DKS Associates
TRANSPORTATION SOLUTIONS

MEMORANDUM

TO:	Hisham Noemi – CCTA
FROM:	Terry Klim
DATE:	August 9, 2004
SUBJECT:	I-680 HOV Lane Extension Freeway Operational Analysis – Revised

P/A No. 02214-000x006

INTRODUCTION

The purpose of the I-680 Investment Options Analysis Study is to identify a set of well-defined projects that can be implemented to improve the transportation system in the I-680 corridor between Walnut Creek and Dublin/Pleasanton. The ultimate goal is to identify specific projects that may be considered for inclusion in the Measure C Reauthorization Expenditure Plan. The study represents a cooperative effort between the Contra Costa Transportation Authority (CCTA), Caltrans, the County of Contra Costa, and several cities within the Southwest and Central County areas, including Danville, San Ramon, and Walnut Creek. Study guidance and direction was provided by a Technical Advisory Committee (TAC) and Policy Advisory Committee (PAC).

A final report has been completed and accepted by the TAC and PAC. A recommended investment option for this corridor, as identified in the final report, included the extension of the existing HOV lanes through the Highway 24/I-680 Interchange. Subsequent to completion and acceptance of the report, additional work related to the proposed extension was requested. This work included the development of scaled striping plans for the proposed southbound (SB) and northbound (NB) HOV lane extensions, and an operational analysis of these extensions. The purpose of this memorandum is to summarize the operational analysis.

ANALYSIS METHODOLOGY

This analysis was conducted for the 2015 horizon year using the FREQ freeway simulation model developed previously for the *Central, East and Southwest Arterial and Freeway Ramp Metering Study*. These models were developed using 2015 forecasts from the CCTA 1997 CMP travel demand model, and assumed HOV percentages of 10% for both the AM and PM peaks in the northbound direction, versus 15% and 17% for southbound AM and PM respectively. Before applying this model, both the demand forecasts and network geometrics were re-visited. In consultation with representatives from various local jurisdictions, a ramp-by-ramp assessment of the demand forecasts was conducted. Recent traffic volumes counts and expected future growth were used to update the model's demand forecasts. Network geometrics were updated to reflect actual current configurations and improvements currently under construction.

The operational analysis was conducted for both the AM (6 to 11) and PM (3 to 9) peak periods. For the southbound direction, three scenarios were analyzed: No Build, Re-Striping Only, and Build. In the northbound direction, two scenarios were analyzed: No Build and Build.

Southbound Scenarios

No Build

The following improvements were assumed as part of the No Build base network for 2015:

- North county HOV lane – new HOV lane from Benicia-Martinez Bridge to N. Main off-ramp (currently under construction)
- San Ramon Valley auxiliary lanes – new auxiliary lanes between interchanges from Diablo Road in Danville to Bollinger Canyon Road in San Ramon

These improvements were included in all three southbound scenarios. Figure 1 at the end of this memo illustrates the assumed 2015 No Build lane striping for the southbound direction.

"Re-Striping Only" Scenario

In this scenario, it was assumed that the HOV lanes to the north (Benicia-Martinez bridge to N. Main) and to the south (Livorna to Alameda County line) would be connected by converting the existing inside (left) general-purpose lane into an HOV lane between N. Main and Livorna. Through Walnut Creek, the physical structure of the freeway would not change, but the inside lane would be re-striped as an HOV lane. Just north of the Livorna off-ramp, realignment of the lanes will be required because the current configuration has a lane drop at the off-ramp and a lane addition at the beginning of the existing HOV lane. Under this scenario, a cross-section of three general-purpose lanes and one HOV lane will be maintained approaching and departing the Livorna off-ramp. The lane diagram for this scenario is presented in Figure 2 at the end of this memo.

This scenario was used as base for identifying potential bottlenecks and candidate locations for addition of new auxiliary lanes as part of the Build Scenario.

Build Scenario

The Build Scenario involves a combination of extending the HOV lane and constructing new general-purpose auxiliary lanes in select locations. The general approach was to re-stripe the inside (left) lane as an HOV lane, and add new outside lanes on the following segments:

- Between the current lane drop south of Highway 24 off-ramp and the Ygnacio Valley on-ramp (i.e., eliminate the current lane drop);
- Between the Ygnacio Valley Rd on-ramp and the Olympic off-ramp (i.e., add a new auxiliary lane); and
- Between the Rudgear on ramp to Livorna off-ramp (i.e., add a new auxiliary lane).

The lane diagram for the 2015 Build Scenario is presented in Figure 3 at the end of this memo.

Northbound Scenarios

No Build

The following improvements were assumed as part of the No Build base network for 2015:

- San Ramon auxiliary lanes – new auxiliary lanes between interchanges from Bollinger Canyon Road in San Ramon to Diablo Road in Danville.
- North county HOV lane – new HOV lane from just north of the SR 242 junction to the Benicia-Martinez Bridge (currently under construction)

These improvements were also assumed in the Build Scenario. The assumed 2015 No Build lane diagram for the northbound direction is illustrated in Figure 1.

Build

Under the Build Scenario, a new HOV lane would be added starting at the Livorna on-ramp to just south of the N. Main off-ramp. This would require a new structure for northbound HOV traffic only through the Highway 24 interchange. Between the Highway 24 on-ramp and the N. Main Street off-ramp, the HOV lane would convert to a general-purpose lane, and the outside general purpose lane would be dropped to maintain the five-lane cross-section at N. Main. This scenario does not assume the continuation of the HOV lane between N. Main and SR242. The lane diagram for the 2015 Build Scenario is presented in Figure 3 at the end of this memo.

