

Risk-Limiting Audits

Philip B. Stark

Department of Statistics
University of California, Berkeley

16 June 2011
Colorado Secretary of State
Risk-Limiting Audit Kick-off Meeting
Denver, CO

Things to keep in mind

The difference between theory and practice is smaller in theory than it is in practice. (Various)

The purpose of elections is to convince the losers that they lost. (D. Wallach)

The [main] purpose of election audits is to convince everybody that the losers lost. (PBS)

What should audits do?

Pro forma audits

Most audit laws have no clear goal: “count and stop,” or “count and report/explain discrepancies.”

Compliance vs. materiality audits

Compliance: Were proper procedures followed? (e.g., secure chain of custody?)

Materiality: Did any errors that occurred despite compliance matter?

Effective materiality audit

Correct the outcome if it is wrong.

Can require counting the entire audit trail by hand.

Big Idea

Risk-limiting Audit

Large, known chance of a full hand count if the outcome is wrong, thereby correcting the outcome.

Risk is maximum chance of failing to correct an apparent outcome that is wrong, no matter what caused the outcome to be wrong.

Risk-Limiting Audits in California

Marin County (February 2008; November 2008, 2009)

Orange County (March 2011)

Yolo County (November 2008, 2009)

Santa Cruz County (November 2008)

Monterey County (May 2011)

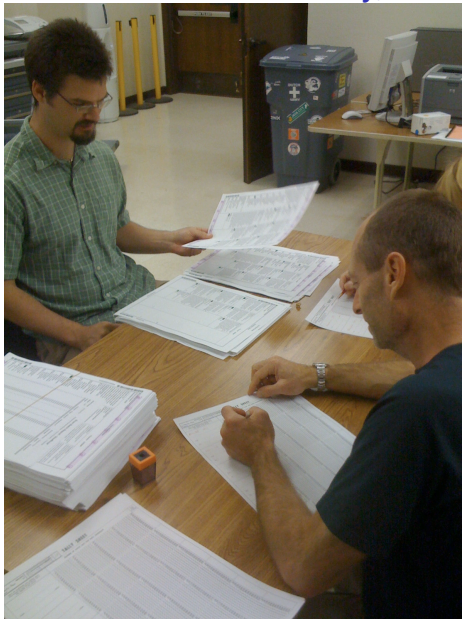
Measures requiring super-majority, simple measures, multi-candidate contests, vote-for- n contests.

Contest sizes ranged from about 200 ballots to 121,000 ballots.

Counting burden ranged from 32 ballots to 7,000 ballots.

Cost per audited ballot ranged from nil to about \$0.55.

2008 Yolo County, CA Measure W Audit





23 TALLY SHEET

NUMBER OF VOTES CAST FOR EACH CANDIDATE

Miss W Yes
Miss W No
W Yes/No Yes
W Yes/No No
Yes
No

	1	2	3	4	5	6	7	8	9	0
1	1	2	3	4	5	6	7	8	9	0
10	10	20	30	40	50	60	70	80	90	00
100	100	200	300	400	500	600	700	800	900	000
1000	1000	2000	3000	4000	5000	6000	7000	8000	9000	0000

SIGN CERTIFICATE ON FRONT COVER

23 TALLY SHEET

NUMBER OF VOTES CAST FOR EACH CANDIDATE

Miss W Yes
Miss W No
W Yes/No Yes
W Yes/No No
Yes
No

	1	2	3	4	5	6	7	8	9	0
1	1	2	3	4	5	6	7	8	9	0
10	10	20	30	40	50	60	70	80	90	00
100	100	200	300	400	500	600	700	800	900	000
1000	1000	2000	3000	4000	5000	6000	7000	8000	9000	0000

SIGN CERTIFICATE ON FRONT COVER

483

153

10060

483

153

10000650200062

Presidential General Election
YOLO COUNTY
November 04, 2008

Vote Both Sides

Vote Both Sides

Precinct 100063

Proposition 8
ELIMINATES RIGHT OF SAME-SEX
COUPLES TO MARRY. INITIATIVE
CONSTITUTIONAL AMENDMENT

Changes California Constitution to eliminate the right of same-sex couples to marry. Provides that only marriage between a man and a woman is valid or recognized in California.

