FEHR PEERS

Memorandum

Date: July 14, 2022

To: Ryan Kuchenig, Redwood City

From: Charlie Coles, Mike Wallace and Robert Eckols, Fehr & Peers
Dr. Stephen Wong, University of Alberta

Subject: Redwood City E. Bayshore Road Evacuation Assessment (Phase 2)

SJ21-2102

The City of Redwood City has requested that Fehr & Peers, Jensen Hughes, and Dr. Stephen Wong (collectively, the Project Team) prepare an evacuation assessment for the E. Bayshore Road and Bair Island Road areas (hereinafter referred to as the "evacuation area") located east of US 101 in Redwood City, California (see **Figure 1**). The City is evaluating development applications at 505 E. Bayshore Road and 557 E. Bayshore Road (hereinafter referred to as the "Projects") that will increase the population in the evacuation area. The City wants to better understand the proposed Projects' environmental effects related to evacuations given that there is currently a single point of vehicular access and egress at the Whipple Avenue interchange.

This evacuation assessment was divided into the following two phases:

- **Phase 1** guided the City through:
  - Identification and evaluation (i.e., likelihood and consequence) of the potential hazards considered to present a threat to the evacuation area.
  - Identification of emergency evacuation/people management strategy for relevant hazards (e.g., shelter in place, evacuate to upper floors, or evacuate immediately).
  - Documentation of evacuation time estimate (ETE)[1] benchmarks for relevant hazards and evaluation of the "30-minute" evacuation benchmark[2].
- **Phase 2** focused on the following efforts:

[1] An evacuation time estimate (ETE) is a metric that is used to identify the time it takes for a selected population to evacuate a hazardous area due to an emergency.
[2] A 30-minute benchmark is in reference to an assumption made in a previous environmental document approved by the City.

- Identification of evacuation scenario definitions to be evaluated.
- Identification of evacuation routes and transportation network capacity available during each evacuation scenario.
- Calculation of evacuation preparation and travel time estimates (last evacuee leaves the evacuation area) for each evacuation scenario.
- Development of potential strategies for the evacuation area that the City could consider to decrease evacuation preparation and travel time estimates.

The **Phase 1** deliverable, *Redwood City E. Bayshore Road Evacuation Assessment (Phase 1)*, was submitted to the City on February 24, 2022. This memorandum is the deliverable for **Phase 2** and provides the City with data related to the proposed Projects' effects on evacuations for inclusion in the Environmental Impact Report (EIR).

Disclaimer

This memorandum provides an assessment of roadway capacity and time needed to evacuate under the described evacuation scenarios. Evacuations can occur due to any number of events. Additionally, any emergency evacuation is unpredictable because it has an element of individual behavior related to personal risk assessment for each hazard event and the associated evacuation instructions provided. As such, this assessment is intended to provide the City with a broad understanding of the capacity of the transportation system during an evacuation scenario; it does not provide a guarantee that evacuations will follow modeling used for the assessment, nor does it guarantee that the findings are applicable to any or all situations.

Moreover, as evacuation assessment is an emerging field, there is no established standard methodology. The Project Team has adapted existing methodologies used in transportation planning that, in our knowledge and experience, we believe are the most appropriate. Nevertheless, such methodologies are necessarily limited by the tools and data available and by current knowledge and state of the practice.

While this assessment should help the City better prepare for hazard related events and associated evacuations in the evacuation area, the City should take care in planning and implementing any potential evacuation scenario. The Project Team cannot and does not guarantee the efficacy of any of the information used from this assessment as such would be beyond our professional duty and capability.

Emergency Evacuation Assessment

Assessing the capacity of the evacuation system can be completed in different ways, from identifying a theoretical hourly capacity of the roadways and comparing it to an expected traffic volume to a full simulation of the roadway network to assesses how traffic will redistribute to

alternative routes during an evacuation and identification of congested locations in the event of an evacuation. For this assessment, the Fehr & Peers' EVAC+ tool was utilized to evaluate the estimated travel time for eleven evacuation scenarios. The EVAC+ tool uses inputs from the Santa Clara Valley Transportation Authority - City/County Association of Governments of San Mateo County Bi-County Model (C/CAG-VTA Travel Model) for a typical day and modifies the travel demand and transportation network to represent evacuation conditions. After determining the evacuation travel demand and associated transportation network, a dynamic traffic assignment with 5-minute intervals is performed to reflect congestion and departure time to estimate evacuation travel times and evacuation time estimates (ETE).

