S.0 SUMMARY

As part of the program environmental process for a statewide high-speed train system, the Authority is currently conducting a screening evaluation of alignment options to focus the upcoming technical studies. The alignments considered in this screening process have been largely constrained by land use related issues and/or associated environmental constraints. However, there are two areas of the state-wide system where this is not the case. Instead, the alignment options and associated costs are more constrained by physical features and associated environmental constraints. These areas are; the northern mountain crossing (Diablo Mountain Range) between the Central Valley and the San Francisco Bay Area, and the southern mountain crossing (Tehachapi Mountain Range) between Los Angeles and Bakersfield. While these areas have been previously studied and evaluated, screening decisions have been difficult since the distinction between alignments is often blurred due to the vast potential for variation in specific alignment (horizontal and vertical) and associated costs and impacts. Even in areas like the southern mountain crossing where the studies have focused on three primary corridors, the potential for differing alignment and grade options can present a significant difference in cost and impact in a given corridor.

Up until now, the Authority has used the standard and "best practices" for conceptual engineering corridor evaluation analyses. Recently, the Authority became aware of a new automated alignment optimization system developed and applied in Australia called "Quantm". Due to the potential for a wide range of impacts within the mountain passes, the Authority embarked upon an alignment optimization and refinement effort to further clarify the screening decisions using the Quantm system. Building on the previous work, this study analyzed millions of horizontal and vertical alignment over a three-week period. While Quantm has been widely utilized in Australia, the Authority's work is the first application of this optimization system in North America.

S.1 STUDY PURPOSE AND OBJECTIVES

The purpose of the alignment refinement/optimization study is to further clarify and strengthen the technical basis for making screening level decisions on the potential high-speed train corridors in the northern and southern mountain crossings. This study is intended to analyze the range of horizontal and vertical alignment options in an iterative manner to provide more confidence that the optimal alignments are being considered and more certainty concerning the cost estimates and potential impacts of each alignment option. To this end, the study was intended to meet the following three objectives:

- To confirm the general corridors considered in the screening studies to date and/or identify any other corridors of equal or greater viability that may have been overlooked in previous studies.
- To refine the alignment options in each general corridor to identify the most viable options in terms of infrastructure requirements and impact minimization.
- To test the sensitivity of the alignment options in each corridor to key defining criteria such as vertical grade, alignment geometry, infrastructure (tunnel, structure) costs and key environmental constraints.

This study was originally scoped to address only the southern mountain crossing. Based on the findings of the Tunneling Conference, which was held on December 3 and 4, and initial results from the Quantm analysis of the southern mountain crossing, the Authority recognized the need for further investigation of alternatives for the northern mountain crossing. Additional funds

were identified, and a subsequent agreement was reached to use the Quantm tool to also address the northern mountain pass.

S.2 THE QUANTM SYSTEM

The Quantm system is a unique route optimization technology supported by a team that incorporates road and rail engineers, GIS technicians, mathematicians, transport researchers and system developers. The Quantm system is an automated route selection and optimization tool that carries out automated alignment searches and corridor screening based on client or user specified geometry, constraints and cost parameters.

S.3 STUDY PROCESS

A study team comprised of key members of the Program Management Team and the Los Angeles to Bakersfield and Merced to Bay Area Regional Teams was brought together and supported by Quantm Australia personnel who traveled to Orange County for three weeks of training and assistance. Available terrain data, environmental constraints and design and cost parameters were input into the Quantm system by the team and the data compiled during this period formed the basic platform for first stage Quantm corridor screening and optimization studies.

Numerous specific alignment options were considered in each of the primary corridors in each mountain crossing. In addition, each alignment was evaluated for maximum vertical grades of 2.5% and 3.5%. The conclusions from the concurrently held tunneling conference were also incorporated into the Quantm analysis. The input data for these runs was sent via email to Quantm in Melbourne and the optimization outputs were available for review just hours later. The Quantm System identified and costed approximately 12 million alignment options with each run and output the best range of lowest cost alignments that endeavour to meet the various constraint parameters. The results below were achieved in three weeks.

S.4 RESULTS AND CONCLUSIONS

In the summary below, the results of the Quantm alignment refinement and optimization study are compared to the alignment options developed during the current alignment screening evaluation as well as alignment options that were developed in the previous Corridor Evaluation Study (1999). There is typically a wide difference in the infrastructure requirements (tunnel and structure length) of the alignment options developed in these two studies, due to the differing objectives of the two studies. It is important to note that the current screening evaluation focused on minimizing potential environmental impacts, while the previous corridor evaluation study focused on minimizing tunnel requirements and cost. Based upon the results of the Tunneling Conference, the Quantm study has attempted to minimize tunneling and capital costs, and therefore is more comparable to the earlier Corridor Evaluation Study results.

S.4.1 Northern Mountain Crossing – Diablo Mountains

A. DIABLO RANGE DIRECT ALIGNMENT (PREVIOUSLY NORTHERN DIRECT TUNNEL)

Of the two primary corridors being considered in the Diablo Mountain Crossing, the northern alignment is advantageous in terms of travel time; however, the terrain is more difficult and remote. Because of time and resource constraints, the previous northern alignment studies in

the screening evaluation had assumed that the crossing needed to be completely in tunnel because of the difficult and remote terrain. As a result, the only alignment considered included a 31-mile long tunnel through the mountain crossing. A tunnel of this length, however, is costly and difficult to construct.

