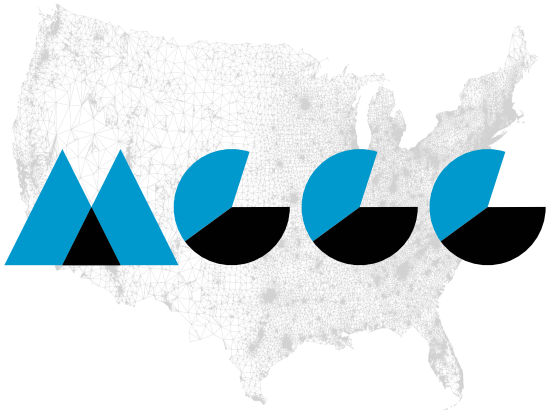
Findings on the City of Lowell's Election Systems



Metric Geometry and Gerrymandering Group

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Contributors

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1 Introduction

1.1 Background

In May 2017 a group of Latinx and Asian-American Lowell residents sued the City of Lowell, challenging the city's At-Large plurality election system as being in violation of Section 2 of the Voting Rights Act. The At-Large system was used to elect the 9-member City Council and 6-member School Committee. Plaintiffs were represented by the Lawyers for Civil Rights. Although as of 2017, Asian-American and Latinx residents comprised 40% of Lowell's population, the City Council and School Committee have historically been all White with few exceptions. This is due to racially polarized voting coupled with an election system that structurally excludes minorities.

The Defendants agreed to a Consent Decree in May 2019 which outlined four categories of remedial elections systems for the City Council and School Committee. The decree also specified a process for choosing a new system as well as its implementation. The four election types are District, At-Large, Hybrid and Combination systems. The case was brought as a coalition claim and throughout this report "coalition" is used to refer to a combination of Lantinx and Asian American voters.

On Novemeber 5th, Lowell residents will be voting on the two election systems narrowed down by the City Council: Hybrid "8+3" which would have 8 single member districts and 3 at large seats, and "1×9", or city-wide Ranked Choice Voting (RCV). The results of this vote are non-binding.

Although the city will be voting on just these two options, we analyze all the systems proposed in the Consent Decree in this report.

1.2 Study Goals

The goal of this study is to analyze the elections systems outlined in the May 2019 Consent Decree, paying particular attention to the opportunity of minority voters to elect candidates of their choice under each system. To analyze the alternative systems outlined in the Consent Decree, we used sampling algorithms to produce district maps for single-member City Council districts. We also used stochastic simulation techniques to model At-Large ranked choice voting using single transferable vote (STV) methods such as currently employed in Cambridge, MA. The analysis incorporated sensitivity testing to understand the likelihood of coalition (Asian-American and Lantinx voters) representation under RCV.

Additionally, we built four customized Districtr modules to allow users to make and assess 3,7,8, and 9-district plans out of Lowell census blocks. The modules are accessible here.

1.3 Basic Stats

The following statistics are from the 2010 Census except for CVAP data which is from the American Community Survey (ACS). Here and throughout the report, Hispanic denotes all respondents of any race who indicated Hispanic ethnicity; White denotes non-Hispanic White; Asian denotes non-Hispanic Asian, and so on.

City of Lowell total population: 106,519

Hispanic population: 18,396 or 17.3%
Asian population: 22,459 or 21.1%
White population: 56,280 or 52.8%

City of Lowell total Voting Age Population (VAP): 81,259
Hispanic VAP: 11,600 or 14.3%
Asian VAP: 15,270 or 18.8%
White VAP: 47,187 or 58.1%

City of Lowell Total Citizen Voting Age Population (CVAP): 72,750 Hispanic CVAP: 12,615[1] or 17.3% Asian CVAP: 12,629 or 17.4% White CVAP: 42,645 or 58.6%

2 Remedial Election System Options for City Council

The May 2019 Consent Decree outlines four types of remedial election systems that can replace the current At-Large plurality system used to to elect both the Lowell City Council and School Committee: District, Hybrid, At-Large and Combination. At the time of this report, the City Council has decided that a Hybrid system ("$8 + 3$") and At-Large Ranked Choice Voting ("1×9") will be put to a non-binding vote on the November 5th, 2019 municipal election ballot. By December 3rd, the City Council is to make its final decision on the election system it will adopt.

