Federal Election Audit Costs
Based on 2002 and 2004 US House and Senate Races
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Using election results from 2002 and 2004 federal elections,[i] three different election audit proposals were evaluated to see how well each audit would detect vote fraud and how much each would cost. The audits evaluated were a proposal by Congressman Rush Holt in HR811[ii]; and two alternative election audit proposals designed to achieve higher success rates for detecting any incorrect election outcomes.

Calculations show that Holt's election audit proposal costs substantially more than audit proposals which produce higher success rates for detecting vote miscount sufficient to alter federal election outcomes.

Summary

The most effective election audit proposal evaluated is also the least costly. Holt's election audit proposal would have resulted in only a 10% chance (one chance in ten) for successfully detecting the amount of miscount that could have wrongly altered the outcome in one 2002 US House race[iii], yet would have cost approximately 45% more than an audit designed to give a 99% chance (99 in 100) for successfully detecting amounts of miscount that could wrongly alter all US House outcomes.

In 2004, Holt's audit proposal would have resulted in a 42.8% chance (43 in 100) for successfully detecting the amount of miscount that could have altered a US House election outcome[iv], yet would have cost roughly 94% more than an audit designed to give a 99% success rate for detecting outcome-altering vote miscount levels in all US House races.

For three different election audit proposals, the table below shows the number of precincts which would be manually counted nationwide; the lowest success rates for detecting vote fraud sufficient to alter election outcomes; and the approximate nationwide cost, for auditing all federal 2002 and 2004 races.

Comparitive Cost & Effectiveness of Three Proposed Election Audits Based on Actual Prior Federal Election Results						
Proposed Election Audit Choices	2002 House & Senate Elections			2004 House & Senate Elections		
	Total #Precincts	Approximate Cost	Minimum Success	Total #Precincts	Approximate Cost	Minimum Success
HR811 Holt Audit with 10% minimum success	10,851	$11,416,960	10.0%	14,098	$14,534,080	42.8%
Tiered Audit with 74% minimum success	10,923	$11,486,080	75.7%	13,472	$13,933,120	74.1%
Fixed Chance Audit with 99% minimum success	7,146	$7,860,160	99.1%	6,766	$7,495,360	99.1%

It would cost roughly $8 million ($7.86 million in 2002 and $7.5 million in 2004) for each federal election cycle to verify, with approximately 99% confidence, the accuracy and integrity of all US House, US Senate and US Presidential elections via manual audits of voter verified paper ballots (an average approximately $160,000 per state). Caveat: All of the above election audit sample sizes were calculated without adjusting for precinct-size variation, so that the probabilities in practice would be somewhat lower than stated.[v]

The following three election audit proposals were evaluated for cost and effectiveness when applied nation-wide to all federal elections in 2002 and 2004 and compared below with optimal 99% audits.[vi]

1. **Holt Tiered Audit which was not calculated to achieve any particular success rate**

Margins	Audit %
0% to .999%	10.0%
1% to 1.999%	5.0%
2% +	3.0%

The table at left gives the audit percentages given by Congressman Rush Holt's HR811 election audit proposal for races with particular margins between the winning candidates. The chart below compares an optimal 99% election audit with the Holt audit.

Notice that, in the chart below, the Holt audit amounts (in pink) fall well below the 99% success optimal audit amounts (orange curve) when margins between candidates are closer. The Holt audit amounts are larger than the optimal audit amount when margins between candidates are larger (at the right side of chart).