Using the Quantm system the study team was able to identify an alignment at a maximum grade of 3.5% that minimizes tunneling to a total of 11.3 miles and limits single tunnel length to just over 5 miles – reducing the associated construction cost by at least $2 billion. Figure S-1 shows the refined northern crossing alignment and profile. The alignment would cross three active and potentially active faults at-grade including the Ortigalita Fault, the southern extension of the Greenville Fault trend, and the Calaveras Fault zone. The most negative aspects of this alignment are that it bisects a portion of the Henry W. Coe State Park and it is located several miles south of the nearest access road (SR-130).

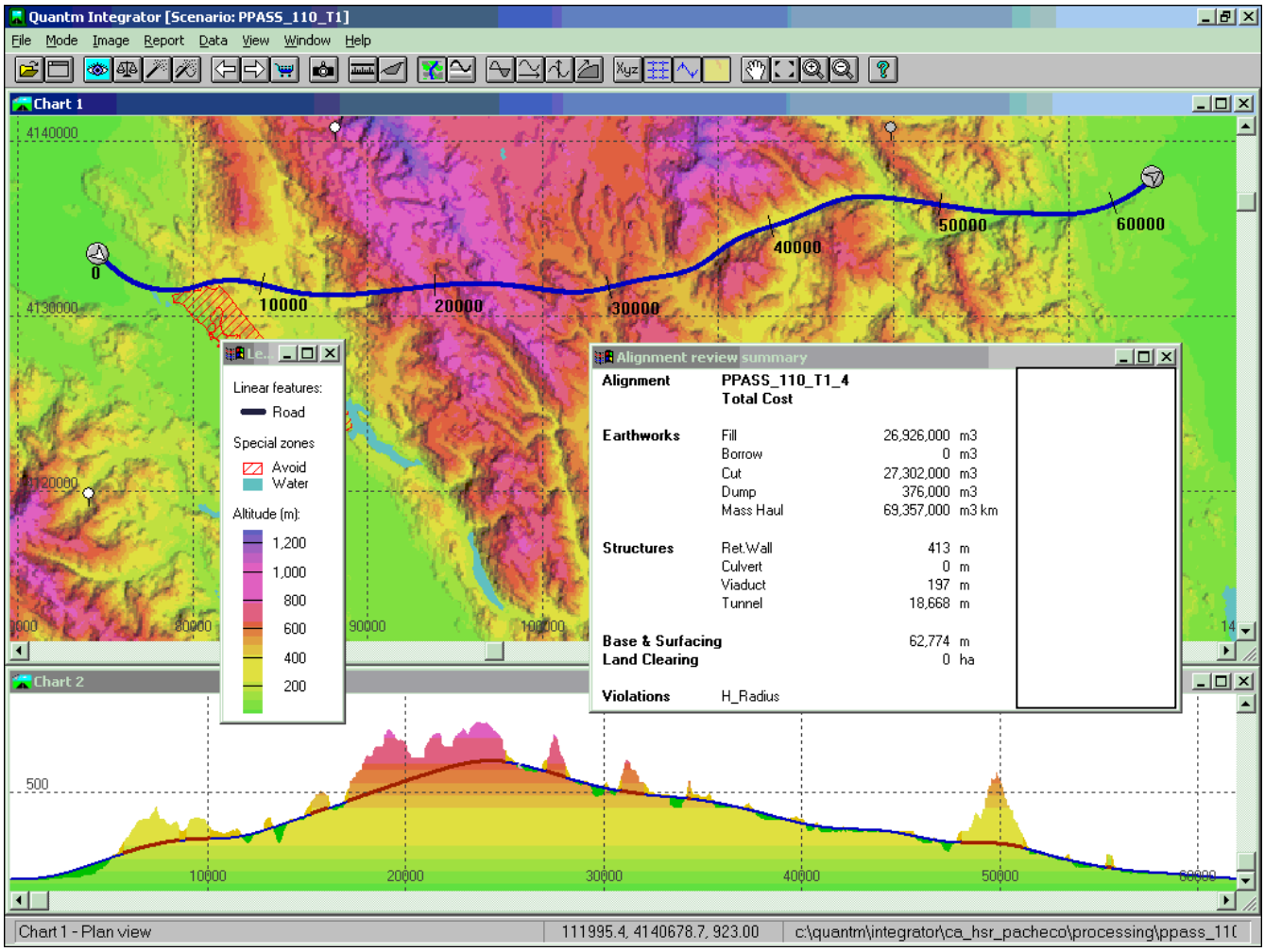

Figure S-1: Diablo Range Direct – Quantm alignment at 3.5% maximum grade

As a possible avoidance alternative to potential impacts to the Henry W. Coe State Park, an additional alignment was developed for the northern crossing that minimizes tunneling (requiring about one-half of the tunneling proposed in the previous direct tunnel option), avoids direct

impact to the Henry W. Coe State Park (a key environmental constraint) and is located in close proximity to SR 130 to provide construction access. This avoidance alignment option has a total tunnel length of 16 miles and a maximum length of continuous tunnel of less than 6 miles.

