Refinery Emergency Air Monitoring Assessment Report

Objective 2: Evaluation of Air Monitoring Capabilities, Gaps, and Potential Enhancements

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ARB Monitoring and Laboratory Division
Incident Air Monitoring Section

California Air Pollution
Control Officers Association

Table of Contents

I. EXECUTIVE SUMMARY 1

II. INTRODUCTION 12

III. BACKGROUND 12

IV. SCOPE OF THE REPORT 17

V. EVALUATION OF AIR MONITORING CAPABILITIES, GAPS, AND POTENTIAL ENHANCEMENTS 23

A. MONITORING 24

1. Continuous Process Unit Monitoring 29
2. Refinery-Specific Ground Level Monitors 32
3. Hand-Held and Portable Air Monitors – On-Site Use 34
4. Hand-Held and Portable Air Monitors – Off-Site Use 35
5. Fixed Real-Time PM Monitors 37
6. Fixed Real-Time Toxics Monitors 40
7. Fenceline Monitoring Systems 43
8. Community Monitoring Systems 47
9. Mobile Incident Monitoring Equipment 50
10. Community Hazard Patrols 51
11. Optical Remote Sensing and Spectral Flux Monitoring Technology 52
12. Community Sensor Network Technology 53

B. MODELING 55

1. USEPA /CalARP Risk Management Plan 57
2. Real-time On-Site Modeling Capability (Immediately Available Modeling) 60
3. Predictive Modeling Capability 63
4. IMAAC Coordination 64

C. COMMUNICATIONS/COORDINATION 66

1. Refinery Emergency Drills and Exercises 67
2. Mutual Aid Organizations 67
3. Support for Local CAER and Similar Community Organizations 68
4. Area Plan/RMP Review 68
5. Community Notification Systems 69
6. Process Safety Management Coordination 74
7. Air Monitoring Coordination/Training 76

VI. CONCLUSION 77

VII. LIST OF APPENDICES 80

LIST OF ABBREVIATIONS

AERMOD	Atmospheric Dispersion Modeling System
ALOHA	Areal Locations of Hazardous Atmospheres
APCD	Air Pollution Control District
APCO	Air Pollution Control Officer
AQMD	Air Quality Management District
AQPSD	Air Quality Planning and Science Division (CARB)
AQ-SPEC	Air Quality Sensor Performance Evaluation Center
BAAQMD	Bay Area Air Quality Management District
CAER	Community Awareness and Emergency Response
CalARP	California Accidental Release Prevention Program
CARB	California Air Resources Board
CalEPA	California Environmental Protection Agency
CalOES	California Office of Emergency Services
Cal/OSHA	California Division of Occupational Safety and Health
CAMEO	Computer-Aided Management of Emergency Operations
CANSAC	California and Nevada Smoke and Air Committee
CAPCOA	California Air Pollution Control Officers Association
CARPA	California Air Response Planning Alliance
CCR	California Code of Regulations
CDPH	California Department of Public Health
CO	Carbon Monoxide
COBRA	Co-Benefits Risk Assessment
CSB	Chemical Safety Board
CRDS	Cavity Ring-Down Spectroscopy
CST	Civil Support Teams
CUPA	Certified Unified Program Agency
CWS	Community Warning System
DIAL	Differential Absorption Light Detection and Ranging
DIR	Department of Industrial Relations
DOAS	Differential Optical Absorption Spectroscopy
DRI	Desert Research Institute
EO	Executive Order
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FTIR	Fourier Transform Infrared Spectroscopy
GLM	Ground Level Monitors
GPS	Global Positioning System
HazMat	Hazardous Materials
HAZOPs	Hazardous Operations
HARP	Hotspots Analysis Reporting Program
HCl	Hydrochloric Acid
HF	Hydrogen Fluoride
Hi-vol	High Volume

Acronyms (cont'd)

H_2S	Hydrogen Sulfide
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IAMS	Incident Air Monitoring Section
IPAWS	Integrated Public Alert & Warning System
IRTF	Interagency Refinery Task Force
ISO	Industrial Safety Ordinance
JIC	Joint Information Center
LEL	Lower Explosive Limits
LEPC	Local Emergency Planning Committee
MAXDOAS	Multi-Axis Differential Optical Absorption Spectroscopy
MOA	Memoranda of Agreement
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	Ammonia
NOAA	National Oceanic and Atmospheric Administration
O_2	Oxygen
OEHHA	Office of Environmental Health Hazard Assessment
ORS	Optical Remote Sensing
PAH	Polycyclic aromatic hydrocarbons
PHAST	Process Hazard Analysis Software Tool
PM	Particulate Matter
PSM	Process Safety Management
RMWG	Refinery Monitoring Working Group
RMP	Risk Management Plan
RSPM	Refinery Safety Program Manager
SAFER	Systematic Approach for Emergency Response
SCAQMD	South Coast Air Quality Management District
SCIMO	Southern California Industrial Mutual Aid Organization
SJVAPCD	San Joaquin Valley Air Pollution Control District
SLOAPCD	San Luis Obispo Air Pollution Control District
SLORHMRT	SLO County Hazardous Materials Response Team
SO_2	Sulfur Dioxide
SOF	Solar Occultation Flux
TAC	Toxic Air Contaminants
TFD	Torrance Fire Department
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
UV-DOAS	Ultraviolet Differential Optical Absorption Spectroscopy
VOC	Volatile Organic Compounds
VOIP	Voice Over Internet Protocol
WEAs	Wireless Emergency Alerts
WCS	Worst Case Scenario

REFINERY EMERGENCY AIR MONITORING ASSESSMENT REPORT

Evaluation of Air Monitoring Capabilities, Gaps, and Potential Enhancements

I. EXECUTIVE SUMMARY

Background

In August, 2012, the Chevron Refinery in Richmond, California experienced a major fire that raised serious concerns among elected officials, regulators, and the public about refinery maintenance, internal safety practices and emergency preparedness in the vicinity of California's oil refineries and other large petrochemical facilities. The Richmond incident, and others that have occurred since 2012, led to intensified community concern in three main areas: 1) lack of sufficient safety controls to prevent accidental releases at refineries and other industrial facilities, 2) inadequate emergency response monitoring systems to effectively inform and protect communities in the event of an accident, and 3) insufficient government oversight to ensure effective emergency preparedness and response to unplanned air contaminant releases.

In response to these concerns, the Governor created the Interagency Refinery Task Force (IRTF) in 2013 with the goal of better coordinating refinery safety and compliance efforts, and improving preparedness for future incidents. The IRTF includes representatives from various state and local agencies including the California Air Resources Board (CARB) and four air districts with refineries in their jurisdictions (Bay Area Air Quality Management District, South Coast Air Quality Management District, San Joaquin Valley Air Pollution Control District, and San Luis Obispo Air Pollution Control District). In support of IRTF goals, CARB and the California Air Pollution Control Officers Association (CAPCOA, represented by the air districts mentioned above) agreed to jointly assess existing emergency air monitoring capabilities and to identify potential improvements to refinery air monitoring systems.

In July 2013, CARB and CAPCOA released the Project Plan, a roadmap document that described a process to achieve four objectives related to California's refineries: 1) identify existing air monitoring assets and resources, 2) evaluate air monitoring capabilities, gaps, potential enhancements and provide recommendations for achieving these enhancements, 3) develop statewide guidance to implement

monitoring recommendations and encourage best practices, and 4) improve ongoing interagency coordination, preparedness and training for air emergencies. CARB and CAPCOA issued the first project report fulfilling Objective 1 in May 2015, identifying the air monitoring and emergency response capabilities for each major refinery and air district in California. Shortly thereafter, the California Environmental Protection Agency's (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA) began a companion survey to identify toxic chemicals emitted by refineries, to inform CARB and CAPCOA's focus of refinery air monitoring systems on key chemicals.

This report fulfills the Project Plan's Objective 2 goal for evaluating air monitoring capabilities, gaps, and potential enhancements by specifically examining monitoring infrastructure, modeling practices, and emergency response protocols for refineries and agencies throughout California. Based on this evaluation and analysis, the report presents recommendations to improve air monitoring within and around refineries, incorporate state-of-the-art air pollutant dispersion modeling, adopt new technologies to communicate real-time data and information, and ensure users are adequately trained.

In addition to improving rapid detection and communication of potentially hazardous releases to responders and the public, the proposed air monitoring system improvements can also provide long-term data to help reduce chronic exposure to ongoing routine releases. This report's recommendations set the stage for better interagency communication, public outreach, and overall improved public health surrounding refineries throughout California. These recommendations may also serve as a model for improving safety practices at other industrial facilities throughout the state.

California already has begun to address some of the report's findings and recommendations. Several recent California statutes and regulations now improve refinery emergency preparedness, require community air monitoring, improve notification systems and establish permanent refinery oversight. One example, Assembly Bill 1647, includes new requirements for significantly enhanced fence-line and community-level air monitoring at and near refineries. Findings of this refinery-focused report will also be a useful resource as CARB and air districts work with stakeholders to implement California's Community Air Protection Program under AB 617, enacted in 2017.

Recommendations

This report presents findings and recommendations organized into three topics: Air Monitoring, Modeling, and Communication and Coordination. A summary of the findings and recommendations for each topic is provided below. Additional detail is provided in Table ES-1.

Air Monitoring

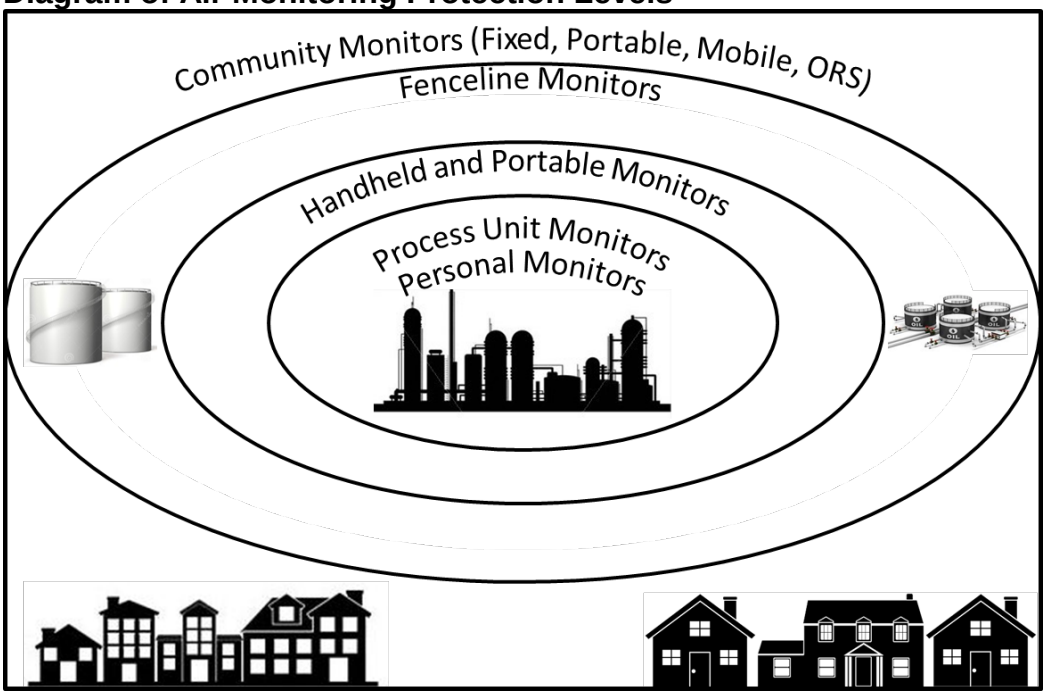
This report recommends enhancements to various air monitoring systems, employing new approaches and technologies that will enable refineries and responders to gather relevant, reliable air quality data in real time and to make well-informed safety decisions based on air data. It addresses needs for new technology and communication applications that will generally require deployment of larger numbers of monitors and sensors to collect and transmit more frequent measurements. Recommendations for improved near-term, site-appropriate air monitoring both within the refineries' boundaries and in surrounding communities include the following:

1. Refineries and response agencies should expand use of personal air monitors and handheld devices equipped with real-time telemetry.
2. Refineries should expand site-appropriate process unit monitoring, ground-level monitoring, and fenceline monitoring, all transmitting real-time data for immediate notification and evaluation.
3. Districts should establish enhanced, site-appropriate community monitoring systems, including fixed, mobile, and community-based sensor systems.
4. Districts should demonstrate and require appropriate deployment of new technologies and systems, such as optical remote sensing (ORS), sensor networks, and other real-time instrument capabilities.
5. Refineries should adopt enhanced off-site community notification, education, and patrol programs.
6. CARB and districts should provide resources for communities to establish their own community-based low-cost sensor networks and assist with network demonstrations.
7. CARB and districts should establish a permanent refinery monitoring working group (RMWG) staffed by emergency monitoring liaisons from each air agency, with a continuous participation and reporting role in IRTF.[1]

The figure below provides a schematic representation of air monitoring methods used to assess emissions and accidental releases in and near refineries.

[1] An interagency refinery air monitoring working group consisting of liaisons from CARB and CAPCOA districts with refineries in their jurisdiction is necessary. This report recommends creation of dedicated refinery emergency liaison functions at CARB and the local district level, likely requiring additional part- or full-time positions. The permanent roles of the emergency liaison function are to further develop specific programmatic framework and implementation details of this report's recommendations, ensure emergency response plans adequately address air monitoring, coordinate with other agencies on the proper role of air district personnel during emergency responses, ensure that necessary resources are available, and ensure all personnel are appropriately trained.

Diagram of Air Monitoring Protection Levels



Modeling

The assessment reviewed a range of predictive and real-time modeling capabilities and found further work could improve the confidence and application of models, while emergency preparedness and response programs could benefit from better use of these models. Specifically, consequence modeling required to meet regulatory requirements for CalARP risk management plans could benefit from a technical review of the required models and their application. For example, including cumulative impacts, cascading effects, and process intermediates could better define the risk posed by refineries than the current, narrower focus on specific processes with substances over a threshold limit.

Further validation of existing and new models would increase confidence in their results and better justify modeling requirements to determine offsite impacts of an incident within minutes after refinery staff become aware of it. Furthermore, the report recommends that refineries establish site-appropriate modeling portfolios and incorporate well-integrated, site-appropriate modeling systems into their emergency response programs and plans. Lastly, CARB and CAPCOA members should work with the federal Interagency Modeling Atmospheric Assessment Center (IMAAC) to ensure refineries and first responders have timely access to IMAAC modeling information for refinery drills, exercises, demonstrations, and real-time emergency needs.

Communications and Coordination

Timely communication and coordination of monitoring data and projections are critical elements of an effective response to any emergency. Many federal, State and local agencies are working collaboratively to address this issue as it relates to refinery incidents. CARB and CAPCOA members evaluated coordination enhancements by other agencies and CARB interviewed local response agencies and managers from all fifteen refineries in California. In most cases, responsibility for enhanced communication and coordination falls within the authority of the local Certified Unified Program Agencies (CUPAs) under California Environmental Protection Agency (CalEPA) oversight, rather than under CARB and CAPCOA members. These include:

- Requirements for more broadly integrated training and exercises,
- Regular refinery participation in mutual aid efforts and maintenance of refinery emergency response plans and overall preparedness,
- Maintenance and participation of Community Awareness Emergency Response (CAER) groups in communities with refineries,
- Improved training for first responders and businesses through the CUPA Forum.

However, this report also includes recommendations for circumstances in which CARB and CAPCOA members should play a greater role in coordination, including:

- Establish a forum to share technical information on wireless communication technology used by CARB, air districts, and other agencies, in consultation with California Office of Emergency Services (CalOES),
- Provide public data on refinery emissions, operating status, continuous and real-time air monitoring data access, and upset conditions, via website and social media,
- Evaluate the feasibility of using air monitoring data as a process safety indicator,
- Develop an interagency protocol for optimal air monitoring as quickly as possible following lead agency notification of a refinery incident/release,
- Initiate air district participation in technical reviews of area plans/RMPs.

Implementation

The recommendations in this report cannot be fully implemented without significant additional commitments by refineries, air districts, local response agencies, and the State. These entities will need to purchase and deploy additional monitoring equipment and communications systems, research and optimize air dispersion modeling tools and systems for emergency releases, maintain and operate the expanded monitoring networks, analyze data collected, provide training and ongoing coordination between refineries and agencies, and assess overall program

effectiveness. These functions are important enough from a public health and safety perspective to warrant establishing refinery air monitoring liaison positions within each air district and CARB. Working with air districts, CARB will assess and identify the most appropriate funding sources, taking into account resources and capabilities made available through AB 617. Ultimately, all costs should be borne by the refineries either directly or through surcharges or fees, with responsibility for implementing the recommendations being divided among the refineries, local air districts, local emergency response agencies, CARB, and community-based organizations. Additional resources will enable CARB and cooperating State agencies to establish and maintain statewide oversight functions, while local air districts and emergency response agencies create enhanced, collaborative air monitoring networks, generate timely air quality data, and improve response capabilities during accidental contaminant releases. Considering the ITRF's refinery safety program goals more broadly, CARB, CAPCOA members, CUPA Forum Board, CalEPA, and other IRTF stakeholders should carefully coordinate for efficiency and to avoid duplication in programmatic framework and implementation details.

Summary of Findings and Recommendations

Table ES-1 summarizes this report's key findings, recommendations, and suggested implementation strategies. The key findings and recommendations broadly indicate the most effective air monitoring and emergency response technologies and practices identified for California refineries in general. There are other findings, recommendations and suggested implementation measures in the report that are not listed here as 'key' elements of primary importance, but are nonetheless worthy of inclusion in a statewide program.

Conclusion

Regional and local differences exist throughout California on the timely detection and communication of data and information used to prevent or respond to unplanned air releases at refineries. Based on the evaluation conducted by CARB and CAPCOA members, we better understand the air monitoring, modeling, communications, and resource gaps that exist, as well as best practices that are being implemented in some regions.

The primary goal of this report is to identify and promote effective methods for providing immediately actionable air quality data to incident commanders directly responsible for public safety during a refinery air contaminant release. An ancillary goal is to provide continuous emissions data to the community as a whole that can in turn be used to evaluate and adaptively manage the impacts of refineries' emissions on the community. It will be essential that this data is made easily available and presented in a clear, understandable format for the public.

The greatest opportunity for improvement exists with respect to emerging technologies for community monitoring, by citizens as well as agencies, not only as relates to emergency response for large unplanned releases, but also as applies to the ongoing evaluation of routine fugitive emissions and their long-term impacts on surrounding communities. Community monitoring by agencies has the advantage of providing high-quality data with reliable telemetry in real-time and near real-time, while citizen-based monitoring has the potential to saturate the community surrounding a refinery with lower-cost, generally indicative air quality sensors. The suggested air monitoring improvements also enable the State to capitalize on broader opportunities for trend analysis using industrial source data required under California's Mandatory Reporting Regulation. Analysis of these data, in conjunction with criteria and air toxic emissions data from local air districts, will inform a broader effort CARB is undertaking with the air districts and stakeholders to identify opportunities for further reducing emissions from stationary, mobile and area sources that impact the health of California residents, particularly those in disadvantaged communities.

While Contra Costa County and BAAQMD responded quickly to the Richmond Refinery fire, response authorities could have had a timelier and more complete assessment and improved communication of the potential hazards had the recommendations in this report been in place. An improved monitoring network and site-specific modeling could have provided real-time data and potential impact information to refinery personnel and emergency responders. The communication and coordination recommendations likely would have improved coordination between refinery managers, first responders and air monitoring professionals, resulting in more complete and timely information to the public.

Other industrial accidents, such as the 2015 ExxonMobil Torrance Refinery[2] explosion and the 2015-2016 natural gas well leak at SoCalGas' Aliso Canyon storage facility have further highlighted the need for improved air monitoring and emergency response capabilities in the vicinity of refineries and other industrial facilities. Although this report focuses on refineries, the recommendations presented here may serve as a model for enhancing emergency response and routine air monitoring for other industrial facilities in California.

[2] ExxonMobil sold the Torrance Refinery to PBF Energy in July 2016.

Table ES-1. Summary of Key Findings, Recommendations, and Proposed Implementation Actions

	Findings	Recommendations	Implementation
	Statewide coordination and unity of messaging are necessary for a consistent emergency air monitoring program. Coordination with county health officials and having only one media contact for all agencies will ensure public health messages are timely, appropriate, and delivered with "one voice."	CARB and the affected air districts should form a permanent Refinery Monitoring Working Group (RMWG) staffed with newly established emergency preparedness liaisons from liaison each district, and CARB staff.	The RMWG will work within the existing IRTF framework to develop guidance and enhance capabilities for more effective refinery air monitoring and emergency response.
Air Monitoring	Ground level monitoring (GLM) for hydrogen sulfide (H_2S) and sulfur dioxide (SO_2), both on site and in communities surrounding refineries, is a proven method for continuous monitoring and mitigation of fugitive emissions. GLM measurements can provide information on off-site consequences to first responders and the public during a release incident.	Require refineries to use GLM or equivalent technology to continuously measure H_2S, SO_2, and other toxic compounds near their boundaries. Data from these sites should be transmitted in real-time to the refinery operations center, posted on a public website, and submitted to the air district and CARB.	The proposed RMWG will collaboratively develop guidelines for districts to require GLM. RMWG and the CUPA Forum will develop and provide training for first responders and air district response staff on the use of data from these fixed monitoring sites.
	Refineries throughout the State use a variety of handheld and portable air monitors. Telemetered, real-time data from handheld and portable monitors transmitted to refinery operation centers could contribute more broadly to an integrated operational picture of each refinery.	Require refineries to incorporate the use of portable and hand-held devices capable of data telemetry to the refinery operations center, and make the data available to refinery personnel and first responders, with routinely collected data available to local air districts.	The proposed RMWG will work with IRTF members to develop means of identifying improved handheld air monitoring systems and capabilities. RMWG will seek opportunities to evaluate devices in consultation with the SCAQMD Air Quality Sensor Performance Evaluation Center (AQ-SPEC) lab and other testing and standards entities, and make the information available through the CUPA Forum to first responders.
	Considering the variability of emergency incidents, particulate matter (PM) monitoring stations augmented by portable monitors and sensors can provide information on the off-site consequences if strategically positioned relative to the release, able to detect elevated PM levels from a major refinery fire, and when combined with other sensors as part of a comprehensive network.	To the extent consistent with their overall PM monitoring strategies, districts should locate additional monitors providing near real-time (hourly) data in a predominantly downwind orientation from refineries and other high-hazard facilities in their jurisdiction. When upgrading or replacing monitors, districts should also seek to employ continuous measuring instruments with real-time telemetry when it is feasible to do so.	The proposed RMWG will collaborate with the USFS, AQ-SPEC, and other test centers to evaluate PM instruments and low cost sensors and make information on these devices publically available. RMWG will develop monitoring and siting guidelines for districts to improve monitoring network capabilities to provide PM data during refinery incidents.