Evacuation Scenarios and Evacuation Routes

There are a wide range of potential hazardous events that could cause the need for evacuation of the evacuation area. Many of these hazards are described and classified in the *Redwood City E. Bayshore Road Evacuation Assessment (Phase 1)* (February 24, 2022) memorandum, which determined that flooding (100-year storm/shoreline overtopping and severe weather), earthquakes (including tsunamis originating in the San Francisco Bay), post-earthquake fires, pipeline failure, and exterior combustible fires are potential risks to the evacuation area needing a people management strategy. Given the natural and physical characteristics of each hazard (e.g., speed of onset, impact to the physical environment, availability for early warning) as well as the potential risk to life safety and the built environment, the *Redwood City E. Bayshore Road Evacuation Assessment (Phase 1)* memorandum identified a preliminary emergency people management strategy for the relevant hazard types. Many hazards identify a shelter-in-place people management strategy as the first/default option, when feasible. This is because the Federal Emergency Management Agency (FEMA) suggests jurisdictions can benefit from considering shelter-in-place, when feasible, since *jurisdictions reduce costs, resource requirements, and negative impacts of evacuations, while promoting improved response and quicker re-entry (for those who spontaneously evacuate) and recovery* (FEMA, 2019).

To test the evacuation system through EVAC+, a set number of evacuation scenarios were defined for this assessment. **Table 1** summarizes the eleven evacuation scenarios developed with staff from the City's Community Development and Transportation Departments along with staff from the Fire Department. For this assessment, a generalized hazard requiring an immediate and rapid evacuation of the evacuation area was assumed. The hazard was assumed to occur either at 3:00 AM (i.e., midnight) or 6:00 PM (i.e., evening commute) to capture different populations and traffic conditions in the evacuation area. Scenarios 1-4 assumed an evacuation occurs at 3:00 AM to account for events when residents in the evacuation area would be at home. Scenarios 5-11 assumed an evacuation occurs at 6:00 PM to account for events when some residents, employees, and visitors would in the evacuation area, and background traffic from the evening commute period would be on the roadways. Baseline (Scenarios 1, 2, 3, 5, 6, and 7) conditions assumed year 2018 and Future (Scenarios 4, 8, 9, 10, and 11) conditions assumed a 2025 horizon year. Future

(2025) Without Projects and Future (2025) With Projects scenarios at 3:00 AM are presumed to be the same as Baseline (2018) Without Projects and Baseline (2018) Without Projects scenarios at 3:00 AM, respectively, since there would be no changes in background traffic along evacuation routes between 2018 to 2025 at 3:00 AM. Scenarios 3, 7, and 10 assume only the build-out of the proposed development at 505 E. Bayshore Road, excluding the 557 E. Bayshore Road development.

Figure 2 shows locations of the evacuation area, evacuation routes, evacuation zones, and proposed Projects in this evacuation assessment. For purposes of estimating evacuation travel times, City staff identified that people/animals should be considered evacuated once they have exited the evacuation area. All potential evacuation routes options (including pedestrian, bicycle, vehicular and waterway egress and options to temporarily provide additional capacity) were used as a starting point for engaging City staff in discussions about defining evacuation routes. Collaborative discussions with staff from the City's Community Development and Transportation Departments along with staff from the Fire Department refined the potential evacuation routes out of the evacuation area. The City's selected evacuation routes are shown in Figure 2, which represent a condition where everyone would need to evacuate the evacuation area by vehicle via evacuation routes #1, #2, and #3, and evacuation route #4 in scenarios that assumed the buildout of the proposed Blomquist Bridge Extension. The assumption that all evacuees would use a vehicle was used to denote a condition where the street network would be most congested. It should be noted that several evacuation routes for pedestrians and cyclists are available to evacuees from the evacuation area, enabling those without access to a vehicle to still evacuate.

The evacuation area was divided into four "evacuation zones" (A, B, C, and D). People living in each evacuation zone would behave differently during an evacuation based on the zone's land use (e.g., there may be more/less people in each zone depending on time of day) and the zone's geographic location and access to the available evacuation routes. Under a scenario with only one evacuation route all zones would use the single evacuation route. However, under a scenario with multiple evacuation routes, the trips from each zone will be distributed to the available routes based on proximity to each route.

Table 1: Evacuation Scenario Summary

Criteria	Scenario[1, 2]										
	1	2	3	4	5	6	7	8	9	10	11
Study Year	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)** With Blomquist Bridge	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)**	**Future (2025)**	**Future (2025)**	**Future (2025)** With Blomquist Bridge
Project Conditions[3]	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects	Without Projects	**With** Projects	**With 505 E Bayshore**	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects
Time of Day	3:00 AM	3:00 AM	3:00 AM	3:00 AM	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**

Notes:
1. Future (2025) Without Projects and Future (2025) With Projects scenarios at 3:00 AM are excluded from this table since they are presumed to be the same as Baseline (2018) Without Projects and Baseline (2018) Without Projects scenarios at 3:00 AM, respectively, since there would be no changes in background traffic along evacuation routes between 2018 to 2025 at 3:00 AM.
2. Day of Week (mid-week), Hazard Type (hazard), Hazard Response (immediate evacuation), Evacuation Area (entire area), and Mode Choice (auto only) assumed consistent for all scenarios.
3. "With Projects" Conditions includes the proposed developments at 505 E. Bayshore Road and 557 E. Bayshore Road.