B. SR 152 – PACHECO PASS

The previous alignment option considered in the screening evaluation required a total length of 18 miles of tunnel with a maximum length of continuous tunnel of 15 miles. The alignment option identified in the previous Corridor Evaluation Study (1999) required 12 miles of tunnel with a maximum segment length of 4.5 miles. Refinement of this SR 152/Pacheco Pass alignment identified an alignment and profile option that can potentially reduce the total required tunneling to only 5 miles. Figure S-2 shows the refined SR 152/Pacheco Pass alignment option.

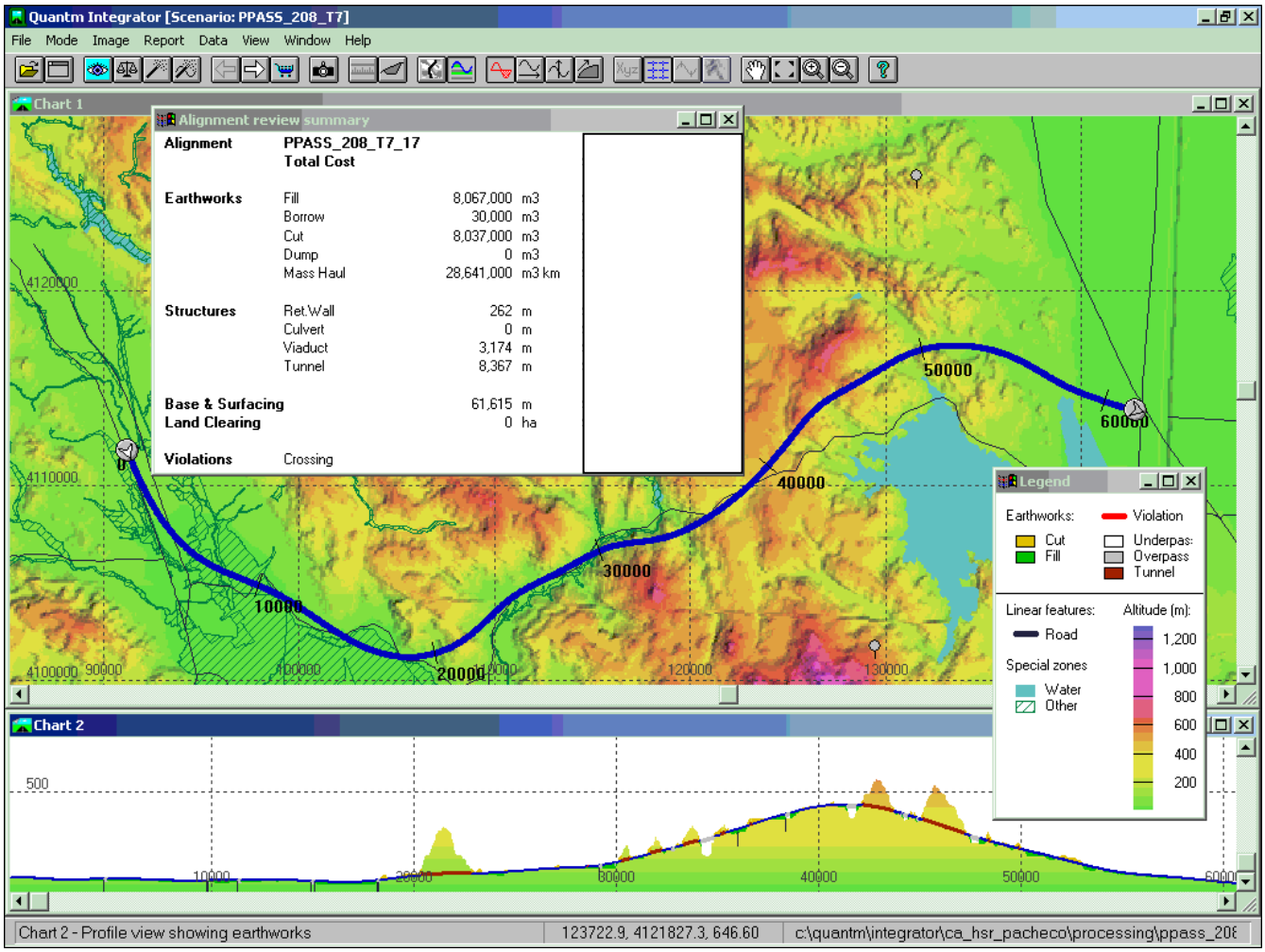

Figure S-2: Pacheco Pass – Quantm SR-152 Alignment (Max. 3.5% Grade)

S.4.2 Southern Mountain Crossing - Tehachapi Mountains

In the Tehachapi Mountain Crossing the alignment refinement/optimization study confirmed the location of the general corridors considered in the screening studies to date.

A. I-5/GRAPEVINE

The alignment refinement/optimization study confirmed past findings as well as identified new alignment options in key seismically constrained areas.

