

# NCPERRC

North Carolina Preparedness and  
Emergency Response Research Center



# A Simulation Model of Local Public Health Response to Pertussis Events

<sup>1</sup>Travis Worth

Jillian Johnson

Javad Taheri, PhD.

Reha Uzsoy, PhD., P.E.

<sup>2</sup>Jean-Marie Maillard, PhD.

<sup>3</sup>Anne-Marie Meyer, PhD.

<sup>4</sup>Erika Samoff, PhD.

<sup>5</sup>Aaron Wendelboe, PhD

1. *Edward P. Fitts Department of Industrial and Systems Engineering, North Carolina State University*
2. *North Carolina Division of Public Health*
3. *Sheps Center for Health Services Research, University of North Carolina at Chapel Hill*
4. *North Carolina Center for Public Health Preparedness, Gillings School of Global Public Health*
5. *University of Oklahoma Health Sciences Center*

**NC STATE UNIVERSITY**

# NCPERCC Mission and Goals

- ***Strengthen and improve public health capacity through systems and services research***
- **Goals:**
  - Conduct research on public health preparedness systems
  - Work with North Carolina practice partners to ensure that research findings are relevant to the practice community and can be translated into practice

# Research Aims

- Engineering the North Carolina Health Alert Network
  
- Research Objective:
  - The Health Alert Network team objective is to understand and quantify response capacity to public health threats and to understand the role of NC HAN in improving response capacity

# Goal of Model

- Develop a model that can study the effects of varying levels of health alerting during a pertussis outbreak on resources within a local health department responsible for controlling and mitigating the impact of an outbreak

# Model Description

- Developed Discrete-Event Simulation model using *Arena*®
- Models the response of a local health department to a pertussis event
- Begins with an initial patient who is infected
  - The initial patient is an entity in the model who creates contacts, who in turn create their own contacts, populating the system
- Model follows the flow of contacts through becoming infectious, infecting others, seeking care and being medicated
  - Until 40 days period without symptoms
- Records data such as contact average time in system, resource utilization, number of contacts created, etc.

