Recommended Audit Procedures

Prepared by the Ohio Joint Audit Working Group[1]

June 2, 2008

Executive Summary

This document on audit procedures was prepared to assist Ohio's Secretary of State, election officials, and legislators as they consider directives and/or legislative action in 2008/2009 to institute post-election audit procedures.   It follows up on broader post-election audit recommendations made in a white paper in Feb 2008[2].

Post-election audits are an integral part of election best practices. Sufficiently thorough and efficient audits can allow for greatest participation while maximizing effectiveness with limited resources; and can help to verify that ballots have been correctly counted and accounted for. Sufficiently transparent audits can foster public confidence by giving citizens the means to see for themselves whether election processes are working properly. At a time of rapid change in Ohio election technology and procedures, post-election audits constitute a crucial investment in election systems' growth, reliability, and transparency. Past Ohio "partial recounts" have not inspired confidence; action is needed now to implement effective transparent audits for the 2008 general election and beyond.

We believe that
- Ohio should proceed expeditiously to plan post-election audits in 2008 and beyond.
- Timely decisions about the scope of the audits, and careful collaborative planning, will help to assure transparent, efficient audits that merit public confidence.
  - A post-election audit using the SAGE (Statistical Audits with Greater Efficiency) precinct selection method[3] is practical and minimizes costs while maximizing effectiveness[4]

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[1] The Joint Audit Working Group includes members of the Secretary of State's Voting Rights Institute's Advisory Council, and an Advisory Panel experienced in election audits. See *Acknowledgements* at the end of this White Paper.

[2] http://www.caseohio.org/Documents/Reports/Ohio_Audit_White_Paper_Feb_2008.pdf

[3] The SAGE method (also known as "APR") uses precinct size and margin of victory to optimize precinct selection, maximize effectiveness and minimize ballots audited. See: Aslam, Popa and Rivest, On Auditing Elections When Precincts Have Different Sizes, http://people.csail.mit.edu/rivest/AslamPopaRivest-OnAuditingElectionsWhenPrecinctsHaveDifferentSizes.pdf

[4] Our audit White Paper comparison of SAGE and a Tiered audit showed audits using SAGE in 2004 and 2006 would have had much higher confidence levels for close races and cost 20%-27% less.

The paper includes:

1. **Audit Design:** Recommendations on audit design decisions that require early planning, and some crucial principles for the audit design.

2. **Statistical Audit Procedures using SAGE:** Detailed procedures (and examples) for implementing a statistical audit using SAGE to provide a high level of confidence and minimize costs. The audit procedures cover the Presidential, US House, and Ohio legislative contests for 2008, but could be expanded to include other contests.

In addition, we include here a list of areas that need further analysis, investigation and recommendations to assure the quality of transparent, efficient audits that increasingly merit public confidence. The Joint Audit Working Group stands willing to assist with such study and planning upon timely request/guidance from the Secretary of State and or the Ohio Legislature.

- Audit procedures for an audit of only the Presidential contest in 2008
- Cost estimates for November 2008
- Comparative analysis of results of March 2008 audits and our recommended procedures
- Analysis of how audits would fit into Ohio election timeframe/calendar
- Recommendations for transparency including guidelines for observers
- Recommendations for checking ballot security
- Recommendations for handling absentee ballots (e.g., when counties gather all absentee ballots into a single special precinct)
- Recommendations for specific escalation triggers and actions to take based on whether the problems appear to be related to specific ballot types or voting machine systems
- Recommendations for finding precincts with large miscounts before auditing starts.
- Recommendations for consistent election results reporting to facilitate comparing results from different elections

1. Audit Design

Transparency and Early Planning

Transparency is a crucial criterion for successful post-election audits. Transparency entails that the public should have the opportunity to observe the audit and to ensure that all phases have been conducted correctly. In the course of the audit, citizens must be able to verify not only that the ballots are counted correctly, but that the ballots have been properly secured until the time of the audit, that a proper random sample has been drawn, and that unused and spoiled ballots have been properly accounted for. Moreover, citizens (including election officials!) must be able to verify that the audit procedure itself is clear, reasonable and complete. Everyone should understand what the procedure requires and why, with little room or need for subjective interpretation during the audit.