Alignment options using 2.5% maximum grades are unable to cross major faults at grade and require a continuous tunnel segment of at least 16 miles. However, alignment options using 3.5% maximum grades were found to provide more flexibility in avoiding the major faults at-grade than previously thought. The alignment options in the I-5 corridor were refined to identify more viable options in the area of the major fault crossings in terms of tunnel requirements, construction difficulty and cost. An alignment was identified to the east of I-5 that allows for an at-grade crossing of the San Andreas Fault zone and an at-grade or trenched crossing of the Garlock Fault zone with no single tunnel longer than 6 miles. This alignment option, as shown in Figure S-3, would require a total of 18 miles of tunneling as compared to 28 – 35 miles of tunneling required for alignment options previously studied. This alignment would require extensive construction in the floodplain area surrounding Castac Lake. The potential impacts will need to be further studied in the program environmental analysis.

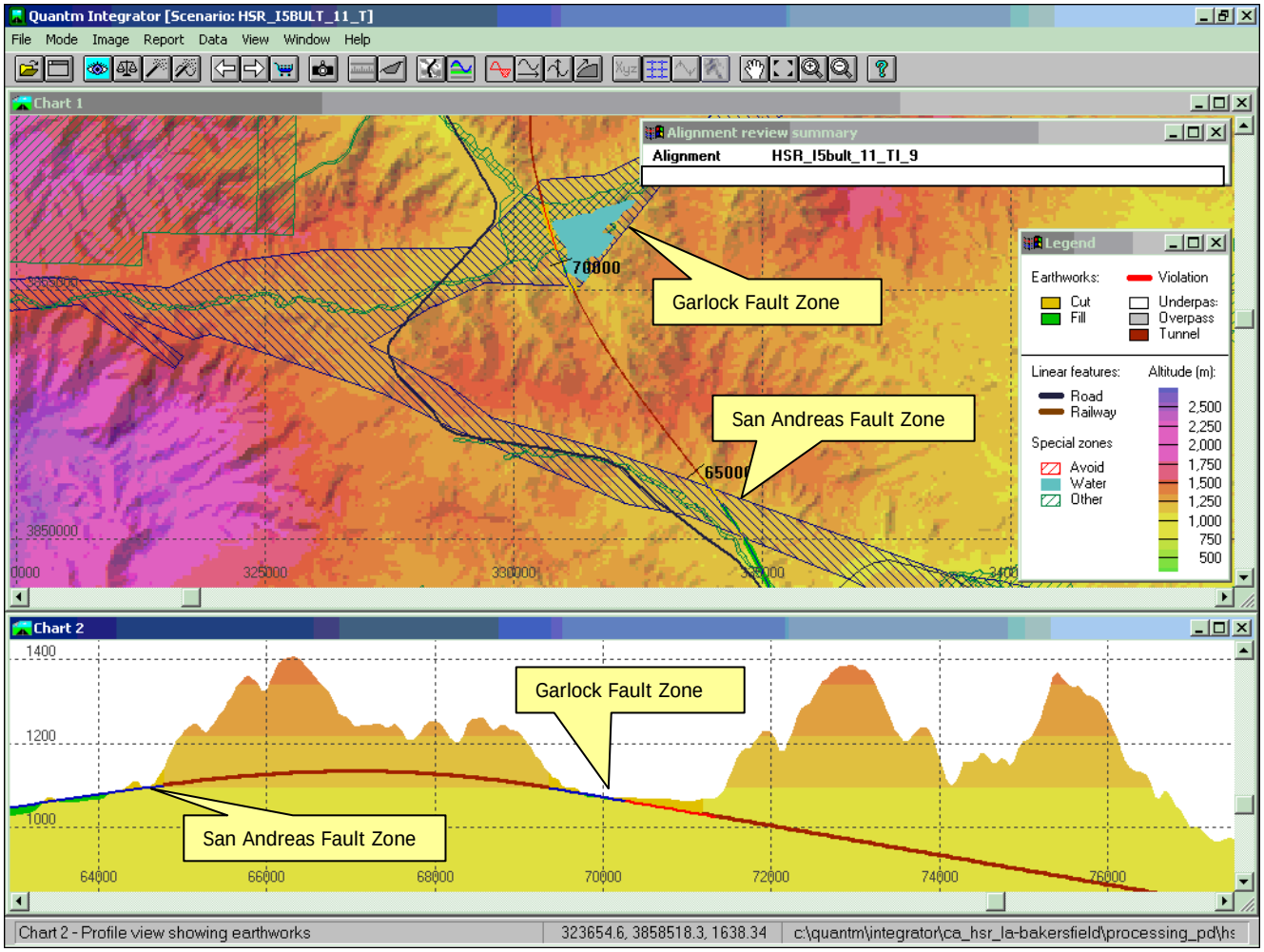

Figure S-3: I-5 Quantm alignment to east of I-5 corridor, crossing fault lines at grade

B. SR-58/MOJAVE

This corridor was investigated in sections: the southern section from Sylmar to Palmdale, the middle section through Palmdale and Lancaster, and the northern section from Lancaster to the Central Valley floor. The middle section is highly constrained due to existing development and transportation corridors. The northern and southern sections were studied more extensively because of the potential for alignment refinement in the mountainous terrain.