In this section we review all four systems outlined in the Consent Decree, including a description of each, our analysis methodology and results where applicable.

2.1 Districted

2.1.1 9×1 Districted

The Districted electoral system would consist of nine single-member districts, one for each member of the City Council. Two districts would be required to be majority coalition districts, or have over 50% of its Citizen Voting Age Population (CVAP) comprised of Asian and Latinx voters.

We used a mathematical technique—a randomized algorithm called a Markov chain—to build thousands of sample plans out of census blocks while ensuring compliance with the stipulations of the Consent Decree. The code to generate plans, which is fully public and open-source, is available at `https://github.com/mggg/GerryChain`.

To visualize the set of plan options that comply with the Decree, we started by ranking the districts within each plan in order of their coalition share of population. We then looked at the collection of districts that had the highest coalition population in their respective plans, the second highest coalition population, etc.

In the resulting image (Figure 1), the district number is on the x-axis, and the coalition percent of district CVAP is on the y-axis. The District 9 data, for instance, shows the range of the coalition share in the highest-concentration coalition district from every map we made. This plot shows that it is very difficult to find a third district with a coalition majority of CVAP.

[1] The higher number of Hispanic CVAP than Hispanic VAP can be due to both demographic changes in Lowell between 2010 Census data collection and the 2017 ACS data as well as errors in ACS data collection/reporting.

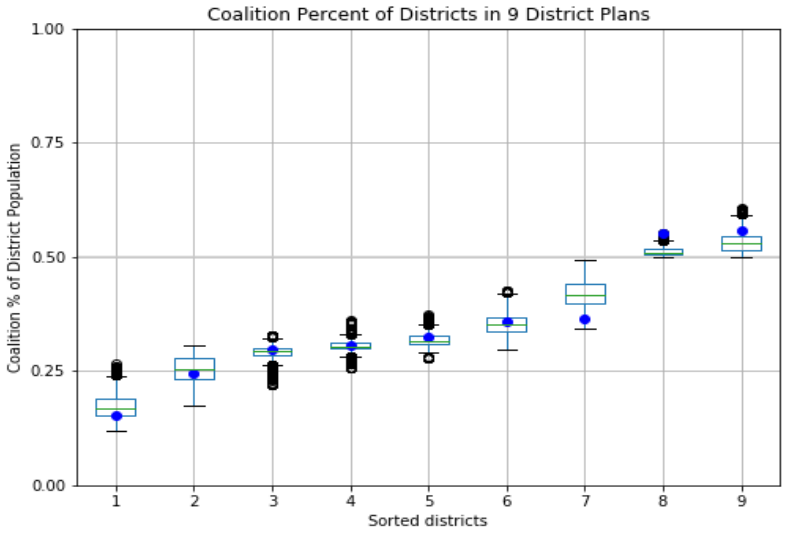

Figure 1. Boxplot of Coalition Population Share by District in Ensemble of 9-District Plans

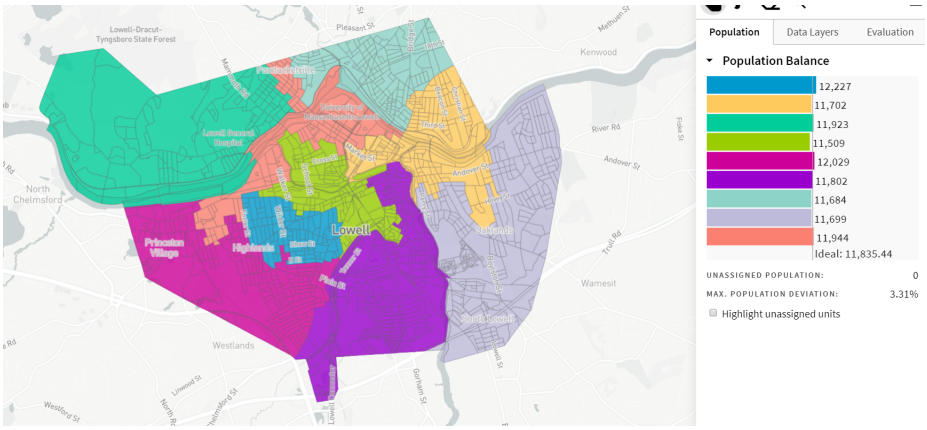

Figure 2. Sample 9-District Plan with Two Highly Concentrated Coalition Districts

Nonetheless, we found a wide variety of ways to comply with the majority-minority requirements of the Consent Decree. For example, some maps have two districts that are very narrowly above 50% coalition CVAP with a third that has coalition CVAP in the high 40s. Alternatively, some maps have much higher than 50% coalition CVAP in one or two districts, and depressed coalition CVAP in the 3rd most populated coalition district.