Table ES-1. Summary of Key Findings, Recommendations, and Implementation Actions (cont'd)

	Findings	Recommendations	Implementation
Air Monitoring	Toxic air contaminant (TAC) monitoring stations positioned to detect H_2S, NH_3, SO_2, volatile organic compounds (VOCs), and TACs from an unplanned air release at a refinery could provide information on the off-site consequences of such an event, if the sites are sufficiently close to and downwind of the release. Such sites might also provide better information about background TAC levels from sources other than the refinery.	Districts should, within existing air monitoring programs, locate additional stations that monitor in real-time for H_2S, NH_3, SO_2, VOCs, and for TACs of concern. When upgrading or replacing equipment, districts should seek to employ continuous measuring instruments with real-time telemetry to gather data and make the preliminary information available in real-time to response agencies and the public.	The proposed RMWG will identify, develop, and share monitoring and siting guidelines and best practices for air districts to use for improving their monitoring networks' ability to provide real-time air toxics data during a refinery incident. The siting, selection, and dissemination of the information can be implemented in a similar way as described for fixed PM monitoring stations.
	Two refineries employ open-path fenceline monitoring systems measuring H_2S and VOCs. Two other refineries utilize fixed point array fenceline monitoring systems measuring H_2S, NH_3, SO_2, and VOCs. There are advantages and disadvantages to either system. Either method may provide immediate, valuable information about refinery releases.	Independent fenceline monitoring systems around refineries should be established based on guidance developed by the proposed RMWG. The monitoring should be funded by refineries and operated with air districts' oversight. Preliminary fenceline monitoring data should be posted to a publicly accessible website and clearly identified as preliminary.	The proposed RMWG will develop guidelines, including standards and exposure action levels, for requiring refineries to install fenceline monitoring systems. Open path systems will be required for large refineries producing light distillation products, while fixed point array systems will be allowed for smaller facilities producing heavier distillation products. RMWG will develop guidance to make data from fenceline monitoring available to first responders and the public. RMWG will support work to validate alternative, real-time fenceline monitoring systems so that these methods are recognized in the U.S. Environmental Protection Agency's (U.S. EPA) fenceline monitoring regulation.
	BAAQMD adopted a district rule in April 2016 that will require open path fenceline monitoring at all Bay Area refineries. The District is working with U.S. EPA to harmonize their rule with a proposed federal monitoring rule.	The proposed RMWG and U.S. EPA should continue to work to validate fenceline systems that will harmonize with the federal requirement for fenceline benzene monitoring.	
	Community monitoring sites could provide valuable additional information on general air quality conditions as well as those during a refinery incident, and warrants statewide adoption. BAAQMD has adopted a district rule whereby the district will locate additional fully-equipped community monitoring stations in each of the refinery communities to better track offsite air pollutants.	Air districts should install and operate site-appropriate community monitoring stations to be funded by the refineries.	The proposed RMWG will develop guidelines for district adoption of a rule, performance of siting analyses, and installation of site-appropriate community monitoring systems.

Table ES-1. Summary of Key Findings, Recommendations, and Implementation Actions (cont'd)

	Findings	Recommendations	Implementation
Modeling	All refineries will be required to model off-site consequences and worst case scenarios under CalARP Risk Management Plan (RMP) requirements revised by the California Office of Emergency Services (CalOES) in August 2017. The opportunity exists to improve modeling methods used to assess risks posed by refineries. Emergency planning and response could be improved by review and validation of existing and emerging dispersion models.	CARB and CAPCOA members should convene technical symposia on emergency applications and validation of air modeling methodologies. The goal of these symposia is to identify new applications and modeling methods, and means to further validate these methods for commercial applications.	The proposed RMWG will coordinate with U.S. EPA to organize technical symposia on emergency air modeling methodologies, and to identify and explore improved modeling capabilities within refineries. RMWG and the CUPA Forum will apply the results of the symposia toward improving emergency planning and response capabilities.
	Refineries, CUPAs, and air districts do not all routinely use modeling tools for mandatory air release drills and exercises. Predictive modeling capabilities are available that could improve emergency response planning, training, and response programs.	A well-integrated, site-appropriate modeling system should be incorporated into each refinery's emergency preparedness and response program. Refineries should be required in their emergency response plans to use predictive modeling for generating realistic emergency exercise scenarios.	CARB and IRTF will investigate opportunities for refineries to improve their emergency preparedness and response modeling capabilities. To improve emergency preparedness, refineries could use predictive modeling to generate emergency scenarios for use in training, drills, and exercises. On the emergency response side, refineries could ensure they have the modeling capability to assess and predict on-site and off-site impacts during actual emergencies.

Table ES-1. Summary of Key Findings, Recommendations, and Implementation Actions (cont'd)

	Findings	Recommendations	Implementation
Communication & Coordination	Four refineries presently maintain public websites displaying real-time refinery operational status, including air monitoring and meteorological data. Two of these also utilize a simple operational status rating system that gives the public a relative sense of any level of upset conditions.	CUPAs and/or the local air district should require each refinery to make publicly available through either a centralized reporting page or individual websites, for the benefit of surrounding communities, information that indicates the status of the refinery with regard to operating conditions, access to real time air monitoring data, upset conditions, and unplanned releases, continuously and in real-time.	CARB will work with IRTF to develop mechanisms to require refineries to maintain a public website, or report information through a centralized reporting webpage, that shows their operating status and provide real time air monitoring data.
	Findings[3]		
	CalOES has issued proposed revisions to CalARP regulations that will integrate air monitoring officials and air districts into training, drills, and exercises for community response.		
	Community Notification Systems: • Refineries and/or response agencies that operate siren warning systems for refinery emergencies should continue to use them, ensuring that the surrounding community is well educated on how the system is operated and what self-protective actions the system is intended to achieve. • Reverse 911 advisories to land lines and cell phones have been a fundamental component of many community warning systems for decades. All response agency jurisdictions in the vicinity of California refineries have reverse 911 capabilities. • Several California refineries and most local response agencies use social media applications to provide the public with direct and timely information on industrial emergencies. However, it is critical for agencies that use social media notifications that all broadcast social messages be considered official information of the sender, be consistent with messages sent by other means of communication, and be approved by the incident command's agency liaison or public information officer. • Integrated Public Alert & Warning System (IPAWS) messaging systems are rapidly becoming part of each local response jurisdiction's suite of communication tools when refineries or other high hazard facilities are present.		

[3] No recommendations or proposed implementation are presented for Communication/Coordination findings that have been or will be addressed by other State and local IRTF member agencies. These agencies conducted similar reviews and assessments of communication and coordination from the perspective of their responsibilities for public and employee safety. Appropriate recommendations fall within these agencies' authority.

II. INTRODUCTION

This report identifies and promotes effective methods for collecting and disseminating immediately actionable air quality data to incident commanders responsible for public safety during a refinery air contaminant release. Existing and emerging technologies are presented to consider for monitoring strategies unique to each refinery. Its ancillary goal is to provide continuous air quality data to the community as a whole, which can in turn be used to evaluate and manage the impacts of refineries' emissions on the community. It will be essential that this data is made easily available and presented in a clear, understandable format. The technologies, methods, and tools recommended in this report may also have value for monitoring other industrial facilities such as oil and gas production and storage facilities, chemical facilities, ports and rail yards.

Most assessments and decisions relating to major public safety incidents need to be made in a matter of minutes. The public and elected officials have high expectations for performance of public safety agencies and corporations with hazardous operations, though they may not fully appreciate the resources required, or planning and preparedness necessary, to achieve the desired level of performance. Effective monitoring and response strategies must find a balance between resource expenditures and expectations although protection of public health is ultimately the highest priority.

There are currently no statewide minimum requirements or standards for localized emergency response air monitoring, or for air monitoring responses related to refineries. Existing regulations are designed to control routine and predictable emissions, not unplanned emergency releases. Furthermore, local preparedness and response practices vary somewhat throughout the state. Real-time or near real-time monitoring systems vary from refinery to refinery, as well as within and between air districts.

This assessment presented an opportunity for those involved in refinery emergency air monitoring to share their experiences, knowledge, and needs. The sections that follow examine a spectrum of practical attributes of refinery air monitoring and highlight opportunities to better utilize available resources for emergency preparedness and response.

III. BACKGROUND

The major fire at the Chevron Richmond Refinery in August, 2012 raised serious concerns among elected officials, regulators, and the public about refinery maintenance, safety practices, and emergency preparedness in the vicinity of California's major oil refineries and other large petrochemical facilities. As a result, the Governor created the Interagency Working Group on Refinery Safety (Working Group) to engage federal, State and local agencies, refineries, and stakeholders to better coordinate refinery safety, compliance, and enforcement activities, and to

improve emergency preparedness for future refinery incidents. The Working Group summarized its findings and recommendations in the February 2014 report "*Improving Public and Worker Safety at Oil Refineries*" (Working Group Report). Although this report focuses on refineries, the recommendations presented here may serve as a model for enhancing emergency response and routine air monitoring for other industrial facilities in California.

One of the opportunities examined by the Working Group was how to better communicate with the public and surrounding communities about refinery safety and health risks. The Working Group found that there was not only a public interest in the acute health impacts caused by a major refinery air release, but concern about the potential long-term health impacts due to chronic exposure to fugitive emissions from these facilities. The public is interested in changes to routine emissions as refineries change their crude slate and throughput, as well as the many unpredictable leaks and minor releases that make quantifying chronic exposure risks difficult.

To address the concerns outlined in the Working Group Report, CARB and CAPCOA members agreed to jointly develop a Project Plan, *"Air Monitoring for Accidental Refinery Releases: Assessment of Existing Capabilities and Potential Improvements"* (Project Plan) to assess existing emergency air monitoring capabilities and suggest potential improvements to California's current refinery monitoring system.

The CARB-CAPCOA Project Plan was released to the public in July 2013. It identified four key objectives for refinery air monitoring:

1. Delineate existing air monitoring assets and resources (including modeling and forecasting) and make information available through an online publicly accessible clearinghouse.
2. Evaluate air monitoring and modeling capabilities, assess gaps and potential enhancements, and make recommendations as needed.
3. Develop statewide guidance to enhance refinery air monitoring and encourage best practices.
4. Improve interagency coordination, preparedness, and training for air emergencies.

The Project Plan goals were two-fold. First, CARB and CAPCOA members sought to identify and promote the most timely and effective methods for providing air quality data to the emergency officials and incident commanders directly responsible for protecting public health during a refinery release incident. Second, CARB and CAPCOA sought to ensure that timely air quality information is disseminated through the incident management system to nearby communities, including schools, medical facilities, transit operators, utilities, and shelter sites.

The Project Plan placed a strong emphasis on the need for multi-agency cooperation, including outreach to the refineries and local emergency responders. CARB and CAPCOA members agreed to evaluate and make recommendations on optimizing the use of existing resources, as well as for additional resources, including equipment, services (e.g., analytical, instrument support, maintenance, modeling, and forecasting), staffing, and training, in order for the air districts' local air emergency response programs to better assess and provide public safety, as part of the integrated response to future refinery release emergencies.

This report fulfills Objective 2 of the Project Plan, building on the air monitoring capabilities inventory presented in the "Refinery Emergency Air Monitoring Assessment Report, Objective 1: Delineation of Existing Capabilities", that was released to the public in May 2015. In Objective 1, CARB and participating air districts inventoried current monitoring protocols, methods, and capabilities. The inventory focused on physical monitoring systems, staff training, methods for equipment deployment for local emergency air monitoring, and procedures to inform emergency management officials and the public. The work included collecting information from refineries, as well as local (i.e., fire and HazMat departments, public health officers, and environmental health departments), State, and federal agencies. Table 1 provides a summary of the key emergency air monitoring program capabilities identified for each of the fifteen refineries evaluated in the May 2015 report. The dot matrix in Table 1 indicates whether each refinery had employed a sufficient number of monitoring features to demonstrate a basic level of implementation for that program[4]. The tabulated range of air monitoring and emergency response capabilities is a continuum that varies widely depending upon the refinery and air district. In general, the larger refineries located in the Bay Area and South Coast have the most robust air monitoring and emergency response systems, while smaller refineries located in the San Joaquin Valley and San Luis Obispo have less comprehensive systems. Similarly, the Bay Area and South Coast have greater emergency response capabilities. Presently, the Bay Area refineries and BAAQMD have the most fully integrated community level monitoring and interaction. For most refineries, with the exception of several in the Bay Area, fenceline monitoring and ongoing community monitoring is sparse or nonexistent.

[4] 2015 information reported late and added to this version.
The asterisk for Alon Refinery's throughput indicates that operations at that refinery have been suspended since commencement of the assessment. The refinery is not operating as of this writing.

Table 1. Refinery Air Monitoring Overview as of May 2015 (From REAMAR Objective 1 Report)

Refineries	Chevron	Phillips 66	Shell	Tesoro[5]	Valero	Chevron	PBF Energy[6]	Phillips 66	Tesoro	Valero	Paramount	ALON	San Joaquin	Kern Oil	Phillips 66
Barrels Per Day (thousands)	245	78	156	166	145	269	150	139	362	85	85	*	15	26	42
Regular drills/exercises with local fire/HazMat	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CalARP Risk Management Plan (RMP)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Mutual aid organization	•	•	•	•	•	•	•	•	•	•	•				
Community hazard patrol - responsive	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Community hazard patrol - proactive	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Continuous process unit air monitoring (OSHA)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Hand held air monitors for off-site use	•	•	•	•		•	•	•	•	•	•	•		•	•
Supports Local CAER or similar community organization	•	•	•	•	•										
Real-time on-site modeling capability									•						
Voluntary fenceline monitor(s)	•	•													
Voluntary community monitor(s)	•														
Social media notifications								•							
Air District	**BAAQMD**					**SCAQMD**						**SJVAPCD**			**SLOAPCD**
Mobile incident monitoring equipment (trailers, portable E-BAMs)					•	•	•	•	•	•	•	•	•	•	
Fixed real-time PM monitors	•	•			•		•	•	•	•	•	•	•		•
Fixed real-time toxics monitors (SO_2, H_2S, NH_3, VOC)	•	•	•	•	•	•	•	•	•	•	•				
Portable and hand held incident air monitors	•	•	•	•	•	•	•	•	•	•	•				•
Required refinery specific ground level monitors	•	•	•	•	•							•			
Regular drills/exercises with refinery															•
Area plan/RMP oversight															
Lead CUPA/Local Responder	**Contra Costa**				**Solano**	**LA County, LA City and/or Local Fire/HazMat**						**Kern**			**SLO**
Community siren alert system	•	•	•	•	•	•	•	•	•	•	•				•
Hand held air monitors	•	•	•	•		•	•	•	•	•	•	•	•	•	•
Reverse 911 community notification	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Local industrial safety order	•	•	•	•			•								
Formal unified command agreement	•						•								
Internal refinery event notification							•								

[5] Tesoro in now Marathon Petroleum.
[6] Information not previously published pending refinery approval.

Ongoing Efforts and Future Opportunities

CARB and CAPCOA members actively participate in the California Environmental Protection Agency's (CalEPA) Interagency Refinery Task Force (IRTF) [7], the oversight group established by Governor Brown to advise on coordination of the State's refinery safety issues, including new regulations for safety management systems, refinery risk assessment, emergency preparedness, and air monitoring.

To implement the findings and recommendations in this report, CARB and the affected air districts propose to form a permanent Refinery Monitoring Working Group (RMWG) staffed through a newly established emergency preparedness liaison function for each district. This is a critical outcome of the assessment. Local and State IRTF agencies have already begun addressing many of this report's findings related to improving communication and coordination. The emergency response liaison function will improve air monitoring coordination between emergency response agencies, U.S. EPA, and air districts in refinery emergency preparedness. Comprised of the district emergency response liaisons and CARB staff, the proposed RMWG will work within the existing IRTF framework to further develop the necessary guidance and capabilities for more effective refinery air emergency responses, as well as for use of real-time data from enhanced monitoring systems.

With appropriate funding, the role of the emergency response liaison will be to ensure emergency response plans adequately address air monitoring, coordinate with other agencies on the proper role of air district staff during emergency response, ensure that the necessary resources are available to effectively respond to incidents, and ensure staff are adequately trained. The liaison will review area plans, refinery risk management plans, and refinery emergency response plans to ensure they adequately address the coordinated collection of air monitoring data. Liaisons will assist public health officials with health advisories, and support coordinated dissemination of uniform messages to the public. To ensure the air district is ready to respond to incidents, the liaison will work with their agency to procure and maintain suitable response equipment. Lastly, the liaison will ensure internal training is adequate and appropriate staff participate in refinery emergency response drills and exercises with regulated facilities so they understand their technical support roles in the incident or unified command.

Thanks to ongoing harmonization of efforts within the IRTF framework, this report also fulfills several elements necessary to develop guidance and best practices for responding to emergency events at California refineries. It provides an overview of the guidance envisioned, with more detail to be presented in a subsequent report at the conclusion of Objective 3, the implementation phase. Once recommendations for new monitoring capabilities are implemented, RMWG efforts will transition to ongoing maintenance of an enhanced monitoring network, continuously improving it over time, and ensuring first responders and support agencies are ready to use it

[7] Appendix B lists all the participating IRTF agencies.

when needed. Additionally, data from these efforts will be made publicly available and can be used to further assess the public health effects of fugitive emissions from refineries.

Public demand for greater oversight of industrial facility safety and monitoring in the aftermath of the 2012 Richmond Refinery fire has been amplified by subsequent major events. These include the Torrance Refinery explosion in February 2015 and the four-month long natural gas release from SoCalGas's Aliso Canyon underground storage field ending in February 2016. This report can serve as a guide for identifying and implementing improved air monitoring, modeling and interagency coordination practices as CARB, CAPCOA members and other regulatory agencies evaluate suitable new oversight measures for other industrial facilities with the potential for hazardous air releases.

IV. SCOPE OF THE REPORT

General Approach

Effective planning and response for unexpected, large air contaminant releases, whether from refineries or other industrial sources, is more than a matter of selecting instruments and applying appropriate data collection methods, although doing so is critical to protecting public health. Ensuring that the incident command can systematically gather and disseminate the best available intelligence also requires immediate situational awareness of upset conditions inside the facility, prediction of likely exposures, application of appropriate health risk factors, and a timely process for informing the public of appropriate self-protective actions.

As a general approach to assuring these outcomes, the assessment team evaluated several aspects of effective air monitoring at refineries: 1) selecting appropriate instruments and equipment; 2) monitoring at multiple levels within and around the refinery; 3) communicating and analyzing data to provide timely and relevant information for decision makers and the community; 4) using information for improving planning and response functions.

Evaluation Process

In this report, taking into account the corollary work completed by air districts and other agencies since July 2013, CARB and CAPCOA members have completed the refinery air monitoring assessment tasks set out in the original Project Plan as Objective 2. The Project Plan listed six tasks for CARB and air districts to complete in this assessment.

1) Evaluate the applicable emergency response protocols and procedures identified under Objective 1, including equipment, inter-agency agreements, deployment plans, and training.

   CARB interviewed air districts, local response agencies, and managers from all fifteen refineries throughout the state to gain a better understanding of emergency response preparedness. In conjunction with the interviews, CARB conducted a written survey to further identify various emergency response resources, protocols and procedures. CARB then conducted a review of air districts' standard emergency monitoring protocols and procedures and developed evaluation criteria, which were discussed with technical staff of affected air districts, to provide a consistent framework for this evaluation of capabilities. CARB also reviewed the documentation and resources of other responding agencies to identify areas of potential interoperability and collaboration, as well as common communication platforms and protocols, including those for communication with the public.

2) Review and assess air monitoring assets including air contaminant modeling capability, meteorological forecasting, health and toxicological impact assessment, communication, and collaborative resources.

   Through site visits, surveys and other communications with air districts, CUPAs, and refineries, as well as information obtained from various RMPs, CARB identified available meteorological and modeling resources, including the ability to obtain scenario models to support risk analysis in advance of incidents. CARB evaluated the capabilities and applicability of these resources, including validation of modeling scenarios, given various emergency response parameters, such as response timing. CARB collaborated with OEHHA to identify and review health hazard and risk assessment resources and produce a refinery risk guidance document, *Analysis of Refinery Chemical Emissions and Health Effects (September 2017)*. CARB also briefed local authorities and refinery communities on its own planning and response capabilities during CARB-led interviews, IRTF safety forums and teleconferences.