Southern Section (Sylmar to Palmdale) - Two corridor alternatives were studied in the southern section, the SR 14 corridor and the Soledad Canyon corridor. The alignment options in these corridors were refined to identify more viable options or reductions in infrastructure requirements and cost. The Soledad Canyon alignment option developed in the screening assumed tunneling along the north side of Soledad Canyon to avoid potential environmental impacts. By eliminating that constraint and taking a more aggressive approach to earthworks, tunneling can be reduced by as much as 16 miles as compared to the alignment option developed in the screening evaluation. The Quantm alignment option was very similar to that developed in the previous corridor evaluation in terms of required tunneling (5 miles total).

Based on that reduction, the Soledad Canyon alignment option allowed for lesser infrastructure requirements (over 3 miles less tunnel) and cost than the refined SR 14 alignment option. Figure S-4 shows the Soledad Canyon alignment option. Figure S-5 shows the refined SR 14 alignment option.

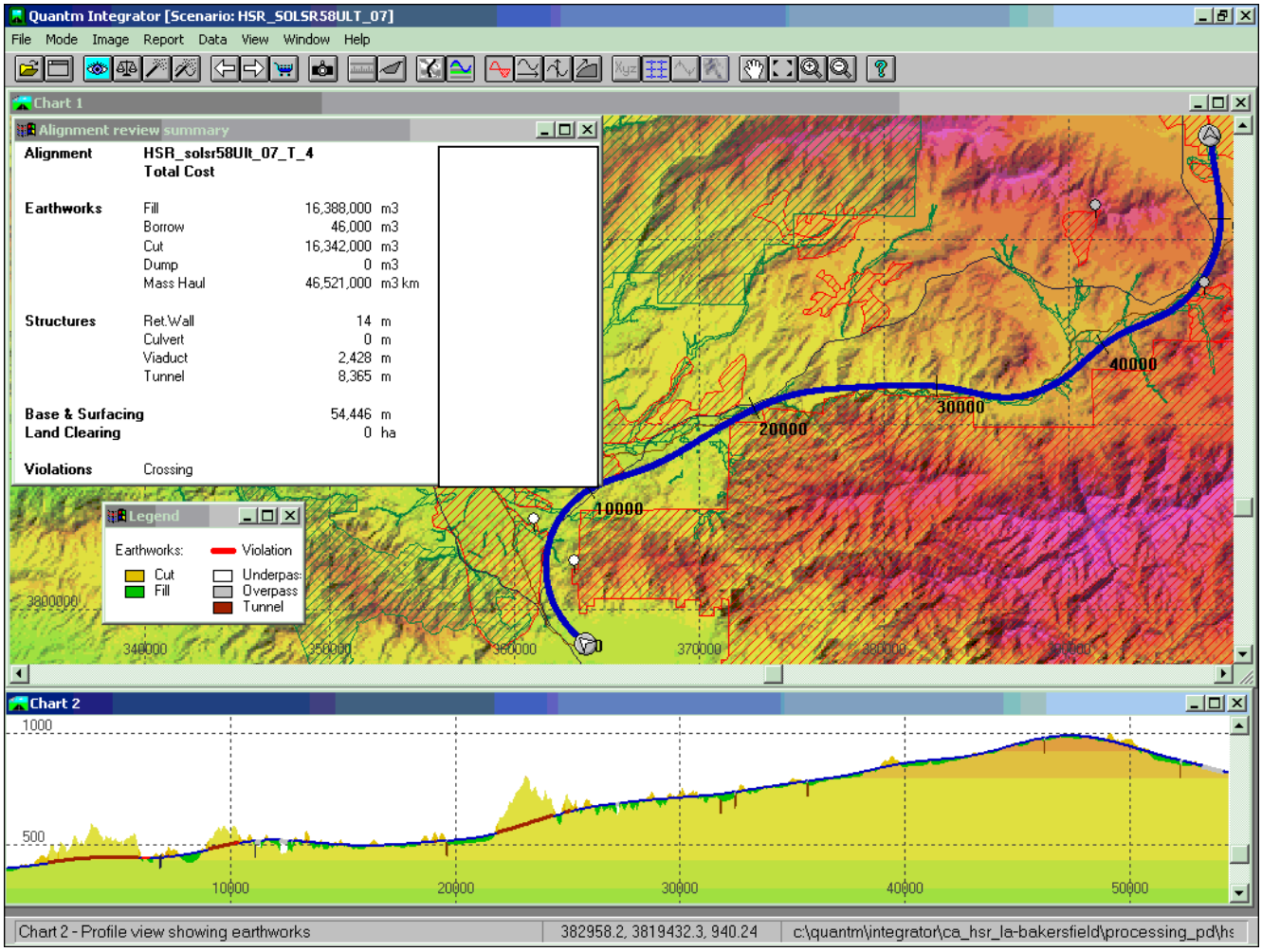

Figure S-4: Soledad Canyon – Quantm Refined Alignment (Max. 3.5% Grade)