Source: Fehr & Peers, 2022.

Evacuation Area

Figure 1

Redwood City E. Bayshore Road Evacuation Assessment - Evacuation Area Location

Evacuation Routes
Evacuation Area
Project Location

Evacuation Zones
A
B
C
D

Figure 2

Redwood City E. Bayshore Road Evacuation Assessment - Evacuation Zones and Evacuation Routes

Evacuation Vehicle Travel Demand

The number of residents, employees, and hotel guests, percent of occupancy by time of day (3:00 AM and 6:00 PM), and anticipated vehicle availability by land use in the evacuation area were used to estimate the total number of vehicles that would need to evacuate by scenario. **Table 2** and **Table 3** summarize the existing (2018) and future (2025) land use information for the evacuation area, respectively, and include the anticipated maximum number of people, percent occupancy by time of day (3:00 AM and 6:00 PM), and vehicle availability by land use. Vehicle accessibility was also reviewed to identify the number of households and unique land uses (such as hotels) in the area that would potentially have issues during an evacuation due to limited mobility options.

A condition was developed where all residents, employees, and visitors in the evacuation area would need to be evacuated according to the land use information in **Table 2** and **Table 3**. The trips assigned to the evacuation route network are estimated based on household and employer demographics (e.g., number of people per household, vehicles owned per household, and mode assumed to/from work). This assessment assumed that employment centers would provide evacuation assistance to employees without access to a vehicle and that some households with more than two vehicles would not utilize all their vehicles during an evacuation (e.g., homes with three or four vehicles but only two licensed drivers). This resulted in the estimated total vehicle trips needing to evacuate the area as shown in **Table 4**. These trips are used to estimate the amount of time needed to evacuate the area using a TransCAD dynamic traffic assignment model.

One component not addressed in the roadway capacity assessment is the evacuation of people who do not have access to a vehicle, such as people with mobility limitations, zero vehicle households, and visitors staying at the Courtyard by Marriott Redwood City (600 Bair Island Rd, Redwood City, CA 94063). While not specifically addressed in this assessment, it is a critical consideration for emergency response personnel to ensure that all persons are evacuated from the area. Further research into possible means of evacuating people who do not have access to a vehicle is recommended. Options for assisting with evacuation in such situations could include, but not be limited to, the following:

- Carpooling or shared mobility program in the evacuation area to link people needing assistance with people willing to assist;
- Coordination with SamTrans to provide public transit assistance;
- Coordination with local school districts to provide school bus assistance;
- Evacuation route signs for pedestrians and cyclists; and
- Increased coordination with emergency response personnel to assist with accessibility.

Table 2: Exiting (2018) Land Use Summary

Evacuation Zone	Name	Land Use	Size	Units	Max People		Occupancy		Vehicles Available[1]	
					Per Unit	Total	3:00 AM	6:00 PM	3:00 AM	6:00 PM
A	Toyota 101	Auto Dealer	41	ksf	2.50	103	0%	100%	1	1
	Alan Steel & Supply Co.	Light Industrial	28.25	ksf	2.22	63	0%	100%	1	1
	Boardwalk Chevrolet	Auto Dealer	23.85	ksf	2.50	60	0%	100%	1	1
	Vacant Movie Theater (auto dealer storage)	n/a	n/a	n/a	0.00	0	0%	0%	0	0
B	Boardwalk Auto Mall	Auto Dealer	54.29	ksf	2.50	136	0%	100%	1	1
	Bair Island Mini Storage	Mini Storage	62.8	ksf	2.22	140	0%	100%	1	1
	Bayport Plaza	Office	40	ksf	3.33	134	0%	75%	1	1
	Bayport Plaza	Light Industrial	45	ksf	2.22	100	0%	100%	1	1
	Marina Pointe	Townhomes	46	d.u.	2.73	126	100%	50%	2	2
C	One Marina Homes	Condominiums	231	d.u.	2.73	631	100%	50%	2	2
	Marriott Courtyard	Hotel (employees)	177	rooms	0.17	30	50%	100%	1	1
	Marriott Courtyard	Hotel (guests)	177	rooms	5	885	100%	50%	1	1
D	Bair Island Marina	Marina	95	slips	0.00	0	0%	0%	0	0
	The Villas	Apartments	155	d.u.	2.73	424	100%	50%	2	2
	Blu Harbor/Pete's Harbor	Apartments	402	d.u.	2.73	1,098	100%	50%	2	2
	Blu Harbor/Pete's Harbor	Marina	64	slips	0.00	0	0%	0%	1	1

Notes:

1. Vehicles Available for non-residential is per person/employee and for residential is per dwelling unit/rooms to account for sharing of rides between household members.
2. ksf = 1,000 square feet, d.u. = dwelling units, and slips = boat slips.