Measures-of-Effectiveness

For the comparison of scenarios in each direction, two measures-of-effectiveness (MOEs) are reported: total vehicle hours of delay and average corridor travel time. These MOEs are described in more detail below:

- *Vehicle hours of delay* – This MOE reflects the additional vehicle hours of travel (VHT) in the corridor for all vehicles that occur under congested conditions above that for the same vehicle miles of travel (VMT) but at free flow speeds. FREQ generates total VHT and VMT. In simple terms, delay was determined by first calculating the number of vehicle hours it would take to travel the reported VMT assuming a free flow speed of 65 mph. These hours of "undelayed travel time" were then subtracted from the total VHT to get the hours of delay. For some scenarios, delay was calculated by looking at the speed for each individual link. When the speed was less than free-flow, the delay was calculated by comparing the travel time for the actual speed minus the free-flow travel time. Link delay was determined by multiplying by volume. In turn, total delay was calculated by summing the link delays for all time slices within the peak period.
- *SOV/HOV travel time* – This MOE represents the average time to travel I-680 from the Benicia Martinez Bridge to the Alameda County line over entire peak period. Travel time was computed by using the output speed to determine the travel time for each link, then summing the link travel times within each 15-minute time slice. The peak period travel time was then calculated by averaging the travel times for the individual time slices. For SOV travel times, link speeds for non-priority lanes were used. For HOV

travel times, link speeds for the priority lanes were used where applicable. For segments where no HOV lane was present, HOV travel times were based on the non-priority lane speeds.

In addition to these MOEs, the congestion or queuing diagrams for each scenario and time period have been incorporated into this analysis. The diagrams are generated directly by FREQ and illustrate bottleneck locations, expected queues, and segments near capacity within the mixed-flow lanes on the freeway mainline. This analysis was limited to the MOEs described above in part to help focus the presentation of results, but also because FREQ is limited in the range of outputs it can generate. For example, FREQ provides outputs based on lane type (i.e. HOV lane versus mixed-flow lane), but does not generate outputs based on mode (i.e. HOV versus SOV). If further analysis of the HOV lane extensions described in this memo is conducted, it may be appropriate to use tools or methods beyond FREQ to generate additional MOEs.

It should be noted that for scenarios involving two, discontinuous HOV segments (e.g. southbound No Build, and both northbound scenarios), it was necessary to combine outputs from two FREQ model networks. This is because FREQ does not allow for the modeling of multiple HOV segments within the same network. Thus, for these scenarios, the reported results are derived by using the link outputs (i.e. volume, travel time, speed) for some links from one network, and for the remaining links from the second network. The exact cut-off point between the two networks varied by scenario and was a function of several factors including the location of HOV lanes and bottleneck queues.

ANALYSIS RESULTS

This section provides a summary of the operational analysis results by direction for the proposed HOV lane extensions. The results are presented in the form of a set of mainline congestion/queue diagrams and summary statistics. The congestion/queue diagrams are generated directly by FREQ and illustrate bottleneck locations, expected queues, and segments near capacity within the mixed-flow lanes on the freeway mainline (see Figure 4 for key). The summary performance measures reported include forecasted total freeway delay and corridor (end-to-end) travel time.

Southbound Results Summary

Figure 5a and Figure 5b provide the southbound freeway congestion/queue diagrams for each scenario (No Build, Re-Striping Only, and Build) described in the previous section and for the AM and PM peak periods respectively. The southbound delay and travel time statistics for each scenario are summarized in Table 1 (AM peak) and Table 2 (PM peak).

For the AM peak period, under the “No Build” Scenario, the primary bottleneck occurs at the Livorna on-ramp, with a queue forecast to extend back as far as Treat Blvd. Because most of this queue length covers the segment without an HOV lane, HOVs would be subject to much of the delay caused by this bottleneck.

With the “Re-Striping Only” Scenario, a new bottleneck at the SR 24 lane drop is exposed. This bottleneck or constraint, in turn, reduces the flow to and queuing generated by the Livorna bottleneck. With the extension of the HOV lane to create a continuous lane through the study area, HOVs would not be subject to the delays caused by either bottleneck. Thus, corridor travel time for HOVs would decrease significantly from 37 minutes to 26 minutes. However, there would be a slight increase (39 to 41 minutes) in Single Occupant Vehicle (SOV) travel time, and an increase in total vehicle hours of delay. Overall delay would increase from 7,500 to 10,250 vehicle-hours.

Under the "Build" Scenario, the addition of selected auxiliary lanes reduces the congestion on I-680 at the SR 24 lane drop, but the increased flow through this location leads again to higher flows and greater queuing at the downstream bottleneck. The queue in the Build Scenario is slightly longer than that forecast for No Build. However, it is important to note that this is in part a result of the reduction in available storage with the conversion of one mixed-flow lane to HOV only. Compared to No Build, total delay and SOV travel times would experience very little change, while HOV travel times would improve significantly.

Table 1 – I-680 HOV Lane Extension Operational Analysis
Summary Statistics – 2015 Southbound (AM Peak) Period

Scenario	Total Vehicle Hours of Travel	Total Undelayed Hours of Travel[2]	Total Delay (vehicle-hours)	HOV Travel Time[1] (minutes)	SOV Travel Time[1] (minutes)
No Build	21000	13500	7500	37	39
Re-Stripe Only	23600	13350	10250	26	41
Build	21400	13500	7900	26	39

Note:
1. Average end-to-end corridor travel time from the Benicia-Martinez Bridge to the Alameda County line over entire peak period.
2. Expected travel time in the network at free flow speed. Total travel time is the sum of the delay plus unconstrained travel time.

