Final Report

Pilot Project for Fixed Segmentation of the Pavement Network

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Part of PPRC Strategic Plan Item 3.2.4

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Executive Summary

This report presents the results of the study, “Pilot Project for Fixed Segmentation of the Pavement Network.”

The goal of this pilot project was to study a small sample of the California Department of Transportation (Caltrans) network to determine the feasibility of expanding the pilot approach to the entire pavement network. The project’s work included evaluating the effectiveness of ground penetrating radar (GPR) and limited coring for measuring pavement layer thicknesses and types, application of an algorithm for determining “fixed” segmentation of the pilot network, population of a database for the pilot network, then assessing costs of these activities.

Fixed segmentation for use in the Pavement Management System (PMS) is required to develop the capability to do pavement performance modeling, which is essential for the following pavement management tasks:

- Predicting future performance of segments of the network, and
- Identifying the most cost-effective maintenance and rehabilitation (M&R) strategies based on life-cycle costs.

Pavement layer-type and thickness data are also needed to develop effective pavement performance models and to conduct effective condition surveys of composite pavements (asphalt overlays of PCC pavement). The data are also useful for project-level engineering.

Background information summarizing the experiences of several other states in using GPR for pavement work is also presented.

The pilot network consisted of a total of eight roadways: three interstate highways (I-5, I-505, and I-80), four state routes (SR-16, SR-45, SR-99, and SR-113), and one U.S. highway (US-50). The roadways chosen are mostly in District 3, except for the I-80 section and part of the I-505 section, which are both in District 4. GPR data was collected on 681 lane-miles of the pilot network and analyzed for 305 lane-miles. Traffic data was obtained from Caltrans. Climate regions were determined from a recent map developed by Caltrans and the University of California Pavement Research Center (UCPRC).

The UCPRC collected coring data for some of the locations on the pilot network. Some of the cores were provided to Infrasense, Inc., for GPR calibration and some were retained by the UCPRC for checking the accuracy of the layer thicknesses and types that Infrasense determined from the GPR data. The UCPRC also collected available as-built information and maintenance records, and the most recent Pavement Condition Survey (PCS) data from Caltrans.

The UCPRC then used the data collected to develop fixed segmentation for the pilot network, resulting in 236 segments for the 305 lane-miles analyzed, with an average segment length of 1.27 miles.

Comparison of the cores retained by the UCPRC with the layer types and thicknesses identified by the GPR showed that the GPR data was reliable, especially for the top two layers of the pavement.

Extrapolation of the costs on the pilot network for data collection and analysis and segmentation results in an estimate of approximately $7.0 million of contracted field work consisting of GPR use and coring (including collection and analysis), plus 12.3 person-years of additional analysis work to complete the segmentation for the entire Caltrans 49,000 lane-mile network.

If Caltrans moves ahead with collection of pavement structure data and fixed segmentation, it will be important to document as-built information in the structural database as future maintenance, rehabilitation, and reconstruction work occurs, in order to keep the database accurate.

Work beyond this pilot study is underway to determine:

- Whether PMS performance data can be used with the fixed segments to develop reasonable performance histories for the segment, and
- Whether the performance models developed by the UCPRC from Washington State Department of Transportation (WSDOT) PMS data can be verified with Caltrans PMS performance histories using the fixed network segments and other necessary data developed in this pilot project.

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1.0 INTRODUCTION

This report presents the findings of the study, “Pilot Project for Fixed Segmentation of Pavement Network.”

The goal of this pilot project was to study a small sample of the California Department of Transportation (Caltrans) network to determine the feasibility of expanding the pilot approach to the entire pavement network. The project’s work included evaluating the effectiveness of ground penetrating radar (GPR) and defining “fixed” pavement segments, then assessing costs of these activities.

The work was conducted as part of the Partnered Pavement Research Center (PPRC) *Strategic Plan* Item 3.2.4 (“Development of Integrated Databases to Make Pavement Preservation Decisions”) for the following objectives.

- To populate databases with existing data, and perform preliminary analyses.
- To develop recommendations for ongoing collection and database management procedures to be implemented and operated by Caltrans functional units.

Work underway on analysis of the data collected is part of, or coordinated with, activities in PPRC *Strategic Plan* Items 3.2.5 (“Documentation of Pavement Performance Data for Pavement Preservation Strategies and Evaluation of Cost-Effectiveness of Such Strategies”) and 4.5 (“Calibration of Mechanistic-Empirical Design Models”).

1.1 Purpose of Work

The general purpose of the work presented in this report is to support Caltrans Maintenance in its development of an improved Pavement Management System (PMS). Specific objectives focus on helping Caltrans Maintenance develop the capability to do pavement performance modeling, which is essential for the following pavement management tasks:

- Predicting future performance of segments of the network.
- Identifying the most cost-effective maintenance and rehabilitation (M&R) strategies based on life-cycle costs.

More specific purposes of the work address three key challenges to performance modeling using the current Caltrans PMS.

1. The use of “dynamic segmentation,” which has logistical benefits but masks the true performance of fixed segments and confounds performance modeling. The current system uses a “dynamic segmentation” procedure in which the pavement is not evaluated over fixed lengths but is divided into segments that have similar distress at the time of each assessment. Consequently, both the segment’s length and its starting and ending points change from year to year, and a given pavement section is identified as appearing in a different segment from one year to the next.
2. The PMS database lacks subsurface pavement structure data, which is a key variable in explaining pavement performance. Pavement structure cross-section data is not available in any central or district Caltrans database and it is not routinely updated when rehabilitation and maintenance activities are performed.
3. The nonexistence of quantification (severity and/or extent) for some pavement distresses, which means that these distresses are observed and identified in the Pavement Condition Survey (PCS), but they are not measured.

1.2 Pilot Project

To meet the stated objectives, a pilot project was developed in which a small representative sample of the Caltrans network in Districts 3 and 4 was selected for field testing and other data collection and analyses. These efforts aimed at evaluating:

- The effectiveness of using ground penetrating radar (GPR) data, limited coring, and available collected office data to provide an uninterrupted measurement of pavement thickness and layer type on a variety of pavement types.
- The effectiveness of establishing static, well-defined (fixed) network segments using the GPR and other data collected on the pavement structures — combined with traffic, climate, and condition survey, and roughness data.
- The costs of collecting the data and performing the segmentation and extrapolation of those costs to the entire pavement network.

This report presents the data collected and the results of the analyses performed to complete these three evaluations. Work will continue outside this pilot project, with additional analyses to be performed to definitively conclude:

- Whether PMS performance data can be used with the fixed segments to develop reasonable performance histories for the segment, and
- Whether the performance models developed by the UCPRC from Washington State Department of Transportation (WSDOT) PMS data can be verified with Caltrans PMS performance histories using the fixed network segments and other necessary data developed in this pilot project.

1.3 Scope, Schedule, and Status of Project Tasks

Specific tasks to be completed for this pilot project were identified in Meeting Minutes from August 30, 2004, "On Developing Objectives for the Highway Network Segmentation & Data Collection in District 3 Using GPR" (Appendix A). The initial project scope was shown as follows:

A. Collect GPR data on identified sections in Districts 3 and 4

- Collect approximately 1,000 lane-miles of data, analyze approximately 300 lane-miles, and retain the remaining raw data for potential analysis later.
- Include (a) low-volume and high-volume traffic segments, and (b) rigid, flexible, and composite pavement structures.

→ *Tasks completed and items are presented in this report. Routes identified to include 1,000 lane-miles actually consisted of about 681 lane-miles when measured (see Appendix B).*

B. Collect other data, including:

- The Caltrans Office of Pavement Rehabilitation's studies of deflections,
- Project as-builts [headquarters (HQ) data, retrieval (intranet) of District data],
- Data from moisture sensitivity studies, and

- Data from the Pavement Performance Evaluation Phase I (Stantec Project[1]

→ *Tasks completed and utilized in this report.*

- Coring Data
  - Some samples are to be provided to the GPR contractor to calibrate the GPR data, and others are to be held by the PPRC to verify GPR measurements
  - Perform coring at only few locations, and only in sections where the GPR data has been analyzed.

→ *Tasks completed for selected sites in Districts 3 and 4.*

C. Perform analyses

- Analyze GPR data for thickness and layer type,
- Map the structures,

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[1] Stantec, Inc. was awarded a research project by the Caltrans Division of Research and Innovation to evaluate the performance of in-service pavements in California and hence, the success of Caltrans' pavement design and rehabilitation procedures. As part of this project, a large number of sections distributed throughout the state of California covering different districts and environmental zones are being tested and many pavement related data attributes are being collected. The test sections include rigid pavements, composite pavements and new and rehabilitated flexible pavements. Phase II of this project is currently underway and is expected to be completed in the summer of 2006.

- Revise GPR structures results based on coring data in areas where GPR identification is questionable,
- Compare verification data with analyzed GPR data, and
- Analyze the costs.

→ *Task completed and results are included in this report.*

Tasks A to C were scheduled to be completed in June 2005 and to be followed by:

D. Segment the 300 analyzed lane-miles by following a procedure (described in the minutes) that accounts for administrative units, pavement structure, climate region, traffic loading, and condition survey, and ride quality data. Complete this item in August 2005.

→ *Task completed. PPRC performed a preliminary segmentation of the network based on traffic, climate, pavement structure (based on GPR data and verified by selected as-builts and GPR core data), condition survey, and International Roughness Index (IRI) data. The results are included in this report.*

Additional scope added to the project later by Caltrans Maintenance includes the following tasks.

E. Extract historical condition survey and IRI data from the Caltrans PMS database for the 300 analyzed lane-miles.

→ *This task has been completed using the last available Caltrans Pavement Condition Survey (2003–2004) based on the fixed segmentation completed as part of Task D and included in this report. Additional condition survey and IRI data are being extracted as part of the PPRC Strategic Plan Item 3.2.5 from previous years and maintenance and rehabilitation histories. A separate report will be delivered.*

F. Check the accuracy of performance prediction models being developed as part of Item 4.5 of the *Strategic Plan* for asphalt overlays on asphalt pavement, and IRI of flexible and rigid pavement against extracted condition survey and IRI performance histories.

→ *Completion of this task is not guaranteed because of the dynamic segmentation present in the California PMS condition survey data. The data collected under Task E as part of the PPRC Strategic Plan item 3.2.5 will be used in the attempt to complete this task, which is scheduled to be completed in March 2006.*

2.0 BACKGROUND

Adequate segmentation of a highway network is fundamental for the successful utilization of a Pavement Management System (PMS), in particular for the use of pavement deterioration models. The homogeneous segments resulting from the segmentation process need to have a consistent traffic level and a comparable pavement structure, and need to correspond to a single climate region. (Section 2.1 presents a detailed discussion of pavement segmentation.)

A key part of the segmentation process is the pavement structure, in terms of materials and layer thicknesses. Since Caltrans does not presently have adequate inventory information about the pavement structure throughout the network, the feasibility of using ground-penetrating radar (GPR) for this purpose is being evaluated. A brief literature review on GPR is presented in Section 2.2.

2.1 Network Segmentation for Pavement Management

Long pavement segments in a PMS will generally be less uniform in composition (i.e., there will be more variation in pavement structure, condition, and other attributes within a segment) than short segments. However, short segments require more data storage space because of the increased number of segments. The final decision on size and method of segmenting should be based on selecting pavement segments that Caltrans will consider as single entities when planning maintenance and rehabilitation. The smallest number of segments that can adequately define the road network will be the most economical and easiest to maintain.

As outlined in a previous report (Lea and Harvey 2002), Caltrans first implemented a PMS in 1977, when the concept of pavement management was relatively new and computers were not as powerful as they are today. Over the subsequent twenty-five years, advances in computer technology and significant changes in the theory and practice of pavement management have changed the way pavements are maintained by Caltrans. These changes have led to the slow evolution of the Caltrans PMS database and its use within the agency. In today's PMS literature, the Caltrans system would be referred to as a maintenance management system because it is geared toward providing information for short-term maintenance activities rather than long-term pavement performance assessment and modeling as well as optimization of expenditures for the pavement network.

2.1.1 Performance Modeling

Performance modeling using PMS field data is essential for continuous improvement of two key Caltrans pavement management tasks at the network level:

- Predicting future performance of segments of the network. "Performance" refers to pavement surface distress in the annual condition survey and ride quality (IRI). Future performance is predicted using models of distress and ride quality as functions of existing condition, structure, traffic, and climate, and maintenance and rehabilitation strategy selection.
- Identifying the most cost-effective maintenance and rehabilitation strategies based on life-cycle costs. Life-cycle costs can be calculated for different conditions across the state network, but the calculation requires the models described above to predict performance at the network level plus cost data for each strategy.

At the network level, performance models derived from observations are "empirical." A pavement performance model becomes "empirical-mechanistic" when the explanatory variables are selected based on the mechanics of pavement damage. To make these models useful for Caltrans management, they must be calibrated using PMS field data. Compared to project-level design, inputs for network performance modeling (structure, traffic, and climate) need a lower level of detail. Collecting data across the network with project-level detail would be cost-prohibitive.

Project-level PMS data for specific segments of the network is needed for calibrating "mechanistic-empirical" design procedures, which rely more heavily on pavement damage mechanics theory. Detailed data for pavement structure, traffic, climate, materials, and construction quality must be collected from the segments in order to predict their performance. Those models must then be calibrated using historical PMS condition survey and ride quality data.

2.1.2 Challenges to Pavement Modeling Using the Current PMS Studied in This Project

As mentioned at the beginning of this report, three crucial aspects of the current PMS are addressed in this project to enable performance modeling (at the network level) and to calibrate design procedures (at the project level).

1. The use of “dynamic segmentation,” which constantly shifts frame of reference;
2. Lack of inputs needed for modeling, because the PMS does not contain data about subsurface pavement structure; and
3. Inadequate quantification of pavement distresses, as some parameters in the Pavement Condition Survey (PCS) do not relate to pavement distress mechanisms or, if observed, are only identified as present but are not measured.

The current Caltrans PMS staff inherited a “dynamic segmentation” procedure established in 1977 in which pavement is not evaluated over fixed lengths. Instead, the pavement is divided into segments that have similar distress at the time of each assessment. Consequently, both the segment’s length and its starting point and its ending point change from year to year. As a result, a given pavement section is often identified as appearing in a different segment from one year to the next. Often, segmentation from year to year changes based solely on the effects of short-lived maintenance treatments that do not change the pavement cross section. Therefore measured distresses and ride quality in the PMS database can vary as a function of segmentation, depending on which sections of pavement are grouped together within the segment. Although this is a good approach for scheduling maintenance, it does not lend itself to statistical sampling of observed performance data or to predicting performance over time. It may also result in inefficiencies for scheduling the rehabilitation of parts of a section as they fail over several years; in reality, the entire section of which they are a part might be failing. Effective performance modeling requires a network of “fixed segments,” reasonably consistent pavement variables (e.g., structure, traffic, climate), and similar maintenance and rehabilitation history.

The second challenge arises from the biggest problem with extracting pavement performance information from the database: the database contains little information regarding pavement structure. In some cases it contains data specifying whether the pavement surface is flexible (asphalt concrete) or rigid (portland cement concrete). In other cases, the database contains a generic description of apparent mix type, such as open-graded or dense-graded asphalt. Missing are data about the true materials and layer thicknesses beneath the surface, which are among the most important variables that explain pavement performance. Without these, pavement performance models often give useless results or incorrect results.

The third challenge arising from the current PCS that Caltrans uses comes from its inclusion of several variables whose presence or absence is noted but not measured, and from others that have no meaning in terms of pavement distress mechanisms. This challenge can be met by making some relatively minor changes in the PCS.

2.2 GPR Technology

2.2.1 Brief Description of the Technology

Ground-penetrating radar (GPR) pavement-related technology, which was developed during the Strategic Highway Research Program (SHRP), operates by transmitting short pulses of electromagnetic energy into the pavement. These pulses are reflected back to the radar antenna with an amplitude and arrival time that is related to the thickness and material properties (dielectric constant) of the pavement layers.

GPR technology has the potential of being extremely useful for pavement management, allowing highway agencies to quickly collect inventory data on all pavements under their jurisdiction. Because GPR data collection is nondestructive, it substantially reduces the need for frequent full-depth pavement coring. Thickness determination of existing pavement layers employing GPR is standardized in ASTM D4748.

GPR is a high-resolution geophysical technique that utilizes electromagnetic radar waves to scan shallow subsurfaces, to provide information on pavement layer thickness or to locate targets. The frequency of the GPR antenna affects the depth of penetration into the pavement. Lower-frequency antennas penetrate further than higher frequency ones do, but the latter type yield higher resolution. To successfully provide pavement thickness information or to scan an interface, the following conditions have to be present (Noureldin 2003): (1) The physical properties of the pavement layers must allow for penetration of the radar wave, (2) the interface between pavement layers must reflect the radar wave with sufficient energy for it to be recorded, and (3) there must be a significant difference in the physical properties of the layers separated by interfaces.

In NCHRP Synthesis 255 (see References) the capabilities of GPR systems are listed as:

- Asphalt layer thickness determination: GPR results are used to estimate thickness to within 10 percent; GPR accurately measures thicknesses of up to 0.5 m.

- Base thickness determination: Thicknesses are estimated, provided that a dielectric contrast between the base and subgrade exists. (The best results occur when the subgrade is made up of clay soils, which are highly conductive compared to sands or gravels.)
- Concrete thickness determination: Depth constraints and accuracy are not yet well defined. This is because portland cement concrete attenuates GPR signals more than asphalt does; PCC conductivity changes as the cement hydrates; reinforcing steel contained in slabs makes interpretation difficult; and the dielectric contrast between PCC and the base may not be adequate for reflection detection.
- Void detection: Although GPR has detected air-filled voids as thin as 6 mm, the detection of water-filled voids is more problematic.

2.2.2 Recent Experience with GPR by Caltrans and Other State DOTs

As nondestructive testing has become an integral part of pavement evaluation and rehabilitation strategies in recent years, Caltrans and other state highway agencies have looked into GPR technology for network inventory and at the project level.

2.2.2.1 Caltrans

An evaluation of GPR and other non-destructive techniques for pavement thickness evaluation was carried out for Caltrans by Infrasense, Inc (2003). The work focused on determining quality control accuracy in newly constructed asphalt and concrete pavements. The work involved theoretical analysis, laboratory testing on small slabs and simulated pavement materials, testing at full-scale testing facilities, and actual testing on recently constructed pavement sections in California. The actual testing was carried out on eleven selected pavement sections, six of asphalt and five of concrete. Test sections were 305 meters (1,000 feet) long. The asphalt sites were selected to represent three main conditions: (a) thick and thin asphalt on aggregate base; (b) asphalt on concrete; and (c) thick and thin asphalt overlays. The concrete sites were selected to represent variations in concrete thickness and age. Age was selected as a variable because of its influence on GPR penetration and on the mechanical wave velocity. The asphalt sites were tested with the horn antenna (typical GPR test) method and the common midpoint, (or CMP, a semi-static GPR) method. The concrete pavements were evaluated with two different impact-echo devices, along with the CMP method. After this evaluation, cores were taken for comparison with the test data. Twenty cores were taken at each asphalt site and ten at each concrete site. The thickness values determined from the various test methods were compared to the core values. The comparison showed generally good correlation, but at each site a calibration was also needed. One core location per site was selected for calibration.

For asphalt pavement, the GPR was found capable of measuring the average section thickness to within 2.5 mm (0.1 inches) of the average core value. This level of accuracy was not achieved on concrete pavements.

2.2.2.2 Indiana

In 2001 the Indiana DOT (Noureldin et al 2003) conducted experimental evaluation of the GPR for network inventory by taking measurements at sections in five interstate highways (I-64, I-65, I-69, I-70, and I-74), five U.S. highways, and nine state routes. GPR was used to test the truck lane for both directions of traffic (east-west or north-south) of each selected roadway at highway speed. Although GPR can display pavement layer thickness continuously, it was decided to collect thickness data at only five incremental locations (every 1,000 ft, or 300 m) of each mile. As part of the study, the researchers also obtained an estimate of the total pavement thickness using FWD testing, which complemented data from the GPR tests regarding the thickness of the top surface portion of the combined surface layers. Top surface portion thickness information is very important for situations in which mill-and-fill operations are needed. The GPR estimates of concrete pavement thickness, of hot mix asphalt (HMA) thickness of flexible pavements, and HMA thickness of composite pavements matched almost perfectly. GPR thickness estimate of pavement layers underneath these layers was not as accurate and needs adjustment through very limited coring. GPR did not provide any estimate of unbound pavement layers or of total pavement thickness.

The relevant conclusions of the study are the following:

- Network-level testing employing the FWD and GPR is a worthwhile, technically sound program that provides a baseline of the structural capacities of in-service pavements.

- GPR is not expected to completely eliminate the need for coring, although GPR can be used to establish the coring requirements, fill the gaps in thickness estimation, and verify thickness results.

2.2.2.3 Virginia

Al-Qadi et al. (2005) report that GPR was used to evaluate the layer thicknesses of seventeen pavement sites of different types (flexible, continuously reinforced, and jointed plain concrete) and different pavement ages (up to five years old, between ten and fifteen years old, older than twenty years with a surface less than ten years old; and older than twenty years with a surface older than ten years). The sites were located in different parts of Virginia on major interstates and high traffic-volume roads.

Analysis of the GPR data collected from all sites showed that for flexible pavements, the GPR thickness error increased with pavement age (4.4 percent error for pavements up to five years old to 5.8 percent error for pavements older than twenty years with surfaces older than ten years). Comparison of sites of the same age but with different pavement types showed that flexible pavements had a relatively high thickness error, while the jointed plain concrete pavement (JPCP) had the lowest thickness error. This could be mainly due to the presence of thin HMA layers in flexible pavements (these layers are significantly smaller than the GPR signal's wavelength) as well HMA layers of different ages. GPR considers layers with the same dielectric constant as one homogeneous layer, thus sometimes introducing an error in the thickness computation.

The study concluded that the error produced in predicting the thickness of HMA and concrete is very reasonable, and that GPR accuracy in predicting pavement layer thicknesses surpasses other available techniques — with the exception of coring, which is time-consuming, has a very low coverage area, and is considered a destructive technique that requires traffic closures.

2.2.2.4 North Carolina

In North Carolina (Corley-Lay and Morrison 2001), thirteen LTPP (Long Term Pavement Performance) sites were tested one or more times with GPR to obtain layer thickness variability over 152.4-m (500-ft) test sites. Duplicate runs were made on the same day on one of the sites, and these paired tests were compared after the GPR data were processed. Five of the sites showed good agreement with a Student's *t*-test. Asphalt layers for the sites varied in average thickness between 89 mm and 292 mm (3.5 and 11.5 in.). Thinner asphalt layers tended to have lower coefficient of variation when the asphalt thickness was less than 152 mm (6 in.). The standard deviation was generally less than 25 mm (1 in.).

2.2.2.5 Other DOT agencies

Other DOT agencies recently involved in verification of GPR technology are New Jersey (Gucunski 2004), Missouri (Cardimona 2003), and Kentucky (Willet 2002). They report good results for thickness determination. The Florida and Texas Departments of Transportation both own GPR equipment. The Florida DOT uses GPR primarily to establish pavement thicknesses. In Texas, the Materials Division of the Texas Transportation Institute (TTI) has developed performance specifications and test procedures for GPR systems. TTI has also developed a GPR training program that has been used to train Texas DOT personnel in the two state districts that own and use GPR.

3.0 DRAFT SEGMENTATION

The initial step in the segmentation pilot project was to identify highways and routes to be analyzed in the study. A total of eight roadways were selected: three interstate highways (I-5, I-505, and I-80), four state routes (SR-16, SR-45, SR-99, and SR-113), and one U.S. highway (US-50). The roadways chosen are mostly in District 3, except for the the I-80 section and the sourthern part of the I-505 section, which are in District 4. The research team selected these roads, which span five counties, for the pilot program because they believed that the extent and diversity of their pavement sections fairly represented the entire state network. Only one lane per selected route was chosen. For GPR purposes, the eight routes were converted into the twelve sections — totaling 305 lane-miles — listed in Table 1. Figure 1 shows the pilot sections with respect to the whole state network; Figure 2 shows the exact testing locations on a partial map of the state overlaid with a GPS generated map (using GPS coordinates obtained during the GPR testing).

The segmentation process consisted of dividing the pilot network into homogeneous segments based on administrative boundaries, traffic load, climate, pavement structure, and pavement condition.

