

ABS advice to AEC on sampling methodology

Executive Summary

The Australian Electoral Commission (AEC) has requested advice from the ABS to determine the number of ballots for assurance as part of the elections for the Australian Senate. The number of ballots that are manually checked for errors should be sufficient to demonstrate with a high level of confidence that the possible national error rate is low.

The ABS recommends that Senate ballots should be assured at the following rate:

- 1 in 3,000 ballots in New South Wales and Victoria;
- 1 in 2,500 ballots in Queensland;
- 1 in 1,250 ballots in Western Australia;
- 1 in 1,000 ballots in South Australia;
- 1 in 350 ballots in Tasmania;
- 1 in 300 ballots in Australian Capital Territory;
- 1 in 120 ballots in Northern Territory.

Based on these rates, it is estimated that 9,895 ballots will be assured nationally for the 2021/22 Senate election. A state breakdown is provided in [Table 1](#):

This assurance approach will provide a high level of confidence in confirming that the national error rate and error rates in each of the states and territories is low.

In comparison with the internal AEC assurance approach implemented in 2019, the proposed allocation delivers a higher confidence in the national error rate, while requiring fewer ballots to be assured. The proposed approach also allows ballot assurance to be undertaken while processing. This is helpful to speed up the assurance.

Background

The Senate assurance process implements two stages of ballot testing. The first stage of testing checks that the scanned image matches the physical ballot paper. The second stage checks that the scanned image of the ballot paper matches the extracted data file, i.e. that the preferences from the scanned image match the datafile that is used to run the preference allocation process.

An assurance of the 2019 Senate election found **no errors** during the first stage at ballot testing. The national estimate of the proportion of errors during the second stage of ballot testing is **0.45%**. The calculation of the national error rate is discussed [here](#).

The emphasis of this report is to determine an appropriate allocation to assurance for stage 2 errors. Given that no stage 1 errors were detected as part of the 2019 assurance from a sample of 1,368, it is evident that the true stage 1 error rate is very low. For the purposes of stage 1 testing, it should be sufficient to assurance 1 in 10 of the ballots selected for stage 2 testing. The practical implementation is discussed [here](#).

Recommended Allocation

This section details the recommended allocation and diagnostics associated with it. Alternate allocations were considered and informed the final recommended allocation. See [Appendix](#).

The allocation utilised the following assumptions.

- While the 2019 assurance indicated that the prevalence of stage 2 errors differed by state, the difference between the state and national proportion of errors was not statistically significant, with the exception of the ACT, which had no errors detected.¹ Therefore, the calculated national stage 2 error rate of **0.45%** was assumed in each state.
- An estimate of 16.095 million Senate forms nationally for the 2021/22 election. The distribution of form by state as provided by the AEC – see [Table A1](#).

The main criterion implemented for designing the target number of ballots to assurance by state was to have 99% confidence that the observed error rate in the sample for each state will be less than 1%, assuming that an error rate of 0.45% (as estimated in 2019) applies for the full population of senate votes.

The minimum sample size to achieve this is to select 828 ballots in each state and territory – see [Appendix](#) for details.

The recommended allocation places sample beyond this minimum value into each state. This is a conservative approach to ensure we have enough sample to meet the accuracy targets, and it produces round numbers for the sampling skips to be used, simplifying the implementation of this proposal. It also helps to ensure robustness. The sample allocation will remain statistically valid if the actual number of Senate ballots in a particular state or the error rate differs slightly from what has been assumed.

Table 1: Number of ballots to assure for stage 2 error by state

State	Estimated Forms 2021/22	Estimated Ballots assured (stage 2)	Assurance Rate (1 in X ballots)	95% confidence limit for maximum error rate	99% confidence limit for maximum error rate
NSW	5,200,000	1,733	3,000	0.72%	0.83%
VIC	4,130,000	1,377	3,000	0.75%	0.88%
QLD	3,180,000	1,272	2,500	0.77%	0.89%
SA	1,200,000	1,200	1,000	0.77%	0.91%
WA	1,590,000	1,272	1,250	0.77%	0.89%

¹ The 2019 assurance found zero errors in ACT, during stage 2 testing. Consequently, there is over 95% confidence that the true ACT stage 2 error rate is less than the national stage 2 error rate. The national second stage error rate is applied to ACT in the interests of simplicity and to ensure that ACT is not under-allocated.