Source: DKS Associates 2003

A similar pattern is forecast in the PM peak. In this case, there are two primary overlapping bottlenecks in the "No Build" Scenario at the Livorna and Stone Valley on-ramps, with the queue extending back to Marina Vista. Under the "Re-Striping" Scenario, upstream bottlenecks are created with the queues overlapping and extending beyond Marina Vista. The addition of new auxiliary lanes in the "Build" Scenario helps address some of these new queues, but the major bottlenecks at Livorna and Stone Valley remain, with the queue still extending past the Marina Vista exit. This slightly longer queue, compared to "No Build", is in part a result of a reduction in available storage with the conversion of one mixed-flow lane to HOV only. Under both the "Re-Striping" and "Build" Scenarios, the extension of the HOV lane to create a continuous lane through the study area would provide a significant benefit to HOVs, with corridor travel time decreasing from 48 to 27 minutes. Under the "Build" Scenario, the benefits to HOVs offset any disbenefits to SOVs, resulting in a negligible change in the overall vehicle hours of delay for vehicles. It should be noted, however, that the person-delay will be lower in the "Build" scenario, as delay for HOVs is reduced.

Table 2 – I-680 HOV Lane Extension Operational Analysis
Summary Statistics – 2015 Southbound (PM Peak) Period

Scenario	Total Vehicle Hours of Travel	Total Undelayed Hours of Travel[2]	Total Delay (vehicle-hours)	HOV Travel Time[1] (minutes)	SOV Travel Time[1] (minutes)
No Build	38000	15530	22470	48	64
Re-Stripe Only[3]	36900	15180	21720	27	73
Build	37800	15480	22320	27	70

Note:
1. Average end-to-end corridor travel time from the Benicia-Martinez Bridge to the Alameda County line over entire peak period.
2. Expected travel time in the network at free flow speed. Total travel time is the sum of the delay plus unconstrained travel time.
3. The lower VHT and delay for this scenario is due in part to the greater level of congestion or queuing still present at the end of the analysis period. In other words, more vehicles remain on the freeway and thus their complete travel time and delay is not fully captured in the reported statistics.

Source: DKS Associates 2003

Northbound Results Summary

For the northbound direction, the freeway congestion/queue diagrams for each scenario are presented in Figures 6a and 6b for the AM and PM peak periods, respectively. Delay and travel time statistics are summarized in Tables 3 and4. In the northbound direction, the forecasted bottlenecks and queues were found in Danville and Pleasant Hill/Concord on segments where HOV lanes exist or are currently being constructed. As such, extension of the HOV lane through the Highway 24 interchange would not help HOVs bypass any forecasted congestion. Similarly, because the proposed extension of the northbound HOV lane involves the net addition of the HOV lane with no mixed-flow lane reduction, no new bottlenecks or congestion in the mixed-flow lanes is created. Through the area of the proposed extension, all lanes under both the “No Build” and “Build” Scenarios are forecast to operate above congested speeds. This situation is reflected in the similarity of the congestion/queue diagrams for the two scenarios and the absence of any significant change in the delay or travel time statistics.

Table 3 – I-680 HOV Lane Extension Operational Analysis
Summary Statistics – 2015 Northbound (AM Peak)

Scenario	Total Vehicle Hours of Travel	Total Undelayed Hours of Travel[2]	Total Delay (vehicle-hours)	HOV Travel Time[1] (minutes)	SOV Travel Time[1] (minutes)
No Build	11360	10100	1260	24	26
Build	11320	10110	1210	24	26

Note:
1. Average end-to-end corridor travel time from the Alameda County line to the Benicia-Martinez Bridge over entire peak period.
2. Expected travel time in the network at free flow speed. Total travel time is the sum of the delay plus unconstrained travel time.

Source: DKS Associates 2003

Table 4 – I-680 HOV Lane Extension Operational Analysis Summary Statistics – 2015 Northbound (PM Peak)

Scenario	Total Vehicle Hours of Travel	Total Undelayed Hours of Travel[2]	Total Delay (vehicle-hours)	HOV Travel Time[1] (minutes)	SOV Travel Time[1] (minutes)
No Build	32310	14450	17870	29	58
Build	32250	14450	17800	29	58