Source: Redwood City, 2022; Fehr & Peers, 2022.

Table 3: Future (2025) Land Use Summary

Evacuation Zone	Name	Land Use	Size	Units	Max People		Occupancy		Vehicles Available[1]	
					Per Unit	Total	3:00 AM	6:00 PM	3:00 AM	6:00 PM
A	Regis Homes[2]	Townhomes	56	d.u.	2.73	153	100%	50%	2	2
	Existing Alan Steel & Supply Co. to be removed[2]	Light Industrial	-28.25	ksf	2.22	-63	0%	100%	1	1
	Syufy Site/SyRes Properties[3]	Multifamily	480	d.u.	2.20	1,056	100%	50%	2	2
	Syufy Site/Villa Sport[3]	Fitness Center	97.1	ksf	1.16	113	0%	100%	1	1
	Vacant Movie Theater (auto dealer storage) to be removed[3]	n/a	n/a	n/a	0.00	0	0%	0%	0	0

Notes:

1. Vehicles Available for non-residential is per person/employee and for residential is per dwelling unit/rooms to account for sharing of rides between household members.
2. The 505 E. Bayshore Road project (i.e., Regis Homes) proposes to demolish the existing Alan Steel & Supply Co. on the site to construct 56 townhouses.
3. The 557 E. Bayshore Road project (i.e., Syufy Site) proposes to add a total of 480 multifamily residential units and a 151,423 square-foot (sf) fitness center (97,101 sf of indoor uses and 51,209 sf of outdoor uses).
4. ksf = 1,000 square feet, d.u. = dwelling units, and slips = boat slips.

Source: Redwood City, 2022; Fehr & Peers, 2022.

Table 4: Number of Vehicle Trips by Scenario

Criteria	Scenario[1, 2]										
	1	2	3	4	5	6	7	8	9	10	11
Study Year	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)**	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)**	**Future (2025)**	**Future (2025)**	**Future (2025)**
Project Conditions[3]	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects and Blomquist Bridge	Without Projects	**With** Projects	**With 505 E Bayshore**	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects and Blomquist Bridge
Time of Day	3:00 AM	3:00 AM	3:00 AM	3:00 AM	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**
Total Vehicle Trips	1,860	2,932	1,972	2,932	1,656	2,242	1,649	1,656	2,242	1,649	2,242
Evacuation Zone A	*0*	*1,072*	*112*	*1,072*	*226*	*812*	*219*	*226*	*812*	*219*	*812*
Evacuation Zone B	*92*	*92*	*92*	*92*	*523*	*523*	*523*	*523*	*523*	*523*	*523*
Evacuation Zone C	*654*	*654*	*654*	*654*	*350*	*350*	*350*	*350*	*350*	*350*	*350*
Evacuation Zone D	*1,114*	*1,114*	*1,114*	*1,114*	*557*	*557*	*557*	*557*	*557*	*557*	*557*

Notes: Total vehicle trips per evacuation zone = units x people per unit x occupancy by time of day / people per vehicle.

1. Future (2025) Without Projects and Future (2025) With Projects scenarios at 3:00 AM are excluded from this table since they are presumed to be the same as Baseline (2018) Without Projects and Baseline (2018) Without Projects scenarios at 3:00 AM, respectively, since there would be no changes in background traffic along evacuation routes between 2018 to 2025 at 3:00 AM.
2. Day of Week (mid-week), Hazard Type (hazard), Hazard Response (immediate evacuation), Evacuation Area (entire area), and Mode Choice (auto only) assumed consistent for all scenarios.
3. "With Projects" Conditions includes the proposed developments at 505 E. Bayshore Road and 557 E. Bayshore Road.

Source: Fehr & Peers, 2022.

Background Traffic

Background traffic is associated with trips traveling on surrounding roadways that serve the evacuation area (i.e., utilizing the interchange or local streets south of US 101). Background traffic may interfere with the evacuation process and cause additional congestion and delay. The background traffic volumes were taken directly from the C/CAG-VTA Travel Model for a typical weekday. The daily traffic is distributed over each hour of the day and refined by 5-minute intervals for the dynamic assignment model. Background traffic is only present for the 6:00 PM condition since the C/CAG-VTA Travel Model does not sperate the late night into the 3:00 AM period and the volumes at this hour of the day are well below the capacity of the roadways.