TAS	387,000	1,106	350	0.79%	0.92%
NT	115,000	958	120	0.81%	0.96%
ACT	293,000	977	300	0.81%	0.95%
AUS	16,095,000	9,895		0.59%	0.65%

Testing conclusions

Based on the observed error rates from the 2019 assurance and the sample sizes in each state the following statistical statements could be made.

- If there is a 0.45% error rate found in the assurance sample, then the AEC can be 95% confident that nationally, there are less than 6 errors per 1,000 ballot papers in the Senate scanning process. It is also true that if the true error rate in the population is 0.45%, then the AEC can be 95% confident that the error rate estimated from the assurance sample will be less than 6 errors per 1,000 ballot papers.
- Similarly, there is 99% confidence that nationally there are less than 6.5 errors per 1,000 ballot papers.
- In any given state, there is 99% confidence that there are less than 10 errors per 1,000 ballot papers.

These statistical statements are illustrative only. They are based on the assumption of a true error rate of 0.45% in the population to give confidence on the size of the estimated error rate from the sample; or similarly on the assumption of an error rate of 0.45% in the assurance sample to give confidence in what the error rate is for the full population. Final confidence intervals will depend on the **actual error rates found** during the 2021/22 assurance.

Comparison with 2019 assurance approach

It is instructive to compare the proposed assurance approach with the assurance approach previously implemented in 2019.

First, it is noted that the total expected number of ballots to assurance (9,895) is slightly lower than in 2019 (10,400).

Secondly, rather than assuring a constant number of ballots in each state, the proposed allocation is assurances of more ballots in the more populous states and less ballots in the less populous states.

Increasing the number of ballots assured in the more populous states allows the proposed allocation to deliver a higher confidence in the national error rate, while assuring a smaller number of ballots.

Third, it is specified to assure at a constant **rate** in each state, rather than a fixed total number of ballots. This is efficient to allow ballots to be assured while processing is ongoing, rather than having to wait for all ballots to be processed before commencing assurance.

Practical implementation of assuring

The AEC arranges senate ballots into bundles of 50. From a logistical perspective, it would be more efficient to first select a number of bundles and then select more than one ballot from each bundle.

Furthermore, selecting bundles at a constant rate allows assurance to be undertaken while processing is ongoing – as it will not be necessary to have every bundle processed for assurance to commence.

This is known as clustered sampling of the ballots. Clustered samples can lead to lower accuracy if errors can also be clustered together, i.e. if errors are not evenly spread across all bundles. We have suggested an approach that we believe balances the risk to accuracy from using a clustered sample with the benefits that it provides, i.e. reducing the number of bundles that need to be selected for the assurance sample. The allocations provided in *Table 1* have already allowed for some 'slack' by selecting more ballots than strictly necessary to obtain a precise national estimate of the stage 2 error.

We propose the assurance selects a certain proportion of 'bundles' (e.g. 1 in every 300 bundles in NSW) and then to select 1/10 of all ballots in the bundle for stage 2 testing (so that overall 1 in every 3,000 ballots is selected in NSW).

Once ballots have been selected for stage 2 testing, select 1 in every 10 of the stage 2 sample for stage 1 testing.

If the sampling rate from *Table 1* is adopted, then the process is described below in *Table 2*.

Table 2: Number of forms to assure by state

State	Estimated Forms 2021/22	Estimated Bundles 2021/22	Assurance Rate (1 in X bundles)	Estimated Bundles selected	Estimated Ballots assured (stage 2)	Assurance Rate (1 in X ballots)	Estimated Ballots assured (stage 1)
NSW	5,200,000	104,000	300	347	1,733	3,000	173
VIC	4,130,000	82,600	300	275	1,377	3,000	138
QLD	3,180,000	63,600	250	254	1,272	2,500	127
SA	1,200,000	24,000	100	240	1,200	1,000	120
WA	1,590,000	31,800	125	254	1,272	1,250	127
TAS	387,000	7,740	35	221	1,106	350	111
NT	115,000	2,300	12	192	958	120	96
ACT	293,000	5,860	30	195	977	300	98
AUS	16,095,000	321,900		1,979	9,895		989

Calculating the national error rate

If an assurance approach uses a different sampling rate in different states, then in order to calculate the national error rate, it is important to weight the number of errors found in each state by the state's proportion of the national population.