3) Engage the federal Interagency Modeling and Atmospheric Assessment Center (IMAAC) and other qualified support agencies, institutions, and contractors to explore the possibility of designing and performing multi-scenario analyses of possible major air releases from refineries.

   During the refinery air monitoring assessment investigation, CARB interviewed refineries, CUPA representatives, model developers and modeling consultants on current industry practices. CARB also joined the U.S. EPA Region IX Air Modeling Working Group to better understand and engage in coordination efforts among responsible emergency planning agencies. Through this group, CARB was able to arrange a working agreement with IMAAC for conducting multi-scenario dispersion modeling for refinery scenarios on an ongoing basis. CARB

obtained a similar agreement from the California National Guard Civil Support Team (CST) to support modeling of refinery atmospheric release scenarios using the IMAAC emergency modeling suite. These arrangements recognize the critical infrastructure role of California's refineries and the importance of quickly assessing the effects of a major release incident on surrounding populations.

4) Evaluate suitable applications for tactical deployment of mobile and portable monitors during release emergencies.

   CARB consulted with the affected air districts to identify locations and gaps in existing monitoring networks. Using existing modeling assessments of offsite consequences and current monitoring locations, CARB identified the need to develop a siting protocol to expand the community air monitoring network. Included in this evaluation was an assessment of best practices and procedures for deployment of mobile and portable emergency monitors to supplement the fixed monitoring network.

5) Evaluate existing ambient air quality monitoring network enhancement opportunities including instruments, methods, siting and data gathering systems, and identifying the primary pollutants of concern.

   The foregoing assessment activities combined with a review of work-in-progress by the four affected air districts have enabled CARB and CAPCOA members to: 1) identify gaps in air emergency data collection procedures and networks, 2) identify the most common chemicals monitored in an accidental refinery air contaminant release, 3) review the best practices and technology available, and 4) develop jointly with local emergency response experts (including refinery personnel) recommendations to improve network capability for air emergency monitoring scenarios.

6) Produce a report to local emergency authorities on local air district findings and recommendations for emergency air monitoring program enhancements and potential available federal, State, or local funding sources for implementation of the recommendations.

   This report fulfills the Objective 2 tasks regarding findings and recommendations for enhanced emergency air monitoring program enhancements around refineries. Discussion of potential funding sources is ongoing and will be informed by implementation of AB 617. A full listing of detailed subtasks for each core task listed above is provided in Appendix C.

Concurrent Assessments and Regulatory Development Projects

Concurrent work by other safety and environmental monitoring experts has yielded valuable reference, context, scope, and collaboration for CARB and CAPCOA

members' assessment. Additional details on each of these collaborative efforts are provided in Appendix D, while a listing of the relevant work follows:

- *Improving Public and Worker Safety at Oil Refineries, Final Report of the Interagency Refinery Working Group on Refinery Safety, February 2014*[8]
- *IRTF Agency-Proposed and Draft Guidelines*
- *U.S. EPA National Emission Standards for Hazardous Air Pollutants (NESHAP) Rulemaking on Fenceline Monitoring, December 2015*[9]
- *Federal Executive Order 13650 Working Group Report on Chemical Facility Safety, May 2014*
- U.S Chemical Safety Board Reports[10]*:*
    - *Interim Investigation Report: Chevron Richmond Refinery Fire, April 2013*
    - *Regulatory Report: Chevron Richmond Refinery Pipe Rupture and Fire, October 2014*
    - *Final Report on Richmond Refinery Fire, U.S. Chemical Safety Board (CSB), January, 2015*
- *Air Monitoring Technology and Methodology Expert Panel Report and Findings, Bay Area Air Quality Management District (BAAQMD), Final Report, June 2014*
- *BAAQMD Air Monitoring Guidelines for Petroleum Refineries, BAAQMD, April 2016.*

The foregoing reports and initiatives assisted CARB and CAPCOA members to create the scope and technical perspective for this report. Relevant findings that corroborate this CARB/CAPCOA assessment are summarized in the following sections. This report incorporates and builds upon the prior findings and recommendations of those studies, while clearly focusing on the aspects of air monitoring, air modeling, and stakeholder communications and coordination that will advance the practice of emergency air monitoring at refineries and similar high-hazard facilities. Appendix F provides a complete list and detail of technical references used for this report.

Establishing a Collaborative Framework for Implementation

This assessment emphasizes the value of continuing collaboration for protecting the public from accidental refinery air contaminant releases and undetected fugitive emissions. We precede the findings and recommendations section of the assessment with an overview of how CARB and the CAPCOA members envision

[8] Findings and recommendations related to the refineries' internal process safety management systems are not directly related and are not summarized or addressed in this Report. The complete list of the Working Group Report findings and recommendations is found in Appendix D.
[9] U.S. EPA finalized the proposed 2015 rule on November 2018 after reconsideration. ARB's October 28, 2014 letter commenting on proposed standards is provided as Appendix E.
[10] CSB and IRTF refinery evaluations are generally divided into two distinct regulatory categories: 1) OSHA-based safety planning, engineering and operations (generally referred to as process safety management or PSM), and 2) EPA-based public health, risk assessment and emergency preparedness. This report deals primarily with the latter body of regulatory work, though some findings and recommendations may have indirect and complementary effects on the former.

this collaboration advancing. Table 2 is a summary of key participant roles and capabilities for implementing the recommendations of this report, while a detailed description of each agency's broader responsibilities and historic background is described in Appendix G.

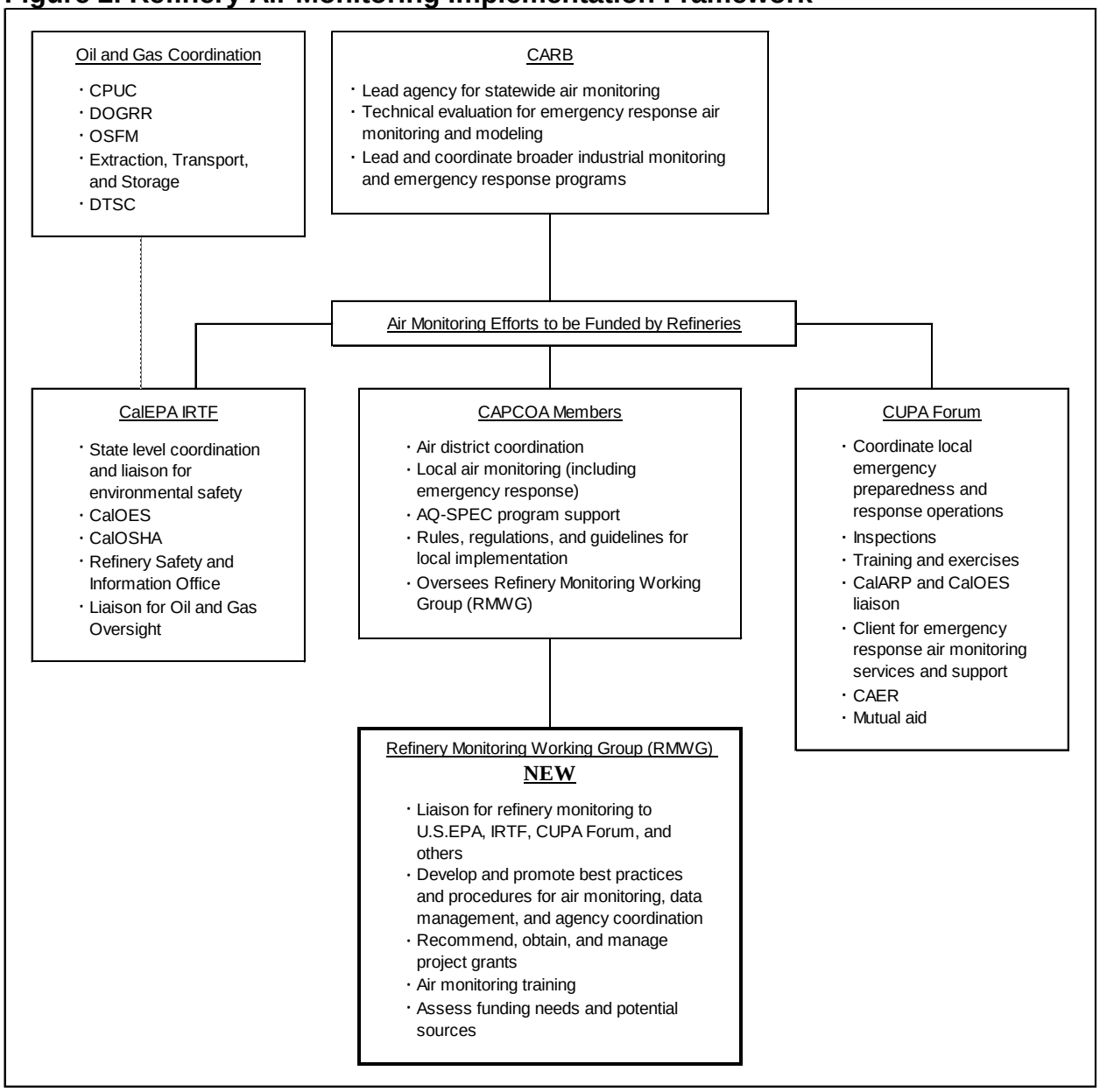
Table 2 Key Participant Roles to Implement Report Recommendations

Agency	Role
CARB	Lead agency for developing the refinery emergency air monitoring program as part of the broader IRTF effort to improve refinery safety.
CAPCOA	Provides organizational structure for air district collaboration on developing unified air monitoring programs, policies best practices for California.
Affected Air Districts • BAAQMD • SCAQMD • SJVAPCD • SLOAPCD	Direct oversight authority for monitoring industrial air emissions and their health effects. Each district has developed an incident response program to augment other available air quality measurements during emergencies in their jurisdictions.
CUPA Forum	Facilitates exchange of regulatory information and best practices between State agencies and local CUPAs. CUPA Forum has established a well-organized, statewide structure of local emergency preparedness and response training to identify and implement best practices for response to industrial contaminant releases.

Figure 2, below, illustrates the proposed implementation framework, reporting relationships, responsibilities, and how resources could also be channeled to state agencies, such as Cal/OSHA and CalOES, for their roles in implementing the broader RMWG recommendations and programs.

The majority of this report's recommendations for improving emergency air monitoring can be implemented through CARB, CAPCOA members, CUPA Forum, and the IRTF. Developing the overall framework and many key recommendations requires spearheading and co-leadership by CARB and the affected air districts. Therefore, the proposed RMWG will have a critical role in developmental and ongoing refinery air monitoring initiatives. It will take advantage of member air districts' monitoring expertise to implement recommendations dealing with fenceline, community, and network monitoring. The proposed RMWG will also draft guidelines for monitoring rules and potential enhancements to network monitoring plans for consideration by air district governing boards.

Figure 2. Refinery Air Monitoring Implementation Framework



The CUPA Forum provides a well-organized training infrastructure to put the air monitoring best practices, developed as a result of this assessment, into the hands of the first responders who staff the front lines during a refinery emergency. The IRTF and RMWG will ensure that first responders and air district staff have necessary data readily available when they arrive on-site during an emergency response.

Resources Needed for Implementation

Significant additional dedicated resources, including staff and equipment, are needed to implement all of the recommendations outlined in this report. Some of the

tasks requiring additional resources include purchasing and installing new monitoring equipment and communications technologies, researching and validating modeling and other technologies, maintaining equipment, analyzing data, conducting training, ensuring ongoing coordination, and monitoring overall program effectiveness. For the immediate needs of refinery monitoring, CARB and CAPCOA members recommend establishing both local rules and a state-level air monitoring oversight program whereby refineries are assessed fees to fund enhanced facility and community monitoring programs recommended in this report. Funding of all recommendations should be allocated among the refineries based on the program needs of CARB, local air districts, other appropriate stakeholder agencies, and community groups. The proposed RMWG will collectively assess funding needs and where necessary identify appropriate funding sources to implement the recommendations of this report. AB 617 also places new fenceline and community monitoring requirements on major sources, such as refineries, so the monitoring and related funding needs of these two complementary programs will need to be coordinated.

V. EVALUATION OF AIR MONITORING CAPABILITIES, GAPS, AND POTENTIAL ENHANCEMENTS

CARB and CAPCOA members have performed collective and individual investigations to evaluate capabilities, gaps, and potential enhancements to air monitoring in and around refineries since the 2012 Richmond Refinery fire. Both BAAQMD and SCAQMD have committed significant resources to evaluating the benefits and costs of enhancing refinery air monitoring through expanded deployment of existing monitoring approaches, and the feasibility of implementing emerging air monitoring technologies for assessment of both permitted air emission releases and unplanned emergency releases. SJVAPCD and SLOAPCD have also evaluated programmatic changes that can improve responses to refinery incidents.

These efforts are ongoing, and will continue for the foreseeable future as monitoring technology is continually improved. CARB conducted extensive report and document reviews, many interviews, and facility tours of refineries and response agency facilities to gain insight and a comparative perspective on the state of preparedness for refinery emergencies. Sections A through C present the results of these consolidated investigations.

‘Key’ findings and recommendations broadly indicate the most effective safety features and practices identified for California refineries in general. These are denoted in the report as Key Finding and Key Recommendation. While many findings, recommendations and suggested implementation measures in the report are not listed as ‘key’ elements, they are nonetheless worthy of inclusion in a statewide program.

Evaluation of Emergency Response Protocols and Procedures

CARB and CAPCOA members began the investigative process by evaluating the applicable protocols and procedures for emergency response identified in the refinery air monitoring assets inventory phase. This evaluation includes equipment, interagency agreements, deployment plans and training.

CARB identified and established evaluation criteria and tools to provide a consistent framework for this evaluation of capabilities, and shared these with the affected CAPCOA member air districts for review. The assessment criteria for this evaluation are:

- Does the technology, method or approach conform to applicable requirements or guidelines of U.S. EPA, CARB, local air district, and/or local emergency response agencies for protection of public safety and health in emergency or nonemergency situations?
- Is the technology, method or approach well developed, independently validated, and commercially available?
  a. Has it been implemented by refineries and/or other industrial facilities?
  b. Has the technology, method, or approach been validated in an industrial environment, or to what degree is further validation necessary?
- How much time does the system give responders from the moment of detection to assess and execute any necessary public protection advisories?
- Is the technology, method, or approach deemed to be cost effective compared with the avoided cost of mitigating employee and public health exposures and consequences?
- Does implementation of the technology, method, or approach conform to the recommendations of IRTF, CSB, and the BAAQMD Expert Panel for improving refinery and community safety?
- Should the technology, method, or approach be deemed a best practice or recommended practice, and if so, why?

  These criteria support the findings and recommendations in this report and serve as the basis for evaluation of the most effective technical methods for providing timely air quality data to the emergency preparedness officials and incident commanders during a refinery release incident.

A. MONITORING

This section presents assessments of and recommendations for how emergency and nonemergency air monitoring are conducted in and near refineries, and how they can be improved.

All air monitoring for industrial emissions and release emergencies is local and multi-level by necessity. The intensity of monitoring – its frequency and spatial distribution

for a given locale - should be proportionate to localized sources and risk factors. Certain types of refinery emergency releases could overwhelm the air monitoring resources of local fire and HazMat agencies before the source of the release can be controlled and potential exposures are mitigated. These circumstances create a gap and a need for agencies like air districts, CARB, U.S. EPA, and others to fill through complementary monitoring and response capabilities.

All of the federal, State, and local agencies involved in the IRTF have specific statutory responsibilities and authorities related to protection of public safety and health in and around refineries. Refineries conduct routine monitoring of their onsite permitted emissions as required by environmental laws, regulations, and rules. They also perform additional, specialized monitoring, such as onsite worker safety monitoring to protect their employees, and - in some cases - offsite community monitoring. Air districts predominantly conduct routine monitoring of ambient air at fixed sites for longer term emissions trends, with some ability to conduct short-term special studies, investigations, and community monitoring support for health emergencies. First response agencies, on the other hand, conduct incident-specific monitoring primarily to protect their response personnel and surrounding communities within an identifiable "hot zone." Figure 3 provides a schematic representation of air monitoring techniques that are used to assess emissions and accidental releases in and near refineries.

Figure 3. Diagram of Air Monitoring Protection Levels

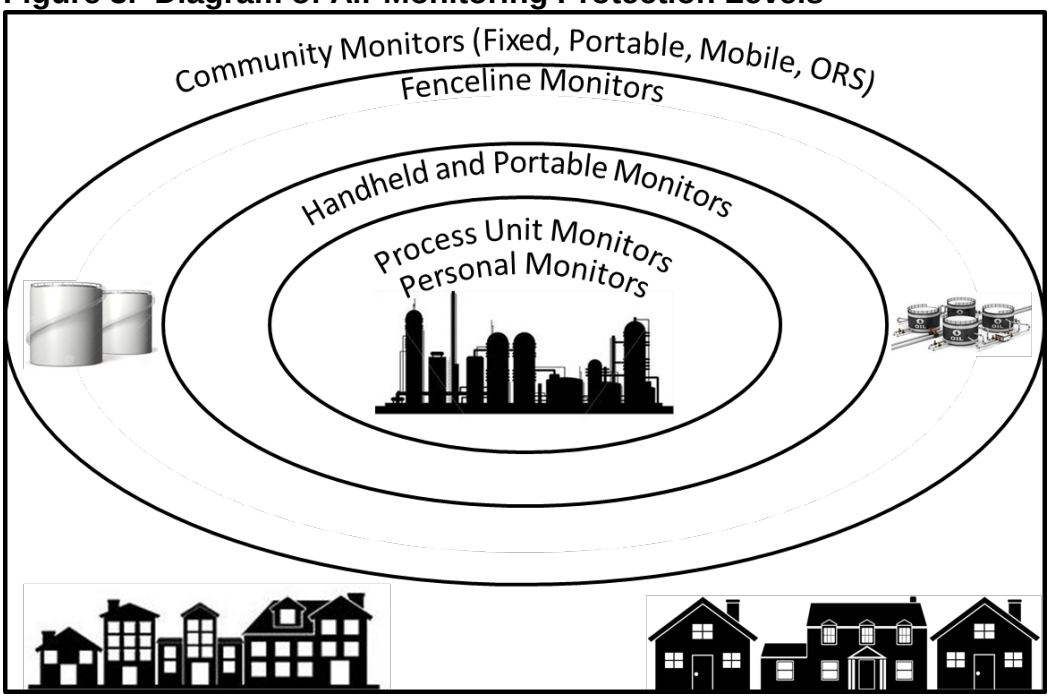


Figure 3 illustrates that on-site emissions are typically monitored by refinery personnel using refinery process unit monitors supplemented by handheld and portable monitors. Fenceline monitors assess potential emissions that may move off

site and impact communities, while community monitors can be useful in assessing near-source community risk if data are available in real- or near-real time.

Table A-1 provides a general overview of systems currently in place at California's refineries. One key takeaway from this information is that current monitoring capabilities are largely focused on assessing on-site emissions and that there is a relatively sparse network of fenceline and community monitors, with several notable exceptions at refineries in the Bay Area. As a result, it is difficult for adjacent communities to develop and maintain a realistic understanding of both acute and longer-term risks to their communities posed by refinery emissions or other nearby, non-refinery sources.

Table A-1. Comparison of Refinery Monitoring Capabilities[11]

Refineries by Air District	Process Unit Air Monitors	Personal and Handheld Monitors	Ground Level H_2S Monitors	Community Monitors	Open Path Fenceline Monitors	Point Fenceline Monitors
BAAQMD						
Chevron Richmond	X	X	X	X	X	
Tesoro Martinez	X	X	X			
Shell Martinez	X	X	X			
Valero Benicia	X	X	X			
Phillips 66 Rodeo	X	X	X	X	X	
SCAQMD						
Chevron El Segundo	X	X				
PBF Energy Torrance	X	X				
Phillips 66 Wilmington	X	X				X
Tesoro Wilmington	X	X				
Valero Wilmington	X	X				
Paramount Petroleum Paramount	X	X				
Tesoro Carson	X	X				
SJVAPCD						
ALON Bakersfield	X	X				X
Kern Oil Bakersfield		X				
San Joaquin Refining Co. Bakersfield	X	X				
SLOAPCD						
Phillips 66 Santa Maria		X				

[11] Ground Level H_2S Monitors refer to equipment installed pursuant to BAAQMD Regulation 9, Rules 1 and 2. Community monitors refers to equipment installed for monitoring outside of the regulatory scope for permitted facility boundaries.

Monitoring for Refinery Chemical Emissions

In September 2017, OEHHA released its draft report, *"Analysis of Refinery Chemical Emissions and Health Effects,"* (Appendix H). OEHHA used publically available data to compile a comprehensive list of 188 chemicals, including emissions levels and toxicity or health impact evaluations where available. From the comprehensive list, OEHHA identified 16 top candidate chemicals for air monitoring based on a number of factors, including whether the chemical is released during routine operations or may be released during unplanned events. Identifying these 16 chemicals as top candidates for air monitoring does not mean that all 16 chemicals are released from every refinery, nor that air monitoring for each of these chemicals would be necessary or appropriate at every refinery. Individual refinery air monitoring plans must consider specific refinery and community conditions to ensure relevant measurements are gathered to inform emergency response decisions as well as reduce potential community exposure.

