

Model Simulations of COVID-19 Mitigation Strategies

Overview

This report explores three scenarios for the evolution of the COVID-19 pandemic in Whatcom County, focusing on the period after the anticipated expiration of some mandatory social distancing measures, which may occur as early as May 5th. Having completed sufficient model validation, we are now able to present forecasts for the state of the pandemic in early May and to estimate the trends of COVID-19 in Whatcom County beyond early May under different hypothetical scenarios for public health policy.

From these model simulations, we conclude that any significant relaxation in mandatory social distancing in early or mid-May will likely allow COVID-19 to start spreading again, leading to a second peak. New infections would reach a second maximum (many times larger than the first) that is likely to occur in late summer to early fall, depending on the selection of a hypothetical scenario.

Given the extreme risks to public health in this scenario, we considered the likelihood that the current restrictive, mandatory policies would need to be reinstated at some point before that second peak occurs. We know (from recent experience) that this could be effective at interrupting the second peak. It suggests, however, that we could see the necessity of a repeated pattern of closing and reopening society as a transitory mechanism for controlling COVID-19 while a vaccine is being developed.

An effective program of testing, contact-tracing, and quarantine of suspected and identified cases could provide a pathway for part or all of the gap of the previous scenarios. We estimate (under the one hypothetical scenario for relaxation of social distancing) that public health officials would need to interrupt half of the new infections in May to prevent the re-emergence of the COVID-19 pandemic locally and regionally. The necessary effort to accomplish this would be most intense for the first weeks of the relaxation of mandatory social distancing, and then, if effective, would decline progressively through the summer.

Key Findings

- Model forecasts for early May
 - By May 4th, the model forecasts that daily new infections in Whatcom County will have dropped to the range of 10 to 17 per day. The predicted number of infected individuals at that time is 25 to 47, with 20 to 27 of those being severe cases. Severe cases here refers to any infection leading to significant health consequences, whether the patient is treated in a hospital, in a non-hospital care setting or remains at home. The total number of individuals having been cumulatively infected with COVID-19 in the County is estimated by the model to be 0.8% to 1% of the total population by that date.

- Scenario 1: The Governor relaxes “stay-home, stay-healthy” order effective May 5th, but keeps schools closed and ban on gatherings in place while encouraging social distancing in all public spaces.
 - In this hypothetical scenario, the transmission of COVID-19 increases beginning in early May, leading to a peak in new infections estimated to occur sometime from August 9th to August 26th. This translates into a peak in severe cases (and demand on the health-care system) from August 24th to September 9th.
 - The number of predicted severe cases in this hypothetical scenario far exceeds the first peak in early April (by a factor of 60 or more), unless some additional measures are employed to slow the spread of COVID-19.
 - As a variation of this scenario, we simulated a later relaxation of social distancing. We selected May 18th, because that has been [suggested by the Institute for Health Metrics and Evaluation](#) (IHME) at the University of Washington as a date by which the mandatory measures could be safely relaxed.
 - The only notable difference between the May 5th and May 18th relaxation dates is the timing of the second peak, which is delayed by a corresponding 13 days. The magnitude of the second peak was undistinguishable in the two simulations.
 - On the low end of our range of simulations, the total number of infected individuals did drop just below 10 in Whatcom County when relaxation was delayed until May 18th, which is tantalizingly close to the ultimate control of the virus. Our statewide simulations, however, do not come close to that threshold, so community spread from neighboring counties is almost a certainty.
- Scenario 2: Situation is the same as in scenario 1, except that “stay-home, stay-healthy” is reinstated to prevent the full emergence of a second peak.
 - For the purposes of illustration only (and not suggesting that this is the appropriate trigger for policy changes), we selected, as a threshold, if/when hospital admissions reach the level seen during the first peak on March 25th.
 - In our statewide COVID-19 simulation, we reach that point (new daily severe cases greater than 150) by June 7th to June 24th.
 - In our Whatcom County simulation, the parallel trigger would be new daily severe cases reaching 3 or greater. Once social distancing is relaxed, we reach that level again by June 9th to June 25th.
 - If we assume a similar duration for the more restrictive period beginning in June (approximately six weeks) to reach a low-enough level of COVID-19 to relax social distancing again, the “lightswitch” scenario appears to alternate between equally long periods of more and less severe mandatory policies, perhaps being required until a vaccine is developed.
- Scenario 3: Situation is the same as scenario 1, except for the assumption that we are able to implement public health interventions. Here we examine the possibility that the focus is primarily on testing, contact-tracing, isolation of cases and quarantine efforts sufficient to keep COVID-19 from increasing again.
 - Because the basic reproduction number (R_t) is modelled to increase to 1.85 on May 5th, and since it must be below 1 to ensure that the number of infected people does not increase, we assume that a 50% intervention effort is necessary in this scenario (lowering R_t to 0.925).