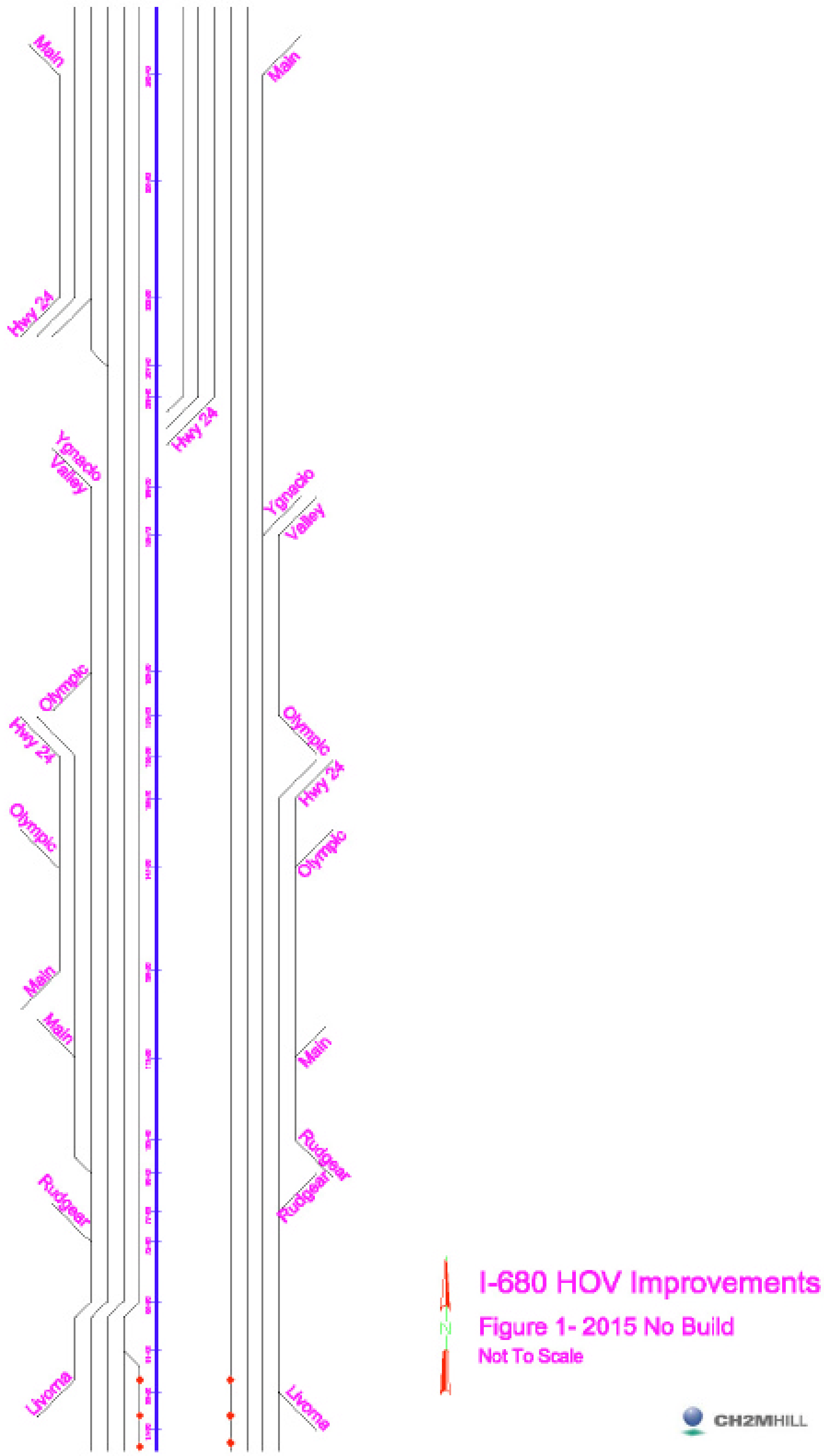
Note:
1. Average end-to-end corridor travel time from the Alameda County line to the Benicia-Martinez Bridge over entire peak period.
2. Expected travel time in the network at free flow speed. Total travel time is the sum of the delay plus unconstrained travel time.

Source: DKS Associates 2003

CONCLUSIONS

In the southbound direction, extension of the HOV lane will fill an important gap in the HOV lane network. This extension is forecast to significantly improve HOV travel times and delays along the I-680 corridor. Combined with the addition of selected auxiliary lanes as part of the Build Scenario, this extension will provide significant benefits to HOVs. While some degradation in SOV travel times is forecast, the change in total vehicle hours of delay is expected to be negligible. With the benefits to HOVs, however, person hours of delay would decrease under the Build scenario, especially in the PM period.

In the northbound direction, the proposed HOV lane extension would not provide noticeable operational benefits without completion of the HOV lane gap closure to the north between North Main and SR 242. This is due to the fact that the impacted segment is not congested. However, there are bottlenecks located to the south in the Danville area where an HOV lane currently exists, and to the north in the Pleasant Hill/Concord area beyond the end of the proposed HOV lane extension. In the long-term, the proposed extension combined with the closure of the gap to the north would be expected to provide benefits to HOVs by allowing them to avoid entirely the northern bottleneck, and most of the queues from the southern bottlenecks.


Main
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Hwy 24
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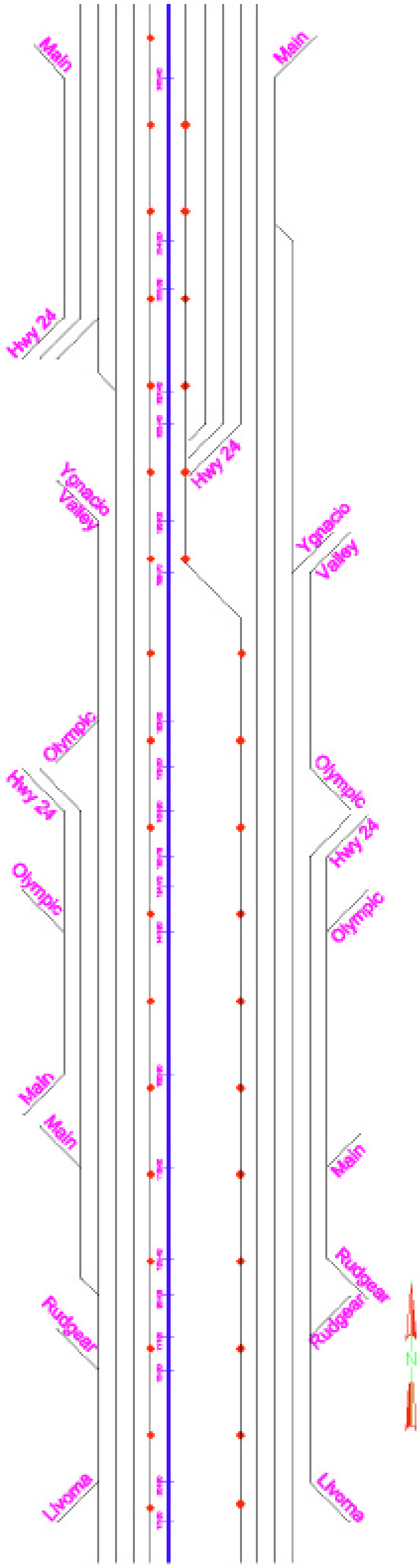
I-680 HOV Improvements
Figure 1- 2015 No Build
Not To Scale
CH2MHILL