Table 1. Initial Sections for Segmentation Pilot Project

ID	Route	County	Description	Dir.	Lane	Length (mi)
CAL009	SR-99	Sacramento	US-50 to San Joaquin Co line	SB	Out	25
CAL011	I-5	Sacramento	US-50 to San Joaquin Co line	SB	Out	24
CAL013	SR-99	Sacramento/Sutter	From I-80 to SR-70 split	NB	Out	16
CAL015	SR-113	Yolo	From Davis to Woodland	NB	Out	11
CAL017	I-5	Sacramento	Yolo/Colusa line SR-113	SB	In	21
CAL031	I-80	Solano	Solano County	WB	Out	45
CAL033	I-5	Sacramento/Yolo	SR-113 to SR-99 split	NB	Out	13
CAL035	SR-16	Colusa/Yolo	Woodland to SR-20	WB	Out	48
CAL041	I-80	Solano	Solano County	WB	In	45
CAL047	US-50	Sacramento	Sunrise Blvd. to El Dor. Co line	EB	Out	11
CAL049	SR-45	Yolo	Yolo County	SB	Out	13
CAL050	I-505	Solano/Yolo	I-5 to I-80	SB	Out	33

Figure 1. Location of roadways in relation to the entire network.

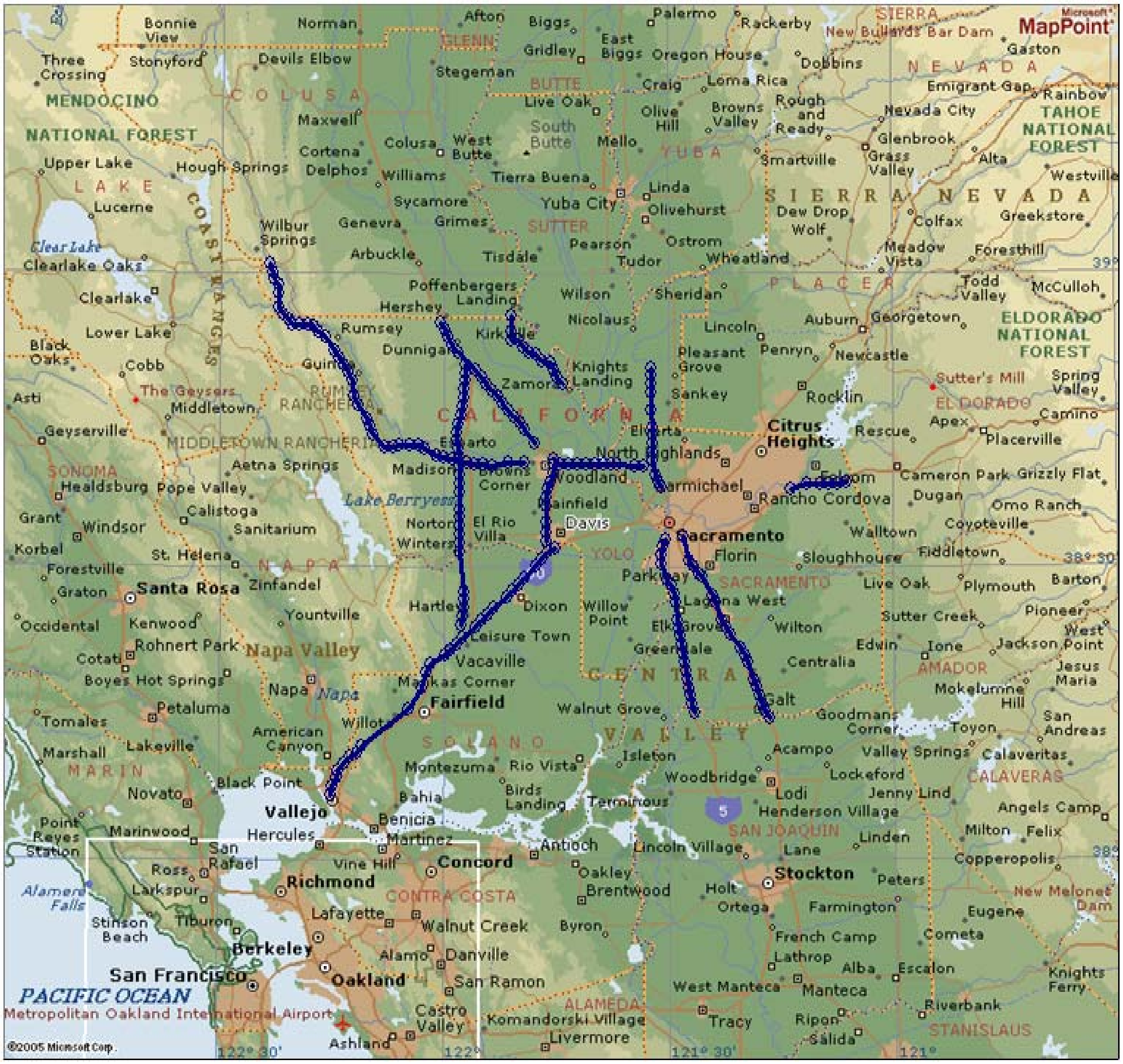

Figure 2. Location of roadways in North Central, California.

The segmentation procedure consisted of five consecutive passes through the network to progressively break down the entire length of the roadways into segments that share common attributes. Section 0 presents the details of the data utilized in the segmentation of the pilot project and the effort involved completing the tasks. *[Note:* The segmentation process was modified with respect to the minutes of the meeting on August 30, 2004 (see Appendix A)]. Review of the data collected resulted in a change in the order of the segmentation passes and in the decision not to use condition survey data in the process. Condition survey data was not used because it was found to be less important for segmentation than originally thought due to its temporary nature. The segmentation process was as follows.

3.1 Administrative Boundaries

The first segmentation pass consists of dividing the roadways into units based on district and county boundaries. This step is based on past Caltrans practice of programming rehabilitation at the district and county levels, which has resulted in different structures on each side of boundaries.

In the pilot project, this pass meant dividing I-505 at the line between District 4 and District 3, and dividing SR-99 and I-5 at the Sacramento/Sutter and Sacramento/Yolo county lines, respectively. This step increased the number of pavement segments to fifteen from twelve.

3.2 Traffic

The researchers divided segments within counties if there was a significant change in traffic loading between them, hence major intersections served as natural boundaries between sections. Intersections are permanent physical reference points that also help in locating the sections in the field and can be used for assigning names to the sections they separate. Traffic data is also required for assignment of priorities during the selection of rehabilitation projects. The current Caltrans highway traffic database was used.

Dividing the network according to changes in traffic increased the number of sections from 15 to 173. The process included intersections that do not currently affect traffic in the route but that could eventually grow and become significant. The length of the new segments ranged from 0.10 miles to 7.12 miles, with approximately 50 percent of them being less than 1.25 mile.

3.3 Pavement Structure

The next step was to divide sections with similar traffic into units that had comparable pavement structure. This includes the surface types and the number and thickness of the layers that constituted the pavement. Ideally the construction history would have been used to identify the materials and the age of the pavement sections, but this information was not available for most sections. Sources checked included as-built records, deflection study reports, and major maintenance archive files.

The thicknesses obtained through the GPR testing on all the roadways, combined with some as-built drawings and existing knowledge of the pavements, permitted the research team to differentiate the sections at the points of change in their structure. The method used at this stage for identification of the point of change was visual and without a statistical analysis because in most cases the GPR data showed a clear distinction between sections that needed to be separated. Statistical algorithms for automatic detection of changes based on GPR pavement structure data will be tested later when checking performance of segments. Figure 3 shows an example of GPR thickness and material for the section on I-5 SB (southbound) in Sacramento County. At postmile 21.80 there was a change in AC thickness (thickness on one side is approximately 5.7 inches and on the other it is 8.4 inches).

The figure also shows the IRI and cracking data from the 2003–2004 PCS. The figure shows alligator cracking data from the PMS database, which illustrates a problem for the Pavement Condition Survey caused by the lack of structural data in the PMS. Alligator cracking was surveyed because the surface of the pavement is asphalt; however, alligator cracking can never occur in this pavement because it is a composite pavement consisting of an asphalt overlay of PCC. The pavement condition surveyor has no way of knowing that this is a composite pavement from the information available in the PMS. There is no option in the PCS for evaluating a pavement as a Composite pavement, only Rigid or Flexible. Composite pavements make up a significant portion of the Caltrans network, and made up 20 percent of the lane-miles in this pilot project. Reflection cracking, the most common distress occurring on composite pavements, is not included in the PCS.

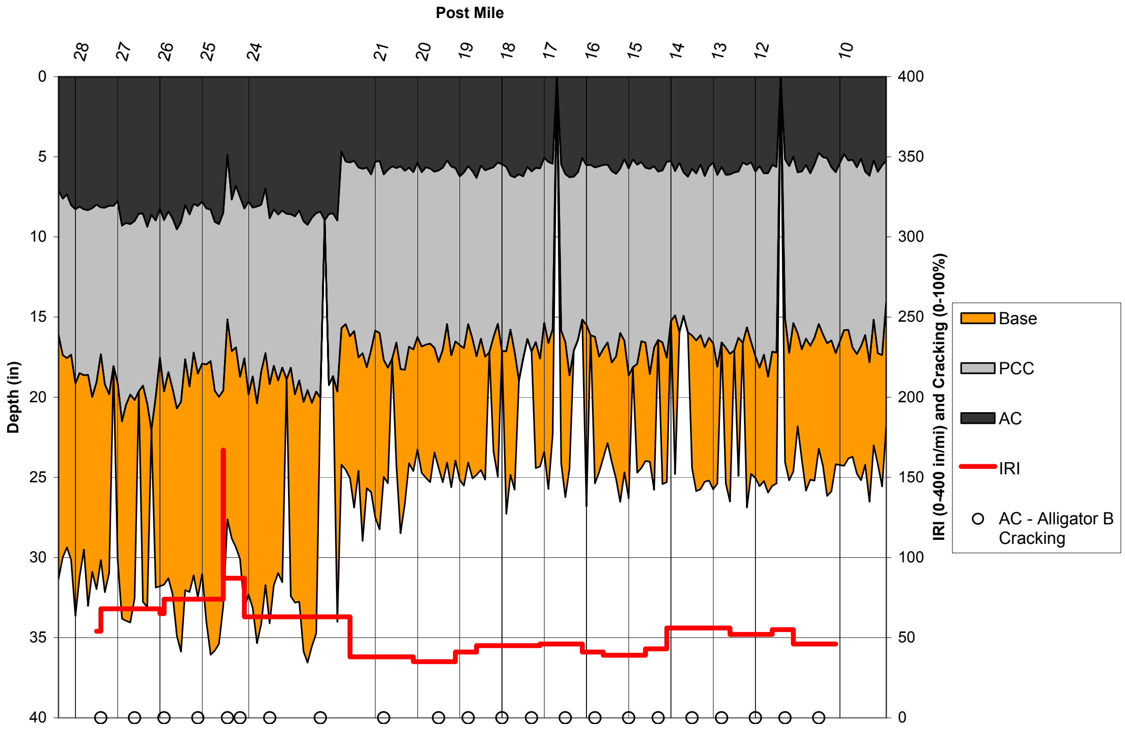

Figure 3. Example of GPR data taken on a GPR section of I-5 in Sacramento County.

After the segmentation by pavement structure was done, the total number of segments increased from 173 to 236. The length of the new segments remained between 0.10 and 7.12 miles, but the average length decreased from 1.68 miles to 1.27 miles. Approximately 50 percent of the resulting segments at this point were shorter than 1.05 miles.

3.4 Climate Region

Differing climate regions (per the Caltrans Climate Region Map, June 2005) were used as a segmentation pass. Most of the sections were contained within the Inland Valley (IV) climate region. The exception was the westernmost ten miles of I-80 in Solano County, which is in the Central Coast (CC) climate region. This pass resulted in one additional segment, increasing the total to 237..

3.5 Condition Survey

The last pass of the segmentation process was to divide the section into homogeneous units from the standpoint of pavement condition. However, analysis of the condition survey data indicated that to rationally partition segments, consistent condition survey data over several years would be necessary, and rehabilitation and maintenance records were needed to explain changes in observed distresses. These could not be obtained within the schedule for this project. In the end, distress and IRI data may not be needed to further divide the segments if the performance and histories show that the segmentation-based administrative boundaries, traffic, pavement cross section, and climate region result in reasonably homogeneous sections with relatively uniform performance within them. Charts with GPR structure results and data from the 2003 Pavement Condition Survey are presented in Appendix C.

The decision not to segment based on condition survey data is further supported by the temporariness of certain maintenance procedures that may conceal existing damage. For example, a slurry seal on a portion of a segment that has uniform structure, traffic, and climate region, and has alligator cracking across its entire length, may show zero alligator cracking in the PCS data for a portion of it because of the seal. However, the cracking remains and will come through the slurry seal after several years. Segmentation based on PCS data such as this may add inaccuracies to the process as time wears through various temporary maintenance solutions.

The segmentation is presented in Appendix D in the form of a table containing the postmiles and the physical references for the resulting segments.

4.0 DATA REQUIREMENTS AND RESOURCES INVOLVED

A variety of data were collected and analyzed for the segmentation process. Sources included private contractors, Caltrans documents, field work data, and project records.

4.1 Pilot Study

Resources employed in the segmentation of the pilot network are as follows.

4.1.1 Traffic Database

A record of the most recent traffic counts can be found on the Caltrans website.[4] Included in the database is the average annual daily traffic (AADT) at certain intersections, political boundaries, and other unique landmarks, along with the corresponding postmiles. The points defined in the traffic log created definitive segments: in the urban areas, these segments tended to be between 0.1 mile and 4.0 miles long; in rural areas, the segments could extend over 30 miles. For the GPR sections covered by the PPRC in this study, the traffic sections typically remained small and only a few extended beyond 5.0 miles long. None of them was over 10 miles long.

This data was used as the second pass for the segmentation, as explained in Section 3.0. A Microsoft *Excel* version of the database is available on the web so no conversions are needed in order to manipulate the data for this project. Once downloaded, locating the desired sections is straightforward and takes very little time. For the twelve GPR sites considered in this pilot study, the process took about three person-hours.

4.1.2 GPR Data

4.1.2.1 GPR data collection and equipment

GPR data was collected at a density of one scan per linear foot of travel. Although this may seem excessive for network-level work, this data rate is desirable for two reasons: (1) according to the contractor, pavement type (JPC, CRCP, AC/PCC, etc.) is more easily identified with denser data; and (2) the data will be available for future project work where the denser scan spacing might be more desirable. The data from this project have already been used for project-level analysis of SR20, providing thicknesses for backcalculation of foamed asphalt stiffnesses.

The GPS system operated concurrently with the GPR data collection. GPS coordinates were recorded once per second with the current GPR scan number in a separate position log file.

Data was collected at speeds of up to 60 mph. Two-hundred-and-fifty-six samples were taken during 20 nanosecond scans using 16-bit data resolution. The 20-nanosecond range provided the potential for layer-depth information capability down to 36 inches. This depth generally exceeds the penetration capability of the GPR equipment.

The GPR equipment used on this project included a GSSI SIR-20 radar control and data acquisition unit, a Model 4108 1-GHz horn antenna, mounting equipment, and an electronic distance-measuring instrument (DMI) attached to the vehicle wheel (see Figure 4). The DMI had a resolution of 500 pulses per foot. The GPR equipment was approved and licensed by the FCC. Also included was Trimble Model AG114 GPS, or an equivalent system, for recording GPS coordinates. This GPS system provided submeter accuracy when used in a differential mode in conjunction with the Omnistar service. According to the manufacturer's specifications, the GPS data obtained with this service is in NAD83-compatible format.

Figure 4. GPR equipment used on this project.

GPR data was analyzed by the contractor at 0.1-mile intervals — based on the vehicle DMI — beginning at the county line or other marked reference point in each test section. GPS coordinates were reported for each GPR data point analyzed. When the 0.1-mile interval point fell on a bridge deck (this was easily identified in the GPR data), a neighboring location on either side of the deck was selected.

The results of the GPR analysis were provided in Microsoft *Excel* data files, one for each section. The data reported at each location represents 200 feet of pavement, ±l00 feet on either side of the reported location. Exceptions to the 200-foot length occurred when there was a bridge deck or other anomaly in the pavement structure within the ±l00-foot interval. Where this occurred, the interval was shortened to include only the pavement representative of the local area.

Within each file, there are five columns for each analyzed layer, and up to four layers analyzed. The five columns for each layer are described as follows:

- Layer type (e.g., AC, PCC, base),
- Layer thickness (average of 200 feet, in inches),
- Layer dielectric constant (average of 200 feet, no units),
- Layer thickness standard deviation over 200-foot length (inches), and
- Layer confidence.

The contractor assigned a number from one to four to each analyzed data point to reflect his degree of confidence. An explanation of the numbering code follows:

1. Layer boundary and type is clear.
2. Layer boundary is unclear – calculated thickness may be affected.
3. Layer type is unclear – best assessment, but it is possible that identified type is incorrect. For example, assigning a “3” to layer 2 when it is suspected to be AC but might be Base.
4. A combination of 2 and 3.

4.1.2.2 GPR cost

Infransense, Inc., the contractor providing the GPR information, charged $30,923 for 305 lane-miles of data, which included planning, mobilization, and the collection and analysis of the raw data. The per-mile cost of data collection was $16.48, while the per-mile cost of analysis was

$51.15. The cost of planning and setup was $1,720; the cost of mobilization and demobilization was $8,575.

4.1.2.3 Plotting results for segmentation

The GPR data received from the GPR contractor were easily plotted using Microsoft *Excel.* Creation of charts showing cross sections of the twelve sections took eight person-hours.

4.1.2.4 Identification and segmentation of structure changes

Depth trends in the plotted GPR data are visually evident in most cases, making identification of major structure changes possible by inspection. Material-type recognition by dielectric constant is not an error-proof process and therefore uncalibrated GPR results do not always properly identify material type. Structure changes based only on material type are difficult to distinguish.

Once structure changes were identified on the charts, the exact corresponding postmile was located in the GPR data and recorded in the segmentation database. Visually identifying the structure changes, locating the precise point of the structure change in the GPR database, and segmenting based on the structure changes took approximately 30 person-hours.

4.1.3 Coring

Coring was completed for thirteen sites: Twelve in District 3 and one in District 4. The sites were cored on nine days between July 7 and September 16, 2005. Closures were performed by Caltrans district Maintenance personnel. The internal cost of these closures to Caltrans is not known. From UCPRC experience, a private contractor would charge approximately $2,000–$3,000 per day for the closures.

A crew of six people was necessary for this work. The crew was responsible for running the coring machine, using the Dynamic Cone Penetrometer (DCP), recording data, and backfilling the core-holes. Including travel, setup, and breakdown, this took approximately 60 person-hours. The DCP provided data regarding layer thicknesses below the depth of cores. Details on the coring are presented in Section 5.1.

4.1.4 As-builts

An attempt was made at collection of as-built information for the GPR sections. Caltrans has provided UCPRC with a limited number of as-builts. District offices were visited to find additional as-builts. However, many segments did not have as-built records because of age, lost documents, and work that has been performed but not recorded. Depending on the organization of records and the availability of the necessary documents, this task could take up to 16 person-hours.

4.1.5 Climate

Most GPR segments for this project were located in the Inland Valley climate region, with two sections split between the Inland Valley and Central Coast regions .Segmentation based on climate boundaries is simplified by the Caltrans Climate Map, making time-demand for this step negligible (zero person hours). Caltrans Maintenance has developed a map that defines the exact postmiles that define boundaries between climatic regions on each route for nearly the entire state.

4.1.6 Condition Survey and IRI

Condition surveys, which include the IRI, are available from the Caltrans Pavement Management System (PMS) database. Though the GPR sections have not been segmented based on the condition survey data, the pavement condition has been entered into the GPR database and it has been used to generate charts for comparison showing pavement condition alongside the GPR results. The plotted data includes the IRI, alligator B cracking (AC), and third stage cracking (PCC).

The raw data from the PMS database needed to be converted into a manageable format, which took about 10 person-hours. This task was completed for the whole state highway network. Loading the PMS data into the GPR database and outputting the resulting plots took another 20 person-hours. In sum, the condition survey data took 30 person-hours.

4.1.7 Database

Development and population of the database for the pilot segmentation project took place at the same time that the data was being retrieved from all the sources. A nominal one person-hour is being accounted for database handling.

Information collected for segmentation is currently stored in *Excel* with location identifiers tied to the distance measured from nearest physical reference, such as structures or paddles, for which the exact GPS coordinates have been obtained. Soon, the data will be loaded into a relational database *(Access)* and delivered to Caltrans.

4.1.8 Summed Effort

The estimated time spent on the segmentation process for the twelve GPR sites sums to 148 person-hours. Other costs include the contract costs for the GPR ($30,923 for 305 lane-miles), lane closures (estimated to be between $14,000 and $21,000 if done by a private contractor), materials for coring (bits, backfill, etc.) and various travel costs.

4.2 Extrapolated Cost and Effort to Whole Network

The Caltrans *2003 State of the Pavement Report* states that there are over 49,000 lane-miles of pavement in the California highway network. If segmentation of 305 lane-miles requires 148 person-hours, then the whole network would take nearly 24,000 person-hours to complete. This amount is approximately 12.30 PY (assuming 1,940 hours per year). At an estimated rate of $94.43 per mile, the GPR data collection, analysis, and calibration, the cost for contracting the GPR testing over the entire network would be approximately $4.63 million, not including mobilization. If mobilization is assumed to be 12 percent of the cost of testing, then the total estimated cost of GPR testing and analysis can be considered $5.2 million.

The cost of lane closures needs to be added to that amount. At an assumed rate of $3,000 per day, and considering about 600 days of closures to complete all the required coring, the cost would be $1.8 million. This brings the total direct cost to an estimated $7.0 million. The direct cost and personnel needed are shown in Table 2.

Table 2. Personnel Needed and Direct Cost for Segmentation of Pilot Study and Estimated for Entire Caltrans Network

Item	Pilot study 305 lane-miles (actual)	Caltrans network 49,000 lane-miles (extrapolated)
Personnel	0.076 PY	12.30 PY
Direct cost	$48,500	$7,000,000

The actual direct and personnel cost, both for field (coring and GPR) and office work, will likely be less than the figures stated above. Time spent retrieving data and segmenting based on that data will drop significantly as personnel become increasingly proficient at the process. Also, the cost per lane-mile of GPR measurement and analysis will decrease if a bid system to determine the lowest price can be implemented.

It must be noted that the pavement structure database for the PMS that could be created by a GPR project would lose its value over time unless it is routinely updated with accurate information regarding the changes to pavement structures caused by future rehabilitation, maintenance, and reconstruction.

5.0 DISCUSSION OF RESULTS FROM THE PILOT PROJECT AND REMAINING WORK

5.1 Utilization of Coring Data

5.1.1 Core Sites

The coring for the GPR was completed on September 16, 2005. A total of 43 cores were extracted from 13 sites in Districts 3 and 4. The original plan called for 16 sites with a total of 65 cores. The difference between these numbers is due to scheduling problems for the Caltrans Maintenance force and time constraints that arose in the field. A summary of the coring locations is shown in Table 3.

Table 3. Final List of GPR Coring Locations

Closure No.	Section ID	County	Route	Direction	Start	End	Coring Date	No. of Cores	Data Given to Infrasense?
1a	CAL050	Solano	505	SB	8.10	8.40	9/16/2005	4	X
1b	CAL050	Solano	505	SB	5.00	5.40	Cancelled – time constraints in the field		
2	CAL013	Sacramento	5	NB	27.70	28.22	Cancelled – could not get closure		
3	CAL013	Sutter	99	NB	5.68	6.18	Cancelled – could not get closure		
5	CAL015	Yolo	113	NB	2.89	3.20	8/22/2005	6	X
5a	CAL015	Yolo	113	NB	8.40	8.70	8/25/2005	3	
9	CAL047	Sacramento	50	EB	17.20	17.50	7/7/2005	4	X
10	CAL047	Sacramento	50	EB	20.01	20.31	7/11/2005	4	
11	CAL049	Yolo	45	SB	10.80	11.10	8/24/2005	4	X
12	CAL049	Yolo	45	SB	7.82	8.12	8/25/2005	4	
12a	CAL049	Yolo	45	SB	9.00	9.30	8/24/2005	4	
14	CAL009	Sacramento	99	SB	8.86	8.96	7/13/2005	2	X
15	CAL009	Sacramento	99	SB	6.26	6.36	7/21/2005	2	
16	CAL035	Colusa	16	WB	3.04	3.14	7/25/2005	2	X
17	CAL035	Colusa	16	WB	1.84	1.94	7/25/2005	2	X
18	CAL035	Colusa	16	WB	0.64	0.74	7/25/2005	2	

Most sites were chosen by Infrasense, Inc., and confirmed by the UCPRC. Sites were chosen based on abrupt changes in the apparent pavement structure and uncertainties in the GPR data. Two sites (Closures 5a and 12a) were chosen strictly by the UCPRC for control purposes.