- This translates into 50% of new infections being prevented by public health interventions.
- The model simulates that the total number of new infections in the week of May 5-11 is predicted to be 53 to 99; thus, the target number for interventions would be approximately 27 to 50 in that week.
 - For example, if, in that week, 27 infected individuals were identified and quarantined before infecting anyone else, that should, statistically, prevent 50 new infections (as we are applying a 1.85 multiplier for the basic reproduction number).
 - Assuming that the combination of remaining social distancing efforts plus this public health intervention are successful at keeping R_t below 1, the number of new infections (and hence the public health effort) would decrease somewhat over time. Figure 1 shows the simulated size of the public health intervention effort to maintain a net R_t of 0.925 (50% reduction).
 - Note that this doesn't account for cases imported via contacts with infected individuals outside the County. If cases were surging upward in neighboring jurisdictions, this would likely be a significant factor, so the strategy described in scenario 3 assumes a regional effort of similar magnitude and effectiveness.

Estimated Number of Prevented Infections from
Community Spread Necessary to Stabilize COVID-19 in
Whatcom County

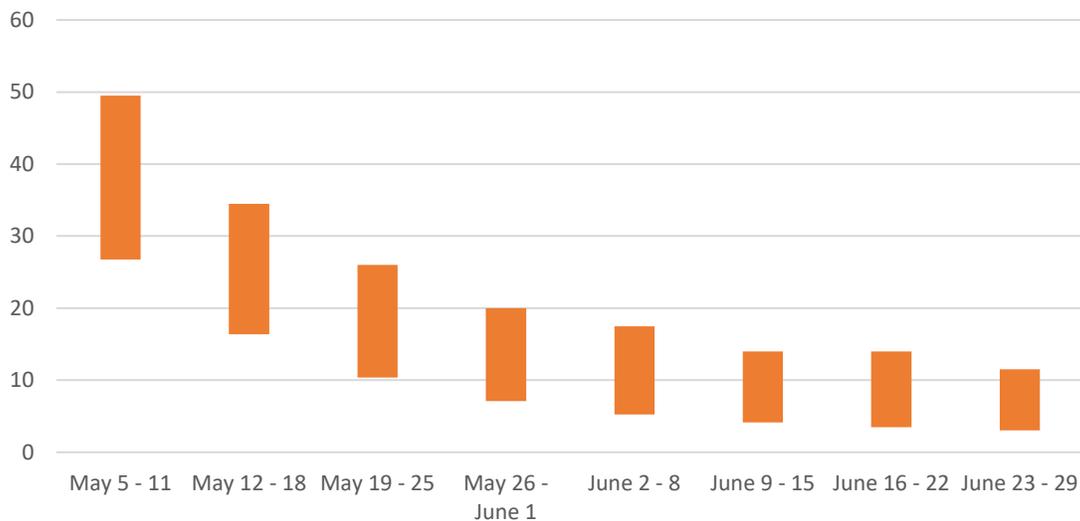


Figure 1. Model estimated number, by week after May 5th, of new infections that would have to be prevented to stop 50% of the COVID-19 infections in Whatcom County and, hence, to stabilize the pandemic in this scenario. Note that this does not take into account infections due to cases imported from contacts outside Whatcom County.

Methods

Building on the model discussed in Herring, 2020, this paper continues the development of the susceptible-exposed-infectious-recovered (SEIR) epidemiological framework to produce a more useful tool for modelling scenarios of COVID-19 in Whatcom County. Here we employ the same mathematical formulation described in [Wu et al.](#) The model implementation used in the first iteration of the model (built by [Goh et al.](#)) have been adapted by Filip Jagodzinski at Western Washington University, including a new user interface. This new iteration of the model provides both more flexibility and certainty compared to the online model user interface (Goh et al.) that was used exclusively for the earlier paper. One of the drawbacks of the online interface was that the sliders that controlled the input variables were difficult to use accurately, and this appeared to lead to some irreproducibility in model results. Additionally, the Goh et al. model limited us to one intervention in the speed of the transmission of the virus. We believe that the Goh et. al. model remains a useful teaching tool for policy-makers (and the general public) seeking a better general sense of how the mathematics of exponential growth works, but that the new iteration of the model will be much better suited to building scenarios which might influence plans and policy decisions. Table 1 shows the epidemiology parameters that were used in all simulations discussed in this paper and where those differed from version 1 of the model.