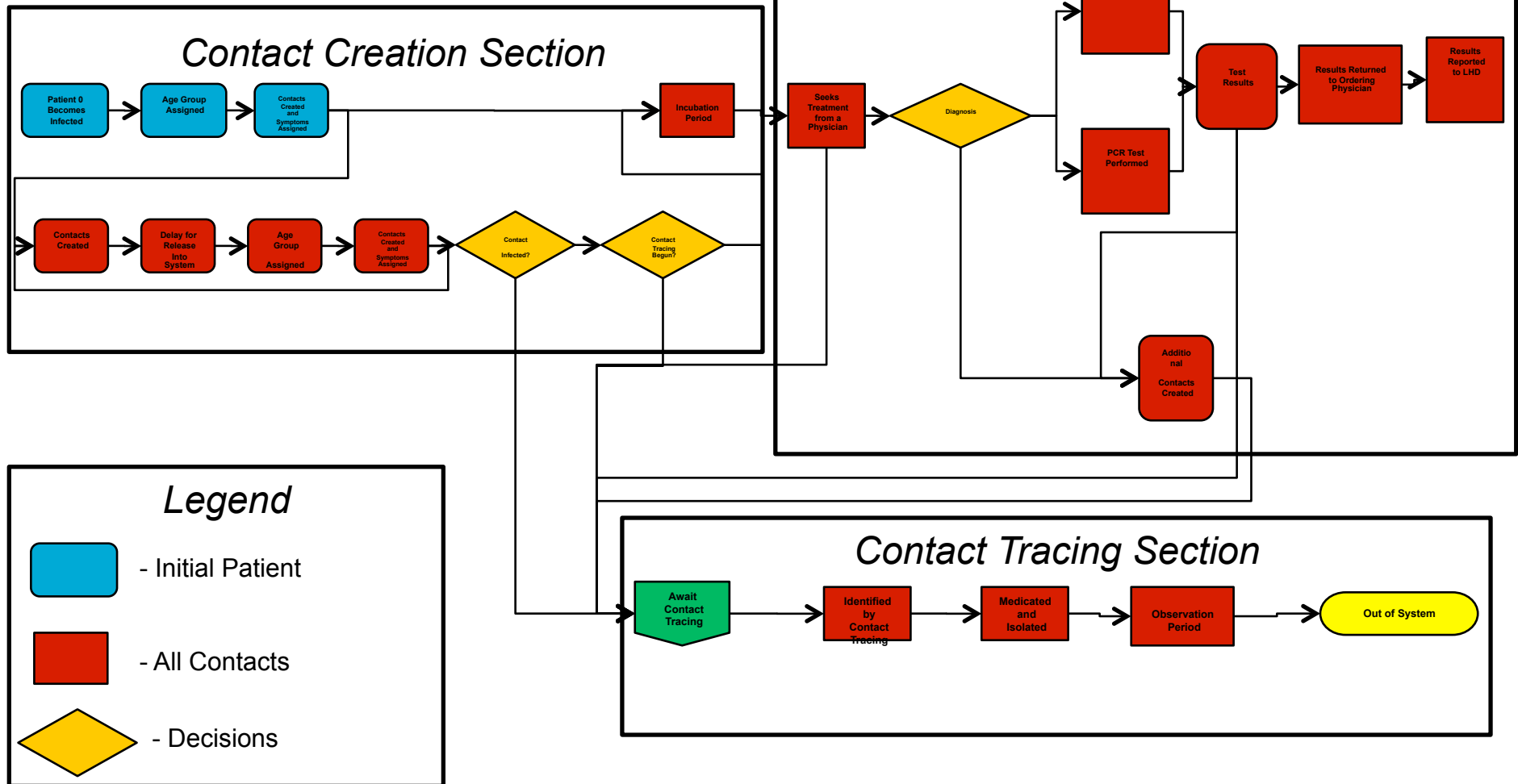
# Model Assumptions

- Simulation model is run for 100 days
- Number of contacts, symptoms, and lab results for each contact based on CDC Age groups
  - Case data obtained from NC Division of Public Health
- Incubation time period and period of communicability data obtained from *Control of Communicable Diseases Manual, 18<sup>th</sup> edition (Heymann, 2004)*
  - Period of communicability assumed at 3 weeks