The Holt audit amounts are burdensome for auditors because Holt's audit requires a 3% audit at larger margins between candidates, even when a smaller audit would do.
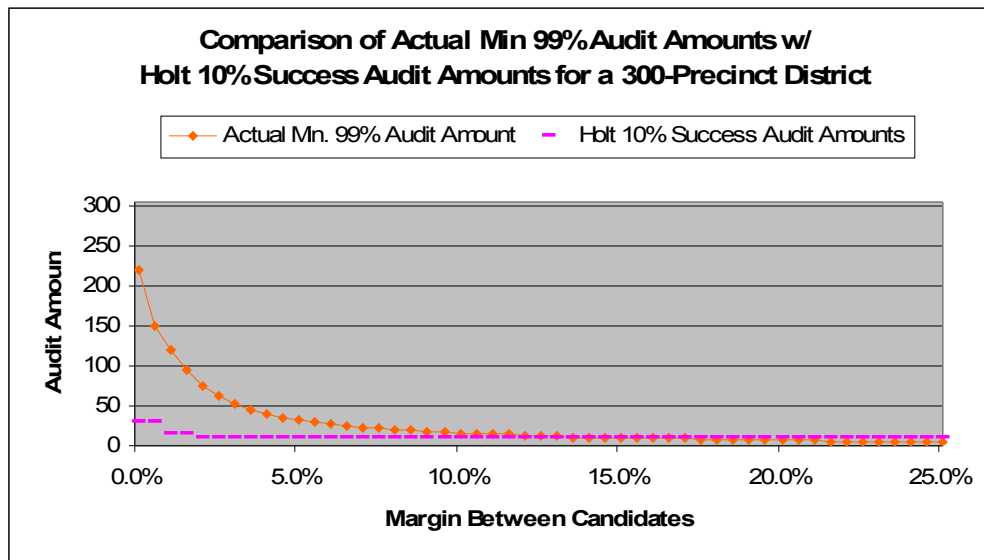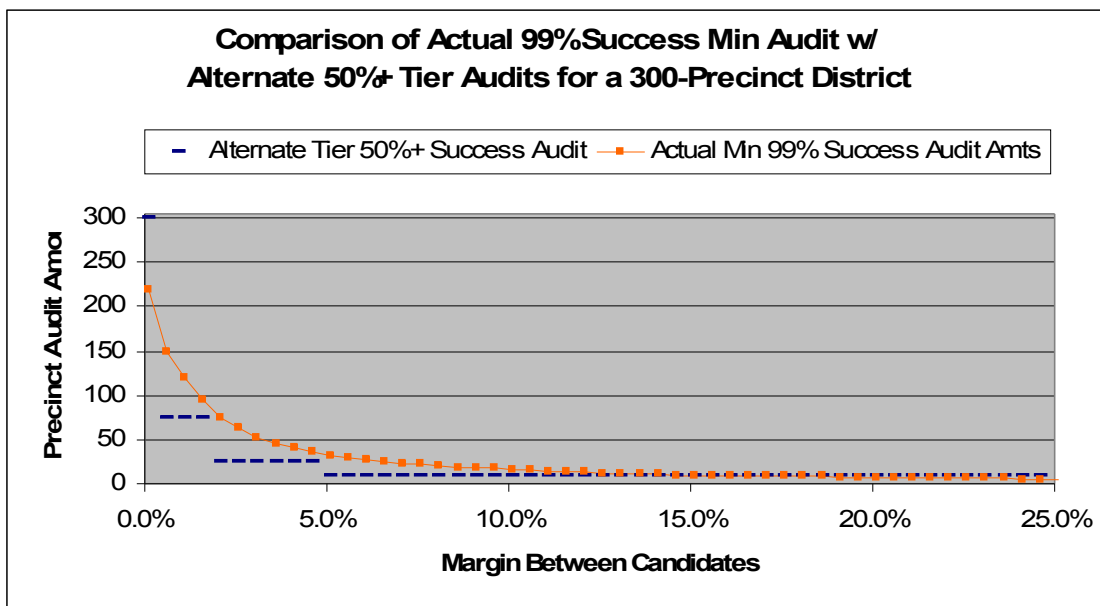
2. A Tiered Audit Calculated to Maintain Over a 50% Probability of Success

Margins Between Candidates	Precinct Audit %	Minimum Audit Amount
0% to 0.49...%	100%	na
0.5% to 1.99...%	20%	75
2% to 4.99...%	5%	25
5%+	2%	10

Notice that this tiered audit (in the table at left and shown in blue dashes in the chart below), although it costs roughly the same to implement nationwide as the Holt audit, audits amounts that conform closer to the optimal minimum audit amounts (orange curve in the chart below) needed to obtain a 99% success rate for the election audits.