Table 1. Model parameters used in model calculations for COVID-19 spread in Whatcom County in model version 1 and version 2.

Parameter	Value Used in Model Version 1	Value Used in Model Version 2 (This Paper)
Duration of Incubation Period	5 days	5 days
Duration of Infectious Period	3 days	3 days
Case Fatality Rate	2.0%	0.66%
Time from onset of symptoms to death	25 days	25 days
Length of Hospital Stay	21 days	21 days
Recovery Time for Mild Cases	11 days	11 days
Hospitalization Rate	10%	3.3%
Time to Hospitalization	8 days	8 days

Version 2 of the model is tuned with a varying rate of COVID-19 transmission that is keyed to changes in public policy. Specifically, we treat the basic reproduction number (R_t) as a time-dependent variable in the model. The assumed values for transmission are consistent with emerging literature and validated against local data through model calculations. Through simulations of the observed drop in new cases and hospitalizations, we are confident that there was a significant decrease in COVID-19 transmission in late March, corresponding well with the date of the Governor’s “stay-home, stay-health” order. Table 2 shows the time periods and values for the basic reproduction number used in these simulations. Model

validation with current epidemiological data shows that the key measurements of the epidemic are decreasing at a rate that best corresponds to a basic reproduction number of 0.3 to 0.5.

Table 2. Values used for the basic reproduction number (R_t)

Period in model simulation	Basic Reproduction Number (R_t)
2/9/20-3/1/20	2.85
3/2/20-3/15/20	2.25
3/16/20-3/25/20	1.85
3/26-20-5/4/20	0.3 and 0.5
5/5/20 onward	1.85 (except in “lightswitch” scenario)

Extensive model validation shows that it does a reasonable job of reproducing the trends and timing of new cases, hospitalizations, and deaths statewide. The model also reproduces trends in new cases well in Whatcom County. In both cases, the number of severe cases predicted by the model is higher than the observed hospitalizations. Some of this difference may be explained by the fact that a significant number of severe cases in Whatcom County (and statewide) occur in care facilities outside of hospital settings.

Assumptions

- COVID-19 Policy and Transmission Scenarios
 - The Governor has announced that he plans to release some of the mandatory measures in place to slow the spread of COVID-19, but not a timeline for doing so. We assume here that he considers, effective May 5th, to roll back the restrictions to what was in place between March 15th and 25th.
 - This includes continued bans on gatherings (public or private), the continued closure of schools while allowing construction, manufacturing, outdoor recreation, and many retail businesses to resume with social distancing measures in place.
 - We simulated this policy option with model values that successfully reproduced the observed epidemiology of COVID-19 from March 15th to March 25th.
 - The value of the basic reproduction number in this scenario (R_t) increases from below 1 to 1.85 on May 5th.
 - The second variation of this scenario was to relax social distancing requirements on May 18th, instead of May 5th, as has been suggested by IHME as a safe date to do so.
 - We also explored the criteria that IHME used for its statewide evaluation of the relaxation date. This was stated to be the date by which there would be less than one new case per million people. For Washington State, that corresponds to less than 8 new daily cases. This compares to the most recent three-day average of 340 new daily cases.
 - Our statewide simulation doesn’t correspond with the IHME projection. For our low-end simulations, that threshold isn’t reached until the beginning of June.

- The second scenario builds upon the first, and assumes that the more restrictive “stay-home, stay-health” measures we are currently operating under would be reinstated after some state or local thresholds were exceeded as the second peak of COVID-19 emerged.
 - This corresponds to the strategy referred to as the “dance” by [Pueyo](#) or the “lightswitch” scenario by [Mordecai et al.](#) at Stanford in which policy-makers reinstate more restrictive measures periodically to prevent the health care system from being overwhelmed.
 - We assume for this scenario that the trigger is the number of new severe cases, and that it is a county or statewide mandate that is activated when we reach levels similar to where we were at on March 25th.
- The third scenario was developed to explore the scale of public health intervention that would be required in early May and beyond to prevent the resurgence of COVID-19 in Whatcom County.
 - This could involve enhancement of non-pharmaceutical intervention (NPIs) options not fully implemented that don’t require a “stay-home” order, such as universal mask usage in public spaces. The strategy that the model scenario addresses is to rely primarily on additional testing, contact-tracing, isolation of infected individuals and quarantine of infected individuals and their close contacts.
 - It does not take into account imported cases, which could be a significant net source if infection rates are increasing more rapidly in surrounding jurisdictions.