Eleven counties recently completed pilot audits of the March presidential preference primary. These pilots evinced noteworthy progress toward the goal of transparency, but some crucial deficiencies must be addressed in order for audits to fulfill their purpose and promise. Transparency does not emerge spontaneously from good intentions alone. It will require careful, collaborative advance planning well in advance of the audit.

Ohio still has plenty of time to plan effective audits for the 2008 presidential election and beyond, but it is important to begin soon, so that implementation details can be worked out. In this White Paper, we engage some specific aspects of audit design that we deferred in our February paper, but we assume that thorough discussion among all stakeholders will yield the best design.

What Races to Audit and How

Ohio elections range from presidential contests to initiatives in a single election precinct. A single ballot often contains dozens of voting choices. It can be argued that every outcome should be subject to post-election audit; however, to actually to audit every one is a far larger undertaking than we would advise at this time. Any audit procedure should dictate that certain contests *must* be audited. The procedure can also specify circumstances under which additional contests *may* be audited, such as the following:

- By stakeholder selection (for instance, the county committees for the major parties may be allowed to choose one race per county to audit)

- By random selection (for instance, one countywide race per county may be chosen at random for a statistical audit [see below])
- Partially, by inclusion in the random audit sample (for instance, in California, 1% of precincts are selected, and all votes in all contests that appear on the ballot in those precincts are audited)

Our previous White Paper recommended, specifically, that certain statewide contests (including president, US Senator, Governor, and other statewide offices or statewide issues with apparent margins under 20%) and most US House and state legislative elections (those with apparent margins under 40%) should be audited. It further proposed that in 2008 a subset of these elections could be audited: the presidential contest, any statewide issues with margin under 2%, and US House and state legislative elections with margins under 10%. We also suggested that it might be desirable to select at random some contests that would not otherwise be audited based on their apparent margins, so that no contest could be rendered un-auditable simply by increasing its margin. We did not propose any other provision for auditing additional contests.

We believe that all federal contests (with the possible exception of manifestly uncompetitive congressional contests) should always be audited using a risk-based statistical audit. Beyond that recommendation, it may be desirable to extend the scope of additional audits, using one or more of the three approaches described above, so that more contests are subject to at least the possibility of being audited. Moving toward stakeholder selection of contests may increase the likelihood that controversial results will be audited; moving toward random selection of contests would reduce the number of contests exempt from audit, and increase the audit exposure of the other contests. It may be reasonable to *require* audits in fewer categories of contests in order to free up resources for such additional audits. We make no further recommendation at this time, but rather underscore that the decision must be made.

The decision of what contests to audit may influence the determination of how many precincts to recount in each one. In general, we recommend risk-based statistical audits following what we here call the SAGE method. The SAGE method is designed to yield a specified high probability (confidence level) of detecting and correcting outcome-altering miscounts, while optimizing the audit sample size for greatest efficiency. In smaller elections (those that span relatively few precincts), achieving high statistical confidence through random samples alone tends to require proportionally larger samples. For this reason we recommended setting a

lower confidence level for state legislative contests (90%) than for statewide and congressional contests (99%), achieving substantial reductions in workload. For the same reason, if it is desired to audit some contests with (e.g.) fewer than 100 precincts, alternatives to risk-based audits may be considered for these contests. For instance, an alternative might combine "tiered" random audit percentages (e.g. 5% in most contests, 10% in the closest contests) with additional "discretionary" audit selections made by losing candidates or other stakeholders. The sampling procedure described below for SAGE precinct selections in multiple contests can readily accommodate "tiered" samples in some contests, if desired.

2. Statistical Audit Procedures using SAGE[5]

Here we focus on how to obtain valid, statistically effective random samples for multiple contests being audited simultaneously. (As such, this discussion clearly does not cover every important aspect of audit procedure; crucial issues such as chain of custody, audit observation, ballot reconciliation, and proper auditing of absentee ballots are beyond the present scope.) In keeping with the transparency criterion, citizens must be able to verify that the sampling method is fair and adequate, in principle and in execution. We do not expect or require that every citizen be able to understand the mathematical rationale – but every step in the procedure can be meaningfully observed and verified by citizens.