Yes
 No

Proposition 9
CRIMINAL JUSTICE SYSTEM. VICTIMS'
RIGHTS. PAROLE INITIATIVE
CONSTITUTIONAL AMENDMENT AND
STATUTE

Requires notification to victim and opportunity for input during phase of criminal justice process, including bail, plea, sentencing and parole. Establishes victim safety as consideration for bail or parole.

Fiscal Impact: Potential cost of state savings on prison operations and increased county jail costs amounting to hundreds of millions of dollars annually. Potential net savings on the low tens of millions of dollars annually on parole programs.

Yes
 No

Proposition 10
ALTERNATIVE FUEL VEHICLES AND
RENEWABLE ENERGY BONDS.
INITIATIVE STATUTE

Authorizes \$5 billion in bonds paid from state's General Fund to help consumers and others purchase certain vehicles, and to fund research in renewable energy and alternative fuel vehicles.

Fiscal Impact: State cost of about \$10 billion over 20 years to repay bonds. Increased state and local revenues, potentially totaling several tens of millions of dollars through 2019. Potential state administrative costs up to about \$10 million annually.

Bonds Yes
 Bonds No

Proposition 11
REDISTRIBUTING INITIATIVE
CONSTITUTIONAL AMENDMENT AND
STATUTE

Change authority for establishing state office boundaries from elected representatives to commission. Establishes multistep process to select commissioners from registered voter pool. Commission comprised of Democrats, Republicans, and representatives of neither party.

Fiscal Impact: Potential increase in state redistributing costs only every ten years due to two entities performing redistributing. Any increase in costs probably would not be significant.

Yes
 No

Proposition 12
VETERANS' BONDS ACT OF 2008

The act provides for a bond issue of nine hundred million dollars (\$900,000,000) to provide term and home aid for California veterans.

Fiscal Impact: Costs of about \$1.8 billion to pay off both the principal (\$900 million) and interest (\$900 million) on the bonds, costs paid by participating veterans. Average payment for principal and interest of about \$39 million per year for 30 years.

Bonds Yes
 Bonds No

**Los Rios Community College District
Measure M**

Shall the Los Rios Community College District be authorized to issue \$475 million in bonds at the lowest available interest rate to improve student academic performance by building classrooms, facilities and labs throughout the district including for teaching green technologies, nursing and health care programs, architecture, engineering and production management, and for an early childhood development and day care center under existing program, and for an art center.

Shall the Los Rios Community College District be authorized to issue \$475 million in bonds at the lowest available interest rate to improve student academic performance by building classrooms, facilities and labs throughout the district including for teaching green technologies, nursing and health care programs, architecture, engineering and production management, and for an early childhood development and day care center under existing program, and for an art center.

Bonds Yes
 Bonds No

**Davis Joint Unified School District
Measure W**

Shall the Davis Joint Unified School District preserve existing education programs? **Yes** including math and science, English, music, physical education, libraries, secondary class size reduction, selected and coordinated programs including drama, debate, and journalism by being authorized to levy a special tax for a period of three years not to exceed the annual rate of \$50.00 per dwelling unit for multi-dwelling parcels and \$100.00 per parcel for all other parcels?

Yes
 No

Vote Both Sides

1003031148

10000650200062

Presidential General Election
YOLO COUNTY
November 04, 2008

Proposition 8
ELIMINATES RIGHT OF SAME-SEX
COUPLES TO MARRY. INITIATIVE
CONSTITUTIONAL AMENDMENT

Changes California Constitution to eliminate the right of same-sex couples to marry. Provides that only marriage between a man and a woman is valid or recognized in California.

Fiscal Impact: Over next few years, potential revenue loss, mainly sales taxes, totaling in the several tens of millions of dollars, to state and local governments. In the long run, likely little fiscal impact on state and local governments.

Yes
 No

Proposition 9
CRIMINAL JUSTICE SYSTEM. VICTIMS'
RIGHTS. PAROLE INITIATIVE
CONSTITUTIONAL AMENDMENT AND
STATUTE

Requires notification to victim and opportunity for input during phase of criminal justice process, including bail, plea, sentencing and parole. Establishes victim safety as consideration for bail or parole.