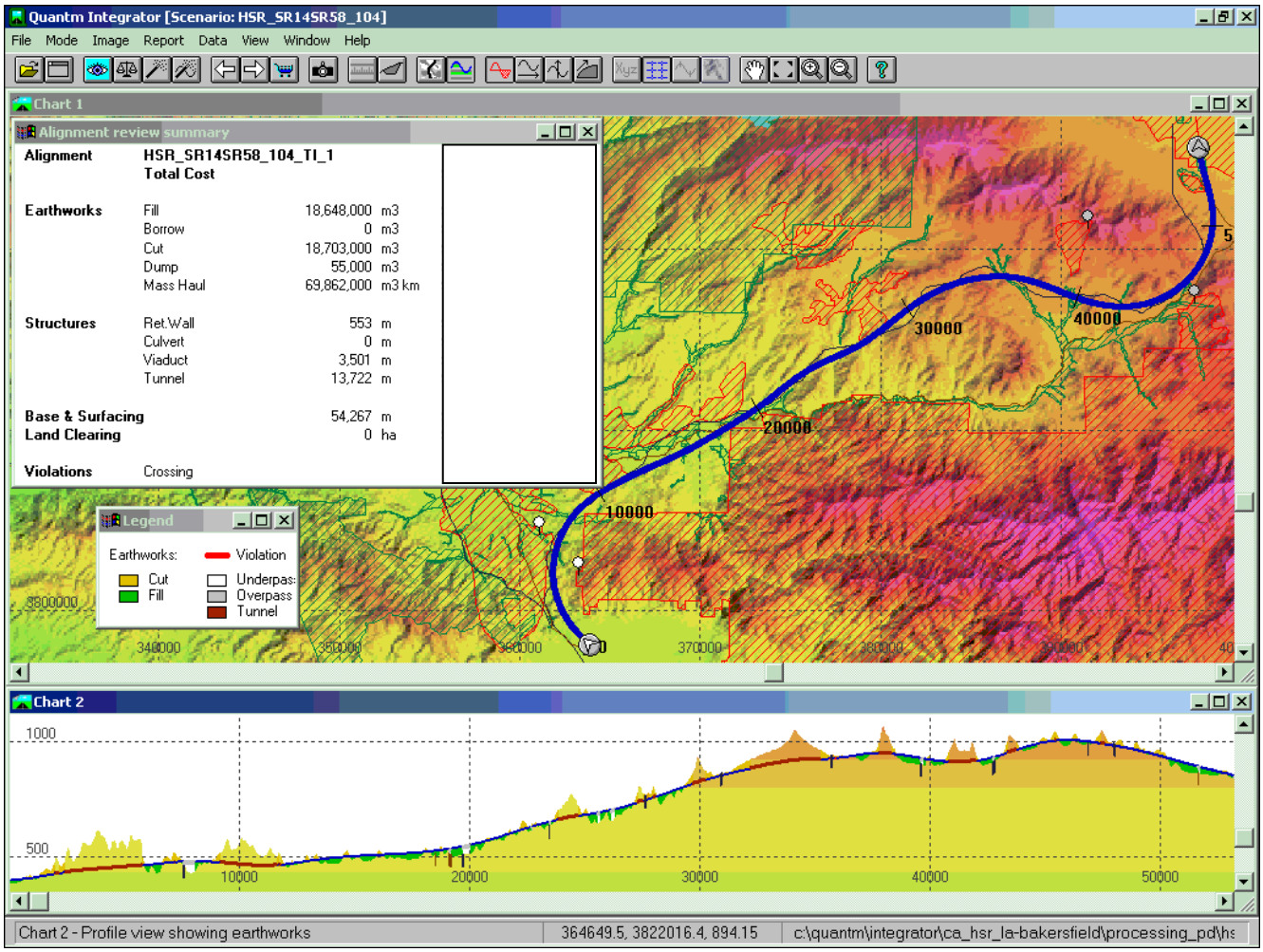

Figure S-5: SR14 – Quantm Refined Alignment (Max. 3.5% Grade)

To avoid the potentially sensitive areas of Soledad Canyon, an avoidance alignment option was identified to the north of Soledad Canyon that would still reduce tunneling requirements as compared to the Soledad Canyon alignment option previously considered in the screening analysis. Potential environmental impacts of this alignment option will be further evaluated in the program environmental studies.

Northern Section (Lancaster to Central Valley) - The alignment options in the SR 58 corridor were refined to identify more viable options or reductions in infrastructure requirements and cost. No new, significantly different corridor options were identified. The minimum length of tunneling required through the Tehachapi Mountain crossing on the SR 58 corridor is about 5.1 miles as compared to 22 miles for the alignment options considered in the screening evaluation (at 3.5% maximum grade) and 5.8 miles for the alignment option considered in the previous corridor evaluation. Figure S-6 shows the refined alignment option. All major fault crossings can be maintained at-grade for the 3.5% maximum grade option in this corridor.