Evacuation Departure Time

The departure time when leaving the evacuation zones varies by many factors including, but not limited to, the time of day, type of hazardous event, perceptions of risk, and relative preparedness of evacuees. For situations where ample notice is given or the family unit is already together, less time is needed to prepare for the evacuation. On the other hand, where there is minimal notice given or when the family unit is not together, the time required to prepare for an evacuation is typically longer as residents need to pack belongings, collect their animals, and conduct other coordination activities before beginning their evacuation trip.

With different evacuation starting times for evacuees, the impact of the evacuation trips on the roadway network will be dispersed. For the evacuation scenario testing, all scenarios assume a minimum of 10-minutes of preparation time, which represents the time from receiving an evacuation order to the time evacuees begin their trip to leave the evacuation area.

Evacuation Time Distribution

The evacuation time distribution is the anticipated rate at which evacuees would vacate and begin their travel on the evacuation routes. The evacuation time distributions by scenario are shown in **Table 5**. Emergency evacuation scenarios are often unpredictable and driver behavior can be disorderly. In addition, evacuation trips are not evenly distributed during the evacuation period; therefore, it is anticipated that evacuees would depart at a rate that resembles a bell curve from the time that the evacuation order is issued until the evacuation is complete (as shown in Table 5).

This is consistent with other research on short-notice evacuations as documented in the *Approach to Modeling Demand and Supply for a Short-Notice Evacuation* (Noh, Chiu, Zheng, Hickman, and Mirchandani, Transportation Research Record 2091) and the *Florida Statewide Hurricane Evacuation Model / TIME* (Roberto Miguel, AICP, December 9, 2015) presentation (although that distribution was for a much longer time period due to advanced warnings of hurricanes). Research by Zhou and Wong (2021) identified that most simulations for wildfire evacuations use a distribution for departure time. Examples include an S-shaped curve for cumulative departures (Chen et al., 2020) and a Poisson distribution (Cova and Johnson, 2002). Empirical data from

California wildfires found that departure times were not evenly distributed across days and departure timing within a day was different between varying wildfire contexts (Wong et al., 2022).

Table 5: Evacuation Time Distribution Assumptions

Time Interval (minutes)	Percent Evacuating in 30-minutes
0-4	0%
5-9	0%
10-14	20%
15-19	30%
20-24	30%
25-29	20%

Source: Fehr & Peers, 2022.

Evacuation Route Assignment

The EVAC+ tool relies on the City's Traffic Analysis Zones (TAZs) and existing roadway network extracted from the C/CAG-VTA Travel Model. Since the evacuation area is represented by only one TAZ, additional refinements to the roadway network and TAZs within the evacuation area were made to separate trips associated with each of the four evacuation zones (A through D). The tool references the model's trip tables for roadways outside of the evacuation area to estimate "background" traffic generated by land uses not affected during an evacuation (i.e., trips traveling on US 101, or the Whipple Avenue interchange). Areas affected by the evacuation are processed through the EVAC+ tool trip estimator to estimate the number and sequencing of trips that occur due to the evacuation.

The sub-area extracted network and trip tables are used as inputs into a Dynamic Traffic Assignment (DTA) model. A DTA model estimates traffic and level of congestion on 5-minute intervals. As link congestion builds (i.e., roads fill with cars), it dynamically reassigns traffic to less congested routes. While it is not guaranteed that all evacuating vehicles would choose the least congested route, the DTA methodology is a reasonable assumption in such a small evacuation area and given broad use of GPS routing technology when driving. Moreover, DTA is a more accurate way of estimating trip assignment and identifying congested locations on the network than selecting a single location that may be the bottleneck during an evacuation. The model assessment may identify multiple locations that impact the flow of traffic during an evacuation.

Since there is only one vehicle route serving the evacuation area in Scenarios 1, 2, 3, 5, 6, 7, 8, 9, and 10, the trip assignments for all four evacuation zones (A-D) are the same, as shown below:

- Route #1 – US 101 North 34%
- Route #2 – Whipple Road 33%
- Route #3 – US 101 South 33%
- Route #4 – Proposed Blomquist Bridge Extension 0%

With the introduction of the proposed Blomquist Bridge Extension as a second evacuation route in Scenarios 4 and 11, the percent of trips assigned to each evacuation route are different for each evacuation zone as shown in **Table 6**. The differences in the assignments reflect each zones proximity and accessibility to the evacuation routes. A behavioral assumption is made that the evacuees will generally distribute themselves among the routes in this manner.