Fiscal Impact: Potential loss of state savings on prison operations and increased county jail costs amounting to hundreds of millions of dollars annually. Potential net savings in the low tens of millions of dollars annually on parole programs.

Yes
 No

Proposition 10
ALTERNATIVE FUEL VEHICLES AND
RENEWABLE ENERGY BONDS.
INITIATIVE STATUTE

Authorizes \$5 billion in bonds paid from state's General Fund to help consumers and others purchase certain vehicles, and to fund research in renewable energy and alternative fuel vehicles.

Fiscal Impact: State cost of about \$10 billion over 20 years to repay bonds. Increased state and local revenues, potentially totaling several tens of millions of dollars through 2019. Potential state administrative costs up to about \$10 million annually.

Bonds Yes
 Bonds No

Proposition 11
REDISTRIBUTING INITIATIVE
CONSTITUTIONAL AMENDMENT AND
STATUTE

Changes authority for establishing state office boundaries from elected representatives to commission. Establishes multistep process to select commissioners from registered voter pool. Commission comprised of Democrats, Republicans, and representatives of neither party.

Fiscal Impact: Potential increase in state redistributing costs once every 10 years due to two entities performing redistributing. Any increase in costs probably would not be significant.

Yes
 No

Proposition 12
VETERANS' BONDS ACT OF 2008

This act provides for a bond issue of nine hundred million dollars (\$900,000,000) to provide term and home aid for California veterans.

Fiscal Impact: Costs of about \$1.8 billion to pay off both the principal (\$900 million) and interest (\$900 million) on the bonds, costs paid by participating veterans. Average payment for principal and interest of about \$39 million per year for 30 years.

Bonds Yes
 Bonds No

**Los Rios Community College District
Measure M**

Shall the Los Rios Community College District be authorized to issue \$475 million in bonds at the lowest available interest rates to improve student academic performance by building classrooms, facilities and labs throughout the district including for teaching green technologies, nursing and health care programs, architecture, engineering and production management, computer sciences, early childhood development, and day and night public safety programs at the American River, Cosumnes River, El Dorado, Folsom, and Sacramento City College campuses?

Shall the Los Rios Community College District be authorized to issue \$475 million in bonds at the lowest available interest rates to improve student academic performance by building classrooms, facilities and labs throughout the district including for teaching green technologies, nursing and health care programs, architecture, engineering and production management, computer sciences, early childhood development, and day and night public safety programs at the American River, Cosumnes River, El Dorado, Folsom, and Sacramento City College campuses?

Bonds Yes
 Bonds No

**City of Davis
Measure N**

Shall the Proposed Charter of the City of Davis be Adopted?

Yes
 No

**Davis Joint
Measure V**

Shall the Davis Joint Unified School District preserve existing education programs including math and science, English, music, physical education, libraries, secondary class size reduction, selected and coordinated programs including drama, debate, and journalism by being authorized to levy a special tax for a period of three years not to exceed the annual rate of \$50.00 per dwelling unit for multi-dwelling parcels and \$100.00 per parcel for all other parcels?

Shall the Davis Joint Unified School District preserve existing education programs including math and science, English, music, physical education, libraries, secondary class size reduction, selected and coordinated programs including drama, debate, and journalism by being authorized to levy a special tax for a period of three years not to exceed the annual rate of \$50.00 per dwelling unit for multi-dwelling parcels and \$100.00 per parcel for all other parcels?

Yes
 No

Vote Both Sides

Vote Both Sides

Precinct 100063

Da Joint Unified School District

Measure W

Shall the Davis Joint Unified School District
 preserve existing classroom programs
 including math and science, English, music,
 physical education, librarians, secondary class
 size reduction, athletics and co-curricular
 programs including drama, debate, and
 journalism by being authorized to levy a
 special tax for a period of three years not to
 exceed the annual rate of \$50.00 per dwelling
 unit on multi-dwelling parcels and \$120.00 per
 parcel for all other parcels?

Yes

No

Bonds Yes

Bonds No

City of Davis

Measure N

Shall the Proposed Charter of the City
 of Davis Be Adopted?