I-680 HOV Improvements
Figure 2- 2015 Proposed Re-Striping - (Southbound)
Not To Scale

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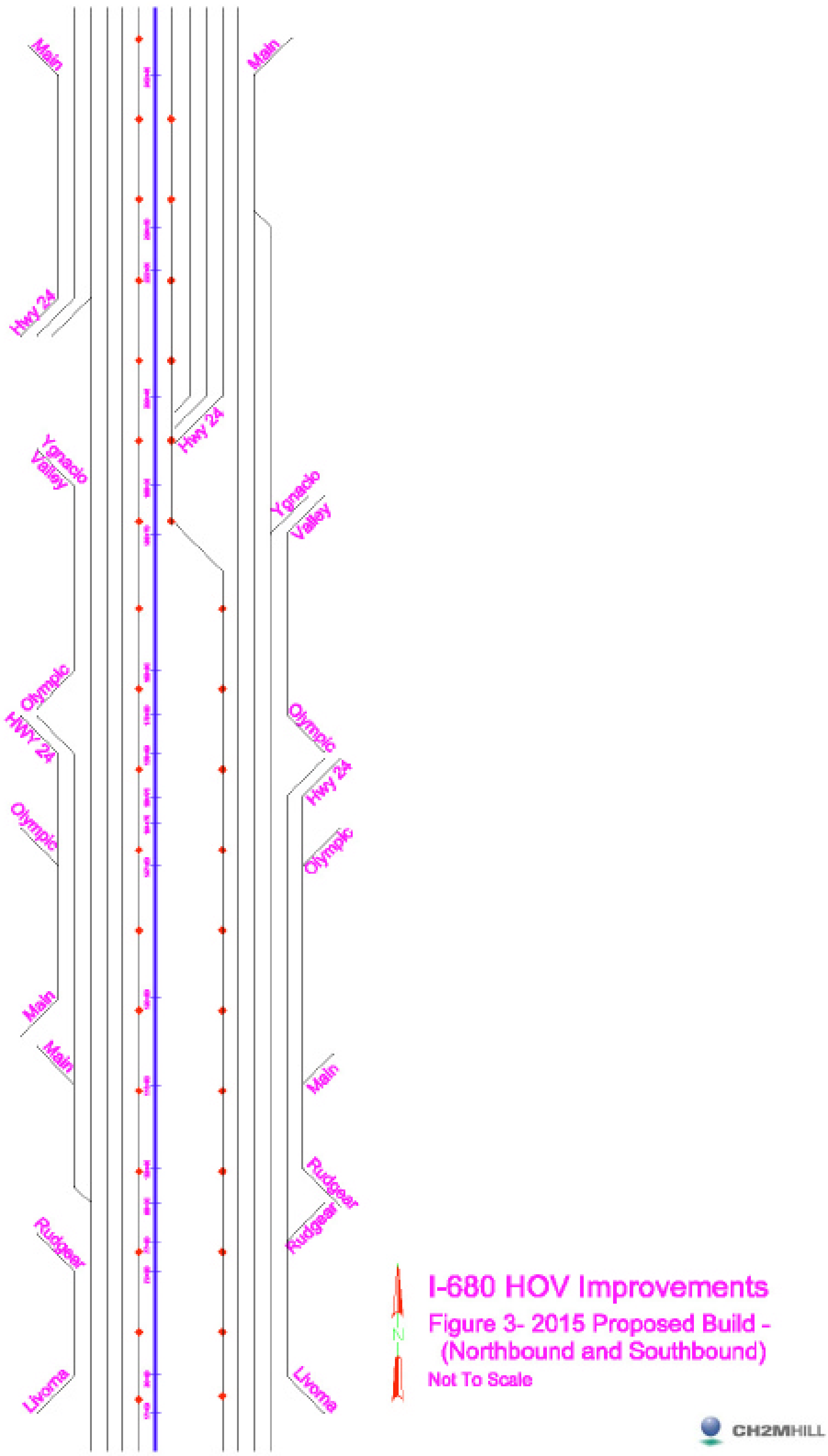
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I-680 HOV Improvements
Figure 3- 2015 Proposed Build - (Northbound and Southbound)
Not To Scale
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Figure 4 – Key to Freeway Analysis Queue Diagrams Diagram Key