- Patients have either a culture or PCR test performed

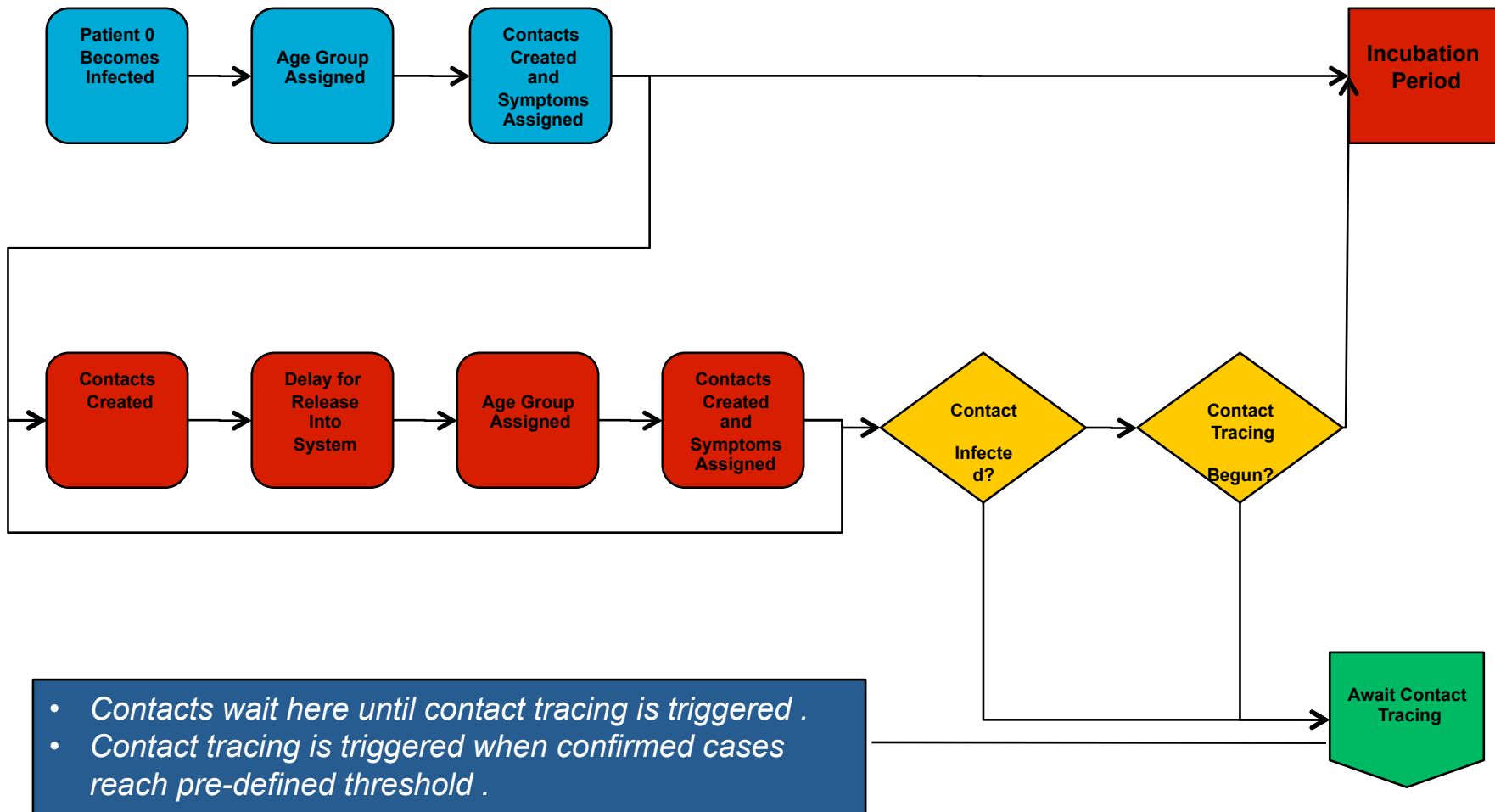
# Model Structure

- The model is composed of 3 basic segments:
  - Contact Creation Section
  - Physician Treatment, Lab Result, and Health Alert Section
  - Contact Tracing Section
- Potential for older patients (25+) to not seek medical attention even if infected
- Percentage of patients misdiagnosed
- Contact Tracing is a resource based delay
  - Takes longer with fewer resources

