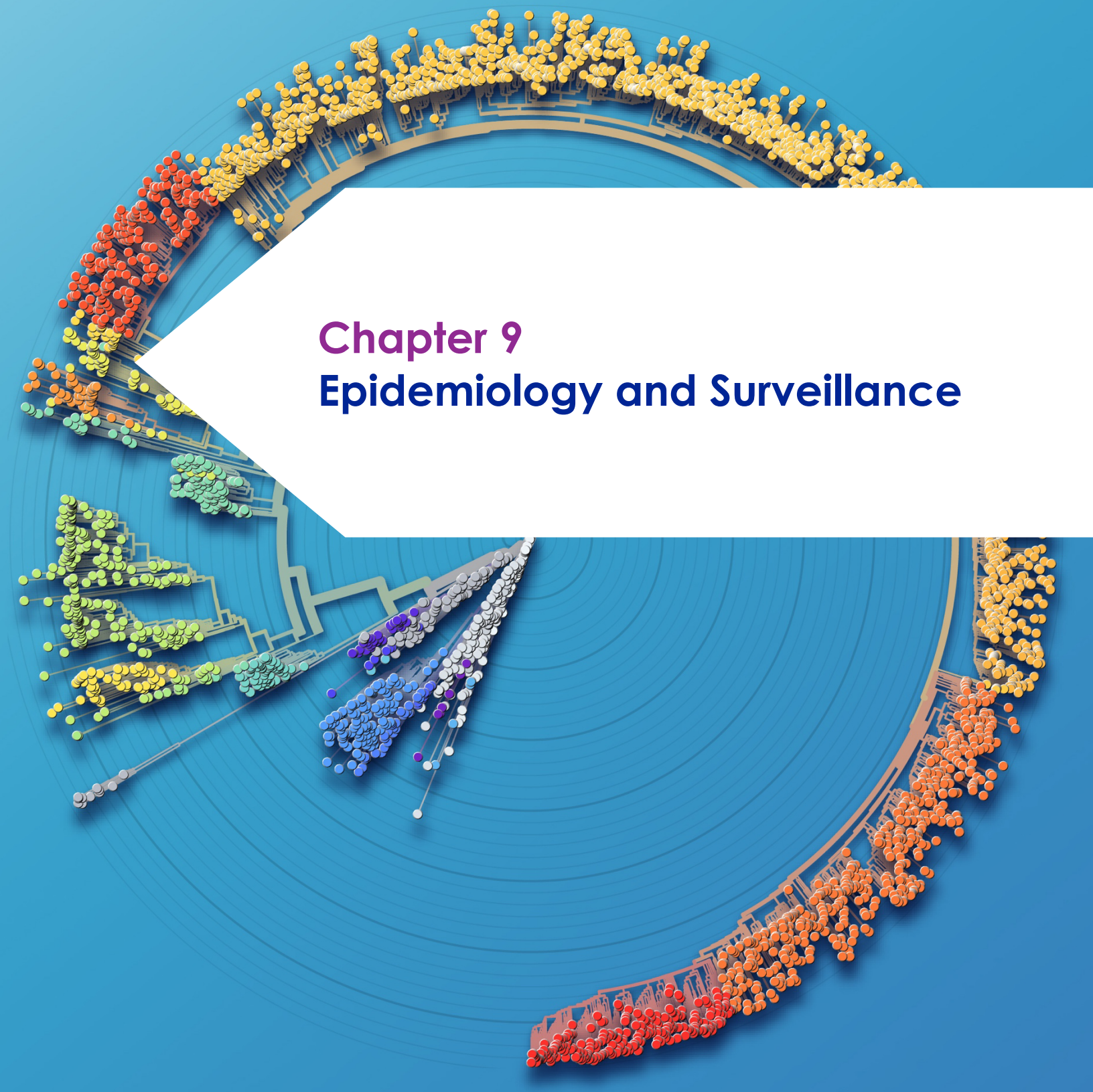

Chapter 9
Epidemiology and Surveillance

Version History

Version #	Date	Notes
0.1	10/11/2023	First Draft submitted to CPR Team
0.2	3/4/2024	Final Draft revised per Expert Review and CPR Leadership review
0.3	3/14/2024	Final Draft revised per CPR Leadership re-review
1.0	9/5/2024	Final revised per CDPH Directorate review
1.1	1/9/2025	Final rebranded

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9. Epidemiology and Surveillance

Related Public Health Emergency Preparedness and Response Capabilities: Public Health Surveillance and Epidemiological Investigation; Information Sharing.

Related CDPH AAR Chapters: Data and Reporting; Testing; Enterprise Technology.

In this chapter, some abbreviations may be used interchangeably with their respective full spellings for ease of reading.

Chapter Summary

Overview

This section provides a high-level overview of milestones and activities related to this chapter.

Within public health, epidemiology and surveillance are core functions that are closely intertwined. Epidemiology is the study and analysis of the distribution, patterns, and determinants of health and disease conditions in defined populations. It is a cornerstone of public health to inform policy decisions and evidence-based practices by identifying risk factors for diseases and preventive healthcare measures.

Surveillance, on the other hand, is operationally focused and is disease- or condition-specific. Its primary aim is to monitor trends over time, detect outbreaks, and guide immediate public health practices. While epidemiology provides the scientific basis for public health action, surveillance is the operational arm that monitors health events as they happen, enabling prompt action. Surveillance systems often generate data that is used in epidemiological studies, and findings from epidemiological studies may, in turn, inform the design and focus of surveillance systems. Since both epidemiological and surveillance rely on data, this chapter describes CDPH's collective activities in this field as epidemiological surveillance.

Within CDPH, prior to the COVID-19 pandemic, public health epidemiological surveillance work for many communicable diseases resided in the Division of Communicable Disease Control (DCDC). Within DCDC, each program devoted

to a different disease (e.g., tuberculosis or vaccine preventable diseases) had their own epidemiologists, who monitor and study these conditions.

At the start of the COVID-19 pandemic in early 2020, CDPH quickly marshalled these epidemiological and surveillance resources to better study, track, and understand the SARS-CoV-2 virus that causes COVID-19 in order to develop appropriate mitigation and response measures. CDPH redirected technical staff to the newly-formed Coronavirus Science Branch, directed laboratories (labs) across the State to report COVID-19 test results, and configured CalREDIE, its existing disease surveillance system, to process COVID-19 data.

As CDPH established traditional case reports from local health departments and laboratory-based surveillance for this new disease, many challenges quickly emerged. Testing was severely limited, CalREDIE could only collect certain types of epidemiological data, and labs struggled to report correctly. (For further discussion of these issues, see the Testing as well as the Data and Reporting chapters in this AAR). Very little was known about the virus that caused COVID-19, and CDPH leadership surmised that COVID-19 was more widespread in California than the surveillance suggested.

Consequently, CDPH began to identify and implement supplemental surveillance projects to help provide a more comprehensive epidemiological assessment of COVID-19 and its impacts. Many of these projects were conducted in partnerships with local health jurisdictions (LHJs), universities, nonprofit organizations, and private industry. Over the course of the pandemic, CDPH conducted new, innovative epidemiological and surveillance projects, developed sophisticated modeling capabilities, and improved its data streams, systems, and infrastructure—which in turn collectively enhanced its surveillance abilities. As one leader noted, "as we went along, it became evident that something was missing, or that we could see the future and knew that we needed to plan for something."

CDPH's epidemiological surveillance strategy evolved over time and adapted to changing pandemic needs. For instance, as new epidemiological questions arose, CDPH launched new surveillance projects to help provide answers. CDPH subsequently discontinued certain initiatives if the questions were resolved or if the data was no longer relevant. Other projects, such as genomic surveillance and wastewater surveillance, remain ongoing.

Additional related initiatives—data modeling and outbreak consultation—used the data derived from epidemiological surveillance to inform response

operations (for instance, to prepare for surges and response to outbreaks). In particular, data modeling became an established part of CDPH's infrastructure and has been adapted beyond COVID-19 to include other infectious disease illnesses.

Figure 1 provides a high-level overview of CDPH's major COVID-19 epidemiological surveillance projects and initiatives. With the exception of laboratory case-based surveillance (which is discussed in the Data and Reporting chapter), the various surveillance types and initiatives are discussed in this chapter.

Figure 1: COVID-19 Epidemiological Surveillance Projects and Initiatives

Surveillance Type/Initiative	Description	Main Program/ Project Name	Discussed in this chapter?
Laboratory case-based surveillance	Laboratory case-based surveillance refers to the routine collection, analysis, interpretation, and dissemination of health data, primarily based on laboratory test results.	COVID-19 cases and test results are reported to CDPH through CalREDIE and the California COVID-19 Reporting System (CCRS).	No – see the Data and Reporting Chapter in this AAR
Wastewater surveillance	Wastewater surveillance refers to the monitoring and analysis of wastewater (sewage). This type of surveillance is often employed as an early warning system for the presence of pathogens in a community and the magnitude of community disease spread.	California Surveillance of Wastewater Systems (Cal-SuWers) Network	Yes
Genomic surveillance	Genomic surveillance involves the sequencing and analysis of genomes from samples of pathogens to monitor changes, identify mutations, and understand the spread of	California SARS-CoV-2 Whole Genome Sequencing Initiative (COVIDNet)	Yes

Surveillance Type/Initiative	Description	Main Program/ Project Name	Discussed in this chapter?
	disease. Genomic surveillance is also known as whole genome sequencing (WGS). Reveals which variants are circulating within a community. Sometimes classified as a form of sentinel surveillance.		
Sero-surveillance	Sero-surveillance involves monitoring the presence (or absence) of specific antibodies in the blood serum of a population. Typically, the prevalence of specific antibodies that are indicative of past or current infections or vaccinations against infectious diseases. Provides insights into immunity levels within populations.	1. COVID-19 Active Perinatal Response to Infection (CAPRI) 2. CalScope	Yes
Sentinel surveillance	Sentinel surveillance is a targeted approach to public health monitoring where data is collected from a subset of the population (a "sentinel" group), rather than from the entire population.	California SARS-CoV-2 and Respiratory Virus Sentinel Surveillance Project (CalSRVSS)	Yes
Case-Control study	Case-Control studies are research methods used to collect data from a sample of individuals identified as cases and matched	California COVID-19 Case-Control Study	Yes

Surveillance Type/Initiative	Description	Main Program/ Project Name	Discussed in this chapter?
	controls (in this case by age, sex, and California region), to compare exposures to estimate risk factors for disease. These surveys are designed to provide insights into various aspects of the cases' characteristics, behavior, opinions, or health status compared to controls.		
Clinical surveillance	Clinical surveillance involves the review and monitoring of clinical data for specific disease conditions, populations, or variables. Clinical surveillance typically relies on clinicians, who have been trained to read medical charts.	Various, including MIS-C and long-COVID	Yes
Hospitalization surveillance	Hospitalization surveillance tracks hospital admissions and related metrics to understand trends and characteristics of severe illnesses, as well as the burden on the health care system. Monitoring the number and characteristics of hospitalized cases provides data that can be used to guide policies on mitigating surges in health care utilization.	1. California Hospital Association/Health and Human Services (CHA/HHS) Survey 2. All Facilities Letter (AFL) 21-25 reported discharge data	Yes

Surveillance Type/Initiative	Description	Main Program/ Project Name	Discussed in this chapter?
Outbreak reporting and consultation	Outbreak consultation in public health refers to the process in which experts and authorities are engaged to assess, manage, and control an outbreak of a disease.	Required outbreak reporting (Title 17, 2500 Health & Safety Code)	Yes
Data Modeling	Data modeling in public health involves the use of statistical, mathematical, or computational methods to analyze, interpret, and predict public health trends, patterns, and outcomes.	California COVID-19 Assessment Tool (CalCAT)	Yes

In June 2022, CDPH developed a COVID-19 Surveillance Roadmap, a strategic document developed by California Health and Human Services Agency (CHHS) and CDPH leadership. The Roadmap was informed by a review of CDC recommendations for surveillance, national data standards and data collection guidelines, the input of a CDPH- Local Health Jurisdiction (LHJ) workgroup, as well as meetings with LHJ communicable disease control leaders. In 2022, CDPH expanded the document to include other respiratory illnesses, and it plans to assess and update the Roadmap annually.

Timeline and Key Milestones

2020	
Winter 2019/2020	• **Mid-January:** New COVID-19 disease condition added to CalREDIE • **January – February:** Clinical, epidemiology, data, and outbreak investigation teams formed within CDPH's newly-created Coronavirus Science Branch • **January – March:** Outbreak Investigations Team began responding to outbreaks in jails, prisons, and other settings
Spring 2020	• **March 19:** Governor's Office issued Executive Order N-33-20 directing Californians to stay home • **March:** Community transmission of COVID-19 began in California • **March:** California Hospital Association and U.S. Health and Human Services (CHA/HHS) daily hospitalization survey established • **April:** CHHS created the "Lane 6" team, inaugurating dedicated COVID-19 early data modeling efforts • **April – May:** Clinical surveillance team launched several surveillance projects, including Multisystem Inflammatory Syndrome in Children (MIS-C) • **May:** CDPH began partnering with LHJs to establish outpatient community sentinel surveillance sites
Summer 2020	• **May – June:** CDPH formed partnerships to pursue genomic surveillance for COVID-19 • **June:** Modeling team launched the California COVID-19 Assessment Tool (CalCAT) • **August**: First U.S. case of reinfection was reported **August**: CDPH formed sero-surveillance team
Fall 2020	• **September – December:** CDPH formed wastewater surveillance team
2021	
Winter 2020/2021	• **Late December:** Vaccines arrived in California • **Late December – early January**: Antigen test kits first became available
Spring 2021	• **February – March:** Clinical team initiated surveillance project on long-COVID • **February:** Case-Control Study launched

	• **April:** First Wave of CalScope data collection launched
Summer 2021	• **June:** First cases of post-vaccination breakthrough infection reported (Delta variant) • **July 7:** California Code of Regulations Title 17 updated to require labs to report COVID-19 whole genome sequencing data • **Late July:** CDPH issued All-Facilities Letter (AFL) 21-25 directing hospitals to report line list discharge data
Fall 2021	• **September:** Outbreak Consultation Team (OCT) formally established • **October**: CalScope Wave 2 launched
	2022
Winter 2021/2022	• **December – February:** Omicron surge • **January:** Wastewater analysis laboratory launched at the CDPH Drinking Water and Radiation Laboratory (DWRL)
Spring 2022	• **April :** CalScope Wave 3 launched
Summer 2022	• **July:** CalScope study ended • **August**: Case-Control Study ended
Fall 2022	• **August – September**: Data modeling team hosted the first Western States Infectious Disease Modeling Symposium
	2023
Winter 2022/2023	• **February 28:** California's State of Emergency for COVID-19 ended
Summer 2023	• **June 30:** CDPH's Medical and Health Coordination Center (MHCC) deactivated from the COVID-19 pandemic response

Main Strengths and Successes

This section describes the Main Strengths and Successes, including findings and corrective actions, related to this chapter. Further elaboration and a more detailed discussion of these strengths and successes can be found in the Analysis of Activities section.

1. CDPH adapted to the changing pandemic by establishing, modifying, and demobilizing many new epidemiological surveillance projects. This provided valuable data to help inform policy and decision-making.

As CDPH navigated the complexities of pandemic response, it continually adapted its epidemiological surveillance strategies to address emerging challenges, meet new priorities, and fill data gaps. New initiatives ranged from clinical, hospitalization, and sero-surveillance projects to advanced approaches like whole genome sequencing (genomic surveillance) and wastewater surveillance. Each individual project offered a different epidemiological perspective, and Science Branch leadership evaluated the results holistically to inform decision-making. The focus of these surveillance strategies often shifted with the appearance of new COVID-19 variants, enabling CDPH to adjust its response plans effectively. Emphasizing a flexible and iterative approach, CDPH continuously assessed the utility, cost, and relevance of each project, underscoring its adaptability in the face of an evolving pandemic landscape. CDPH also developed, documented, and updated its COVID-19 and Other Respiratory Surveillance Roadmap, a strategic document that identified surveillance objectives and resources needed.

Finding/Corrective Action: In future responses, CDPH should maintain its flexible and strategic approach to epidemiological surveillance, as well as continue to maintain and update its Surveillance Roadmap *(ID: Epidemiology 1)*

2. CDPH collaborated with universities, LHJs, private industry, and others on multiple new epidemiological surveillance projects.

CDPH's ability to launch new, innovative epidemiological surveillance projects was possible due to its extensive collaborations and partnerships. On most of its projects, from wastewater surveillance to

genomic surveillance, CDPH staff partnered with University of California (UC) institutions, in addition to other academic institutions across the nation. Other partners included private companies, philanthropic organizations, public utility companies, and LHJs. Whether initiating a project due to an identified data gap (e.g., sero-surveillance) or integrating emerging academic research into a Statewide perspective (e.g., genomic surveillance), CDPH maintained a flexible approach with its partners. These partnerships were essential to CDPH's COVID-19 surveillance work. In the words of one SME, "it was a requirement to have the unique public/private partnerships, because there was no other way."

Finding/Corrective Action: CDPH should evaluate, maintain, and build on (as needed) its surveillance-related cross-sector partnerships that were developed during the COVID-19 response. *(ID: Epidemiology 2)*

3. Epidemiological surveillance team overcame significant technology and data limitations and established new data systems, tools, and processes, collected and analyzed surveillance data, and integrated datasets while preserving patient privacy and security.

At the onset of the pandemic, many epidemiological surveillance teams confronted significant technological challenges to initiate their innovative projects, as data systems and infrastructure were notably deficient. Nonetheless, through agile and strategic adaptations (often achieved via academic partnerships that granted access to software tools such as REDCap and Qualtrics) these teams successfully established new databases, tools, and processes. Among the key achievements was genomic surveillance team's successful "marriage" of genomic sequencing data with epidemiological data, a pioneering integration which optimized the State's response to outbreaks. Additionally, the Outbreak Consultation Team's dataset helped streamlined outbreak data analysis, while the clinical surveillance team's Multisystem Inflammatory Syndrome in Children (MIS-C) surveillance system (built on top of CalREDIE) emerged as a national benchmark, according to SMEs. Throughout these endeavors, an emphasis on partnerships and collaboration amplified the state's capacity for robust

genomic surveillance, while the security of protected health information remained paramount.