The blue dots in Figure 1 show statistics from the plan with the highest coalition share in District 8 (the one with second-highest coalition share overall). We chose to highlight this plan as an option that offers a potentially safest way to get two coalition representatives on the City Council. Because of wide variation in coalition turnout in past municipal elections, we note this as a potentially safer choice for coalition representation than a plan with 2 districts narrowly above 50% coalition and a third in the high 40s. Although low coalition turnout can make any district competitive that was designed to be safe for coalition voters, this effect can be mitigated by choosing a plan with safer margins in the two highest-concentration districts.

The plan highlighted in Figure 1 is shown in Figure 2 (after some slight modifications to get rid of particularly jagged boundaries). The coalition Percent of CVAP in plan's districts with highest non-White CVAP is District 9 - 55.5%, District 8 - 53.4%, District 7 - 39.0%.

We have thousands more 9-district plans that can be made available upon request.

2.2 Ranked Choice

2.2.1 1×9 RCV - *On the Ballot*

This electoral system would have no districts and instead all nine members of the City Council (and six members of the School Committee) would be elected in one Lowell-wide vote. Voters would rank candidates in order of preference on their ballot and could include up to the total number of candidates running for election (Ranked Choice Voting, or RCV).

To select the nine members of the City Council, ballots would be counted and combined in a method similar to that used in Cambridge, MA City Council Elections. This process is roughly as follows:

1. Ballots are sorted by their first choice candidate
2. Any candidate whose number of first choice ballots exceeds a pre-set threshold [2] is elected
3. If an elected candidate had a surplus of first-place ballots (above the required threshold) the surplus ballots are randomly selected and redistributed to the next preferred candidate
4. The candidate with the fewest number of first choice ballots is then eliminated and their ballots are redistributed to the next preferred candidate
5. This process repeats until all City Council spots are filled

To assess the outcomes under a possible move to the above system, we built a stochastic model and devised eight different scenarios of voter behavior. In all cases, we assume that for the 9-seat City

[2] In Cambridge, MA the threshold is set by dividing the total ballots cast by the number of seats to be elected plus one, then adding one to the result

Council, there will be nine coalition-preferred candidates and nine White candidates running. We also assume all voters rank all eighteen candidates exactly once. We vary voter behavior in 8 ways, described below in the *Explanation of Terms*, which illustrates the case of three White and three coalition candidates but is easily generalized to other magnitudes.

Our stochastic model relies on turnout data as well as crossover data - the latter of which means the rate at which White voters would rank coalition candidates first and vice versa. We usually approximate crossover voting with Ecological Inference (EI). However, because of wide variation in turnout rates in Lowell municipal elections, EI was inconclusive in this case. Instead we ran a sensitivity analysis that varied both turnout rates (for coalition voters) and crossover voting rates (for all voters). For each combination of turnout and crossover inputs, we ran the RCV simulation model 200 times and averaged the results to get the expected coalition representation on the City Council for the fixed combination of inputs.

Model runs: 200 runs of 5,000 voters for each scenario coded in Python. Average outcomes are reported in the table below (number of coalition-preferred candidates elected out of 9 City Council members). Each row is a different scenario, determined by the crossover and turnout vector columns.

The city-wide racial and ethnic shares of CVAP are: Hispanic CVAP: 17.3%, non-Hispanic Asian CVAP: 17.4%, non-Hispanic White CVAP: 58.6%, non-Hispanic Other CVAP: 6.7%.

Explanation of Terms in Stochastic RCV Model

Total polarization: all White voters vote WWWCCC and non-White voters vote CCCWWW.

Crossover: A crossover White voter votes CWCWCW and coalition voter votes WCWCWC. Note, in crossover scenarios not all voters are crossover voters, only the percentage of each population specified by input crossover data.

Unanimous order: White candidates always ranked W1W2W3, coalition-preferred C1C2C3. This simulates community agreement or coordination about which are the preferred candidates.