Modeling the Spread of COVID-19 in Whatcom County

Figures 2 and 3 show the timing of changes in key epidemiological variables calculated by the model in scenario 1 (described in more detail above) when social distancing is relaxed in the model on May 5th. In this scenario, about 75% of the population in the County contracts the SARS-nCOV2 virus (with the vast majority recovering). We emphasize here, again, that recent evidence and statements by leaders and public health officials demonstrate that there is significant will to prevent the second peak, and a couple of likely strategies they could use to interrupt it. The primary purpose of this report is not to highlight the magnitude of the second peak, but, rather, to explore what is the best combination of strategies to avoid it.

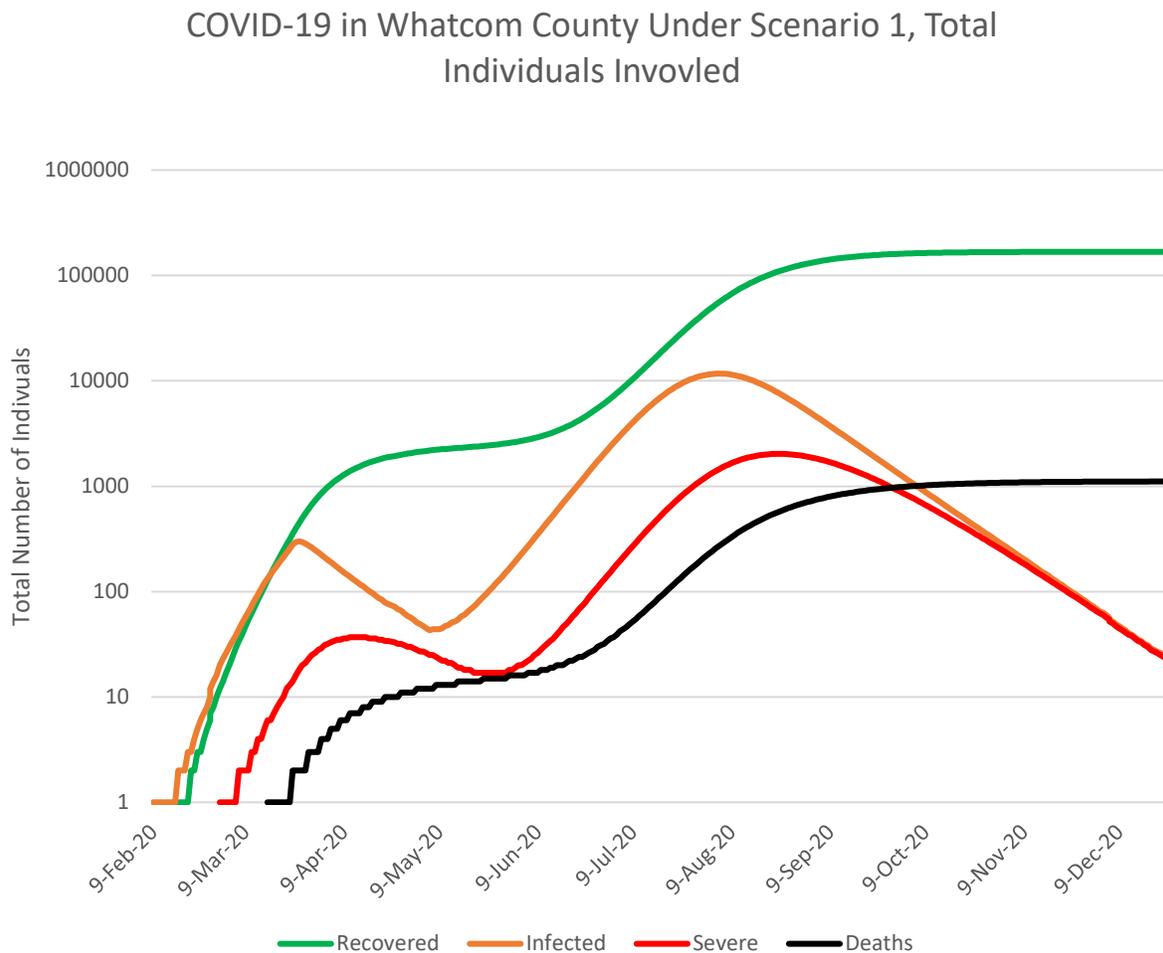


Figure 2. Simulated progression of total individuals impacted by COVID-19 in Whatcom County under the scenario that some mandatory social distancing requirements are lifted effective May 5th, resulting in a basic reproduction number (R_t) of 1.85.