This tiered audit was designed to achieve no lower than 50% plus success rates and when applied to nationwide election data from all 2002 and 2004 federal elections, results in a minimum probability for success of 74.1% as opposed to the minimum success for Holt's audit of 10%. Thus this audit burdens auditors and election administrators as much as Holt's audit but achieves much greater

Comparison of Actual 99% Success Min Audit w/ Alternate 50%+ Tier Audits for a 300-Precinct District

confidence for successfully detecting any vote miscount that could alter an election outcome. This is because, relative to Holt's audit, this tiered audit does not audit as much when margins between candidates are larger, and audits more when margins between candidates are smaller.
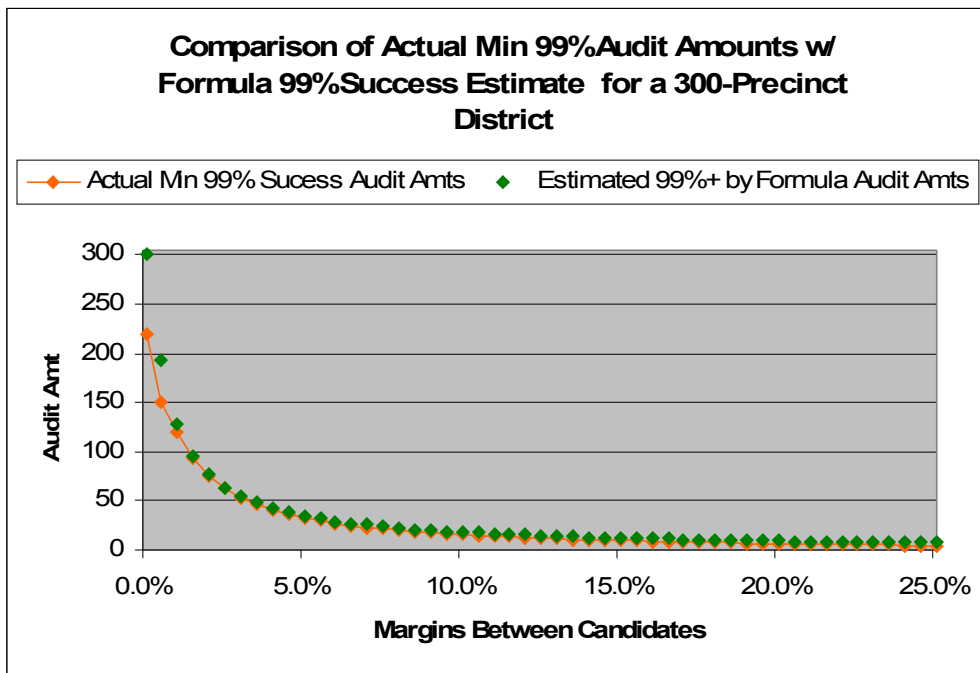
3. Audit Amounts with 99% Success Using a Formula Derived by Kathy Dopp and Ron Rivest[vii]

This formula for audit sample size, S was derived by Ronald Rivest, where the formula for the number of corrupt vote counts, C that could alter an election outcome was derived by Kathy Dopp where N is total number of precincts or vote counts in an election district; m is the margin between the two leading candidates; P is the probability for success of the audit for detecting at least one or more corrupt counts if C precinct counts are corrupt; and v is the assumed maximum wrongful shift per precinct vote count that would not be immediately suspicious[viii]

$$S = N(1 - e^{\frac{\ln(1-P)}{C}})$$

$$C = N\frac{m}{2v}$$

As seen in the chart below, using this formula for estimating optimal audit amounts, more closely approximates the actual optimal audit amount, and always over-estimates the optimal audit amount. The formulaic estimate overestimates the audit amount especially when margins between candidates are very small.

Comparison of Actual Min 99%Audit Amounts w/ Formula 99%Success Estimate for a 300-Precinct District

Legend: Actual Mn 99% Sucess Audit Amts — Estimated 99%+ by Formula Audit Amts

Y-axis: Audit Amt. X-axis: Margins Between Candidates

Notice that this audit, which can be easily calculated for many races at once using a spreadsheet, conforms closely to the optimal audit amounts, requires a minimum audit rate of only 1% and thus over audits less than a tiered election audit designed for a 99% success rate would.