5.1.2 Determining Exact Core Locations

Determining exact core locations was critical to the success of the project. Cores taken in the field needed to be matched up with the GPR results for exactly the same location so that an accurate comparison of the two could be made.

Infrasense provided location data relative to a local physical reference at each site. This data included a unique local reference point, distances from the reference point, and GPS coordinates. Physical references were Caltrans postmile paddles, bridge decks, and obvious changes in surface material (i.e., from PCC to AC overlay). Examples of this data appear in Table 4.

Table 4. Selected Coring Locations and Physical Reference Points

Closure No.	Section ID	County	Route	Dir.	Approx PM	Local Physical Reference	Dist from Ref. (ft)	Latitude (ddmm.mm)	Longitude (dddmm.mm)
10	CAL047	SAC	50	EB	20.21	SAC RP 20	1113.00	3838.523859	12108.28717
10	CAL047	SAC	50	EB	20.31	SAC RP 20	1641.00	3838.528628	12108.17718
9	CAL047	SAC	50	EB	17.20	E Joint Bridge Deck	377.00	3838.402881	12111.69367
9	CAL047	SAC	50	EB	17.30	E Joint Bridge Deck	905.00	3838.416024	12111.58439
9	CAL047	SAC	50	EB	17.40	E Joint Bridge Deck	1433.00	3838.429634	12111.47536
9	CAL047	SAC	50	EB	17.50	E Joint Bridge Deck	1961.00	3838.443318	12111.36599
10	CAL047	SAC	50	EB	20.01	SAC RP 20	57.00	3838.513709	12108.50724
10	CAL047	SAC	50	EB	20.11	SAC RP 20	585.00	3838.518535	12108.39712

In the field, core locations were marked using a digital survey wheel taken from a given local reference point. GPS measurements were taken at each core and used as a distance check once the data was entered into the database. The database shows discrepancies between Infrasense's GPS coordinates and the UCPRC's field GPS coordinates ranging from 4.7 feet to 158.6 feet. These values can be found in Table 9 of Appendix F. Possible reasons for the discrepancies include:

- Inherent inaccuracies in the UCPRC GPS receiver, which did not have differential capability (this device provided a typical error of ±3m, with extreme error up to ±30m at some locations.);
- Inexact physical reference locations measured by Infrasense;
- On-the-fly measurements may be prone to inaccuracies;
- Mileposts were not necessarily in the same location in each direction;
- Equipment malfunction;
- Survey wheel was decommissioned by the UCPRC after CAL015 sites because of malfunctions that might have affected previous sites; or
- Other human errors.

The "Approximate Postmiles" were used as a check to ensure coring was done in the right vicinity. They were also used to coordinate the closures with Caltrans maintenance yards. Infrasense calculated the postmiles as a distance from certain physical features, such as paddles or county lines. Because of the complexities in the Caltrans postmile system (equations, inaccuracies, etc.), coring locations were recorded independently of the approximate postmiles.

5.1.3 Core Results

Core layer thicknesses, layer material types, and DCP results were disclosed to Infrasense for the seven sites noted in Table 3. This data was used by Infrasense to verify and calibrate both their thickness and material-type results. After a review of the core data disclosed to them, Infrasense determined that a systematic calibration was not necessary. However, the following changes were made to CAL15-5 by Infrasense:

- Layer 2 thickness (PCC): Reduced by 12%;
- Revised GPR data locations to match UCPRC core locations — shifted ~0.1 miles to account for GPS discrepancies in a few cases.

Minor changes were recommended by Infrasense for two sites that had not been disclosed to them:

- CAL15-5a: Reduce thickness of PCC layer by 12 percent
- CAL035-18: Change layer 3 material to "base"

After the changes were made, the GPR results were compared to the remaining cores. DCP results were used to estimate underlying layer materials and very approximate thicknesses. The comparisons can be found in Appendices E (plots) and F (tables).

Review of the results shows that the GPR technology is effective for determining layer thicknesses for all layers. The accuracy level decreases with depth, with layers 1 and 2 being more accurate than layers 3 and 4. The average thickness difference (absolute percentage of total layer) and accompanying standard deviations are presented in Table 5. A comparison of the GPR versus core (UCPRC) thicknesses is plotted in Figure 5.

Table 5. Average Thickness Differences (Absolute) and Standard Deviations

	Layer 1	Layer 2	Layer 3	Layer 4
No. of Cores	31	22	15	3
Average Difference	12.62%	10.17%	27.88%	20.89%
Standard Deviation	11.2%	15.0%	23.4%	11.3%

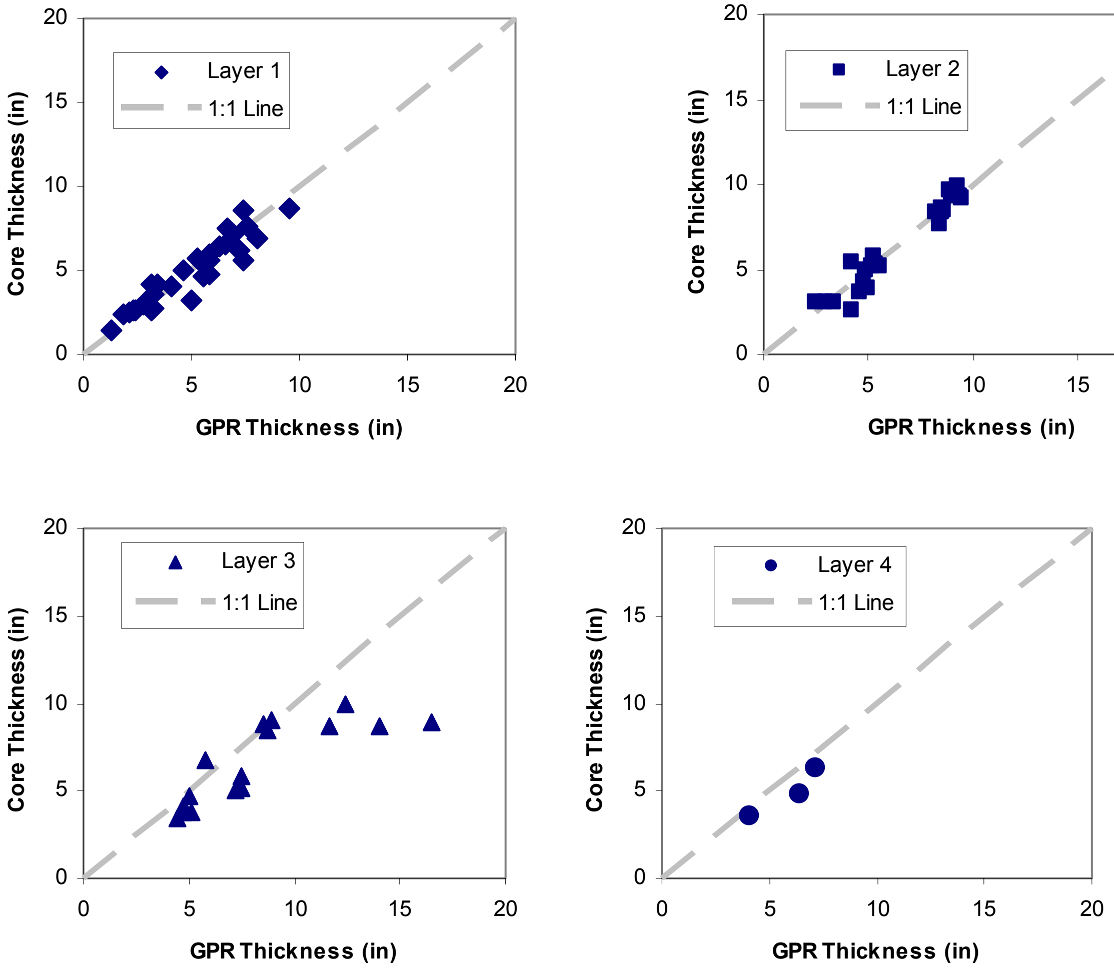

Figure 5. GPR versus core (UCPRC) thicknesses.

Some of the more extreme values in Figure 5 may be a result of the discrepancy between the GPR readings location and core locations discussed in 5.1.2. At some sites, layer thicknesses are highly variable over small areas, so even a small difference in between the GPR reading and the core location can result in a large difference in layer thicknesses. These extreme values affect the averages and standard deviations expressed in Table 5.

Layer types as indicated by the GPR reading matched up well with the UCPRC cores. Deeper AC was sometimes recorded as “Base” or “BB” (bituminous base). These layers sometimes exhibited aging effects (such as the breakdown of materials) that may have caused the misnaming. The GPR was unable to differentiate between base types, including cemented bases

(LCB or CTB) or asphalt-treated permeable bases (ATPB). Open-graded AC (OGAC) layers were not distinguished from other AC types and were grouped together with the underlying AC layers. For example, if a layer consisted of 25mm OGAC and 100mm DGAC, the GPR output would be 125mm AC.

5.2 Comparison of Current Caltrans Maintenance Dynamic Segmentation versus Fixed Length Segmentation

The length of segments that Caltrans uses for evaluation of pavement condition was obtained from the program, "Pavement Condition Reporting System."[*] Statistics were obtained for data in the years 2000 and 2004 for about 305 miles of roadway for the pilot segmentation study. Histograms with the number of segments in 0.1-mile intervals are presented in Figure 6 for each of these two years. The charts show that the number of segments identified by the Caltrans dynamic segmentation for the pilot network increased from 225 to 431 between 2000 and 2004, and that average length dropped from 1.17 to 0.66 miles. One-mile segments seem to be the most common survey unit.

The same chart was prepared for the fixed segmentation performed as part of this study and is presented in Figure 7. It can be noted that the fixed-length segmentation produced

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[*] Version 3.0.0 March 17, 2005.

segments whose lengths are spread over a wider range. Figure 7 shows segments only up to 5 miles long, but there were four additional sections between 5.0 and 7.3 miles long.

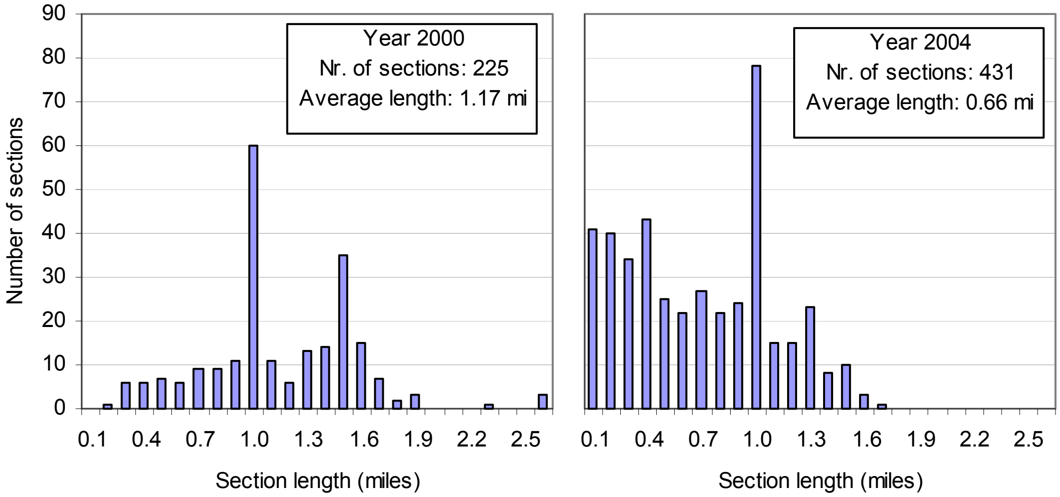

Figure 6. Histograms of sections versus length with Caltrans segmentation.

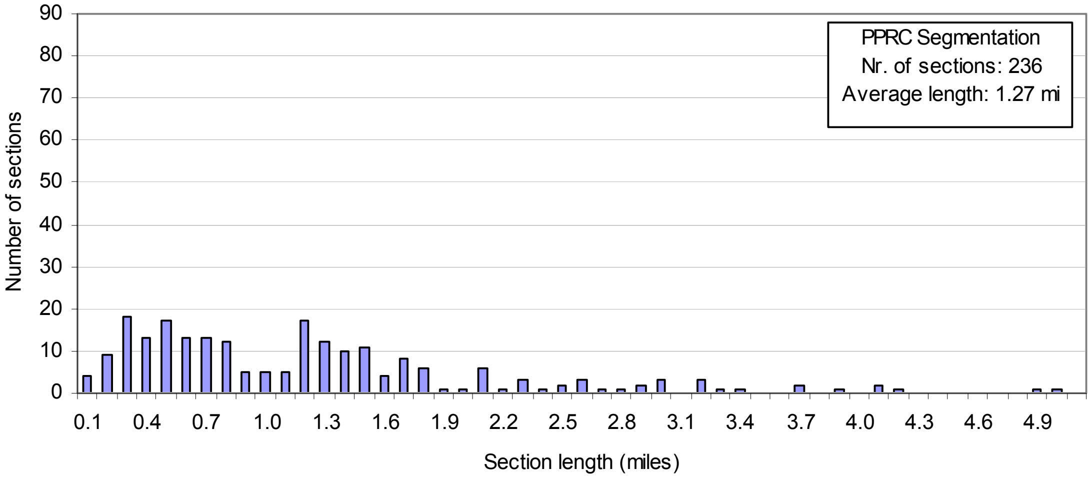

Figure 7. Histogram of sections versus length with fixed-length segmentation.

A comparison between the 2004 Caltrans segmentation versus the fixed-length segmentation indicates that there would be roughly 200 fewer segments to survey (237 instead of 431) in the pilot network, and that the average segment length would be 1.27 miles rather than 0.66 miles. The validity of these conclusions is limited until segmentation by surface condition is performed; however this indicates that fixed segments could result in fewer segments to survey, reducing the cost of the Caltrans Pavement Condition Survey.

5.3 Collection of Pavement Condition Indicators for Performance Modeling in PMS

As mentioned in Section 2.1, collection of pavement condition data depends on whether the information is going to be used for PMS or for project-level maintenance. In order to collect the necessary data to develop or calibrate empirical models for pavement management and to calibrate mechanistic-empirical pavement design models, some minor changes to the PCS procedure have to be implemented. It seems that there are two possible approaches.

1. The first option is to continue with the current scheme of condition surveys, but to use the fixed-length segments as breakpoints (PCS hits the same ends as the PMS segments) so the results can be tracked year after year. Since more than one PCS segment is likely to be found within a PMS segment, a weighted average of the condition in the segments, based on length, can be obtained to represent the condition of the entire PMS segment.
2. The second alternative is to conduct condition surveys for PMS purposes, independent of the Pavement Condition Survey for maintenance. Since the level of detail in a PMS condition survey is lower, it is a common practice to report smaller segments with an equivalent condition simply as "same as previous" because there is no need for extensive auscultation and to reduce the cost of the field work.

This report contains a list of recommendations regarding the type of information necessary for PMS purposes. The recommended items are shown in the table in Appendix G, in which data included in Caltrans current Pavement Condition Survey Method is compared with information required for PMS purposes. In that table, recommended items to be changed are shaded.

6.0 CONCLUSIONS, FUTURE WORK, AND RECOMMENDATIONS

6.1 Conclusions

The conclusions that can be drawn from the pilot segmentation study and the GPR testing are as follows:

1. Fixed-length segmentation is a process that involves analysis of roadway information from various sources. Once the segmentation process is completed, the resulting segments will provide a theoretically sound frame for future pavement condition data collection that would allow for the development of performance models.
2. Segmentation of the pilot network showed that the best approach to break down segments of roadway is by means of the following steps: (a) administrative boundaries, (b) traffic load, (c) pavement structure, (d) climate region, and (e) pavement condition (if needed).
3. The direct cost to implement PMS segmentation and to collect GPR data for inventory of pavement structure for the entire network is estimated — based on extrapolation from this pilot project — at approximately $7 million of contracted field work, while the approximate need for personnel for segmentation analysis is an additional 12.3 PY.
4. Ground-penetrating radar (GPR) pavement-related technology has been evaluated by Caltrans and by other DOTs, and it has been found to be reliable, both for project-level assessment, and for network-level inventory.
5. GPR testing supplemented with limited coring and DCP data to populate the inventory database with pavement structures throughout the California highway network appears feasible. The information provided by the GPR contractor was easy to use and reliable, based on the coring by the UCPRC. The available data indicates that GPR provides reasonable cross-sections.

6.2 Recommendations

The following are the recommendations based on this project.

1. A condition survey for PMS purposes needs to be implemented. It will consist of either minor changes to the current Pavement Condition Surveys or the

implementation of a parallel data collection unit, focused only on the variables needed for adequate performance modeling.

2. If funding the segmentation of the entire network is an issue, the process can be staged, adding more roads each year to spread the costs over several years.
3. After inventory information is generated for parts of the network (using GPR), it is important to document as-built information in the structural database as future maintenance, rehabilitation, and reconstruction work occurs, in order to keep the database accurate.

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§3.2.4[1]

Minutes - 8/30/04 Meeting On Developing Objectives for the Highway Network Segmentation & Data Collection In D-3 Using GPS[2]

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Introduction

This meeting dealt with the development of objectives for the "Highway Network Segmentation & Data Collection In D-3 Using GPS" or what is being called "The Segmentation Pilot Project." The objectives developed during the meeting were broken down into five key areas: A) which highways/routes and which lanes to collect data from, B) the types of data to collect, C) the kinds of analysis to be performed, D) the phases of segmentation and whether all five phases can be achieved, E) deliverables, and F) lane miles versus cost option selection.

A key issue to be resolved by this project is whether ground-penetrating radar (GPR) for the continuous measurement of pavement thickness can be used effectively (i.e., is the technology sufficiently developed such that the use of GPR hardware and software generates measurements that are reproducible and repeatable).

Background

In the last meeting John Harvey presented a plan and costs for testing pre-selected parts of the highway network in District 3 (Sacramento & Yolo counties). Since that meeting it was decided to revisit the rationale behind what and how much of the network would be sufficiently representative to meet the main objective of understanding how segmentation, data collection, population of data bases, and the subsequent analyses can be done in future by Caltrans resources and whether addition resources will be required. These issues are addressed Sections A, B, C, & D with a final determination of the optimum amount of lane miles versus cost is made in Section F.

A Data Collection Locations

The parts of the D-3 network (highways and route) listed below were previously identified as being good candidates that should include a sufficiently diverse set of roadway structural sections to be representative of the overall highway systems within California.

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[1] "*Development of Integrated Databases to Make Pavement Preservation Decisions*" – PPRC Strategic Plan 03/04.

[2] The segmentation of highway networks and related data collection was not originally envisioned as part of the PPRC 03/04 Strategic Plan Section 3.2.4. It evolved as a logical next step that will precede the development and population of the integrated databases originally intended.

Highways / Route

- I-80 (Solano Co./Yolo Co./Sacramento Co – 35 miles)
- I-5/US 99 (Sacramento Co. -? X miles)
- SR 20 (Lake Co. to Grass Valley -? X miles)

Lanes, Lane Directions, Measurement

- 1 to 2 lanes per direction
- 4-lane facility (outside – 1 direction, inside – other direction
- 6-lane facility (outermost 2 lanes in each direction)
- 2-lane facility (1 direction)
- Type of initial measurement using GPR:
  - General thickness (homogeneous sections)
  - Changes in structural cross section (need horizontal sub-meter precision – get information from Surveys)

B Other Data Collection Needs

Office Data

- Office of Pavement rehabilitation deflection studies
- As-Builts (HQ data, retrieval [intranet] of District data)
- Data from Moisture Sensitivity studies
- Data from the Pavement Performance Evaluation Phase I (Stantec project)

Coring Data

- Use for verification of GPR measurements
- Take in questionable areas (visually distinct fro the surrounding pavement)
- Use to calibrate GPR units used in the pilot
- Criteria for sampling
  - A few random sites
  - Areas designated for analysis only

Criteria to Define Changes In Pavement Structure

- Where the average thickness changes greater than 50 mm (between 0.1 mile sections)
- Where the order of layer type changes
- Where independent METS GPR data shows significant changes

C Analysis

1. Pick 1000 lane miles from 2850 lane miles (narrow sections – contact Pat Kelley @ D-3 Design)
2. Take office data and map out structures
3. Collect existing coring data
4. Analyze GPR data
5. Identify questionable areas and do coring
6. Compare verification data with GPR information from analysis
7. Do the economic analysis

D Segmentation[3]

A successful segmentation plan will consist of five passes through the network, each one resulting in a further segmentation:

1. In the first pass, administrative considerations will prevail. This will lead to dividing the highway network according to districts and routes. For example, I-5 would first be segmented according to the Caltrans districts that it lies along.
2. In the second pass, segments within an administrative unit (route and district) are further segmented according to pavement structure (AC on granular, PCC, AC on PCC, AC on LCB, AC on CTB, etc), subgrade type, with each segment having a “uniform” pavement structure with regard to type and general thicknesses, and underlying subgrade type.
3. In the third pass, uniform pavement structure segments are broken if they cross a climate region boundary.
4. In the fourth pass, segments are broken if there is a significant change in traffic loading (which means that major intersections are natural boundaries between sections).
5. In the fifth pass, segmentation is based on surface measurements. At this level, the objective is to divide the highway into sections that are homogeneous in their current condition (general state of surface distresses and IRI).

For this pilot process the first three passes will be done and the fourth and fifth passes will be conducted depending on time, budget, and availability of traffic data.

Deliverables (due dates)

Pilot Project Technical Deliverables

1. (C1) – Develop a list of the 1000/300 lane miles (GPR measurements/coring & other data collection) **[9/04]**
2. (C3) – Develop information on preliminary structures/sections (include available information from databases and maps) **[12/04]**
3. (C5) – Final structures/sections information (database information & maps) **[3/04]**
4. (C6) – Write Tech Memo (technical feasibility of segmenting highway network) **[6/05]**
5. (C7) **-** Write Tech Memo (Economic Analysis) **[6/05]**
6. (D1) - Write Tech Memo (Segmentation Pilot Project) **[8/05]**

Other Deliverables

1 Marketing plan for upper management (with technical backup)

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[3] Segmentation process details are from “A Plan for Segmentation of Highway Pavements for Use in Caltrans’ Pavement Management System,” Samer Madanat, April 29, 2004**.**

Lane Miles Involved Vs. Costs[4]

Plan	# Lane miles to be measured with GPR	# Lane miles to collect additional data on for analysis	Estimated cost
A	2,850	300	$76,000
B	1,000	1,000	$76,000
C	2,000	2,000	$147,000
D	300	300	$36,000
E	500	500	$50,000
F	**1,001**	**300**	**$40,000**

Recommendation: Go with Plan F

Post Meeting Information/Discussion

The purpose of the Segmentation Pilot is to demonstrate the feasibility of segmenting the highway network into homogeneous sections that will allow for accurate prediction of pavement performance and the optimization of the Maintenance budget process. However it is not clear how actual future segmentation activities will be performed or who will perform them. What is anticipated is the development of a data warehouse that will incorporate a tremendous amount of data from a wide variety of sources. This will include the following:

- Research databases including the HVS field and laboratory databases and several others.
- Databases from the Pavement Performance Evaluation project, Phases I & II – Phase II to be started in late 2004.
- The Pavement Management System (PMS) including the existing database and the new one to be developed starting in 2005.
- METS database(s).

Decision/Action Needed

The above projects need to be coordinated closely to assure that data collected is compatible in terms of populating what could become the PMS data warehouse. This raises a number of issues that will need to be addressed:

1. Who will be the lead to verify that the right kinds of data are being collected (essential and helpful variables)?
2. How will the meta data be developed and by whom?
3. How will data quality be assured?
4. Do we need a Department-wide data collection, preservation, and availability policy, i.e., should the Districts and Headquarters be required by a Directive to actively participate in an enterprise pavement system in which design, construction, maintenance, research, and traffic data is available to all potential users of pavement data? This was answered previously (more-or-less) in the affirmative but no strategy was developed to address this issue.

Suggestion:
It has been suggested that either Research or the Pavement Standards PMS Team write a white paper for review by the Acting Director and the Acting Deputy Director for Maintenance and Research.

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[4] Cost estimates are based on a consultant's estimate to do data collection and analysis for varying lengths of roadway (Infrasense Inc. *PPRC Pilot GPR Project Ground Penetrating Radar Survey in Sacramento and Yolo Counties,* August 25, 2004.