COVID-19 in Whatcom County Under Scenario 1, Epidemiology Curves for Daily Emergence of COVID-19

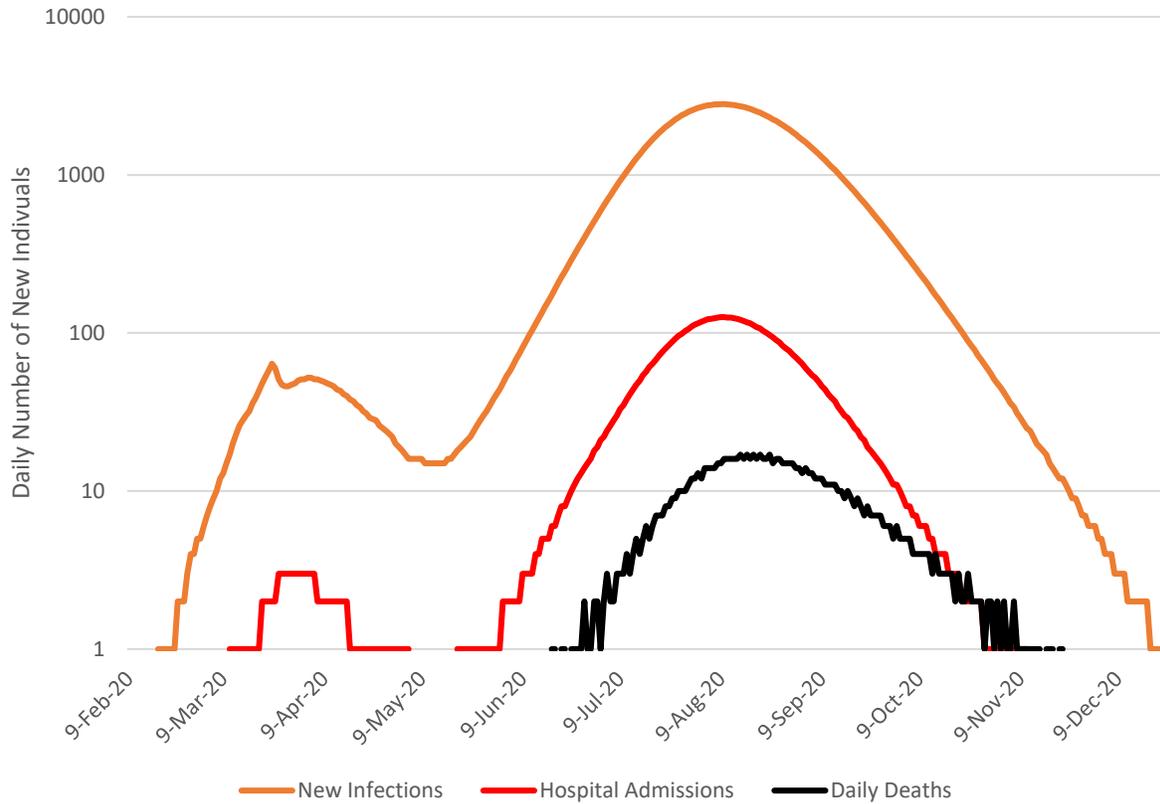


Figure 3. Simulated daily infections, hospital admissions, and deaths in Whatcom County under the scenario that some mandatory social distancing requirements are lifted effective May 5th, resulting in a basic reproduction number (R_t) of 1.85.

In Figure 4, we contrast the curve of daily new infections in scenario 1 (upper curve) with the trajectory we suggest as the goal of scenario 3. This scenario is calculated with $R_t = 0.925$ after May 4th, or 50% of the value in scenario 1. At this level, the number of new daily infections continues to decrease steadily through May, June, and July, reaching 2 per day by late July.

