%	36.1
CEN_COASTAL_STS	13.4	± 24%	17.5	12.6	± 37%	18.3
CEN_TABLELAND_STS	17.3	± 18%	19.8	18.3	± 43%	23.4
All CEN STS Total	17.2	± 14%	21.9	16.7	± 19%	24.4
CEN_BBT_STSRegen	30.9	± 27%	43.8	19.5	± 56%	33.4
CEN_COASTAL_STSRegen	11.8	± 53%	18.0	11.3	± 56%	21.3
All CEN STSRegen Total	23.6	± 30%	33.8	16.4	± 42%	28.8
SOU_STS	19.5	± 12%	22.1	15.1	± 27%	18.9
TU_STS	33.3	± 38%	36.9	33.2	± 70%	37.9
All SOU STS Total	22.5	± 13%	25.4	19.0	± 28%	23.1
Combined Total	**16.0**	**± 8%**	**21.1**	**14.7**	**± 12%**	**21.1**

Notes: PLE denotes Probable Limits of Error at 95% probability level.

There is no significant difference (95% probability level) between Actual and Predicted HQL volumes/hectare for any Analysis Group

Probable Limits of Error in Estimating Actual and Predicted HQL Volumes per hectare

PLEs are important in this study, because the size of the PLEs determines the likelihood of statistically significant differences between actual and predicted HQL volumes per hectare.

The PLEs for actual HQL volumes per hectare are typically less than ±30%, which reasonably reflects the variability that has traditionally been assumed in this log class. There are three Analysis Groups with PLEs above ±30%.

- Central Region Coastal forests STSRegen: PLEs are high for this Analysis Group because there were only 14 harvesting events contributing to the actual volumes per hectare (the average is 77 harvesting events for an Analysis Group). The small number of harvesting events is reflected in the fact that the estimated harvested area for this Analysis Group is the smallest overall.
- North East Region Tableland forests STS and Tumut sub-region STS: Both of these Analysis Groups represent locations where there is inherently higher variability in log quality and a higher proportion of species that are less desirable in the market than is the case either in coastal forests or in Central Region.

The PLEs for predicted HQL volumes per hectare are almost always higher than for actual HQL volumes per hectare. This is not surprising, since strategic inventory plots cover the full range of variability within an Analysis Group, while actual harvesting events are likely to be skewed towards the more productive and/or less variable compartments. The Analysis Groups with the highest PLEs for predicted HQL volumes per hectare are those with the smallest number of strategic inventory plots and hence the smallest capacity to cover the inherent variability. With the exception of Central Region Tableland forests STS at ±43%, all of the Analysis Groups with PLEs above ±40% have 20 or less strategic inventory plots. It could reasonably be expected that PLEs in these Analysis Groups would be reduced to more desirable levels if more strategic inventory plots had been available to contribute to the analysis.

Overall, the PLEs for predicted HQL volumes per hectare are considered reasonable. FRAMES was designed to target PLEs for HQL of ±30% (a typical target for managed native forests), but does so using the full complement of strategic inventory plots. Less than 20% of all strategic inventory plots intersected with harvested areas and were used in this study. Hence achieving PLEs for predicted HQL volumes per hectare that were generally less than ±40% is considered an acceptable result.

Actual vs Predicted HQL Volumes at Analysis Group level

There were four Analysis Groups in which actual HQL volumes differed notably from predicted HQL volumes, even though the differences were not statistically significant.

- Casino Management Zone STS: An analysis of the actual HQL volumes by Price Zone showed that a higher proportion (by area) of HQL harvested in the selected period came from higher productivity Price Zones. The absolute difference between actual HQL volume per hectare and predicted HQL volume per hectare is only 1.5 m^3/ha, but the differences are accentuated because this has the largest area of any Analysis Group.
- North East Region Tableland STS: Harvesting rules used in FRAMES do not differentiate between species. Consequently, actual HQL volumes per hectare may be lower than predicted if markets that are sensitive to species were poor at the time of harvest. Predicted HQL volumes per hectare rely on sub-models in FRAMES that convert estimates of HQL in standing trees to harvest volumes. These models are less reliable in the tableland forests where defect levels are highly variable.

- Central Region Blackbutt-rich STSRegen: Reasons for the actual HQL volumes being so much higher than the predicted HQL volumes were not readily explained. It may be that harvesting operations from July 2005 to June 2010 were skewed towards more productive compartments. The number of plots used for predicting HQL volumes was low for this Analysis Group, which increases the probability that the strategic inventory plots used in the study were not particularly representative of operations in the areas actually harvested.
- Southern RFA region STS: The assessment process for log quality classification used in strategic inventory plots until recent years under-estimated the potential availability of HQL, both in terms of standing tree quality classification and in conversion of these classifications to expected harvested volume by log class. As a consequence, FRAMES models using this historical strategic inventory plot information tend to under-estimate HQL volumes per hectare. The assessment process has now been corrected.

Actual vs Predicted HQL Volumes at Price Zone level

An exercise was conducted to estimate whether bias had been introduced into the analysis when aggregating Price Zones in to Analysis Groups. The predicted volumes per hectare and their PLEs were kept unchanged with this disaggregation from Analysis Groups back to Price Zones, because there were too few strategic inventory plots in each Price Zone to generate meaningful estimates and PLEs at that scale. Actual HQL volumes per hectare and their PLEs were recalculated at Price Zone level.

The same tests as were used for Analysis Groups showed that there was a statistically significant difference (95% probability level) between actual yields per hectare and predicted yields per hectare for only two of the 38 Price Zones. The statistically significant difference arose because these particular Price Zones (which were in separate Analysis Groups) had actual yields per hectare that were much higher and much lower respectively than the average for their Analysis Group.

Conclusion

It is widely acknowledged that it is difficult to undertake a reconciliation between a model such as FRAMES which is designed to predict volumes by log class at strategic level, and actual harvesting operations. Forests NSW anticipates that this kind of reconciliation may be more practical in the future with a forest stratification and post-harvest assessment using remote sensing technologies such as LiDAR. This may also improve the ability to estimate the area of a compartment actually harvested.

Despite these difficulties, the study demonstrated that FRAMES predicted HQL volumes are very similar to the volumes of HQL actually harvested between July 2005 and June 2010, at both Analysis Group and Regional level, with the only exception being the highly variable Tableland forests in North East Region. There was no statistical difference between actual and predicted HQL volumes per hectare at Analysis Group level.