Finding/Corrective Action: Despite technological limitations, CDPH's epidemiological surveillance teams built innovative data systems, tools, and processes to support COVID-19 surveillance efforts that should be maintained and expanded for other communicable diseases of public health significance. *(ID: Epidemiology 3)*

4. Data modeling, outbreak consultation, and some surveillance projects incorporated equity in meaningful ways.

Equity considerations played a different role in data modeling, outbreak consultation, and surveillance efforts. Early in the pandemic response, the data modeling team integrated health equity into epidemiological workstreams and the State's overall COVID-19 response by first uncovering disparities through geo-coding data, and then successfully conveying key messages to CDPH and State leaders. Through its analysis, the team was able to "describe case rates by social advantage," revealing very early insights into the disproportionate, unequitable impact of COVID-19. The modeling team continually incorporated these messages in its communications to leadership. The contributions of the modeling team were pivotal as they established a precedent for incorporating health equity into ongoing policy conversations and response strategies. While the modeling team provided data insights that helped shape policy, other epidemiology teams worked to operationalize equity. For instance, CDPH's outbreak consultation team focused on equity by providing its services to rural LHJs who were strapped for resources, and to facilities serving the unhoused, incarcerated, and other vulnerable populations. Lastly, CDPH's sentinel surveillance project collaborated with LHJs to establish testing sites in underserved areas.

Finding/Corrective Action: CDPH's COVID-19 surveillance, outbreak, and data modeling teams successfully incorporated equity into their work in new and meaningful ways, and CDPH should continue to look for innovative ways to include equity in its public health surveillance activities. *(ID: Epidemiology 4)*

5. CDPH partnered with utilities, laboratories, local health jurisdictions and universities to establish the State's first wastewater surveillance network, which served as an "early warning" system for COVID-19.

During the COVID-19 pandemic, wastewater surveillance emerged as a new, low-cost epidemiology surveillance method to detect the virus early, including its variant strains. With funding from the CDC and State funding, CDPH enlisted multiple wastewater treatment plants across the State to create the Cal-SuWers Network. CDPH also established its own wastewater analysis laboratory in January 2022. Support for wastewater surveillance grew over the course of the pandemic, as CDPH leadership overcame initial doubts and learned of its many benefits: it is more cost-effective than testing and not dependent on test-seeking behavior or practices to monitor large populations, it can serve as an "early warning system" of surges, it can help identify new variants, and it can alert to the presence of disease that is shed in wastewater when testing is limited or under-reported.

Finding/Corrective Action: CDPH should maintain its wastewater surveillance program and expand its sites to include broad geographic representation of the State, and adapt to other relevant infectious diseases. *(ID: Epidemiology 5)*

6. With its academic and private industry partners, CDPH successfully established whole genome sequencing, a new form of epidemiological surveillance that enabled California to identify and monitor COVID-19 variants and investigate outbreaks.

In early spring 2020, CDPH explored the possibility with academic institution and private organizations to establish a whole genome sequencing program for COVID-19, which did not exist. Several months later, CDPH and its partners launched COVIDNet, which leveraged nascent technology to establish public health's first genomic surveillance program. CDPH developed an extensive infrastructure for the COVIDNet program, including staffing, a network of laboratories to source and process samples, data management systems, and a panel of experts. One of the program's key successes was successfully merging epidemiological data with sequencing data, which better positioned

the State to genomic surveillance to respond to outbreaks. In addition, COVIDNet enabled the State to identify new COVID-19 variants and determine the variants circulating in communities to help inform intervention and response strategies. Lead by CDPH, the COVIDNet program generated more than 450,000 SARS-CoV-2 genome sequences since its inception, and sequencing data contributed with 20 to 30 COVID-19 outbreak investigations. While California is still working towards using genomic surveillance to respond to outbreaks, hot spots, and concerning cases in "real-time," the establishment of genomic surveillance for public health in California was an unmitigated success.

Finding/Corrective Action: CDPH should maintain and build on its genomic surveillance program through investments in workforce, infrastructure, and technology, and consider leveraging COVIDNet for other diseases. *(ID: Epidemiology 6)*

7. CDPH used sero-surveillance projects to help understand COVID-19 infection and immunity patterns early in the pandemic response, and implemented a successful, extensive serological survey project, CalScope.

Early in the pandemic response, it became clear that testing challenges were causing cases to be drastically under-reported. CDPH initiated several sero-surveillance projects to help it better understand which population segment in California was getting infected with COVID-19 (based on the presence of antibodies in a person's blood). CDPH established a sero-surveillance team and identifying existing and new data streams for analysis. It also planned and implemented CalScope, an extensive Statewide study conducted in coordination with LHJs, universities, and private industry. Ultimately, nearly 27,000 Californians, including adults and children, completed the home-based antibody test and survey study over three waves of data collection. Over the course of the study, CDPH developed close ties with participating LHJs and collaborated with them extensively on project communications. Although CalScope proved too costly and labor-intensive to maintain long-term, the study infrastructure can be leveraged for future pandemic responses. The utility of sero-surveillance to monitor evolution of infections and immunity informed public health interventions over

time, and it was most useful early in the pandemic when testing was very limited and prior to vaccine availability.

Finding/Corrective Action: CDPH can leverage CalScope's study infrastructure and materials for future epidemiological studies and can use sero-surveillance as a supplemental surveillance strategy. *(ID: Epidemiology 7)*

8. CDPH conducted a sentinel surveillance project to monitor COVID-19 and other respiratory viruses, and worked with LHJs to establish sentinel testing sites in areas that served at-risk or underserved populations.

Early in the pandemic, the CDC provided funding for states to establish sentinel surveillance projects. In May 2020, CDPH initiated the SARS-CoV-2 and Respiratory Virus Sentinel Surveillance Project (CalSRVSS) and partnered with 11 LHJs to establish outpatient community testing sites. The CalSRVSS team focused on reaching populations that had limited access to testing; many sites served at-risk or underserved populations. The CalSRVSS team shared the on-going collected information back with participating LHJs. Ultimately, CalSRVSS produced a robust dataset that connected symptom profiles, respiratory viruses, and demographic data. Although the project was not used as much as other epidemiological surveillance projects to inform the State's COVID-19 policies, California was one of the few States to successfully establish a sentinel surveillance project and collect data for over 10,000 patients during the pandemic.

Finding/Corrective Action: The CalSRVSS project can be used as a model for future sentinel surveillance projects and could inform broader influenza and respiratory surveillance in the future. Existing respiratory surveillance (e.g. influenza) infrastructure should be leveraged early on and coordinated for future respiratory pandemics *(ID: Epidemiology 8)*

9. In partnership with the University of California, CDPH conducted a telephone-based Case-Control study that collected data on COVID-19 risk factors and interventions, which was used to inform policy development.

As part of its sentinel surveillance efforts, CDPH began planning a case-control survey towards the end of 2020. This Statewide, telephone-based

Case-Control survey aimed to collect data about COVID-19 risk factors and intervention effectiveness, with the goal of informing exposure and risk factors to develop policies and mitigation efforts. Funded by the CDC and carried out in partnership with the University of California, the California COVID-19 Case-Control Study launched in February 2021. The study aimed to answer real-world questions on vaccine effectiveness, immunity, masking utility, vaccine hesitancy, and exposure risk factors for infection. The study took approximately 18 months and enrolled over 4,700 participants. The utility and agility of the study model helped provide evidence for policy and nuanced Statewide measures. CDPH team members shared their findings with CDPH, CalHHS leadership and in peer-reviewed journals.

Finding/Corrective Action: The Case-Control Study developed for COVID-19 provides a model for successful academic collaboration and a foundation for timely implementation and results that CDPH can use as a template for future public health outbreak investigations and evaluations of public health interventions. *(ID: Epidemiology 9)*

10. CDPH's clinical team of medical officers, in addition to writing literature reviews, investigating deaths, and providing clinical guidance, conducted multiple clinical surveillance projects on specific populations and COVID-19-related conditions.

CDPH created the clinical surveillance team in March 2020 to serve as California's primary authority on clinical aspects of COVID-19. This team was comprised of approximately 10-12 physicians who served as public health medical officers. In the first half of 2020, all clinical questions related to COVID-19—including who was eligible for testing—was handled by this team. The team counted early cases and hospitalizations manually, investigated early deaths, and developed death definitions. Additionally, the team developed clinical guidance to inform policy and reporting, conducted literature reviews, and implemented multiple clinical surveillance projects, including studies of MIS-C, long-COVID, vaccine effectiveness, and COVID-19 reinfections. The clinical team also developed communications in collaboration with its in-house communications specialists. According to SMEs, many of its surveillance projects, including MIS-C and long-COVID, constitute

significant successes, and are considered exemplary in comparison to other states.

Finding/Corrective Action: CDPH should continue to fund and support clinical surveillance projects of COVID-19 (and other diseases) as part of its overall surveillance strategy. *(ID: Epidemiology 10)*

11. Hospitalization surveillance improved significantly over the pandemic, due in part to team collaboration as well as improvements in informatics team staffing and technology.

Despite initial challenges in navigating data interpretation of hospitalization surveillance data, CDPH staff and contractors effectively collaborated to establish, process, and refine several key data streams. Through cross-training, consultation with CHCQ, and the inclusion of external experts, informatics specialists and epidemiologists managed and answered questions on hospitalization surveillance data. In 2021, when the team launched a new hospitalization data stream of line-list discharge data, it also collaborated with large counties to tap into existing systems and avoid duplicate work. CDPH's technological advancements over the course of the pandemic, including adding a data warehouse, facilitated these collaborative efforts and enabled teams to receive, process, and share hospitalization surveillance data. Overall, the team's robust collaborations, enriched by external expertise and advanced technology, were instrumental in overcoming initial challenges and achieving success.

Finding/Corrective Action: CDPH should maintain its hospitalization surveillance team and infrastructure created during the COVID-19 response, so it can be adapted or leverage for other reportable diseases and future responses. *(ID: Epidemiology 11)*

12. The Outbreak Consultation Team provided technical assistance, outbreak consultations, and ventilation consultations to LHJs, while collaborating with internal and State partners to break down siloes and build LHJ's capacity for outbreak response.

As part of its initial response to the COVID-19 pandemic, CDPH established an Outbreak Investigations Team in early 2020. This initial team of rotating, redirected staff struggled to function effectively. Based on lessons learned from this experience, CDPH established the more

formal Outbreak Consultation Team (OCT) in Fall 2021. This team was composed of dedicated, full-time staff members, including medical officers, epidemiologists, industrial hygienists, health educators, and administrative personnel. They provided technical assistance and consultation to LHJs and other State partners on outbreaks in non-health-care settings, including correctional facilities, schools, and homeless shelters. Over the course of the next year, the team provided 116 outbreak consultations to LHJs and 23 industrial hygienist site visits focused on ventilation consultation. The team collaborated extensively with other CDPH programs, and helped bolster communication between CDPH's sequencing laboratory and LHJs so that sequencing data flowed to the right stakeholders in a timely manner. The team also created three unique toolkits to assist LHJs with outbreak management in different environments, built LHJ's capacity to deal with multi-jurisdictional outbreaks, and helped LHJs access the different State pandemic resources.

Finding/Corrective Action: The infrastructure, resources, and processes created by the Outbreak Consultation Team can be leveraged in future pandemic responses and for other disease conditions. Development of an Incident Command System (ICS) structure specific to outbreak consultations should be created based on this response to inform future pandemics and epidemics *(ID: Epidemiology 12)*

13. Over the course of the pandemic, CDPH initiated and organized a successful data modeling team. The modeling team's forecasts and models quickly became critical information used by CDPH and State leadership in the pandemic response.

Before the pandemic, CDPH lacked coordinated data modeling capabilities. In early 2020, CDPH epidemiologists started adapting flu models for COVID-19 and began collaborating with private sector data scientists and academic partners on an early model that could help predict case trends. Over the next half year, CDPH continued to invest in its data modeling team, infrastructure, and technology. With the establishment of a new Data Modeling Section in Fall 2020, the 10-person data modeling began to refine its models, deepen external collaborations, and establish its reputation. Gaining recognition in a national modeling network, in 2021 the team established a joint COVID-

19 Modeling Consortium in partnership with the University of California, and in 2022 it organized the inaugural Western States Infectious Disease Modeling Symposium. Overall, data modeling in public health grew from nonexistence into an established, well-respected program over the course of the pandemic, and has gained significant acceptance in California's public health policy for its ability to forecast disease trends. One leader emphasized the importance of maintaining this expertise for ongoing disease control and prevention as well as quicker implementation in future infectious disease emergencies and pandemics. This team was also utilized to inform mpox projections during the summer 2022 mpox emergency.

Finding/Corrective Action: CDPH should maintain its data modeling capability so that modeling can be utilized for other infectious disease trends and projections, and implemented earlier during the next infectious disease response. *(ID: Epidemiology 13)*

Main Challenges and Lessons Learned

This section describes the Main Challenges and Lessons Learned, including findings and corrective actions, related to this chapter. Further elaboration and a more detailed discussion of these challenges and lessons learned can be found in the Analysis of Activities section.

14. CDPH struggled to develop sustainable, timely, and representative surveillance data streams.

CDPH's COVID-19 epidemiological surveillance strategy grappled with its legacy inflexible and outdated surveillance system and gateways, and had difficulty identifying and receiving surveillance data streams that were timely, representative, and sustainable. Many project-based data streams were specific to particular populations, which resulted in biased data. Other data streams had inherent delays, or others were too costly and labor-intensive to sustain long-term. As one SME noted, "some were representative but not timely, and some were timely but not representative." For future responses, teams noted that a "key takeaway" was to think strategically about—and invest in—epidemiological sustainable, timely, and representative data streams.

Finding/Corrective Action: CDPH should update its core surveillance system and informatics capacities to allow for improved ongoing disease surveillance and increased adaptability for future public health emergencies. CDPH surveillance strategies and systems should meet its three main surveillance criteria: timeliness, representativeness, and sustainability. *(ID: Epidemiology 14)*

15. Epidemiology teams were sometimes rushed to deliver results quickly.

The unparalleled scale and visibility of the COVID-19 response presented CDPH with public scrutiny to deliver timely information, particularly epidemiological insights. CDPH launched many epidemiological surveillance projects, not all of which were immediately useful for the pandemic response. While it is impossible to identify in advance which projects will be most valuable, SMEs emphasized the importance of slowing down and thinking strategically and comprehensively to plan and implement surveillance projects. It would have been helpful for CDPH's epidemiological and data teams to have adequate staffing

and technology to allow senior epidemiologists the space needed for more thoughtful, less reactive work focused on strategy rather than the pandemic experience focusing on data processing and troubleshooting when data receipt and quality issues continued to arise.

Finding/Corrective Action: In future responses, CDPH should have adequate epidemiology and informatics staffing and technology to allow epidemiology teams the time to work more strategically and less reactively. *(ID: Epidemiology 15)*

16. CDPH's epidemiological surveillance projects lacked robust data and technology infrastructure, especially early in the pandemic.

The lack of robust data systems and technology infrastructure severely impeded CDPH's epidemiological surveillance during the early stages of the pandemic. Surveillance teams universally encountered technology challenges, especially as they embarked on novel projects. Such ventures often demanded the design of new databases, tools, and processes. The majority opinion among SMEs was that the existing outdated data and technology infrastructure was a major barrier to surveillance data collection and analysis. To navigate these hurdles, teams created data infrastructures from scratch or on an "ad hoc" basis in collaboration with academic and private entities. For example, several teams relied on university and private partners to access software tools like REDCap and Qualtrics. While these collaborations were successful, SMEs identified the need for CDPH to have direct access to these tools.

Finding/Corrective Action: CDPH should continue to invest in its technology modernization efforts, including granting teams access to needed analytical software like REDCap, Qualtrics, and similar tools. *(ID: Epidemiology 16)*

See the related finding *Data and Reporting – 9* in the Data and Reporting chapter in this AAR and the related finding *Enterprise Tech – 5* in the Enterprise Technology chapter in this AAR.

17. Epidemiology and surveillance teams faced numerous staffing challenges throughout the pandemic, including burnout, hiring delays, and rigid hiring and funding constraints.

During the response' early stages, epidemiology and surveillance response teams primarily consisted of staff from CDPH's Infectious Disease and Immunization Branches. As the situation intensified, more staff were redirected from CDPH's diverse programs to the newly-formed Coronavirus Science Branch. Not all staff had an infectious disease background, which led to communication and coordination challenges across epidemiological, surveillance, and outbreak consultation teams. As CDPH launched its surveillance projects, the project teams experienced a wide array of staffing challenges. For instance, the wastewater surveillance team faced staffing difficulties due to federal funding constraints and rigid State hiring guidelines, while the genomic surveillance team was frustrated by the slow pace of resource onboarding and mobilization. CDPH's medical officers (who formed the clinical surveillance team) reported they were consistently overworked, resulting in burnout and low morale. The consultation team lacked staff who were trained in conducting field investigations and patient interviews, due to a recent discontinuation of a communicable disease job series. Only the sero-surveillance team reported no staffing challenges; through a partnership with a contractor, the team was able to scale rapidly and successfully.

Finding/Corrective Action: In future pandemic responses, CDPH should anticipate and plan for likely staffing-related challenges by expediting hiring and onboarding processes, implementing measures to prevent responder burnout, and working with human resources, State leadership, and partners to temporarily waive funding and hiring restrictions. *(ID: Epidemiology 17)*

Finding/Corrective Action: CDPH should collaborate with CalHR and attempt to reestablish a Communicable Disease job series and State classification, in order to hire staff with the appropriate knowledge, skills, and abilities. *(ID: Epidemiology 18)*

See the related findings *Data and Reporting – 19, 20, and 21* in the Data and Reporting chapter, and *Infection Prevention – 8* in the Infection Prevention chapter.

18. Epidemiology and surveillance teams experienced challenges when communicating with CDPH leadership, ranging from a lack of guidance to uncoordinated and duplicative requests for information.