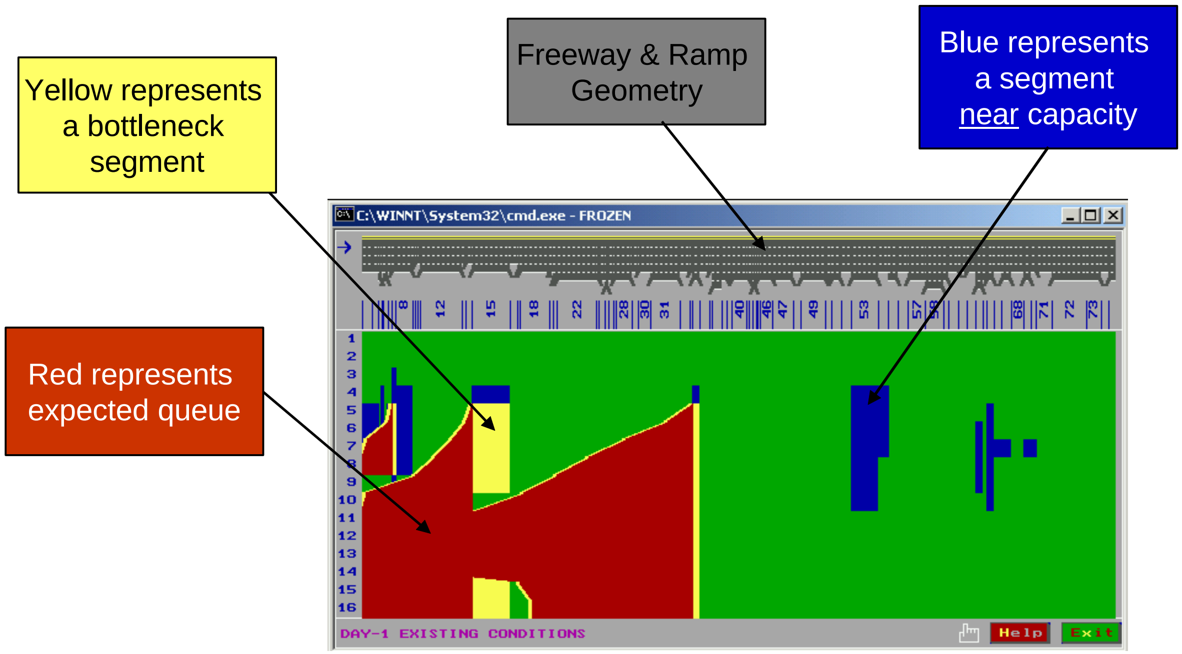


Figure 5a – 2015 Southbound A.M. Peak Congestion/Queue diagrams

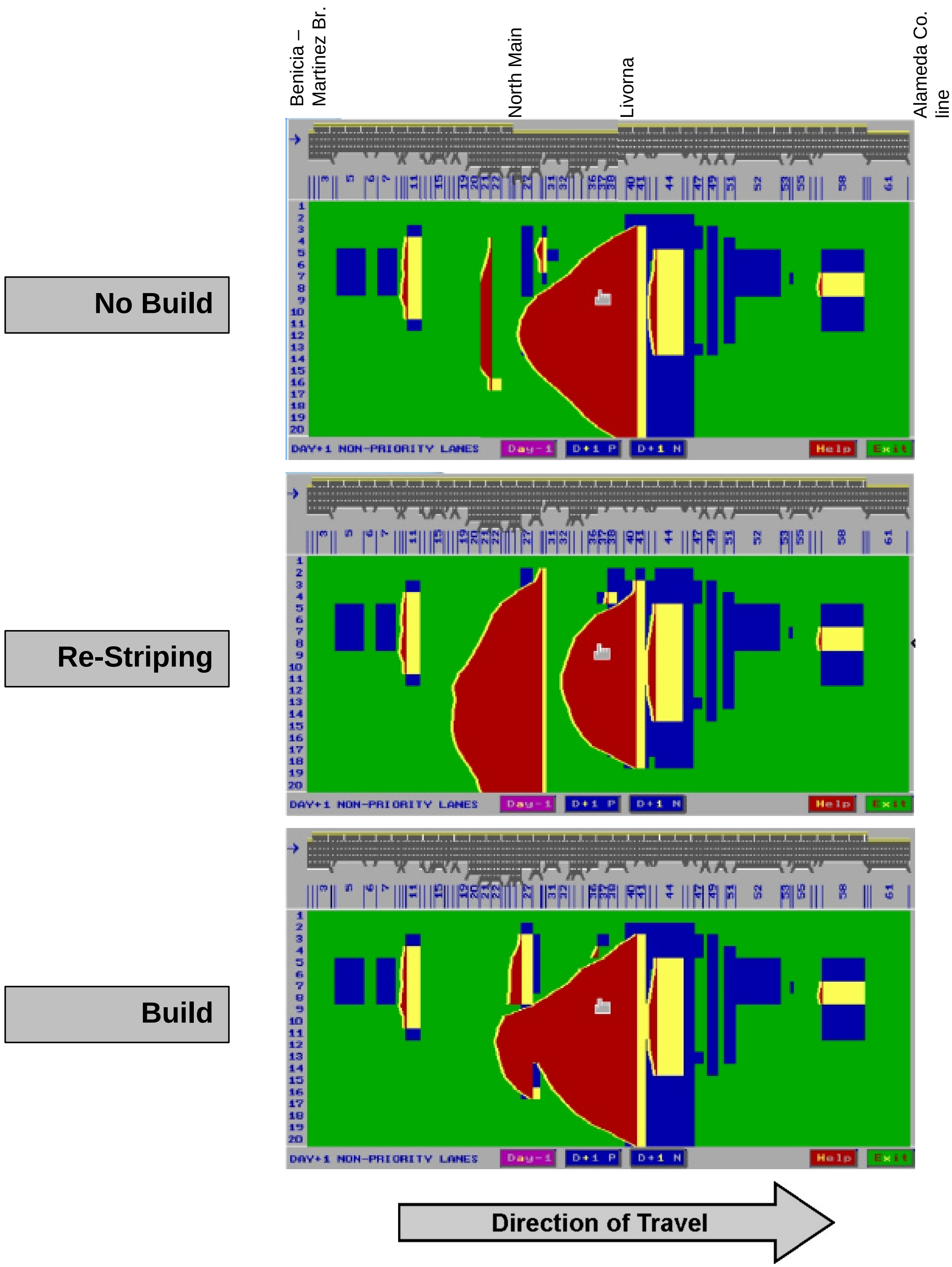