Yes

No

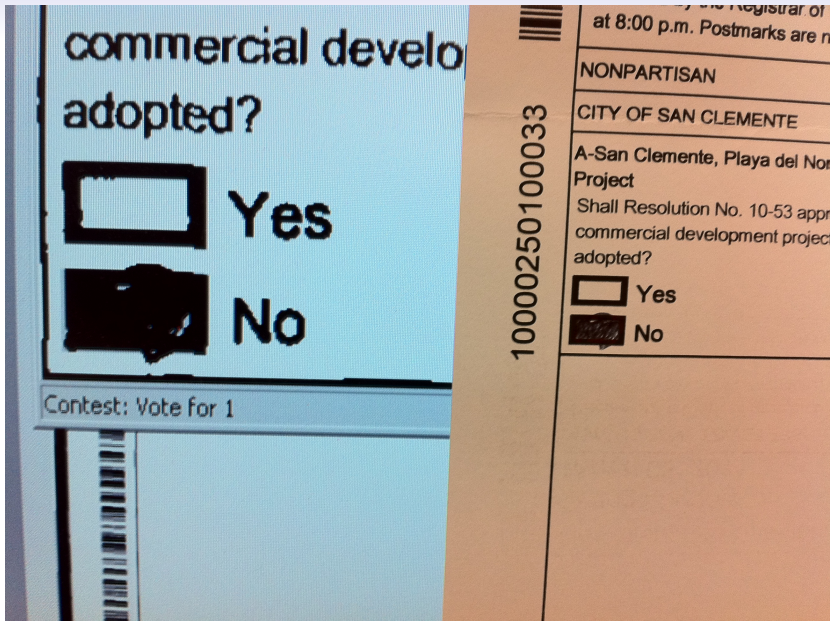
2011 Orange County, first audit under AB 2023

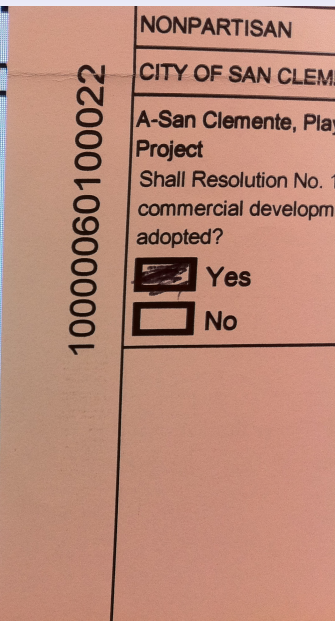
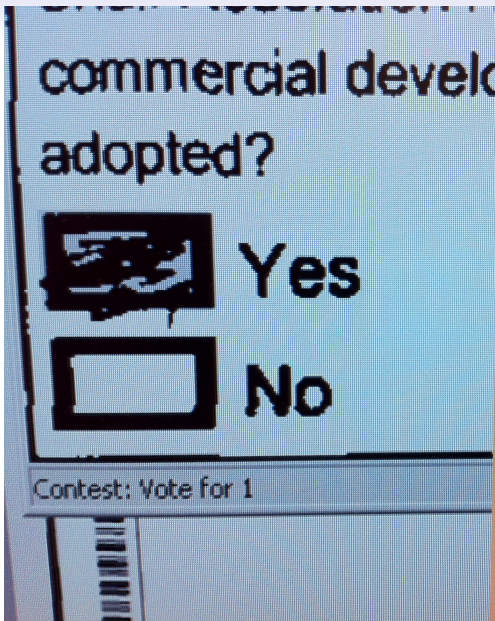


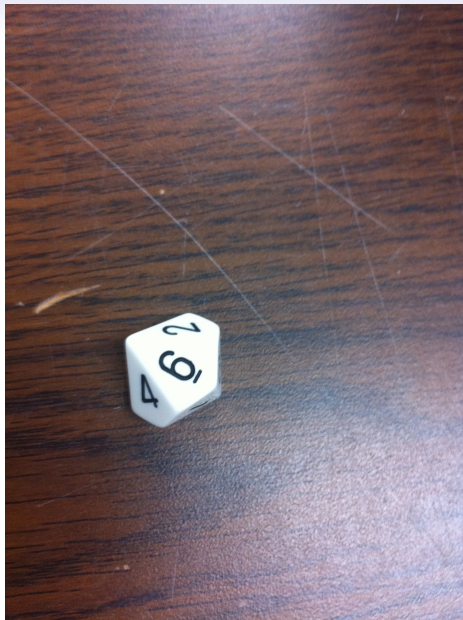












OFFICIAL BALLOT / BOLETA OFICIAL

SPECIAL ALL MAIL ELECTION
ELECCIÓN ESPECIAL POR CORRESPONDENCIA
COUNTY OF MONTEREY / CONDADO DE MONTEREY
TUESDAY, MAY 3, 2011 / MARTES, 3 DE MAYO DE 2011

