Appendix A

Modelling of NSW Roadmap to Freedom

ICU Capacity for the Delta epidemic 2021

Modelling done by Biosecurity Program, The Kirby Institute, UNSW, with input from ICU Working group.

13 September 2021

Modelling of different roadmap scenarios for the NSW health system

Summary: We estimate about 1890 daily cases in NSW at the time the first freedoms are granted on October 18th when the 70% adult vaccination target is met. The virus outpaces the vaccine, spreading every few days while vaccine immunity takes two months to achieve. This is why vaccination, whilst our ultimate exit strategy, cannot control the current NSW epidemic. We estimate rapid, timely contact tracing capacity is low at current high case numbers. We looked at six scenarios based on the NSW Roadmap, with either a single relaxing of restrictions at 70%, 80% or with further relaxing of restrictions at the 80% target. We estimated the number of daily cases in NSW at the time restrictions are relaxed by fitting our model to the case data. This may be 1890 around the projected date the 70% target is met, October 18th. In the better scenarios, no further freedoms are granted when 80% is reached, but more people become eligible for those freedoms. In these scenarios code black can be avoided but the stress on ICU and hospital capacity will be roughly double to triple what it is currently. If restrictions are relaxed further in November following the 80% target being met, NSW would face code black conditions for five weeks. In all scenarios, once restrictions are relaxed in October, a second, larger peak will occur around Christmas day. If restrictions are only relaxed in November when the 80% target is reached, the second peak occurs in January. If testing capacity remains high and contact tracing capacity can be massively scaled up, these scenarios could be mitigated. If restrictions are relaxed on October 18th, we recommend no further relaxation occur in November, to avoid code black conditions. All scenarios where restrictions are relaxed in October will result in the worst epidemic to date occurring around December 24-26th. If restrictions were relaxed only when the 80% target were reached in November, starting case numbers would be lower and this would also mitigate the epidemic and likely move the peak to January. The current discussions about "the peak" refer to an epidemic peak under current restrictions – NSW faces a second, larger peak under all scenarios where restrictions are relaxed. If restrictions are relaxed, movement restriction should not fall to low levels (below 40%). As an adjunct to relaxing increasing movement and mixing of people under the roadmap, we recommend enabling high testing capacity, maintaining masks at high level and massively scaling up rapid contact tracing capacity using digital methods to mitigate epidemic growth. Reduction in any of these will be detrimental. Stockpiling for the health system and protection of health workers are a high priority.

Background: NSW plans to relax restrictions when national vaccination targets of 70% and 80% of the eligible population 16 years and over are met. The initial premise of the planning was an epidemic of 30 cases when restrictions are lifted. However, the epidemic in NSW will result in cases in the hundreds or thousands at the time of planned relaxing of restrictions. The virus spreads between people, and when movement of people increases, so will spread of the virus, especially if large numbers of cases are present. The current strategy of mass vaccination is needed, but cannot control an epidemic that began in June when fully vaccinated rates were less than 5%. This is because the virus spreads much faster (days) than the time taken to benefit from vaccine immunity after 2 doses (2 months with a 6 week interval between doses and two weeks after the second dose to get maximal immunity).

The modelling presented here uses a published, peer reviewed COVID-19 model, and uses conservative estimates to model different possible scenarios in the NSW Roadmap to Freedom. It does not include rising case fatality rate, which would be expected if ICU capacity is exceeded. Data from 2020 shows that case fatality rises as availability of ICU beds declines. This is because when there are no ICU beds for people who require ICU, they are more likely to die. Code black is defined in NSW as the point when ICU occupancy (of COVID and non-COVID patients) is over ~900 cases on a single day. This is the point when ICU capacity is exceeded and alternative models of care (such as using operating theatres) are required.