1. **Decide contests to be audited and desired confidence level(s)**
   Responsibility: legislation or directive

   The State, in consultation with *all stakeholders*, will select the contests to be audited and a desired confidence level for each contest. For example, the table summarizes the recommendations in our earlier White Paper:

Jurisdiction	Level	Confidence Level[6]	Margin of Victory	Contest
Federal	Statewide	99%	Any	President
			Any	US Senate
	Non-statewide	99%	<40%	US House
State	Statewide	99%	<40%	State offices (Governor, SoS, etc.)
		90%	<40%	Supreme Court Justices
		90%	<40%	Issues
	Non-statewide	90%	<40%	State Senate
		90%	<40%	State House

   Determine if a minimum percentage of votes in each county should be audited in each election, e.g., 1% of all ballots cast. If this requirement is not met through the use of a statistical risk-based method such as SAGE, and to enhance the randomness and confidence level of the statistical sample (already achieved without such a minimum),

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5 Aslam, Popa and Rivest, op. cit.

6 The confidence level can be thought of as the statistical effectiveness of the random portion (generally the largest part) of the audit. More specifically, it is the minimum probability that, if the WPM in Step 2 below is not exceeded, the random audit will report the same winner(s) of the contest as would be reported by a properly conducted 100% hand-to-eye count of the same ballots (but without a full recount being necessary in most cases). (This minimum probability is based on the worst-case assumption that the apparent outcome was wrong and that the actual outcome was a tie.)

the minimum may be met by picking randomly from the remaining unaudited precincts in the county, or by allowing candidates to choose precincts they believe may contain miscounted votes.

Notes
- o The same confidence level should apply to all elections for a particular office or type of ballot question in the state, but may be different for different elected offices or types of ballot questions. E.g., 99% confidence level for all federal and statewide legislative and executive offices and constitutional amendments, 90% for other elections.
- o The contests selected for November 2008 might be a smaller set than would be done in the long run.
- o The Margin of Victory should be calculated for each contest by taking the difference between the top two candidates or issue positions and dividing by the ballots cast (not the votes cast as is traditionally done) for the contest.[7] For example, if candidates A and B received 6,000 and 4,000 votes, respectively, and 10,000 voters did not vote for either A or B, the margin of victory would be 10% (2,000 divided by 20,000 ballots), not 20% (2,000 divided by 10,000 votes). Likewise, the selection probabilities below are based on ballots cast. The difference between ballots cast and votes cast – the number of undervotes and/or overvotes – will usually make little difference. However, if a problem caused a large number of undervotes in some precincts, it would not be appropriate to make these precincts less likely to be selected.

2. **Determine maximum *within precinct miscount* (WPM)**
   Responsibility: legislation or directive

   The State, in consultation with *all stakeholders*, will specify the maximum *within precinct miscount* (WPM) for any precinct, assumed for purposes of the random sample. Within precinct miscount (WPM) is defined as a proportion of ballots on which the votes are miscounted. For instance, a WPM of 15% might mean that 15% of ballots were counted as votes for one candidate but should have been counted for another candidate.

   The SAGE precinct selection method assumes that if a precinct has a miscount beyond a specified maximum WPM, the result will arouse suspicion that will result in the precinct's being audited. For example, if a candidate receives around 1% of the votes in most precincts A–Y, but 43% in precinct Z, it is clear that precinct Z deserves to be

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[7] This definition holds in contests with single winners, including every kind of contest assumed to be audited here. The definition would change slightly for contests with more than one winner.

audited. Historical returns and returns from neighboring precincts are among the criteria that might be used to judge whether a result is suspicious. Based on analysis of historical election returns, some authors have suggested 20% of ballots cast as a reasonable figure for maximum WPM, as long as procedures exist for investigating suspicious precinct results.[8]

3. **Determine escalation procedures in the event of discrepancies**
   Responsibility: legislation or directive

   Clear procedures for expanding the audit in the event that discrepancies are found must be established prior to the election.
   - Tolerable (low) error rates can be established so that, if not exceeded, elections can be certified.
   - These require slightly larger sample sizes than a single-precinct miscount trigger.
   - Triggers for escalation may be based on changes in candidates' vote shares, e.g., 0.1% – not on small "random" errors that cancel each other out.
   - Larger errors should trigger an expansion of the audit, even if they cancel each other out in the initial audit sample.