CDPH's epidemiology teams faced numerous internal communication challenges during the surveillance efforts. Researchers on CDPH's sentinel surveillance projects (CalSRVSS and the Case-Control Study), indicated they struggled with a lack of transparency, direction, and communication from leadership, which led them to doubt their relevance and role within the broader response. Teams expressed uncertainty regarding the value of their work and a lack of direction regarding how to best share data with leadership, a process that was "opaque" and "cryptic," according to some SMEs. Other teams, such as the clinical surveillance team, said they were overwhelmed by a continuous flow of information requests from CDPH leadership; these requests were often duplicative and uncoordinated, and led to inefficiencies and confusion. The wastewater and genomic surveillance teams recall that they spent considerable effort in explaining and conveying the utility and intricacies of their surveillance projects to CDPH leadership. Overall, these experiences underscored a pervasive leadership communication gap from multiple teams.

Finding/Corrective Action: CDPH should develop and implement a more standardized ICS epidemiology and surveillance structure to improve communications and clarity of coordination and decision-making authority between and across multiple surveillance projects. This structure would clarify the process for information-sharing, the development of the surveillance strategy, and explain how individual projects fit into the overall response surveillance strategy. *(ID: Epidemiology 19)*

See the related finding *Data and Reporting – 22* in the Data and Reporting chapter in this AAR.

19. Sero-surveillance data proved less useful than other COVID-19 surveillance projects, as it was not as timely, less representative, and increasingly difficult to interpret.

The various sero-surveillance data streams established by CDPH had their own limitations and varying degrees of utility for the COVID-19

response. Ultimately, CDPH found that sero-surveillance was not as useful as other surveillance methods to help inform its COVID-19 response strategy. In contrast to other projects (e.g., wastewater surveillance and data modeling) that could be used to predict and anticipate case trends, sero-surveillance data was less timely, less representative, and became more difficult to interpret over time. The timeliness issues inherent to sero-surveillance were exacerbated by contracting delays in the roll-out of CalScope (CDPH's major sero-survey), which ultimately made the study more of a review of previous surges.

Finding/Corrective Action: CDPH should continue to monitor and evaluate and prioritize the implementation of sero-surveillance as part of its overall surveillance strategy for COVID-19 and other future diseases. *(ID: Epidemiology 20)*

20. The clinical team encountered challenges in working with the coroner system on death surveillance.

Early in the response, CDPH's clinical team encountered formidable challenges in investigating pediatric and other deaths, particularly with county coroners. There was no easy way for public health officials to access coroners' information systems, so clinicians had to call coroners offices every week to obtain updates on deaths. Many early deaths were classified as "pending" because high death volumes had created backlogs in the morgues. As a result, death surveillance and investigations were delayed. The cumbersome and often slow determination of death certificates (which sometimes took up to six month) underscored the importance of addressing and overcoming these challenges between the public health system and the coroner system.

Finding/Corrective Action: CDPH should collaborate with the coroner system to promote improved, more timely coordination regarding death investigations in preparation for the next pandemic response. *(ID: Epidemiology 21)*

21. Early in the response, the clinical surveillance team was frequently diverted to develop guidance and conduct literature reviews, which were often inefficient and not aligned with leadership needs.

CDPH's clinical team faced multiple challenges to disseminate COVID-19 guidance and conduct literature reviews early in the pandemic. The State's lengthy approval process significantly delayed the release of important guidance documents, rendering some of them either obsolete or less useful by the time they were approved. In addition, the clinical team was tasked with conducting time-consuming (and sometimes retrospective) literature reviews to inform State policy decisions. However, these reviews were often misaligned with the needs of State leadership, either in format or timing. The literature reviews also disrupted the clinical team's longer-term COVID-19 surveillance projects, and most of the reviews could have been conducted by specialists without a medical degree. As a result, the team was not always efficiently utilized. Ultimately, the clinical team's work on developing guidance and conducting literature reviews was frequently misaligned and inefficient, and revealed communication gaps between response teams, CDPH leadership, and State leadership.

Finding/Corrective Action: In future responses, CDPH should consider augmenting its clinical team with dedicated support staff to help with conducting literature reviews, utilize a clear ICS structure for developing and approving clinical and public health guidance, or explore other solutions so that resources and staffing for clinical surveillance projects are balanced with other response needs. *(ID: Epidemiology 22)*

22. CDPH's Outbreak Investigations Team suffered from using rotating, redirected staff and from a lack of bench depth. It was not until Fall 2021 that CDPH established a permanent Outbreak Consultation Team comprised of dedicated, full-time staff.

For the first 18 months the pandemic, CDPH's Outbreak Investigations Team experienced numerous challenges. The team was composed of high-level redirected staff, many of whom lacked infectious disease and interviewing experience. This was partially the result of the discontinuation of a communicable disease-focused job classification, which occurred before the pandemic. After this job was discontinued,

the number of CDPH staff who had experience in case investigations and in-person patient interviews declined, leading to a lack of "bench depth" in these areas, which are critical to outbreak response. In addition, the team suffered from the inconsistencies associated with a rotational, redirected staffing approach: sixteen people cycled through the team, which made it difficult to consistently follow-up on outbreaks. The team was initially "dysfunctional," one SME noted. In response to these challenges, CDPH eventually established a dedicated, permanent Outbreak Consultation Team, which incorporated these lessons learned. However, this did not occur until Fall 2021. Many SMEs agreed that such a team must be in place much earlier given the LHJs' need for outbreak support.

Finding/Corrective Action: Leveraging the infrastructure build during COVID-19, CDPH should establish an Outbreak Consultation Team much earlier during the next pandemic response, and ensure a minimum number of months redirection to allow for adequate training and continuity for this and similar teams. *(ID: Epidemiology 23)*

23. CDPH lacks authority to electronically collect hospital activity data and electronic patient records in real-time. This hinders the State's clinical, hospitalization, and death surveillance capabilities.

During the COVID-19 pandemic, CDPH faced challenges in hospitalization and clinical surveillance. Within CDPH, CHCQ is responsible to regulate California's hospitals and for all licensing, enforcement, and citation activities. Due to its limited authority and capacity, CDPH initially relied upon a federal survey for hospital data, and on contractors to interpret that data. Eventually, CDPH initiated a California-specific hospital survey that supplemented the federal admissions data with more detailed, line-list discharge data. Concurrently, CHCQ shifted from facility enforcement to facility support during the pandemic.

The clinical surveillance team, which counted cases, hospitalizations, and deaths early in the pandemic response, painstakingly collected patient data directly from providers and coroners via fax and phone. They manually reviewed medical charts and often struggled to obtain data, especially from coroners.

SMEs on both the clinical and hospitalization surveillance teams agreed on the need for a long-term solution to replace manual chart review and hand-completed surveys. For a long-term solution, many experts suggested leveraging automated Electronic Health Record (EHR) data, which would require new legislation to address data privacy and data quality. SMEs noted that CDPH, Emergency Medical Services Authority (EMSA), and/or Department of Health Care Access and Information (HCAI) as possible sponsors for this initiative. The consensus was that a more robust, automated clinical and hospitalization surveillance system is essential for effective public health emergency response.

Finding/Corrective Action: The State should explore legislative solutions to authorize it to strategically improve its hospitalization surveillance capabilities, potentially through anonymized, secure sharing of EHR data. *(ID: Epidemiology 24)*

See related finding *Data and Reporting – 23* in the Data and Reporting chapter of this AAR.

24. Data modeling findings to inform the early COVID-19 response were initially hard to obtain and apply in a timely manner.

CDPH's data modeling team was initially challenged due to data quality, lack of coordination, and limited expertise in specialized modeling. Before the COVID-19 pandemic, CDPH primarily outsourced its data modeling and had limited internal capabilities. Building an in-house team was hampered by limited data availability and CDPH's technology infrastructure. Various other challenges, including CalHHS' early creation of a similar team known as "Lane 6," further complicated the modeling process and caused some confusion. Additionally, technology systems to improve data streams were not yet in place, making it difficult to align the modeling team's ambitions with reality. CDPH eventually established a new Modeling Section, reduced organizational siloes, and drastically improved its data systems. According to one leader, when it came to using data modeling for policy decisions, "it took a long time to get initial information from the modeling team that would have been helpful earlier in the process."

Finding/Corrective Action: CDPH should maintain its data modeling infrastructure so the team can deliver useful products earlier in the next emergency response. *(ID: Epidemiology 25)*

Analysis of Activities

This section elaborates and provides more detail on the findings, corrective actions, and lessons learned that are presented in the Main Strengths and Successes and the Main Challenges and Lessons Learned sections. This section is organized into the following topics:

- Overall Epidemiology and Surveillance Approach
- Wastewater Surveillance
- Genomic surveillance
- Sero-Surveillance
- Sentinel Surveillance
- Clinical Surveillance
- Hospital Surveillance
- Outbreak Consultation
- Data Modeling

Overall Epidemiology and Surveillance Approach

Early in the Pandemic Response, CDPH Created the Coronavirus Science Branch

- In early 2020, CDPH quickly established clinical, epidemiology, data, and outbreak teams within the newly-created Coronavirus Science Branch, housed within CDPH's Center for Infectious Diseases (CID). The staff on these mainly technical teams were redirected from other CID programs, including the Immunization Branch (IZB). Early on, there was frequent overlap between teams responsible for epidemiological, outbreak, clinical, and modeling work, due in part to a rotational, redirected staffing approach as well as a lack of centralization and structure. Cumulatively, over 200 staff worked on these related efforts. Over time, however, CDPH delineated these teams and workstreams.
- Initially, when very little was known about the virus that caused COVID-19 or how it was transmitted, the Coronavirus Science Branch focused on outbreak investigations. Outbreaks are typically defined by places and time. CDPH's early epidemiological work focused on investigating the first outbreaks in California's skilled nursing facilities (SNFs). When community transmission of COVID-19 began in California in March 2020, CDPH's response strategy shifted towards surveillance, while continuing to investigate and respond to outbreaks.

- At the time, one of the main epidemiological challenges related to case finding was limited testing capacity and the resulting lack of data. In early spring 2020, the CDC controlled the limited testing available. According to one leader, California was only testing individuals for COVID-19 who met a very narrow case definition: individuals who had either been to Wuhan, were hospitalized, or were very ill. As a result, the SME noted, "we just missed a lot of cases in the beginning and didn't fully understand the clinical epidemiology of this virus, because we were only testing a very small subset of people." (For more information see the Testing chapter in this AAR.)
- California focused on ramping up its testing capacity in late spring and early summer 2020. CDPH, worked with the many new laboratories who began offering COVID-19 testing to help them report correctly. At this stage, CDPH was working on getting its "regular lab-based and case-based surveillance going," according to one SME. However, gaps in these and other data streams became evident very quickly: testing data was likely incomplete. Not all individuals who were sick were getting tested, and labs were struggling to report correctly. Other surveillance gaps quickly emerged—for instance, it became clear that California's hospitalization surveillance was inadequate, leaving CDPH and State leadership with little insight into the status of the State's hospitals. (For a discussion of laboratory case-based surveillance, see the Data and Reporting chapter in this AAR.)

CDPH Launched Multiple New, Innovative Epidemiological Surveillance Projects

- As CDPH became aware of these surveillance gaps, it moved to fill them by introducing new epidemiological and surveillance projects. These epidemiological surveillance projects included a new hospitalization surveillance project, a sero-surveillance project, and many others. While some projects filled a gap, others proactively addressed a future need. As the pandemic response evolved, CDPH continued to adapt its surveillance strategy by launching new initiatives, including genomic surveillance (whole genome sequencing), wastewater surveillance, and others. "As we went along, different components were added to fill a gap, or to give more context to the whole of what was happening," one leader noted.

- These different surveillance projects each offered slightly different scientific lenses, and each had unique strengths and drawbacks. While each project had its own specific area of focus, the teams worked closely together, and Science Branch leadership evaluated the results holistically to make recommendations. As SMES explained, on their own none of the surveillance methods "tell the complete story", rather each one answers slightly different questions. For instance, wastewater surveillance answers questions about community disease spread, sero-surveillance provides insights into immunity levels within populations, and genomic surveillance reveals which variants are circulating within a community.
- At different moments in the pandemic, various surveillance and epidemiological strategies took precedence depending on the insights they offered. "For the most part we look at things by variants, because there tended to be a surge with each variant, which shifted severity and outcomes," one SME explained. For example, using whole genomic sequencing, CDPH was able to track and monitor the Omicron variant as it overtook the Delta variant in late 2021. Using this information, CDPH changed its response to account for differences between the variants.
- Overall, CDPH and the Science Branch adapted its epidemiological and surveillance strategies throughout the pandemic. New surveillance projects (with their accompanying data streams) came and went depending on their utility, cost, and timeliness. Some studies were ultimately more useful than others, but this was impossible to know at the outset. According to one leader, this dynamic strategy reflects the changing nature of pandemics: "sometimes you have to answer a question in the moment, but then you stop because it's no longer relevant." Ultimately, when it came to COVID-19 epidemiology and surveillance, CDPH was "really iterative and flexible" in an "unprecedented way," added another.
- At the same time, the Science Branch developed two teams (data modeling and outbreak consultation) that used surveillance data in a more operational focus. While various surveillance projects collected and analyzed data streams, the data modeling team used the data to develop projections and anticipate surges, while the outbreak consultation team used the data to identify and respond to outbreaks. The work of these teams is discussed further below in this Analysis of Activities.

Epidemiological Surveillance Project Teams Faced Numerous Staffing Challenges

- Initially, epidemiology and surveillance response teams were primarily comprised of redirected staff from the Immunization Branch (IZB). This team was used to working together and had a shared understanding of infectious diseases. However, as the response expanded, CDPH staff from different centers, programs, and offices were redirected to various COVID-19 response teams. Initial communication challenges arose between laboratory, data, and epidemiology teams. According to a SME, since these teams are typically located in "different branches with different rules," a significant learning curve needed to be overcome. The teams did eventually work well together, in part because leadership designated leads for each team.
- As the response grew, CDPH began hiring contractors dedicated to the COVID-19 response full-time. Many of these new team members were either recent graduates or had experience in different fields. Onboarding these new hires to the epidemiology and other technical teams proved challenging, as new team members required extensive mentoring and on-the-job training.
- An additional challenge was aligning appropriate staff skillsets with CDPH's evolving epidemiological surveillance projects. The new funding streams (many of them federal) made many new projects and hiring additional staff possible. However, when projects ended or transitioned, it was difficult to move staff to where they were now needed. Some staff, for instance, wanted to return to their home programs or only wanted to work on certain projects. "Instilling flexibility has been hard," one leader commented. While staffing was a critically important factor, it was sometimes tough "to get enough people with the right skills to do all of this work," one leader noted.
- For a discussion of the early rotational staffing approach used by the epidemiology and data teams, see the Data and Reporting chapter in this AAR. For a discussion of staffing specific to the various epidemiological surveillance projects, see the relevant sections in the Analysis of Activities below.

Wastewater Surveillance

CDPH Received Grant Funding from CDC and State-allocated Funding to Conduct Wastewater Surveillance, Building on Networks Established by the State Water Resources Control Board

- Wastewater surveillance is an innovative public health approach to monitor and assess the health of communities. A type of environmental surveillance, wastewater (also known as sewershed) surveillance collects and analyzes wastewater (sewage) to detect and estimate the presence of specific infectious agents. Samples of wastewater can be used to monitor community-level transmission of hundreds of millions of people. Before the COVID-19 pandemic, CDPH did not use this novel surveillance method.
- California's State Water Resources Control Board (State Water Board) pioneered wastewater surveillance to monitor COVID-19. Before the pandemic, they had entered partnerships with several large wastewater utilities in the State to test for other infectious diseases such as cryptosporidium. When the pandemic began, they pivoted to testing for SARS Cov-2.
- Over the spring and summer of 2020, academic institutions became interested in tracing the COVID-19 virus through municipal wastewater. Several universities across the country and in California initiated partnerships with local wastewater treatment plants to conduct testing. Within CDPH there was initial skepticism about the usefulness of wastewater surveillance for public health purposes. As one SME noted, "there were lots of doubts about this surveillance method for public health purposes."
- In September 2020 the CDC launched its National Wastewater Surveillance System (NWSS) and offered epidemiologists in CDPH's Center for Infectious Diseases (CID) a $200,000 Epidemiology and Laboratory Capacity (ELC) grant to join the inaugural pilot program. Setting up a new program in the middle of a pandemic was challenging with so many other response workstreams underway. "When you have a new program that needs to be assembled quickly, it's hard to get attention because so much else is going on," one SME noted.

- In December 2020, the newly-formed wastewater surveillance team at CDPH began working with the State Water Board and six California utilities that were part of its data-sharing network. The largest utilities in the network tested their own wastewater; others sent samples to private labs for testing. CDPH epidemiologists used that data to begin running analyses, and also began collaborating with other partners in the State who were conducting wastewater surveillance:
  - UC Berkeley Covid-WEB (Wastewater Epidemiology for the Bay Area)
  - SCAN (Sewer Coronavirus Alert Network) comprised of Stanford University, Emory University and University of Michigan
  - UC Davis and UC Merced's Healthy Central Valley Together network
- CDPH consolidated these existing data streams and established the California Surveillance of Wastewater Systems (Cal-SuWers) Network, accompanied by a public dashboard. CDPH published the data collected from this network of participants on the dashboard and collected into weekly summary reports for leadership.

Building the Case for the Public Health Benefits of Wastewater Surveillance

- Public health opinion about the utility of wastewater surveillance began to shift. "The tides were changing in 2021," one SME noted, as the team discovered and reported on correlations between wastewater data and the more traditional human case data (which is based on laboratory test results). California and national news outlets began reporting on wastewater surveillance results, bringing public attention to the correlation.
- The team discovered that in some communities, wastewater trends predicted the human case trend. For instance, wastewater samples indicated increasing levels of the COVID-19 virus one to two weeks in advance of COVID-19 cases being reported and hospital admissions rising. Cal-SuWers data also revealed which variants of the virus were circulating at any given time. For LHJs, this information allowed them to prepare for a surge by notifying hospitals, reinforcing vaccination campaigns, and reminding people to wear masks.
- By the end of 2021, the CDPH wastewater surveillance team received a second NWSS grant from the CDC. Wastewater-based epidemiology was

gaining recognition as a valuable piece of the State's COVID-19 defense. For the 2022-2023 fiscal year, CDPH allocated $6.5 million for wastewater surveillance as part of its SMARTER Plan, introduced in February 2022. The SMARTER Plan outlined seven key initiatives for the State's COVID-19 emergency response: **S**hots, **M**asks, **A**wareness, **R**eadiness, **T**esting, **E**ducation, and **R**x.