What is modelling:

Modelling is a science used to predict future outcomes under various conditions. Infectious diseases modelling is a long-established science that is helpful for informing policy decisions in public health. Each model depends on assumptions made, and contain a range of possible scenarios. The purpose of modelling is to show worst and best case scenarios, and scenarios in-between, to inform optimal decision making. A modelled output does not present a certain future – only a possible one, and usually governments act to prevent bad scenarios when warned by modelling. For pandemic planning, it is essential to model best and worst case scenarios, so that we know our range of options, and whether existing resources for dealing with surge capacity are adequate to protect the health system. A simulated worst-case scenario helps avoid that scenario from ever occurring. The modelling below provides worst and best case scenarios under different conditions around the Roadmap to Freedom, modelled on conditions presented in the roadmap, including options for a two stage relaxing of restrictions after the 70% and 80% targets is met, or a single stage relaxing of restrictions. Vaccination alone with currently available vaccines is not enough against Delta, as we have seen in Israel, the US and the UK. In reality, a worst-case scenario may not occur, because once the health system starts failing, governments will re-introduce various public health measures to control the epidemic. So, the worst-case scenario below illustrates what would happen if we relax restrictions too rapidly or fail to improve epidemic control measures, but is only one possibility.

What does living with COVID mean for NSW?

COVID-19 is an epidemic disease, not an endemic disease, and these are important technical differences. It will not become endemic, but will continue to cause epidemics. COVID-19 will always find pockets of unvaccinated or under-vaccinated people and grow exponentially. With over 40% of the population unvaccinated, often not by their own choice (eg. children), when the 80% target for 16+ is met, the virus will spread as restrictions are lifted.

Which peak?

Talk of the "peak" occurring in September which we have heard so far refer to conditions under current restrictions. The virus spreads by finding people to infect. As we relax restrictions with substantial community transmission still occurring, the spread will increase. So the Roadmap plan will result in a second peak which occurs as freedoms return. That is what the modelling below shows. We also show the potential impact of the timing of lifting restrictions in October on the Christmas and New Year period.

Aims: To determine the required hospital and ICU capacity for a range of possible disease control scenarios and dates of lifting of restrictions for New South Wales, and to determine when "code-black" conditions may occur.

Methods: The modelling was conducted by The Biosecurity Program, The Kirby Institute, UNSW, using a published and peer reviewed COVID-19 model. Details appear at the end of this document.

Scenarios

Six scenarios were examined (Table 1), based on the modelled epidemic shown in Figure 2 (see methods), with projected cases at 1890 on October 17th 2021. Dates of lifting of restrictions were assumed to be 18 October (when the vaccination target of 70% of the 16+ is expected to be reached), to 6 November (when the vaccination target of 80% of the 16+ is expected to be reached). The current lockdown used in NSW equates to 60% movement restriction, while masks use is estimated to currently be 65% of the NSW population. We assume timely contact tracing ability (identifying and quarantining contacts within 24 hours of case identification) dropped to 20% once daily cases exceeded 600 (17 August), based on fitting of the model to observed data (see methods). Contact tracing done more than 48 hours after identifying an infected person is usually too late, as the virus has already spread. The scenarios show decreased mask use at 50% corresponding to the Roadmap (indoor mask use only), and rapid contact tracing remaining at 20% (current estimate) or increased to 50%. Scenarios 1 and 2 show movement restrictions relaxed from 60% to 46% on October 18th, with no new freedoms, but more people becoming fully vaccinated and eligible for "freedoms" by November when the 80% target is reached. Scenario 3 and 4 shows two-stage relaxing of restrictions on October 18th and November 6th, with additional freedoms granted to vaccinated people on November 6th and movement restriction dropping to 30% after that date (corresponding to the new freedoms) with and without enhanced contact tracing. Scenarios 5 and 6 shows the first relaxing of restrictions occurring on November 6, at the 80% target, but with movement restrictions dropping from 60% to 30%, with and without enhanced contact tracing. In scenario 6, enhanced contact tracing starts on October 18th, before restrictions are lifted.

Table 1: Scenarios for NSW, September 2021 to February 2022 (yellow shaded boxed indicate date of lifting of all lockdowns)