Table 3: 2019 assurance calculation of national error rate

State	Total Senate ballots 2019 (formal + informal)	Proportion of national total	Stage 2 errors 2019	Stage 2 sample 2019	Error rate	Estimated total errors
NSW	4,905,472	32.3%	7	1,300	0.54%	26,414
VIC	3,896,236	25.7%	6	1,300	0.46%	17,983
QLD	2,999,372	19.8%	6	1,300	0.46%	13,843
SA	1,134,556	7.5%	5	1,300	0.38%	4,364
WA	1,497,532	9.9%	4	1,300	0.31%	4,608
TAS	365,272	2.4%	6	1,300	0.46%	1,686
NT	108,994	0.7%	2	1,300	0.15%	168
ACT	276,651	1.8%	0	1,300	0.00%	0
AUS	15,184,085				0.45%	69,065

The error rate in each state is estimated by dividing the number of errors in each state by the assurance sample size. For example, in NSW the assurance for 7 errors from a sample of 1,300, giving an error rate of 0.54%. An error rate of 0.54% would mean that there is a total of 26,414 errors from the full population of 4,905,472 votes in NSW.

After calculating the estimated number of total errors in each state they can be added to produce an estimate of total number of errors in Australia. This total is 69,065 based on the 2019 assurance results.

Dividing the estimate of 69,065 errors by the total national votes of 15,184,085 gives the estimated national error rate of 0.45%.

An alternate approach to calculate this national error rate is to multiply the error rate in each state by the proportion of votes in that state. This gives:

$$\begin{aligned}
 & (0.323 \times 0.0054) + (0.257 \times 0.0046) + (0.198 \times 0.0046) + (0.075 \times 0.0038) + \\
 & (0.099 \times 0.0031) + (0.024 \times 0.0046) + (0.007 \times 0.0015) + (0.018 \times 0) \\
 & = 0.0045.
 \end{aligned}$$

Appendix

Table A1: Estimated senate forms by state for 2021/2022 Senate Election – source AEC

State	Estimated Senate Forms
NSW	5,200,000
VIC	4,130,000
QLD	3,180,000
SA	1,200,000
WA	1,590,000
TAS	387,000
NT	115,000
ACT	293,000

Table A2: number of stage 2 errors by state – 2019 Senate assurance – source AEC

State	Stage 2 errors 2019 assurance	2019 Error rate
NSW	7	0.54%
VIC	6	0.46%
QLD	6	0.46%
SA	5	0.38%
WA	4	0.31%
TAS	6	0.46%
NT	2	0.15%
ACT	0	

Alternate allocations

This section outlines various allocation options that were considered, that informed the final recommended approach. These options are presented for technical background and can be skipped.

The allocation described in [Table 1](#) represents the ABS' main recommendation.

Option A1: Allocation using a constant national sample rate

The first option considered is to apply a constant assurance rate across each state nationally. This would differ from the assurance process from 2019, which assured a constant number of ballots (1,300) in each state as part of stage 2 testing.

The advantages of applying a constant sample rate nationwide, is that it would allow the same assurance procedure to be applied in each state. Furthermore, the estimate of the national error rate would be easier to interpret as no weighting would be required.

The disadvantage of applying a constant sample rate is that the smallest states would have relatively few ballots assured. This would result in a less confidence in the estimate of the state error rate.

Sample allocations

Table A3 shows the national level of accuracy associated with different sample sizes, while applying a constant sample rate nationally.

Table A3: National sample size vs 95% margin of error of estimate

Scenario	National sample size	1 in Rate	One-sided 95% confidence level	One-sided 99% confidence level
A	10,400	1,548	0.56%	0.61%
B	5,810	2,770	0.60%	0.66%
C	6,438	2,500	0.59%	0.65%

Scenario A represents the national sample size that was used for stage 2 testing as part of the 2019 assurance. Scenario B represents the minimum national sample size to be 95% confident that the national error rate is less than 0.6%.