CDPH Wastewater Surveillance Team Set Up Its Own Lab and Expanded the Cal-SuWers Network

- With its second CDC grant, the CDPH team set up their own lab at its existing facility in Richmond to perform COVID-19 wastewater surveillance. The wastewater analysis laboratory launched at the CDPH Drinking Water and Radiation Laboratory (DWRL) in January 2022. All participating sites began sending their samples to the CDPH lab, rather than use outside labs or conduct their own testing. This consolidated laboratory methods and generated more standardized and comparable results.
- During 2022 the team also incorporated seven new sites into the Cal-SuWers Network, with a focus on smaller utilities. As the wastewater team focused on expanding its network, core tasks included communication and outreach. It was a challenge to find smaller and moderately sized utilities willing to join the voluntary program, since these utilities did not necessarily have the staff to support specimen collection. However, CDPH focused on recruiting smaller utilities for equitable representation within the network. "We wanted equity in terms of representation from all sites in California, especially rural areas," one SME explained. CDPH staff worked diligently to explain the importance of the program, conducted outreach, and onboarded new utilities to the network.
- Within CDPH, new collaborations formed between staff in clinical areas, epidemiology, and environmental health, as data from all three of these domains had to be synthesized into meaningful information.
- Academic partnerships also helped to advance the science of wastewater surveillance. Together, the university-anchored partnerships contribute data representing wastewater treatment plants in 18 California counties. In addition to sharing data, the network's academic partners develop methods for sampling wastewater and detecting specific pathogens. "Academics can assemble resources and methodologies

really quickly," observed a SME. Having access to these partners was a major benefit when setting up the CDPH lab, and will continue to be important as the Cal-SuWers team works toward its goal to have a statewide network of sewersheds.

Wastewater Team Experienced Staffing and Funding Challenges

- As the small wastewater surveillance team established its new program, many of the challenges it faced were staffing-related. The program relies primarily on annual, renewable CDC funding, which means that CDPH can only offer limited-term positions. This made it difficult to attract and retain skilled staff. "If we had sustained permanent funding, then people would take these positions," said a SME. However, the team indicated that even if more permanent State funding were available, state hiring guidelines would need to be waived in order to hire staff at the appropriate levels.
- Another staffing-related barrier relates to dependency on contractors, according to SMEs. Many staff at CDPH that were redirected to the COVID-19 response, including the wastewater team, are contractors who have been working for the State for many years. The nature of their funding source often limits their ability to work in—and be compensated for—higher-level roles. Yet during the pandemic response many assumed higher-level responsibilities that they were unrecognized and uncompensated for, known as working "out of class." Ultimately, these inflexible hiring and staffing practices limit the State's ability to invest in its public health workforce. As one SME noted, "once federal funding expires and the majority of COVID-staff leave, wastewater and other teams will not have the ability to respond to new pandemics or emerging threats."
- For further discussion of working "out of class," see the Effects on Staff chapter in this AAR.

Numerous Benefits of Wastewater Surveillance Emerged

- As the pandemic unfolded, wastewater surveillance emerged as a new and useful method to detect SARS-CoV-2 early, including variant strains. There were many benefits to this novel and supplemental surveillance method. Wastewater surveillance provides an opportunity to monitor many individuals with a small number of tests. This is very useful when and where testing is limited, and to rapidly identify and monitor new variants. Detecting pathogens in wastewater can sometimes provide an early

warning of disease outbreaks in a community, especially if individuals are shedding the pathogen before showing symptoms.

- Wastewater surveillance is more cost-effective than testing and contact-tracing when monitoring large populations. According to a SME, it is relatively easy to establish wastewater surveillance, as opposed to the more labor-intensive clinical testing and contact tracing that was used early in the pandemic response.
- Another benefit of wastewater surveillance emerged when home-based antigen testing began and laboratory-based polymerase chain reaction (PCR) testing declined. Antigen test kits first became available in late 2020 and grew in popularity throughout 2021 and 2022. In contrast to lab-based PCR testing results, people using at-home antigen testing kits did not generally report their results. As this shift occurred, CDPH realized that cases were under-reported. Wastewater surveillance demonstrated that transmission was still ongoing despite lower case rates. It was thus a better gauge of disease spread, one SME noted.
- Ultimately, CDPH's wastewater surveillance program as a supplemental and novel surveillance method was "a big success," according to one SME. While the program went through growing pains, it emerged as a valuable monitoring tool during the COVID-19 pandemic and has the potential to be applied to other diseases as well. According to its latest surveillance strategy, CDPH aims to expand wastewater surveillance as a statewide early warning and surveillance system. This entails recruiting utilities from smaller, more rural areas for more equitable representation. As one SME concluded, "we need to invest in this in order to improve public health."

Genomic Surveillance (Whole Genome Sequencing)

Early Whole Genome Sequencing Partnerships

- Whole genome sequencing (WGS) studies the genetic makeup of an organism. Within public health, epidemiologists use whole genome sequencing to monitor genetic changes in viruses; this is termed "genomic surveillance." Before the pandemic, whole genome sequencing was conducted for a few diseases (e.g., Zika virus and other respiratory viruses) by CDPH laboratories, and by the CDC and academic partners for other reportable diseases such as tuberculosis, but was not a significant part of

California's public health laboratory capacity. While WGS was one of several surveillance modalities that were "bubbling up in the academic work," according to one leader, CDPH lacked high volume experience in whole genome sequencing at the start of the COVID-19 pandemic. However, whole genome sequencing was promising as it offered the potential to identify new variants of concern, understand how different variants evolved and circulated within communities, and evaluate and inform the potential source of clusters and outbreaks.

- In March 2020, CDPH began having conversations about using whole genome sequencing and other novel surveillance methods to better understand the virus that causes COVID-19 and supplement its traditional surveillance methods. CDPH was approached by the Chan Zuckerberg Biohub (CZB), a philanthropic organization led by experts in genomic science. The CZB established a diagnostic lab at the University of California, San Francisco (UCSF) to conduct polymerase chain reaction (PCR) testing for COVID-19. After establishing its lab, the CZB began performing WGS of some test samples to better understand SARS-CoV-2.

CDPH Established the California SARS-CoV-2 Whole Genome Sequencing Initiative (COVIDNet)

- Other entities were also interested in establishing a joint public-private partnership to implement whole genome sequencing. In May and June 2020, CDPH formed a partnership, called COVIDNet, that included the CZB, public health laboratories, universities, and private companies to pursue COVID-19 whole genome sequencing. In designing the program, CDPH and Testing Task Force leadership assembled an advisory panel of internationally recognized experts in genomic sciences, viral evolution, and mathematical modeling. The program's objectives included determining the appropriate sample size, developing a network of public health laboratories with long-term sequencing capabilities, and building genomic epidemiology capabilities at the State and local levels.
- By June 2020 the program had a goal of sequencing 5,000-10,000 genomes per month, with diverse geographic and demographic representation. Next, the team worked on developing the infrastructure to scale up the State's sequencing capabilities. Most diagnostic and public health laboratories who performed PCR tests lacked the equipment to perform whole genome sequencing. This meant that the COVIDNet

program needed to: a. identify diagnostic and public health labs to source and submit the positive samples; b. identify processing labs to extract RNA from samples; c. identify sequencing labs to conduct the genome sequencing; d. identify genomic and bioinformatics experts to receive or download the data, model and analyze the results; and d. collaborate with LHJs to use the sequencing data for focused public health action.

- Next, CDPH epidemiologists approached university-based labs with established genomic centers and contracted with these academic labs to conduct genome sequencing. In addition, two private companies agreed to sequence up to 10,000 samples per month at no cost to the State. CDPH also worked to build a network of local public health laboratories, clinical laboratories, and commercial laboratories to source samples for genomic surveillance, with an emphasis on equity.
- Throughout 2020, CDPH piloted data management systems to manage sample data and ensure patient privacy, developed workflows for transporting specimens between labs, and determined how to work most effectively with its public and private partners. "Many programs had to come together to make this work" and it was a "huge learning curve for everyone," noted one SME. Building partnerships and creating a common language were the keys to success in navigating these "nascent technologies" and new stakeholder relationships, said a SME. While COVIDNet was conceived in spring and summer 2020, scaling-up laboratory operations did not begin until March 2021.

COVIDNet Built Data Capacity and Sharing Capability to Merge Datasets

- With so many different types of entities involved in COVIDNet, it was critical to establish data protocols and procedures that addressed data storage, protocols, and the privacy of protected health information (PHI). In order to do this, the COVIDNet team needed to devise a way to combine (or "marry," as SMEs called it) the sequencing data, which was stored in one location, with epidemiological data, which contained PHI and was stored in CalREDIE, the State's disease surveillance system. These datasets were kept separate to protect patient privacy. However, CDPH needed to join these datasets so that genomic data could be matched to specific cases and used to inform public health action. Merging the

epidemiological data with sequencing data was a key goal as well as a key challenge for COVIDNet. It would allow CDPH to respond more quickly to outbreaks and drive timely, meaningful public health action.

- In April 2021, the COVIDNet team collaborated with UC Santa Cruz (UCSC), who was building a technology tool to link these datasets. Sequence data was housed in Terra.Bio, a new cloud-based platform, and was subsequently linked with epidemiological information in a secure environment that protected patient information. The COVIDNet team, with UCSC, developed a tool called the "Big Tree Investigator" to automate the integration of sequencing data with epidemiological data. According to one SME, "this is the first time we were marrying these two different types of datasets together," representing a major success to achieve a key programmatic goal.
- With the "marriage" between epidemiological data and sequencing data, CDPH was better positioned to use genomic surveillance to respond to outbreaks. This entailed working closely with local public health labs and LHJs to conduct outbreak sequencing, including making sure that the sequencing was representative. As one SME put it, "If there's an outbreak, we don't want to get everybody sequenced from that outbreak; we want to get good representation from different parts of the community."
- Despite this successful data "marriage," challenges persisted in getting useable, genomic sequence data into the system in a timely manner. This challenge was due in part to the many different types of labs who participated in COVIDNet. Labs had onboarded to the program at different times and had varying levels of compliance in reporting their data. In July 2021, CDPH informed all labs of a change to Title 17 of the California Code of Regulations, which required labs reporting COVID-19 test data to CDPH to include additional data elements, including the GISAID number, which would enable identification and tracking of the sequence.
- However, this requirement was difficult for labs to meet and for the State to enforce. CDPH assisted the labs and vendors that were part of COVIDNet, helping them understand the technical requirements and import the required information into CalREDIE. The COVIDNet team hosted a weekly working group to troubleshoot compliance barriers with the new regulation. While COVIDNet established a two-week turnaround time for

sequence results, it often took longer to process and ship samples. CDPH spent much time and effort on compliance, and despite the Title 17 notification, one SME observed that the team is still working on "getting labs to just do what they're supposed to do."

COVIDNET Team Navigated Staffing and Resource Challenges

- Some CDPH staff were frustrated by the slow mobilization of resources to build the COVIDNet program. The team of five responsible for building the program juggled COVIDNet responsibilities with their other duties, and many wanted to devote more time to launch the new program. For instance, one SME noted that working with the labs to get their reporting established could have been a full-time job. SMEs regretted not being able to "give attention to where it was needed," including working with labs as well as with LHJs to help them understand the program's complexities.
- The pace at which resources were onboarded was also a frustration. According to one SME, "the needs were so incredibly obvious, yet the pace at which we were onboarding people to fill critical roles was too slow."
- In general, the team also found it challenging for the stakeholders and leadership to appreciate COVIDNet's complexity. "Sometimes it's hard to impress upon leadership how incredibly difficult this all is," one SME noted.

Institutionalizing Whole Genome Sequencing Within CDPH

- In 2020, before the start of the pandemic, CDPH had minimal internal genomic surveillance capabilities. It lacked the necessary bioinformatics and data analytics infrastructure, staffing infrastructure, and had "very low capability" at public health labs to do the "bench lab work needed," according to SMEs.
- Throughout the pandemic, CDPH and its partners built much of this infrastructure and moved whole genome sequencing to a much higher level of capacity. The public-private partnerships were an essential requirement to scaling up genomic sequencing in California; "there was no other way" to accomplish this, according to one SME. Leveraging these partnerships, CDPH expanded whole genome sequencing capability at the State and local level, including establishing a statewide network of labs, implementing sophisticated bioinformatics technology

tools, and collaborating with experts to interpret the genomic data. Within the network of 29 California State and local public health laboratories, whole genome sequencing capacity and bioinformatics capability increased significantly. By the end of 2021, a total of 15 (52%) of 29 PHLs were conducting SARS-CoV-2 genomic surveillance via COVIDNet. To date, whole genome sequencing capacity for SARS-CoV-2 has been established at 19 of the 29 (66%) PHLs in the state.

- COVIDNet data has been used to understand outbreaks of COVID-19 across the State. Over the course of the pandemic response, the sequencing data has contributed to between 20-30 outbreak investigations. COVIDNet data has helped to characterize and better understand outbreaks within skilled nursing facilities (SNFs), schools, and other settings. The genomic surveillance data also helped identify and characterize cases and variants associated with vaccine breakthrough infections and re-infections. In mid-2022, CDPH established a new Genomic Epidemiology Section. As of March 2023, CDPH has received more than 660,000 samples and processed and extracted more than 217,000 samples that meet whole genome sequencing criteria.
- While COVIDNet laid the foundation to use genomic surveillance for COVID-19 public health response, California is still working towards using sequencing data to address outbreaks, hot spots, and concerning cases in "real-time." In particular, CDPH is developing ways to get actionable data to all levels of the public health system as soon as possible. "We're still not here, but we want to be there," one SME noted, adding that "public health is all about the most immediate action." According to SMEs, it is imperative that the State continue to build its whole genome sequencing infrastructure via investments in equipment, workforce, supplies, and technology. "Hopefully we can build on what we have, so that we're prepared for the next disease," one SME noted.

Sero-Surveillance

CDPH Proactively Sought Data on COVID-19 Antibodies to Supplement Test Data

- As California began to scale up its laboratory-based surveillance in early 2020 (which relies on test data), it became increasingly clear that not all individuals infected may get tested for COVID-19, thus the State's test

data was incomplete to understand the level of population immunity. As a result, in April 2020, CDPH began investigating sero-surveillance as a supplemental surveillance strategy to inform progression towards community immunity.

- Sero-surveillance helps measure the proportion of the population with SARS-CoV-2 antibodies (i.e., prevalence). Serology data usually looks for the presence of antibodies in a person's blood. Antibodies in the bloodstream is typically evidence of a past infection or a post-vaccination immune response. Serology data is useful for measuring the total number of people who have been infected by SARS-CoV-2 when testing is not universal or when some infections do not cause symptoms that would trigger testing. According to one SME, "the idea behind sero-surveillance was to get a sense of what segments of the population have been infected geographically and demographically – who is getting infected, and where?"
- Epidemiologists within CDPH's Science Branch identified methods and partners to conduct sero-surveillance. Unlike other novel surveillance strategies (such as whole genome sequencing) that were initiated by outside partners, CDPH initiated sero-surveillance based on gaps identified in COVID-19 case identification and reporting. Since testing was so limited early in the response, "there was a lot of need to understand who was actually being infected, and the level of protection in terms of the population," one SME explained.

CDPH Initiated Various Sero-Surveillance Projects and Data Steams

- As part of its early sero-surveillance efforts, CDPH began exploring partnerships, funding opportunities, and potential data streams. Some data streams were already in place. For instance, laboratories who were performing COVID-19 PCR testing were required by Title 17 to report serology data to CalREDIE (if it was available). Additionally, CDPH also received reported serology data for SARS-CoV-2 from blood banks, also in accordance with Title 17. These two passive data streams were established early in the pandemic response, and CDPH began building infrastructure to analyze them in summer and fall 2020. In August and September 2020, CDPH hired four staff members, and this team began analyzing existing sero-surveillance data. Through a partnership with Heluna Health, CDPH hired rapidly. According to one SME, it was helpful

to have the authority and ability to "hire people and expand as needed in a timely manner."

- Concurrently, CDPH prepared to launch two new sero-surveillance projects: 1)the COVID-19 Active Perinatal Response to Infection (CAPRI); and 2) CalScope. CalScope was a new, large-scale sero-surveillance project and is discussed later in this section. CAPRI used blood samples from newborns. In California, dried blood spot cards are routinely collected as part of existing Statewide newborn and pre-natal screening programs. This project aimed to study SARS-CoV-2 prevalence among pregnant women and transmission of antibodies from mothers to newborns.
- These different sero-surveillance data streams each had their own limitations and varying degrees of utility for the COVID-19 response. From March 2021 to June 2021, CDPH used the antibody test data from CalREDIE and blood banks to develop and publicly post Statewide seroprevalence estimates. However, because the data was specific to certain populations, it was inherently biased. During the spring of 2021 as large numbers of Californians were receiving vaccinations, fewer people were tested for antibodies, and blood banks also discontinued routine antibody testing of donor blood. As a result, CDPH no longer had sufficient data from those sources, so publicly posted Statewide seroprevalence estimates based on these data streams was discontinued (although CDPH continued to monitor the data internally).
- For the CAPRI study, the sero-surveillance team analyzed newborn blood from a random sample of banked specimens that represented all regions and racial and ethnic groups across California. While CAPRI was a cost-effective surveillance approach, the data was limited to pregnant women and seroprevalence estimated lagged by approximately 2 months. However, after the arrival of COVID-19 vaccines in December 2020, CAPRI data helped CDPH identify patterns in pregnant women's uptake of the vaccines, which was useful for the State's overall surveillance efforts.

CDPH Planned CalScope, a Statewide Sero-Survey Conducted in Partnership with LHJs, Universities, and Private Industry

- In the spring and summer of 2020, CDPH partnered with Emory University to conduct an antibody study in California as part of a larger, federally-

funded nationwide study. Informed by that experience, CDPH decided to undertake a similar, California-specific study, and began conversations with potential partners. CDPH partnered with Stanford University in mid-summer 2020, and consequently began preparing for the CalScope study, including hiring staff, developing a study proposal, and designing and building the study infrastructure.