Table 6: Evacuation Route Assignment

Evacuation Zone	Evacuation Route	Scenarios without Blomquist Bridge Extension	3:00 AM Scenarios with Blomquist Bridge Extension	6:00 PM Scenarios with Blomquist Bridge Extension
A	Route #1 (101 North)	34%	34%	34%
	Route #2 (Whipple)	33%	33%	33%
	Route #3 (101 South)	33%	33%	33%
	Route #4 (Blomquist Bridge Extension)	0%	0%	0%
B	Route #1 (101 North)	34%	17%	26%
	Route #2 (Whipple)	33%	16.5%	24.75%
	Route #3 (101 South)	33%	16.5%	24.75%
	Route #4 (Blomquist Bridge Extension)	0%	50%	25%
C	Route #1 (101 North)	34%	17%	26%
	Route #2 (Whipple)	33%	16.5%	24.75%
	Route #3 (101 South)	33%	16.5%	24.75%
	Route #4 (Blomquist Bridge Extension)	0%	50%	25%
D	Route #1 (101 North)	34%	0%	0%
	Route #2 (Whipple)	33%	0%	0%
	Route #3 (101 South)	33%	0%	0%
	Route #4 (Blomquist Bridge Extension)	0%	100%	100%

Source: Fehr & Peers, 2022.

Evacuation Preparation and Travel Time Estimates

As described earlier, an evacuation time estimate (ETE) is a metric that is defined as the estimated time necessary to safely evacuate all evacuees, from the time when a hazard is first identified until the time when either the last evacuee leaves the evacuation area or the remaining population is forced to shelter-in-place. The determination of whether it is the last evacuee or forced shelter-in-place is made by emergency response personnel and is hazard specific and considers factors, such as the type of hazard or threat, level of notice, population characteristics of the area at the time of the hazardous event, and evacuee behavior. There are several phases of an ETE described below:

- Hazard Detection: Time when hazard is first identified.

- Hazard Notification to the Public: Time when any official releases an evacuation order to the public.
- Evacuation Order Received: Time when people receive the evacuation order.
- Preparation: Time it takes to prepare to depart after receiving evacuation order.
- Travel Time: The total elapsed time until all vehicles are out of the evacuation area including time driving (moving) and delay due to congestion. The calculated travel time does not account for unexpected complications or incidents on the roadways during the evacuation.

It should be noted that some phases may not occur. For example, research on California wildfire evacuations found that some people evacuated their home prior to receiving an evacuation order (Wong et al. 2020). This can result from a variety of events including: failure of officials to identify the hazard, slow response in sending evacuation orders, damaged or non-functional communication networks, and/or a sufficiently high perceived threat of the hazard from residents. This assessment assumed that City officials and emergency response personnel will be able to send out informed evacuation orders in a timely manner.

The EVAC+ tool calculated the evacuation preparation and travel time estimates (last evacuee leaves the evacuation area) after an evacuation order was received by the public. The evacuation preparation and travel time estimates do not account for time it takes for a hazard to be identified (i.e., hazard detection) or the amount of time it takes for the official release of an evacuation order to the public (i.e., hazard notification to the public). **Table 7** summarizes the evacuation preparation and travel time estimates (last vehicle out) for each of the evacuation scenarios included in this assessment.

Table 7: Evacuation Scenario Summary and Results

Criteria	Scenario[1, 2]										
	1	2	3	4	5	6	7	8	9	10	11
Study Year	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)**	Baseline (2018)	Baseline (2018)	Baseline (2018)	**Future (2025)**	**Future (2025)**	**Future (2025)**	**Future (2025)**
Project Conditions[3]	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects And Blomquist Bridge	Without Projects	**With** Projects	**With 505 E Bayshore**	Without Projects	**With** Projects	**With 505 E Bayshore**	**With** Projects and Blomquist Bridge
Time of Day	3:00 AM	3:00 AM	3:00 AM	3:00 AM	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**	**6:00 PM**
Total Vehicle Trips	1,860	2,932	1,972	2,932	1,656	2,242	1,649	1,656	2,242	1,649	2,242
Evacuation Zone A	*0*	*1,072*	*112*	*1,072*	*226*	*812*	*219*	*226*	*812*	*219*	*812*
Evacuation Zone B	*92*	*92*	*92*	*92*	*523*	*523*	*523*	*523*	*523*	*523*	*523*
Evacuation Zone C	*654*	*654*	*654*	*654*	*350*	*350*	*350*	*350*	*350*	*350*	*350*
Evacuation Zone D	*1,114*	*1,114*	*1114*	*1,114*	*557*	*557*	*557*	*557*	*557*	*557*	*557*
Evacuation Preparation and Travel Time Estimate (minutes)[4]	90-95	110-115	90-95	105-110	120-125	150-155	120-125	150-155	170-175	150-155	125-130

Notes:
1. Future (2025) Without Projects and Future (2025) With Projects scenarios at 3:00 AM are excluded from this table since they are presumed to be the same as Baseline (2018) Without Projects and Baseline (2018) Without Projects scenarios at 3:00 AM, respectively, since there would be no changes in background traffic along evacuation routes between 2018 to 2025 at 3:00 AM.
2. Day of Week (mid-week), Hazard Type (hazard), Hazard Response (immediate evacuation), Evacuation Area (entire area), and Mode Choice (auto only) assumed consistent for all scenarios.
3. "With Projects" Conditions includes the proposed developments at 505 E. Bayshore Road and 557 E. Bayshore Road.
4. Dynamic Traffic Assignment (DTA) model estimates traffic and level of congestion on 5-minute intervals.