4. **Report precinct-level official results**
   Responsibility: Counties

   As soon as possible after the election, all counties shall report their official counts to the State, specifying:
   - precinct-level vote counts for each contest
   - total ballots cast in each precinct
   - total ballots cast in absentee precincts or federal-only precincts, if ballots are not sorted by geographical precincts

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[8] See John McCarthy et al., "Percentage-Based versus Statistical-Power-Based Vote Tabulation Audits," *The American Statistician* 62, 1 (February 2008), available http://verifiedvoting.org/downloads/TAS_paper.pdf.
As with many statistical assumptions, the WPM assumption does not have to be literally true in order for the audit to be effective. The SAGE method essentially assumes that miscounts less than or equal to the WPM value will not arouse suspicion, which (for a reasonable value of WPM) is a very conservative assumption. If WPM is set at 20%, miscounts of (say) 30% in one or two precincts usually will not suffice to alter an election outcome, especially if miscounts in many other precincts are less than 20%. It is crucial, however, that the audit procedure allow for suspicious results to be pursued – for instance, by allowing (apparently) losing candidates to select certain precincts to be included in the audit.

o all batches of centrally scanned ballots not sorted by precinct

o any other ballots counted electronically, including provisional ballots

If absentee (or other) ballots are not allocated to precincts, they must be counted and reported in audit units, or "batches" analogous to precincts. An example of data to be reported is shown below with data from the November 2004 general election.[9] Adams County are used in this and following examples only because Adams is first alphabetically. This example will be used in the rest of the procedure.

COUNTY NUMBER	COUNTY NAME	STATE PRECINCT CODE	PRECINCT NAME	CONGRESS	SENATE	HOUSE	SCHOOL BOARD	COURT OF APPEALS	REGISTERED VOTERS	VOTES CAST
01	ADAMS	AAA	BRATTON TOWNSHIP BRATTON TOWN	2	14	89	10	4	902	661
01	ADAMS	AAB	BRUSH CREEK TOWNSHIP - CEDAR M	2	14	89	10	4	307	213
01	ADAMS	AAC	BRUSH CREEK TOWNSHIP - LYNX PRE	2	14	89	10	4	549	376
01	ADAMS	AAD	FRANKLIN TOWNSHIP - LOCUST GROV	2	14	89	10	4	752	557
01	ADAMS	AAE	GREEN TOWNSHIP - GREEN PRECINCT	2	14	89	10	4	466	290
01	ADAMS	AAF	GREEN TOWNSHIP - ROME VILLAGE	2	14	89	10	4	102	70

5. **Gather election results data for each contest to be audited and combine with confidence level and WPM**

   Responsibility: State

   For each contest to be audited, gather
   o maximum within precinct miscount (WPM – from Step 2 above)
   o confidence level (from Step 1 above)
   o number of ballots cast in the entire contest
   o percentage margin of victory (using the percentage calculation in Step 1 above)

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[9] Results taken from http://www.sos.state.oh.us/sos/ElectionsVoter/results2004.aspx?Section=2982

For example:

Contest	District	Margin in Votes	Max WPM %	Confidence Level %	Total Ballots Cast	Margin %
President		118,601	20.00%	99.00%	5,722,439	2.07%
US Senate		1,503,402	20.00%	99.00%	5,722,439	26.27%
US House	1	57,195	20.00%	99.00%	309,180	18.50%
US House	2	137,504	20.00%	99.00%	337,833	40.70%

6. **Calculate percentage of ballots cast for each audited contest in each precinct**

   Responsibility: State

   For each contest to be audited, calculate the percentage of the contest's total vote in each precinct where the contest appeared by dividing the total ballots cast in the precinct by the total ballots cast in all precincts in the contest.