Air monitoring for most of the 16 top candidates is presently conducted in some refineries and surrounding communities. Table A-2 identifies the status of air monitoring for each of the top candidates, with chemicals OEHHA identified as expected during unplanned releases highlighted in yellow. Most refineries require their workers to wear personal monitoring devices that detect hydrogen sulfide. Some refineries have process unit, ground level, fenceline, or community monitoring to measure ammonia, benzene, 1,3-butadiene, hydrogen sulfide, PM2.5, sulfur dioxide, and toluene. The Chevron Richmond refinery has a community monitoring program for polycyclic aromatic hydrocarbons (PAHs) that is activated upon an emergency release. CARB and the districts' statewide air toxic monitoring network measures many of the chemicals on OEHHA's list, including metals, aldehydes, volatile organic compounds and particulate matter. Three of the chemicals OEHHA identified (diethanolamine, naphthalene and sulfuric acid) require laboratory analysis, new air monitoring methods or other resources not currently available. The proposed RMWG will develop guidance for refinery air monitoring plans considering individual refinery and community conditions, identifying which chemicals should be monitored in each case and the associated approaches and methods appropriate to individual circumstances.

Table A-2. OEHHA-Identified Top Candidates for Air Monitoring

Chemical	Status of Air Monitoring				Comments
	Routine at many refineries	Monitoring at some refineries	Ambient air monitoring in some communities	Not currently monitored	
Acetaldehyde			X		Statewide air toxics monitoring network (major urban areas).
Ammonia		X			Process unit level and community monitoring at some refineries.
Benzene		X	X		Fenceline monitoring at some refineries. Statewide air toxics monitoring network (major urban areas).
1,3-Butadiene		X	X		Fenceline monitoring at some refineries. Statewide air toxics monitoring network (major urban areas).
Cadmium			X		Statewide air toxics monitoring network (major urban areas).
Diethanolamine				X	Monitoring will require method development.
Formaldehyde			X		Statewide air toxics monitoring network (major urban areas).
Hydrogen Sulfide	X	X	X		Personal monitors at most refineries. Process unit level, ground level, fenceline, and community monitoring at some refineries.
Manganese			X		Statewide air toxics monitoring network (major urban areas).
Naphthalene				X	Resources and/or contract laboratory services required.
Nickel			X		Statewide air toxics monitoring network (major urban areas).
PAHs		X			Chevron Richmond community monitoring program (requires contract laboratory analysis).
PM		X	X		Community monitoring at some refineries (PM2.5 only). Regulatory and special purpose monitoring programs
Sulfur Dioxide		X			Process unit level monitoring, ground level monitoring, fenceline monitoring at some refineries.
Sulfuric Acid				X	Resources and/or contract laboratory services required.
Toluene		X	X		Fenceline and community monitoring at some refineries. Statewide air toxics monitoring network (major urban areas).

Evaluation and Recommendations

The following section presents an evaluation of various air monitoring capabilities and includes findings and recommendations for enhanced application to improve planning and response to unexpected air contaminant release incidents, as well as assessment of health impacts to the public and surrounding communities.

1. Continuous Process Unit Monitoring

Finding

F-A1. Data from personal (wearable) monitors and fixed process unit monitoring systems within the refinery provide first lines of defense for identifying potentially large release incidents with off-site consequences. Older systems use alarm threshold sensors, whereas newer systems often provide real-time concentration measurements of target compounds with instantaneous data transmission to the refinery operations center.

Recommendations

R-A1a. As part of their community sensor evaluation programs, CARB and/or CAPCOA members should assess personal safety monitors and provide findings and recommendations to CalOSHA and the CUPA Forum Board.

R-A1b. Refineries should be required to install or expand fixed process unit air monitoring systems sufficient to ensure that releases with potential off-site consequences are detected and responded to quickly. Refinery process unit sensors and monitors need to transmit measured concentrations in real-time to the refinery operations center and directly to first response agencies if a possible off-site impact is indicated.

Analysis

All refineries have, to some degree, established multiple lines of defense using internal monitoring to protect workers, emergency responders, and the surrounding public from unplanned releases. These lines of defense can and should help to inform public protection decisions even before a release from an incident can reach a fence line or community monitor.

Lines of defense begin with refinery operators themselves, stationed at process unit and operations center control panels, actively assessing operating conditions. Refineries monitor multiple process parameters, relay data via an automatic control system, and provide alarms if preset limits of process parameters are exceeded. Often there will be an indication to the panel and/or control center operators of a problem before there is an actual leak or unplanned release, allowing operators to take preventative action. In theory, operators and technicians, through experience and adequate training, gain proficiency to detect problems early and can initiate action via radio to prevent problems from growing.

All equipment operators and technicians working in process units and storage/transfer areas are equipped with wearable personal air monitors that alarm when a measured concentration exceeds a preset limit. This constitutes the second line of monitoring defense. When these devices alarm, plant staff can evacuate the area and notify the panel operator via radio. Typically, sensors detect excess H_2S, while some monitor for flammable gases, insufficient O_2, and carbon monoxide (CO). Some refineries utilize personal monitors that automatically alert a panel operator and the refinery operations center by telemetry. Often, since odor thresholds are lower than device detection limits for some substances, refinery personnel can take action before a monitor alarm sounds.

A drawback of reporting personal monitor alarms via radio or a stationary panel is the remote chance that refinery personnel could be overwhelmed by a chemical release before they can make a radio call or activate a stationary alarm. For that reason, the response personnel of every local HazMat response agency in the greater Los Angeles area and other locales use personal monitoring devices that transmit exposure data to a remote control center that locates and automatically evaluates the exposure against standard health risk criteria.

- **Phillips 66 Rodeo refinery reports uses approximately 7,000 process unit and operating system monitors, including pressure, temperature, flow rate, tank level, and air monitoring.**
- **In addition to use of process control panels and personal badge sensors, the PBF Energy Refinery in Torrance maintains dedicated safety alarm panels at locations throughout its main process area. Each station has three alarm buttons - fire, medical, and product release – that instantly communicate the type of incident and location to the refinery operations center and to fellow employees.**

For this reason, CARB and CAPCOA members will evaluate and report to Cal/OSHA and the CUPA Forum Board on the feasibility of increasing the use of personal monitors equipped with telemetry to transmit real-time measured value and location data to the refinery operations center. The telemetered data from personal monitors in hazardous material release environments enable remote assessment of contaminant levels and safety risks against standard health indices, as well as provide an additional layer of awareness and record of plant conditions.

- **Shell Martinez utilizes a small-scale open path IR detection system to monitor for releases and upset conditions in its LPG storage area. The system is tuned to the light wave frequency that best detects LPG with the least interference from atmospheric oxygen and nitrogen. If LPG in the air is detected by the beam receiver unit, an alarm warns the control room operator and the access roads to the LPG storage area are automatically closed to prevent accidental ignition. Shell has found the monitors to be reliable.**
- **Chevron El Segundo Refinery has an extensive network of H2S, NH3, CO, SO2 and LEL (flammability) sensor alarms that provide actual ppm readouts at its operations center.**

A third line of defense is the automated system of stationary air monitors located at the process unit level within the plant. Monitors are designed to detect leaks or unplanned releases for safety of plant staff and proper operation of the unit. These monitors are process unit specific, designed to detect substances expected to be released from each type of unit, and use various methods to notify when a substance is detected over a preset limit. The numbers of these monitors at each refinery throughout the state varies from as few as four to several hundred, depending on refinery size. In some cases, the monitors sound a locally audible and visible alarm. Other refineries send a measured value, as well as an alarm signal, to the panel operator or operations center. The instantaneous data from a network of process level unit monitors can create an accurate and immediate operational picture of a refinery air release, providing essential information for emergency response to both the refinery and to emergency response agencies. It is critical for worker and public safety that sufficient process unit air monitors be employed, calibrated, and properly maintained. Cal/OSHA favors an approach of enhancing automated process unit monitoring and reporting because it operates continuously and without the need or potential for employee exposure to a sudden release.

Implementation

In support of possible regulatory changes, the proposed RMWG will:

Work with Cal/OSHA to develop an inventory of recommended devices and with SCAQMD's Air Quality Sensor Performance Evaluation Center (AQ-SPEC) or similar test laboratories to evaluate their performance,

Work with IRTF to develop an inventory of best practices to improve monitoring at the process unit level in refineries,

Collaborate with IRTF and CUPA Forum to provide training for first responders and air district staff on the availability of expanded process unit level monitoring data during emergency response, as warranted.

2. Refinery-Specific Ground Level Monitors

Key Finding

F-A2. Ground level monitoring (GLM) to measure H_2S and SO_2, both onsite and in communities surrounding refineries, is a proven method for continuous monitoring and mitigation of fugitive emissions. GLM measurements can provide information on off-site consequences to first responders and the public during a release incident.

Key Recommendation

R-A2. Refineries should be required to utilize GLM or equivalent systems to continuously measure H_2S, SO_2, and other toxic air contaminants at strategic locations near their boundaries. Data from these sites should be transmitted in real-time to the refinery operations center, posted as preliminary data on a public website, and submitted to the air district and CARB monthly after data validation.

Analysis:

GLM, when combined as part of an integrated air monitoring network, has the potential to provide more comprehensive measurement of toxic air contaminants from unplanned releases. Presently, GLM for refineries is unique to the Bay Area. A BAAQMD program was originally established under a 1982 area source rule to ensure that non-source-specific levels of certain fugitive contaminants did not exceed safe off-site thresholds. As it currently applies to refineries, the rule requires that three or more continuous-reading H_2S and SO_2 monitors and one real-time met station be located near the property lines of each refinery in a predominantly downwind orientation. The refinery is required to maintain this system in a continuous monitoring state, and report regularly to BAAQMD.

The BAAQMD GLM program employs a standardized array of point analyzers. Refineries log, check, and archive a continuous GLM data stream and report to the District monthly or at prescribed intervals. When an upset condition results in elevated contaminant levels with potential downwind consequences, the data is made available to BAAQMD immediately with the incident notification. Generally, the data is not released to the public except as necessary to inform public safety measures during an incident; however, the district is considering changes to the GLM rule's manual of procedures to make the data publicly available on the Internet.

- **Fixed array monitoring system consists of an array of discrete air samplers that monitor for the compound of interest in real-time. The array of samplers detects compounds only at the locations of their sampling inlets. Unlike open path system's path average concentration, a fixed array system gives the actual concentration of compound at the sampling location.**
- **Open path monitors transmit a beam of infrared or ultraviolet electromagnetic radiation from a transmitter to a receiver to measure the path average concentration of compounds along the beam in real-time. The compounds are identified by the unique frequencies they absorb, with the amount of energy absorbed related to its concentration.**

The GLM rule was not designed to reduce fugitive emissions, but to ensure that H_2S and SO_2 concentrations do not exceed thresholds set in the regulation. Certainly, by shining a spotlight on these emissions with the GLM rule, fugitive emissions have been reduced, while public involvement is likely to increase efforts to control these emissions. Data from GLM sites have been used in compliance actions when significant increases in contaminants correlate to releases from refinery sources. GLM monitors can detect minute concentrations of H_2S and SO_2, even from sources other than the host refinery. During interviews, environmental health and safety managers from several Bay Area refineries volunteered that the GLM network is sensitive enough to detect releases from other refineries and, with meteorological data, can trace them back to a likely origin.

Because GLM data is only reported to the air district on a monthly basis or immediately following an incident, the current system is limited in its ability to provide real time information to first responders and the public. The technology for detecting ground level toxic emissions is advancing and may present new alternatives to current GLM networks. Applications of open path and ORS monitoring systems are constantly evolving. As a result, BAAQMD plans to correlate data from open path monitors that will be required by its refinery monitoring rule to data from the existing GLM monitors. If there is adequate correlation, the district will revise the GLM manual of procedures to replace the point analyzers with open path systems.

In more diverse industrial settings, such as those found in areas of the South Coast Air Basin, it may be more difficult to identify and trace the likely sources of background air contaminants. For example, the detection limit of traditional GLM techniques may not be adequate at this point to identify small, but above-background levels of benzene and other VOCs in downwind communities. Additionally, hourly real-time air toxics monitoring beyond H_2S and NH_3 needs more development before it can be considered routine. More emphasis will be necessary on evaluating non-refinery emission profiles in these complex settings. Nevertheless, with additional air monitoring of H_2S and SO_2 using GLM networks in conjunction with meteorological data, profiles can be developed and modeled that can help distinguish refinery emission excursions from those of surrounding sources. As with all the monitoring systems reviewed in this analysis, it is important to have a sufficient number of monitors strategically placed, and adequate meteorological monitoring to determine likely release sources.

Another similar example of regulatory GLM is that of SCAQMD's mandatory monitoring and reporting for hydrofluoric acid by the two southern California refineries that use modified hydrofluoric acid for alkylation. Data from monitors on the alkylation unit and in the immediate vicinity is relayed directly to SCAQMD, as well as to controllers at the refinery operations center.

Implementation

The proposed RMWG will work to develop guidelines for a district rule requiring refineries to utilize GLM, or equivalent methods from emerging technology such as optical remote sensing, to measure H_2S, SO_2, and other specific toxic air contaminants as appropriate, at strategic locations near their boundaries and make the information available to the public. Refineries will be required to submit monitoring plans, followed by agency and public review, which meet minimum standards. The proposed RMWG and CUPA Forum will provide training for first responders on accessing data from GLM monitoring sites.

3. Hand-Held and Portable Air Monitors – On-Site Use

Key Finding

F-A3. Refineries throughout the State use a variety of handheld and portable air monitors. Some of these devices utilize telemetry; others do not. Telemetry systems are available that enable transmission of real-time data to refinery operations centers and incident commands. Data from handheld and portable monitors used in and around the refinery could contribute to an integrated operational picture of all air monitoring data from multiple on-site and off-site sources for use by first responders.

Key Recommendation

R-A3. Refineries should be required to use site-appropriate handheld devices capable of automated, real-time data telemetry to the refinery operations center and to first responders in cases of active hazardous releases, except in situations where telemetering personal monitors and fixed monitors are already in use. Routinely collected data should also be provided to the local air districts.

Analysis:

Refineries all reported maintaining a cache of portable and handheld gas monitoring instruments, for routine on-site and off-site use and as upset situations dictate. In portable instruments, we refer to compact, self-contained devices that are larger than hand-held and are likely to be delivered to a site by vehicle. Because these instruments are relatively inexpensive ($2,000 - $25,000) and quite reliable when properly maintained and calibrated, refineries tend to make these instruments readily available to safety and fire personnel. Most commonly, refineries use flammability, H_2S, and O_2 detectors for routine hazard checks. Some are quite sophisticated. For example, Tesoro Martinez recently acquired a portable infrared video recorder with telemetry capability, for detecting hydrocarbon leaks from a safe distance.

Handheld monitors are particularly useful in remote areas of a refinery where fixed leak detection systems are widely scattered or nonexistent. They also help to detect leaks or emissions drifting onto the refinery property from off-site sources. It is critical however that these devices be properly maintained and calibrated to ensure optimal accuracy and reliability.

Implementation

The proposed RMWG will work with IRTF to develop an inventory of best practices that affects, where appropriate, the transition to improved handheld air monitoring devices used in refineries. The proposed RMWG will evaluate these devices with the assistance of SCAQMD's AQ-SPEC, CalOSHA, CUPAs, and other test centers, and make the information available through the CUPA Forum and a public website. Inventory guidance will make clear that proper maintenance and calibration practices must be documented.

4. Hand-Held and Portable Air Monitors – Off-Site Use

Finding:

F-A4. Most first response and emergency air monitoring agencies have portable air monitoring equipment to protect personnel in and near the hot zone of an incident. These monitors are certified and maintained to Underwriters Laboratories and Institute of Electrical and Electronics Engineers standards; a statutory, independent emergency response standards board, FIRESCOPE periodically updates a list of certified

instruments; they are generally not tested or compared in-use. Detection and sensor technologies are progressing rapidly, providing opportunity to utilize lighter, more versatile equipment with improved capabilities.

Recommendation:

R-A4. The proposed RMWG should identify opportunities to comparatively evaluate handheld and portable monitoring instruments and collaborate with CUPA Forum Board, CalOES and FIRESCOPE to publish any findings or recommendations on devices suited to meet response agency needs.

Analysis:

First response agencies have a wealth of experience using various types of portable and hand-held gas analyzers and monitoring devices. Initiatives are underway to provide response agencies with up-to-date information on portable and hand-held emergency monitoring devices. The CUPA Forum updated a comprehensive statewide inventory of emergency monitoring tools and issued its inventory in May, 2015. This online reference manual provides a single source of information on hazardous material detection equipment useful for incident response. FIRESCOPE periodically updates a similar list. New and upgraded devices are constantly being introduced to the emergency response community, driving the need for their evaluation. The proposed RMWG should work with the CUPA Forum to evaluate these instruments and keep the reference guide up to date.

In a related effort, CARB is presently collaborating with Desert Research Institute and other agencies to evaluate a number of new and upgraded portable PM2.5 monitors suitable for monitoring major fires in real- or near-real time. CARB is also exploring opportunities for expanded testing capabilities for small portable monitors and low cost sensors in collaboration with AQ-SPEC and other facilities.

Implementation

The proposed RMWG will:

- Develop a plan to assess handheld and portable monitoring instrument capabilities with the assistance of air districts, CUPAs, and/or suitable contractors,
- In collaboration with CalOSHA, CalOES, and CUPA Forum, use emergency response expertise to continuously evaluate the reliability of new devices, and air monitoring expertise to validate their accuracy,
- With the CUPA Forum, provide training for first responders and air district response staff on the capabilities of hand-held and portable air monitors,
- Assist the CUPA Forum, CalOES, and FIRESCOPE to maintain an on-line clearinghouse of current information on these devices.

5. Fixed Real-Time PM Monitors

Key Finding

Findings:

F-A5. All four affected air districts in collaboration with CARB perform ambient air PM monitoring in the urban areas around refineries. Data from these instruments is available either on an hourly or daily basis. Although the monitoring network was not designed for isolated event monitoring, there are a number of fixed real-time PM monitoring stations that may be positioned to locally detect elevated PM levels from a major refinery fire. However, due to the variability associated with emergency incidents, experience with smoke monitoring shows that smoke from relatively small, short-lived, point source fires can be difficult to track or detect on fixed systems.

Key Recommendation

Recommendations:

R-A5. To the extent consistent with their overall PM monitoring strategies, districts should locate additional monitors providing real-time hourly data in a predominantly downwind orientation from refineries and other high-hazard facilities in their jurisdiction. When upgrading or replacing monitors, districts should also seek to employ continuous measuring instruments with real-time telemetry when it is feasible to do so. Agencies attempting to measure PM concentrations from a refinery fire should rely on portable monitors with a measurement frequency resolution of one hour or less.

Analysis:

Fixed PM monitors typically transmit data as an hourly average making them near real-time. Some mass monitors (e.g., hi-vols) provide daily or weekly data. Fixed PM monitoring at existing stations is generally adequate to detect significant changes in particulate matter levels from a major refinery fire that could affect public health, provided that the monitor is located in the outfall path of the smoke plume. PM monitoring for emergencies would be for smoke, not chemical or petroleum emissions.

Experience with PM data from the Chevron Richmond refinery fire and other fire monitoring events demonstrates that detecting ground-level PM levels from urban and suburban fires is problematic due to plume rise. As an example, BAAQMD hourly PM data for several sites surrounding the 2012 Richmond refinery fire within a radius of 2-5 miles showed no increase above background levels. CARB has had similar experiences in the past using pre-positioned and fully portable PM monitors for explosives, tire, and refuse fires. The heat associated with these smoke plumes often drives PM well above the local area and into a broad and distant regional dispersion zone.

CARB is investigating the use of nephelometer technologies suitable for continuous, real-time monitoring of lower-lying smoke and dust plumes. Figures 4 through 6 show the spatial relationship between existing stations with continuous PM2.5 monitors and refineries under the jurisdiction of BAAQMD, SCAQMD, and SJVAPCD. SLOAPCD has three PM2.5 monitors located near the P66 refinery. The Objective 1 report provides a comprehensive inventory of sites and equipment for stations with continuous PM2.5 air monitors in the vicinity of major refineries.