- The purpose of the CalScope study was learn how many Californians had COVID-19 antibodies (whether from infection or from vaccination), and how antibody levels were changing over time. The researchers also sought to identify areas or populations with high amounts of undiagnosed infections and subgroups of those populations that might need additional health resources. The study would rely on dried blood samples collected at home from Californians using a test kit. In October 2020 CDPH submitted the study proposal to the Institutional Review Board (IRB).
- Meanwhile, CDPH continued to work with its partners to build out needed tools to implement the study. This included working with Stanford programmers to develop a technology tool to capture data, contracting with Enable Biosciences to develop blood sample collection kits, and collaborating with seven LHJs to disseminate study information and recruit participants across California.
- By November 2020 the basic infrastructure for conducting CalScope was established. However, delays caused by Enable's contracting processes and overall supply chain issues impacted the usefulness of the CalScope study. Due to these delays, the three "waves" of CalScope's study had to be pushed back. Consequently, "our study was more of a review of previous surges," rather than a study of real-time COVID-19 trends, one SME noted. Another added, "it impacted [the] timeliness and relevance of the data."

CalScope Study Was Conducted in Three Waves

- The first wave of CalScope data collection launched in April 2021 and continued through August 2021. Wave 2 took place from October 2021 – January 2022 and Wave 3 occurred from April 2022 – July 2022. In partnership with seven LHJs, CDPH randomly selected over 600,000 households from these seven counties and invited the households to participate in the study, which involved taking a free, anonymous, at-home COVID-19 antibody test and survey. Nearly 27,000 Californians,

including adults and children, completed the antibody test and survey study over three waves of data collection. Result summaries from each wave of the CalScope study were posted on the CDPH website. The sero-surveillance team published a scientific paper about CalScope in an open-access journal.

- Overall, the study found the percentage of participants who had antibodies rose significantly from mid-2021 to mid-2022. While the researchers acknowledged there was still much to learn about how closely immunity is related to the presence of antibodies in the blood, they did find that serostatus varied regionally and by demographic group. These findings provided some insight into disparate impacts of the virus on communities and differences in vaccine uptake.
- As the waves completed, the CalScope team communicated the key findings to CDPH Science Branch leadership via PowerPoint presentations. Leadership considered all the surveillance information being generated by the various concurrent projects to make public health policy recommendations, including projections for future surges and impact on healthcare capacity.

CalScope Communicated with Internal and External Partners to Develop Study Materials and Recruit Participants

- Internally, the CalScope study team collaborated with CDPH's communications team to help refine their recruitment materials, online survey content, and press releases. This partnership was a "key resource and a success for us," noted one SME.
- The CalScope team collaborated with the LHJs to develop and refine the project communications. After each wave, the CalScope team presented the study results to its LHJ partners and invited them to provide input on how to improve project communications for subsequent waves.
- In addition to providing study materials in multiple languages, CDPH also made them editable so that LHJs could adapt or translate them as needed. These materials included fact sheets, FAQs, and scripts for public service announcements. As one SME noted, "we don't know the best way to communicate in El Dorado versus Monterey, but the locals would," underlining the benefits of the shared outreach approach.

- CDPH publicly posted all the CalScope study communications materials shared with LHJs, including translated versions in three additional languages, and customizable versions for counties to adapt. Though the study has ended, the materials remain available for adaptation to future projects that require similar community outreach.

Sero-Surveillance Contributed to the State's COVID-19 Epidemiology Efforts in Different Ways Over Time

- Over the course of the pandemic response, the role of sero-surveillance and its relationship to other COVID-19 epidemiological surveillance efforts evolved. In early 2020, when testing was very limited and labs were struggling to report test results accurately, sero-surveillance helped public health officials better understand case numbers. "It gave you a sense of what the prevalence was in the population," one SME noted. After COVID-19 vaccines rolled out in early 2021, "what sero-surveillance data could tell us changed," one SME noted. The sero-surveillance team began collaborating with the data modeling team, using the integrated datasets to try to understand how much protection against COVID-19 existed in the community whether from immunity or vaccination (there are different types of antibodies depending on past infection versus vaccination).
- One of the main disadvantages of sero-surveillance is its retrospective perspective—in contrast to other surveillance methods, such as wastewater surveillance, which can predict trends. According to one leader, sero-surveillance data is "much more difficult to interpret and understand what it really means over time," since the data is "lagged" and "not in real-time." Another team member agreed that "it's hard to find data that is both timely and representative." These timeliness issues inherent to sero-surveillance were exacerbated by the initial CalScope contracting delays.
- Furthermore, CalScope was a costly, labor-intensive study. As a result, SMEs observed that it was "only appropriate for a short period of focused time." For future pandemic responses, SMEs noted that it would be important to identify sustainable, timely, and representative data streams for epidemiological surveillance.

Sentinel Surveillance and Population-Based Surveillance

CDPH Initiated a Respiratory Virus Sentinel Surveillance Project to Examine Virus and Clinical Symptom Data Together

- Sentinel surveillance data is collected from a select group or location, ideally from a representative sample, rather than from the entire population. This method is less resource-intensive and is commonly used to track trends in infectious diseases or other health conditions. Sentinel sites are strategically chosen to provide data that is representative of a larger group.
- In March 2020, there was limited COVID-19 testing available, and limited information about at-risk groups and symptom presentation. CDC began funding sentinel surveillance projects throughout the country, and invited CDPH to participate. Using CDC funding, CDPH initiated the California SARS-CoV-2 and Respiratory Virus Sentinel Surveillance Project (CalSRVSS) and began to plan, budget, and recruit LHJ partners to participate.
- Starting in May 2020, CDPH began partnering with LHJs to establish outpatient community surveillance sites. These sites would provide both the specimens and individual demographic and clinical data from a weekly sample of outpatients with asymptomatic or mild illness. The CDPH CalSRVSS team (comprised of three full-time staff) worked with LHJs to onboard them gradually into the program, the timing of which depended on LHJ capacity and bandwidth. CDPH also funded counties to hire CalSRVSS coordinators who coordinated clinical sites and helped manage data. Over the course of the project eleven LHJs enrolled.
- The team focused on reaching populations that had limited access to testing. Testing equity influenced which LHJs were encouraged to enroll in the project. This approach was successful, and many participating counties enrolled testing sites that served at-risk or underserved populations.
- Data collection was staggered due to the funding cycles and the need to troubleshoot and adjust. "With each local partner we would be going through these overlapping phases," said a SME. At the testing sites, patients who agreed to participate in the study were interviewed to collect demographic, clinical, and epidemiological information, and

were tested for COVID-19 and a panel of 20 other respiratory pathogens, including rhinovirus and influenza.

- Once data collection began, the CalSRVVS team generated an overall weekly project report and LHJ-specific reports. A SME noted that sharing data with LHJ partners was a "really valuable use of our time." Reporting back to the LHJs—who were themselves investing time and effort in coordinating with clinics and local labs—helped increase the LHJs' commitment to the project. As a result, said the SME, "they wanted to participate more." By consistently reporting back to their local partners, CDPH built stronger relationships with LHJs.

CalSRVSS Provided an Individual Dataset Connecting COVID-19 Positivity with Health and Demographic Factors

- CalSRVSS collected data beginning in May 2020 and continuing through late 2022. In addition to viruses, variants, and clinical symptoms, CalSRVSS tracked demographic data, comorbidities such as cardiovascular disease and diabetes, workforce status, occupation, recent travel, and housing status. In this way, said a SME, CalSRVSS functioned as a "mini-surveillance system" within CDPH's larger surveillance efforts. CalSRVSS was California's only source of integrated syndromic and virologic surveillance. While the CDC asked several States to launch a sentinel surveillance project for COVID-19, California was one of the few to accomplish it and successfully collect data for over 10,000 patients. "For the first time, California has a robust dataset on patients tested for over twenty respiratory pathogens, which has value," a SME noted.
- At the beginning of the pandemic, CalSRVSS played a role similar to other surveillance methods used by CDPH to estimate the number of COVID-19 cases circulating in the community. However, its data tool was completely separate from CalREDIE. "We essentially built and maintained our entire system," said a SME. It was challenging to receive and handle data from multiple sources in multiple formats without a CalREDIE or REDCap (the data management tool used in CalScope) system.
- Since many of the sentinel sites were established to serve at-risk or underserved populations, the resulting data did not represent all of California's population. Still, CalSRVSS provided a steady source of specimens to CDPH over two and a half years, as well as robust data connecting symptoms, demographics, and circulation of respiratory

viruses. Existing respiratory (e.g, influenza) surveillance was not augmented or leveraged for COVID-19 response.

Ambiguous Role of CalSRVSS in the Larger COVID-19 Response

- The most significant challenge for the CalSRVSS project was the lack of clarity regarding its role and utility in relationship to CDPH's larger epidemiological surveillance efforts and COVID-19 response. Without clear goals and guidance for the project, "it wasn't always totally clear what we were contributing to the response and if our information was valuable," one SME noted. Another added that "we were working really hard, but in the chaos of the pandemic it was difficult to know what role we were playing in a practical, usable way." This ambiguity lasted for the entirety of the project.
- With CDPH leadership focused on the Statewide pandemic response, which was unprecedented in size and scope, the CalSRVSS team struggled to get clear answers and guidance on the project. "In many situations we had important questions and had to make decisions, but wouldn't get super clear direction or answers," one SME noted.
- The CalSRVSS team did its best to navigate this ambiguity and developed strong partnerships with other CDPH epidemiology teams working on different surveillance projects. Other successes included the partnerships it built with LHJs, as well the project's role in expanding testing and laboratory capacity around the State via its funding.
- SMEs noted that a key lesson learned is the importance of taking time to think strategically, even in the midst of an emergency response when there was tremendous pressure to provide epidemiological information quickly.

CDPH Initiated a Large Case-Control Survey to Deepen Understanding of COVID-19 and Provide Evidence to Inform State Policy

- Towards the end of 2020, CDPH planned a case-control survey for acute COVID-19. This Statewide, telephone-based Case-Control survey aimed to interview individuals who tested positive for COVID-19 ("cases") and individuals who had tested negative ("controls") to collect and compare data about COVID-19 risk factors and intervention effectiveness, with the goal of informing policies and mitigation efforts. The California COVID-19 Case-Control Study was a CDC-funded project initiated from within CDPH

and carried out in partnership with the University of California (UC) Berkeley School of Public Health.

- After an extensive process of Institutional Review Board review and budgeting-related work, study implementation began with recruitment and training of interviewers at the end of December 2020. The interviewers were all students from UC Berkeley's School of Public Health. Interviewers went through rigorous training to administer the 20-25 minute surveys using a guided script, including how to keep protected medical information confidential and how to navigate difficult conversations.
- During this time, the CDPH team also designed the survey, including determining the study sample and developing interview questions and topics, such as masking behaviors, vaccine hesitancy, and exposure risk factors for infection such as eating out in restaurants. Objectives early in the study included determining what levels of community exposure could be considered safe, and whether wearing masks (and which types) were effective in reducing virus spread.
- The survey launched in February 2021. Using test results and contact data from CalREDIE, interviewers then called potential study participants each day to recruit them and to administer the survey. From February 2021 through August 2022, a team of about 25 interviewers recruited and collected data from 2,382 cases and 2,359 controls.

Changes in the Pandemic Landscape Necessitated Changes to the Case-Control Study and Interviewer Training

- Over time it became harder to recruit participants for the Case-Control Study, as the pool of those with lab-confirmed test results shrank and more people used at-home antigen tests that were not reported to public health and not in the CalRedie database. At the same time, the pool of potential controls who had never been infected with COVID-19 also shrank. In response to these trends the research team updated eligibility criteria to allow use of antigen tests and to allow people who had a previous COVID-19 infection to participate as controls.
- As the study progressed through the vaccination rollout in 2021, the researchers incorporated new objectives into the study. They investigated vaccine status and doses received, vaccine hesitancy, and whether participants got a seasonal influenza vaccine, among other factors. The project timeline was extended from 12 months to 18 months; while it

originally aimed to enroll 2,000 participants, it eventually enrolled over 4,700.

- Each of these changes required adaptation on the part of the CDPH study team. Shifts in policy presented special challenges, as these rendered some initial questions less relevant. Shifting parts of the survey and adding in new questions took considerable time and energy, and necessitated retraining.
- In addition, the CDPH study team was challenged by frequent turnover and burnout among the interviewers. Some quit after their first six months, necessitating repeated rounds of hiring. In all, the team had four phases of hiring for interviewers. In successive phases, the CDPH study team included more training and tools on how to engage in sensitive, difficult conversations.
- The CDPH team was also confronted by an unexpected need for mental wellness support for the interviewers. "We didn't anticipate the impact of them asking difficult questions and hearing about terrible situations," one SME noted. As a result of these difficult conversations, "the need for mental wellness support was really huge," added another. In response, the CDPH team added new components to its interviewer training program and found that later interviewer cohorts had a more positive experience. The CDPH team also created a resource guide for interviewers with links to social service providers, which interviewers could use during calls as a "one stop shop." While extensive training and resources were provided for the thousands of California Connected contact investigation interviewing staff, this study team did not access these resources.

Sharing Evidence from the Case-Control Study

- The Case-Control study team presented its findings periodically throughout the response with CDPH leadership, yet not all participants were aware of these briefings. "We couldn't figure out how to streamline or make it more transparent," said a SME. The Case-Control Study team also shared their evidence with other public health colleagues through peer reviewed journals. "We had amazing evidence, and the way that we made that productive was to get into peer-reviewed journals," noted one SME. They published multiple papers, including one in the CDC's journal, which was a major success.

- According to CDPH's COVID-19 Surveillance Strategy (a technical document developed in the middle of the pandemic that outlines the various strategies used), the utility and agility of the study model helped provide evidence for policy and nuanced Statewide measures. A cornerstone of the model's success was the collaboration with UC Berkeley, and CDPH plans to use the model as a template for future research questions. While the Surveillance Strategy was useful as a guiding, strategic document, it was not developed until a year into the pandemic response. SMEs noted that it would have been helpful to have a broad surveillance strategy in place earlier on that could be referred to and adapted.

Clinical Surveillance

CDPH Formed the Clinical Team with a Focus on Surveillance

- At the start of the COVID-19 pandemic in early 2020, CDPH's clinical team answered the very first questions. This team was comprised of approximately 10-12 physicians who served as public health medical officers. In the first half of 2020, all medical and clinical questions related to COVID-19—including who was eligible for testing—was handled by this team of medical officers. The team also worked closely with LHJs to determine eligibility and provide approvals for testing according to the CDC criteria, which was quite specific and narrow due to the lack of adequate testing capacity. According to one SME, "very early on, our function was almost entirely approving COVID tests."
- Beginning spring 2020, the clinical team began working on unique clinical surveillance projects. These included death reviews for both adults and children, pediatric mortality, COVID-19 in pregnant women, Multisystem Inflammatory Syndrome in Children (MIS-C), COVID-19 reinfections, and long-COVID (also known as post-COVID). In general, the clinical team was responsible for any type of surveillance that necessitated a review of medical charts, since this was a specialized skillset only possessed by clinicians.
- In the beginning, these clinical surveillance projects were paper-based and relied on a manual review of medical charts and records. However, over time, data collection for some of the projects were automated in CalREDIE and were subsequently handed over to CDPH's epidemiology

and data teams for routine, ongoing surveillance. As one SME noted, the clinical team often performed the initial exploratory "legwork," which required extensive review to understand a new condition or phenomenon. Once the clinical team identified the trends, medically important details, questions, eligible projects would be handed over to other epidemiology and data teams. One SME mentioned the possible need for better templates to adapt electronically for future emerging diseases.

- By handling all clinical COVID-19 questions as well as overseeing data collection and surveillance for new clinical surveillance projects, the team occupied a unique role in CDPH's pandemic response structure. The team "straddled a wide range of topics," according to one SME, and usually worked cross-functionally with other response teams and LHJs.

Clinical Team Monitored and Counted Early Cases and Hospitalizations

- In the early days of the pandemic, when laboratory testing was very limited, CDPH's clinical surveillance team used manual surveillance methods to track COVID-19 cases in California. Initially, before community transmission began, all infections were travel-related, so the team coordinated local health jurisdictions conducting extensive returning traveler monitoring. "We initially followed every returning traveler," one SME noted.
- However, following the first reported case of community transmission in March 2020, the work of the clinical surveillance team began to shift. Initially, the team tracked every single reported case of COVID--19 in the State. But as the numbers quickly rose, this became unrealistic. Unable to follow each case in the burgeoning pandemic, the clinical team narrowed their focus to more discrete populations, such as hospitalized patients, pregnant women, and children.
- As concerns about changes in clinical presentation or severity continued throughout the pandemic, especially once new variants were identified, there was ongoing attention to hospitalized cases and their clinical profiles, which public health is not used to tracking at such a high volume nor with such frequent cadences to assess for changes. By monitoring every single COVID-19 hospitalization, the clinical team felt "the sense that leadership needed to know how everyone was doing in the hospital," according to SMEs. However, this manual task proved unsustainable and

did not continue for very long. This information could be accessible through improved technology infrastructure (e.g., an improved surveillance system or Electronic Health Record [EHR] access). As one SME explained, "CDPH wasn't able to tap into the fact that medical records are all online now, which definitely hampered us." Lastly, many SMEs believed that the individualized hospitalization tracking continued longer than necessary, and "was not a good use of anyone's time or skillset."

- For additional discussion of CDPH's lack of ability to access EHR records, see the Hospital Surveillance discussion later in this section. For further discussion of returning traveler monitoring, see the Repatriation, Quarantine, and Returning Traveler Monitoring chapter in this AAR. For further discussion of case reporting, see the Data and Reporting chapter in this AAR.

Clinical Surveillance Team Conducted Initial Death Reviews and Defined Definitions

- During the early phase of the pandemic, when testing was limited and very little was known about the virus, the clinical team also assisted with death reviews and determinations. The team conducted a retrospective surveillance of over 200 adult deaths in order to better understand them; this "massive review" was conducted when "no one understood who was dying, and why they were dying," one SME noted.
- The clinical team also helped developed death definitions and assisted LHJs classify COVID-19 deaths. Initially, no COVID-19 death definition existed, and there was "a lot of discrepancy" about how deaths were being classified. In the absence of federal guidance, the clinical surveillance team developed clear death determination guidance for adults and children, and then helped LHJs apply it. This involved a critical distinction between dying "from" COVID-19 and dying "with" COVID-19. It took until 2021 to develop this death determination guidance and obtain the necessary approvals. During this time, Cal OES was the State's source for COVID-19 deaths (which is discussed in the Data and Reporting chapter in this AAR). CDPH used the death definition developed by the clinical surveillance team until December 2021, at which point it adopted the interim definition that was released by the Council of State and Territorial Epidemiologists (CSTE).