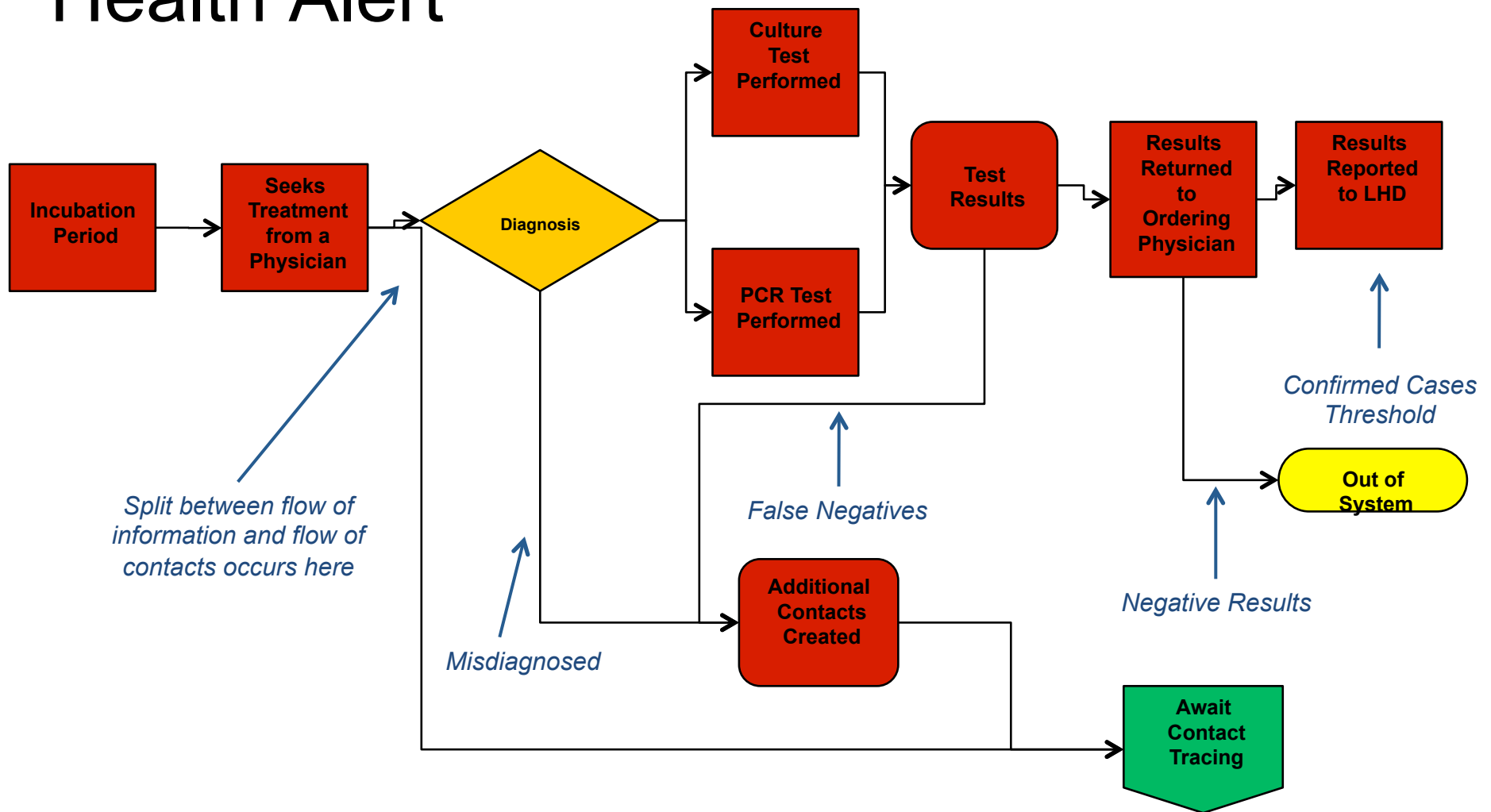
# Contact Flow



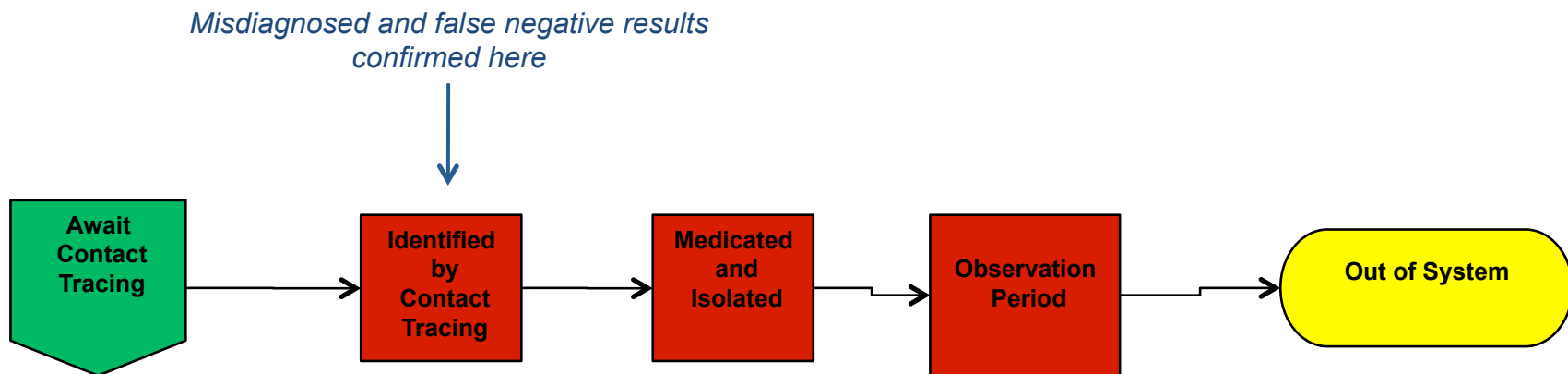
# Contact Creation



# Physician Treatment, Lab Result, and Health Alert



# Contact Tracing

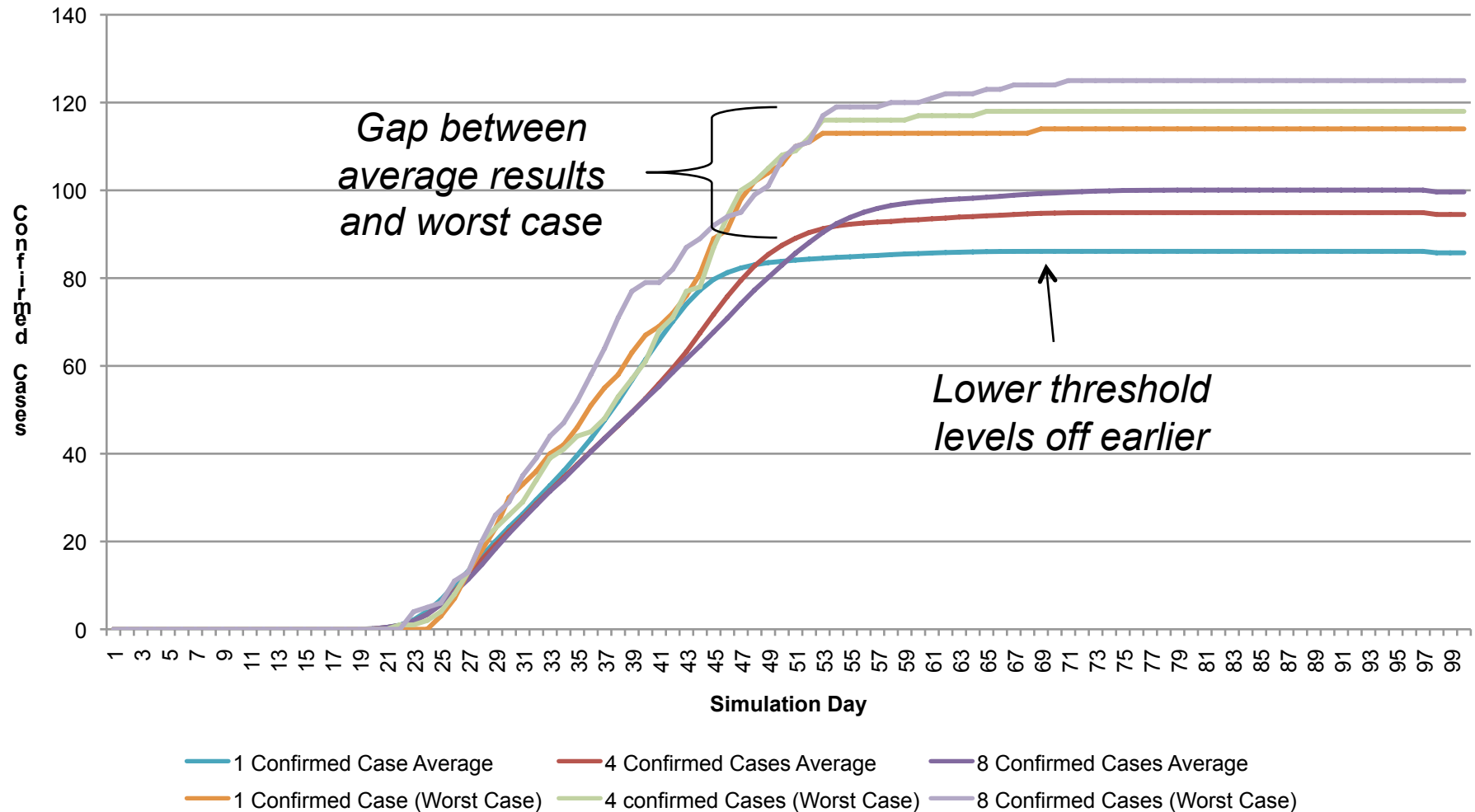


# Featured Results

- Plotted the average cumulative number of confirmed cases per day, as well the as the average number of confirmed cases per day over 255 replications
- Examine the plots of 3 different scenarios
  - Varied threshold of the number of confirmed cases required before an outbreak is determined and contact tracing begins
    - 1 confirmed case required
    - 4 confirmed cases required
    - 8 confirmed cases required
- under 4 sets of conditions:
  - Base Case – 3 CD Nurses work 24 / 7
  - 3 CD Nurses work 10/7
  - 4 CD Nurses work 10/7
  - 5 CD Nurses work 10/7