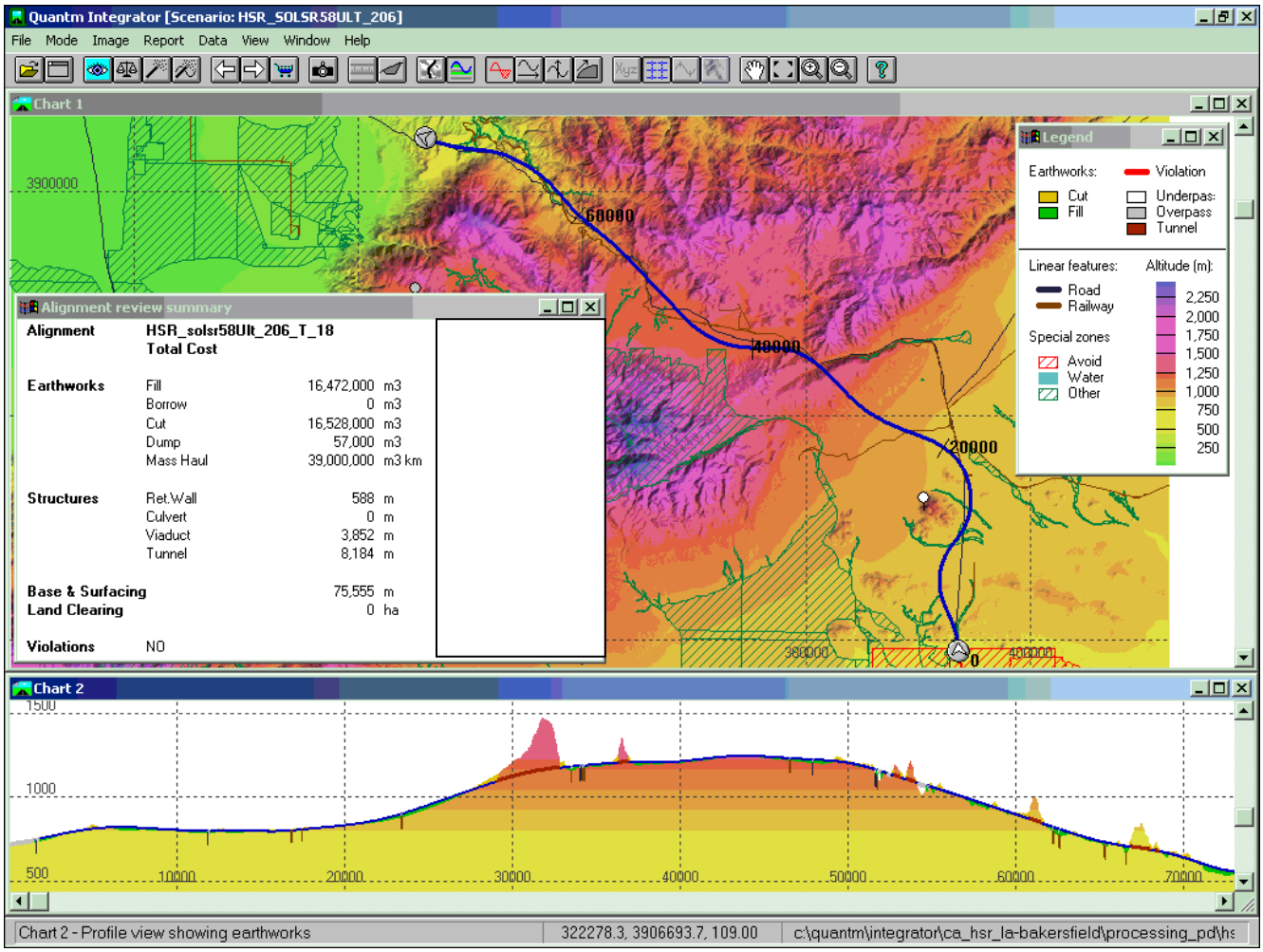

Figure S-6: SR 58 North – Quantm Refined Alignment (Max. 3.5% Grade)

C. SR 138/PALMDALE ALIGNMENT

The southern section of this alignment is the same as the SR 58/Mojave alignment option discussed above.

The alignment and profile options through the Tehachapi Mountain Crossing were refined to identify more viable options that reduce infrastructure requirements and cost. A single tunnel segment is required for this crossing and was estimated at 14.3 miles long in the screening evaluation. The length of tunnel required on this crossing can be reduced as low as 12.8 miles at 2.5% maximum grade and to 10.4 miles at 3.5% maximum grade. Figure S-5 shows the refined alignment option at 3.5% maximum grade. No new, significantly different corridor options were identified.