Source: Fehr & Peers, 2022.

Key Takeaways

The following key takeaways were developed based on observations of the EVAC+ model scenarios, comparison of data in each scenario, and resulting evacuation preparation and travel time estimates shown in **Table 7**:

- Congestion forms along primary evacuation route in all scenarios and also in existing parking areas due to design factors (narrow roadways and drive aisles) and density of existing land uses.
- Limited background traffic in the AM as compared to PM scenarios; however, there are more trips to evacuate during the AM when everyone is home.
- ETEs increase in "With Projects" scenarios with only one primary evacuation route along E. Bayshore Road.
    - Projects' trips are the first out due to location near the Whipple Avenue interchange (Zone A).
    - Projects' trips create queues early in the evacuation and upstream congestion for other evacuation zones (Zones B, C, & D).
- Proposed development Projects at 505 and 557 E. Bayshore would increase evacuation area ETEs by approximately 20 to 30 minutes depending on the scenario.
- ETE results for "With 505 E. Bayshore" scenarios are within the same 5-minute range as the "Without Projects" range under the same study year and time of day conditions.
- Proposed Blomquist Bridge Extension improves ETEs by providing an alternative route. The greatest improvement occurs during the PM scenarios when evacuees can avoid the congestion caused by background traffic at the Whipple interchange.
- Magnitude of the benefit from the Blomquist Bridge Extension depends on time of day, background traffic, and where evacuation trips are generated (e.g., existing residential in Zone D).

Strategies to Reduce Evacuation Time Estimates

Several strategies are available to decrease preparation and travel times. These strategies can be divided between demand-side, supply-side, and communication/information strategies. For informational purposes, **Table 8** presents commonly used strategies, which was adapted from Lindell et al. (2019) and Wong (2020), and an order-of-magnitude feasibility rating specific for the evacuation area. Other literature, including Lindell and Prater (2007), and Pel et al. (2010), Li et al. (2019), Herrera et al. (2019), and Zhao and Wong (2021), helped inform this table.

In addition to these response strategies, infrastructure changes such as roadway widenings to eliminate bottlenecks may be beneficial in reducing evacuation times. However, due to the cost of

construction and sustainability issues that could arise, this option is generally not recommended. In lieu of roadway expansion, jurisdictions could also consider flexible infrastructure (as noted in several supply-side strategies) that temporarily increase roadway capacity during an evacuation.

The following strategies to reduce ETEs are informed by the emergency evacuation assessment summarized above and are applicable to most of the evacuations that were investigated.

Table 8: Strategies to Reduce ETEs

Strategies	Description	Applicability
Demand-Side		
Timely departures	Encouraging residents to evacuate in a timely manner to reduce last-minute evacuation or rapid loading of the road network	High: Quicker and clearer evacuation orders across communication methods and formats (e.g., languages, visual, audio) can increase timely departures. Training for residents in the area and assistance in creating go-bags could also be used.
Phased evacuation	Issuing mandatory evacuation orders and releasing evacuees by pre-designated zone to reduce rapid loading of the road network	Low: The evacuation area cannot be divided easily into manageable zones, per information from Redwood City.
Triggered evacuations	Issuing mandatory evacuation orders based on characteristics of the hazard, such as wildfire spread characteristics	Low: Wildfires are an unlikely threat to the evacuation area. Triggered evacuations are generally not applicable for the evacuation area.
Vehicle reduction	Encouraging residents to take only one or two vehicles (based on household size) to reduce the number of evacuating vehicles	Moderate: Vehicle reduction would significantly reduce ETEs. However, challenges would exist in convincing residents to conduct evacuations without all their vehicles. Training and education may be needed. If a household decides to take all vehicles, they should also be encouraged to give a ride to someone without a vehicle.
Supply-Side		
Contraflow	Switching all or some lanes of a highway or other road to flow away from the hazard to increase roadway capacity	Low: Depending on the hazard, both lanes of E. Bayshore Road could lead away from the hazard. However, contraflow requires significant resources and takes time to set up (perhaps as long as the evacuation). Emergency vehicles would need an alternative method to enter the hazard area.