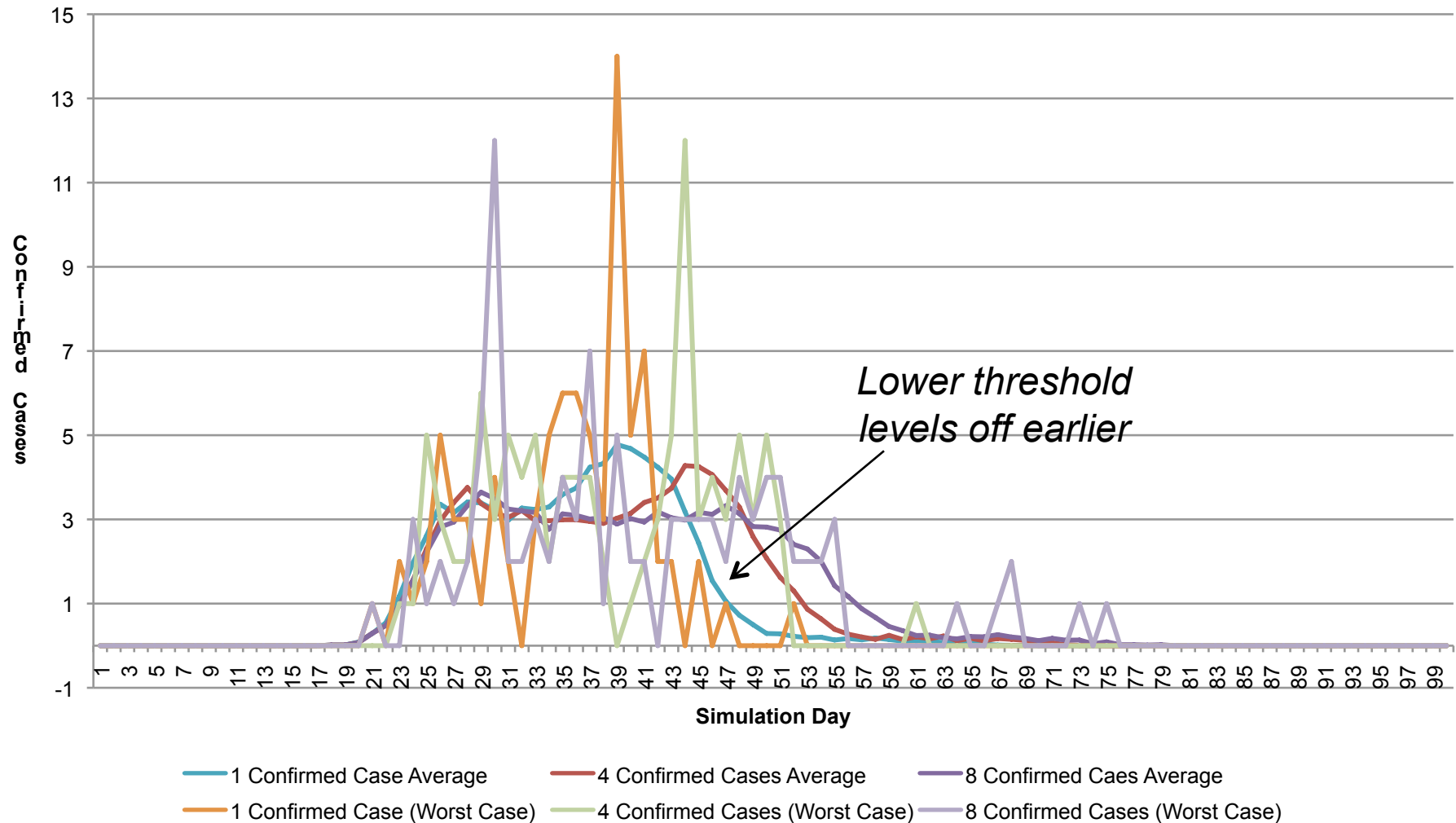
# Base Case –CD Nurses Work 24/7

*Cumulative Average and Worst Case Results (255 Replications)*



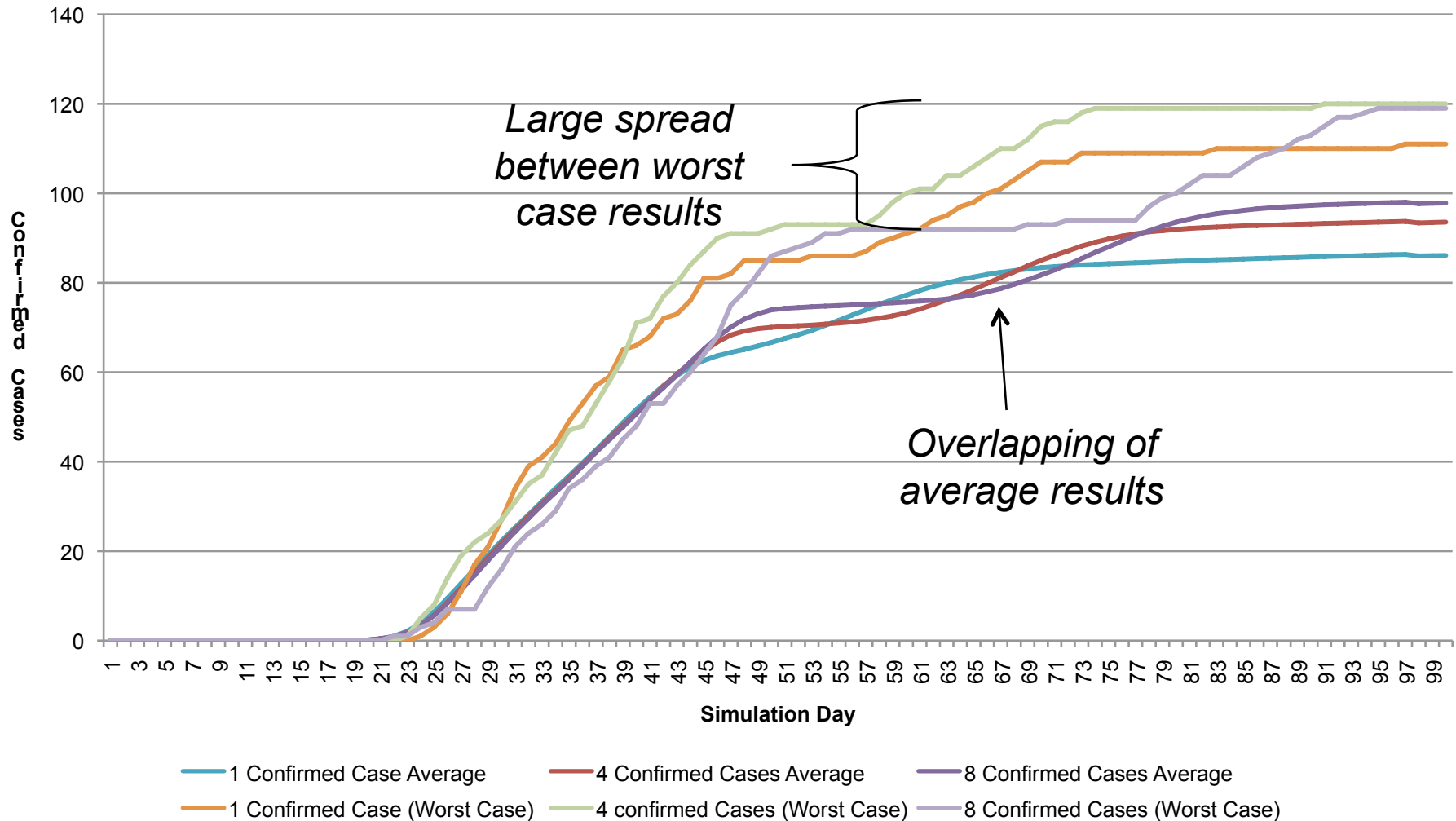
# Base Case – CD Nurses Work 24/7

Confirmed Cases Per Day Average and Worst Case Results (255 Replications)