Figure 4. Bay Area Refineries and Nearest Continuous PM2.5 Monitors

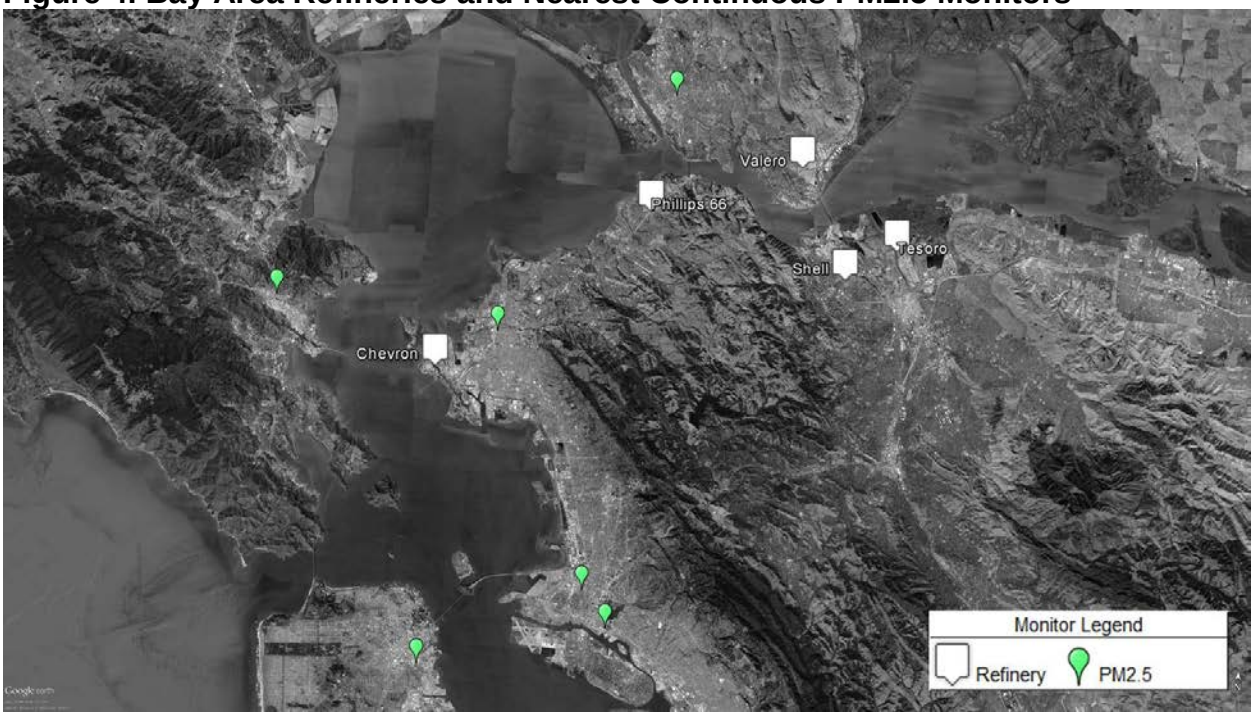


Figure 5. South Coast Refineries and Nearest Continuous PM2.5 Monitors

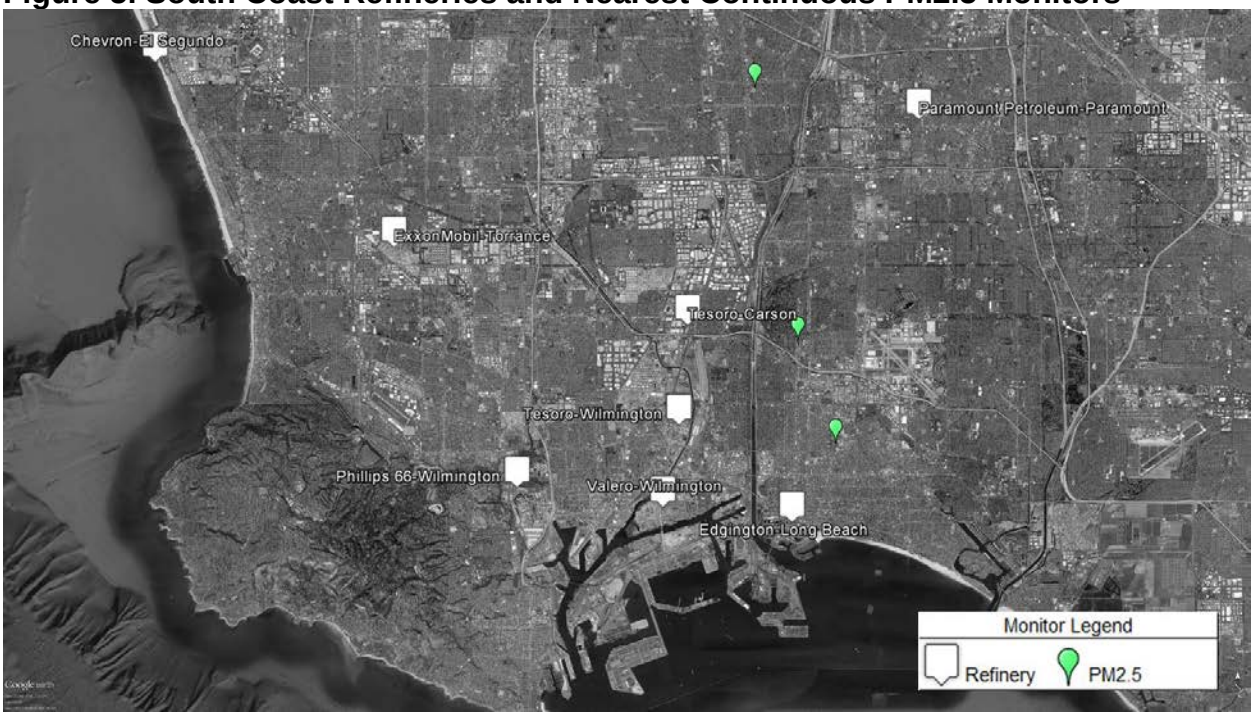
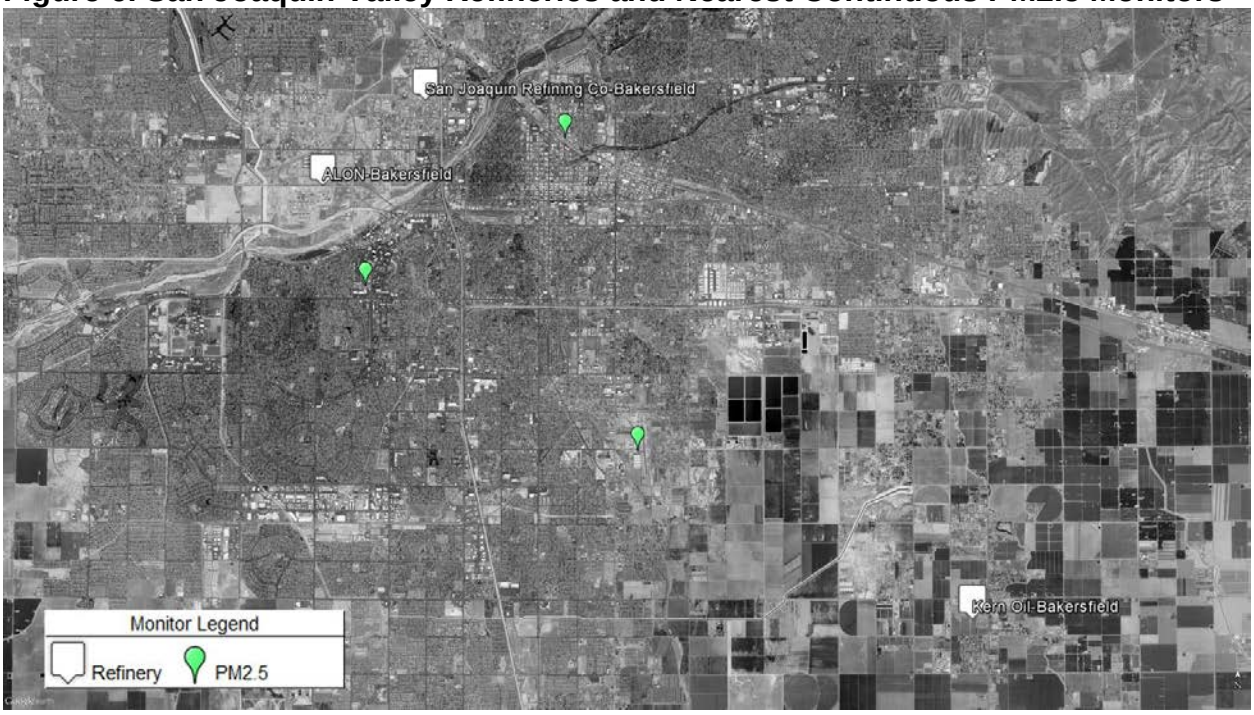


Figure 6. San Joaquin Valley Refineries and Nearest Continuous PM2.5 Monitors



Implementation
CARB and CAPCOA members, through the proposed RMWG, will collaborate with the USFS, SCAQMD AQ-SPEC lab, and other test centers that are conducting evaluations of low cost PM sensors. The proposed RMWG will maintain information on these devices and will work to make information available publicly on an internet clearinghouse. The proposed RMWG will develop monitoring and siting guidelines for air districts to use for improving their monitoring network's ability to provide adequate PM data during a refinery incident. The proposed RMWG will develop guidance for selecting appropriate monitors.

6. Fixed Real-Time Toxics Monitors

Key Finding

Findings:
F-A6. Air district monitoring for toxic air contaminants (TACs), such as H_2S, NH_3, SO_2, VOCs, polycyclic aromatic hydrocarbons (PAH) and toxic metals varies statewide and is limited with respect to proximity to refineries. Stations monitoring TACs do not monitor in real-time, but provide an hourly or longer-period average measurements. TAC monitoring stations positioned to detect H_2S, NH_3, SO_2, and VOCs from an unplanned air release at a refinery could provide information on the off-site consequences of such an event, if the sites are sufficiently close to and downwind of the release. Such sites might also provide better information about background TAC levels from sources other than the refinery.

Key Recommendation

Recommendations:
R-A6. Districts should, within existing air monitoring programs, locate additional stations that monitor in real-time for H_2S, NH_3, SO_2, and VOCs in a predominantly downwind orientation from refineries and other high-hazard facilities. When upgrading or replacing equipment, districts should seek to employ continuous measuring instruments with real-time telemetry to gather data on all TACs of concern and make the preliminary information available in real-time to response agencies and the public.

Analysis:
The State's present air monitoring network has relatively little capability for monitoring toxic air contaminants associated with refinery releases. For example, none of the fixed monitoring stations located within the four principal air districts is able to monitor NH_3. None of the SCAQMD air monitoring stations measure H_2S, NH_3, or VOCs. While the SCAQMD has multiple SO_2 monitoring stations in its air basin, the only station within the vicinity of refineries that presently measures SO_2, Los Angeles - LAX, is positioned upwind or crosswind of all of the major refineries located in the South Coast

Basin. None of the air monitoring stations located in the SJVAPCD monitor H_2S, NH_3, or SO_2.

One SLOAPCD station measures SO_2, and it is well positioned downwind of the Santa Maria refinery. As air districts expand and enhance their TAC monitoring networks, it makes sense to give due consideration when siting and equipping these stations to consider what useful information may be gained by proximity to refineries and other high hazard facilities. Figures 7 through 10 show the spatial relationship between existing stations with continuous toxic air contaminant monitors and refineries under the jurisdiction of BAAQMD, SCAQMD, SLOAPCD, and SJVAPCD. The Objective 1 report provides a comprehensive inventory of sites and equipment for stations with continuous toxic air contaminant monitors in the vicinity of the State's major refineries.

Figure 7. Bay Area Refineries and Nearest VOC, H_2S, or SO_2 Monitors

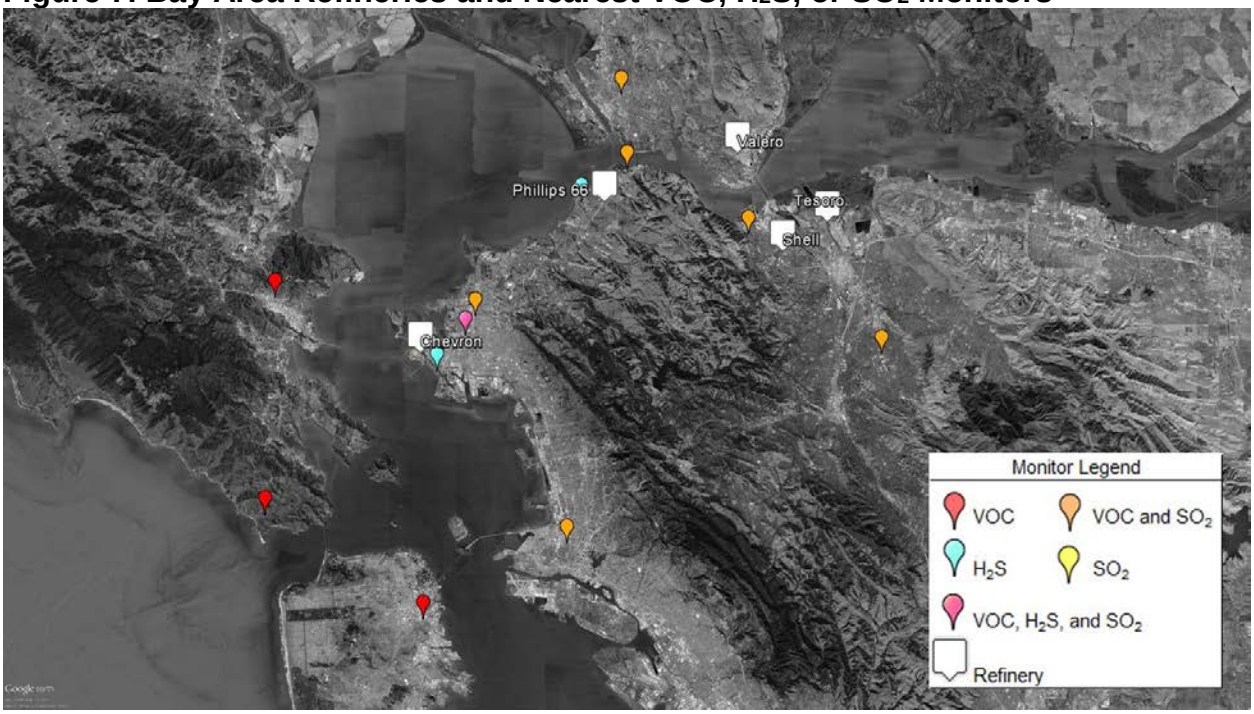
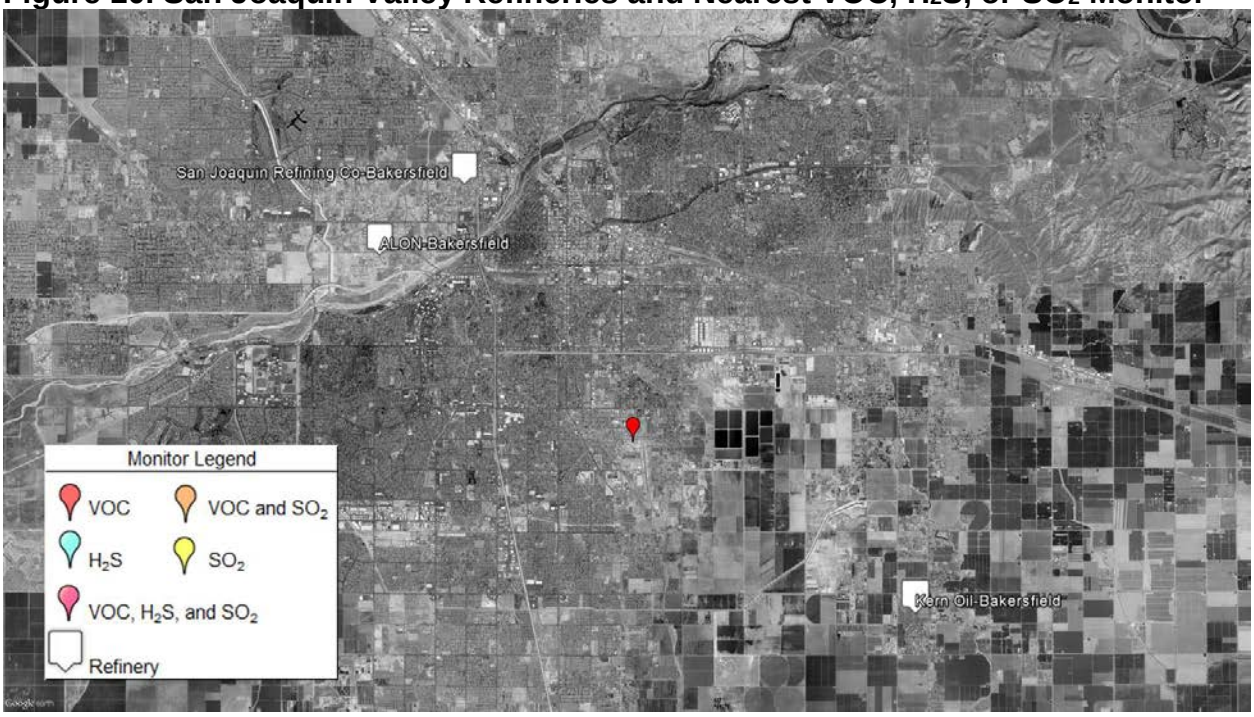


Figure 8. South Coast Refineries and Nearest VOC, H_2S, or SO_2 Monitors

Figure 9. San Luis Obispo Refinery and Nearest VOC, H_2S, or SO_2 Monitor

Figure 10. San Joaquin Valley Refineries and Nearest VOC, H_2S, or SO_2 Monitor



Implementation

The proposed RMWG will identify, develop, and share monitoring and siting guidelines and best practices for air districts to use for improving their monitoring networks' ability to provide real-time air toxics data during a refinery incident. The siting, selection, and dissemination of the information can be implemented in a similar way as described for fixed PM monitoring stations.

7. Fenceline Monitoring Systems

Key Finding

F-A7a. Phillips 66 Rodeo and Chevron Richmond have established open-path fenceline monitoring systems measuring the path average concentration of H_2S and VOCs along their length. ALON USA and Phillips 66 Wilmington employ fixed point array fenceline monitoring systems measuring H_2S, NH_3, SO_2, and VOCs. There are advantages and disadvantages in choosing an open path system over an array of fixed point monitors. Either method can provide immediate, valuable information about refinery releases at or near the facility perimeter.

Key Finding

F-A7b. BAAQMD adopted a district rule and guidance in April 2016 that requires open path fenceline monitoring at all Bay Area refineries, and the

State passed legislation authorizing districts to conduct fenceline monitoring in specified areas. The District is taking steps to validate open path systems and thereby harmonize its rule with proposed U.S. EPA fenceline monitoring regulations that are under review.

Key Recommendation

R-A7a. State and air district requirements for real-time (fixed point systems) or near real-time (open path systems) fenceline monitoring around refineries are warranted and should be implemented. Site-specific modeling should be considered in siting fenceline monitors. Fenceline monitoring data should be posted to a publicly accessible website and clearly identified as preliminary data. For emergency monitoring purposes, fenceline systems should monitor for VOCs and H_2S at a minimum, and for NH_3, HCl, HF, and other TACs, if these compounds are used or produced by the refinery. Data from fenceline monitoring collected during periods of routine operations should be analyzed and used in fugitive emission reductions strategies if applicable, and made available to the public to help identify potential upset conditions and assess long-term exposure.

Key Recommendation

R-A7b. CARB, CAPCOA members, and U.S. EPA should continue to work with BAAQMD, the only California air district with refinery fenceline monitoring requirements, and U.S. EPA in seeking to validate fenceline systems that will harmonize with proposed federal requirements for benzene monitoring.

Analysis:

Properly designed and integrated fenceline monitoring provides a reasonable indication of air contaminants leaving the refinery property at or near ground level. An effective fenceline system requires site-specific engineering and design to account for differing meteorology, topography, and receptor populations in the placement of monitors. The brief descriptions below provide an orientation to the refinery fenceline systems presently employed in California.

Chevron Richmond - Open Path System

Chevron operates three-path fenceline monitor arrays installed in 2013. Locations were selected collaboratively with the City of Richmond, the design consultant, environmental groups, and community representatives. The arrays are aligned downwind and between the refinery and populated areas of the city. The system posts preliminary data to a public website, providing nearby communities with a means of tracking air quality at the refinery's fenceline.

The Richmond system consists of a laser refraction gas analyzer for measuring CO and H_2S in the low parts per million ranges and a UV-DOAS refraction analyzer measuring ozone, VOCs, and SO_2 in the low parts per million range. Adaptive software is employed to maintain accuracy in variable atmospheric conditions while producing real-time results.

Phillips 66 Rodeo - Open Path System
This system installed in 1989 is among the world's oldest open path systems in industrial use. The refinery maintains two nearly parallel path arrays designed to detect emissions corresponding to the two predominant wind flow patterns. As with the Chevron Richmond system, the monitoring results for Rodeo are posted to a public website that allows the community to receive preliminary and invalidated information in near-real-time.

The Rodeo system utilizes a four-component open path monitor array and a dedicated meteorological system. The system is similar to the Chevron system in its ability to detect H_2S and SO_2 in the low parts per million range.

More detailed descriptions of the Richmond and Rodeo open path monitoring systems can be found in Appendix I.

ALON Bakersfield - Fixed Point System
ALON Bakersfield is equipped with a four-point fenceline monitoring array located near the four corners of the refinery, measuring NH_3, H_2S, and non-methane hydrocarbons. The sites use wireless transmitters, relays and receivers to transmit data to ALON's operations center. Data enters the refinery's process information system for operational analysis, and is posted to a public website as real-time, preliminary data. The ALON configuration was installed as a condition of obtaining the facility's County use permits.

Phillips 66 Wilmington - Fixed Point System
The Phillips 66 Wilmington fenceline system is an array of four point sensors aligned along the refinery's eastern property boundary and adjacent to a residential community. The monitors continuously detect flammables and H_2S, and are hard-wired to the refinery operations center.

In addition to the above listed sites, there are several refineries that, due to their small size or orientation of facilities, have existing process unit monitors that effectively serve as fixed point perimeter or fenceline monitors. Recognizing the variability in refineries and the need for multiple solutions, to the extent these individual devices are real-time and data-connected directly

to the refinery operations center, they can be deemed to serve an equivalent purpose as a fenceline monitoring system.

BAAQMD adopted rules that will require fenceline monitoring at refineries within their jurisdictions, while the U.S. EPA regulation requires fenceline monitoring for benzene, serving as a surrogate, to approximate and control fugitive emissions of hazardous air pollutants. The U.S. EPA rule requires a passive diffusive benzene sampling system arrayed radially around the refinery at 15 degree intervals, requiring a minimum of 24 samplers. Because samples are only collected biweekly for lab analysis, the method does not provide value as an emergency monitoring tool.