Vary order of non-White: C1C2C3 equally likely to C2C1C3, C1C3C2, etc. Each voter orders the candidates randomly. This simulates vote-splitting among coalition-preferred candidates by non-White voters.

Vary order: Same random order for White candidates

Turnout vector: Relative turnout rates by race for White, Hispanic, Asian, Other as a share of CVAP (which tracks with eligible voters). For instance, Run 13 has $[1, .25, .75, 1]$, meaning that White and Other voters turn out at the highest rate of eligible voters, while Hispanic turnout is 25% of that level and Asian turnout is 75% of that level. This is a relative turnout only and is meant to address worries about low coalition participation in the election.

Crossover vector: This records the share of members of one group whose first-choice vote goes to a different group. For instance, Run 13 has $[.1, .3, .3, .3]$, meaning that 10% of White voters prefer a Coalition candidate most, while 30% of Asian, Hispanic, and Other voters prefer a White candidate most. These are values that are typically computed in a racially polarized voting analysis such as that used in the current lawsuit. However, this sensitivity analysis is used to verify that the findings are not completely dependent on the empirical RPV data.

Run Number	Turnout *(White, Hispanic, Asian, Other)*	Crossover *(White, Hispanic, Asian, Other)*	Total polarization, Unanimous vote	Total polarization, Coalition permute coalition	Total polarization, all permute all	Total polarization, White permute all	Crossover, Unanimous vote	Crossover, Coalition permute coalition	Crossover, All permute all	Crossover, White permute all
1	[1, 1, 1, 1]	[0.1, 0.3, 0.3, 0.3]	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
2	[1, 1, 1, 1]	[0.3, 0.3, 0.3, 0.3]	4.0	4.0	4.0	4.0	5.0	5.0	4.0	3.0
3	[1, 1, 1, 1]	[0.1, 0.5, 0.5, 0.1]	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0
4	[1, 1, 1, 1]	[0.1, 0.1, 0.1, 0.1]	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0
5	[1, 1, 1, 1]	[0.1, 0.1, 0.5, 0.1]	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
6	[1, 1, 1, 1]	[0.1, 0.5, 0.1, 0.1]	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
7	[1, 0.5, 0.5, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
8	[1, 0.5, 0.5, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.2	2.0
9	[1, 0.5, 0.5, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	1.6	2.0
10	[1, 0.5, 0.5, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
11	[1, 0.5, 0.5, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
12	[1, 0.5, 0.5, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
13	[1, 0.25, 0.75, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
14	[1, 0.25, 0.75, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.2	2.0
15	[1, 0.25, 0.75, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	1.6	2.0
16	[1, 0.25, 0.75, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
17	[1, 0.25, 0.75, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
18	[1, 0.25, 0.75, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
19	[1, 0.75, 0.25, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
20	[1, 0.75, 0.25, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.2	2.0
21	[1, 0.75, 0.25, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	1.5	2.0
22	[1, 0.75, 0.25, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
23	[1, 0.75, 0.25, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
24	[1, 0.75, 0.25, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
25	[1, 0.33, 0.33, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	2.6	1.0	1.0
26	[1, 0.33, 0.33, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.0	2.0
27	[1, 0.33, 0.33, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	2.1	1.0	1.0
28	[1, 0.33, 0.33, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
29	[1, 0.33, 0.33, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0

Figure 3. RCV Simulation Output, designed to stress-test predictions in worst-case coalition turnout and crossover scenarios