- Early on, the clinical team also conducted extensive surveillance of pediatric deaths, especially those that were unusual, suspicious, or inconclusive. Deaths were "very thoroughly investigated" in a challenging process that involved working with county coroners. They encountered months-long delays, a lack of responsiveness, an unwillingness to provide specific information, and resistance from some coroners who were suspicious of their motives. SMEs noted that some coroners are elected, non-medical officials who are more aligned with law enforcement. "We'd just have to call back every week to see if there was an update," one SME noted. Sometimes it would take six months for a final determination on the death certificate, and sometimes the team had to first contact law enforcement to reach the coroner.
- Overall, SMEs found the process was "cumbersome" and "really challenging," and in need of improvement given its criticality. The relationship and communication system between public health and the coroners is important to invest in and strength in preparation for future pandemics.
- Eventually, the urgency and level of detail associated with the clinical surveillance of pediatric deaths lessened. "It reached a point where we didn't need that level of detail, and then epi could take over," one SME noted. At that point, the reporting process was automated through CalREDIE (using hospital codes and other data sources) and managed by CDPH's data and epidemiology teams.

Clinical Team Conducted Various Surveillance Projects of Specific Populations and Conditions

- In addition to tracking every COVID-19 hospitalization and pediatric death early in the response, in April and May 2020 the clinical team began contacting the medical providers of pediatric and pregnant COVID-19 patients to better understand and characterize the disease in these vulnerable populations. While CDPH had been monitoring COVID-19 in children and in pregnant women already, in the summer of 2020 the CDC released updated clinical definitions for COVID-19. Consequently, these clinical surveillance efforts were formalized.
- In an effort to anticipate adverse outcomes among these specific groups, "we were trying to collect outcomes by picking up the phone and talking to providers," another SME noted. This was a significant undertaking, and

yet it was the best available strategy at a time when electronic surveillance systems were not yet capable of capturing such data.

- Concurrently, the team also initiated clinical surveillance of Multisystem Inflammatory Syndrome in Children (MIS-C), a condition that was first reported in May 2020. MIS-C is a rare but serious condition associated with COVID-19 in which different internal and external body parts become inflamed, including the heart, lungs, and brain. According to SMEs, the MIS-C case definition is very nuanced and medically complicated, and expertise is required to assess a case. The clinical surveillance team helped established CDPH's MIS-C surveillance platform within CalREDIE, which was a notable success. According to one leader, California's MIS-C surveillance project became a "gold standard" as a result of numerous successes, including its functional reporting system and its programmatic outreach and communications work. Due to its complexity, the MIS-C surveillance project continues to be overseen by the clinical team.
- The first U.S. case of reinfection was reported in August 2020, and the clinical team subsequently started tracking reinfections. After the arrival of vaccines in late December 2020, this work became even more significant. According to one SME, this was "a really big deal because initially people didn't think you could get reinfected, and no one really wanted to accept that." The team tracked reinfections manually in Excel, since CalREDIE lacked the functionality to distinguish between original infections and reinfections. The volume of data and the data structures "make looking at reinfection incredibly difficult," noted one SME. For further discussion of reinfection and CalREDIE, see the Data and Reporting chapter in this AAR.
- In early 2021, the clinical team initiated another surveillance project on long-COVID. This effort started slowly, since at the time there were very few studies on the condition. In August 2021, the project began in earnest. However, during surges, the long-COVID surveillance work was temporarily deprioritized. As one SME noted, during surges LHJs often lack the bandwidth and "need to focus on what is urgent and what is killing people right in front of you." Despite these temporary pauses, SMEs felt that California led other states in its successful effort to establish and maintain a long-COVID surveillance project.

Clinical Team Wrote Guidance and Conducted Literature Reviews to Inform COVID-19 Policy

- As the CDPH's clinical experts, one of the key roles of the clinical team was to provide technical guidance on COVID-19, such as transmission, masking, and outpatient monitoring. Getting the guidance documents through the leadership approval chain, including CDPH Legal Counsel, CalHHS, and the Governor's Office, was sometimes such a lengthy process that the final guidance arrived too late to be useful. According to one SME, "we took weeks and weeks to clear a single strategy document."
- Towards the end of the pandemic the State became more adept to release guidance that was not in lock step with CDC. Recognizing the need to further streamline and expedite policy development and approval processes for emergencies and standard operations, CDPH created the Office of Policy and Guidance, initially within the response in the fall of 2020, and eventually sustained a portion of the team within the Center for Infectious Diseases, in March 2023. The Office developed and maintains a standard operating playbook to review, revise, maintain, and route policies and guidance for CDPH's response to public health risks. For further discussion, see the Policy Development and Guidance chapter this is AAR.
- Early in the response the clinical team also conducted literature reviews and summarized research in response to policy questions from CDPH and State leadership. For instance, leadership requested research on masking, surface transmission, and testing to help inform new policies. SMEs thought the literature reviews were time-consuming and inefficient. "A lot of it could have been done by someone who wasn't a physician," one SME noted. The SMEs recommended that in a future pandemic a specialty team should be dedicated solely to literature reviews.
- The timeliness and usefulness of the team's literature reviews were also impacted by the communications chain between CDPH and the Governor's Office. Oftentimes, the team wrote a lengthy document when a high-level summary would have sufficed. From a leadership perspective, the high level summary was what was most needed and often long, detailed documents were created that leadership did not have time to review closely. It was also a challenge to align timing. For instance, the

team worked on a literature review demonstrating the effectiveness of masking, only to hear in the news that masking restrictions were being lifted.

- Lastly, the clinical team was challenged by last-minute and disparate requests for information, analysis, and presentations. Sometimes, the team would receive similar requests from different leadership within CDPH, which could lead to duplicate work. SMEs expressed a desire to have such requests be better coordinated and communicated, and could be routed similar to data requests in an ICS structure.

Communications Specialist Assisted with Clinical Surveillance Projects

- In September 2021 the clinical team hired a dedicated communications specialist. Having a communications person embedded within the small team was unique. The communications specialist helped develop campaigns, resources, newsletters, and outreach around MIS-C, long-COVID, and therapeutics, and in doing so fostered relationships between the clinical team, Science Branch leadership, and CDPH's Office of Communications. Having this ~~built in~~ "in-house" communications resource was a significant success for the team "that really created a powerful synergy," according to SMEs. Given the success of this communications model, SMEs felt it would be a good model for other teams to use as well, and addressed an important need for bridging public health SMEs with communications specialists.
- For further discussion of public communications, see the Public Communications chapter in this AAR. For further discussion of therapeutic communications, see the Therapeutics chapter in this AAR.

Staffing Challenges Led to Medical Officers and Clinical Team Burnout

- During the pandemic response the clinical team was in high demand for their expertise. According to one SME, "the medical officers were the group that people kept reaching out to for an extraordinary amount of work." Early in the response, CDPH established clinical rotations and assigned some of the medical officers to help implement California Connected, the State's new contact tracing program (and CalCONNECT, its new technology system). However, the new program was not linked to CDPH's existing Divisions or Centers, even though most of the program staff were drawn from the Division of Communicable Diseases (DCDC). When the medical officers and staff burned out due to a lack of sleep,

untenable workload, and inability to rotate off, they lacked HR support since the program was outside of DCDC's response structure. One leader acknowledged that "we burned out of medical officers in our first six months; they were working crazy hours."

- This dynamic sometimes resulted in poor morale, distrust, and an unwillingness to volunteer for future emergency response work. As one SME noted, "people do not trust that our system will take care of the staff that are being assigned." Consequently, very few staff volunteered for later emergency activations, such as mpox, due to a belief that they would "never be able to leave the response," noted one SME. In general, team members felt that CDPH needs to provide more support for its responders. Areas of improvement for emergency responders include more robust occupational health efforts, a structured rotational or shift-based schedule, clear response guidance, a documented reporting structure, and clarity on compensation. As one SME noted, these elements need to be laid out in advance and be "crystal-clear."
- For further discussion of staff support, see the Effects on Staff chapter in this AAR. For a discussion of early staffing rotations for epidemiology and technical teams, see the Data and Reporting chapter in this AAR.

Hospital Surveillance

Early Hospitalization Surveillance Established via Federal Survey

- In early 2020, it became clear that CDPH lacked adequate surveillance of California's hospitals. There were no systems to collect important metrics from hospital facilities, such as number of occupied beds or ICU space. CDPH representatives called hospitals every day to compile this data for reporting purposes. However, this process was improved in March 2020 when the California Hospital Association (CHA) and U.S. Health and Human Services (HHS) established a daily hospitalization survey. The CHA/HHS survey dictated a daily reporting cadence of approximately 140 metrics, including several California-specific data variables. Over time, some of these variables were fine-tuned and customized, and CDPH added fields to the survey for its internal use.
- Around this time, CDPH established its hospitalization surveillance team comprised of redirected clinicians, informatics specialists, epidemiologists, and representatives from CDPH's Center for Healthcare Quality (CHCQ),

which regulates and licenses California's hospitals. Since many early challenges related to working with the CHA/HHS survey data, this team focused on data informatics and reporting work. The data was provided to response teams, including the Medical Surge Task Force (a joint partnership between CDPH, Cal OES, and EMSA) and the CHCQ regional District Offices, who maintained relationships with individual hospitals within their district jurisdictions. For further discussion how CHA/HHS data was used to respond to medical surges, see the Medical Surge chapter in this AAR.

- The hospitalization surveillance team used the CHA/HHS data to create a hospital burden score (and later a pediatric burden score), which analyzed metrics and values to identify strained hospitals that might need State intervention. This data was provided to CHCQ District Offices, who would proactively reach out to hospitals scoring below a certain threshold to offer assistance. Sometimes, data entry errors that had contributed to a hospital's low score. According to SMEs, "there weren't very many facilities that had problems and didn't know it," and these facilities would usually reach out to the State first for resources and support.
- Using the CHA/HHS data, CDPH also established an internal dashboard that it shared with LHJs and other State agencies. It also created a public dashboard, which included data visualization to customize charts and datasets.
- The CHA/HHS survey had several limitations, including that the reporting requirements are federally dictated. "We only have so much control, and are a little bit at their mercy," one SME noted. Additionally, the CHA/HHS survey only captured aggregated, de-identified, facility-level data, which makes it difficult to merge with other datasets for enhanced epidemiological surveillance.

CDPH Directed Hospitals to Report More Detailed Discharge Data via State Survey

- In June 2021, in order to supplement the CHA/HHS data, CDPH initiated a process to collect line-list level hospitalization information from all hospitals in California. This had never been done before. The team began to work with the California Hospital Association to obtain input on how to accomplish this, since "we didn't really have a way to do that," one SME noted. The team built the process, workflow, and data fields "from scratch

very quickly and a little bit blind," according to one SME. Since it was established so rapidly and CDPH lacked a way to require hospitals to send data in certain formats, the All-Facilities Letter data stream suffered from early data quality issues. For a discussion of how this data stream was processed, see the Data and Reporting chapter in this AAR.

- CDPH issued an All-Facilities Letter (AFL 21-25) in late July 2021 directing hospitals to report line list discharge data to CDPH. This guidance directed hospitals to send line list data on a weekly basis that included all patients that had been discharged the prior week that were hospitalized and had tested positive for COVID-19. This was an important supplemental data source, since it requested hospital discharge data of individual patients with identifying information (hospitalized COVID-19 patient reporting was required by Title 17, 2500), as opposed to the aggregate hospital admissions data received via the CHA/HHS survey.
- The more granular AFL "line list" data was not reported publicly but was used for internal surveillance. The AFL data captures data at the individual level, including the vaccination status of hospitalized individuals. This data was instrumental in distinguishing what proportion of patients may have been hospitalized due to COVID-19 infection versus those that may have been admitted for an alternative reason and happened to test positive during hospital screening for COVID-19 infection. The hospital surveillance team merged AFL data with other datasets, including the case registry in CalREDIE, to yield important surveillance insights. One SME noted that AFL and the CHA/HHS data, which have different benefits and limitations, "each one gives us different angles for analysis."
- The AFL data collection survey created initial confusion among hospitals about the differences between the AFL and CHA/HHS survey. Some counties, such as Los Angeles County, already had existing line-level local surveillance hospitalization system. When CDPH learned of this, it worked with LA County and its hospitals to coordinate and leverage the existing surveillance methods to avoid increasing the reporting burden. However, one SME indicated that there remains "lot of room for improvement for the whole AFL data pipeline."
- In addition to the AFL and CHA/HHS hospitalization survey data, several other supplemental data sources were also available, including data

fields from CalREDIE and CalCONNECT. However, these sources were inconsistent and were not relied upon for regular surveillance.

Liability and Authority Issues Arose Regarding Hospitalization Data Collection

- An ongoing challenge for CDPH was its limited ability to collect hospitalization surveillance data. CHCQ's Licensing and Certification (L&C) Program conducts regulatory oversight of California's licensed healthcare facilities and healthcare professionals, including certifications, enforcement, and citation for deficient practices. As one SME explained, due to CHCQ's oversight role, "we do not have the legal or regulatory capacity to have ongoing monitoring of hospitals in a real-time fashion." Thus, CHCQ did not have the technological and resource capacity to conduct hospitalization surveillance. Early on, CDPH relied on contractors, redirected staff, and the federal CHA/HHS survey for hospitalization data collection and processing. In 2022, CHCQ began building out its Data and Analytics unit to meet this need "after the fact."
- During the pandemic response, CHCQ temporarily suspended most of its licensing and enforcement actions, and transitioned licensing surveyors from enforcement to COVID-19 consultative roles. This diminished the inherent adversarial relationship as CHCQ "made it clear" to California's hospitals that "we were 100% in support mode" rather than in enforcement mode.
- Despite the new focus to support the hospitals, "there has always been a question about liability around the data," noted one SME. With California hospitals reporting their data directly to federal and State regulatory oversight entities, there is an awareness that "they also don't want to start giving us data that might make them look bad." While CDPH's hospitalization data has improved significantly over the course of the pandemic response, questions around liability, authority, and data reliability remain.

Need to Improve Hospitalization Surveillance

- While both the CHA/HHS and AFL surveys provided useful insight into hospitals during the COVID-19 pandemic, one SME pointed out the "inherent problem" associated with surveys: "they are being filled out by overworked hospital staff during a medical emergency." As such,

California needs an improved, longer-term solution for future hospitalization surveillance during emergency responses. "Ongoing surveillance of hospital capacity and function is essential," another SME noted. For CHCQ, which maintains an emergency response team in the event that hospitals need to be evacuated and patients moved, maintaining awareness of a facility's patient numbers and staffing ratios is critical.

- Many agreed that tapping into existing automated Electronic Health Record (EHR) data could offer a long-term solution. Sharing selected EHR data with the State could help CDPH continue ongoing hospitalization surveillance and respond to public health emergencies, but this would require legislation and resources to develop the informatics pipeline and receive the data into a CDPH data system. A legislative solution and IT resources could increase automation, help reduce data quality issues associated with manual data entry, and enable linkages to other surveillance datasets via anonymized information.
- SMEs indicated that other possible State departments, such as EMSA or HCAI, could assume ownership of such a program to avoid a conflict of interest with CDPH's oversight authority. Regardless of where this function would be located, one SME noted that "it's really having that foundation there and being able to turn to it in a public health emergency." Others echoed that the ability to access some EHR data is "definitely a direction we're trying to go in."

Hospitalization Surveillance Team Benefited from Collaboration and Technology Advancements

- Informatics specialists working on the CHA/HHS survey data Interpreted the various data sets. However, it soon became obvious that additional staff needed to receive training on these data streams due to a lack of existing in-house capacity and infrastructure. As one SME noted, "there was always a lot of changes about who could answer which questions about the data sets." The team eventually cross-trained on the necessary programmatic knowledge, which enabled informatics specialists to field questions about the datasets. For a future pandemic, SMEs indicated that a key lesson learned is to maintain the capacity for this type of analytical work within CDPH and "make sure we have talent in-house as an immediate response."

- Ultimately, the collaboration across teams given their "makeshift nature" was a success. Once informatics specialists drew on experts who possessed programmatic and field knowledge in hospital operations, they were able to build tools that met many of the identified surveillance needs. Additionally, the hospitalization surveillance team collaborated successfully with CHCQ to understand what data was available and build upon it. Lastly, CDPH's significant advances in technology, data, and reporting (especially creating the Snowflake data warehouse) contributed to this team's success. For additional discussion of Snowflake, see the Enterprise Technology and Data and Reporting chapters in this AAR. As one SME summarized, "both technology advancement and then finding the people with CDPH that were able to maximize that technology was a success." It is important to maintain these advances in order to better understand ongoing hospital capacity and surveillance for seasonal respiratory surges and other emerging diseases.

Outbreak Consultation

Redirected CDPH Staff Conducted Early Outbreak Investigations

- The earliest COVID-19 outbreaks with the highest mortality occurred in congregate care settings such as Skilled Nursing Facilities (SNFs). CDPH's existing Healthcare Associated Infections (HAI) program, housed within the Center for Health Care Quality (CHCQ), was responsible to go into SNFs and other health care facilities and assist them with infection prevention and outbreak management. However, as outbreaks started occurring in schools, workplaces, prisons, and non-healthcare facilities—areas that fell outside of HAI's scope and bandwidth—it became clear that additional help was needed. (For further discussion of the HAI Program, see the Infection Prevention chapter in this AAR.)
- Drawing first on redirected staff from the Center for Infectious Diseases (CID) housed within the Division of Communicable Disease Control (DCDC), CDPH began to establish an Outbreak Investigation Team. By late March 2020, CDPH began tapping other branches and centers that also had relevant experience, including the Occupational Health Branch (OHB). OHB's knowledge of workplace safety, Cal/OSHA standards, and team of industrial hygienists provided expertise on workplace outbreaks. Similarly, the Environmental Health Investigation Branch provided expertise

on cleaning products and ventilation. As one SME noted, this was an early phase of "activating different areas of expertise within CDPH."