   For example:

COUNTY NUMBER	COUNTY NAME	STATE PRECINCT CODE	PRECINCT NAME	PRESIDENT	Percent of Total Vote	US SENATE	Percent of Total Vote	US House	Percent of Total Vote
01	ADAMS	AAA	BRATTON TOWNSHIP BRATTON TOWNSHIP		0.0116%		0.0116%		0.1957%
01	ADAMS	AAB	BRUSH CREEK TOWNSHIP - CEDAR MILLS PRECINCT		0.0037%		0.0037%		0.0630%
01	ADAMS	AAC	BRUSH CREEK TOWNSHIP - LYNX PRECINCT		0.0066%		0.0066%		0.1113%
01	ADAMS	AAD	FRANKLIN TOWNSHIP - LOCUST GROVE PRECINCT		0.0097%		0.0097%		0.1649%
01	ADAMS	AAE	GREEN TOWNSHIP - GREEN PRECINCT		0.0051%		0.0051%		0.0858%
01	ADAMS	AAF	GREEN TOWNSHIP - ROME VILLAGE		0.0012%		0.0012%		0.0207%

   Notes
   - The percentage of ballots cast in a precinct is the same for all statewide contests (e.g., President, US Senate Governor, etc.).

7. **Calculate the SAGE probability for selecting each precinct in each contest**

   Responsibility: State

   Calculate the SAGE probability (p) that a precinct will be audited for a specific race[10].

   $$p = 1 - (1-C)^{2 * WPM * b / B / m}$$

   where C=confidence level, WPM=maximum within-precinct miscount, b=ballots cast in the precinct, B=ballots cast in the entire contest, m=victory margin

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[10] From equation (14) of Aslam, Popa and Rivest, op. cit.

The probability that a given precinct will be audited for a specific contest will
- o **Increase:** if victory margin is lower, ballots cast in the whole contest is lower, ballots cast in the precinct is higher, confidence level is higher
- o **Decrease:** if margin is higher, ballots cast in the whole contest is higher, ballots cast in the precinct is lower, confidence level is lower

For example:

COUNTY NUMBER	COUNTY NAME	STATE PRECINCT CODE	PRECINCT NAME	PRESIDENT	% of Total Vote	p	US SENATE	% of Total Vote	p	US HOUSE	% of Total Vote	p
01	ADAMS	AAA	BRATTON TOWNSHIP BRATT		0.0116%	0.0102		0.0116%	0.0008		0.1957%	0.0088
01	ADAMS	AAB	BRUSH CREEK TOWNSHIP -		0.0037%	0.0033		0.0037%	0.0003		0.0630%	0.0028
01	ADAMS	AAC	BRUSH CREEK TOWNSHIP -		0.0066%	0.0058		0.0066%	0.0005		0.1113%	0.0050
01	ADAMS	AAD	FRANKLIN TOWNSHIP - LOCU		0.0097%	0.0086		0.0097%	0.0007		0.1649%	0.0074
01	ADAMS	AAE	GREEN TOWNSHIP - GREEN		0.0051%	0.0045		0.0051%	0.0004		0.0858%	0.0039
01	ADAMS	AAF	GREEN TOWNSHIP - ROME V		0.0012%	0.0011		0.0012%	0.0001		0.0207%	0.0009

Notes
- o The p (SAGE probability) value for the US Senate race is much smaller than for the Presidential race because the margin was much higher.

8. **Publish results to Counties and the public**
Responsibility: State

The following (at least) shall be published in printable (e.g., PDF) and machine readable form (e.g., spreadsheet):
- o Criteria for selecting contests and contests selected
- o Vote totals for each audited contest in each precinct (may be too long to print)
- o Calculated results for percentage of votes cast and SAGE probability

Notes
- o The examples for this paper were done in a single spreadsheet starting with the Ohio November 2004 results spreadsheet. The changes to calculate the SAGE probability are straightforward, although the spreadsheet is large because of the large number of precincts.

9. **Check accuracy of probability calculations**
   Responsibility (optional): Counties, citizens

   Counties (or anyone) may check the published results.
   - o Prior to the audit, selected contests may be compared against the selection criteria and pre-audit results.
   - o Probability calculations (the chance that a contest will be audited in any given precinct) can be checked on a hand calculator, trusted software such as an off-the-shelf spreadsheet, or a published lookup table that will contain approximate minimum values for all probabilities as well as the published SAGE equation.
   - o If the table or equation probabilities are greater than those supplied by the State, an error has occurred and can be corrected prior to the random selection of precincts.