The BAAQMD rule requires a system utilizing open path monitoring, allowing a maximum five-minute time resolution for data averaging and reporting. The minimum proposed monitoring requirement would be for H_2S and VOCs as organic compound indicators. The BAAQMD approach has other, nonemergency objectives, such as tracking of fugitive emission trends, monitoring data to identify potential reductions, and correlating crude slate changes to emissions changes. The approach will provide valuable, time-sensitive data for assessing the off-site impacts of certain contaminant releases, while putting in place the tools to assess the risk posed to surrounding communities by routine refinery operations. Additionally, due to recent incidents, SCAQMD is working with the Torrance Refinery to address community concerns about specific chemicals of high concern, such as HCl and HF, creating a need to assess fenceline monitoring systems to detect these chemicals.

Air districts report they are satisfied with the available and emerging technologies for fenceline monitoring at refineries. What is needed is a more thorough analysis of site-appropriate monitor siting and how best to get real-time or near real-time data to emergency responders and to communities potentially affected by unplanned releases and ongoing fugitive and upset emissions. Proper siting for open path monitoring systems has been discussed and addressed at some length in the BAAQMD's proposed refinery monitoring rules and guidelines. Localized air flow modeling is an appropriate tool for proper siting. The merits of open path vs. fixed point fenceline monitors have been evaluated by BAAQMD and U.S.EPA for their respective fenceline monitoring programs. The open path system provides a long, continuous detection path for contaminants of concern that may improve the quantitative detection of unplanned releases, but does not provide the fixed detection point(s) of a conventional fixed point system that can use multiple readings to triangulate likely leak sources. There are open path monitoring systems available that can scan multiple segments of different lengths along a single boundary when compounds are detected and have a similar ability to locate leaks as the arrays of fixed point systems. GLM networks such as those at Bay Area refineries essentially function like a small fixed point array

of fenceline monitors, though not all monitors are on the fenceline and the range of detected pollutants is limited.

Since both open path and fixed point fenceline monitoring systems have merit for detecting major unplanned releases as well as fugitive and upset emissions of different types of contaminants, CARB and CAPCOA members believe that statewide guidance is appropriate for each air district to determine which systems are appropriate for the refineries in its jurisdiction and require fenceline monitoring plans from each refinery. The plans should take into account geospatial layout of the plant, potential release sources, local meteorology, atmospheric dispersion characteristics of the compounds of concern, and the relative risk to likely receptors based on these criteria.

Implementation

The proposed RMWG will develop guidelines, including exposure action levels, for district rules for refineries to install fenceline monitoring systems. An assessment is needed for fenceline systems capable of detecting HCl and HF to address specific community concerns. Open path systems, including optical remote systems, will be required for large refineries producing light distillation products, while fixed point array systems will be allowed for smaller facilities producing heavier distillation products. Refineries will be required to submit monitoring plans that meet minimum standards followed by agency and public review. The proposed RMWG will support BAAQMD's work as needed to validate alternative, real-time fenceline monitoring systems so that these methods establish equivalency to the U.S. EPA's fenceline monitoring regulation. The proposed RMWG will develop guidance to make data from fenceline monitoring systems available to first responders and the public. The proposed RMWG will develop protocols for analyzing data collected during routine operations to identify opportunities to reduce or mitigate emission impacts.

8. Community Monitoring Systems

Key Finding

F-A8. With the exception of the GLMs described previously, only one California refinery - Chevron Richmond - currently utilizes off-site, real-time community monitors placed to measure neighborhood levels of pollutants associated with refineries.

The Richmond community air monitoring network is in many respects a state of the art system. Each site gathers real-time data on multiple air contaminant parameters and transmits measurements directly to Chevron and to a publicly accessible website where it is posted as preliminary data. Data is posted in a matter of minutes, rather than hours or days. The stations are also equipped with auto samplers that are activated when real-time

measurements exceed a preset threshold. The automated bag or canister samples are then collected manually for off-site analysis.

In addition to fixed, regulatory-like community monitoring systems, technologies for mobile monitoring platforms and low cost sensor networks are developing that have the potential to increase the geographic reach, resolution and timeliness of community air pollution data. These systems have been demonstrated on relatively small scales. Public and private interest in further development and demonstration is increasing rapidly.

Key Recommendation

R-A8. Air districts should install and operate site-appropriate, real-time community monitoring systems, as described in the analysis below. In addition, CARB and air districts should, through grants or other available funding mechanisms, support community organizations in acquiring, managing, and demonstrating community air monitoring systems that have been evaluated and recognized as capable of providing reasonably reliable baseline data regarding neighborhood air quality. These systems should be funded by the refineries.

Analysis:

The Chevron Richmond Refinery is currently the only refinery in the State with an active, continuous community-level monitoring system.[12] The system is comprised of three community sites located in the residential and business communities east of and nearest to the refinery boundary. The sites contain identical sets of instrumentation designed to continuously monitor for uncontrolled and fugitive emissions from the Chevron Refinery. The sites are also equipped with automated samplers that can be remotely activated to gather air samples for later analysis. A detailed description of the Richmond community monitors' instrumentation is provided in Appendix J.

Acknowledging that BAAQMD already has plans for community monitoring in each of the Bay Area refinery communities, CARB and CAPCOA members propose requirements for site-appropriate, real-time air monitoring in communities downwind of refineries. Community monitoring programs would be developed and operated by air districts at the refineries' expense. Each district would propose a community monitoring plan in consultation with local CUPA emergency response and health officials. The community monitoring plan would contain, at a minimum:

1) A list of compounds to be monitored, including VOC (BTEX and other flammables), H_2S, SO_2, PM2.5, and also NH_3, HCl, HF, other hazardous

[12] Several sites within the BAAQMD GLM program are located in communities remote from refinery operations. By rulemaking, BAAQMD plans to establish and operate at least one additional fully equipped community monitoring site in each of the five Bay Area refinery communities.

compounds identified in the RMP worst case scenarios, and other TACs, if these compounds are present at the refinery.

2) A siting plan that includes:

- Surrounding demographics within the radius established by the farthest toxic endpoint calculated for off-site consequences in the refinery RMP, including sensitive receptors such as residential neighborhoods, schools, medical facilities, senior communities, and outdoor public event venues.
- Prevailing meteorological conditions that support the siting.
- An analysis of surrounding non refinery air contaminant sources that could affect monitoring results.
- Results of predictive modeling assessments that support the chosen site(s).

3) A list of proposed instruments and samplers to be used and the theory of operation and methodology for collecting and disseminating measurements from each instrument and sampler.

The BAAQMD rule details more specific and complex siting requirements that are appropriate for many, but not all California refineries. This community monitoring requirement is also complementary to the community level focus on AB 617 and proposed CalOES and CalEPA regulations for development of expanded emergency response plans by refineries. These latter regulations require that refineries submit site-appropriate emergency plans for local agency review and approval in a public process.

Emerging technologies in mobile monitoring and community-based sensor networks are rapidly increasing the possibilities for expanding community air monitoring beyond traditional fixed systems of instruments used for regulatory purposes.

Low-cost air pollutant sensor research and development is producing instruments that can be widely deployed and transmit information via the Internet. Similarly, advanced optical systems are being adapted to mobile platform use as a means of continuously collecting real-time data over a broad geographic area. These systems have the capability to generate and transmit data in real-time or near-real-time, creating a valuable asset for detecting sudden temporal or geographic changes in air quality but also posing a substantial challenge for data quality, interpretation, and management.

California has become a focus of demonstration and evaluation activity for these technologies. BAAQMD and SCAQMD have both collaborated on recent demonstrations of advanced optical remote systems at refineries. To

address quality assurance concerns in the emerging low-cost sensor field, SCAQMD has established a leading role in evaluating these devices through the Air Quality Sensor Performance Evaluation Center, with sponsorship from U.S. EPA. CARB has participated in recent sensor field performance evaluations in disadvantaged communities of San Diego and Imperial Counties, and is currently developing a strategic plan for enhanced community monitoring that will serve as a roadmap for future state involvement in this area.

Real-time community air monitoring does not typically afford the ability to forewarn responders and the public of unanticipated hazardous releases into a neighborhood. Its primary value is in providing an early, ongoing, and realistic indication of air contaminant exposure levels in the community, enabling responders to make effective decisions regarding the use of shelter-in-place, evacuation, and safe re-entry. However, during times of normal refinery operations, data from these systems helps inform the public of possible risks posed by any fugitive air emissions and may point to systemic refinery operational issues that should be addressed.

Implementation
The proposed RMWG will develop guidelines for district adoption of a rule, performance of siting analyses, and installation of district-approved, site-appropriate community monitoring systems.

9. Mobile Incident Monitoring Equipment

For purposes of this report, mobile monitoring refers to the deployment of specialized incident support equipment, instruments, and samplers that are mobile by vehicle, but that: 1) may not be self-contained, 2) too large or cumbersome to be considered hand-held or manually portable, or 3) may not provide real-time or near-real-time analyses. Examples of mobile monitors include portable gas chromatographs, portable FTIR spectrometers, E-BAM particulate monitors, and any kind of sampling device such as a SUMMA canister or bag sampler.

Finding:
F-A9. CARB, SCAQMD, BAAQMD, and SJVAPCD utilize mobile monitoring systems for certain special studies, investigations, and longer term emergency incidents that are not dependent on real-time results for public safety. They are valuable for forensic assessments of incidents, and with enhancements could be more useful for real-time incident monitoring.

Recommendation:
R-A9. Establish an advisory forum among mobile monitoring-capable agencies including CARB, SCAQMD, BAAQMD, SJVAPCD, CalOES,

U.S.EPA, CST, and local first responders to optimize the utilization, effectiveness, and geographic support of mobile monitoring assets based on available resources. This forum should consider assessing upcoming equipment and sensor technologies for pollutants, levels, and potential for rapid deployment on mobile platforms and small networks, as well as standardizing equipment and instrumentation for mobile response units, based on the method CalOES presently uses for "typing" or certification of standard equipment for local HazMat response units.

Analysis:
Certain types of refinery emergency releases could overwhelm the air monitoring resources of local fire and HazMat agencies before the source of the release can be controlled and potential exposures are mitigated. These circumstances create a gap and a need for agencies like SCAQMD, BAAQMD, U.S. EPA, CARB, and others to fill through the development of mobile monitoring capabilities. These support capabilities are limited by several critical factors: 1) staffing is not on call or available 24/7 for response, 2) staff are not trained or classified for hot zone responses, and 3) mobilization and travel time to an incident limit the timeliness of the monitoring. These real limitations challenge the practicality of fully resourced mobile monitoring systems operated by local air districts and others.

There is a precedent for this approach to leveraging resources. CalOES developed a HazMat response "team typing" assessment and certification program for local emergency response agencies. These certifications have tangible value. They assist in the development of mutual aid agreements and provide benchmarks for local agency budgeting, program improvements, and grant opportunities.

Implementation
The proposed RMWG will convene the recommended forum to enhance and integrate mobile monitoring-capabilities into refinery emergency response programs. The forum should explore a process for assigning an equipment "type" rating for mobile air emergency response units similar to the CalOES method for certifying local HazMat units.

10. Community Hazard Patrols

Finding:
F-A10. Most refineries employ both proactive and responsive community patrols to identify odors, investigate odor complaints, check for security and environmental hazards, and conduct basic monitoring during emergencies around the facility's fenceline. Proposed CalARP regulations contain a general requirement for refineries to plan for off-site responses, taking into account the surrounding communities.

Recommendation:
R-A10. CUPAs should require all refineries to conduct and document routine off-site community patrol programs to check for environmental hazards outside the facility's fenceline, and to conduct basic pre-planned VOC and H_2S monitoring with handheld devices during emergencies. CUPAs should require refineries to provide logs and information from community hazard patrols with appropriate agency response personnel upon request.

Analysis:
All refineries conduct some level of leak-detection patrolling as a regular daily routine, whether around the refinery perimeter or checking for environmental hazards outside the facility. Most refineries also patrol in the community as requested to investigate odor complaints and conduct basic VOC monitoring during emergencies. Proactive monitoring consists of routine patrols at least daily to look for leaks or odors, and establish baseline or background conditions. Responsive community patrols consist of deploying teams during an emergency or when complaints are received, and reporting back findings to the refinery operations center or EOC.

As an example, the Tesoro Martinez Refinery contracts with a certified odor detection service to respond to complaints and conduct periodic odor surveys. The independent service provides a measure of objectivity that the refinery and community value. The Shell Martinez Refinery has a prioritized community patrol plan within its emergency response plan that deploys employees to pre-determined zones to take and report measurements during an air release emergency. The priority for monitoring is determined by real-time meteorology. The plan also identifies specific sensitive receptor locations, such as schools and medical facilities that are priority monitoring sites.

Implementation
CARB and the proposed RMWG will work with CalEPA and CUPA Forum to ensure refineries conduct/document routine off-site community patrol programs and share resulting information with appropriate agency response personnel.

11. Optical Remote Sensing and Spectral Flux Monitoring Technology

Finding:
F-A11. SCAQMD and BAAQMD have supported and/or demonstrated various optical remote sensing (ORS) and spectral flux-measuring technologies. Differential optical absorption spectroscopy (DOAS), multi-axis differential optical absorption spectroscopy (MAXDOAS), solar occultation flux (SOF), and cavity ring-down spectroscopy (CRDS) have been successful in estimating fugitive emissions in certain environmental conditions. These technologies currently have limited but growing capability for measuring air contaminants in emergency release situations as well as for more routine

monitoring of fugitive emissions. Further demonstration and application of these technologies would be valuable to improve validation.

Recommendation:
R-A11 CARB and CAPCOA should support demonstration and implementation of ORS and spectral flux technology projects in SCAQMD and elsewhere as these technologies are validated for refinery air monitoring applications.

Analysis:
DOAS, MAX-DOAS, SOF, CRDS and similar optical methods could provide a more complete picture of an industrial release. Unlike point monitoring and static linear (open path) monitoring systems, these systems are designed to detect and measure pollutant flux changes with a movable beam, enabling gas detection surveys in two or three dimensions. Each has demonstrated ability to measure a limited range of atmospheric trace gases, though the scope of refinery chemicals measurable is somewhat limited. Optical flux-measuring systems fall into two general groups, active – those with an incorporated light source (DOAS, CRDS) and passive – those that utilize the sun or moon as a light source (MAX-DOAS, SOF.)

Development and demonstration of these emerging technologies continue. In a 2015 testimony before a State Senate committee on refinery safety, SCAQMD summarized its ongoing optical remote sensing demonstration projects and welcomed support and assistance from State and federal regulators. SCAQMD supports implementation of ORS/spectral flux technology as a more appropriate technique than line-of-site or point monitoring to measure refinery emissions and help characterize community exposures.

Implementation
The proposed RMWG will support SCAQMD's work and related projects for developing and validating advanced spectral flux monitoring technologies with grant assistance, in-kind support, and other available resources. The RMWG will disseminate information on technologies that prove to be effective throughout the State and help other districts to adopt it.

12. Community Sensor Network Technology

Finding:
F-A12. Technological interest in low-cost community sensors and sensor network systems has increased rapidly in the last decade. This system needs further development, demonstration, and validation before they can be considered viable as an emergency assessment or response tool. SCAQMD has established a permanent Air Quality Sensor Performance Evaluation Center (AQ-SPEC) that is being used to assess sensors and similar air monitoring instruments.

Recommendation:
R-A12. CARB and CAPCOA members should support sensor and instrument evaluations through programs such as SCAQMD's AQ-SPEC laboratory with available grants, funding, and in-kind resources such as instrument loans. This would include direct funding of community sensor network demonstrations.

Analysis:
Defense, environmental, and communications technology companies have been working for a decade on developing low-cost, networkable micro sensors for air contaminant monitoring, and advancements are ongoing. Devices reviewed by SCAQMD and CARB show some promise for certain pollutants – principally PM, carbon monoxide and a small number of other gases - but data formatting, telemetry, interoperability, power consumption, calibration, and geospatial networking remain challenges, particularly for devices intended for low-cost, mass distribution, and continuous air quality monitoring. In addition to work by CARB, districts, and contractors, the AQ-SPEC sensor evaluation laboratory, that began operations in 2015, holds promise for standardizing sensor evaluations and should find ample demand from the developers of many market ready consumer and industrial air sensors. In its 2015 testimony before a State Senate committee, SCAQMD summarized its AQ-SPEC project and welcomed support and assistance from State and federal regulators.

Low-cost commercially available air sensors provide the potential to saturate an area around refineries with monitors that can increase the spatial and temporal resolution of collected air quality data, provided these instruments are accurate and reliable. These sensors can be deployed in fixed networks by agencies, individuals, or community environmental groups such as the Los Angeles Community Environmental Enforcement Network. SCAQMD's AQ-SPEC field tested these sensors alongside one or more of SCAQMD's existing air monitoring stations using federally approved methods to gauge overall performance. Sensors demonstrating acceptable performance in the field are then brought to the AQ-SPEC for more detailed testing. The results are to be posted on a dedicated website along with guidelines and considerations for use of the new technology.

Implementation
The proposed RMWG will support sensor and instrument evaluations, including SCAQMD's AQ-SPEC program for real-time and emergency monitoring sensors. The proposed RMWG and CUPA Forum will recommend instruments for evaluation by SCAQMD's AQ-SPEC program as needed and appropriate. The proposed RMWG will pursue funding for evaluation work and community-based network demonstrations with grants and other available sources.

B. MODELING

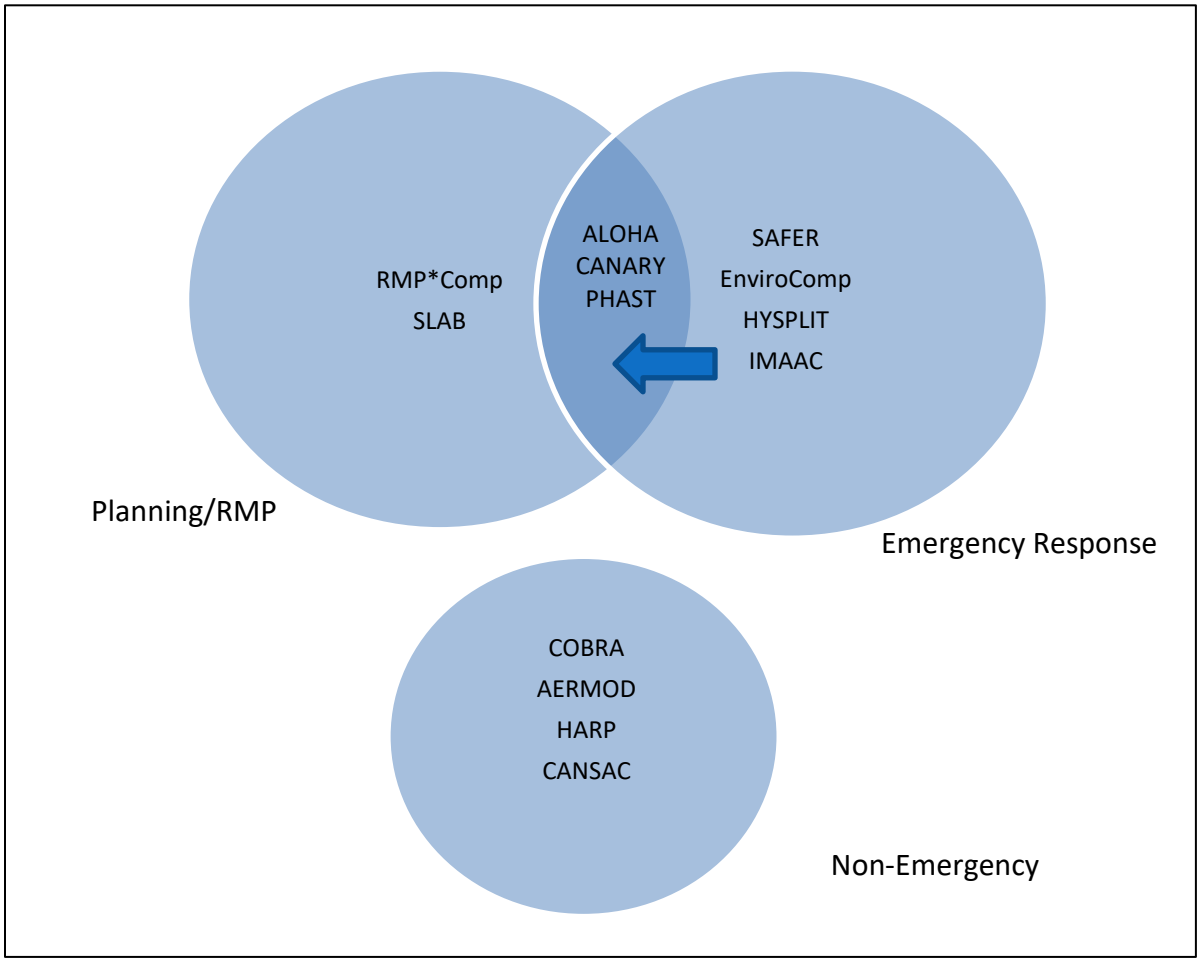
Several air release modeling strategies exist that provide valuable planning and response tools for industrial releases. Two such strategies are predictive and real-time modeling. Predictive modeling refers to modeling performed prior to a release with entirely pre-defined scenarios for source characteristics, release rate, topographic influences, and meteorology. Predictive modeling is useful for planning and preparedness purposes, exercises, drills, and for development of monitoring plans. The precise release source, release parameters, and meteorology are based on real world probabilities, but the overall scenario is hypothetical. Real-time modeling refers to modeling performed for an actual release situation, when some of the parameters are known (typically the source location and meteorology) and only the release rate and duration need be estimated. Real-time modeling provides the opportunity for self-validation when it is accompanied by concurrent air quality monitoring data. In some cases, post incident, or forensic, modeling is used to better characterize the releases from actual incidents.