Appendix B: GPR Survey Summary

GPR File #	Date Collected	Route	Map Direction	Target Lane Type (speed)	Layout Description	Approx. Survey Length (mi)	GPR Data Characteristics	Section Analyzed
CAL009	Mar. 7, 2005	SR-99	SB	low	US-50 to San J. Co line	25	Mostly AC/PCC, some full depth AC, somewhat variable	x
CAL010	Mar. 7, 2005	SR-99	NB	faster	US-50 to San J. Co line	25	Mostly AC/PCC; fairly homogeneous	
CAL011	Mar. 7, 2005	I-5	SB	low	US-50 to San J. Co line	24	PCC, very homogeneous, some radio interference at S end.	x
CAL012	Mar. 7, 2005	I-5	NB	faster	US-50 to San J. Co line	22	PCC, very homogeneous, some radio interference at S end.	
CAL013	Mar. 7, 2005	SR-99	NB	low	From I-80 to SR-70 split	16	Mostly full depth AC, fairly homogenous	x
CAL014	Mar. 7, 2005	SR-99	SB	faster	From I-80 to SR-70 split	16	Mostly full depth AC, fairly homogenous	
CAL015	Mar. 7, 2005	SR-113	NB	low	From Davis to Woodland	11	Very homogeneous PCC; North section appears to have Bituminous Base. Is this possible?	x
CAL016	Mar. 7, 2005	I-5	NB	low	Yolo/Colusa line SR-113	21	Very homogeneous AC/PCC, with several local full depth AC patches, especially near YOL RP 11	
CAL017	Mar. 7, 2005	I-5	SB	faster	Yolo/Colusa line SR-113	21	Very homogeneous AC/PCC	x
CAL030	Mar. 8, 2005	SR-113	SB	faster	From Davis to Woodland	11	Very homogeneous PCC; North section appears to have Bituminous Base. Is this possible?	
CAL031	Mar. 8, 2005	I-80	WB	low	Solano County	45	Long homogeneous sections of full depth AC and PCC, some AC/PCC, layer type interpretation clear except in some sections near western end.	
CAL032	Mar. 8, 2005	I-80	EB	low	Solano County	45	Long homogeneous sections of full depth AC and PCC, some AC/PCC, layer type interpretation clear except in some sections near western end.	
CAL033	Mar. 8, 2005	I-5	NB	low	SR-113 to SR-99 split	13	homogeneous, looks like AC/PCC/Base. Not sure about the PCC	x
CAL034	Mar. 8, 2005	I-5	SB	faster	SR-113 to SR-99 split	13	homogeneous, looks like AC/PCC/Base. Not sure about the PCC	
CAL035	Mar. 8, 2005	SR-16	WB	low	Woodland to SR-20	48	Mostly full depth AC, extremely variable, numerous pavement layers, may be difficult distinguishing bound from unbound layers	x
CAL036	Mar. 8, 2005	SR-20	EB	low	Lake Co. line Sutter RP9	47	Mostly full depth AC, somewhat variable	x
CAL037	Mar. 8, 2005	SR-20	EB	low	Sutter RP9 to Grass Valley	41	Mostly full depht AC, some homogeneous sections, other areas hightly variable, may be difficult to distinguish bound from unbound layers in some areas	
CAL041	Mar. 9, 2005	I-80	WB	faster	Solano County	45	same as low speed, includes CRCP section in Fairfield	x
CAL042	Mar. 9, 2005	I-80	EB	faster	Solano County	45	same as low speed	
CAL043	Mar. 9, 2005	SR-160	SB	low	From I-80 to Rio Vista	46	Mix of full depth AC and AC/PCC. Some long homog. sections, some areas with high variability;	
CAL047	Mar. 10, 2005	US-50	EB	low	Sunrise Blvd. to El Dor. Co. line	11	2 Miles of homogenous PCC; the rest full depth AC, with lots of layers, and variable.. Maybe difficult to distinguish bound from unbound layers	x
CAL048	Mar. 10, 2005	US-50	WB	faster	Sunrise Blvd. to El Dor. Co. line	11	2 Miles of homogenous PCC; the rest full depth AC, also mostly homogeneous	
CAL049	Mar. 10, 2005	SR-45	SB	low	Yolo County Sect.	13	Full depth AC. Homogeneous in the north end; extreme changes in pavement structure in the south end.	x
CAL050	Mar. 10, 2005	I-505	SB	low	I-5 to I-80	33	Mostly PCC, some AC/PCC, very homogeneous	x
CAL051	Mar. 10, 2005	I-505	NB	faster	I-5 to I-80	33	Mostly PCC, some AC/PCC, very homogeneous	
					Total Lane Miles Data Collection =	**681**	**Analysis Total =**	**307**

APPENDIX C: CHARTS WITH GPR STRUCTURE RESULTS AND DATA FROM THE 2003 PAVEMENT CONDITION SURVEY

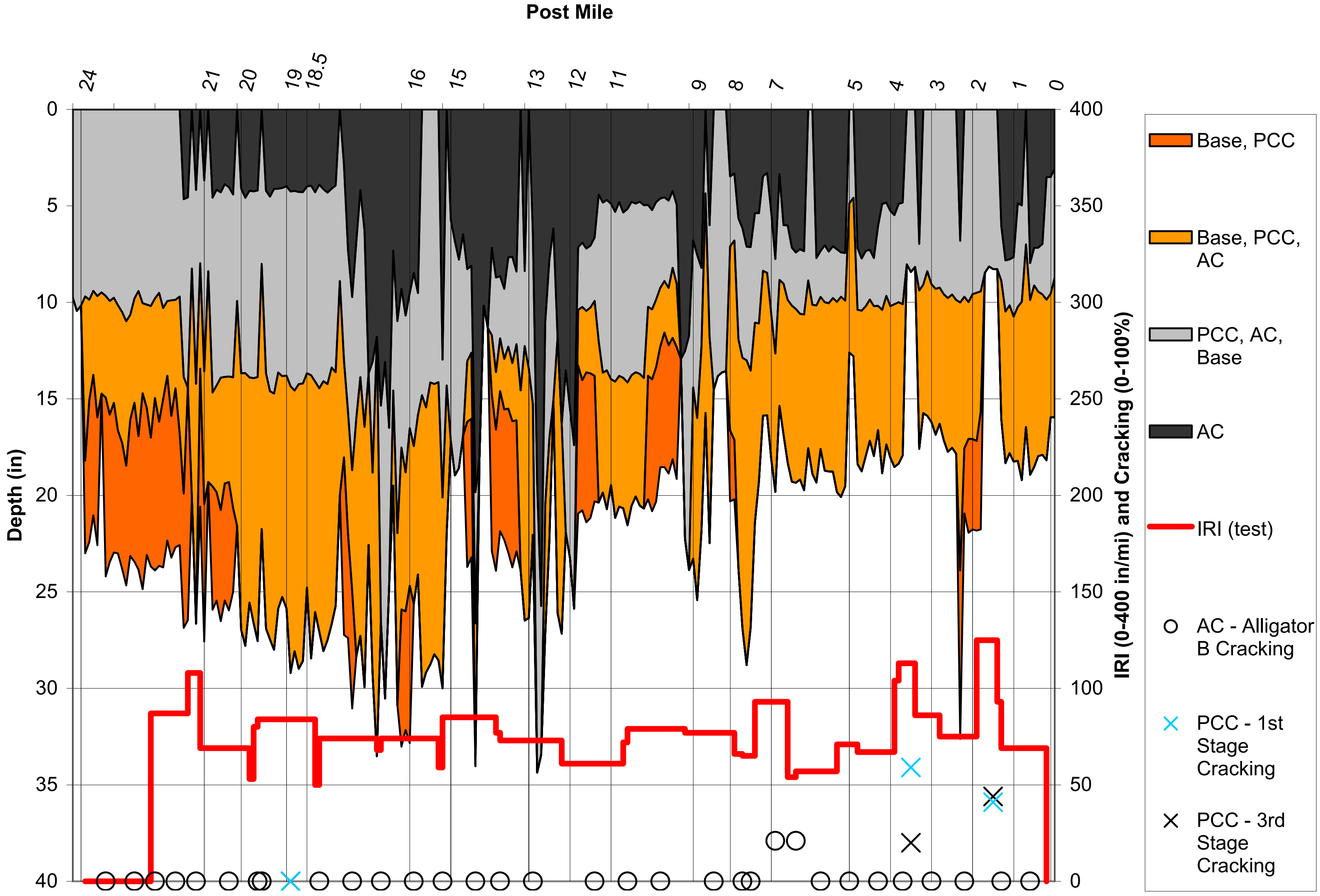

Figure C1. GPR cross section with selected PCS data – Sacramento SR-99 SB (outside lane), CAL009.

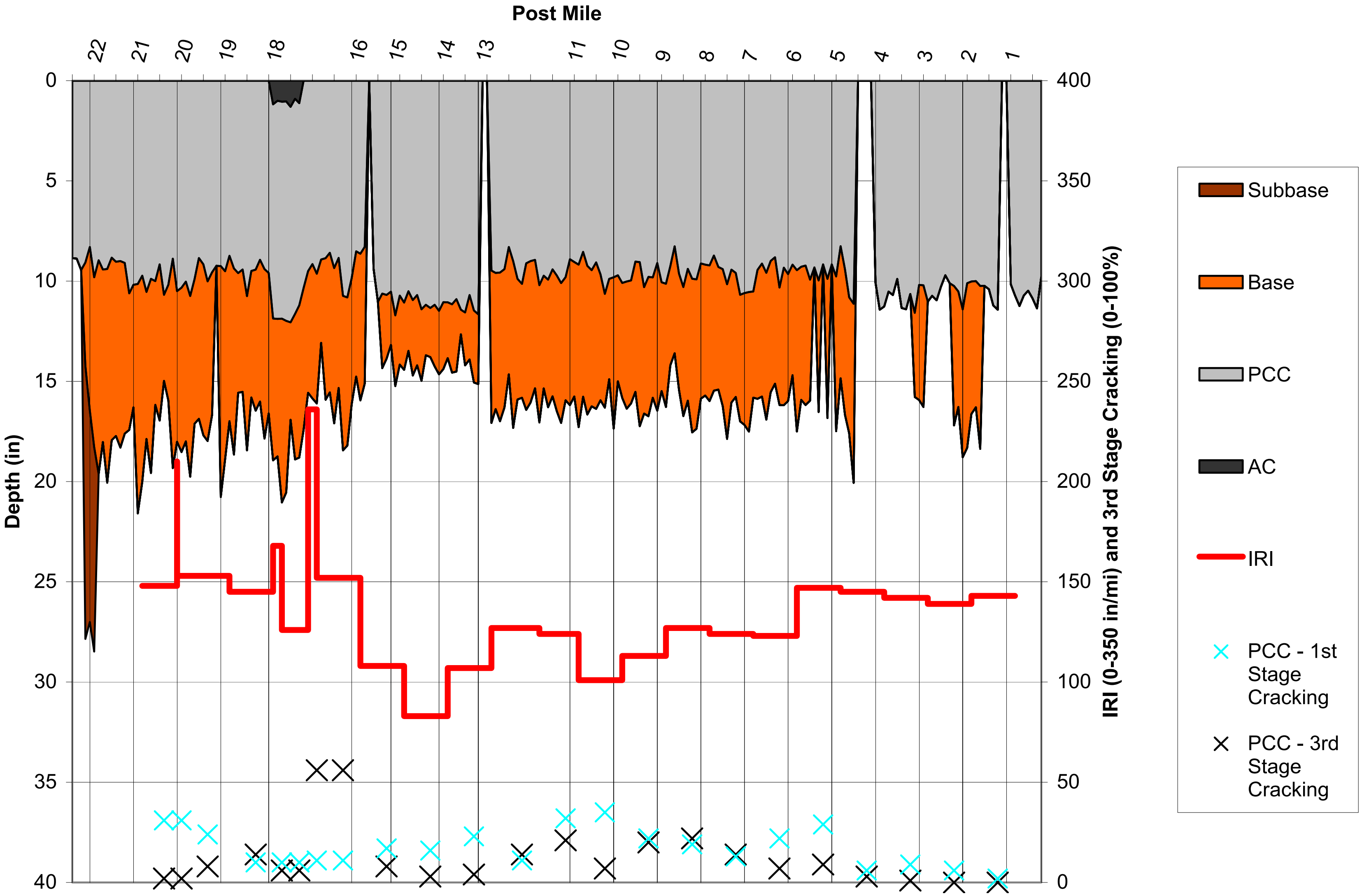

Figure C2. GPR cross section with selected PCS data – Sacramento I-5 SB (outside lane), CAL011.

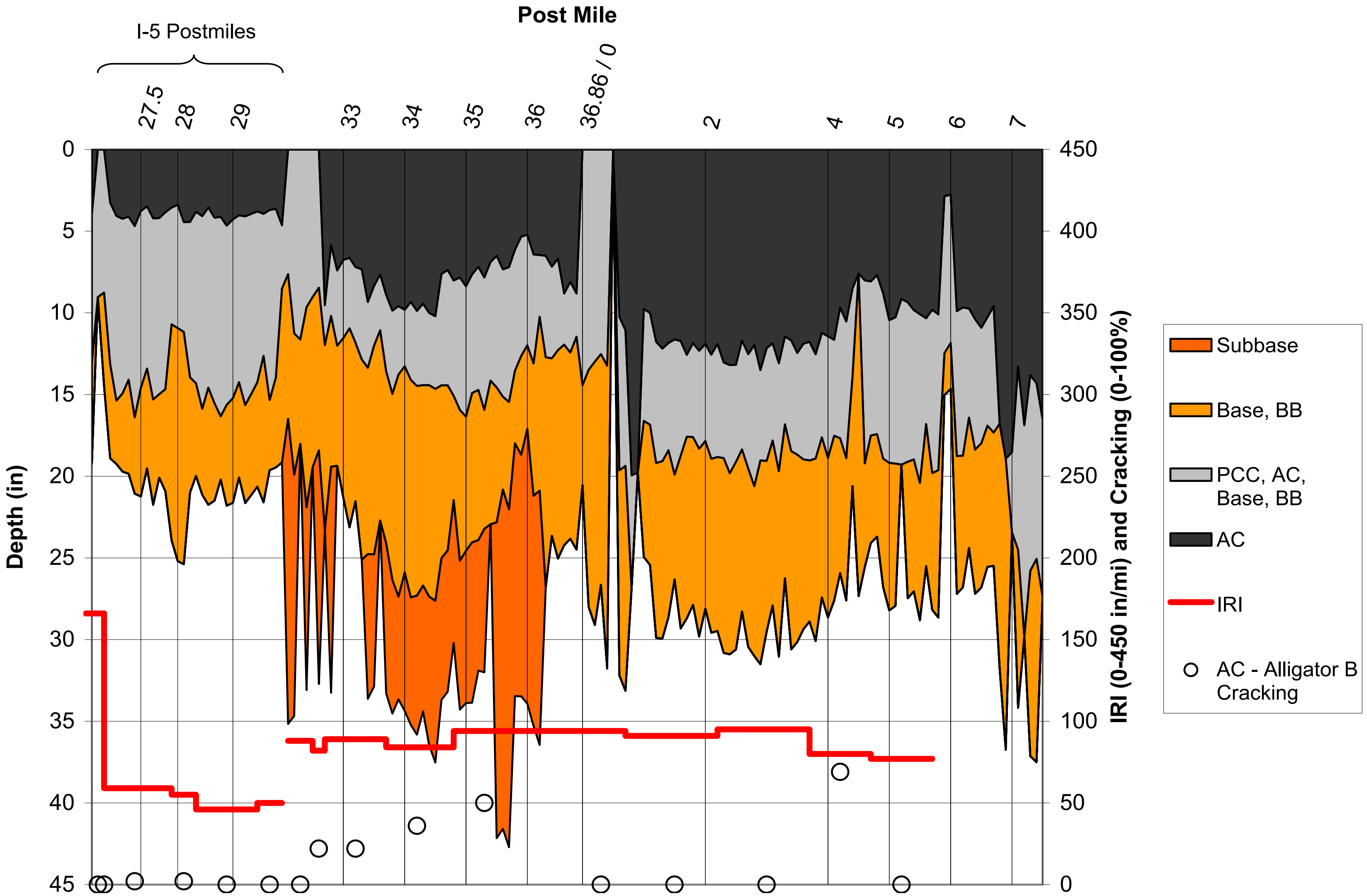

Figure C3. GPR cross section with selected PCS data – Sacramento and Sutter SR-99 NB (outside lane), CAL013.

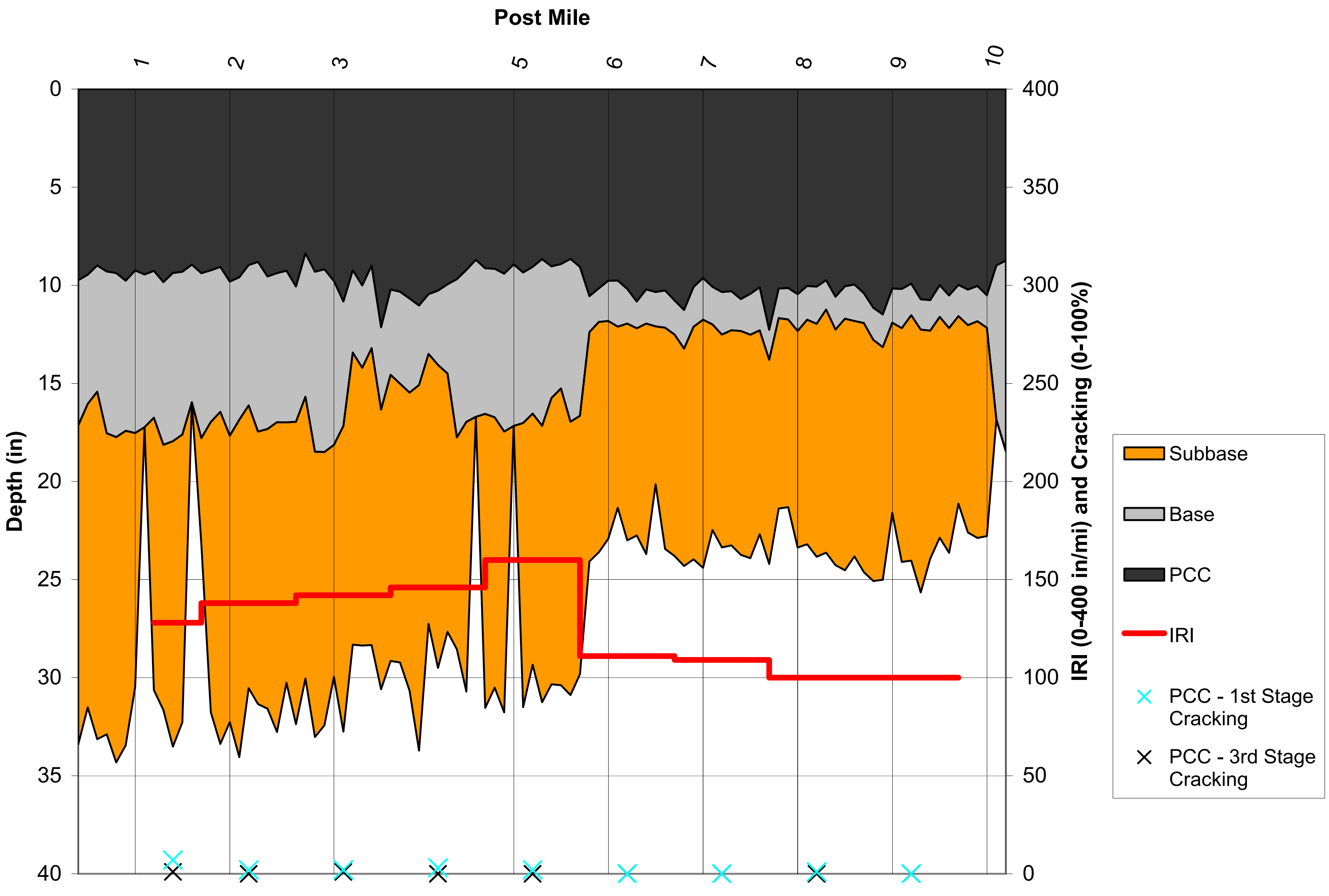

Figure C4. GPR cross section with selected PCS data – Yolo SR-113 NB (outside lane), CAL015.

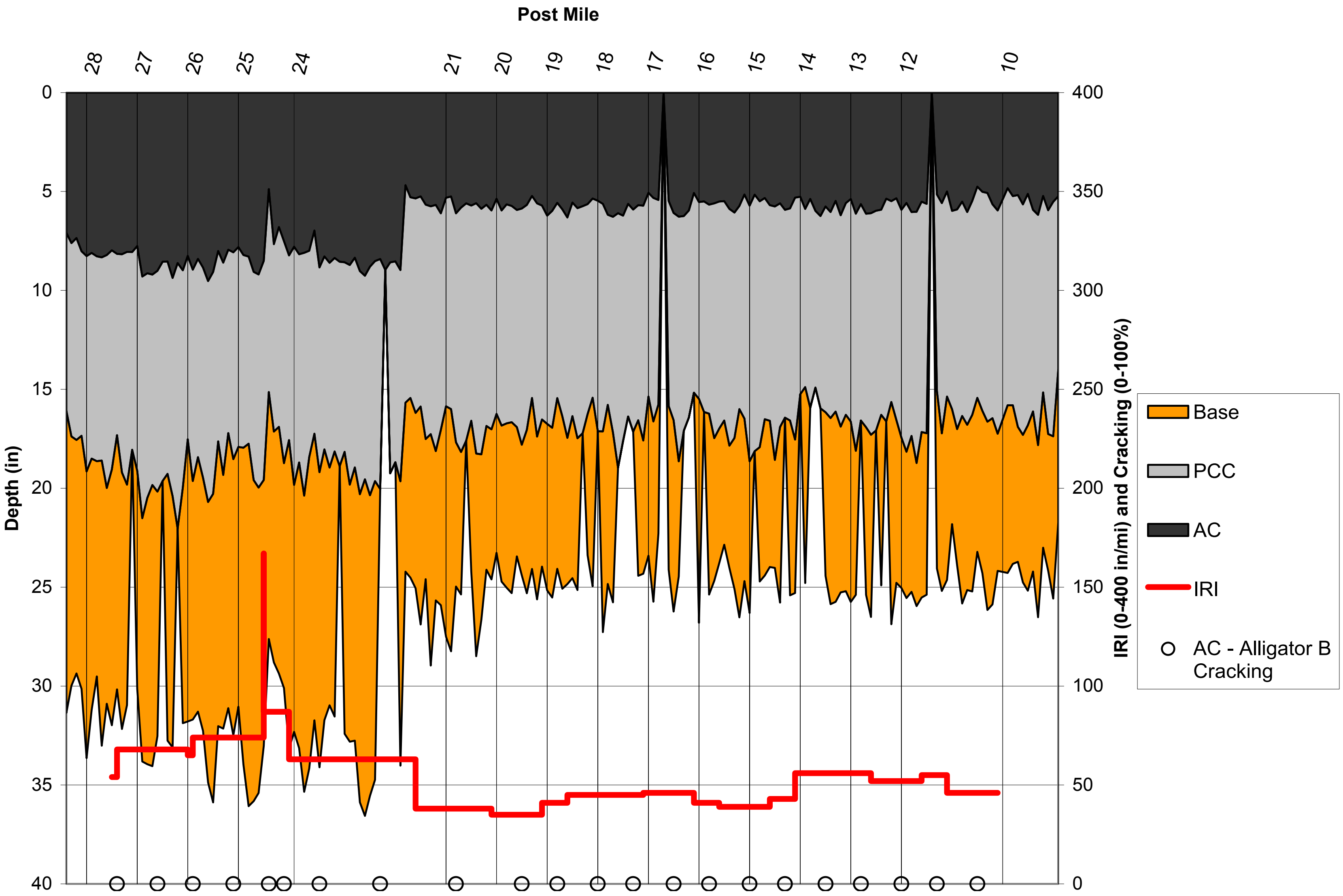

Figure C5. GPR cross section with selected PCS data – Sacramento I-5 SB (inside lane), CAL017.