Run Number	Turnout *(White, Hispanic, Asian, Other)*	Crossover *(White, Hispanic, Asian, Other)*	Total polarization, Unanimous vote	Total polarization, Coalition permute coalition	Total polarization, all permute all	Total polarization, White permute all	Crossover, Unanimous vote	Crossover, Coalition permute coalition	Crossover, All permute all	Crossover, White permute all
30	[1, 0.33, 0.33, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
31	[1, 0.1, 0.9, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
32	[1, 0.1, 0.9, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.2	2.0
33	[1, 0.1, 0.9, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	1.6	2.0
34	[1, 0.1, 0.9, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
35	[1, 0.1, 0.9, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
36	[1, 0.1, 0.9, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
37	[1, 0.9, 0.1, 1]	[0.1, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
38	[1, 0.9, 0.1, 1]	[0.3, 0.3, 0.3, 0.3]	2.0	2.0	2.0	2.0	4.0	4.0	2.2	2.0
39	[1, 0.9, 0.1, 1]	[0.1, 0.5, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	1.6	2.0
40	[1, 0.9, 0.1, 1]	[0.1, 0.1, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
41	[1, 0.9, 0.1, 1]	[0.1, 0.1, 0.5, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
42	[1, 0.9, 0.1, 1]	[0.1, 0.5, 0.1, 0.1]	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0
43	[1, 0.8, 0.8, 1]	[0.1, 0.3, 0.3, 0.3]	3.0	3.0	3.0	3.0	4.0	4.0	2.0	2.0
44	[1, 0.8, 0.8, 1]	[0.3, 0.3, 0.3, 0.3]	3.0	3.0	3.0	3.0	5.0	5.0	3.0	3.0
45	[1, 0.8, 0.8, 1]	[0.1, 0.5, 0.5, 0.1]	3.0	3.0	3.0	3.0	4.0	4.0	2.0	2.0
46	[1, 0.8, 0.8, 1]	[0.1, 0.1, 0.1, 0.1]	3.0	3.0	3.0	3.0	4.0	4.0	3.0	3.0
47	[1, 0.8, 0.8, 1]	[0.1, 0.1, 0.5, 0.1]	3.0	3.0	3.0	3.0	4.0	4.0	2.9	2.5
48	[1, 0.8, 0.8, 1]	[0.1, 0.5, 0.1, 0.1]	3.0	3.0	3.0	3.0	4.0	4.0	2.9	2.5

RCV Simulation Output, continued

From this sensitivity analysis we can see that an RCV At-Large system can afford coalition communities opportunity to elect candidates of choice in near proportion to their percent of the overall Lowell population. We see 2-4 coalition candidates elected in almost all $48 \cdot 8 = 384$ scenarios in the table, with 2 candidates occurring in generally the most extreme low-turnout scenarios for coalition voters (i.e., 50% the turnout rate of White voters).

2.3 Hybrid

A Hybrid electoral system would consist of single- member districts as well as at-large seats. The at-large seats are not required to use RCV as in the At-Large and Combination Electoral systems. The Consent Decree describes three Hybrid-system variants.

2.3.1 8 + 3 Hybrid - *On the Ballot*

The $8 + 3$ Hybrid system consists of eight single member districts and three at-large seats for the City Council, expanding its size from nine to eleven members.

Districts: The 8-district plan requires two majority-coalition districts. We used Markov chains again to generate compliant 8-district plans and highlighted those with the highest coalition-population in the second district. See Figure 5.

As we would expect, it is harder to generate 8-district plans with a third district that is close to majority-coalition than we saw in the 9-district case. The blue dots show the plan with the highest coalition population in the second most populated coalition district. Such a plan may have a better chance of securing two districts that are likely to perform for coalition voters. We note again that because of Lowell's high variation in turnout, these districts cannot guarantee coalition representation. This plan is pictured in Figure 6, after some minor modifications to smooth boundary lines. Coalition Percent of CVAP in plan's districts with highest Non-White CVAP: District 8 - 54.9%, District 7 - 53.9%, District 6 - 40.3%.

At-Large Seats: The Consent Decree does not specify if the at-large seats in the Hybrid options will be chosen via RCV or At-Large plurality. For the former, we have repeated the RCV sensitivity analysis described in Section 2.2 to model outcomes for the at-large seats in all of the Hybrid system options. These are summarized at the end of this section.

If the at-large seats are elected via plurality voting and there are White candidates running for each of them, we predict they will win every seat (under reasonable assumptions for turnout and crossover voting in Lowell).

2.3.2 8 + 1 Hybrid

The 8+1 Hybrid system consists of eight single member districts and one at-large seat for the City Council. Two districts are required to be majority-coalition CVAP. The 8-district plan analysis is the same as described in the $8 + 3$ Hybrid system. We used the stochastic model described in Section 2.2 to analyze the one at-large seat, should it be elected via RCV. Results are presented at the bottom of this section, along with at-large seat results for the other Hybrid system variants. Again, if the seat is elected via plurality voting with at least some White candidates running, we predict a White candidate will win under reasonable crossover and turnout voting assumptions.