Three predictive and real-time modeling approaches warrant further discussion: CalARP RMP modeling, immediately available modeling, and IMAAC modeling. CalARP risk modeling is a special case of predictive modeling in that there are regulatory standards in place describing what processes will be modeled as well as the methodology used, while the other models have no minimum standard associated with them. Immediately available modeling refers to methods that enable refineries to assess off-site consequences of specific releases as soon as they become aware of the incident. Some of these approaches are starting to integrate predictive and real-time modeling. Lastly, the IMAAC modeling suite can be a valuable emergency response asset for predictive use and for major events of extended duration.

The refinery air monitoring assets inventory identified a variety of contaminant release models in current use. Some are employed exclusively to assess off-site consequences for emergency planning purposes and RMPs. Other models are used only for emergency response, while there are some that are used for both. Several methods have the ability to rapidly predict the consequences of an unplanned release as soon as refinery staff becomes aware of it. Several modeling tools identified in the refinery air monitoring assets inventory are not used directly for source-specific release modeling (COBRA, AERMOD, HARP, and CANSAC), and those will not be discussed further here.

Figure B-1 depicts the relationship between the emergency preparedness planning/RMP, emergency response, and nonemergency dispersion models reviewed in this assessment. Recommendation R-B3 seeks to incorporate predictive and real-time modeling into each refinery's emergency preparedness and response program. Appendix K provides a description of the models suitable for emergency planning, preparedness, and response.

Figure B-1. Air Release Models Inventoried in Objective 1



In addition to identifying modeling objective(s), consideration must be given to proper characterization of different releases expected from a refinery incident. Some models work well for one type of plume but may not accurately predict the off-site consequences of another. For example, denser-than-air releases tend to form a mass that is moved by gravity until it is substantially diluted. Other releases, such as the 2012 Richmond fire, are comprised of hot vapors and smoke that have more vertical rise initially before winds carry and disperse them downstream, where they may ultimately impact ground level at extremely low or undiscernible concentrations. Initially, rough estimates of the release must be made based on limited information to make a timely prediction; however, the trade-off is accuracy. Subsequent post incident modeling uses more refined release estimates, but the difference in results can sometimes lead the public to second guess their validity. Lastly, the components of a chemical release can vary widely, from easy-to-model single component releases to the unknown multicomponent mixture found in the smoke from a refinery fire.

Quality and timely meteorological data is a key component of all modeling strategies. Predictive modeling used for risk management planning requires historical data

averaged over several years to predict likely release scenarios, while emergency responders will need at least wind speed, direction, and atmospheric stability class for their emergency response models. Immediately available models require real-time meteorological data from several locations to accurately predict plume dispersion.

The following findings and recommendation provide more detail and analysis on specific opportunities for refinery emergency preparedness and response programs to benefit from well-integrated modeling systems. With increasing availability of air monitoring data, stakeholders should focus on conducting more model validation. CARB and CAPCOA members also propose taking necessary steps to maintain access to emergency modeling tools such as IMAAC for modeling refinery drills, exercises, demonstrations, and real-time emergency needs.

1. USEPA /CalARP Risk Management Plan

Key Finding

F-B1. All refineries model specified off-site consequences and worst case scenarios under CalARP RMP requirements. The requirements provide for a standardized and conservative risk modeling exercise that is largely unchanged since the regulations were promulgated in 1988. CalOES finalized revisions to the California RMP program in August 2017. Further assessment of modeling techniques presents an opportunity to redefine the risk management planning area for each refinery and give CUPAs greater authority on the method of determining off-site consequences.

Key Recommendation

R-B1. CARB and CAPCOA members should convene one or more technical symposia on emergency applications of air modeling methodologies as part of the ongoing coordination and education of refinery emergency responders. A symposium might, for example, be structured to compare the merits of RMP methodologies with more recently developed modeling techniques that can be used to site fenceline and community monitors. The annual CUPA training conference may be an appropriate venue for training on methodologies and sharing practical modeling information.

Analysis:

RMP models are a narrow subset of predictive modeling that most refineries use to satisfy pre-incident modeling requirements of Section 112(r) of the 1990 Clean Air Act amendments. In some cases, the same models may be used to inform facility managers during the initial phases of an emergency response. Facilities subject to the RMP rule must perform at least one hazard analysis using modeling to determine whether chemical transfer, processing, or storage puts nearby populations at risk.

Refinery RMPs contain standardized information on refining processes, chemical hazards, risk analysis, and emergency planning, as prescribed by CalARP regulations. RMPs must be updated every five years at a minimum, with addenda submitted whenever there is a significant change that affects the potential on-site or off-site emergency preparedness or response procedures in the refinery's emergency plan. Refineries are required to model worst-case-scenario (WCS) releases for a single toxic substance and a separate flammable compound. They are allowed to provide one or more alternative release scenarios for toxic and flammable compounds that the refineries consider being more likely than the prescribed WCS. The local CUPA reviews RMP adherence at least once every three years. Table B-1 provides a summary of the models used to assess off-site consequences for the RMPs prepared by refineries.

CARB participated in IRTF discussions on RMP modeling and revisions to the RMP program. The RMP program is well established and the requirements provide a standardized and conservative risk modeling exercise. In this assessment and in discussions with stakeholders, technical issues emerged indicating the RMP requirements have limitations that may indicate a review of the program is warranted. These issues include:

- Calculation uses limited, prescribed inputs.
- Does not consider cumulative or cascading release effects.
- Process intermediates are not considered.
- Does not consider fire emissions.
- Limited suitability for making immediate public health and safety decisions during an actual event if real-time source and atmospheric data are available.

Table B-1 Risk Management Plan Air Dispersion Models Used by Refineries

Refinery	RMP*COMP[13]	ALOHA	CANARY	PHAST	SLAB
Tesoro Martinez	Yes (Urban)				
Phillips 66 Rodeo	Yes (Urban)				
Shell Martinez		Yes			
Chevron Richmond	Yes (Urban)		Yes (v3.1,4.4)		
Valero Benicia	Yes (Urban)				
Tesoro Wilmington (Refinery)	Yes (Urban)			Yes (v5.2)	
Tesoro Carson (Tank Farm)	Yes (Urban)				
Tesoro Carson (Sulfur Recovery)	Yes (Urban)			Yes (v5.2)	
Phillips 66 Carson	Yes (Urban)				Yes
Phillips 66 Wilmington	Yes				Yes
PBF Energy Torrance	Yes (Urban)				
Chevron El Segundo	Yes				
Paramount Petroleum Paramount	Yes (Urban)				
Valero Wilmington	Yes				Yes
Alon USA Bakersfield	Yes (Urban)				
Kern Oil Bakersfield	Yes (Rural)				

The existing RMP program uses WSC modeling as a starting point for discussions with emergency response planners on the extent of a refinery's response plan. August 2017 revisions to the RMP program by CalOES present the opportunity to address several modeling-related issues. For example, the opportunity exists to review modeling advancements and identify any recommendations for improvement of RMP modeling to better define the WCS. Along with better defined maximum offsite consequences, emergency planners and industry can better define the area covered by their emergency response plans.

During the assessment, it was noted that the Phillips 66 Santa Maria Refinery was exempt from the RMP requirements on a technicality. That concern was addressed by the CalARP regulatory revisions. The new regulations will subject all California refineries to a new Program 4 section that covers all refinery operating processes, with the exception of utility and laboratory facilities.

[13] RMP*COMP has the ability to model dispersion over rural or urban topography and is indicated when this information was provided in the refinery's RMPs.

BAAQMD has determined that instrumentation to continuously measure upper air meteorology is necessary to improve air modeling accuracy along its 20 mile refinery corridor. The equipment needed costs significantly more than surface level meteorological stations.

Implementation

CARB and CAPCOA will coordinate with U.S. EPA to organize and hold one or more technical symposia on emergency air modeling methodologies to identify improved modeling capabilities within refineries and post the proceedings on the internet. The proposed RMWG and CUPA Forum will apply the results of the symposia to improve first responder and air district response capabilities, including evaluations and demonstrations.

2. Real-time On-Site Modeling Capability (Immediately Available Modeling)

Finding:

F-B2. Various real-time modeling capabilities exist throughout the State with varying levels of training for responders. The level to which these models have been validated is unknown. All real-time models can inform emergency responders of off-site consequences during an incident; however, only two methods have the potential to inform public safety decisions during the initial stages of a refinery incident.

Recommendation:

R-B2. Refineries should establish a site-appropriate modeling portfolio using live modeling capability based on real time in-plant air monitoring data once such models are properly validated. The proposed RMWG should develop a plan to validate these real-time immediately available models, in collaboration with U.S. EPA and modeling experts.

Analysis:

Modeling is used throughout the state to inform decisions to protect workers, responders, and the public from unplanned air releases during all phases of a refinery incident. In theory, release dispersion models could be used for these various aspects of emergency response, although further validation of model capabilities and application methods would be needed and likely would require several years to develop. During the first moments of an incident, modeling may inform decisions to protect on-site workers, establish the hot zone for emergency responders, and inform public protection advisories. As the incident progresses, modeling may be used to react to changing conditions, incorporate additional information as it is collected, and direct placement of air monitoring instruments to validate the calculated off-site consequences. Towards the end of an incident, modeling may be used in conjunction with monitoring to terminate public protection advisories and issue all clear orders.

It is critical in the early stages of an incident to notify the surrounding community of off-site consequences so they have time to seek protection. During a major release, responders have very limited time to issue public safety orders for them to be effective. The technique of using immediately available modeling systems to issue public protection advisories during the initial phases of a refinery incident shows promise as a way to target only the portions of the community affected by the off-site consequences of a refinery incident. The disadvantage of modeling performed by emergency first responders is that it may not be accomplished promptly enough to warn a community before they are impacted by unplanned air emissions during a refinery incident, or may not be performed at all due to limitations of the emergency response models.

Additionally, modeling capabilities and training levels of emergency responders varies statewide. Often, emergency responders will use emergency response guidelines to inform community warning alerts to ensure a timely notification. These guidelines are conservative and may require notifying significantly larger portions of the surrounding population than necessary, posing an all or nothing decision for the incident commander. The need exists to accurately predict off-site consequences within minutes after a facility becomes aware of a release.

Two immediately available methods show promise of the ability to inform decisions during the initial stages of a refinery incident: SAFER and pre-planned emission/meteorological scenarios databases such as the proposed EnviroComp method and PHAST software. Installing an immediately available real-time system consists of purchasing the software, inputting real-time meteorological data, and adding site specific process information. The immediately available real-time system has the advantage over the predictive modeling approach in that it can react to a changing incident and meteorological conditions, while the predictive approach has the advantage of being able to use more sophisticated, time-intensive air pollution models in advance.

Currently, only the Tesoro Refinery in Carson has installed SAFER and has not reported its use in any incident to date. SAFER has many users in the chemical industry and refineries outside California. The other two immediately available modeling approaches, the proposed EnviroComp approach and PHAST software, have not been demonstrated at any refineries in California. Nevertheless, the need to be able to accurately determine off-site consequences of unplanned air releases warrants the use of an immediately available modeling approach.

Other real-time models are of use to responders if available at the site or brought to the response. While these models are not able to inform incident command decisions in the first moments of an incident, they may be used to

inform secondary public protection advisories and to help direct deployment of portable monitoring equipment used to supplement fixed monitoring sites. There is also a general role in modeling for forensic analysis of an incident with unplanned air releases. This post incident modeling, generally performed by experts or third-party consultants, can be useful to provide input for improved emergency response in the future.

This assessment found a wide variation of emergency responders modeling capabilities throughout the state. Making improvements to existing capabilities requires decision makers to consider the following factors:

> It is important to choose models for the scenarios they were designed for. For example, NOAA cautions that ALOHA (like any model) can be unreliable in certain situations and unable to model some types of releases. Specifically, ALOHA is not accurate for stable atmospheric conditions or determining the impacts close to the release source. Additionally, it does not factor in the effects of particulates, fires, chemical reactions, or chemical solutions or mixtures. It is important for first responders to understand the capabilities and limitations of emergency response models.
>
> The accuracy of models is another consideration for emergency planners and first responders. They must have confidence that the consequences they predict when using these tools accurately portray the risk to first responders and the surrounding community. There is a need to make the work done to validate these models available for training purposes and conduct additional validation work where it is needed.
>
> Cost effectiveness plays a role in the selection of commercially available models over those provided by government agencies. The capabilities of commercially available products are improving; however, work is needed to determine their cost effectiveness. More information on the cost effectiveness of CANARY, SAFER, EnviroComp, and PHAST would be helpful to industry and the emergency response community.

Additional scoping work is needed to accomplish the goals of validating the accuracy of the models inventoried, determining their applicability to refinery-specific release scenarios, and making the information available to the emergency planning and response community. The guidelines for suitable model selection and additional work needed could be a topic of the technical symposia on emergency air modeling described in recommendation R-B1. Table B-2 compares the characteristics of available modeling tools and identifies where additional information is needed.

Table B-2 Comparison of Modeling Tools and Future Modeling Assessment Needs

Criteria	RMP*Comp	PHAST	SLAB	ALOHA	CANARY	SAFER	EnviroComp	HYSPLIT	IMAAC
Conforms to RMP Regulatory Requirements	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A	N/A
Available	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Suitable for Use at High Hazard Facility	Yes	Yes	Yes	Yes	Yes	Yes	Unk	Yes	Yes
Accurate	Unk	Unk	Unk	Unk	Unk	Yes	Unk	Unk	Unk
Cost Effective	Yes	Yes	Yes	Yes	Unk	Unk	Unk	Yes	Yes
Immediately Available	No	Yes	No	No	No	Yes	Yes	No	No

Implementation

The proposed RMWG will develop a timeline, coordinate evaluation and validation of real-time industrial release models, and inform local response jurisdictions in their use through the CUPA Forum. The CUPA Forum will post the information developed on-line. CARB and CalEPA will investigate opportunities to incorporate improved modeling capabilities into refinery emergency response programs.

3. Predictive Modeling Capability

Key Finding

F-B3. Refineries, CUPAs, and air districts do not all routinely use modeling tools for mandatory air release drills and exercises. Predictive modeling capabilities are available for emergency response planning and training.

Key Recommendation

R-B3. A well-integrated, site-appropriate modeling system should be incorporated into each refinery's emergency preparedness and response program. At a minimum, refineries should be required in their emergency response plans to use predictive modeling for generating emergency response exercise scenarios and siting for community air monitoring systems.

Analysis:

Refineries and response agencies benefit from integrating modeling tools into their emergency preparedness and response programs. Models used for predictive modeling are those discussed in the preceding analysis. RMP*Comp, PHAST, SLAB, ALOHA, and CANARY are all accepted by the

U.S. EPA and local emergency response agencies for use in completing refinery RMPs. Additionally, ALOHA and CANARY are used by local response agencies and refineries for emergency response, while real-time models such as SAFER and EnviroComp show promise for emergency response, as well as performing predictive modeling. The modeling available through CSTs including the IMAAC suite can also be a valuable planning tool for refinery emergency planning.

Predictive models serve as a valuable tool in developing realistic air release scenarios, both for training on potential incidents as well as informing emergency responders and the public of potential off-site consequence. Using models to develop realistic off-site consequence scenarios provides a basis for responders to practice methods and procedures to protect the surrounding community. Part of the training should be in emergency response modeling that would or could be used to accurately determine what the off-site consequences would be and the limitations of those models. The annual CUPA training conference may present an opportunity to provide training developed from the proposed RMWG modeling review and symposia described earlier.

Implementation

CARB and IRTF will investigate opportunities for refineries to improve their emergency preparedness and response modeling capabilities. To improve emergency preparedness, refineries could use predictive modeling to generate emergency scenarios for use in training, drills, and exercises. On the emergency response side, refineries could ensure they have the modeling capability to assess and predict on-site and off-site impacts during actual emergencies.

4. IMAAC Coordination

Finding:

F-B4. IMAAC is the leading federal source of emergency atmospheric modeling for major air release incidents. CARB and air districts do not have direct access to IMMAC, but can request modeling through credentialed partners including CalOES Law Enforcement, U.S. EPA, and the California National Guard CST.

Recommendation:

R-B4. The proposed RMWG should take necessary coordinative steps to maintain regular use of IMAAC for modeling refinery drills, exercises, demonstrations, and real-time emergency needs.

Analysis:

IMAAC coordinates and disseminates federal atmospheric dispersion modeling and hazard prediction products and services. Through plume modeling analysis, it provides emergency responders with predictions of

hazards associated with atmospheric releases to aid in the decision making process to protect the public and the environment.

IMAAC provides a suite of plume modeling tools that incorporate meteorological, geographic, and demographic data, as well as hazardous material information, to predict the transport and potential downwind consequences of biological, chemical, radiological/nuclear, and natural releases. IMAAC experts are available 24/7 to produce detailed quality-assured model predictions, utilize observations and field measurement data to refine analyses, and assist decision makers in product interpretation.

IMAAC is typically activated by local law enforcement, State, and federal emergency managers and decision makers for real-world emergencies involving significant hazardous atmospheric releases that exceed local response capabilities. Local hazardous materials response agencies do not typically have direct access to these services. Once activated, IMAAC: 1) collects information on the incident including time, location, and type of incident, 2) develops model predictions and standard reports showing health effects and protective actions, 3) refines predictions based on real-time field measurements or updates from the incident responders, 4) distributes the products and reports to the appropriate parties, and 5) provides expert advice and consultation on interpretation and use of the products. Because of the human reporting inputs and interaction embodied in the IMAAC method, results are considered very good, but can take 30-60 minutes for development and interpretation, too long to be useful in many local, short-duration emergencies with a relatively small impact radius.

IMAAC personnel conduct regular training and outreach activities, subject to national prioritization. Additionally, IMAAC provides atmospheric modeling support for local exercises on a prioritized, as-available basis. In California, the principal designated authorities are CalOES and CST. Emergency modeling requests from the local level must be initiated by a law enforcement agency, even when the potential risks are primarily health or environmental.

During the investigation of refinery air monitoring capabilities, CARB staff joined the U.S. EPA Region IX Air Modeling Working Group to better understand coordination efforts among responsible emergency planning agencies. Through this group, CARB was able to arrange a working agreement with IMAAC for conducting multi-scenario plume dispersion modeling for refinery scenarios on an ongoing basis. CARB arranged a similar agreement from the CST to support modeling of refinery atmospheric release scenarios. These arrangements recognize the critical infrastructure role of California's refineries and the importance of assessing the effects of a major release incident on surrounding populations. CARB and CAPCOA should continue efforts to enable regular use of IMAAC for modeling refinery drills, exercises, demonstrations, and real-time emergency needs.

Implementation

The proposed RMWG and CARB will continue to maintain and strengthen the relationships necessary for the regular use of IMAAC services in refinery drills, exercises, demonstrations, and real-time emergency needs. CARB will work to improve protocols and relationships to enable local hazardous materials response agencies' access to these services. The proposed RMWG will encourage the use of IMAAC modeling by sharing information on-line through the CUPA Forum, while refineries will consider incorporating IMAAC services into their emergency preparedness and exercise programs as described in recommendation R-B3.

C. COMMUNICATIONS/COORDINATION

Timely and effective communication and coordination between the party responsible for an industrial release, the various responding agencies, and the public are critical elements of a successful response. Sharing pertinent and timely air monitoring data and modelling projections is an essential component of this communication. CARB and CAPCOA members have a valuable role in pursuing best practices not only for air monitoring and modeling, but also rapid interpretation of the resulting data and ensuring coordinated, consistent, and accurate communication of that information to the public by various local and state entities.

Both the CARB/CAPCOA Project Plan and the Governor's Refinery Safety Working Group report identified the need for an assessment of interagency communication and coordination for refinery emergency air monitoring activities. As part of this independent assessment, CARB staff interviewed local response agencies and managers from all fifteen refineries throughout the state to gain a better understanding of how refinery emergency preparedness and air release event information is communicated and coordinated at the local and regional levels. These interviews focused on emergency planning, response, and notification procedures for a refinery incident. There are many dimensions to these critical activities that CARB and CAPCOA members divided into eight interrelated topics for purposes of this assessment.

Concurrently, other State and local IRTF member agencies including CalOES, CalEPA, and the participating CUPAs have conducted similar reviews and assessments of communication and coordination from the perspective of their responsibilities for public and employee safety. In most cases, findings and recommendations for enhanced communication and coordination fall within the authority of these entities and not with CARB or participating air districts. Nevertheless, these topics are of vital importance to effective use of time-sensitive air monitoring data. Therefore, the findings are presented below, even though they have been or will be resolved principally by regulatory or administrative actions by CalEPA, CalOES, and the participating CUPAs. In several cases where CARB or CAPCOA members' direct authorities and capabilities are indicated, recommendations and analyses appropriate to those roles are presented.

Findings Addressed by IRTF Collaboration

1. Refinery Emergency Drills and Exercises

Key Finding

Finding:
F-C1. All refineries conduct regular emergency drills and exercises, including at least one annually with local fire and HazMat authorities. Drills and exercises focus on controlling releases and correcting operational problems. Few exercises fully involve all aspects of an integrated external response that include air districts and health and public information officers, although these are becoming more common. CalOES has issued proposed revisions to CalARP regulations that will integrate air monitoring officials and air districts into training, drills, and exercises for community response.

Discussion:
Generally, fire response agencies report satisfactory training and exercise relationships with refineries in their jurisdiction. A number of refineries in California have gone so far as to provide or cost-share highly specialized, industrial petroleum fire training for local response managers and teams. CARB and participating air districts concur with CalOES and CUPA leadership that a broad spectrum of stakeholders will benefit from improved cross-training between air monitoring and public health officials, refinery managers, and other responders.