- It was difficult to determine roles and responsibilities during the early formation of the investigations team. "There was a lot of confusion once outbreaks started happening, in terms of who does what," one leader noted. For instance, there were questions regarding if (and to what extent) the Outbreak Investigations Team should work with the HAI Program. Adding to the complexity the Outbreak Investigations Team was comprised of redirected CDPH staff who rotated on and off until August 2021; over the first 18 months of the pandemic about 16 CDPH staff cycled through this team.
- As CDPH redirected resources from its various program areas to form the Outbreak Investigations Team, it also began identifying its stakeholders and audiences. The team determined that LHJs needed to be its core customers, and subsequently developed communications geared towards the counties (rather than employers who had questions about outbreaks). The communications also included guidance for prisons, workplaces, schools, and other settings. For further discussion, see the Policy Development and Guidance chapter in this AAR.
- The team also identified its key State partners. Since many early outbreaks were occurring in prisons, the California Department of Corrections and Rehabilitation (CDCR) emerged as a critical partner. Outbreaks were also occurring in major workplaces (such as meat and food processing facilities) so CDPH also partnered with the California Department of Industrial Relations (Cal/OSHA) and the California Department of Food and Agriculture (CDFA).
- CDPH lacked staff who had experience in conducting field investigations and in-person patient interviews, which was a major part of the required work. This was in due in part to the recent discontinuation of the Communicable Disease job series, which focused on communicable disease prevention and control. This series was folded into a broader Health Program job series. As a result, "when the pandemic hit and we needed staff who knew how to go into the field and conduct patient interviews, we had very little bench depth there," one SME noted. In the future, SMEs recommend CDPH attempt to reestablish a Communicable

Disease job series, in order to ensure it has staff with the appropriate knowledge, skills, and abilities.

Outbreak Investigations Team Provided Consultation and Guidance to California Department of Corrections and Rehabilitation Early in the Pandemic

- With the HAI Program focused on outbreaks in SNFs, the Outbreak Investigations Team focused primarily on jails and prisons, which were experiencing large outbreaks in early 2020. CDPH's role early involved providing consultation and guidance to CDCR to help mitigate the outbreaks in their facilities. Identifying an effective model for working with CDCR was challenging. As one SME noted, "we struggled to figure out what our best role was in providing support to our partner, in a situation where there were many unknowns."
- Initially, CDPH team members were assigned to work with key stakeholders from specific prisons. However, CDPH soon realized it also necessary to coordinate closely with leaders at California Correctional Health Care Services (CCHCS), which provides public health guidance to the prison system as well as central leaders of CDCR. CDPH found that it was very challenging to navigate the relationship between CCHCS and the individual institutions, according to one SME. Several key team members left the effort given these difficulties. Ultimately, CDPH created a suitable model to provide consultation and guidance to CDCR.
- For a discussion of CHCQ's infection prevention work in congregate care settings and its early investigations of SNF outbreaks, see the Infection Prevention chapter in this AAR.

Outbreak Consultation Team Officially Formed to Provide Technical Assistance, Consultation, and Resources

- Through August 2021, CDPH relied on its group of rotating, redirected staff to provide outbreak investigations. However, it was clear that a more formal, centralized, and consistent approach to outbreaks was needed. Using federal funding, CDPH established the Outbreak Consultation Team (OCT) in September 2021. This dedicated team was made up of five core team members (including physicians, epidemiologists, health educators, and industrial hygienists) and one administrative staff person. By

November 2021, right before the start of the Omicron surge, most of the team members had been hired.

- When forming the OCT, CDPH applied lessons learned from its previous experience and selected individuals who had extensive experience interviewing and working with LHJs. The inclusion of a high-level administrative position also reflected the need for help with team administration and project coordination. According to one SME, the OCT was designed specifically "to reach out to LHJs and meet their needs as much as possible."
- The goal of the OCT was to provide consultation and technical assistance to LHJs for COVID-19 outbreaks in non-healthcare settings. Outbreak consultations at schools were co-led by the Safe Schools for All Team. Support to LHJs took several forms, such as outbreak management and data support, on-site or virtual ventilation assessments, occupational health consultations, and targeted health education resources.
- Additionally, OCT worked on breaking down silos to foster better communication between labs, LHJs, and other State partners. Over the course of the pandemic response, communication and coordination siloes arose due to the unprecedented size of the response, as well as the multidisciplinary nature of outbreak work. In particular, siloes existed between CDPH outbreak teams, CDPH's Viral and Rickettsial Disease Laboratory (VRDL), which was conducting whole genome sequencing, and LHJs and State partners, would act on the sequencing results. In response, the OCT established regular meetings between the sequencing labs, LHJs, CDCR, and CCHCS, and appointed a team member to foster communication and ensure the timely transfer of information. According to one SME, it was "absolutely critical" and "a real success" for these partners to receive the sequencing information being produced by the lab for the purposes of outbreak investigation.
- From the fall of 2021 to September 2022 the Outbreak Consultation Team provided 116 outbreak consultations to LHJs on outbreaks in a variety of non-health-care settings, primarily shelters, prisons, and schools. These consultations spanned 42 out of the 61 LHJs in the State. Each consultation included follow-up conference calls once or twice weekly until case numbers declined (referred to as "longitudinal follow-up.")

- Additionally, the OCT also provided technical assistance, including 23 industrial hygienist site visits focused on ventilation consultation. Some visits were conducted jointly with CHCQ's HAI Program, and took place largely at schools, shelters, prisons, and rehabilitation centers in remote areas. Approximately half of these visits were in response to outbreaks, and half were conducted as part of a pilot project to build LHJ capacity. Early in the pandemic, there had been "very limited bandwidth for ventilation assessment and promotion of ventilation," but once the OCT was formed it helped CDPH promote the importance of ventilation to LHJs, noted a SME.
- While providing its services, the OCT also educated LHJs on how to access other CDPH pandemic resources and tools. These included Infection Preventionists (IP) visits through the HAI Program, Industrial Hygienist assessments conducted through OHB, and the rapid deployment of testing and vaccination resources through the Outbreak Response Team (ORT), which was a free-floating team. The ORT collaborated closely with the OCT, but was more focused on immediate deployment of physical resources to support outbreak response and mitigation. For further discussion of the ORT, see the Testing chapter in this AAR.
- The OCT also created three unique toolkits to assist LHJs with outbreak management in different environments—correctional facilities, homeless shelters, and workplaces. These toolkits contained information on outbreak data management, data reporting, testing, vaccination, respiratory protection, medical isolation and quarantine, and clinical resources.
- For a discussion of contact tracing and case investigation in schools, and the Schools/Shared Portal for Outbreak Tracking (SPOT), see the Contact Tracing chapter in this AAR.

Outbreak Consultation Team Built LHJs' Capacity and Created a Robust Infrastructure

- Supported by the OCT, LHJs developed their capacities to conduct investigations into outbreaks, especially multi-jurisdictional outbreaks that came into California from other states. "We immediately saw their capacity increase and expand," one leader noted. As a result of the OCT's work, LHJs also grew familiar with the variety of existing pandemic resources and teams that CDPH offered, and how to access them. The

OCT also guided local health officials when faced with difficult policy decisions such as employer testing and time off, and to make workplace modifications to keep workers safe.

- One of the team successes was its responsiveness to LHJs. According to one SME, despite the overwhelming workload, "we responded to every request for support, and our local partners would often express gratitude and would call back again." CDPH's partnership with LHJs was especially critical in navigating some of the early outbreaks in State and federal prisons located in California, which brought up complex questions around jurisdictional authority.
- The OCT also included LHJs when it led a series of workgroup meetings regarding updates to outbreak reporting and definitions in early 2022. The workgroup included 20 LHJs from five regions, in addition to CDPH representatives from the Safe Schools for All team, CalCONNECT and the contact tracing program, the CalREDIE program, and others. OCT led a series of discussions that helped delineate outbreak reporting requirements, identify challenges and potential updates, built consensus, and improved process efficiencies.
- The infrastructure, products, and processes built by the OCT represent significant achievements that can be leveraged in future pandemic responses. "We have lasting infrastructure on how to do this again if it's needed," one SME said, which include the toolkits, materials, checklists, and standardized reports. Beginning with the first incarnation of the Outbreak Investigation Team and then continuing with the Outbreak Consultation Team, CDPH made significant progress in learning how to best structure its outbreak response, including learning from each outbreak to improve its response. SMEs emphasized the need to preserve this knowledge; "it would be a shame for it to go to waste."
- Lastly, representatives from different responses workstreams acknowledged that although the OCT was ultimately successful, it was not created soon enough. It "could've been started earlier" and the delay constituted a "weakness in the system," noted one SME.
- Part of the delay related to the multidisciplinary nature of outbreak response. The contact tracing team indicated that "we saw all these pieces of data coming in" on outbreaks, including data from technical assistance efforts, from schools, and from State partners. However, there

was no mechanism or "trigger" to "bring all these voices together" and develop resources to respond effectively.

- Going forward, CDPH SMEs agreed that a well-supported, well-resourced, and coordinated outbreak consultation infrastructure needs to be in place early on. "Outbreaks will always occur with any emerging infections," one SME noted; "it's better to establish a group early with adequate early support."

Data Modeling

Early Efforts Identified Potentially Useful Models, Data Sources, Key Partners and Team Members

- Data modeling in epidemiology helps predict the spread of diseases—including where and when the spread may occur. Data modeling also may help to discern the most vulnerable populations likely to contract a disease and provide recommendations for intervention. Prior to the COVID-19 pandemic, CDPH's data modeling capabilities were very limited. Much of its data modeling work was outsourced, CDPH lacked trained data modelers who could create the scenario-based models to help identify trends and plan for surges. While infectious disease modeling is closely related to epidemiology, traditionally epidemiologists focus more on statistical analysis.
- In February 2020, CDPH epidemiologists working in the Center for Infectious Diseases (CID) began exploring the possibility of adapting influenza models to COVID-19. This first stage included identifying the State's internal capacity in terms of personnel as well as available data. CDPH began to form an internal data modeling, but it was a challenge to identify personnel with the right skillsets. Early members of the team included epidemiologists and redirected staff that had modeling-related skills such as programming, data visualization, or statistics.
- In addition to assessing its internal capacity, CDPH assessed and defined the data products it would use. In these early days of limited testing, there was very limited data to work with. Consequently, the data modeling team began reaching out to academic organizations to form partnerships. According to a SME, "we went shopping for models that could potentially support us with data they already had or provided us with access to data to generate information to support our needs."

- CDPH consulted with academic researchers at Johns Hopkins University (JHU) Bloomberg School of Public Health regarding a model they were developing. Additionally, the modeling team established connections with modelers at Stanford University and the Institute for Health Metrics and Evaluation (IMHE) at University of Washington, as well as private sector modelers. According to a SME, making these outside connections was "a big lift in March 2020" because it allowed the State to augment its resources and scale up its COVID-19 model. Adapting models from these partnerships to California, the modeling team was able to provide draft results to the CDPH Directorate and State leadership by March 1.
- The data modeling team continued to iterate and refine its models. In mid-March, the data modeling team presented to leadership the influential projection (derived from the JHU model) that would drive California's first-in-the-nation Stay-at-Home order. The model represented various scenarios, including the State's projected hospital bed capacity with and without the stay-at-home order. A day later, on March 19, 2020, the Governor issued Executive Order N-33-20, directing Californians to stay home except as needed to maintain critical infrastructure sectors.
- With the reality of limited data, the State relied on a "simple growth model" to make its policy decisions, since it was easy to interpret and already well-established. However, the modeling team favored an "ensemble" model, which was more complex and incorporated different model types into its calculations. Although ensemble models provided more accurate inflection points than the simple growth model, including disease peaks and valleys, it was more complicated to understand. Some SMEs felt that the simple growth model had an exaggerated influence on policy.

Lane 6 Workstream Disrupted Standard Operating Procedure and Reporting Structures but Expedited Data Modeling Efforts

- At the start of the pandemic in early 2020, CDPH data and epidemiology staff assigned to the early COVID-19 response worked in the same section. The "data team," as it was known, was comprised of data managers and data informaticians, who worked alongside the "epi team," which was made up epidemiologists. Both teams worked closely together within CID.
- However, in late April 2020, select team members were moved to a newly created separate team known as "Lane 6" that reported directly to the

CDPH Directorate and CalHHS leadership. Lane 6 was one of six key indicators outlined in California's early pandemic roadmap. The Lane 6 team was tasked with very similar activities that were already underway, and its purpose and relationship to other workstreams was unclear. Ultimately, it ended up creating siloes within CDPH data and reporting structures that took time to rectify. For additional discussion of Lane 6, see the Data and Reporting chapter in this AAR.

- CDPH's epidemiologists outside of Lane 6 provided data requested by leadership, but were not asked to interpret the data, how it should be considered to inform policies, or formulate modeling scenarios to create different policy alternatives
- Some SMEs pointed out the merits of Lane 6. These included high-level support from CalHHS and the Governor's Office, in addition to the creation of a path for epidemiological information "to get up the chain" to top decision-makers. Because the modeling team did not have many approval layers, it was able to iterate with speed, developing models and messaging that went directly to CalHHS and State leadership. This structure helped the nascent modeling team establish itself quickly. As one SME noted, "to start things up that quickly you have to throw some lessons out the window and be ok with that."
- After the modeling team's work was elevated, it learned to disseminate information and convey complex science in ways that decision-makers could understand. The team focused on brevity, clarity, and expressing its findings in layperson's terms. According to one SME, this was successful: "science comms continues to be an important part of what our team does," and has contributed to the modeling team's "impact and influence."

CDPH's Modeling Team Codified and Enhanced

- In late summer and early fall 2020, the State's COVID-19 pandemic response underwent several changes that impacted data modeling efforts. Lane 6 was discontinued, new CDPH leadership came onboard, and data and reporting streams were centralized. CDPH established a new Modeling Section and hired more staff, including a new Section Chief. The 10-person team had more data and improved data systems at its disposal, and more direction about the specific models and outputs.

- With the establishment of the permanent data modeling infrastructure within CDPH, the team generated more models and collaborated with its external partners. Building on its early academic partnerships, the team gradually established a national reputation for its cross-cutting work. In the words of one SME, "we're not solely ingesting outside academic work but generating our own work, which is a tremendous success." In 2022, CDPH helped establish the first Western States Infectious Disease Modeling Symposium, which brought together public health epidemiologists, modelers, and biostatisticians from Western States to share modeling projects and public health insights. The Symposium was held again in 2023.
- An additional success is the widespread acceptance of data modeling's importance to public health policy within California. Over the course of the pandemic response, CDPH and State leadership gained "model literacy" and developed trust in the value of data modeling for public health overall. According to one leader, it will be critical to maintain this capability so that modeling can be used to inform other public health policies, intervention, and resources, as well as implemented earlier during the next pandemic response.
- The Modeling Section continues to produce and compile "nowcasts" (current status), "forecasts" (two- to four-week projections), and scenario modeling (long-term impacts) for diseases of interest to the State, including COVID-19, influenza, and mpox. This information is shared publicly via CalCAT and with added context and content to LHJs and CDPH leadership for situational awareness. The team also conducts advanced analytics projects related to public health questions of interest to CDPH.

California COVID-19 Assessment Tool (CalCAT) Launched

- The data modeling team launched the California COVID-19 Assessment Tool (CalCAT) in June 2020. CalCAT (which was later renamed to the California Communicable Diseases Assessment Tool) disseminates nowcasts, forecast, and scenario modeling for diseases of interest to the public, LHJs, and other audiences.
- With the launch of CalCAT, CDPH began hosting open forums to discuss infectious disease modeling methods, COVID-19 trends and analyses, and updates to the tool. CalCAT's development culture was a "move-fast-

and-break-things ethos," according to one SME, which was largely successful. Improvements were made to CalCAT over time; in summer 2022 the modeling team reengineered much of the system's internal data pipelines. The system was also expanded to include other diseases such as influenzas and mpox. In 2023, the team rolled out several major CalCAT deployments, including variant nowcasting, wastewater-based R-effective estimation, and combined respiratory burden forecasting.

- CalCAT brings the most relevant infectious disease models together in one place to support policy and public health action. By providing ensemble estimates of critical COVID-19 and influenza metrics from a variety of models, the site facilitates comparison, dialogue, and clarity around trends in the COVID-19 pandemic and across broader infectious disease surveillance. In addition to the current rate of disease spread, the tool shows which variants are most prevalent. It also depicts anticipated hospital and ICU trends for the upcoming two to four weeks, and generates long-term forecasts based on different scenarios such as whether a given population has received vaccination boosters.

University of California Health-CDPH COVID-19 Modeling Consortium Established

- In summer 2020, concurrent with the launch of CalCAT, the CDPH data modeling team formalized their academic partnership with the University of California Health (UCH) system. While the State had been pursuing its own data modeling projects, universities including UC Berkeley and UC San Francisco were partnering with LHJs on local modeling projects. With similar work being done at both the State and local levels, State leadership saw an opportunity to collaborate, share resources, and establish a forum to share data and ideas related to COVID-19 modeling.
- Previously the relationship between CDPH and UC was more informal, but this new effort, which included a steering committee and shared governance structure, established a precedent for how to engage more uniformly and consistently.
- The consortium was announced in February 2021 and began meeting officially in June 2021. One of the biggest hurdles was finalizing data-sharing agreements. The data modeling team advocated to share detailed data, but it had to overcome the tendency for public health to "regard surveillance data as sacrosanct" according to one SME. The

team made "monumental efforts" to share certain datasets. While it was a significant accomplishment that data was eventually shared through the consortium, it was "much slower than it could have been and should have been," another SME added. Foundational data sharing agreements with key partners should be established in advance or templates for "just in time" data sharing should be created to avoid preventable delays in the future.

- Ultimately, the SMEs concluded the consortium was a significant success. It established robust bi-directional communication channels, provided avenues for sharing ideas and data analytics methods, and gave the State access to more data to include in its modeling. As of 2023, the consortium continues to meet monthly to discuss high-priority topics.

Equity

This section describes equity considerations specific to this chapter.