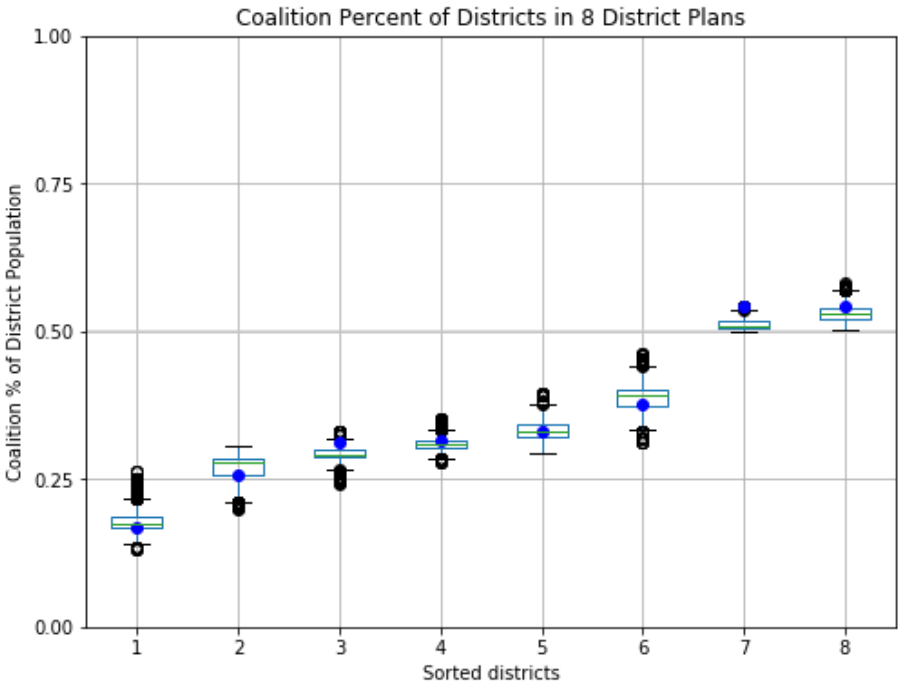

Figure 5. Boxplot of Coalition Population Share by District in Ensemble of 8-District Plans

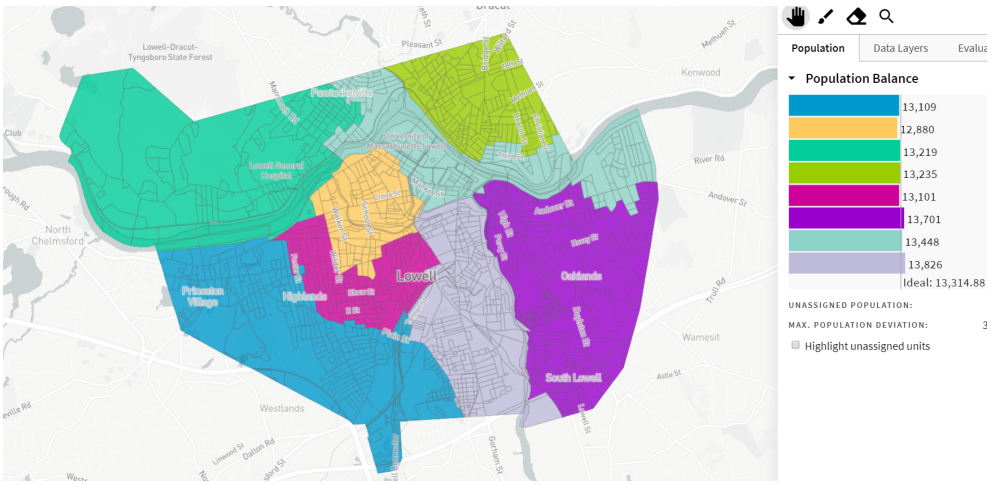

Figure 6. Sample 8-District Plan with Two Highly Concentrated Coalition Districts

2.3.3 $7+2$ Hybrid

The $7+2$ Hybrid system consists of seven single member districts and two at-large seats for the City Council. Two districts are required to be majority-coalition CVAP. Stochastic model results for the two at-large seats are included below. If the at-large seats are elected via plurality vote we again predict winners will be White. Plots and sample plans are available upon request.

2.3.4 Hybrid At-large Seats Analysis with RCV

In the event of using a hybrid system with at-large seats, we expect the City to select the plurality system for electing those at-large members. If they do, then recent voting patterns would indicate that all three seats would go to White candidates.