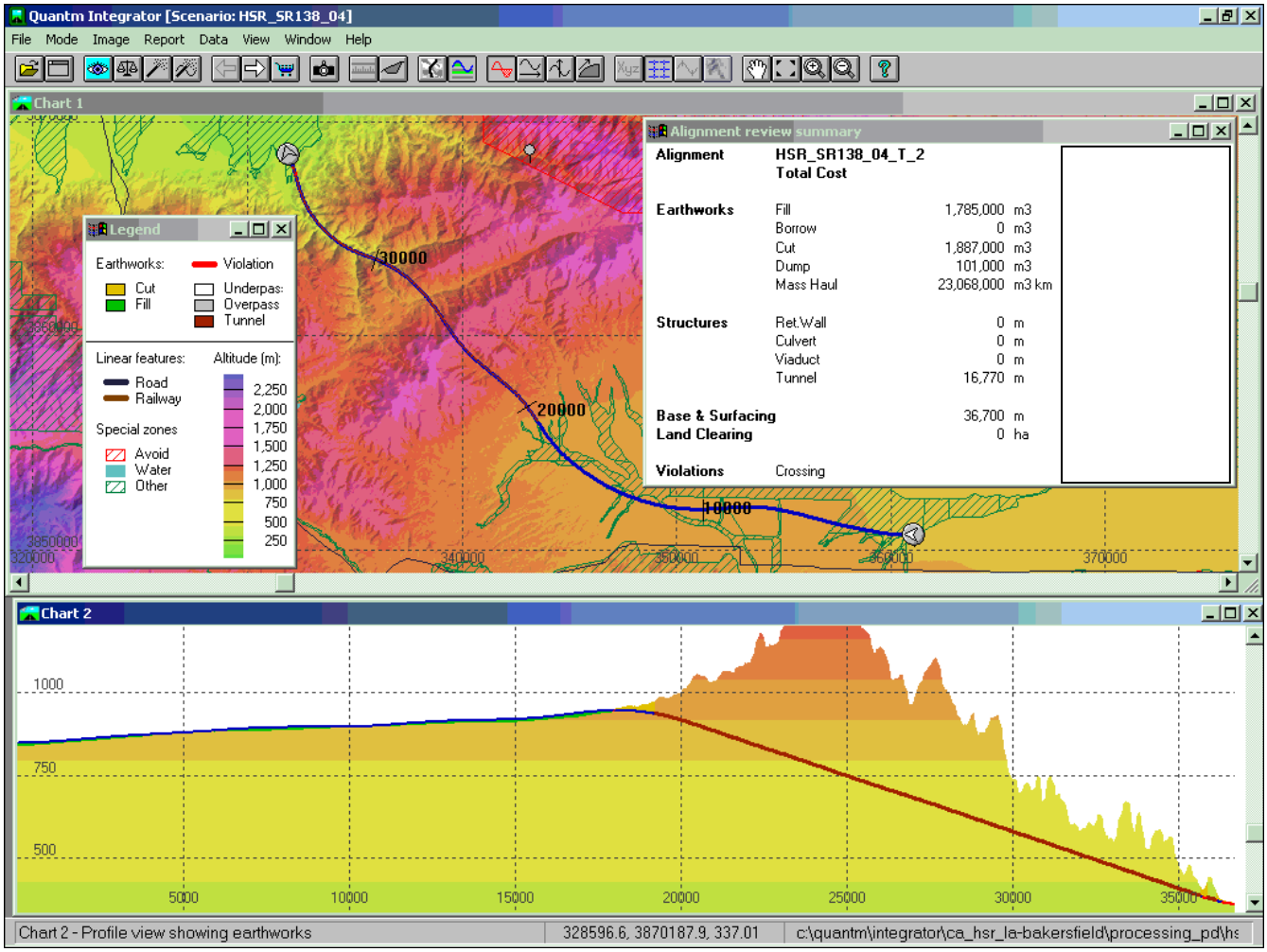

Figure S-6: SR 138 – Quantm Refined Alignment (Max. 3.5% Grade)

S.4.3 Quantm System Evaluation

The study team and Authority staff concurred that the primary benefit of the Quantm system and this alignment refinement/optimization study was the confidence gained that the optimal alignment options are being considered in terms of minimizing infrastructure requirements and costs for both of the mountain crossings studied. The Authority would not have had the time or resources to identify and evaluate the broad range of potential options/variations (literally millions) through these mountain crossings and achieve this level of confidence through any other means.

Although this summary does not detail the cost estimates of the alignments produced, since further analysis and constraint definition is required, early indications are that the Quantm system will also deliver significant cost savings due to its ability to determine the optimal alignment.

This three-week study identified alignment options and refinements that significantly improved on the original alignments that had been developed in previous studies. The Quantm system was particularly applicable to the screening evaluation process. The ability to quickly test a wide

range of alignment options in the context of all of the key environmental and physical constraints, as well as the main design and cost parameters, was critical to achieving the objectives of this study. It became apparent that the earlier this type of comprehensive evaluation is conducted in a corridor/alignment study, the more effective the outcomes. This is particularly true in terms of providing early, accurate indications of alignment options and associated cost and potential impacts.

The ability to input new constraints to protect sensitive areas or avoid physical features was demonstrated in the investigation of the I-5 corridor where constraint zones were used to minimize the impact of crossing the fault zones, based on input from the tunneling conference. While these concerns can certainly be addressed through conventional study means, the Quantm system provided a comprehensive plan, profile and costing analysis in a very short period of time.

The study team confirmed that it was able to use the Quantm system as a powerful support tool to analyze a wide range of alignment options and identify beneficial refinements in remarkably short time with more flexibility to respond to specific engineering and environmental issues. The study team also confirmed that the Quantm system will be applicable to subsequent stages of the alignment development process to optimize the alignments as new constraints are defined through the further consultation and environmental analysis phases.