10. **Select precincts to be audited**
    Responsibility: Counties, citizens

    Counties shall select precincts using the following steps
    - o Announce a public meeting to select the precincts at least 5 days in advance.
    - o The selection shall be publicly observable and not involve computers.
    - o Select a four-digit random number from .0000 to .9999 for each precinct that has at least one audited race. Here are two methods that counties could choose from. The second one requires fewer dice rolls which might be easier for large counties.
      - ▪ Roll a ten-sided die four times (or four color coded dice one time) for each precinct
      - ▪ Roll a ten-sided die four times once[11] to determine an initial "seed" random number. Random numbers for each precinct are determined from a published table of random numbers, using the seed to determine the starting page and column.
    - o This requires only one random number per precinct regardless of the number of audited contests.

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[11] Alternatively, a county's precincts could be divided into several groups, each with its own initial seed, to provide additional assurance that the die is not unduly influencing the random sample.

- o For each contest in each precinct, determine if it will be audited by seeing if the calculated SAGE probability (p value) from Step 6 is larger than the random number selected for the precinct.

For example:
- o The four-digit random number is recorded for each precinct as the number is selected (shown in bold/italics in the third column).
- o When the random number is less than or equal to the SAGE p value for a contest, the contest is audited for that precinct. The number of ballots to audit can be written in the appropriate column for the contest.
- o In this case, two of the precincts shown will be audited for the Presidential contest and one for the US House race.

PRECINCT NAME	VOTES CAST	Random Number	PRESIDENT				US SENATE				US HOUSE			
				% of Total Vote	p	Ballots to Audit		% of Total Vote	p	Ballots to Audit		% of Total Vote	p	Ballots to Audit
BRATTON TOWNSHIP BRATTON TOWN!	661	*0.9848*		0.0116%	0.0102			0.0116%	0.0008			0.1957%	0.0088	
BRUSH CREEK TOWNSHIP - CEDAR MI	213	*0.2341*		0.0037%	0.0033			0.0037%	0.0003			0.0630%	0.0028	
BRUSH CREEK TOWNSHIP - LYNX PRE	376	*0.3820*		0.0066%	0.0058			0.0066%	0.0005			0.1113%	0.0050	
FRANKLIN TOWNSHIP - LOCUST GROV	557	*0.0072*		0.0097%	0.0086	557		0.0097%	0.0007			0.1649%	0.0074	557
GREEN TOWNSHIP - GREEN PRECINCT	290	*0.0040*		0.0051%	0.0045	290		0.0051%	0.0004			0.0858%	0.0039	
GREEN TOWNSHIP - ROME VILLAGE	70	*0.9431*		0.0012%	0.0011			0.0012%	0.0001			0.0207%	0.0009	

11. Perform audit

Responsibility: Counties, citizens

Counties shall perform the audit using the following steps:
- o Start the auditing immediately after the precincts are selected.
- o The audit shall be publicly observable including checking voter selections on ballots.
- o Official ballots shall be hand-counted for the selected contests in the selected precincts.

12. **Report results**

    Responsibility: State, Counties

    Counties shall report their results to the State and to the public:
    - Audit (hand-count) results for each precinct and audited contest
    - Comparison of audit results and official results
    - List of problems encountered (e.g., missing paper audit trails, optical scan ballots, security seals)

    State shall aggregate results and report their results to the Counties and to the public
    - Aggregated results for each precinct and audited contest
    - Comparison of audit results and official results
    - List of problems encountered (e.g., missing paper audit trails, optical scan ballots, security seals)

13. **Expand the audit in the event of discrepancies**

    Responsibility State, Counties

    Particular discrepancies may or may not entail that the audit be expanded, depending upon their size and the decisions made at step 3. Because an audit sample may contain a lower miscount rate than the election as a whole, a correctly designed audit procedure will *sometimes* mandate expansion even if the miscount rate in the audit sample appears insufficient to affect the outcome. All miscounts should be reported and all non-trivial miscounts should be investigated whether they affect the outcome or not.

    With careful design and if election systems are functioning reasonably well, audit expansions should be unusual.

Acknowledgments