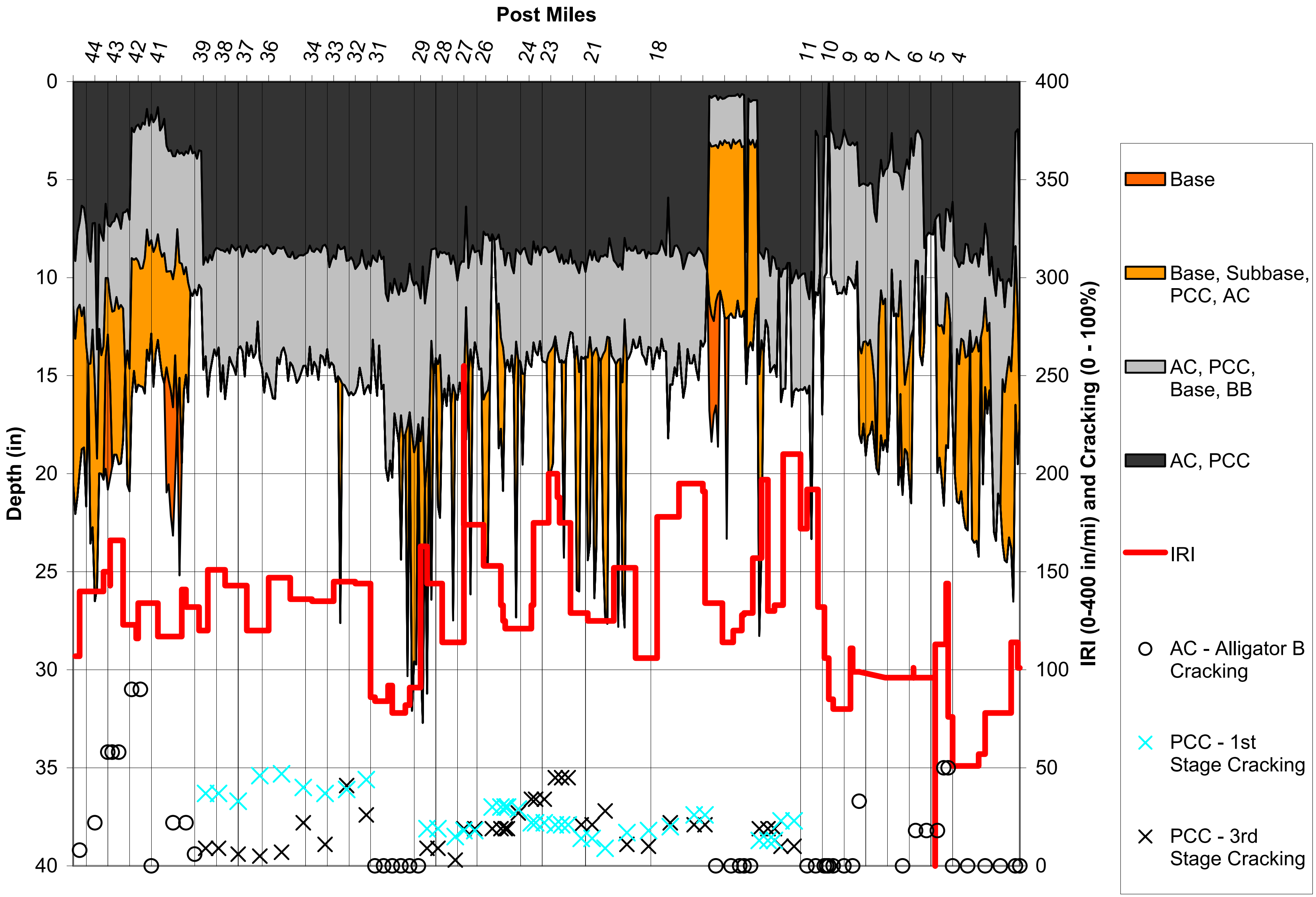

Figure C6. GPR cross section with selected PCS data – Solano I-80 WB (outside lane), CAL031.

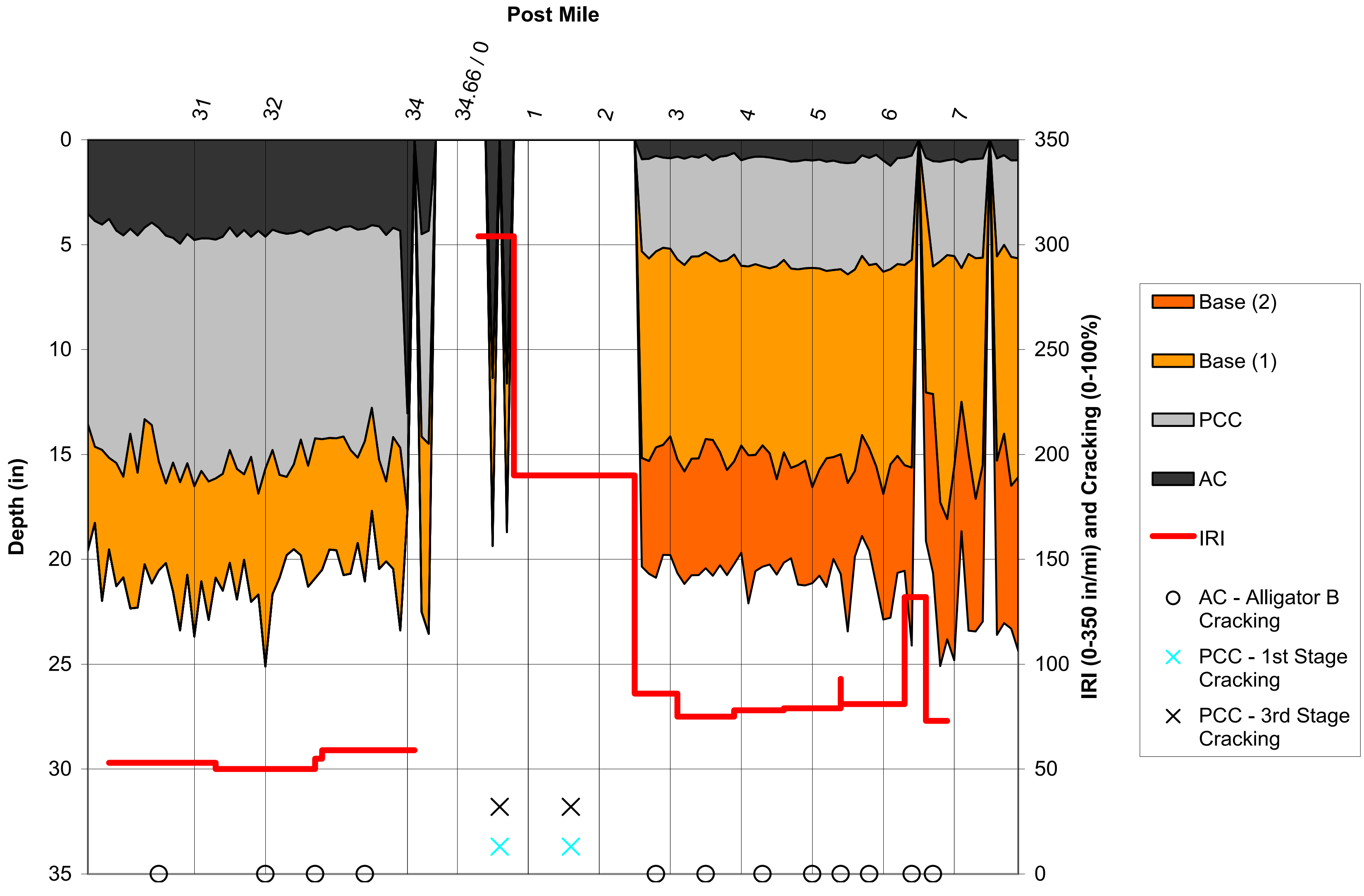

Figure C7. GPR cross section with selected PCS data – Sacramento and Yolo I-15 NB (outside lane), CAL033.

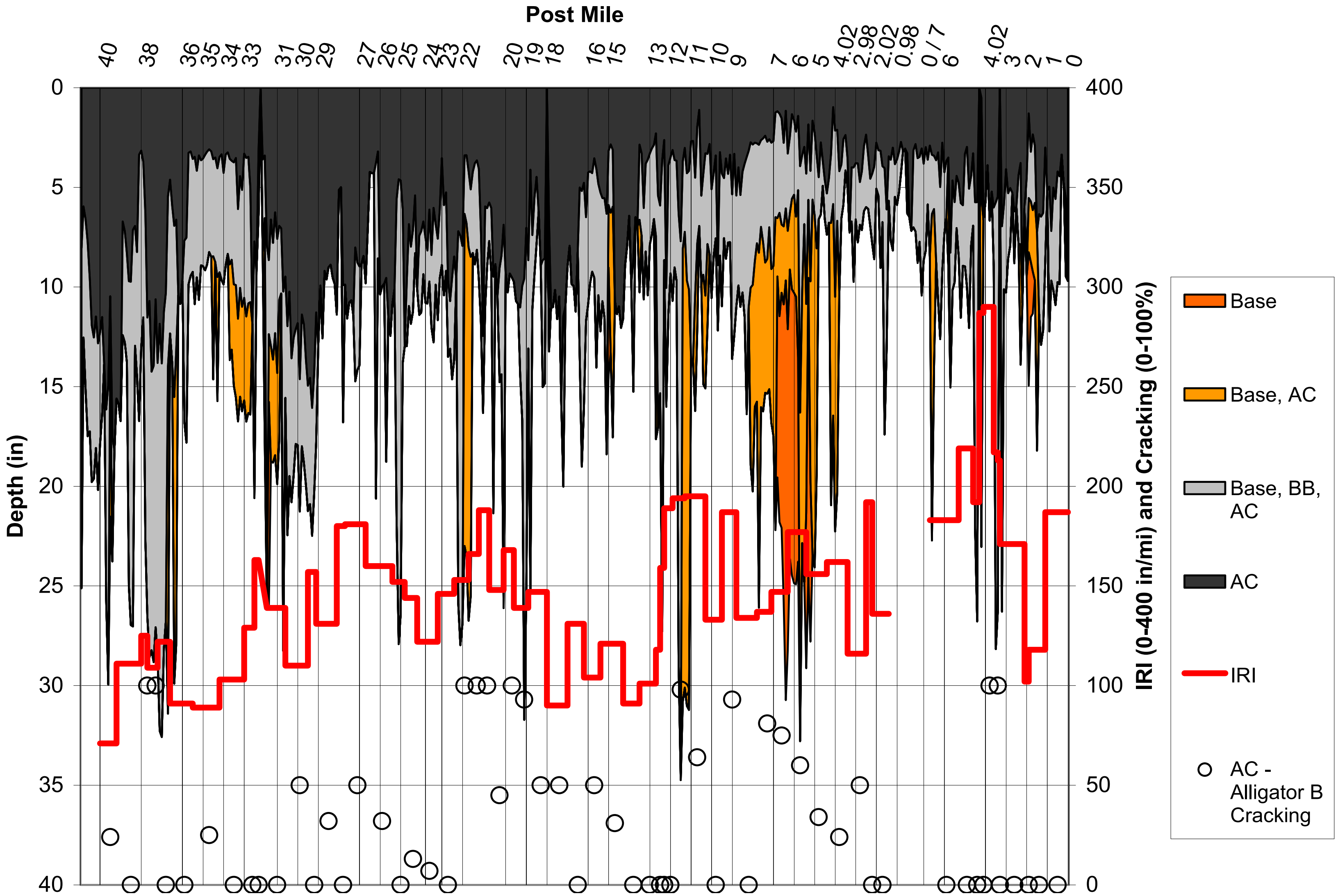

Figure C8. GPR cross section with selected PCS data – Colusa and Yolo SR-16 WB (outside lane), CAL035.

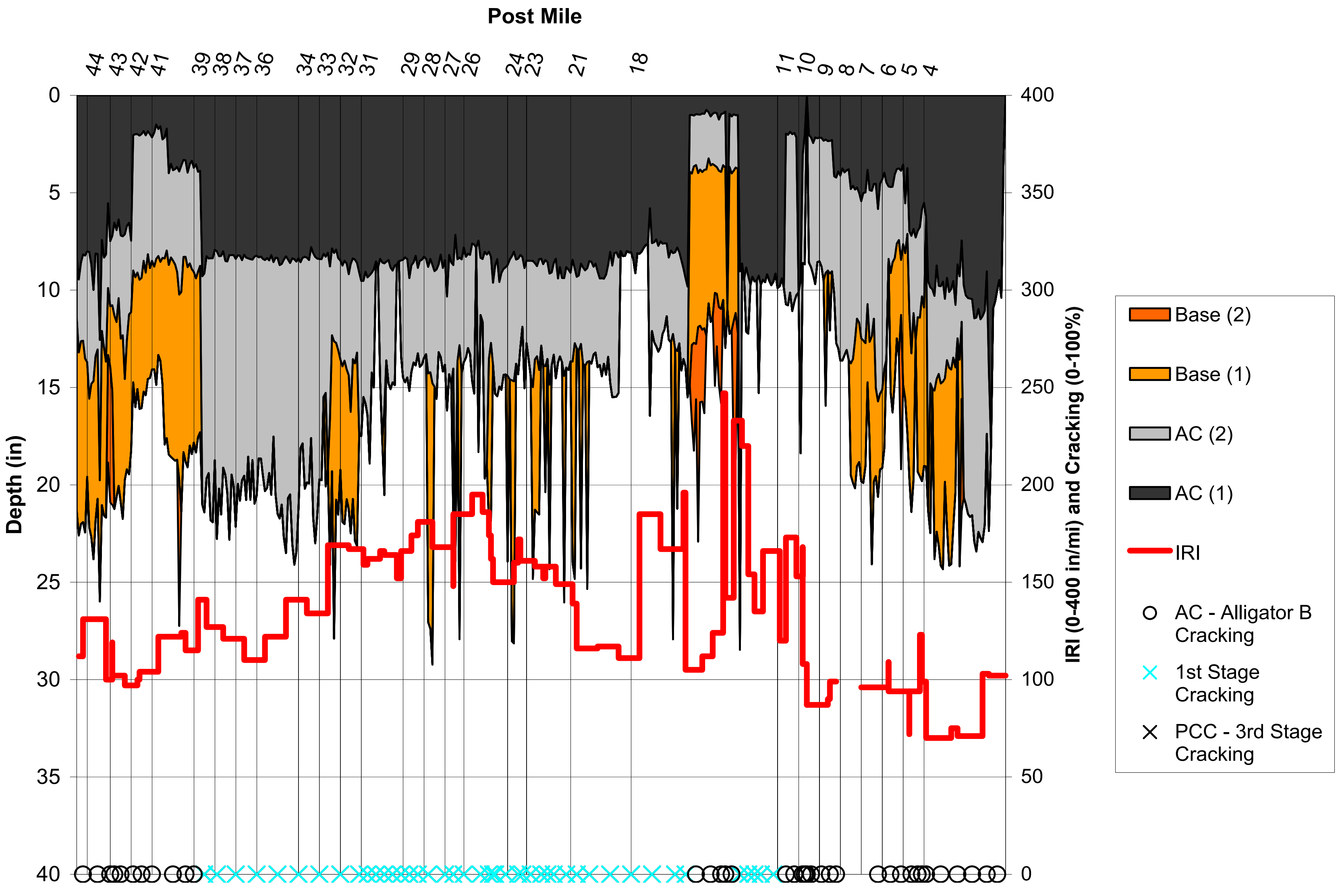

Figure C9. GPR cross section with selected PCS data – Solano I-80 WB (inside lane), CAL041.

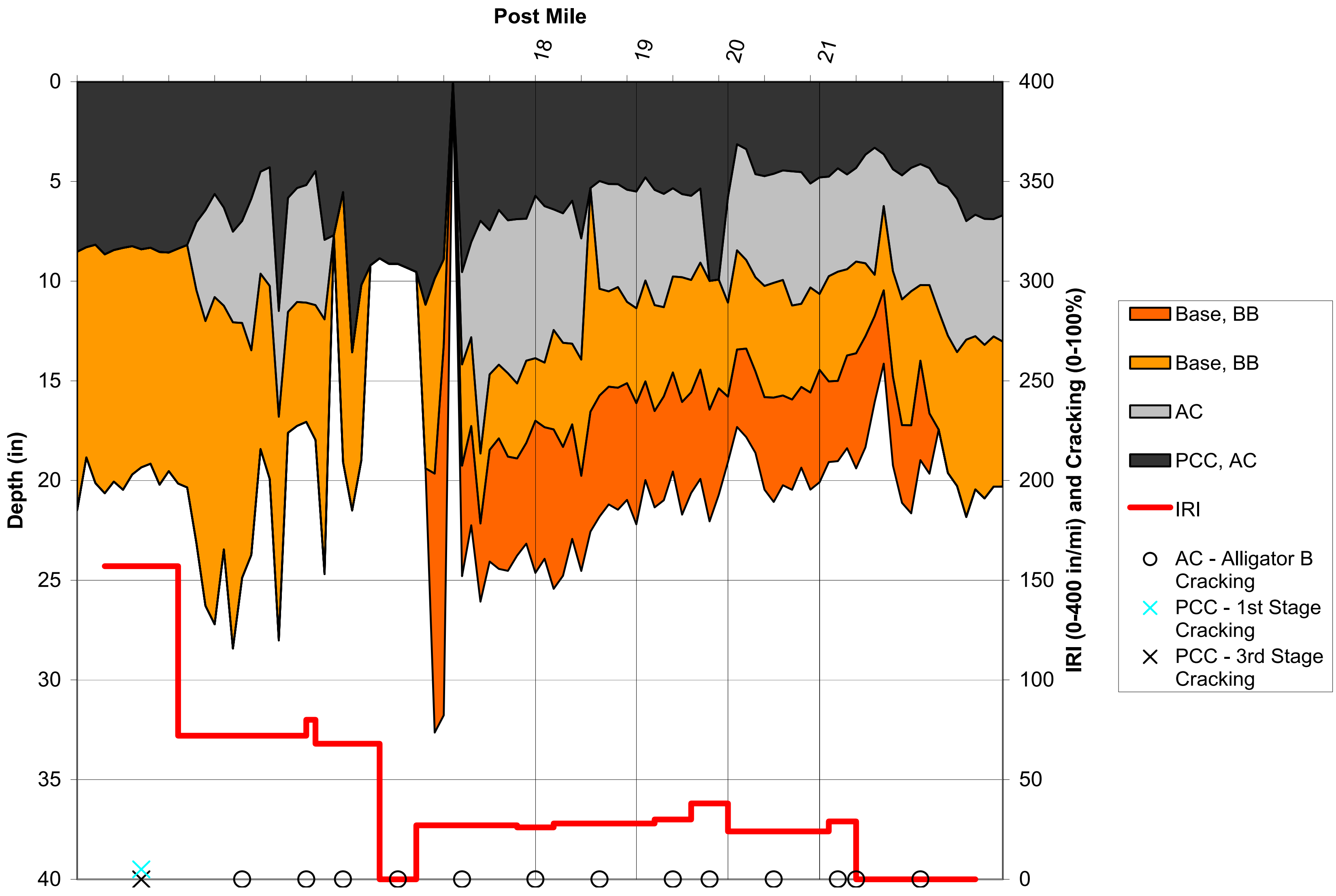

Figure C10. GPR cross section with selected PCS data – Sacramento US-50 EB (ouside lane), CAL047.

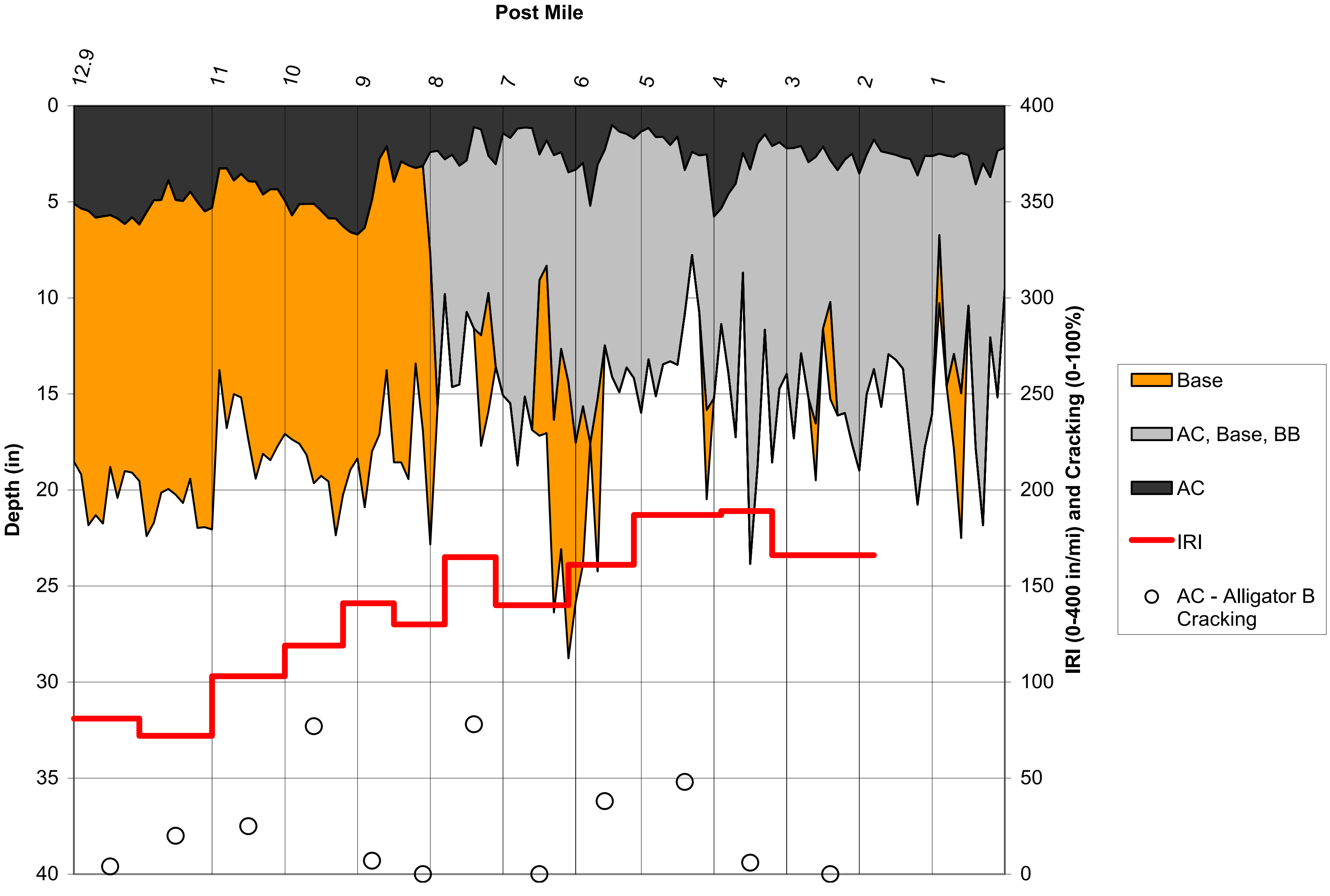

Figure C11. GPR cross section with selected PCS data – Yolo SR-45 SB (outside lane), CAL049a.

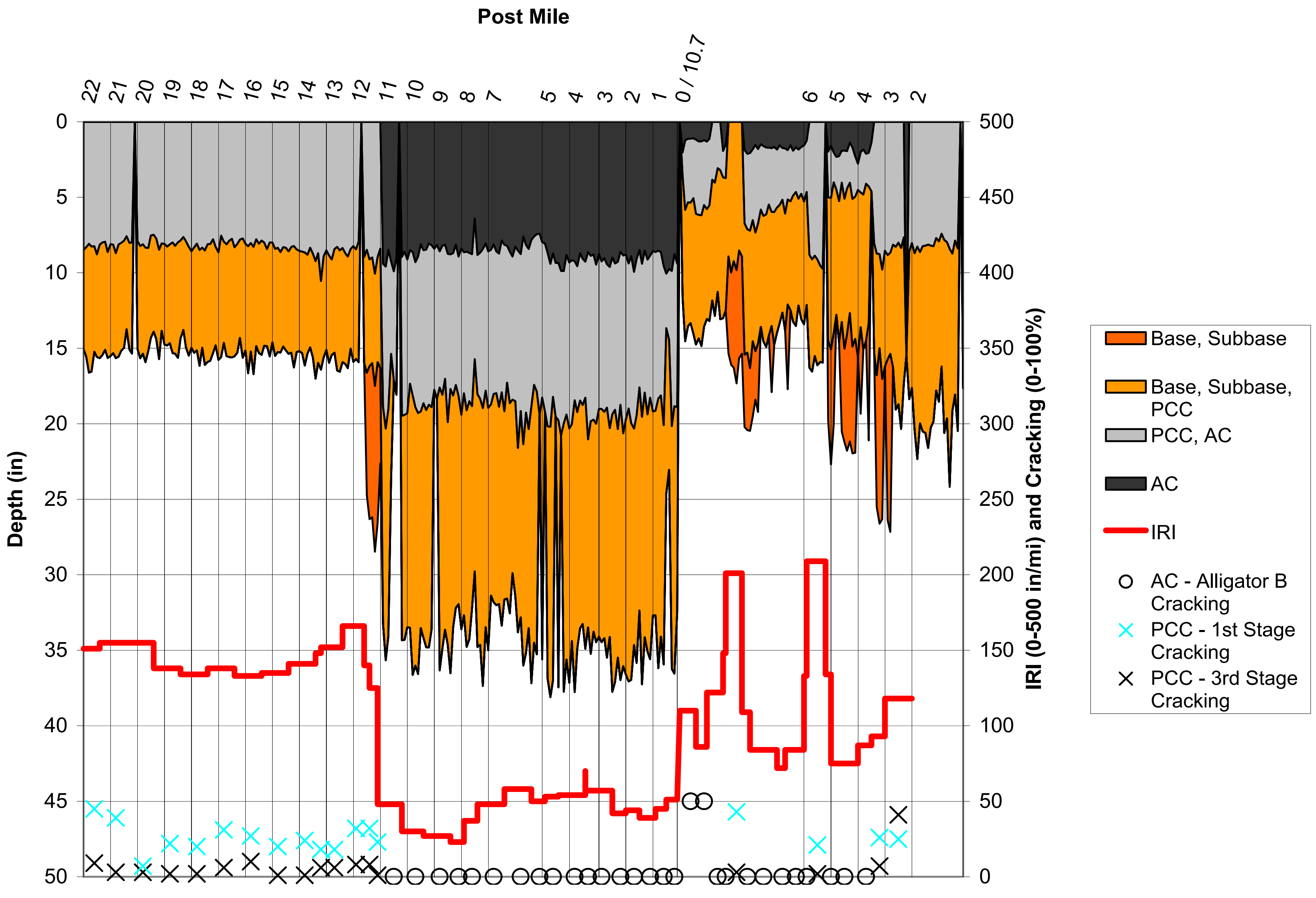

Figure C12. GPR cross section with selected PCS data – Yolo and Solano I-505 SB (ouside lane), CAL050.