However, the city could adopt a ranked choice system for its at-large seats, which would give a stronger chance of coalition representation. The stochastic RCV model was used to analyze one, two and three at-large seats by RCV. The model assumptions, number of runs and votes were the same as described in Section 2.2. The values in the table below are the number of coalition candidates elected to the at-large seats averaged across simulation runs and across sensitivity inputs. Results broken out by crossover and turnout inputs are available upon request.

Voter Behavior	1 At-Large Seat	2 At-Large Seats	3 At-Large Seats
Total polarization, Unanimous vote	0	0.25	0.88
Total polarization, Coalition permute coalition	0	0.25	0.88
Total polarization, All permute all	0	0.25	0.88
Total polarization, White permute all	0	0.25	0.88
Crossover, Unanimous vote	0	0.56	1.00
Crossover, Coalition permute coalition	0	0.46	1.02
Crossover, All permute all	0	0.09	0.53
Crossover, White permute all	0	0.24	0.65

Figure 7. Average number of coalition candidates elected for 1,2, and 3 at-large seats by RCV

2.4 Combination

2.4.1 3×3 RCV

Under a Combination system three districts would be drawn, each of which would elect three City Council members (and two School Committee members) via the same RCV method described in Section 2.2. Below is an example of a three district plan with approximately equal coalition CVAP in each district.

Coalition Percent of CVAP in plan's three districts: District 3 - 35.9%, District 2 - 34.7%, District 1 - 33.6%. We can provide thousands more 3-district plans upon request.

To analyze how this plan would perform, we used our stochastic RCV model to predict 3-member outcomes in each of the three districts. We again ran a sensitivity analysis, now doing it a total of three times, using each district's CVAP breakdown. The results for each district are summarized

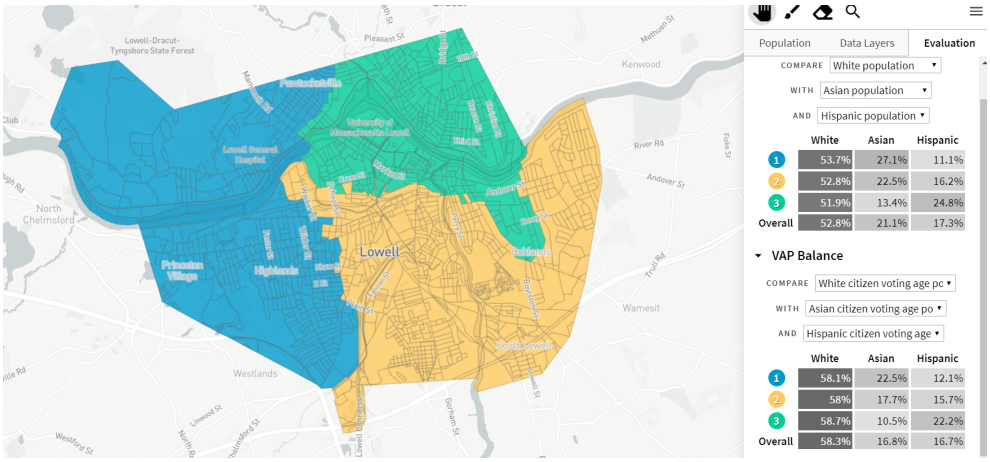

Figure 8. Sample 3-District Plan with Approximately Equal Coalition CVAP in Each District

below. Fractional values are attributable to results being averaged across sample runs, turnout and

Voter Behavior	District 1	District 2	District 3
District CVAP Breakdown *(White, Hispanic, Asian, Other)*	58.5%, 16.4%, 18.3%, 6.9%	58.4%, 12.8%, 23.1%, 5.7%	59%, 22.7%, 10.9%, 7.5%
Total polarization, Unanimous vote	0.88	0.88	0.75
Total polarization, Coalition permute coalition	0.88	0.88	0.75
Total polarization, All permute all	0.88	0.88	0.75
Total polarization, White permute all	0.88	0.88	0.75
Crossover, Unanimous vote	1.00	1.00	1.00
Crossover, Coalition permute coalition	1.02	1.02	1.02
Crossover, All permute all	0.54	0.51	0.52
Crossover, White permute all	0.70	0.67	0.71

Figure 9. Average results for elected POC representatives in each district (out of 3 seats per district)

crossover inputs. We used all voter scenarios shown in Figure 3, which includes some scenarios with extremely low coalition turnout relative to White turnout. Bearing this in mind with the results in Figure 8, RCV can be expected to produce a coalition candidate in each of the 3 districts, resulting in 3 out of 9 on the City Council.