Scenarios	13 September to 17 October	18 October to 5 November	6 November – February 1
1. NSW Roadmap with single stage lifting of restrictions	Current restrictions Movement restriction 60% Mask use 65% Contact tracing 20%	First freedoms. Movement restriction 46% Mask rate 50% Contact tracing 20%	No new freedoms, but increase to 80% adults vaccinated. Movement restriction 44% (from additional vaccinated adults with freedoms) Mask rate 50% Contact tracing 20%
2. Same as scenario 1 with enhanced contact tracing	Movement restriction 60% Mask use 65% Contact tracing 20%	First freedoms. Movement restriction 46% Mask rate 50% Contact tracing 50%	No new freedoms, but increase to 80% adults vaccinated. Movement restriction 44% (from additional vaccinated adults with freedoms) Mask rate 50% Contact tracing 50%
3. NSW Road map with 2-stage lifting of restrictions at 70% and 80% targets met	Movement restriction 60% Mask use 65% Contact tracing 20%	First freedoms. Movement restriction 46% Mask rate 50% Contact tracing 20%	New freedoms when 80% adults vaccinated. Movement restriction 30% Mask rate 50% Contact tracing 20%
4. Same as scenario 3 with enhanced contact tracing	Movement restriction 60% Mask use 65% Contact tracing 20%	First freedoms. Movement restriction 46% Mask rate 50% Contact tracing 50%	New freedoms when 80% adults vaccinated. Movement restriction 30% Mask rate 50% Contact tracing 50%
5. NSW Road map with 1-stage lifting of restrictions at 80% target met	Movement restriction 60% Mask use 65% Contact tracing 20%	Movement restriction 60% Mask use 65% Contact tracing 20%	First freedoms. Movement restriction 30% Mask rate 50% Contact tracing 20%
6. Same as scenario 5 with enhanced contact tracing	Movement restriction 60% Mask use 65% Contact tracing 20%	Movement restriction 60% Mask use 65% Contact tracing 50%	First freedoms. Movement restriction 30% Mask rate 50% Contact tracing 50%

We estimated that on October 17th, just before the first freedoms are granted, there may be about 1890 daily cases in NSW. Table 2 shows the modelled scenarios to February 2022, as well as the highest daily number of people requiring hospitalisation or ICU admission at the peak. The infections include asymptomatic infection. The best scenarios do not relax restrictions further when 80% of adults are vaccinated, and some have enhanced contact tracing capacity of least 50% after reaching vaccination targets. The dates when "code black" is required and duration of code black are shown in Table 2. The worst case scenario is 3, where additional freedoms are granted after 80% of adults are vaccinated will result in prolonged code black conditions over the Christmas- New Year period. All scenarios show the second and higher peak occurring around Christmas day. If relaxing of restrictions is delayed until the 80% target is reached in November, starting case numbers would be lower and this would also move the peak to January.

The model presents optimistic scenarios, as it does not include rising case fatality when ICU care cannot be provided, and uses a mean length of stay in ICU of 7 days (when reported length is 14 days for ventilated patients). It also assumes testing capacity is optimal. If testing capacity drops, the epidemic would be worse.

Table 2: Outputs for all scenarios – red shaded reflects worst possible outcomes.

Scenarios	Number of daily cases when restrictions lifted	Total infections by February 1 2022	Total deaths by February 1 2022	Peak daily number of Hospital beds needed for COVID-19	Peak daily number of ICU beds needed (including for 300 non-COVID patients)	Date of peak ICU beds needed	"Code Black" for ICU (over 926 ICU beds needed)
1	1890	778,263	689	3144	737 (437 COVID)	24/12/21	No, but more than triple the current stress on ICU.
2	1890	576,100	470	1889	562 (262 COVID)	23/12/21	No, but double the current stress on ICU
3	1890	891,065	1169	6340	1192 (892 COVID)	26/12/21	9/12/21 to 15/1/22 (5 weeks of code black)
4	1890	905384	866	4379 (28/12/21)	905 (605 COVID)	29/12/21	27/12/21 to 1/1/22 (1 week of code black)
5	1686	1,044,603	1004	5589 (28/12/21)	968 (768 COVID)	28/12/21	24/12/21-21/1/22 (4 weeks of code black)
6	1254	867,182	714	3801 (11/1/22)	813 (513 COVID)	11/1/21	No, but more than triple the current stress on ICU.

**the numbers reflect the patients requiring hospitalisation or ICU. Whether they receive that level of care will depend on capacity. Scenarios 5 and 6 result in higher case numbers because a sudden drop from 60% restriction of movement to 30% causes a bigger surge than 1 and 2 where a greater level of movement restriction is maintained.*

The following figure shows hospital and ICU requirements over time for all scenarios. Scenario 3 is the worst case. Every scenario where restrictions are relaxed in October produces a surge of cases around Christmas day. Delaying the relaxing of restrictions will push the peak to January.