Caveat: The actual probabilities for success of any audit for detecting vote miscount that could alter an outcome would be lower if vote fraud were targeted to the fewest number of the largest-size precincts, as a smart fraudster would do to increase the chances of avoiding detection in a manual audit. Anyone wanting to strictly maintain a minimum probability for success, must exactly calculate the amount of corrupt precinct vote counts, C, needed to wrongly alter an election outcome using the number of ballots (or if not available votes) cast for a particular race, in every precinct, as described in "The Election Integrity Audit".[ix]

If the exact amount of miscounted precincts to detect is not exactly calculated, then when a precinct or batch vote count is very large relative to the median sized vote count in a county, then such large-size precincts, if they are not selected randomly for auditing, should be manually audited in addition to the random sample. Alternatively, "suspicious" precincts could be calculated, or candidates could be allowed to select a few "discretionary" precinct (or batch) vote counts, for auditing in addition to randomly selected precincts.

For 2002 federal elections, the chart to the right gives the number of total precincts nation-wide that must be audited for each of the three election audit proposals I evaluated. You can see that the audit with the highest probability of success audits the least amount of total precincts, because the two tiered election audits over-audit many federal races and under-audit others. All Senate races are sufficiently audited by all three proposed audits because of the large number of precincts in state-wide US Senate races.

Number of Precincts Which Must be Audited Under Each Proposal for Federal Election Audits
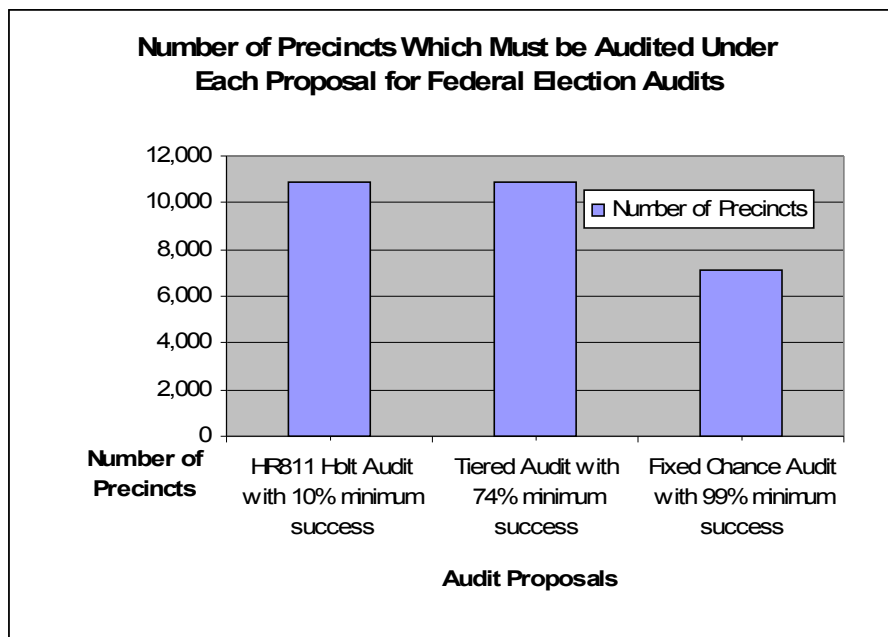
The Method Used for Estimating Nationwide Election Audit Costs

Cost estimates for manually auditing federal elections were calculated using:

➤ the election results data for all 2002 and 2004 US House and Senate elections including the margins between the two leading candidates for all US House and Senate races[x], and

➤ an estimate for the number of precincts in each US House district obtained by using the U.S. census numbers for the total number of voting age population in each US House district in each county as a proportion of the total voting age population in each county and multiplying that proportion times the total number of precincts in each county, and

➤ an estimated fixed cost of $20,000 per state, plus an average $10/hour wage for a team of four persons (one reader and one observer, each representing different parties and two recorders, each representing different parties), counting an average of 15 ballots/hour with an average of 350 ballots/precinct = 24 hours for an average total cost of $960 for manually auditing one precinct[xi], and

➤ audit sample sizes calculated based on margins between candidates, as described above, assuming a 20% maximum wrongful vote shift per precinct vote count for the calculated 99% success audit.[xii]

Conclusion

Legislation requiring mandatory independent manual audits of election outcomes would be less administratively burdensome and more effective than current proposals by simply requiring that:

a) at least 1% (one per centum) of each county's precinct or batch vote counts are audited; and

b) a sufficient number of vote counts shall be audited to give at least a 99% probability for detecting at least one corrupt vote count if the amount of corrupt vote counts were sufficient to alter the election outcome of any election contest, taking into account the margin between the candidates; and

c) at least one vote count is audited in each election contest submitted to the voters within each county's jurisdiction; and

d) in addition to randomly selected precincts in a), b), and c) above, a small number of discretionary precinct vote counts selected by candidates, or alternatively, precinct vote counts which calculations show are "suspicious"[xiii] should be manually audited.