In addition to having comparable results for coalition representation to the city-wide RCV (or 1×9) option, the 3×3 has the benefit of guaranteeing geographic diversity; it will have members of the City Council elected from three regions of the City. Candidates only have to campaign in their district and voters can still show preferences for many candidates without having to become familiar with an overwhelming slate. In this way we think the Combination 3×3 system combines the best features of the other proposed election options for both candidates and voters.

3 School Committee

For each proposed election system the Consent Decree also specifies how member of Lowell's 6-member School Committee are to be elected. Here we provide a brief note on coalition representa-

tion on the School Committee under the two systems on the November ballot.

Under the $8 + 3$ City Council option, the decree calls for Lowell's 8 council districts to be combined into 4 School Committee districts, one of which has to be majority coalition (measured by CVAP). Two additional seats will be elected at-large. While its not specified if RCV or plurality will be used for the at-large seats, we expect plurality to be chosen.

With this assumption we expect 0-1 member of the 6-member School Committee to be coalition-preferred.

On the other hand, if the RCV (1×9) City Council system is adopted, all six School Committee members will also be elected via RCV. We again performed a sensitivity analysis using our stochastic model. The results predict 2 coalition-preferred candidates out of 6.

4 Conclusion

In this report we have analyzed not only the two election systems on the ballot in November, but all of the systems proposed in the Consent Decree. We have aimed to provide a comprehensive overview of tradeoffs between districts and RCV, calling particular attention to an option not on the ballot that we think combines the benefits of both (Combination, 3×3). We have summarized expected outcomes for coalition representation in each system in the table below.

Election System	Coalition Representation, At-Large Seats RCV	Coalition Representation, At-Large Seats Plurality
District, 9 x 1	0-2 out of 9 (0 - 22%)	0-2 out of 9 (0 - 22%)
RCV, 1 x 9	2-4 out of 9 (22 - 44%)	2-4 out of 9 (22 - 44%)
Hybrid: 8 + 3	0-3 out of 11 (0 - 27%)	0-2 out of 11 (0 - 18%)
Hybrid: 8 + 1	0-2 out of 9 (0 - 22%)	0-2 out of 9 (0 - 22%)
Hybrid: 7 + 2	0-3 out of 9 (0 - 33%)	0-2 out of 9 (0 - 22%)
Combination, 3 x 3	2-3 out of 9 (22% -33%)	2-3 out of 9 (22% -33%)

Figure 10. Summary results for expected coalition representation under election system alternatives. Green denotes systems that are on the November municipal ballot in Lowell.

Appendix A: Summary of Citizen Voting Age Population (CVAP) for Demonstration Maps

The Lowell landing page of our Districtr web tool links to eight sample districting plans: two each containing 3,7,8 and 9 districts. The White CVAP/ non-White CVAP in the three lowest WCVAP districts are provided in the table below.

City-wide CVAP values are: White - 58.6 %, Asian - 17.4 %, Hispanic - 17.3 %, Other - 7 %

Plan	**Highest Coalition District** White/non-White	**2nd Highest Coalition District** White/non-White	**3rd Highest Coalition District** White/non-White
3 Districts - Plan A	42.9%/57.1%	64.6%/35.4%	68.0%/32.0%
3 Districts - Plan B	58.4%/41.6%	58.5%/41.5%	59.0%/ 41.0%
7 Districts - Plan A	41.2%/58.8%	44.0%/56.0%	51.0%/49.0%
7 Districts - Plan B	41.4%/58.6%	43.4%/56.6%	53.1%/46.9%
8 Districts - Plan A	42.4%/57.6%	42.7%/57.3%	46.3%/53.7%
8 Districts - Plan B	38.5%/61.5%	39.3%/60.7%	50.6%/49.4%
9 Districts - Plan A	39.0%/61.0%	42.3%/57.7%	44.9%/55.1%
9 Districts - Plan B	38.4%/61.6%	39.0%/61.0%	51.9%/48.1%