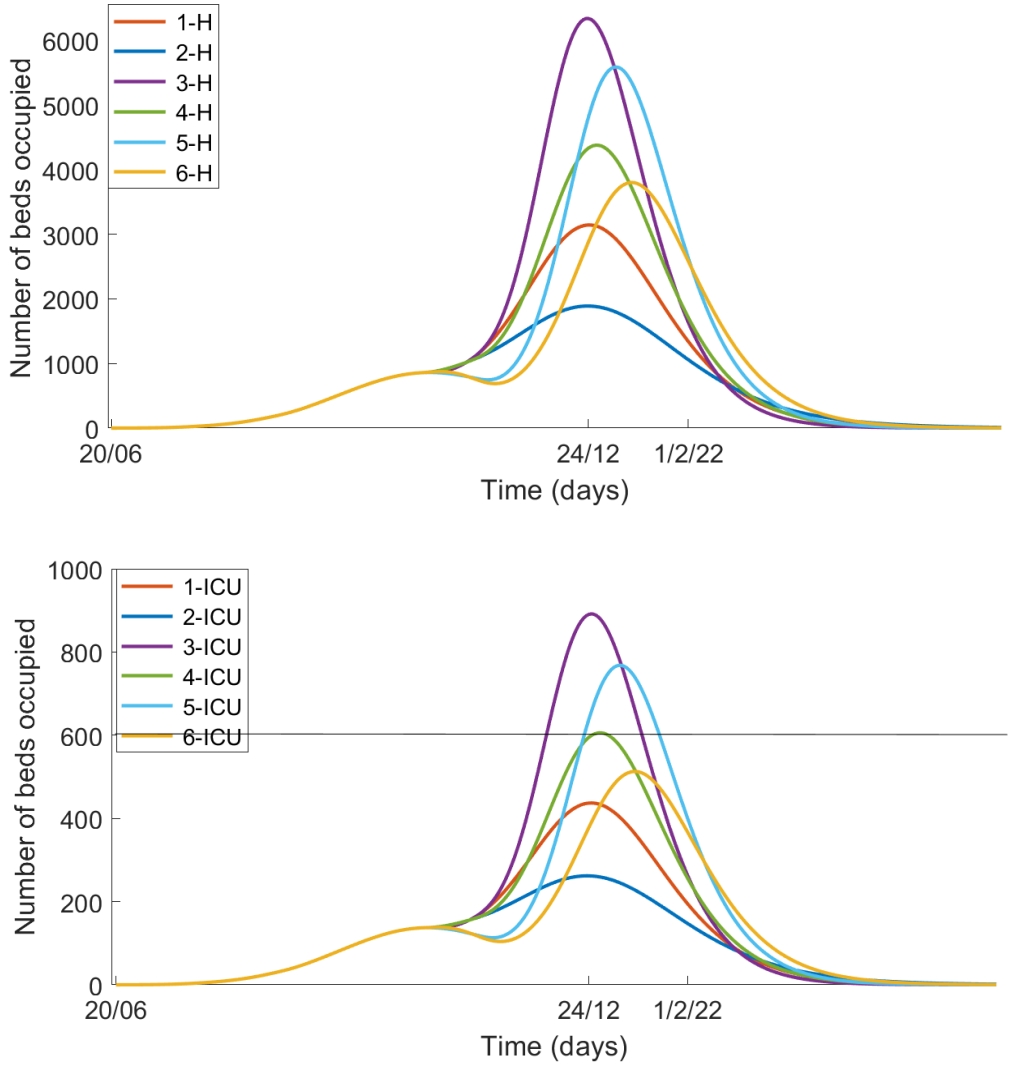

Figure 1: Surge in ICU and Hospital bed (H) requirements for six possible NSW Road Map scenarios (1-6 are scenarios outlined in Table 1). The threshold of 600 COVID-19 patients in ICU corresponds to code black, as we expect 300 non-COVID patients requiring ICU at the time.