This doc is found at: http://electionarchive.org/ucvAnalysis/US/paper-audits/FederalAuditCosts.pdf

Appendix A: Sample Election Data Used to Calculate Audit Costs and Success Probabilities

stabb	year	officename	estpreci	totalvotes	topcand_r	topcan	topcand_v	%_TopCa	seccand_r	seccan	seccand_v	%_2ndCar	margin
AL	2002	U.S. Congres	296	178,687	BONNER,	REP	108,102	60.50%	BELK, JUC	DEM	67,507	37.78%	40,595
AL	2002	U.S. Congres	394	195,171	CRAMER,	DEM	143,029	73.28%	ENGEL, S	REP	48,226	24.71%	94,803
AL	2002	U.S. Congres	245	198,346	BACHUS,	REP	178,171	89.83%	MCALLIST	LBR	19,639	9.90%	158,532
AL	2002	U.S. Congres	439	166,309	DAVIS, AF	DEM	153,735	92.44%	MCCAY, L	LBR	12,100	7.28%	141,635
AL	2002	U.S. Congres	524	161,101	ADERHOL	REP	139,705	86.72%	MCLENDC	LBR	20,858	12.95%	118,847
AL	2002	AL U.S. Sena	2,826	1,353,023	SESSIONS	REP	792,561	58.58%	PARKER,	DEM	538,878	39.83%	253,683
AL	2002	U.S. Congres	394	181,223	ROGERS,	REP	91,169	50.31%	TURNHAM	DEM	87,351	48.20%	3,818
AL	2002	U.S. Congres	531	187,965	EVERETT	REP	129,233	68.75%	WOODS, C	DEM	55,495	29.52%	73,738
AR	2002	U.S. Congres	1,003	197,537	ROSS, MII	DEM	119,633	60.56%	DICKEY, J	REP	77,904	39.44%	41,729
AR	2002	U.S. Congres	510	153,626	SNYDER,	DEM	142,752	92.92%	GARNER (	UNK	10,874	7.08%	131,878
AR	2002	AR U.S. Sena	3,352	803,959	PRYOR, M	DEM	434,890	54.09%	HUTCHINS	REP	369,069	45.91%	65,821
AR	2002	U.S. Congres	659	143,055	BOOZMAN	REP	141,478	98.90%	LYNE (WI)	UNK	1,577	1.10%	139,901
AR	2002	U.S. Congres	1,180	194,058	BERRY, R	DEM	129,701	66.84%	ROBINSOI	REP	64,357	33.16%	65,344
AZ	2002	U.S. Congres	218	66,065	PASTOR,	DEM	44,517	67.38%	BARNERT	REP	18,381	27.82%	26,136
AZ	2002	U.S. Congres	263	167,502	FRANKS,	REP	100,359	59.92%	CAMACHC	DEM	61,217	36.55%	39,142
AZ	2002	U.S. Congres	252	169,812	HAYWOR	REP	103,870	61.17%	COLUMBU	DEM	61,559	36.25%	42,311
AZ	2002	U.S. Congres	418	174,687	RENZI, RI	REP	85,967	49.21%	CORDOVA	DEM	79,730	45.64%	6,237
AZ	2002	U.S. Congres	234	156,337	THOMAS,	DEM	103,094	65.94%	FLAKE, JE	REP	49,355	31.57%	53,739
AZ	2002	U.S. Congres	258	103,818	GRIJALVA	DEM	61,256	59.00%	HIEB, ROS	REP	38,474	37.06%	22,782
AZ	2002	U.S. Congres	244	155,751	SHADEGC	REP	104,847	67.32%	HILL, CHA	DEM	47,173	30.29%	57,674
AZ	2002	U.S. Congres	324	200,428	KOLBE, J/	REP	126,930	63.33%	RYAN, MA	DEM	67,328	33.59%	59,602
CA	2002	U.S. Congres	515	136,642	ROYCE, E	REP	92,422	67.64%	AVALOS, (	DEM	40,265	29.47%	52,157