Table 8: Strategies to Reduce ETEs

Strategies	Description	Applicability
Shoulder usage	Allowing vehicles to drive on the side of a road (typically a highway) to increase roadway capacity	High: Parking along Bayshore is already restricted in most conditions. A second lane could be created to increase the roadway capacity. However, personnel and/or signage will be necessary for residents to know that they should use the shoulder.
Ramp closures	Closing ramps to highways to reduce bottlenecks and improve travel speeds of vehicles on the highway	High: Ramps exiting onto Whipple Avenue could be closed by police or Caltrans. This would reduce the number of vehicles entering or traveling near the evacuation area (i.e., reduce background traffic).
Route closures	Closing routes to reduce vehicle movements into the hazardous area or reduce conflict with non-evacuees (e.g., freight)	High: Routes toward US 101 from the center of Redwood City could be closed to reduce background traffic. Only evacuating and emergency vehicles would occupy roadways in the Whipple Ave interchange area.
Turn restrictions	Restricting turning at an intersection to increase flow through the intersection or prioritize evacuating vehicles	Moderate: While turn restrictions are not necessary for this situation, lane changing could be restricted such that the shoulder lane evacuates onto US 101 North, and the typical travel lane evacuates onto Whipple Avenue and/or US 101 South. Officials will be needed to restrict lane changing.
Signal priority	Setting traffic signals to prioritize certain traffic movements to increase flow through the intersection or prioritize evacuating vehicles	High: Both traffic signals for the Whipple Avenue interchange could prioritize traffic moving away from the evacuation area. An operator may be necessary to change the signal patterns at the traffic light.
Manual traffic control	Controlling the flow of traffic through an intersection manually to increase flow through the intersection or prioritize evacuating vehicles	High: Officials could direct traffic through the Whipple Avenue interchange to increase flow.
Public transit	Using high-capacity public transit vehicles to reduce the use of single-occupancy vehicles and increase the number of evacuees	Moderate: Since there is limited access to the evacuation area, public transit buses that are only in the vicinity should be rerouted to assist carless individuals. A plan would need to be in place to contact SamTrans and nearby bus drivers. Public transit also provides an equitable option for carless individuals.

Table 8: Strategies to Reduce ETEs

Strategies	Description	Applicability
Mode shift	Identifying faster and more efficient means of evacuating large populations of people (context and geography dependent), such as carpooling, shared mobility, cycling, or walking	Moderate: The evacuation area has several routes for pedestrians and cycling. Able-bodied and carless individuals could use these routes. Carpooling and shared mobility could be effective for able-bodied and non-able-bodied individuals, especially for vehicles that have extra capacity. A program would need to be developed ahead of time to connect providers and users of shared mobility.
Parking restrictions	Restricting parking periodically or permanently along roadways to reduce pinch points and increase flow of vehicles	High: Parking appears already restricted on E. Bayshore Road. Other restrictions at key pinch points and along evacuation routes within the development could be conducted permanently or temporarily.
Information-Side		
Rapid information delivery	Reducing the notification time between hazard detection and the issuance of mandatory evacuation orders by obtaining and transmitting information quickly and making informed, quick decisions	Moderate: While hazard identification and notification could be faster, some communication methods are naturally slower (e.g., reverse 911) or people may not check communication methods regularly. City officials may need to use wireless emergency alerts, social media, and even sirens to alert the public quickly.
Evacuation preparation	Encouraging residents to prepare for an evacuation, such as making a household evacuation plan or making a go-bag with essential documents and emergency supplies	High: Training and education of residents and businesses would enable faster evacuation preparation and lower ETEs.
Route preparation	Presenting possible route options for evacuees in advance of disasters through educational campaigns or physical infrastructure (e.g., evacuation signs)	High: Evacuation signs could be used for shoulder usage and walking/cycling routes out of the evacuation area. Consistent viewing of these signs would also familiarize residents and customers with the risks in the area.
Dynamic route guidance	Providing evacuees with guidance on safe and efficient routes along with dynamic rerouting information to decrease travel times and reduce congestion on highly-traveled roads (can include GPS-routing systems)	Low: Due to the small size of the evacuation area and limited evacuation routes, dynamic route guidance would not be an effective strategy to reduce ETEs in this case.
System monitoring	Monitoring traffic using intelligent transportation system (ITS) technology to identify accidents and problem areas, determine the effectiveness of responses, and change responses as needed	Moderate: Drone technology could assist in identifying problems during the evacuation. Cameras in the area (especially Whipple Avenue) interchange could provide real-time feeds.

Table 8: Strategies to Reduce ETEs

Strategies	Description	Applicability
Travel information	Communicating traffic and service information to evacuees before and during the evacuation to convey shelter locations, alternate evacuation routes, congestion alerts, and location of services	High: Training and education could empower residents and customers to prepare for an evacuation.

Source: Lindell et al., 2019; FEMA, 2019; Wong 2020; Zhao and Wong, 2021; Dr. Wong, 2022; Fehr & Peers, 2022.

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