APPENDIX D: SEGMENTATION RESULTS

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
CAL009	99	Sacramento	SB	IV	24.35	23.13	SACRAMENTO, JCT. RTE. 51, NORTH JCT. RTE. 50; END FREEWAY	SACRAMENTO, 12TH AVENUE
				IV	23.13	21.94	SACRAMENTO, 12TH AVENUE	SACRAMENTO, FRUITRIDGE ROAD
				IV	21.94	21.57	SACRAMENTO, FRUITRIDGE ROAD	MARTIN LUTHER KING JR. BOULEVARD
				IV	21.57	21.46	MARTIN LUTHER KING JR. BOULEVARD	observed structure change
				IV	21.46	20.86	observed structure change	47TH AVENUE
				IV	20.86	19.61	47TH AVENUE	FLORIN ROAD
				IV	19.61	17.66	FLORIN ROAD	SACRAMENTO, MACK ROAD
				IV	17.66	17.46	SACRAMENTO, MACK ROAD	observed structure change
				IV	17.46	17.24	observed structure change	SACRAMENTO, STOCKTON BOULEVARD
				IV	17.24	15.90	SACRAMENTO, STOCKTON BOULEVARD	COSUMNES RIVER BOULEVARD/ CALVINE ROAD
				IV	15.90	15.66	COSUMNES RIVER BOULEVARD/ CALVINE ROAD	observed structure change
				IV	15.66	15.16	observed structure change	observed structure change
				IV	15.16	14.87	observed structure change	SHELDON ROAD
				IV	14.87	13.84	SHELDON ROAD	LAGUNA BOULEVARD/BOND ROAD
				IV	13.84	12.76	LAGUNA BOULEVARD/BOND ROAD	ELK GROVE BOULEVARD
				IV	12.76	11.26	ELK GROVE BOULEVARD	observed structure change
				IV	11.26	10.07	observed structure change	GRANT LINE ROAD
				IV	10.07	9.26	GRANT LINE ROAD	observed structure change
				IV	9.26	8.96	observed structure change	ESCHINGER ROAD
				IV	8.96	8.46	ESCHINGER ROAD	observed structure change
				IV	8.46	7.96	observed structure change	observed structure change
				IV	7.96	7.36	observed structure change	DILLARD ROAD
				IV	7.36	6.01	DILLARD ROAD	ARNO ROAD
				IV	6.01	4.39	ARNO ROAD	MINGO ROAD
				IV	4.39	3.56	MINGO ROAD	observed structure change
				IV	3.56	3.53	observed structure change	TWIN CITIES, JCT. RTE. 104 EAST
				IV	3.53	3.26	TWIN CITIES, JCT. RTE. 104 EAST	observed structure change
				IV	3.26	3.16	observed structure change	observed structure change
				IV	3.16	2.70	observed structure change	WALNUT STREET
				IV	2.70	2.26	WALNUT STREET	observed structure change
				IV	2.26	2.16	observed structure change	observed structure change
				IV	2.16	1.88	observed structure change	GALT, PRINGLE AVENUE
				IV	1.88	1.57	GALT, PRINGLE AVENUE	GALT, SIMMERHORN ROAD
				IV	1.57	1.26	GALT, SIMMERHORN ROAD	observed structure change
				IV	1.26	0.79	observed structure change	GALT, C STREET
				IV	0.79	0.33	GALT, C STREET	GALT, FRONTAGE ROAD
				IV	0.33	0.12	GALT, FRONTAGE ROAD	SAN JOAQUIN-SACRAMENTO COUNTY LINE
CAL011	5	Sacramento	SB	IV	22.57	20.53	SACRAMENTO, JCT. RTE. 50	SACRAMENTO, SUTTERVILLE ROAD
				IV	20.53	19.30	SACRAMENTO, SUTTERVILLE ROAD	SACRAMENTO, SEAMAS AVENUE (FRUITRIDGE)
				IV	19.30	18.65	SACRAMENTO, SEAMAS AVENUE	SACRAMENTO, 43RD AVENUE

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
							(FRUITRIDGE)	
				IV	18.65	17.19	SACRAMENTO, 43RD AVENUE	SACRAMENTO, FLORIN ROAD
				IV	17.19	16.15	SACRAMENTO, FLORIN ROAD	SACRAMENTO, POCKET/ MEADOWVIEW ROADS
				IV	16.15	15.65	SACRAMENTO, POCKET/ MEADOWVIEW ROADS	observed structure change
				IV	15.65	13.05	observed structure change	observed structure change
				IV	13.05	12.04	observed structure change	LAGUNA BOULEVARD
				IV	12.04	10.83	LAGUNA BOULEVARD	ELK GROVE BOULEVARD
				IV	10.83	8.49	ELK GROVE BOULEVARD	HOOD-FRANKLIN ROAD
				IV	8.49	4.65	HOOD-FRANKLIN ROAD	Lambert Road
				IV	4.65	2.13	Lambert Road	TWIN CITIES ROAD
				IV	2.13	0.02	TWIN CITIES ROAD	SAN JOAQUIN-SACRAMENTO COUNTY LINE
CAL013	99	Sacramento/ Sutter	NB	IV	26.72	26.76	SACRAMENTO, JCT. RTE. 80 (I-5 Postmile)	observed structure change
				IV	26.76	26.96	observed structure change	observed structure change
				IV	26.96	29.02	observed structure change	SACRAMENTO, DEL PASO ROAD (I-5 Postmile)
				IV	29.02	29.91	SACRAMENTO, DEL PASO ROAD (I-5 Postmile)	SACRAMENTO, JCT. RTE. 99 NORTH (I-5 Postmile) - Start SR 99 Postmiles
				IV	32.12	32.67	SACRAMENTO, JCT. RTE. 99 NORTH (I-5 Postmile) - Start SR 99 Postmiles	observed structure change
				IV	32.67	33.36	observed structure change	ELKHORN BOULEVARD
				IV	33.36	35.37	ELKHORN BOULEVARD	ELVERTA ROAD
				IV	35.37	36.86	ELVERTA ROAD	Sacramento-Sutter County Line
				IV	0.00	0.61	Sacramento-Sutter County Line	observed structure change
				IV	0.61	0.95	observed structure change	RIEGO ROAD
				IV	0.95	4.21	RIEGO ROAD	observed structure change
				IV	4.21	5.91	observed structure change	observed structure change
				IV	5.91	6.11	observed structure change	observed structure change
				IV	6.11	6.83	observed structure change	observed structure change
				IV	6.83	8.07	observed structure change	JCT. RTE. 70 NORTH
CAL015	113	Yolo	NB	IV	0.42	1.08	HUTCHINSON DRIVE	DAVIS, RUSSELL BOULEVARD
				IV	1.08	2.08	DAVIS, RUSSELL BOULEVARD	COUNTY ROAD 31
				IV	2.08	4.11	COUNTY ROAD 31	COUNTY ROAD 29
				IV	4.11	5.80	COUNTY ROAD 29	observed structure change
				IV	5.80	6.11	observed structure change	COUNTY ROAD 27
				IV	6.11	7.66	COUNTY ROAD 27	COUNTY ROAD 25
				IV	7.66	9.23	COUNTY ROAD 25	WOODLAND, GIBSON ROAD
				IV	9.23	10.15	WOODLAND, GIBSON ROAD	WOODLAND, EAST MAIN STREET
				IV	10.15	10.72	WOODLAND, EAST MAIN STREET	WOODLAND, JCT. RTE. 5
CAL017	5	Yolo	SB	IV	28.92	25.57	YOLO COUNTY-COLUSA COUNTY (COUNTY	COUNTY ROAD 6
				IV	25.57	23.79	COUNTY ROAD 6	COUNTY ROAD 8
				IV	23.79	22.61	COUNTY ROAD 8	JCT. RTE. 505 SOUTH

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
				IV	22.61	21.80	JCT. RTE. 505 SOUTH	observed structure change
				IV	21.80	17.62	observed structure change	ZAMORA INTERCHANGE, COUNTY ROAD 13
				IV	17.62	12.34	ZAMORA INTERCHANGE, COUNTY ROAD 13	YOLO INTERCHANGE, COUNTY ROAD 17
				IV	12.34	10.81	YOLO INTERCHANGE, COUNTY ROAD 17	JCT. RTE. 16, COUNTY ROAD 18
				IV	10.81	9.41	JCT. RTE. 16, COUNTY ROAD 18	COUNTY ROAD 99/WEST STREET
				IV	9.41	8.26	COUNTY ROAD 99/WEST STREET	WOODLAND, JCT. RTE. 113 NORTH
CAL031	80	Solano	WB	IV	44.72	42.67	SOLANO-YOLO COUNTY LINE	JCT. RTE. 113 NORTH
				IV	42.67	41.90	JCT. RTE. 113 NORTH	observed structure change
				IV	41.90	40.30	observed structure change	observed structure change
				IV	40.30	39.74	observed structure change	Pedrick
				IV	39.74	38.60	Pedrick	observed structure change
				IV	38.60	38.21	observed structure change	JCT. RTE. 113 SOUTH
				IV	38.21	36.90	JCT. RTE. 113 SOUTH	Pitt School Road
				IV	36.90	35.55	Pitt School Road	DIXON AVENUE/GRANT ROAD
				IV	35.55	32.62	DIXON AVENUE/GRANT ROAD	Midway
				IV	32.62	31.36	Midway	Meridian
				IV	31.36	29.86	Meridian	Leisure Town
				IV	29.86	28.36	Leisure Town	VACAVILLE, JCT. RTE. 505 NORTH
				IV	28.36	27.24	VACAVILLE, JCT. RTE. 505 NORTH	VACAVILLE, MONTE VISTA AVENUE
				IV	27.24	26.46	VACAVILLE, MONTE VISTA AVENUE	Mason/Elmira
				IV	26.46	26.01	Mason/Elmira	VACAVILLE, DAVIS STREET
				IV	26.01	25.31	VACAVILLE, DAVIS STREET	VACAVILLE, ALAMO DRIVE
				IV	25.31	23.96	VACAVILLE, ALAMO DRIVE	PLEASANT VALLEY/Pena Adobe Road
				IV	23.96	20.80	PLEASANT VALLEY/Pena Adobe Road	FAIRFIELD, NORTH TEXAS STREET
				IV	20.80	19.18	FAIRFIELD, NORTH TEXAS STREET	FAIRFIELD, AIRBASE PARKWAY
				IV	19.18	17.92	FAIRFIELD, AIRBASE PARKWAY	FAIRFIELD, TRAVIS BOULEVARD
				IV	17.92	17.20	FAIRFIELD, TRAVIS BOULEVARD	FAIRFIELD, WEST TEXAS STREET
				IV	17.20	15.82	FAIRFIELD, WEST TEXAS STREET	FAIRFIELD, EAST JCT. RTE. 12
				IV	15.82	15.20	FAIRFIELD, EAST JCT. RTE. 12	observed structure change
				IV	15.20	13.49	observed structure change	FAIRFIELD, SUISUN VALLEY ROAD
				IV	13.49	12.84	FAIRFIELD, SUISUN VALLEY ROAD	FAIRFIELD, JCT. RTE. 680 SOUTH
				IV	12.84	12.70	FAIRFIELD, JCT. RTE. 680 SOUTH	observed structure change
				IV	12.70	11.98	observed structure change	FAIRFIELD, JCT. RTE. 12 WEST
				IV	12.22	11.98	MILEPOST EQUATION =12.20	FAIRFIELD, JCT. RTE. 12 WEST
				IV	11.98	11.39	FAIRFIELD, JCT. RTE. 12 WEST	FAIRFIELD, RED TOP ROAD
				IV	11.39	9.65	FAIRFIELD, RED TOP ROAD	observed structure change/climate region change
				CC	9.65	~8.2	observed structure change	observed structure change
				CC	~8.2	8.10	observed structure change	AMERICAN CANYON ROAD
				CC	8.10	8.00	AMERICAN CANYON ROAD	NAPA-SOLANO COUNTY LINE
				CC	8.00	6.81	NAPA-SOLANO COUNTY LINE	SOLANO-NAPA COUNTY LINE
				CC	6.81	5.63	SOLANO-NAPA COUNTY LINE	VALLEJO, JCT. RTE. 37 WEST
				CC	5.63	~5.2	VALLEJO, JCT. RTE. 37 WEST	observed structure change
				CC	~5.2	4.43	observed structure change	VALLEJO, REDWOOD STREET

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
				CC	4.43	3.49	VALLEJO, REDWOOD STREET	VALLEJO, TENNESSEE STREET
				CC	3.49	3.23	VALLEJO, TENNESSEE STREET	VALLEJO, SPRINGS ROAD
				CC	3.23	2.88	VALLEJO, SPRINGS ROAD	VALLEJO, GEORGIA STREET
				CC	2.88	2.22	VALLEJO, GEORGIA STREET	VALLEJO, JCT. RTE. 780 SOUTHEAST
				CC	2.22	1.78	VALLEJO, JCT. RTE. 780 SOUTHEAST	VALLEJO, MAGAZINE STREET
				CC	1.78	1.14	VALLEJO, MAGAZINE STREET	VALLEJO, JCT RTE 29 NORTHWEST
				CC	1.14	0.00	VALLEJO, JCT RTE 29 NORTHWEST	SOLANO COUNTY (CARQUINEZ BRIDGE)
CAL033	5	Sacramento/ Yolo	NB	IV	29.91	32.73	SACRAMENTO, JCT. RTE. 99 NORTH	AIRPORT BOULEVARD
				IV	32.73	34.35	AIRPORT BOULEVARD	observed structure change
				IV	34.35	34.65	observed structure change	Sacramento-Yolo County Line
				IV	0.00	0.50	Sacramento-Yolo County Line	observed structure change
				IV	0.50	0.80	observed structure change	observed structure change
				IV	0.80	2.60	observed structure change	observed structure change
				IV	2.60	5.53	observed structure change	COUNTY ROAD 102
				IV	5.53	6.51	COUNTY ROAD 102	WOODLAND, EAST MAIN STREET
				IV	6.51	7.09	WOODLAND, EAST MAIN STREET	WOODLAND, JCT. RTE. 113 SOUTH
				IV	7.09	8.26	WOODLAND, JCT. RTE. 113 SOUTH	WOODLAND, JCT. RTE. 113 NORTH
CAL035	16	Colusa/Yolo	WB	IV	40.57	39.56	WEST MAIN STREET/COUNTY ROAD 98	COUNTY ROAD 97
				IV	39.56	36.71	COUNTY ROAD 97	COUNTY ROAD 94B
				IV	36.71	35.44	COUNTY ROAD 94B	observed structure change
				IV	35.44	32.34	observed structure change	observed structure change
				IV	32.34	31.87	observed structure change	JCT. RTE. 505; MADISON, EAST
				IV	31.87	31.03	JCT. RTE. 505; MADISON, EAST	MADISON, COUNTY ROAD 89
				IV	31.03	28.27	MADISON, COUNTY ROAD 89	COUNTY ROAD 21A
				IV	28.27	27.96	COUNTY ROAD 21A	GRAFTON STREET
				IV	27.96	27.55	GRAFTON STREET	ESPARTO, ORLEANS STREET
				IV	27.55	26.37	ESPARTO, ORLEANS STREET	COUNTY ROAD 85B
				IV	26.37	25.15	COUNTY ROAD 85B	CAPAY, CAPAY CANAL BRIDGE
				IV	25.15	20.17	CAPAY, CAPAY CANAL BRIDGE	COUNTY ROAD 78A
				IV	20.17	19.43	COUNTY ROAD 78A	INDIAN BINGO ROAD
				IV	19.43	19.20	INDIAN BINGO ROAD	WINNERS WAY
				IV	19.20	18.78	WINNERS WAY	COUNTY ROAD 78
				IV	18.78	18.13	COUNTY ROAD 78	MOSSY CREEK BRIDGE
				IV	18.13	~14.4	MOSSY CREEK BRIDGE	observed structure change
				IV	~14.4	12.21	observed structure change	GUINDA, COUNTY ROAD 57
				IV	12.21	10.80	GUINDA, COUNTY ROAD 57	COUNTY ROAD 45
				IV	10.80	7.15	COUNTY ROAD 45	RUMSEY, MANZANITA AVENUE (TO ARBUCKLE)
				IV	7.15	0.00	RUMSEY, MANZANITA AVENUE (TO ARBUCKLE)	Yolo-Colusa County Line
				IV	7.26	0.00	Yolo-Colusa County Line	BEAR CREEK, JCT. RTE. 20
CAL041	80	Solano	WB	IV	44.72	42.67	SOLANO-YOLO COUNTY LINE	JCT. RTE. 113 NORTH

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
				IV	42.67	41.90	JCT. RTE. 113 NORTH	observed structure change
				IV	41.90	40.20	observed structure change	observed structure change
				IV	40.20	39.74	observed structure change	Pedrick
				IV	39.74	38.60	Pedrick	observed structure change
				IV	38.60	38.21	observed structure change	JCT. RTE. 113 SOUTH
				IV	38.21	36.90	JCT. RTE. 113 SOUTH	Pitt School Road
				IV	36.90	35.55	Pitt School Road	DIXON AVENUE/GRANT ROAD
				IV	35.55	32.62	DIXON AVENUE/GRANT ROAD	Midway
				IV	32.62	31.36	Midway	Meridian
				IV	31.36	29.86	Meridian	Leisure Town
				IV	29.86	28.36	Leisure Town	VACAVILLE, JCT. RTE. 505 NORTH
				IV	28.36	27.24	VACAVILLE, JCT. RTE. 505 NORTH	VACAVILLE, MONTE VISTA AVENUE
				IV	27.24	26.46	VACAVILLE, MONTE VISTA AVENUE	Mason/Elmira
				IV	26.46	26.01	Mason/Elmira	VACAVILLE, DAVIS STREET
				IV	26.01	25.31	VACAVILLE, DAVIS STREET	VACAVILLE, ALAMO DRIVE
				IV	25.31	23.96	VACAVILLE, ALAMO DRIVE	PLEASANT VALLEY
				IV	23.96	20.80	PLEASANT VALLEY	FAIRFIELD, NORTH TEXAS STREET
				IV	20.80	19.18	FAIRFIELD, NORTH TEXAS STREET	FAIRFIELD, AIRBASE PARKWAY
				IV	19.18	17.92	FAIRFIELD, AIRBASE PARKWAY	FAIRFIELD, TRAVIS BOULEVARD
				IV	17.92	17.20	FAIRFIELD, TRAVIS BOULEVARD	FAIRFIELD, WEST TEXAS STREET
				IV	17.20	15.82	FAIRFIELD, WEST TEXAS STREET	FAIRFIELD, EAST JCT. RTE. 12
				IV	15.82	15.20	FAIRFIELD, EAST JCT. RTE. 12	observed structure change
				IV	15.20	13.49	observed structure change	FAIRFIELD, SUISUN VALLEY ROAD
				IV	13.49	12.84	FAIRFIELD, SUISUN VALLEY ROAD	FAIRFIELD, JCT. RTE. 680 SOUTH
				IV	12.84	12.70	FAIRFIELD, JCT. RTE. 680 SOUTH	observed structure change
				IV	12.70	11.98	observed structure change	FAIRFIELD, JCT. RTE. 12 WEST
				IV	12.22	11.98	MILEPOST EQUATION =12.20	FAIRFIELD, JCT. RTE. 12 WEST
				IV	11.98	11.39	FAIRFIELD, JCT. RTE. 12 WEST	FAIRFIELD, RED TOP ROAD
				IV	11.39	~10.5	FAIRFIELD, RED TOP ROAD	observed structure change
				IV	~10.5	9.65	observed structure change	climate region change
				CC	9.65	~8.2	climate region change	observed structure change
				CC	~8.2	8.10	observed structure change	AMERICAN CANYON ROAD
				CC	8.10	8.00	AMERICAN CANYON ROAD	NAPA-SOLANO COUNTY LINE
				CC	8.00	6.81	NAPA-SOLANO COUNTY LINE	SOLANO-NAPA COUNTY LINE
				CC	6.81	5.63	SOLANO-NAPA COUNTY LINE	VALLEJO, JCT. RTE. 37 WEST
				CC	5.63	~4.6	VALLEJO, JCT. RTE. 37 WEST	observed structure change
				CC	~4.6	4.43	observed structure change	VALLEJO, REDWOOD STREET
				CC	4.43	~3.7	VALLEJO, REDWOOD STREET	observed structure change
				CC	~3.7	3.49	observed structure change	VALLEJO, TENNESSEE STREET
				CC	3.49	3.23	VALLEJO, TENNESSEE STREET	VALLEJO, SPRINGS ROAD (Solano)
				CC	3.23	2.88	VALLEJO, SPRINGS ROAD (Solano)	VALLEJO, GEORGIA STREET
				CC	2.88	2.22	VALLEJO, GEORGIA STREET	VALLEJO, JCT. RTE. 780 SOUTHEAST
				CC	2.22	1.78	VALLEJO, JCT. RTE. 780 SOUTHEAST	VALLEJO, MAGAZINE STREET

Section ID	Route	County	Direction	Climate Region	PM from Traffic Data		Physical Reference	
					Start	End	Start	End
				CC	1.78	1.14	VALLEJO, MAGAZINE STREET	VALLEJO, JCT RTE 29 NORTHWEST
				CC	1.14	0.00	VALLEJO, JCT RTE 29 NORTHWEST	SOLANO COUNTY (CARQUINEZ BRIDGE)
CAL047	50	Sacramento	EB	IV	12.50	14.30	SUNRISE BOULEVARD	observed structure change
				IV	14.30	15.76	observed structure change	NIMBUS ROAD/HAZEL AVENUE
				IV	15.76	16.10	NIMBUS ROAD/HAZEL AVENUE	AEROJET ROAD
				IV	16.10	17.01	AEROJET ROAD	FOLSOM BOULEVARD/NATOMA
				IV	17.01	17.20	FOLSOM BOULEVARD/NATOMA	observed structure change
				IV	17.20	18.70	observed structure change	observed structure change
				IV	18.70	19.23	observed structure change	PRAIRIE CITY ROAD
				IV	19.23	21.50	PRAIRIE CITY ROAD	SCOTT ROAD/E Bidwell
				IV	21.50	22.70	SCOTT ROAD/E Bidwell	observed structure change
				IV	22.7	23.14	observed structure change	Sacramento - El Dorado County Line
CAL049	45	Yolo	SB	IV	12.92	8.02	Yolo - Colusa County Line	observed structure change
				IV	8.02	5.80	observed structure change	COUNTY ROAD P98A
				IV	5.80	0.27	COUNTY ROAD P98A	COUNTY ROAD 108
				IV	0.27	0.00	COUNTY ROAD 108	Yolo - Colusa County Line
CAL050	505	Yolo/Solano	SB	IV	22.36	20.11	DUNNIGAN, JCT. RTE. 4	COUNTY ROAD 12A
				IV	20.11	17.45	COUNTY ROAD 12A	COUNTY ROAD 14
				IV	17.45	13.43	COUNTY ROAD 14	COUNTY ROAD 19
				IV	13.43	10.93	COUNTY ROAD 19	observed structure change
				IV	10.93	10.62	observed structure change	JCT. RTE. 16; MADISON, EAST
				IV	10.62	6.53	JCT. RTE. 16; MADISON, EAST	COUNTY ROAD 27
				IV	6.53	4.03	COUNTY ROAD 27	COUNTY ROAD 29A
				IV	4.03	0.40	COUNTY ROAD 29A	JCT. RTE. 128 WEST; RUSSELL BOULEVARD
				IV	0.40	0.00	JCT. RTE. 128 WEST; RUSSELL BOULEVARD	Solano - Yolo County Line
				IV	10.63	9.36	Solano - Yolo County Line	observed structure change
				IV	9.36	8.96	observed structure change	observed structure change
				IV	8.96	8.76	observed structure change	observed structure change
				IV	8.76	8.16	observed structure change	observed structure change
				IV	8.16	5.76	observed structure change	observed structure change
				IV	5.76	5.57	observed structure change	ALLENDALE ROAD
				IV	5.57	5.06	ALLENDALE ROAD	observed structure change
				IV	5.06	3.36	observed structure change	observed structure change
				IV	3.36	3.06	observed structure change	VACAVILLE, MIDWAY ROAD
				IV	3.06	1.45	VACAVILLE, MIDWAY ROAD	VACAVILLE, VACA VALLEY PARKWAY
				IV	1.45	0.00	VACAVILLE, VACA VALLEY PARKWAY	VACAVILLE, JCT. RTE. 80; BEGIN FREEWAY