CA	2002	U.S. Congres	604	194,918	OSE, DOU	REP	121,732	62.45%	BEEMAN,	DEM	67,136	34.44%	54,596
CA	2002	U.S. Congres	770	88,027	NAPOLIT/	DEM	62,600	71.11%	BURROLA	REP	23,126	26.27%	39,474
CA	2002	U.S. Congres	471	70,178	SANCHEZ	DEM	42,501	60.56%	CHAVEZ,	REP	24,346	34.69%	18,155
CA	2002	U.S. Congres	678	124,336	MCKEON,	REP	80,775	64.97%	CONAWAY	DEM	38,674	31.10%	42,101
CA	2002	U.S. Congres	649	164,285	THOMAS,	REP	120,473	73.33%	CORVERA	DEM	38,988	23.73%	81,485
CA	2002	U.S. Congres	920	122,497	ISSA, DAF	REP	94,594	77.22%	DIETRICH	LBR	26,891	21.95%	67,703
CA	2002	U.S. Congres	547	149,296	FARR, SAI	DEM	101,632	68.07%	ENGLER, (	REP	40,334	27.02%	61,298
CA	2002	U.S. Congres	786	209,563	WOOLSEY	DEM	139,750	66.69%	ERICKSON	REP	62,052	29.61%	77,698
CA	2002	U.S. Congres	761	95,346	SANCHEZ	DEM	52,256	54.81%	ESCOBAR	REP	38,925	40.82%	13,331
CA	2002	U.S. Congres	779	85,079	SOLIS, HII	DEM	58,530	68.79%	FISCHBEC	REP	23,366	27.46%	35,164
CA	2002	U.S. Congres	561	131,578	MATSUI, F	DEM	92,726	70.47%	FRANKHU	REP	34,749	26.41%	57,977
CA	2002	U.S. Congres	1,024	102,787	FILNER, B	DEM	59,541	57.93%	GARCIA, N	REP	40,430	39.33%	19,111
CA	2002	U.S. Congres	715	160,441	PELOSI, N	DEM	127,684	79.58%	GERMAN,	REP	20,063	12.50%	107,621
CA	2002	U.S. Congres	937	185,593	WAXMAN,	DEM	130,604	70.37%	GOSS, TO	REP	54,989	29.63%	75,615
CA	2002	U.S. Congres	541	179,549	COX, CHR	REP	122,884	68.44%	GRAHAM,	DEM	51,058	28.44%	71,826
CA	2002	U.S. Congres	683	167,197	TAUSCHE	DEM	126,390	75.59%	HARDEN,	LBR	40,807	24.41%	85,583
CA	2002	U.S. Congres	685	138,376	MILLER, G	DEM	97,849	70.71%	HARGRAV	REP	36,584	26.44%	61,265
CA	2002	U.S. Congres	666	133,022	HONDA, N	DEM	87,482	65.77%	HERMANN	REP	41,251	31.01%	46,231
CA	2002	U.S. Congres	806	103,326	BERMAN,	DEM	73,771	71.40%	HERNAND	REP	23,926	23.16%	49,845
CA	2002	U.S. Congres	420	135,533	LEWIS, JE	REP	91,326	67.38%	JOHNSON	DEM	40,155	29.63%	51,171
CA	2002	U.S. Congres	707	178,985	HERGER,	REP	117,747	65.79%	JOHNSON	DEM	52,455	29.31%	65,292
CA	2002	U.S. Congres	867	143,751	HARMAN,	DEM	88,198	61.35%	JOHNSON	REP	50,328	35.01%	37,870

[i] The data was obtained on Thursday, March 15, 2007 from Election Data Services. 2006 data is not available yet, pointing out the need to require better standards for election data reporting practices.

[ii] The exact same audit proposal is sponsored by Senator by Bill Nelson in S559, and by Senator Hillary Clinton in S804 and also in a recent proposal by Congresswoman Tubb-Jones.