INSTRUCTIONS TO VOTERS:
 To VOTE, connect the arrow pointing to your choice. Use blue
 & SINGLE LINE IS SUFFICIENT. Use blue or black ink. Do not use felt tip pens.
 To vote for a qualified voter in candidate, write the person's name on the blank space provided and
 CONNECT THE ARROW.

INSTRUCCIONES A LOS VOTANTES:
 Para VOTAR, complete la flecha a su derecha de su deseo, como está.
 LINE SÓLO LA LÍNEA ES SUFICIENTE. Use tinta azul o negra. No use marcadores con punta de
 feltro. Para votar por un candidato calificado por escrito, escriba el nombre de la persona en el
 espacio provisto y CONECTE LA FLECHA.

01332

NONPARTISAN	
NO PARTIDISTA	
DISTRICT / DISTRITO	
MONTEREY PENINSULA	
WATER MANAGEMENT DISTRICT	
DISTRITO DE ADMINISTRACIÓN	
DE AGUAS DE LA PENINSULA DE	
MONTEREY	
Director, Division 1 / Director, División 1	
Vote for One / Votar por Uno	
BRENDA LEWIS Community Volunteer Voluntaria Comunitaria	←←←←
THOMAS M. MANCINI Retired Teacher Maestro Jubilado	←←←←

CA27-14066

4066 - 1



Batch size matters

100 bags of 100 jelly beans, various flavors.

What fraction are coconut?

Compare pulling a bag at random to stirring all the beans together in a big pot and sampling 100 beans.

Vote-tabulation errors are like coconut jelly beans.

Less information in checking bags of beans—or batches of ballots—than in checking the same number drawn individually from the “pot.”

Yolo County Measure P, November 2009: For 10% risk limit, initial sample 6 batches, 1,437 ballots (11.33%).

Could have gotten 10% risk limit by checking 6 individual ballots (less than 0.05%).

Orange County Statutory Audit

Votes in one precinct counted by hand. No errors found.

Chance the 1% audit would find no errors even if the outcome is wrong could be over 88%.

The error rate in the sample says little about the error rate in the whole contest because the batch is large:
One bag might have no coconut jelly beans, even though the rest have many.

Orange County Audits: Costs

Statutory Audit: \$257.68

Scales as the size of the contest: a contest twice as large would cost about twice as much to audit.

AB 2023 risk-limiting audit (10% risk): \$483.79 (not including my time or airfare)

Would have cost essentially the same for any contest with the same percentage margin, no matter how large the contest.

Only have to taste a teaspoon of soup to tell if the soup is too salty, no matter how big the pot—if it's stirred well.

Advantages of ballot-level RLA

Like sampling jelly beans from a big pot, instead of sampling bags of jelly beans.

- cheap (if technology supports it—working with vendors)
- fast and observable
- easy computations
- easy to explain

Tested in Yolo, Orange, and Monterey Counties.

Expect to audit two contests simultaneously in San Luis Obispo in September 2011.

Hope to have ballot-level audits in at least 15 California jurisdictions in 2012.

Secret sauce: have to associate individual CVRs with ballots.

Strategies for Colorado

- Need to understand systems at the county level: systems, procedures, logistical constraints.
- Parallel system versus modifications to existing systems.
- Parallel probably easier, closer to one-size-fits-all. Pros and cons.

Big-picture questions

- Need audit trail: paperless DREs are a problem.
- Need to curate audit trail.
- Need to check the integrity of the audit trail before the audit starts (“compliance audit”)
- Need to “commit” to results before the audit starts.
- Need rules for public observation, etc.
- Need simple, usable rules for determining initial sample size, selecting batches or ballots at random, and stopping the audit.
- Need to figure out how to coordinate audits of multi-jurisdictional contests.