2. Mutual Aid Organizations

Finding:
F-C2. There are petrochemical response mutual aid organizations and agreements in place for all California refineries. The frequency and level of organization of these meetings varies somewhat by region. Regular refinery participation in mutual aid meetings to keep knowledge of assets and capabilities current is important to properly maintaining each refinery's emergency response plan and overall preparedness.

Discussion:
Mutual aid is a well-established practice for California refineries to provide available assistance to any member requiring aid during an emergency situation. Typically, these arrangements combine the fire-fighting, rescue, oil spill, and HazMat response capabilities of a much broader spectrum of refinery, other industry, and local response agencies. They are usually formed under a formal agreement and response plan that details participation, equipment availability, coordination, and training.

3. Support for Local CAER and Similar Community Organizations

Finding:

F-C3. Community Awareness Emergency Response (CAER) groups are a recognized means of informing and educating community stakeholders on potential emergencies and appropriate protective actions. Not all CAER groups involving refineries are equally supported, active, and well organized. CUPAs with refinery response jurisdiction have authority under existing area plans and support the establishment and maintenance of an active CAER organization funded as needed by local industry contributions, with at least one work group or committee dedicated to educating community stakeholders on basic refinery risks and preparedness for emergencies.

Discussion:

Where they function effectively, CUPAs support CAER organizations' outreach tools, including current websites that highlight education and training on community warning systems, shelter-in-place, evacuation, and educational events. CARB cites participation in CAER organizations as a best practice for coordinating community education, and observed they succeed where they are incorporated, funded, and run by paid managerial staff. CAER organizations can play a vital role in educating the public on the availability of the data from proposed enhancements to the air monitoring networks surrounding refineries and the proper application of known health and risk values (i.e. acute vs. chronic health effects.)

4. Area Plan/RMP Review

Finding:

F-C4. In the past, air districts have not routinely reviewed the hazardous material area plans or refinery RMPs required by California Health & Safety Code §25503 and Section 112(r) of the federal Clean Air Act respectively. An understanding of these documents and periodic changes made to them by refineries would aid air districts in understanding emergency preparedness practices, and could increase collaboration and coordination during air release responses.

Discussion:

A regulatory role for air agencies in industrial air emergencies has been limited historically by exclusion from the State CUPA statutes. However, CARB and the Working Group recommended that RMP and area plan reviews would benefit if affected air districts have the opportunity to participate in technical reviews and provide perspective to CUPA programs for cross-training, preparedness exercises, coordination and communication.

As a result, CalOES revisions to CalARP and area plan regulations acknowledge a consultative role for local air districts that have refineries within their jurisdiction.

5. Community Notification Systems

CARB staff reviewed various community warning systems used to issue public advisories during refinery incidents throughout the state. All the notification programs were similar in that they used some combination of: 1) reverse 911 systems for land line notification, 2) subscriber notifications for use by registered cell phones, 3) audible warning sirens, and 4) media notifications. Many community warning systems have incorporated social media as part of their incident communication strategy.

Finding:
F-C5a. Response agencies require a variety of warning communications systems to achieve a locally acceptable coverage of timely alert notifications. Varying local strategies make interoperability and coordination across jurisdictional boundaries more challenging.

Recommendation:
R-C5a. The proposed RMWG should work with the CUPA Forum Board, CalEPA, and CalOES to develop and maintain a state inventory of local wired, wireless, web, audible warning, and synchronization technologies used by jurisdictions with refineries and other high hazard facilities. This will serve as a technical tool for jurisdictions evaluating their systems and seeking to expand or improve them.

Analysis:
CalOES is the State's coordinating agency for many regional and local emergency planning and technical functions. Current examples include CalOES' implementation of the CalEOC-standardized incident management and communication platform, the Next Generation 911 project enacted by State law in 2014, implementation of the federally mandated FirstNet communication system, and the HazMat Team Typing program. The rapid changes in electronic notification and situational data exchange systems warrant the creation of an ongoing function to track features and usage of these different communication methods.

Implementation
The proposed RMWG will share technical information on wireless communication technology used by CARB, air districts, and other agencies with CUPA Forum Board and CalOES in support of this inventory.

Key Finding

Finding:

F-C5b. Four refineries presently maintain public websites displaying a real-time refinery operational status, including air monitoring and meteorological data. Two of these also utilize a simple operational status rating system that gives the public a relative sense of any level of upset conditions.

Key Recommendation

Recommendation:

R-C5b. As is recommended elsewhere in this report, the local CUPA and/or the local air district, as permitting authorities, should require each refinery to make publicly available through either a centralized reporting page or individual websites, for the benefit of surrounding communities, information that indicates the status of the refinery with regard to operating conditions, access to real time air monitoring data, upset conditions, and unplanned releases, continuously and in real-time.

Analysis:

The existing refinery websites offer ample evidence that refineries can provide operating information that emergency responders, regulators, neighboring communities, and the public value. The Working Group Report and the BAAQMD Expert Panel Report concur in this finding. A well-crafted and well-integrated website can provide response agencies and the public with a direct portal into a refinery's current operational status, a capability that should create trustworthy and valuable situational awareness of upset conditions. Because of the potential magnitude of a worst case scenario event at refineries and similar high hazard facilities, CARB and CAPCOA members believe that real-time access to certain internal operating functions, such as Level 1 leak repairs or small fires, are warranted and would improve the collaborative preparedness of the refinery and response agency should an event escalate to posing off-site health and safety risks. Communities surrounding refineries will value access to real time air monitoring data during nonemergency, routine operations made available on the proposed websites.

The August 2017 CalARP regulatory revisions include a requirement for CalOES to collect process safety management information from refineries and post it to a website. This information does not include air quality measurements. To harmonize web information posting requirements, this recommendation may be suited to further development by the IRTF regional Safety Forums.

Implementation

RMWG will work with CalEPA to develop mechanisms that require refineries to maintain a public website, or report information through a centralized

reporting webpage, that shows their operating status and provide real time air monitoring data.

Community Siren Alert System

Key Finding

Finding:
F-C5c. Audible siren systems are a simple, effective, and reliable way to warn surrounding communities of serious incidents at refineries. Refineries and/or response agencies that operate siren warning systems for refinery emergencies should continue to use them, ensuring that the surrounding community is well educated on how the system is operated and what self-protective actions the system is intended to achieve. Warning sirens are suitable for industrial locations as a simple, low-tech back-up to other warning systems, provided that ongoing community education on use of the system is provided.

Discussion:
Audible sirens are used in the Bay Area refinery corridor and at the PBF Energy Torrance refinery to warn surrounding residents of serious emergencies at the refinery. Residents within a roughly one-mile radius of each refinery receive education on the siren system and necessary protective actions, through community meetings, mailings, and other media announcements. Training materials are provided through a number of outreach programs to instruct residents on how to shelter in place and seek more information.

There are some disadvantages to siren warning systems. One disadvantage is that individuals may not be trained or proficient in steps to take in the event of a siren. Another disadvantage is that not all citizens will hear the siren. Sirens may warn more of the community than necessary, even when conservative decisions are made on what segment of the population is to be warned. Timely notification can be adversely affected by inconsistent criteria for activating the system. If refineries control the system, they may delay notification by their reluctance to announce there are problems within their facility. On the other hand, the notification may be delayed if the refinery has to go through a local response agency to activate the alarm. Contra Costa County has partly resolved this problem with a dual activation system where either party can activate the alarm.

Reverse 911

Key Finding

Finding:
F-C5d. Reverse 911 advisories to land lines and cell phones have been a fundamental component of many community warning systems for decades. All response agency jurisdictions in the vicinity of California refineries have reverse 911 capabilities.

Discussion:
The reverse 911 system is a trademarked public safety communications system developed to meet the need for rapid emergency notification. It is used by public safety organizations throughout North America to communicate by telephone with people in a defined geographic area. The system uses a database of telephone numbers and associated addresses that deliver recorded emergency notifications to a selected geographic set of telephone service subscribers.

Reverse 911 has been used effectively to notify residents in the vicinity of emergency situations, though it has limitations. Call blocking and caller ID features of some telephone service providers can interfere with notifications. There is a limit to the number of calls that can be made in a timely manner, as was reported during the Chevron Richmond fire and the more recent Torrance Refinery explosion. Not all voice-over-internet-protocol (VOIP) telephone systems support reverse 911. Because of the evolving consumer transition away from landline phones to more convenient cell and VOIP phones, reverse 911 is increasingly considered a supplemental component of community notification systems.

Social Media Notification

Key Finding

Finding:
F-C5e. Several California refineries and most local response agencies use social media applications to provide the public with direct and timely information on industrial emergencies. However, it is critical for agencies that use social media notifications to ensure that all broadcast social messages be considered official information of the sender, be consistent with messages sent by other means of communication, and be approved by the incident command's agency liaison or public information officer.

Discussion:
Social media, such as Twitter, Facebook, and Instagram offer an increasingly popular mechanism for the quick distribution of situational information. When used in official capacities, social media has been widely reported as effective in notifying informed users of developing emergency situations. It is also effective for dispelling rumors created by incomplete information or misinformation. It also offers the general public with a simple means of subscribing to the media channels of choice. It is important that social media applications be used judiciously during public safety emergencies, and through joint incident command oversight, in order to provide consistent, official information that is vetted by the ranking agency liaison and/or public information officer for the incident.

The proposed CalOES Area Plan regulation revisions include a requirement to use SEMS in emergency responses and to create a joint information center (JIC) to process all official communications. A JIC is able to use every type of communication technology to provide information to the community. Air district coordination with the JIC is critical for effective social media notifications during an emergency.

Targeted Cellular Alert Systems

Key Finding

Finding:
F-C5f. There are several commercially available systems that transmit text messages to all smartphones in targeted geographic segments of the community. Some response agencies are adding this capability to their notification suite of methods. Integrated Public Alert & Warning System (IPAWS) messaging systems are rapidly becoming part of each local response jurisdiction's suite of communication tools when refineries or other high hazard facilities are present.

Discussion:
One technical shortcoming identified in reviewing community warning systems is that many cellular-based call-out systems require users to subscribe and register their cell phones in order to receive advisories during a refinery incident or other emergency. The alert is then transmitted, whether the user is in the vicinity or not. San Luis Obispo County, Los Angeles County, and Contra Costa County have CWS systems that deliver text advisories to all cell phones physically operating near a refinery via a "push notification" without requiring the user to register the device. These systems are provided by vendors using FEMA's IPAWS protocol that require no action by the cell phone users in the vicinity of the incident to receive a text notification.

IPAWS represents a significant modernization and standardization of the nation's alert and warning infrastructure. Federal, State, local, tribal, and territorial alerting authorities can use IPAWS and integrate local systems that use Common Alerting Protocol standards with the IPAWS infrastructure. IPAWS provides public safety officials with an effective way to alert and warn the public about serious emergencies using the Emergency Alert System, Wireless Emergency Alerts (WEAs), NOAA Weather Radio, and other public alerting systems from a single interface. WEAs can be sent to IPAWS capable cell phones in the vicinity of a refinery during an emergency, while many existing systems require those wanting notification to pre-register their cell phone.

6. Process Safety Management Coordination

Local Industrial Safety Ordinances

Finding:
F-C6a. Contra Costa County and the City of Richmond each adopted and implemented industrial safety ordinances (ISO) to augment federal and State accidental release and process safety management regulations. Both CalOES and Cal/OSHA have incorporated ISO provisions into their respective updates to safety, inspection, and reporting regulations and process safety management (PSM) regulations.

Discussion:
In 1988, Contra Costa County enacted a landmark ISO that expanded upon existing State and federal accidental release prevention programs in order to further minimize the risks of serious accidents at the County's refineries and chemical plants. The City of Richmond adopted a similar ISO shortly thereafter. The addition of the ISOs to existing State and federal risk reduction regulatory efforts culminated in the most stringent accidental release prevention programs in the United States and serves as a model for the State. CalOES and Cal/OSHA used these ISOs as a basis for an enhanced statewide regulatory PSM program that will help foster improved air district involvement in responding to refinery incidents.

Air Monitoring Data as a Process Safety Indicator

Finding:
F-C6b. Air monitoring data from refineries (inventory, upsets, and incidents) are potential process safety leading and lagging indicators at refineries.

Recommendation:
R-C6b. As additional monitoring systems are put in place, the proposed RMWG will investigate whether sufficiently detailed monitoring data from

refineries could serve more broadly as a process safety indicator. RMWG will report any such findings to CalOSHA.

Analysis

CSB recommended that the State Legislature or Governor identify process safety leading and lagging indicators at refineries and require refineries to report them to state and local authorities that have chemical release prevention authority.[14] CSB suggested that air quality data gathered in and around the refineries be evaluated as possible leading and lagging indicators. Direct involvement of CARB and CAPCOA members in process safety management is outside of the scope the Work Plan; however, the common goal of incident prevention provides an opportunity for interagency collaboration.

Routine emission inventory activities and process upset data at refineries could serve as indicators of a facility's overall process safety management. Emissions data has previously not been used explicitly for that purpose, i.e., exchanged between air pollution and industrial safety regulators. The BAAQMD's refinery emissions monitoring and tracking rule, adopted in April 2016, could provide a substantial amount of new data on refinery emission trends, and is in fact designed to do so. Since air districts have different amounts and types of air monitoring data at their disposal that may be subject to evaluation as a process safety indicator, this will be an appropriate project for the air district's emergency preparedness liaison (proposed elsewhere in this report) to explore with Cal/OSHA.

Implementation

The proposed RMWG will periodically review air monitoring data sets provided by refineries and determine correlations with available CalOSHA incident data.

Finding:

F-C6c. The coordination practiced between refineries and their local emergency response jurisdictions for assessing and managing unplanned hazardous air releases is not consistent. Refineries and response agencies with well-defined authorities and responsibilities demonstrate a higher degree of mutual trust and response effectiveness.

Discussion:

One of the 2013 Working Group Report recommendations was that CalOES should consider regulations to clarify key terminology in Health and Safety code section 25504, subdivision (a), specifying criteria for reporting thresholds and a clearer definition of the terms, "immediate" and "threatened release." The basis for this proposal is that some response agencies believe refineries liberally interpret requirements for immediate notification of

[14] U.S. CSB Recommendation 2012-03-I-CA-R10.

threatened releases, potentially delaying public notification and jeopardizing public safety.

New CalOES regulations adopted in 2015 establish the local response agencies' authority to access refineries' emergency status and operating information as needed to make informed public safety decisions for any fire or air contaminant release, including a hazard and operability study (HAZOPS), emergency fire and release drills, response training, exercises, and all refinery environmental release data.

Once implemented, the newly granted authority for refinery facility and information access by local public safety officials should have the effect of creating a more effective unified command with the refineries during significant incidents

7. Air Monitoring Coordination/Training

Finding:
F-C7. CARB and air district monitoring and compliance personnel lack certain first response capabilities, including specialized hazard training, 24/7 on-call response capability, and geographic proximity to provide reliable, immediate response to major air release events. However, CARB and air districts have valuable expertise in monitor siting and operation, air sampling, and other necessary elements of a public safety and health assessment. There is a clear opportunity for increased awareness, training, and coordination of air monitoring services.

Recommendation:
R-C7a. CARB and affected air districts, through the proposed RMWG and the CUPA Forum, should advise and help train local first response agencies and regulated businesses on air monitoring and sampling methods to more effectively gather actionable data for emergency releases, including the expanded systems recommended in this report.

R-C7b. The proposed RMWG should develop and provide an interagency procedural template for optimizing the air monitoring that is achievable within one hour, or as quickly as possible, of the lead agency's notification of a refinery incident.

Analysis:
All emergencies are local; that is a mantra of emergency response and it is especially true for short term incidents such as refinery fires and individual toxic releases. Most assessments and decisions relating to public safety need to be made in minutes. The public and elected officials have high expectations for performance of public safety agencies and corporations with hazardous operations, though they may not fully appreciate the resources required, or planning and preparedness necessary, to achieve the desired

level of performance. A balance is necessary between expenses and expectations.

Promoting cooperation, coordination, and an appropriate level of standardization is a means of optimizing available resources and controlling cost increases. Establishment of the IRTF provided an opportunity for many agencies with regulatory jurisdiction over refineries and high hazard facilities to focus and align their roles toward the goal of making all stakeholder systems more inherently safe and cost-effective.

With respect to emergency air monitoring specifically, there is a need and an opportunity for ongoing technical collaboration through training focused on public safety. Much experience and knowledge resides in refineries, local response agencies, air districts, State safety and response agencies, U.S. EPA response teams, National Guard Civil Support teams, IMAAC, technology companies, consultants and other stakeholders. These entities can work together to better understand one another's missions and capabilities through additional collaboration in exercises, training and drills.

Implementation

The proposed RMWG and the CUPA Forum will develop training on district air monitoring capabilities for local first response agencies and regulated businesses. The information developed can be shared via an on-line clearinghouse and at emergency response training venues. Additionally, air district staff tasked with the industrial emergency preparedness liaison function described in recommendation R-D5 will collaborate with response agencies and regulated businesses to improve air monitoring and sampling methods.

The proposed RMWG will also work with CARB to develop emergency response procedures that optimize the air monitoring that is achievable within one hour, or as quickly as possible, of the lead agency's notification of a refinery incident.

VI. CONCLUSION

This report provides a framework to address public concerns about the risks refineries pose from flammable and toxic air releases during emergencies and routine operations. The statewide inventory and assessment of monitoring and response capabilities showed a wide regional variation in capabilities with the opportunity for improvement in several areas. Local best practices in air monitoring, modeling, and coordination emerged that, if adopted statewide, can improve community health and safety surrounding California's refineries.

While regulatory improvements to process safety management programs[15] by other IRTF agencies will reduce the likelihood of future incidents, implementation of this report's recommendations will improve the air monitoring networks around these facilities, better enabling response to refinery emergencies and assessment of risks from routine refinery operations. Had the recommendations in this report been in place prior to the 2012 Richmond Refinery fire, response authorities would have had a more timely and complete assessment of the potential hazards and could have more effectively communicated those hazards. An improved monitoring network and site-specific modeling could have provided real-time data and risk assessment information to refinery personnel and emergency responders. The communication and coordination recommendations would likely have enabled first responders and air monitoring professionals to more quickly and fully inform incident commanders and the public about offsite health risks, or the absence thereof.

This report finds that an improved near-refinery air monitoring network can be achieved through site-appropriate implementation of: 1) continuous, real-time or near-real-time air monitoring inside the refinery, 2) predictive and real-time dispersion modeling of unplanned refinery releases, and 3) real-time or near real-time community monitoring. Better coordination is also necessary so that these networks can provide timely information to responders and the public. For successful implementation, State and local agencies may need additional authority and funding to undertake the report's recommendations. While some recommendations may likely be achieved over a longer time frame without additional new resources, timely and successful implementation of report recommendations may require statutory changes and a dedicated new funding source.

Not only are communities near refineries and other industrial facilities concerned about dangerous emissions from catastrophic events at refineries, there is now growing public concern about the risks from unpredictable and unquantified fugitive emissions during routine operations. Used in conjunction with an improved air monitoring network to assess possible trends in localized air quality impacts, implementing the recommendations in this report can help more accurately assess routine emissions from industrial sources.

As a consequence, demand has increased for advanced approaches like fenceline, optical remote sensing, and community air monitoring. Additionally, communities are beginning to explore deployment of low cost sensor networks that they can create, even as authorities are taking steps to evaluate this new class of monitors. Without proper evaluation and controls, these low cost sensors can cause problems of their own due to reliability, data quality, improper use, or misinterpretation of data. This report's recommendations place emphasis on funding timely evaluation and deployment of these and other emerging technologies.

[15] CalOSHA added new section 5189.1 in Chapter 4, Title 8 of the California Code of Regulations and Cal OES added new article 6.5 in Chapter 4.5, Title 19 of the California Code of Regulations, in August 2017.

This report acknowledges that implementing best practices does not imply a one-size-fits-all solution for refinery air monitoring. Recognizing the variability among refineries, implementation of each recommended strategy must be suited to each facility's size, operations, specific location, and its surrounding receptors, keeping in mind the practical limitations of current and emerging technologies and the timeframes necessary for full implementation.

Key details to be fleshed out in the next phase – best practices guidance development and implementation to enhance refinery air monitoring – include how to best present newly available monitoring data in a format the public can understand and utilize for self-protection. Other key elements to be addressed include:

- Targeted compounds
- Health effects and risk assessment
- Timing of monitoring technology application
- Siting considerations
- Data analysis
- Data retention

Implementing the recommendations in this report will provide response agencies and the public more timely and complete information on the air quality in communities near refineries during emergencies and routine operations. Properly implemented, these recommendations will strengthen the early detection and increased mitigation of adverse impacts to facility employees and nearby communities from unplanned refinery releases. While this report has focused on refineries, it may also serve as a framework for improving emergency response and air monitoring at other types of industrial facilities.

VII. LIST OF APPENDICES

A. Full text of AB 617 (Garcia, C.)

B. Interagency Refinery Task Force Agencies and Members

C. Project Plan Objective 2 Tasks, *Air Monitoring for Accidental Refinery Releases: Assessment of Existing Capabilities and Potential Improvements*

D. Concurrent Assessments and Regulatory Development Projects

E. CARB Comments on U.S. EPA Proposed Rule Incorporating Refinery Fenceline Monitoring

F. Technical References for Objective 2

G. Description of Key Agencies to Implement Report Recommendations

H. OEHHA *Analysis of Refinery Chemical Emissions and Health Effects,* September 2017

I. Descriptions of Open Path Monitoring Systems and Related References

J. Description of Richmond Community Monitoring Station Instrumentation

K. Summary of Air Dispersion Models