[iii] There were four races in 2002 that had less than a 50% chance that Holt's audit would be able to detect an amount of miscount that could wrongly alter their outcomes. I.e. the following US House races: ROGERS, MIKE vs. TURNHAM, JOE; BEAUPREZ, BOB vs. FEELEY, MIKE; MARSHALL, JIM versus CLAY, CALDER; and JOHNSON, TIM versus THUNE, JOHN.

[iv] In 2004 the Holt audit would have had less than a 50% chance to detect outcome-altering miscount in the SHAYS, CHRISTOPHER versus FARRELL, DIANE race.

[v] None of the audits discussed here are designed to compensate for precinct-size variation, which means they are, in practice somewhat less than effective than stated because vote miscount could be hidden in fewer of the largest-sized precincts. Ronald Rivest of MIT is currently working on a random sampling procedure that would help overcome this deficiency, or precinct-sizes can be used to directly calculate a minimum audit sample size. The data used in this cost analysis did not include precinct-level data.

[vi] Optimal minimum audit amounts are calculated to achieve any desired probability, in this case 99%, for successfully detecting sufficient miscount to alter election outcomes, via a numerical program as shown in "The Election Integrity Audit" by Dopp and Stenger, September, 2006, or by or trial and error.

[vii] The following academic papers describe the derivation of the mathematics developed to date on election audits:
Wand, 2004, "Auditing an Election Using Sampling: The Impact of Bin Size on the Probability of Detecting Manipulation", http://wand.stanford.edu/elections/probability.pdf
Dopp and Baiman, 2005, "How Can Independent Paper Audits Ensure Election Integrity"
http://electionarchive.org/ucvAnalysis/US/paper-audits/Paper_Audits.pdf
Dopp and Straight, 2006, "Proposal for Utah Election Audit"
http://electionarchive.org/ucvAnalysis/US/paper-audits/VoteCountAudit-UT.pdf
Dopp and Stenger, 2006, "The Election Integrity Audit"
http://electionarchive.org/ucvAnalysis/US/paper-audits/ElectionIntegrityAudit.pdf
Rivest, 2006, "How Big Should a Statistical Audit Be?"
 http://theory.csail.mit.edu/%7Erivest/Rivest-OnEstimatingTheSizeOfAStatisticalAudit.pdf
Dopp, 2007, "How Big Should an Election Audit Be?"
http://electionarchive.org/ucvAnalysis/US/paper-audits/ElectionAuditEstimator.pdf
Dopp, 2007, "Fool Me Once: Checking Vote Count Integrity"
http://electionarchive.org/ucvAnalysis/US/paper-audits/TierElectionAuditEval.pdf

[viii] 100% of votes in each precinct count are not available to switch from the target candidate. To be logically complete, an audit should also include calculated or discretionary precincts in addition to the randomly sampled ones, to ensure that "suspicious" precinct counts are also included in any manual audit. Note that a 20% wrongful vote shift would result in a 40% wrongful margin shift between the candidates.

[ix] Ibid footnote x. Dopp and Stenger

[x] The data, obtained from Election Data Services, is publicly available here:
http://electionarchive.org/ucvAnalysis/US/paper-audits/dopp_b.csv

[xi] Of course more than one four-person team could be used per precinct to reduce the manual audit to fewer than 4 days. It is likely that more than 15 ballots per hour could be counted by one audit team. In Utah, counting all the ballots on one DRE voter verified paper audit trail took about one hour, so a 15 ballot/hour (4 minutes/ballot) estimate may be conservative.

[xii] My 20% vote shift assumption and probability calculations agree exactly with the assumptions by the academic group whose partial analysis supported the Holt audit. A 20% wrongful vote shift takes 20% from one candidate and gives it to another, resulting in a 40% wrongful margin shift between candidates. Calculated or discretionary precincts should also be included in any election audit for logical consistency.

[xiii] Using the assumed maximum vote shift that is used to calculate the number of precinct vote counts to randomly select for audit, and the voter history file required by the NVRA, if the voter history file could be updated prior to the audit, it would be possible to calculate precinct vote counts that looked "suspicious" in relation to the partisanship of actual voters in the election being audited. This is necessary for logical completeness of the calculation for optimal audit amounts. If "suspicious" precinct vote counts are not calculated, then candidates should be allowed to select a few precinct vote counts for audit, in addition to the randomly selected precincts.