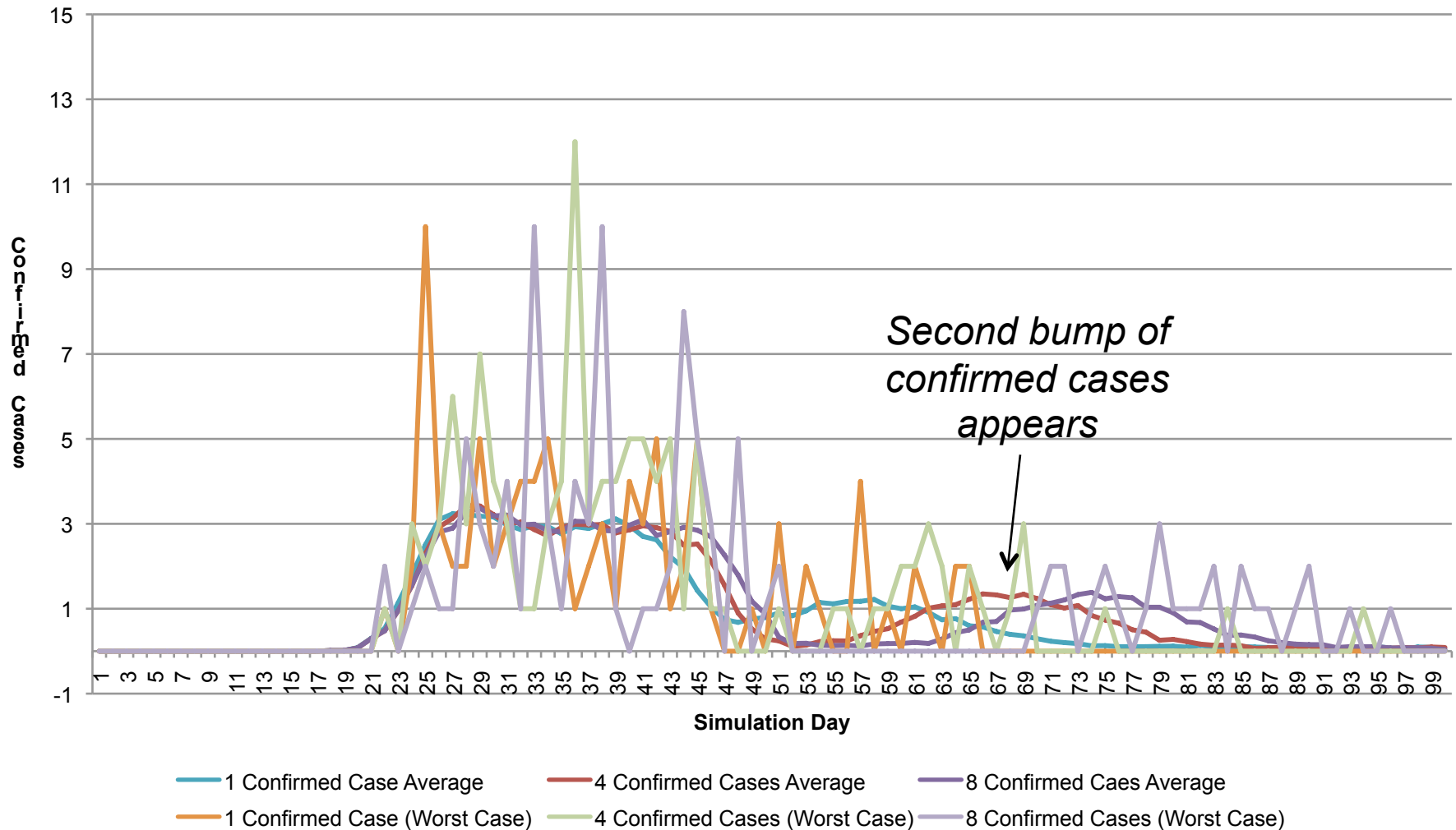
# 3 CD Nurses Work 10/7

Cumulative Average and Worst Case Results (255 Replications)



# 3 CD Nurses Work 10/7

Confirmed Cases Per Day Average and Worst Case Results (255 Replications)

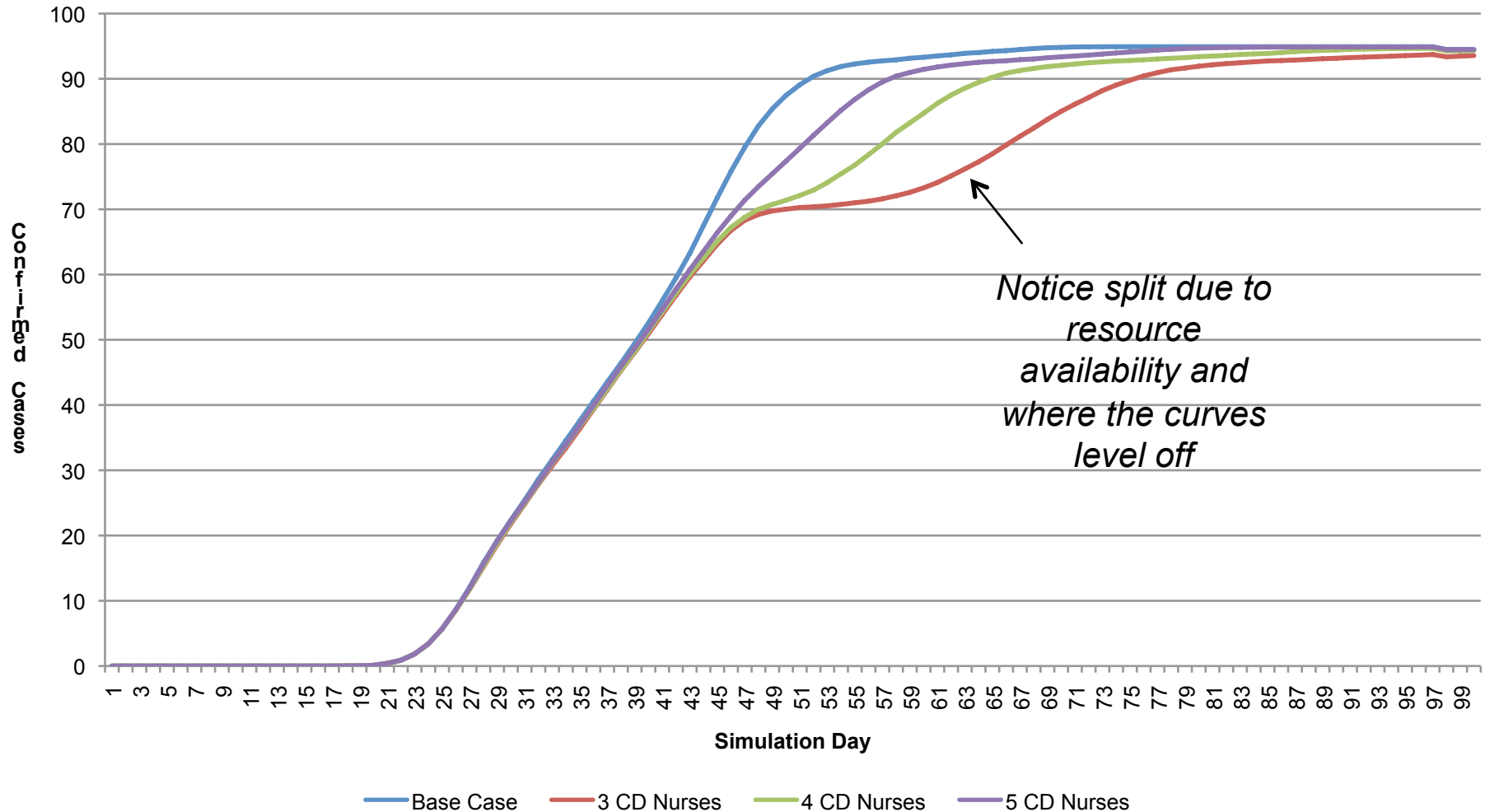


# Comparison

- Examined the resource capacity and availability constraint effects by plotting only one threshold under the 4 different conditions
- Threshold of 4 confirmed cases required for an outbreak and contact tracing to begin plotted over:
  - Base Case – 3 CD Nurses work 24/7
  - 3 CD Nurses work 10/7
  - 4 CD Nurses work 10/7
  - 5 CD Nurses work 10/7