Conclusions

The current discussion has been around "the peak" occurring during current restrictions. We show that when current restrictions are relaxed, a larger, second peak will occur that may threaten the provision of healthcare. Relaxing of restrictions while community transmission is high and a substantial proportion of the community is unvaccinated or under-vaccinated will result in a second, larger peak, because the virus will spread faster with increasing movement and mixing of people. The 70-80% targets correspond to 56-64% of the whole population, leaving a substantial proportion unprotected. If the first relaxation of restrictions occurs on October 18th, in all scenarios, a second, larger epidemic peak will occur between December 24-29th 2021. If restrictions are only relaxed on November 6 when the 80% target is met, the peak occurs later, between January 6-12th 2022 instead of around Christmas day. The worst-case scenario, with prolonged code black conditions occurs if there is a 2-stage relaxing of restrictions when the 70% and 80% targets are met. If relaxing of restrictions occurs around October 18th when the 70% target is met, we recommend that no further relaxation occurs at the 80% target in November, to avoid code black conditions. If further relaxation of restrictions occurs in November, NSW could face a prolonged period of code black conditions, with a consequent rise in death rate because standard ICU care cannot be provided. We did not model the increased deaths due to code black, so the scenarios are conservative/best case. Unfortunately, in all scenarios, substantial community transmission at the time of lifting restrictions will result in a surge in cases. All scenarios involve a reduction in mask use with freedoms, as per the Roadmap. We provide a range of scenarios that can inform the safest approach to the roadmap and choices can be made to mitigate risk. Maintaining high testing rates, scaling up contact tracing capacity and higher mask use and ensuring mixing of people does not increase substantially, would all mitigate the epidemic.

Limitations: All models have uncertainty in them. Models predict a range of possibilities under different conditions, and worst-case scenarios usually do not eventuate, because authorities use the models to inform mitigation and prevention of severe scenarios. They may also reinstate restrictions when the health system is under threat. Models also allow us to understand how different public health measures can be optimised when movement and mixing of people increases. The number of cases on the day restrictions are relaxed is one factor that determines the size of the second peak. We estimated this by fitting the model to the cases reported so far, but the actual case number on the day may not exactly match our estimate. If testing and tracing capacity is reduced further, the case numbers may be substantially higher. We assumed testing rates are constant and high in the models, but if testing capacity drops, the epidemic will be worse. We did not model slight relaxation of restrictions in September, which means our outputs are optimistic. We also under-estimated deaths by not including rising case fatality rate if ICU care cannot be provided; and we used an optimistic average length of stay in ICU, which

would under-estimate ICU requirements. The model accounts for rising vaccination rates, protection from vaccines and high vaccine protection against severe outcomes.

Methods

The model is a deterministic SEIR mathematical model of COVID-19 in NSW and is based on a published and peer-reviewed model, which provides details of the model structure and assumptions. The COVID-19 model parameters were updated for the Delta variant, including R0 of 6 and an incubation period of 5 days. The model also incorporated age-specific vaccination and vaccine protection at current rates of uptake. Vaccine effectiveness against Delta was assumed to be 31% following one dose for both vaccines, and 88% and 67% for Pfizer and AZ respectively after two doses. The vaccine effectiveness against hospitalisation, ICU and death was assumed to be >90% for both vaccines. Assumptions for face masks effectiveness were taken from a published, peer reviewed study of mask effectiveness during the Victorian second wave.

The eligible population for vaccination in NSW is 6,656,700 people. The vaccination rate was obtained from the publicly available data on first and second dose coverage over time in NSW. Based on these projections, it was estimated the eligible population (aged 16 years and over) would be 70% fully vaccinated by October 18th 2021, and 80% by November 6th 2021.

Hospitalization, ICU and deaths rates were taken from NSW data and assumed to be 12% hospitalisation rate and 2% ICU admission. Age-specific deaths rates, calculated using age-specific case incidence and adjusted for vaccination rates by age groups, with 90% protection against these outcomes for fully vaccinated people. Median length of hospital stay and ICU stay was taken from a systematic review, which estimated a mean length of stay in ICU of 7 days. This is an optimistic scenario, based on reports from NSW that intubated patients have a considerably longer length of stay.

It provides modelling of the requirements for ICU and hospital care for NSW under different vaccination scenarios to assist with planning for surge capacity in NSW and understanding the health system impact of policy decisions. The worst-case scenario involved 2-stage lifting of restrictions on October 18th and November 6th, with no further intervention as cases surge.