Equity considerations in epidemiology depended on the surveillance project and team. As one SME explained, epidemiologists would analyze the data, identify patterns and trends related to race, ethnicity, region, and other metrics, and then provide the data to the numerous COVID-19 response teams. "We were the ones providing the stratifications and point out 'you might want to explore why this group or region has a higher case rate,'" one SME noted. Epidemiologists also provided specific equity-related data based on requests from specific populations or groups. One SME noted meeting with Native Hawaii and Pacific Islander groups to present their data.

Equity was addressed and incorporated differently depending on each team and project, as discussed further below.

Equity and Sero-Surveillance

- The CalScope research team designed the study to ensure the CalScope sample adequately represented California's population. This included taking demographic and equity measures into account when developing the study sample. As the study waves were completed, the team analyzed and presented its data by Healthy Places Index (HPI) categories. The HPI is a composite measure of socioeconomic opportunity applied to census tracts that includes 25 individual indicators across economic, social, education, transportation, housing, environmental and neighborhood sectors. It predicts life expectancy and compares community conditions that shape health across the State. By analyzing its data by HPI, CalScope aimed to better understand how COVID-19 antibodies may differ across groups and identify which populations could benefit from additional resources.
- Additionally, the CalScope team ensured that all informational and survey materials were available in multiple languages. The materials were also provided to LHJs in an editable format, so that LHJs could translate them into other languages or customize the messaging to meet the needs of their communities. While CalScope was a web-based survey, the team also provided physical and phone options for individuals.

Equity and Sentinel Surveillance and Population-Based Surveillance

- Starting in May 2020, the CalSRVVS team began partnering with LHJs to establish outpatient community sentinel surveillance sites. The team focused on reaching populations that had limited access to testing. "An inherent goal from the start was to provide testing in areas where it was lacking, and to provide extra testing for marginalized populations," one SME explained. Another added that this was "an integral part of what we tried to do." This informed which LHJs CDPH reached out to, and which testing sites within their communities were encouraged to enroll in the project. This approach was successful, and many participating counties enrolled testing sites that served at-risk or underserved populations.
- When designing the Case-Control Study, CDPH considered language equity. Anticipating that language might be a barrier, the survey team established a group of bilingual interviewers that were fluent in Spanish. It also translated the survey and guide into Spanish, "so that the folks who were doing bilingual interviewing had a guide that was just as robust as the English version." The team did not make the survey or guide in additional languages, which SMEs acknowledged was a limitation. However, "creating those resources and seeing them be used was one small thing we did to tackle equity," one SME noted.

Equity and Clinical Surveillance

- Members on the clinical surveillance team considered equity when developing their early guidance and answering clinical questions. "From a clinical standpoint, there was an equity issue about how the virus was named, and about how initial names can lead to racism and stigma," one SME explained. Consequently, the clinical team was careful in its consultations to avoid terminology that could stigmatize certain populations. When the clinical team weighed in on the development of California's contact tracing program, "there were also a lot of considerations about how to provide that service" in a way that would not be stigmatizing for the recipients. As one clinician observed, "it's just something that we need to have on our radar."
- Additionally, the clinical surveillance team noted the growth of other diseases (such as tuberculosis and HIV) that were eclipsed by the

attention and resources devoted to COVID-19. Many individuals with these preventable diseases went untreated during the pandemic, and infection numbers increased. In the words of one SME, the "inequity burden grew for these other conditions."

Equity and Outbreak Consultation

- The CDPH's Outbreak Consultation Team was largely focused on meeting equity needs via providing consultations and technical assistance to populations disproportionately affected by COVID-19. These included incarcerated persons, individuals in homeless shelters, and farmworkers in shared housing—locations in which it was difficult to isolate and quarantine. "Our team was able to help strategize" in those situations, said a SME.
- Additionally, OCT focused on providing assistance and helping build capacity in more rural, resource-limited LHJs, including those who served Native American reservations, schools with limited resources, and rural populations. According to a SME, "a lot of time they didn't have the workforce, especially when going through a surge," and so the team provided technical, "hands-on" assistance.

Equity and Data Modeling

- The data modeling team played an influential role in incorporating health equity into epidemiology workstreams and the State's overall COVID-19 response. Beginning in early 2020, several team members leveraged their background in health equity to focus on vulnerable populations. The data modeling team focused on equity and vulnerable populations through working with CDPH's informaticians to analyze COVID-19 data by zip code, also known as "geo-coding."
- Associating COVID-19 data with locations allowed the team to identify trends, patterns, findings, and disparities. After analyzing geocoded COVID-19 data alongside the Healthy Places Index, the team could "describe case rates by social advantage" in a way that that it had never done before. For instance, the modeling team demonstrated that people in wealthier communities were able to stay at home more than those in less wealthy communities, highlighting inequities resulting from the stay-at-home order.

- During and after Lane 6, the modeling team communicated key messages about health equity directly to CalHHS and the Governor's Office. In addition to providing information about the "nuts and bolts" of modeling, the team also included information about the disproportionate impacts of COVID-19 in its reports. As the team received information about disproportionate COVID-19 outcomes, it continued to reinforce equity-related messages and findings to leadership. "We were able to convey this evidence to decision-makers," one SME noted.
- The health equity findings and data "eventually worked their way into policy," according to one SME. This was an unprecedented success and major milestone. For instance, the State's reopening policy, Blueprint for a Safer Economy, incorporated a health equity metric, which was the first of its kind to use an equity metric influencing when and what could re-open in each county. When vaccines became available, equity was integrated into the State's vaccine policies to prioritize vaccine allocations in disproportionately impacted communities.
- Overall, SMEs emphasized the modeling team's contributions to California's ground-breaking focus on health equity throughout the COVID-19 response. In the word of one SME, "setting the tone early on really impacted the response, and equity is in all the conversations now."

Data and Technology

This section describes data and technology specific to this chapter.

- All of the surveillance teams found technology to be challenging when they initiated their surveillance projects. Many of the projects were innovative and novel, and thus required new databases, applications, tools, datasets, and processes. Many SMEs agreed that "data systems and infrastructure were totally lacking" at the start of the pandemic. This was a significant obstacle to the collection and analysis of epidemiological surveillance data.
- The core communicable disease surveillance system, CalREDIE, is a legacy system that is not flexible for data extraction or analysis or additions of new fields. CalREDIE is dependent on one small vendor for support when the system has issues or is down, and has a small data pipeline between it and the State's contact tracing system (CalCONNECT) that frequently experiences challenges. In order to better monitor and respond to current and future diseases of public health significance in California, an updated and more flexible system is necessary.
- Consequently, many epidemiological surveillance projects built their data infrastructure "ad hoc in a manual, miracle way," according to SMEs. This involved relying on academic partners to provide access to systems and resources. For instance, when CDPH partnered with Stanford University to conduct the CalScope sero-survey the university provided REDCap, a HIPAA-compliant secure web application to build and manage online surveys and databases. Similarly, the Case-Control Study team, through its partnership with the University of California, was able to access REDCap and another cloud-based software tool, Qualtrics. While this was successful, one SME noted that "we have to partner to get access to a system to really do this work in a consolidated way." A key takeaway was that CDPH should have access to tools on their own without having to rely on a partnership.
- For the clinical and hospitalization surveillance teams, the lack of access to real-time hospital surveillance and to coroner's data necessitated manual work-arounds. As discussed in the Analysis of Activities, in the early phases of clinical surveillance, the clinical team called providers and

coroners directly to gather patient information and manually review medical charts. For hospitalization surveillance, CDPH initially relied on a federal survey, and then later a State survey, which each have their own limitations. As discussed earlier in greater detail, both clinical and hospitalization surveillance SMEs emphasized the need for the State to tap into EHR records, which would require data systems, resources, staffing, and legislation.

- Over the course of the pandemic, CDPH made significant improvements in its data and reporting infrastructure. These included new systems and tools, including the Snowflake data warehouse and the COVID-19 Reporting System (CCRS) for processing electronically submitted lab data. Data and epidemiological teams were also centralized into new units. This helped alleviate communication challenges between data teams who produced the data, and the various other response teams who used the data products in their analysis. For further discussion, see the Enterprise Technology and Data and Reporting chapters in this AAR.
- Many of CDPH's COVID-19 epidemiological surveillance projects successfully created new applications, datasets, and systems, including COVIDNet (genomic surveillance), CalCAT (data modeling), and Cal-SuWers (wastewater surveillance). These systems are discussed in detail in the Analysis of Activities.
- Additionally, the Outbreak Consultation Team created sustainable processing system that coded outbreak data by industry and setting, which generated products used by team members and other response teams. This system made it easier to look up past outbreaks, understand historical patterns and compare events across time, and identify and monitor high-risk settings. Using this system, "we were able to combine our efforts and use the outbreak data to inform who and what to target, and reach out to LHJs in a proactive manner."

Communications

This section describes communications specific to this chapter.

Figure 2 presents a summary matrix of internal, external, and other communications by surveillance team and/or project. For additional details and project-specific communications, see the relevant section in the Analysis of Activities.

Figure 2: Summary Matrix of Internal, External, and Other Communications by Surveillance Team/Project.

Surveillance Team/Project	Internal Communications	External Communications
Wastewater surveillance	• The wastewater surveillance team reported up to twice weekly to CDPH leadership. Their reports consisted of a slide deck and an email summarizing project updates and highlights from wastewater testing results. Leadership also had access to an internal dashboard. The presentation of the data to visualize trends by geographic region continued to evolve and improve.	• The wastewater surveillance team maintained a public-facing dashboard (updated weekly) to share data with interested stakeholders. The team also held monthly stakeholder calls for LHJs and utilities in the Cal-SuWers Network to go over results and major project updates.
Genomic surveillance	• The genomic surveillance team communicated its findings to CDPH leadership and its partners. It communicated regularly with its	• CDPH maintains a website that includes data on genomic surveillance, current variant

Surveillance Team/Project	Internal Communications	External Communications
	advisory panel, laboratory network, private partners, and LHJs. The team also met with sequencing laboratories monthly for quality control.	proportions, and modeling estimates. The website is updated bi-weekly.
Sero-surveillance	• As the CalScope study progressed, communicated the key findings to CDPH Science Branch leadership via PowerPoint presentations. Periodic updates to CDPH leadership were also conducted, and summaries of each phase were included in summary reports to CDPH, CalHHS leadership and the Governor's Office.	• The CalScope team collaborated heavily with LHJs develop and refine its project communications. After each wave, the CalScope team presented study results to its LHJ partners and solicited their input on how to improve project communications for subsequent waves. The team also solicited LHJ feedback via a survey on project messaging and how to make it more targeted.
Sentinel surveillance	• The CalSRVSS team shared a weekly report and roadmap with leadership via email. It also shared a weekly report with CDPH response teams and other groups interested in the project. The team also created an online, internal dashboard to share data.	• The CalSRVSS team conducted in-person site visits with LHJs, clinics, and labs. These helped State and local public health teams build partnerships and clarify methods. The team also sent weekly, customized reports to all LHJs who were participating in the project. It also shared data and

Surveillance Team/Project	Internal Communications	External Communications
		findings with VRDL, which helped with specimen testing.
Case-Control Study	• The Case-Control Study team shared quarterly reports with Science Branch and CDPH leadership. The team responded to requests for information with informal, internal reports on an ad hoc basis.	• The Case-Control Study team shared their evidence primarily through peer reviewed journals. They published multiple papers, including one in the CDC's journal. The team also delivered presentations to classrooms as part of its educational outreach.
Clinical surveillance	• The clinical surveillance team reported its work to CDPH leadership through email and in Science Branch team meetings. Regular branch chief meetings were discontinued during the response.	• The clinical surveillance team had a dedicated communications specialist, who helped create messaging and materials about its surveillance projects. The clinical surveillance team also used an LHJ SharePoint site to provide resources with LHJs, which was deemed successful.

Surveillance Team/Project	Internal Communications	External Communications
Hospitalization surveillance	• The hospitalization surveillance team reported to CDPH leadership at least weekly via email and to the Governor's Office via a PDF report of its dashboard.	• The hospitalization surveillance team reported to the public via public-facing dashboards. It also reported directly to the federal government via its upload system. The team also provided data to LHJs, although it mainly directed LHJs to the public-facing dashboards or granted them access to Snowflake, CDPH's internal data warehouse.
Outbreak consultation	• The Outbreak Consultation Team communicated to CDPH leadership through written weekly reports and also included CDPH leadership in high-profile outbreak investigations. Additionally, the team took part in weekly Science Branch calls and monthly branch updates. The team held both standing and ad-hoc weekly meetings with multiple response teams (including HAI, VRDL, OHB, ORT, LCT, and others).	• The Outbreak Consultation Team maintained twice-weekly standing meetings with CDCR and CCHSCS. • It also communicated extensively with LHJs as it provided its outbreak consultation and technical assistance services.
Data Modeling	• During the pandemic, the modeling team reported initially on a daily basis to the Governor's	• The modeling team shared its data and information widely during the pandemic response. It was presented

Surveillance Team/Project	Internal Communications	External Communications
	Office, CalHHS leadership, and CDPH leadership. These reports were usually in the form of slidedecks and memos. As the pandemic evolved the cadence of reporting decreased as with other internal reports.	at weekly meetings with California Conference of Local Health Officers (CCHLO) and County Health Executives Association of California (CHEAC). It established and maintains the CalCAT website. The modeling team also hosts a CalCAT open house every other week for LHJs and other interested parties. Additionally, the team helped established the UCH-CDPH COVID-19 Modeling Consortium, which meets monthly.

Workplan

This section is designed to be used as a workplan for future pandemics.

Definitions:

- **Phase**: The phase of the response in which the major tasks should be conducted (Planning; Initial start-up, Ongoing operations, or Close-out).
- **Major Tasks:** The tasks and activities that have to be conducted as part of the public health emergency response to a respiratory pandemic.
- **Success Criteria:** Criteria used to assess whether a task has been achieved successfully.
- **Considerations Based on COVID-19 Response:** Things to consider, including pitfalls, risks, and lessons learned, based on the COVID-19 response.
- **Finding ID:** The ID(s) from the related Finding/Corrective Action (where applicable).
- **Lead:** The lead person(s) responsible for task completion.

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
Planning; Initial start-up	Explore legislative solutions to improve hospitalization surveillance	• CDPH has access to de-identified real-time hospitalization data, enabling it to better respond to surges and pandemics.	• CDPH lacks the authority to monitor hospitals in real-time. • CHCQ is responsible for licensing and enforcement of	• Epidemiology 24; Data and Reporting 23	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
		• Private patient data is protected.	California's hospitals. • HCAI or EMSA could have this authority instead of CDPH to leverage their existing core functions.		
Planning; Initial start-up; Ongoing operations	Maintain and improve surveillance data streams and technology infrastructure	• Surveillance data is timely, representative, and sustainable. • Teams have access to the necessary technology to conduct surveillance work.	• Evaluate and prioritize surveillance data streams from a holistic, strategic perspective. • Continue current technology modernization efforts (e.g., Future Disease Surveillance System). • Explore ways to access tools such as REDCap.	• Epidemiology 3, 14, 16, 25; Data and Reporting 9; Enterprise Tech 5	
Planning; Initial start-up;	Identify and initiate strategic epidemiological	• CDPH's surveillance approach is	• Develop a surveillance strategy early.	• Epidemiology 1, 5, 6, 7, 8, 9,	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
Ongoing operations; Close-out	surveillance projects	flexible, strategic, and can evolve in response to changing pandemic needs. • CDPH develops a surveillance strategy template or menu for emerging diseases and a process for prioritizing projects during an emerging activation.	• Identify and anticipate surveillance gaps. • Recognize that some surveillance projects may not have immediate utility. • Allocate resources across surveillance projects strategically. • Continue to monitor and invest in innovative, cutting-edge surveillance strategies (e.g., wastewater, genomic). • Initiate, adjust, and discontinue projects as needs change. • Maintain and continuously	10, 11, 15, 20, 21	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
			update the Surveillance Roadmap document to guide future activations. • Improve collaboration between public health and the coroner system.		
Planning; Initial start-up; Ongoing operations	Maintain and expand epidemiological partnerships and collaborations across CDPH and with academic partners	• CDPH has access to the knowledge and expertise in other sectors. • CDPH maintains an MOU, data sharing, and governance structure for academic collaboration with University of California.	• Most COVID-19 epidemiological surveillance projects (especially the most cutting edge) relied heavily on partnerships, including partnerships with universities, private industry, and other entities.	• Epidemiology 2	
Planning; Initial start-up;	Initiate epidemiological data modeling	• Data modeling and outbreak consultation	• During the COVID-19 response, it took	• Epidemiology 12, 13, 23, 25	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
Ongoing operations	and outbreak consultation early	infrastructure are in place to begin work immediately when needed.	several iterations for the modeling team to produce products that were useful for leadership. • During the COVID-19 pandemic, it took too long for CDPH to establish a dedicated Outbreak Consultation Team.		
Initial start-up; Ongoing operations	Establish and maintain consistent, clear epidemiological communications	• Teams have clarity regarding their role, scope, and purpose. • Communication between teams and leadership is bi-directional.	• Establish and maintain ICS structure. • Coordinate leadership requests for information to avoid overwhelming teams and duplicating work. • Communicate how individual	• Epidemiology 19; Data and Reporting 22	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
			projects into the broader response.		
Initial start-up; Ongoing operations	Develop and implement an epidemiological staffing (and resource/funding) and ICS activation plan	• CDPH has adequate technical staff with the right skillsets to support all epidemiology and surveillance efforts. • Burnout is mitigated. • Resources are used appropriately and efficiently.	• Anticipate staff burnout and develop a mitigation plan. • Obtain administrative support to assist with non-technical or non-epidemiological tasks. • Dedicate a non-clinical team to conduct literature reviews. • Expedite hiring and onboarding processes. • Collaborate with CalHR to establish a Communicable Disease job series. • Collaborate with CalHR to relax rigid requirements	• Epidemiology 17, 18, 22, 23; Data and Reporting, 19, 20, 21; Infection Prevention 8	

Response Phase	Major Tasks	Success Criteria	Considerations	Finding ID	Lead
			for long-term contract staff.		
Initial start-up; Ongoing operations	Incorporate equity into epidemiology and surveillance efforts	• CDPH incorporates equity into its surveillance efforts when possible.	• Recognize that equity considerations mean different things for teams. • For epidemiology, having an equity focus often means identifying trends and supplying the metrics/data to other, more operational response teams.	• Epidemiology 4	