Figure 5b – 2015 Southbound P.M. Peak Congestion/Queue diagrams

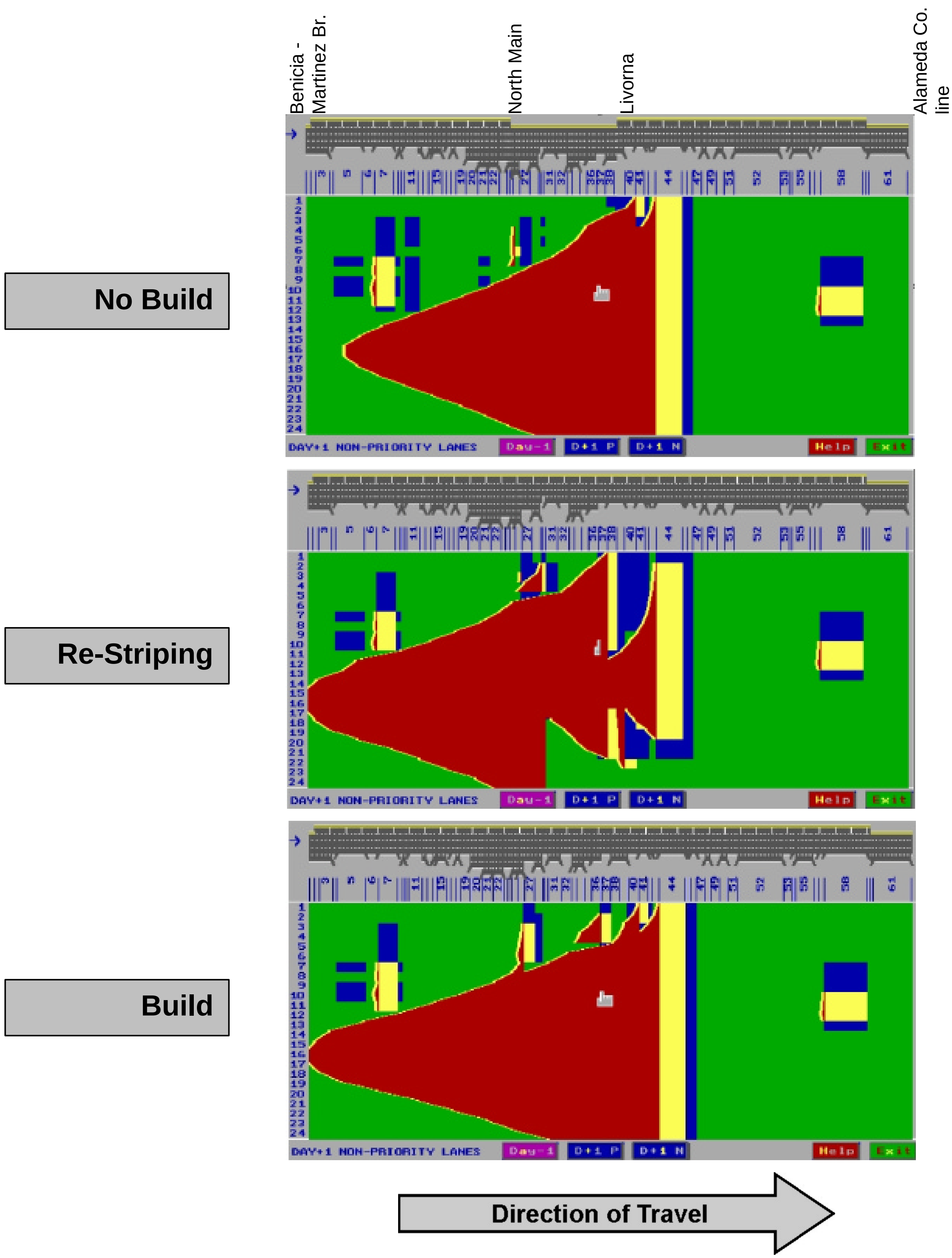


Figure 6a – 2015 Northbound A.M. Peak Congestion/Queue diagrams

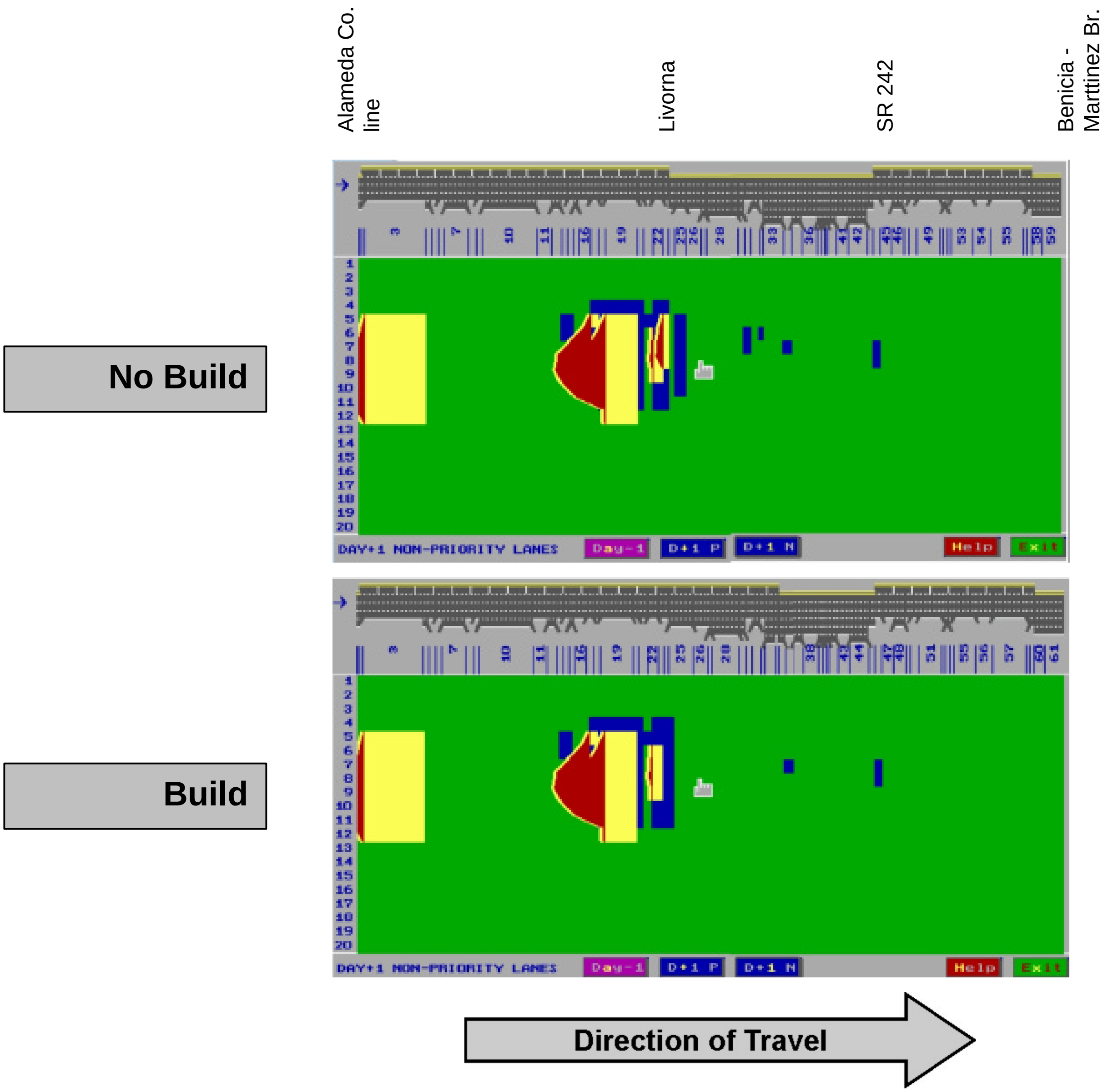