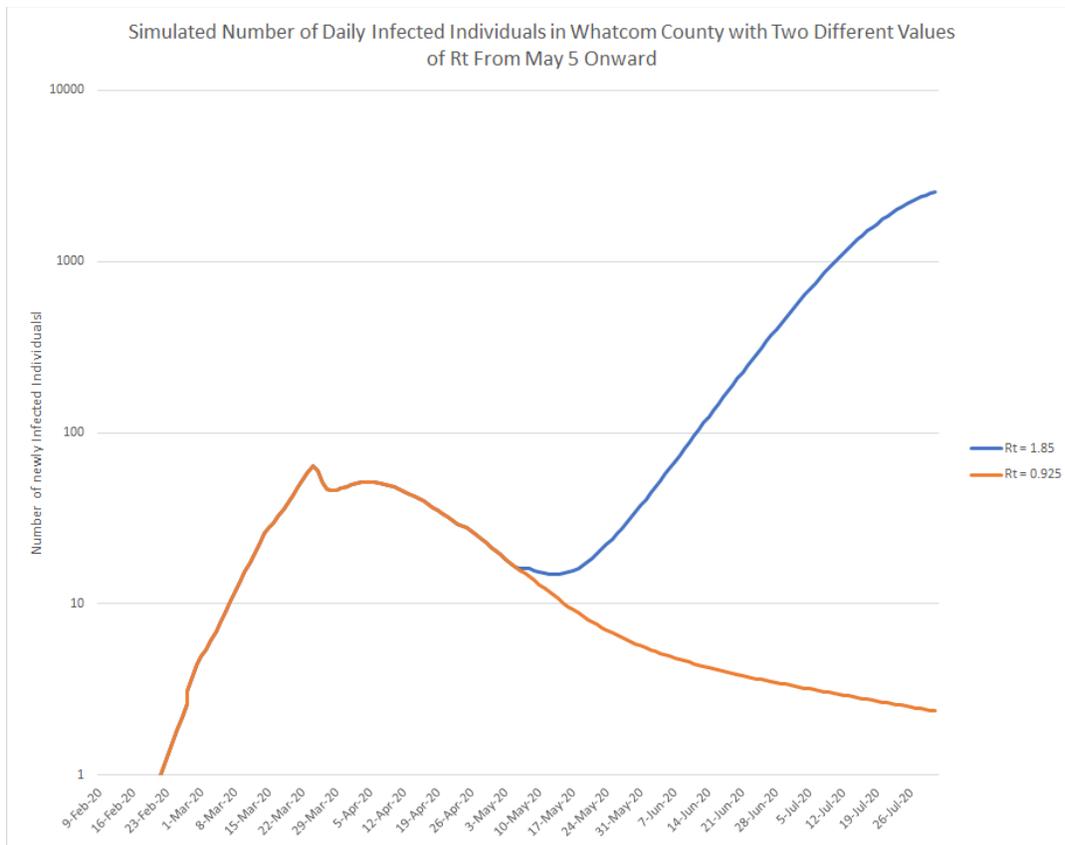


Figure 4. Simulated number of daily new infections for scenario 1 (top curve) and scenario 3 in which public health interventions have been successful in preventing 50% of new infections.

Surveillance Team Observations

We note that it seems likely that if a second wave were to emerge as predicted in scenario 1, that policies would be implemented to prevent it from reaching its unmitigated peak. Thus, the high numbers of hospitalizations and deaths shown in Figures 2 and 3 are unlikely to come to pass. One of the purposes of this analysis is to help policy-makers to be better informed as they examine the best options for avoiding that second peak.

Limitations

The model simulations described in this paper rely on several assumptions about policy decisions that will be made at the state and local levels that have not yet been made. Thus the simulations of the possible evolution of COVID-19 in Whatcom County beyond May 4th must be treated as hypotheticals rather than predictions. It is hoped that these hypotheticals may help inform some of those choices.

While the public health effort necessary to stabilize COVID-19 in Whatcom County described in the scenarios sounds tractable at first glance, there are several reasons why this task won't be an easy one. First, there is growing evidence (e.g., the recent studies from Santa Clara County and the Netherlands) that give strong credence to the hypothesis that the majority of those infected with SARS CoV-2 do not

exhibit any symptoms. Second, the reported case numbers in most countries are underreporting the true extent of COVID-19 by perhaps an order of magnitude. The fact that some transmission originates from asymptomatic individuals is also now well established. Thus, simply testing those who exhibit symptoms and tracing their contacts is probably insufficient to interrupt 50% of the new infections due to community spread in the County.

Next Steps for the Intelligence Unit

- Develop a more accurate representation of the factors that led to the observed late March/early April inflection point in the COVID-19 pandemic in Whatcom County and Washington State.
- Continue surveillance to detect possible softening of social distancing between now and May 4th.
- Modify model simulations to match policy options as they emerge at the local and state levels.

Sources

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