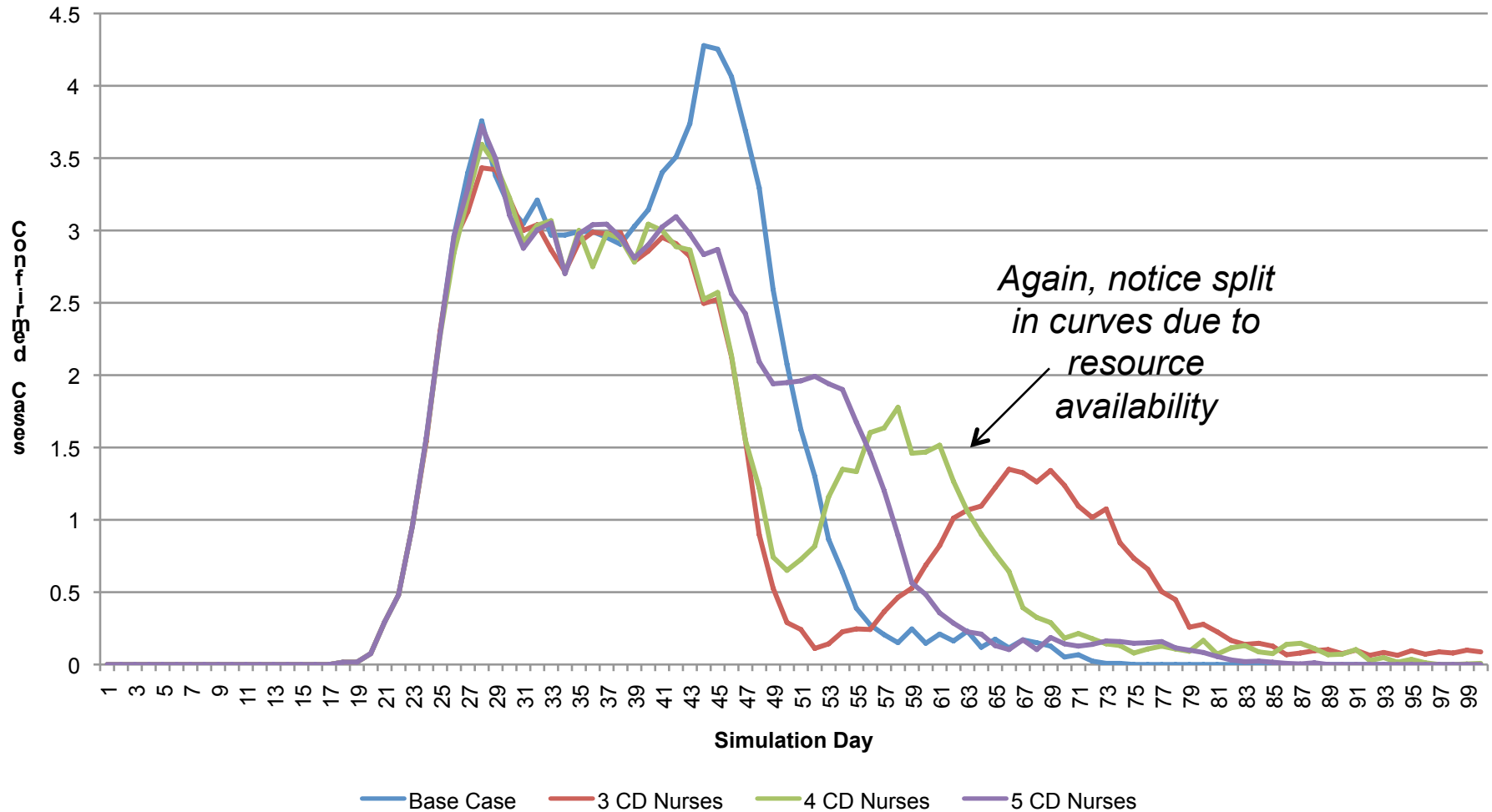
# 4 Confirmed Cases Threshold

*Cumulative Average Results (255 Replications)*



# 4 Confirmed Cases Threshold

Confirmed Cases Per Day Average Results (255 Replications)



# Conclusions

- Curves generated are promising
  - Have been shown to and validated by pertussis experts
- Initial insights
  - Lower thresholds have fewer confirmed cases and level off earlier in the simulation
  - Disease outcomes are sensitive to changes in resource availability and capacity
- Model can be used to determine the effectiveness of resources within a specific situation

# Next Steps

- Model is a work in process
  - Needs to be refined and fine tuned
  - Need more review by and input from domain experts
- Collect data from specific pertussis events to help validate the model
- Continue to examine other parameters in the model
- Incorporate NC HAN and NC EDSS information into the model to examine effects of these surveillance networks
- Eventually, consider adding other disease outbreaks to study the effects of resource levels and allocation

# Acknowledgements

- This research was carried out by the North Carolina Preparedness and Emergency Response Research Center (NCPERRC) at the University of North Carolina at Chapel Hill's Gillings School of Global Public Health and was supported by the Centers for Disease Control and Prevention (CDC) Grant 1PO1 TP 000296-02.
- The contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC. Additional information can be found at <http://nccphp.sph.unc.edu/ncperrc/>
- We also gratefully acknowledge the contributions of Meredith Davis of the NC Center for Public Health Preparedness, NC Institute for Public Health, Gillings School of Global Public Health.