From a practical perspective, it would make sense to use a larger sample size than this. Scenario C represents this, using a 'round' sample rate of 1 in 2,500 dwellings for each state.

Table A4: Number of forms to assurance by state by scenario

State	Estimated Forms 2021/22	Scenario A	Scenario B	Scenario C
NSW	5,200,000	3,360	1,877	2,080
VIC	4,130,000	2,669	1,491	1,652
QLD	3,180,000	2,055	1,148	1,272
SA	1,200,000	775	433	480
WA	1,590,000	1,027	574	636
TAS	387,000	250	140	155
NT	115,000	74	42	46
ACT	293,000	189	106	117
TOTAL	16,095,000	10,400	5,810	6,438

It is evident that if precisely estimating the national error rate is the key objective, than the sample rate required can be significantly lower than what was applied in 2019 (Scenario A). It is also clear that this approach results in a relatively small number of ballots being sampled in Tasmania, Northern Territory and Australian Capital Territory.

Option A2: Allocation with maximum state margin of error (MOE) constraint

A notable disadvantage of applying a fixed sampling rate across all states is that the number of ballots assured in the smaller states is low. This will result in wide confidence intervals for the state level estimates of proportion of errors in smaller states/territories.

The following two allocations examine the number of ballots required to be assured in each state in order to be 95% or 99% confident that the true state level error rate would be less than 1%

Table A5 : state assurance size required to be 95/99% confident that the true error rate < 1%

State one-sided confidence interval	95%	99%
State sample	413	828
National 95% confidence interval bound	0.71%	0.64%
National 99% confidence interval bound	0.82%	0.71%

Therefore, the state allocation to be 99% confident that the observed error rate is less than 1% in each state (assuming a 0.45% error rate in the population) is as in *Table A6*.

Table A6 : State sample size and rate to be 99% confident that the assurance error rate is less than 1%

State	Estimated Forms 2021/22	State sample	State sample rate (1 in X)
NSW	5,200,000	828	6,280
VIC	4,130,000	828	4,988
QLD	3,180,000	828	3,841
SA	1,200,000	828	1,449
WA	1,590,000	828	1,920
TAS	387,000	828	467
NT	115,000	828	139
ACT	293,000	828	354

Table A6 was used as the basis behind the recommended option in *Table 1*. Additional sample was put into each state, in order to round off the sampling rates, and to allow a small buffer for

error (e.g. if total votes in a state is smaller than expected; or if the true population error rate is higher than 0.45%).



Confidence Interval

A confidence interval is an interval which has a known and controlled probability (generally 95% or 99%) to contain the true value. In the context of senate assurance, one-sided confidence limits are calculated for the stage 2 error rates, to determine the maximum error rate that could potentially occur, for the given level of confidence.

Margin of Error (MoE)

Margin of Error describes the distance from the population value that the assurance estimate is likely to be within, for a specified given level of confidence. For instance, at the 95% confidence level, the MoE indicates that there are about 19 chances in 20 that the estimate will differ from the population value (the figure obtained if all senate ballots had been assured) by less than the specified MoE. Equivalently it is one chance in 20 that the difference is greater than the specified MoE, i.e. outside the MoE. .

Significance testing

To determine whether a difference between two survey estimates is a real difference in the populations to which the estimates relate, or merely the product sampling variability, the statistical significance of the difference can be tested. The test is performed by calculating the standard error of the difference between two estimates and then dividing the actual difference by the standard error of the difference. If the result is greater than 1.96, there are 19 chances in 20 that there is a real difference in the populations to which the estimates relate.

Standard error

The square root of the variance of the sampling distribution of a statistic (square root of variance of state or national error rate in the context of senate assurance)

Variance

The variance is the mean square deviation of the variable around the average value. It reflects the dispersion of the empirical values around its mean.

² Glossary definitions have been taken from ABS publications and [The OECD Glossary of Statistical Terms](#) and modified to fit the context of senate assurance