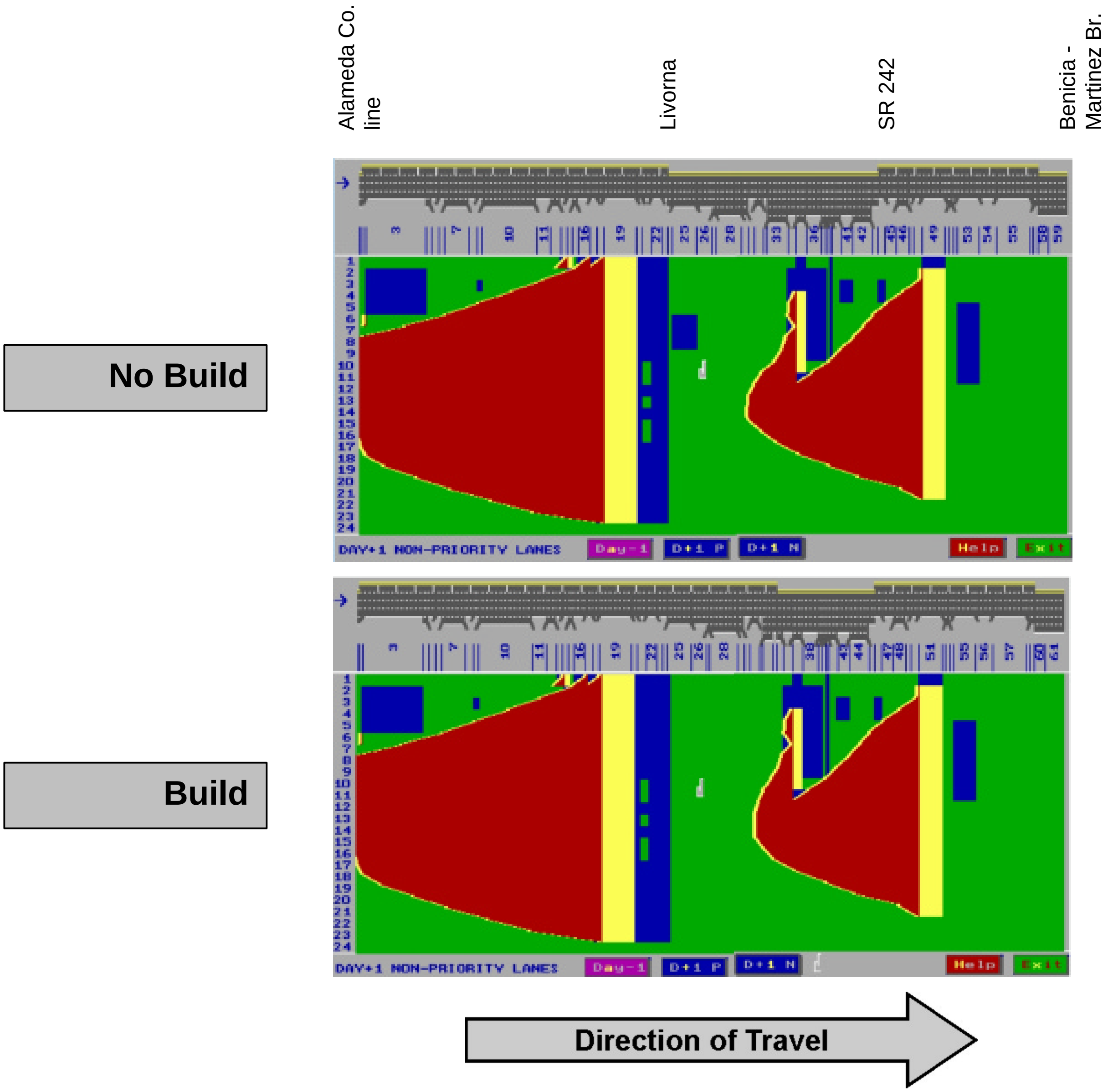


Figure 6b – 2015 Northbound P.M. Peak Congestion/Queue diagrams



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