APPENDIX E: GPR DATA AND UCPRC CORE COMPARISON: PLOTS

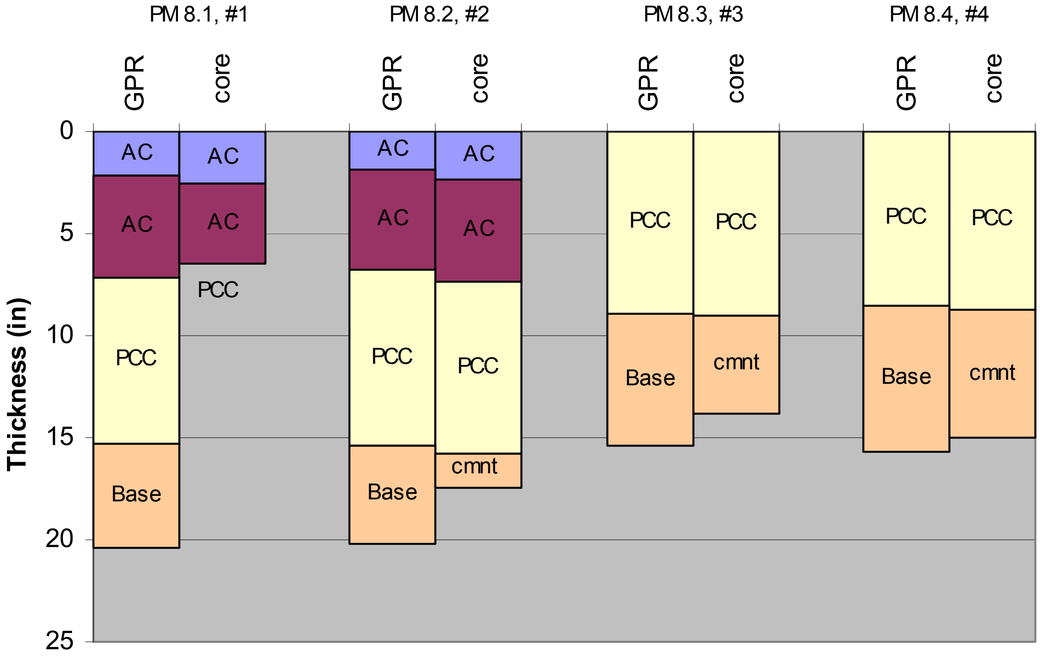

Figure E1. GPR/core thickness - Solano 505 SB, CAL050-1a.

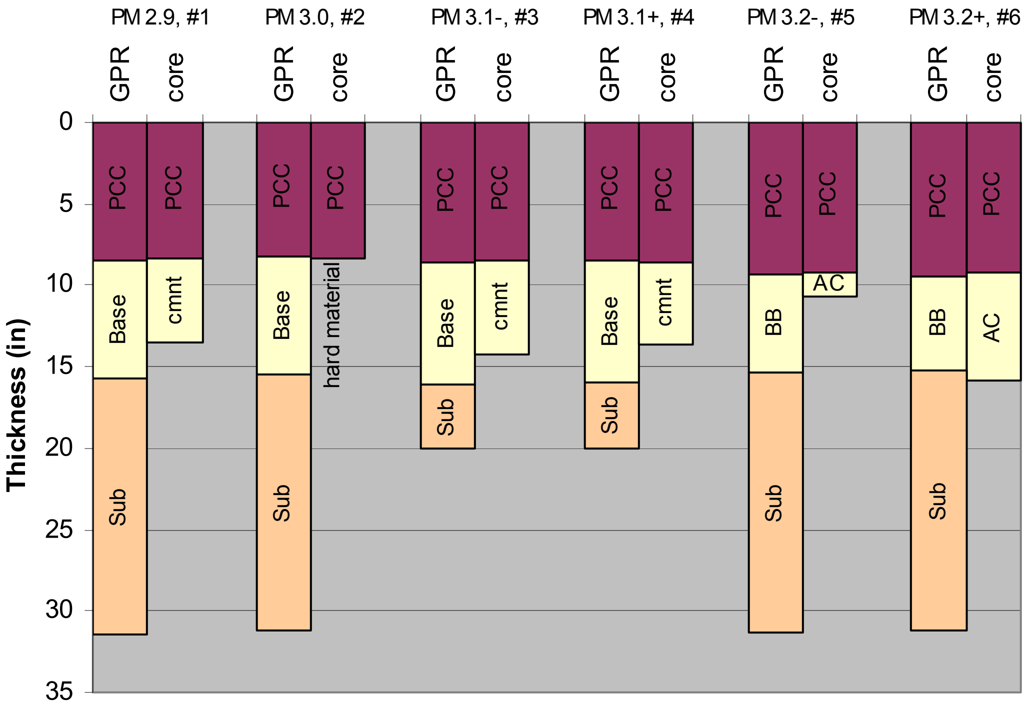

Figure E2. GPR/core thickness - Yolo 113 NB, CAL015-5.

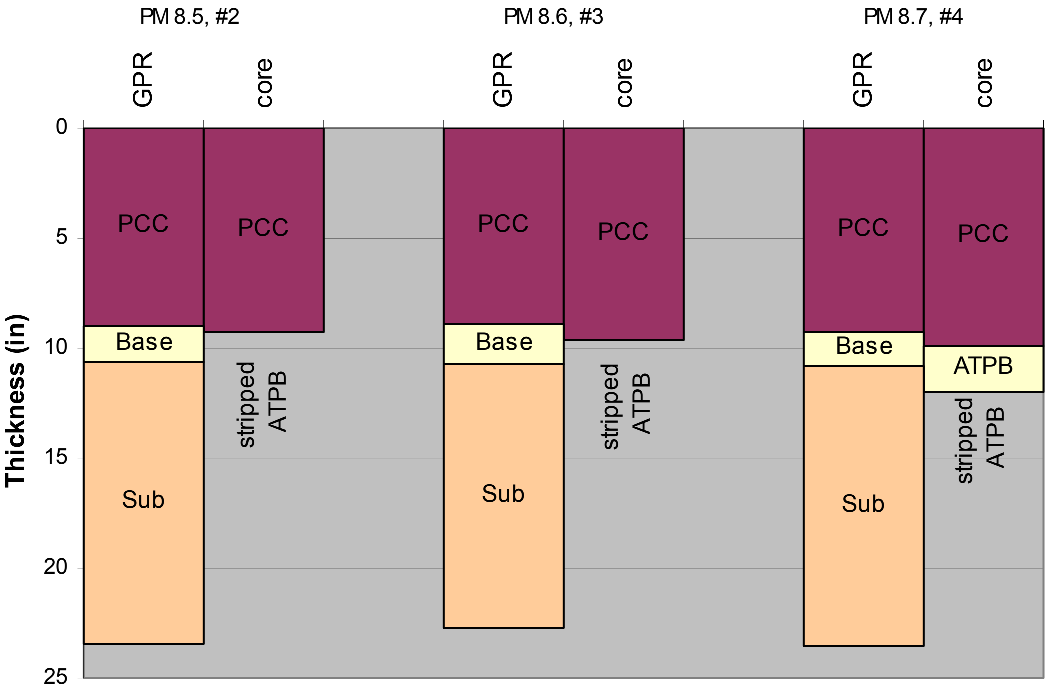

Figure E3. GPR/core thickness - Yolo 113 NB, CAL015-5a.

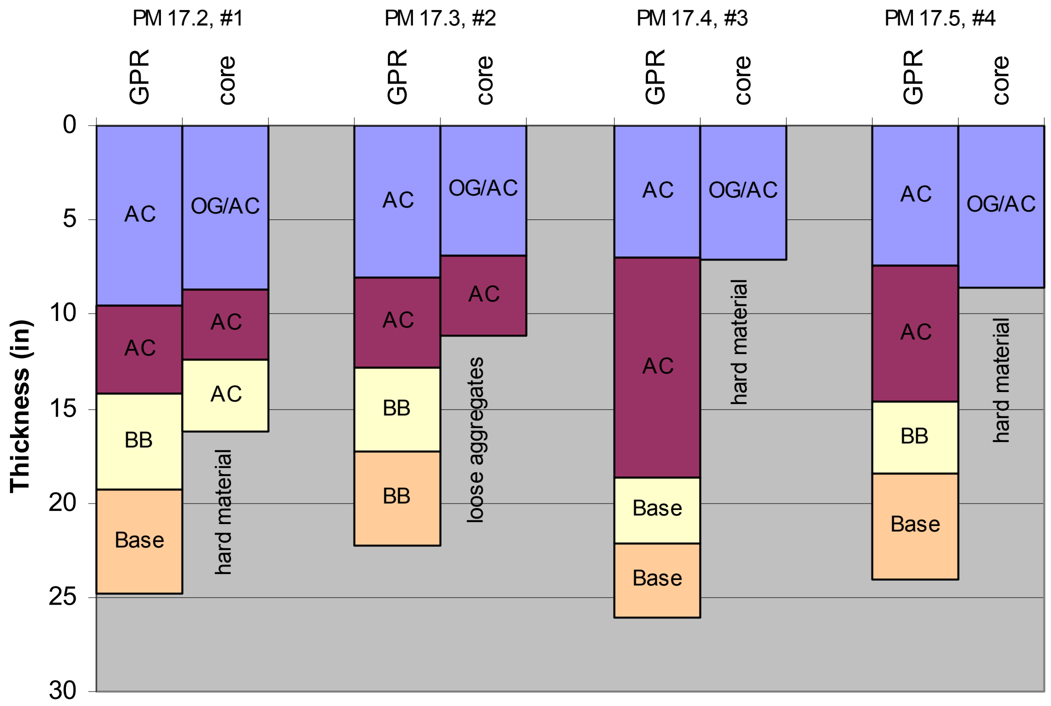

Figure E4. GPR/core thickness - Sacramento 50 EB, CAL047-9.

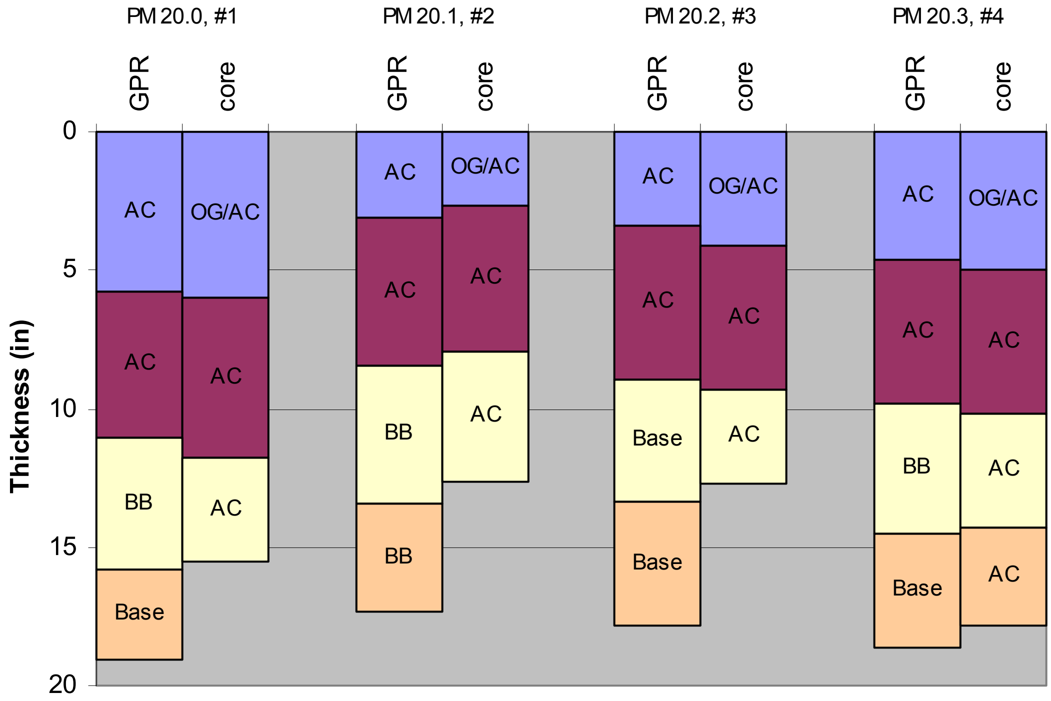

Figure E5. GPR/core thickness – Sacramento 50 EB, CAL047-10.

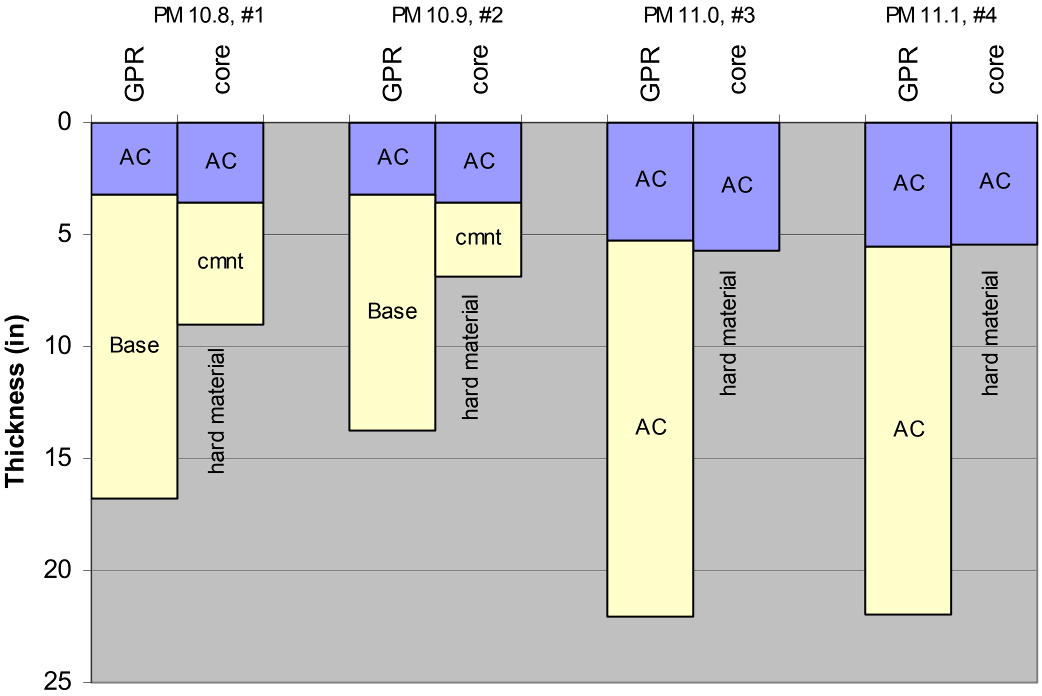

Figure E6. GPR/core thickness - Yolo 45 SB, CAL049-11.

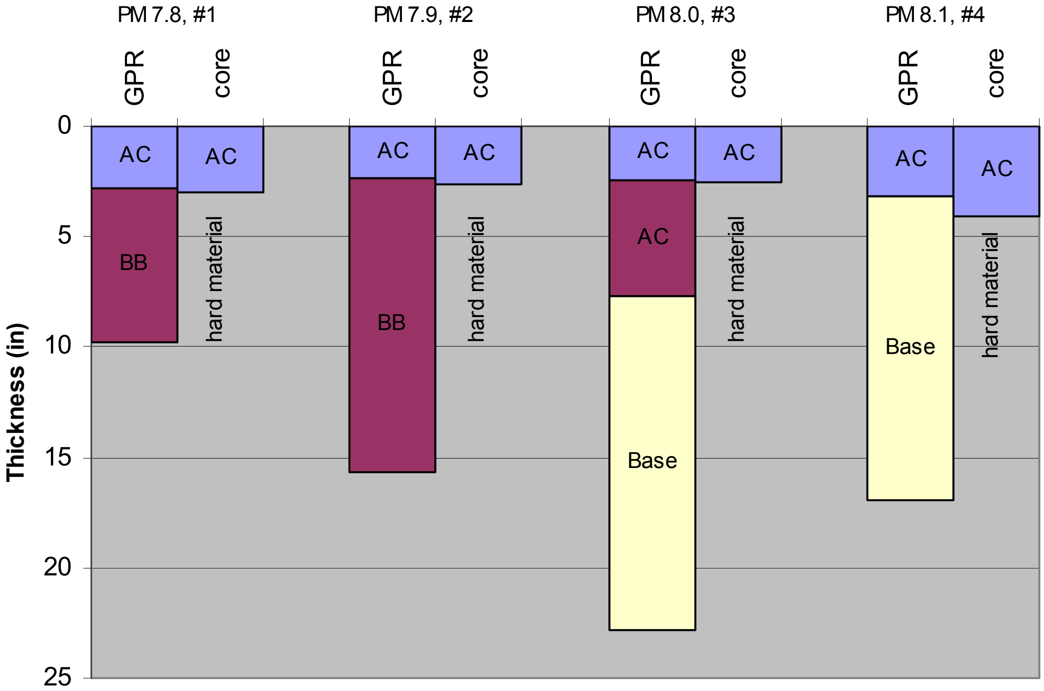

Figure E7. GPR/core thickness - Yolo 45 SB, CAL049-12.

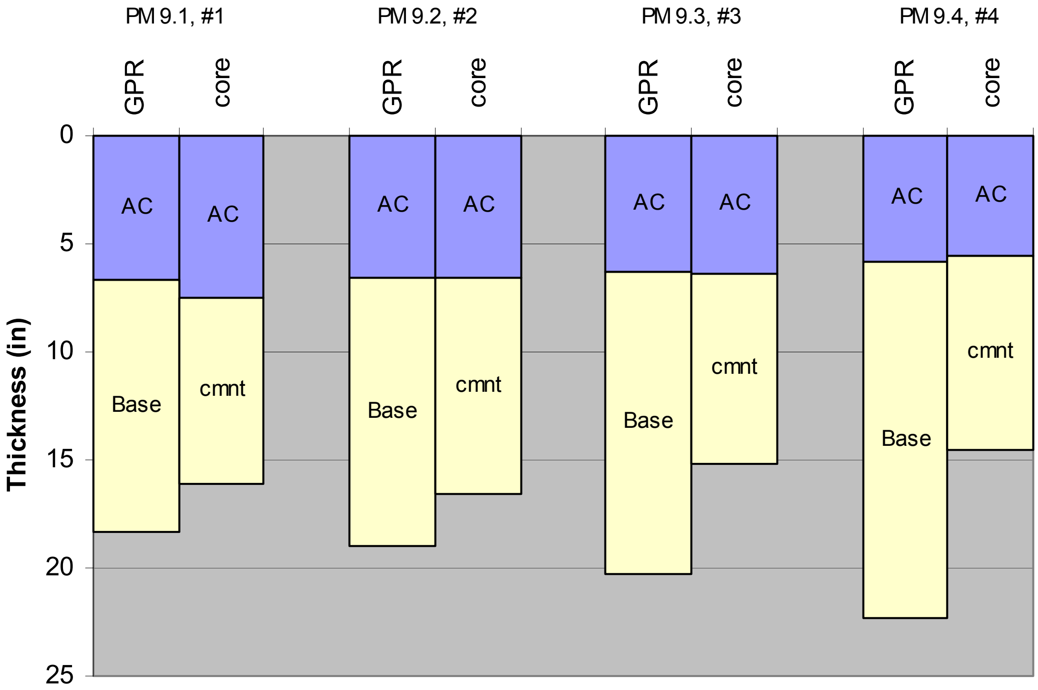

Figure E8. GPR/core thickness - Yolo 45 SB, CAL049-12a.

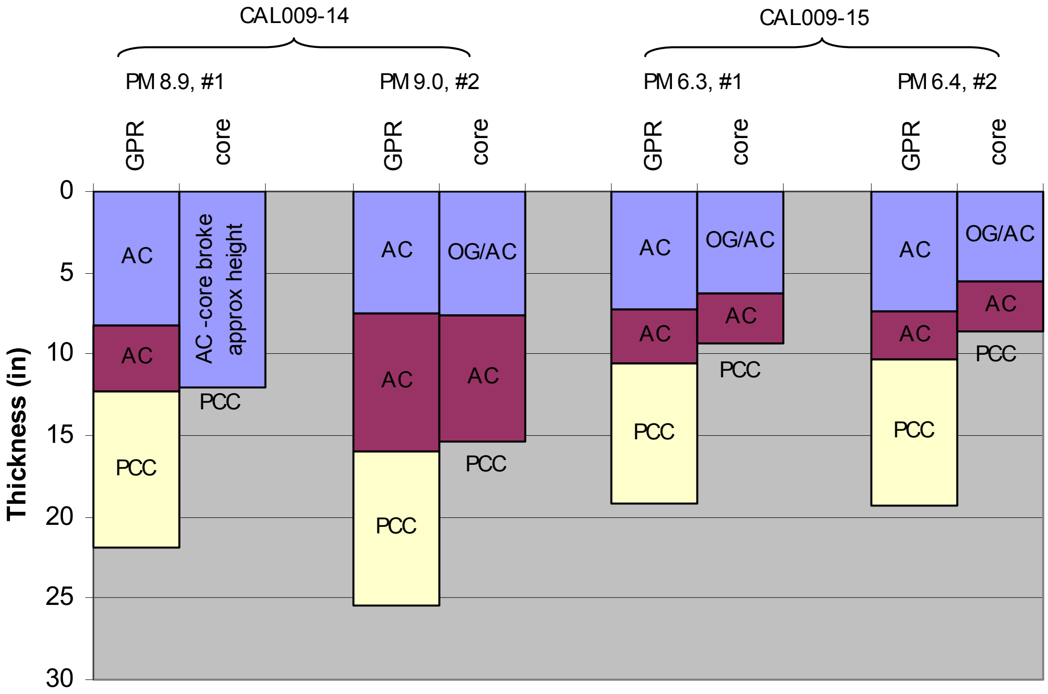

Figure E9. GPR/core thickness - Sacramento 99 NB, CAL009-14,15.