The model starts from the 20 June 2021, when 7 cases were reported, and runs until February 2022. Until the 17th October it is assumed the current restrictions of lockdown (60% movement/contact reduction) and masks (65% usage) remain unchanged. The starting conditions for the Roadmap (number of cases when restrictions are relaxed) was estimated by fitting the modelled epidemic to notification data.

Modelled cases were fitted to the notified data to estimate mask use, contact tracing and reduction of movement/contacts during four periods of the NSW epidemic with changing recommendations (Table 3, Figure 2). In order to model the epidemic at the time restrictions are lifted, we considered four periods prior to restrictions being lifted, based on the type and degree of restrictions being used.

Period 1, 26/06 to 8/07 – localised lockdown in greater Sydney.

Period 2, 9/07 to 17/07- extended lockdown in NSW and masks indoors

Period 3, 18/07 to 22/08 - further restrictions for LGA areas of concern

Period 4, 23/08 to 17/10 – lockdown and masks indoors and outdoors

The best fit resulted in the following estimates for percentage of people using a mask, percentage of contacts traced per case and reduction in movement/contacts because of lockdown restrictions.

Table 3: Estimates of mask use, contact tracing and movement restriction in NSW derived from fitting the model to observed data*.

	Period 1	**Period 2**	**Period 3**	**Period 4**
Period	26/06 to 8/07	9/07 to 17/07	18/07 to 22/08	23/08 to 17/10
Percentage mask use	50%	50%	50%	65%
Percentage of contacts traced within 24 hours for each case and effectively quarantined	90%	80%	40% until 16/08 then 20% following > 600 cases per day	20%
Movement restriction	50%	60%	60%	60%

*It appears there was no real overall reduction in movement/contacts between the second and third period of lockdown. This may be due to higher epidemic growth outside the LGAs with the severest lockdowns.

Figure 2 shows the model fit to data using the estimation listed in Table 3 (methods)

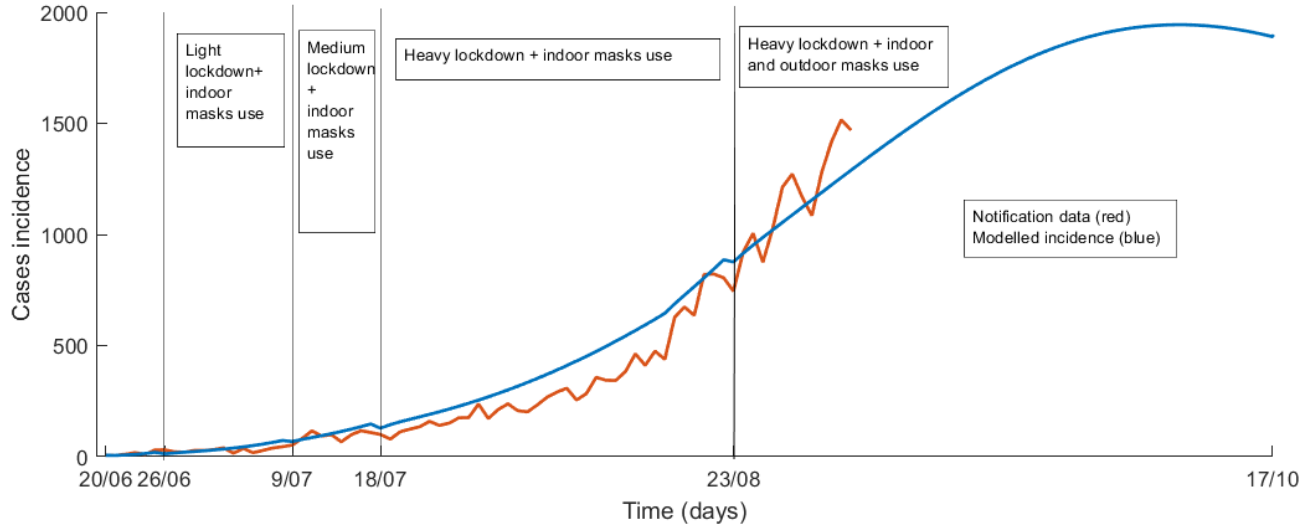

Figure 2: Modelled incidence fit to notification data from 20/06 to 4/09 end forecasted until the 17th October.