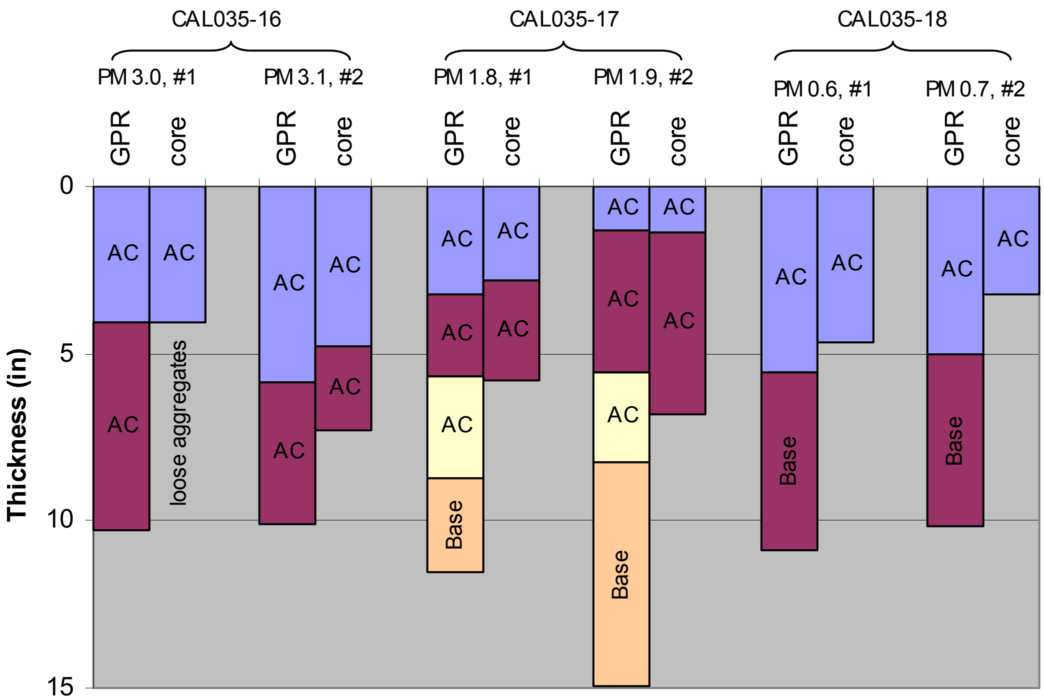

Figure E10. GPR/core thickness - Colusa 16 WB, CAL035-16,17,18.

APPENDIX F: GPR DATA AND UCPRC CORE COMPARISON: TABLES

Table F1. GPR Data and UCPRC Core Thicknesses

Site, Closure, Core #	Co., Route, Approx PM, Dir	GPR - Layer Thicknesses (in)				Cores - Layer Thicknesses (in)			
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 1	Layer 2	Layer 3	Layer 4
CAL009-14 #1	Sac 99, PM 8.9 SB	8.22	4.05	9.56		n/a			
CAL009-14 #2	Sac 99, PM 9 SB	7.55	8.44	9.44		7.67	7.68		
CAL009-15 #1	Sac 99, PM 6.3 SB	7.25	3.34	8.59		6.21	3.11		
CAL009-15 #2	Sac 99, PM 6.4 SB	7.41	2.93	9.00		5.59	3.05		
CAL015-5 #1	Yolo 113, PM 2.9 NB		8.50	7.22	15.68		8.41	5.05	
CAL015-5 #2	Yolo 113, PM 3 NB		8.22	7.22	15.77		8.35	0.00	
CAL015-5 #3	Yolo 113, PM 3.1 NB		8.57	7.48	4.00		8.46	5.83	
CAL015-5 #4	Yolo 113, PM 3.1 NB		8.50	7.51	3.95		8.56	5.10	
CAL015-5 #5	Yolo 113, PM 3.2 NB		9.38	5.93	16.02		9.26	1.37	
CAL015-5 #6	Yolo 113, PM 3.2 NB		9.45	5.82	15.95		9.17	6.70	
CAL015-5a #1	Yolo 113, PM 8.4 NB		9.46	1.66	12.01		n/a		
CAL015-5a #2	Yolo 113, PM 8.5 NB		8.97	1.65	12.83		9.26		
CAL015-5a #3	Yolo 113, PM 8.6 NB		8.90	1.86	12.00		9.68		
CAL015-5a #4	Yolo 113, PM 8.7 NB		9.29	1.53	12.69		9.87	2.14	
CAL035-16 #1	Col 16, PM 3 WB	4.09	6.20			4.06			
CAL035-16 #2	Col 16, PM 3.1 WB	5.87	4.25			4.77	2.55		
CAL035-17 #1	Col 16, PM 1.8 WB	3.22	2.49	3.04	2.76	2.79	3.02		
CAL035-17 #2	Col 16, PM 1.9 WB	1.29	4.25	2.73	6.68	1.40	5.42		
CAL035-18 #1	Col 16, PM 0.6 WB	5.58	5.33			4.65			
CAL035-18 #2	Col 16, PM 0.7 WB	5.01	5.16			3.25			
CAL047-9 #1	Sac 50, PM 17.2 EB	9.55	4.63	5.07	5.54	8.71	3.70	3.78	
CAL047-9 #2	Sac 50, PM 17.3 EB	8.05	4.77	4.45	4.97	6.89	4.29		
CAL047-9 #3	Sac 50, PM 17.4 EB	6.98	11.67	3.51	3.92	7.13			
CAL047-9 #4	Sac 50, PM 17.5 EB	7.45	7.23	3.78	5.60	8.62			
CAL047-10 #1	Sac 50, PM 20 EB	5.79	5.29	4.72	3.28	6.01	5.75	3.74	
CAL047-10 #2	Sac 50, PM 20.1 EB	3.13	5.32	4.98	3.88	2.64	5.28	4.68	
CAL047-10 #3	Sac 50, PM 20.2 EB	3.39	5.56	4.44	4.44	4.13	5.15	3.42	
CAL047-10 #4	Sac 50, PM 20.3 EB	4.64	5.17	4.72	4.08	4.99	5.19	4.09	3.55
CAL049-11 #1	Yolo 45, PM 10.8 SB	3.25		13.52		3.55		5.51	
CAL049-11 #2	Yolo 45, PM 10.9 SB	3.26		10.50		3.58		3.31	
CAL049-11 #3	Yolo 45, PM 11 SB	5.31		16.75		5.72			
CAL049-11 #4	Yolo 45, PM 11.1 SB	5.50		16.44		5.47			
CAL049-12 #1	Yolo 45, PM 7.8 SB	2.78	7.02			3.01			
CAL049-12 #2	Yolo 45, PM 7.9 SB	2.35	13.36			2.60			
CAL049-12 #3	Yolo 45, PM 8 SB	2.41	5.33	15.09		2.57			
CAL049-12 #4	Yolo 45, PM 8.1 SB	3.14		13.78		4.12			
CAL049-12a #1	Yolo 45, PM 9 SB	6.70		11.66		7.48		8.66	
CAL049-12a #2	Yolo 45, PM 9.1 SB	6.57		12.38		6.57		10.00	
CAL049-12a #3	Yolo 45, PM 9.2 SB	6.27		13.98		6.41		8.73	
CAL049-12a #4	Yolo 45, PM 9.3 SB	5.88		16.48		5.56		8.97	
CAL050-1a #1	Sol 505, PM 8.1 SB	2.12	4.99	8.17	5.14	2.54	3.92		
CAL050-1a #2	Sol 505, PM 8.2 SB	1.87	4.86	8.69	4.80	2.40	4.92	8.46	1.65
CAL050-1a #3	Sol 505, PM 8.3 SB			8.92	6.44			9.05	4.81
CAL050-1a #4	Sol 505, PM 8.4 SB			8.53	7.14			8.75	6.27

Table F2. GPR Data and UCPRC Core Layer Materials

Site, Closure, Core #	Co., Route, Approx PM, Dir	GPR - Material Type				Cores - Material Type			
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 1	Layer 2	Layer 3	Layer 4
CAL009-14 #1	Sac 99, PM 8.9 SB	AC	AC	PCC		(OG/AC)			
CAL009-14 #2	Sac 99, PM 9 SB	AC	AC	PCC		OG/AC	AC	(PCC)	
CAL009-15 #1	Sac 99, PM 6.3 SB	AC	AC	PCC		OG/AC	AC	(PCC)	
CAL009-15 #2	Sac 99, PM 6.4 SB	AC	AC	PCC		OG/AC	AC	(PCC)	
CAL015-5 #1	Yolo 113, PM 2.9 NB		PCC	Base	Sub		PCC	cmnt	
CAL015-5 #2	Yolo 113, PM 3 NB		PCC	Base	Sub		PCC	(cmnt)	
CAL015-5 #3	Yolo 113, PM 3.1 NB		PCC	Base	Sub		PCC	cmnt	
CAL015-5 #4	Yolo 113, PM 3.1 NB		PCC	Base	Sub		PCC	cmnt	
CAL015-5 #5	Yolo 113, PM 3.2 NB		PCC	BB	Sub		PCC	AC	
CAL015-5 #6	Yolo 113, PM 3.2 NB		PCC	BB	Sub		PCC	AC	
CAL015-5a #1	Yolo 113, PM 8.4 NB		PCC	BB	Sub		(PCC)		
CAL015-5a #2	Yolo 113, PM 8.5 NB		PCC	BB	Sub		PCC	(ATPB)	
CAL015-5a #3	Yolo 113, PM 8.6 NB		PCC	BB	Sub		PCC	(ATPB)	
CAL015-5a #4	Yolo 113, PM 8.7 NB		PCC	BB	Sub		PCC	ATPB	(ATPB)
CAL035-16 #1	Col 16, PM 3 WB	AC	AC			AC			
CAL035-16 #2	Col 16, PM 3.1 WB	AC	AC			AC	AC		
CAL035-17 #1	Col 16, PM 1.8 WB	AC	AC	AC	Base	AC	AC		
CAL035-17 #2	Col 16, PM 1.9 WB	AC	AC	AC	Base	AC	AC		
CAL035-18 #1	Col 16, PM 0.6 WB	AC	Base			AC			
CAL035-18 #2	Col 16, PM 0.7 WB	AC	Base			AC			
CAL047-9 #1	Sac 50, PM 17.2 EB	AC	AC	BB	Base	OG/AC	AC	AC	
CAL047-9 #2	Sac 50, PM 17.3 EB	AC	AC	BB	BB	OG/AC	AC		
CAL047-9 #3	Sac 50, PM 17.4 EB	AC	AC	Base	Base	OG/AC			
CAL047-9 #4	Sac 50, PM 17.5 EB	AC	AC	BB	Base	OG/AC			
CAL047-10 #1	Sac 50, PM 20 EB	AC	AC	BB	BB	OG/AC	AC	AC	
CAL047-10 #2	Sac 50, PM 20.1 EB	AC	AC	BB	BB	OG/AC	AC	AC	
CAL047-10 #3	Sac 50, PM 20.2 EB	AC	AC	BB	BB	OG/AC	AC	AC	
CAL047-10 #4	Sac 50, PM 20.3 EB	AC	AC	BB	BB	OG/AC	AC	AC	AC
CAL049-11 #1	Yolo 45, PM 10.8 SB	AC		Base		AC		cmnt	
CAL049-11 #2	Yolo 45, PM 10.9 SB	AC		Base		AC		cmnt	
CAL049-11 #3	Yolo 45, PM 11 SB	AC		Base		AC			
CAL049-11 #4	Yolo 45, PM 11.1 SB	AC		Base		AC			
CAL049-12 #1	Yolo 45, PM 7.8 SB	AC	BB			AC			
CAL049-12 #2	Yolo 45, PM 7.9 SB	AC	BB			AC			
CAL049-12 #3	Yolo 45, PM 8 SB	AC	AC	Base		AC			
CAL049-12 #4	Yolo 45, PM 8.1 SB	AC		Base		AC			
CAL049-12a #1	Yolo 45, PM 9 SB	AC		Base		AC		cmnt	
CAL049-12a #2	Yolo 45, PM 9.1 SB	AC		Base		AC		cmnt	
CAL049-12a #3	Yolo 45, PM 9.2 SB	AC		Base		AC		cmnt	
CAL049-12a #4	Yolo 45, PM 9.3 SB	AC		Base		AC		cmnt	
CAL050-1a #1	Sol 505, PM 8.1 SB	AC	AC	PCC	Base	AC	AC	(PCC)	
CAL050-1a #2	Sol 505, PM 8.2 SB	AC	AC	PCC	Base	AC	AC	PCC	cmnt
CAL050-1a #3	Sol 505, PM 8.3 SB			PCC	Base			PCC	cmnt
CAL050-1a #4	Sol 505, PM 8.4 SB			PCC	Base			PCC	cmnt

( ) materials in parenthesis were determined from field observations and review of the DCP results.

Table F3. DCP Results from Coring

		DCP Results					
		Layer 1		Layer 2		Layer 3	
Site, Closure, Core #	Co., Route, Approx PM, Dir	Thickness (in)	mm per 5 blows	Thickness (in)	mm per 5 blows	Thickness (in)	mm per 5 blows
CAL009-14 #1	Sac 99, PM 8.9 SB	No DCP - PCC underneath					
CAL009-14 #2	Sac 99, PM 9 SB	2.2	0.7				
CAL009-15 #1	Sac 99, PM 6.3 SB	No DCP - PCC underneath					
CAL009-15 #2	Sac 99, PM 6.4 SB	No DCP - PCC underneath					
CAL015-5 #1	Yolo 113, PM 2.9 NB	11.0	2.3	24.5	13.4		
CAL015-5 #2	Yolo 113, PM 3 NB	10.6	0.8				
CAL015-5 #3	Yolo 113, PM 3.1 NB	3.9	2.5	21.7	8.1	23.5	3.0
CAL015-5 #4	Yolo 113, PM 3.1 NB	7.0	2.5	20.7	8.7	22.4	0.7
CAL015-5 #5	Yolo 113, PM 3.2 NB	No DCP - rest of AC core stuck in hole (~2-6 inches AC)					
CAL015-5 #6	Yolo 113, PM 3.2 NB	23.9	7.6				
CAL015-5a #1	Yolo 113, PM 8.4 NB	No Core/DCP - problems with closure					
CAL015-5a #2	Yolo 113, PM 8.5 NB	8.9	2.3	28.3	6.6		
CAL015-5a #3	Yolo 113, PM 8.6 NB	11.2	1.8	27.3	5.9		
CAL015-5a #4	Yolo 113, PM 8.7 NB	10.2	2.2	26.7	7.0		
CAL035-16 #1	Col 16, PM 3 WB	18.3	5.0	25.8	2.7	32.7	8.8
CAL035-16 #2	Col 16, PM 3.1 WB	26.0	3.0	28.2	0.6		
CAL035-17 #1	Col 16, PM 1.8 WB	17.3	4.9	27.8	3.3	33.3	7.1
CAL035-17 #2	Col 16, PM 1.9 WB	4.9	2.5	34.8	6.9		
CAL035-18 #1	Col 16, PM 0.6 WB	1.9	1.2	5.1	4.2	22.6	19.9
CAL035-18 #2	Col 16, PM 0.7 WB	6.9	4.4	10.3	0.6	32.4	7.6
CAL047-9 #1	Sac 50, PM 17.2 EB	11.9	0.8				
CAL047-9 #2	Sac 50, PM 17.3 EB	No DCP - stopped coring b/c of stripped AC layer					
CAL047-9 #3	Sac 50, PM 17.4 EB	No DCP - hard material underneath					
CAL047-9 #4	Sac 50, PM 17.5 EB	6.2	0.4				
CAL047-10 #1	Sac 50, PM 20 EB	19.6	2.4				
CAL047-10 #2	Sac 50, PM 20.1 EB	10.6	1.3				
CAL047-10 #3	Sac 50, PM 20.2 EB	5.8	0.8				
CAL047-10 #4	Sac 50, PM 20.3 EB	8.5	1.1				
CAL049-11 #1	Yolo 45, PM 10.8 SB	6.7	0.7	29.6	9.7		
CAL049-11 #2	Yolo 45, PM 10.9 SB	5.1	0.9	33.7	10.4		
CAL049-11 #3	Yolo 45, PM 11 SB	2.6	0.6				
CAL049-11 #4	Yolo 45, PM 11.1 SB	8.3	0.9	30.6	11.3		
CAL049-12 #1	Yolo 45, PM 7.8 SB	8.7	0.6				
CAL049-12 #2	Yolo 45, PM 7.9 SB	10.9	0.8				
CAL049-12 #3	Yolo 45, PM 8 SB	3.1	0.3				
CAL049-12 #4	Yolo 45, PM 8.1 SB	4.9	0.4				
CAL049-12a #1	Yolo 45, PM 9 SB	22.3	14.2				
CAL049-12a #2	Yolo 45, PM 9.1 SB	19.4	16.4				
CAL049-12a #3	Yolo 45, PM 9.2 SB	22.8	14.5				
CAL049-12a #4	Yolo 45, PM 9.3 SB	22.6	19.1				
CAL050-1a #1	Sol 505, PM 8.1 SB	No DCP - bottom part of core stuck in the hole					
CAL050-1a #2	Sol 505, PM 8.2 SB	8.5	1.2				
CAL050-1a #3	Sol 505, PM 8.3 SB	7.1	2.0	12.6	7.0	13.4	1.2
CAL050-1a #4	Sol 505, PM 8.4 SB	3.3	2.1	21.9	6.9		

Table F4. GPR Data and UCPRC Core GPS Coordinates and Relative Distance Errors

Site, Closure, Core #	Co., Route, Approx PM, Dir	GPR GPS Coordinates (d)ddmm.mmmmmm		Core GPS Coordinates (d)ddmm.mmm		Relative Error (ft)
		Latititude	Longitude	Latititude	Longitude	
CAL009-14 #1	Sac 99, PM 8.9 SB	3821.748054	12120.881090	3821.745	12120.878	23.69
CAL009-14 #2	Sac 99, PM 9 SB	3821.815252	12120.951460	3821.814	12120.951	7.92
CAL009-15 #1	Sac 99, PM 6.3 SB	3819.697283	12119.729590	3819.694	12119.728	21.34
CAL009-15 #2	Sac 99, PM 6.4 SB	3819.778739	12119.767090	n/a		n/a
CAL015-5 #1	Yolo 113, PM 2.9 NB	3834.355402	12146.047810	3834.359	12146.047	22.20
CAL015-5 #2	Yolo 113, PM 3 NB	3834.442231	12146.046420	3834.447	12146.048	29.93
CAL015-5 #3	Yolo 113, PM 3.1 NB	3834.525676	12146.045050	3834.538	12146.045	74.88
CAL015-5 #4	Yolo 113, PM 3.1 NB	3834.528797	12146.045000	3834.541	12146.045	74.15
CAL015-5 #5	Yolo 113, PM 3.2 NB	3834.615533	12146.042400	3834.633	12146.042	106.15
CAL015-5 #6	Yolo 113, PM 3.2 NB	3834.622258	12146.042080	3834.639	12146.041	101.85
CAL015-5a #1	Yolo 113, PM 8.4 NB	3839.047231	12145.331290	no core		n/a
CAL015-5a #2	Yolo 113, PM 8.5 NB	3839.129390	12145.296110	3839.105	12145.308	158.57
CAL015-5a #3	Yolo 113, PM 8.6 NB	3839.211667	12145.260990	3839.195	12145.270	109.92
CAL015-5a #4	Yolo 113, PM 8.7 NB	3839.293810	12145.225860	3839.283	12145.232	71.85
CAL035-16 #1	Col 16, PM 3 WB	3858.542766	12220.328030	3858.542	12220.328	4.66
CAL035-16 #2	Col 16, PM 3.1 WB	3858.459888	12220.331160	3858.445	12220.344	108.91
CAL035-17 #1	Col 16, PM 1.8 WB	3859.237040	12221.086380	3859.222	12221.082	93.69
CAL035-17 #2	Col 16, PM 1.9 WB	3859.154003	12221.059450	3859.139	12221.058	91.41
CAL035-18 #1	Col 16, PM 0.6 WB	3900.257134	12221.291310	3900.264	12221.298	52.33
CAL035-18 #2	Col 16, PM 0.7 WB	3900.172922	12221.266270	3900.179	12221.269	39.11
CAL047-9 #1	Sac 50, PM 17.2 EB	3838.402881	12111.693670	3838.406	12111.697	24.68
CAL047-9 #2	Sac 50, PM 17.3 EB	3838.416024	12111.584390	n/a		n/a
CAL047-9 #3	Sac 50, PM 17.4 EB	3838.429634	12111.475360	3838.432	12111.475	14.48
CAL047-9 #4	Sac 50, PM 17.5 EB	3838.443318	12111.365990	3838.447	12111.369	26.54
CAL047-10 #1	Sac 50, PM 20 EB	3838.513709	12108.507240	3838.514	12108.505	10.78
CAL047-10 #2	Sac 50, PM 20.1 EB	3838.518535	12108.397120	3838.519	12108.394	15.07
CAL047-10 #3	Sac 50, PM 20.2 EB	3838.523859	12108.287170	3838.522	12108.285	16.28
CAL047-10 #4	Sac 50, PM 20.3 EB	3838.528628	12108.177180	3838.530	12108.172	25.96
CAL049-11 #1	Yolo 45, PM 10.8 SB	3853.657878	12150.622350	3853.657	12150.624	9.45
CAL049-11 #2	Yolo 45, PM 10.9 SB	3853.744427	12150.622210	3853.745	12150.624	9.15
CAL049-11 #3	Yolo 45, PM 11 SB	3853.831161	12150.621760	3853.832	12150.622	5.22
CAL049-11 #4	Yolo 45, PM 11.1 SB	3853.917887	12150.620910	3853.918	12150.622	5.20
CAL049-12 #1	Yolo 45, PM 7.8 SB	3852.180759	12148.815340	3852.166	12148.820	92.35
CAL049-12 #2	Yolo 45, PM 7.9 SB	3852.251657	12148.881740	3852.242	12148.875	66.78
CAL049-12 #3	Yolo 45, PM 8 SB	3852.320266	12148.946930	3852.319	12148.946	8.86
CAL049-12 #4	Yolo 45, PM 8.1 SB	3852.390331	12149.012510	3852.395	12149.019	41.80
CAL049-12a #1	Yolo 45, PM 9 SB	3852.926873	12149.552700	3852.926	12149.551	9.63
CAL049-12a #2	Yolo 45, PM 9.1 SB	3852.927037	12149.663590	3852.927	12149.667	16.13
CAL049-12a #3	Yolo 45, PM 9.2 SB	3852.926891	12149.774450	3852.927	12149.784	45.17
CAL049-12a #4	Yolo 45, PM 9.3 SB	3852.926895	12149.885340	3852.927	12149.901	74.07
CAL050-1a #1	Sol 505, PM 8.1 SB	3829.360340	12156.902580	3829.358	12156.905	18.29
CAL050-1a #2	Sol 505, PM 8.2 SB	3829.445690	12156.922030	3829.444	12156.923	11.26
CAL050-1a #3	Sol 505, PM 8.3 SB	3829.531063	12156.942160	3829.530	12156.942	6.50
CAL050-1a #4	Sol 505, PM 8.4 SB	3829.616665	12156.961780	3829.615	12156.961	10.78

APPENDIX G: RECOMMENDATION FOR CHANGES TO CALTRANS PAVEMENT CONDITION SURVEY

Shaded Rows Indicate Items Recommended for Change

Current Caltrans Condition Survey Method							Comparison of Methods					PMS Recommend.
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recom-mendations**	**Recommend for use in PMS**
770	RIGID CRK LONG.	Rigid Cracking (Longitu-dinal)	N/A				N/A	No cracks,1 or 2 cracks per slab; %slabs that have 1 crack and % slabs that have 2 cracks		R	These map back into items 1 and 2	yes
780	RIGID CRK TRANS.	Rigid Cracking (Transverse)	N/A				N/A	Severity: cracked/not cracked per slab; Extent: % slabs cracked		R		yes
9	CORNER CRACKING PCT	Percent of rigid slabs with corner cracks	PCT		1	100	%	Severity: 0,1,2,3,4,cracks per slab; Extent: % slabs with 0,1,2,3,or 4 cracks		R		yes
3	ALLIGATOR A CRK FT	Linear feet of Alligator A cracking in wheelpaths	FT	<1/4;> 1/4; CLOSED	1	200	%	Severity:L,M,H; Extent cumulative crack length in both wheel paths.		F, SR	CAN BE MAPPED BACK INTO % OF WP	yes
4	ALLIGATOR B CRK FT	Linear feet of Alligator B cracking in wheelpaths	FT	<1/4; >1/4; CLOSED	1	200	%	Same as Alligator A crack - doesn't rate them separately		F, SR		yes
5	ALLIGATOR C CRACKING	Alligator C cracking in lane.		<25%; >25%			X=exists at this location	N/A		F, SR		yes
8	BLEEDING	Asphalt pavement binder bleeding					N/A	Severity: L,M,H;Extent: % of wheel path		F, SR, C	% OF WP	yes
10	CRACK SPALLING	Crack edges spalling.					N/A	Severity (L,M,H) and extent(% of spalled joints)	Apply to rigid pvmt corner cracking: Low, Med or High Spalling	R	% OF CRACK SPALLED (NO SEVERITY)	yes

Current Caltrans Condition Survey Method							**Comparison of Methods**					**PMS Recommend.**
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recom-mendations**	**Recommend for use in PMS**
20	JOINT SPALLING	Joint spalling					N/A	Severity:L,M,H; Extend:% spalled joints out of total no. of joints in the segment.	Degree of joint spalling and joint spacing	R	% OF JOINT SPALLED (NO SEVERITY)	Yes
12	CRACKS SEALED	Cracks filled with sealant					N/A	N/A		R	Severity (>6mm), extent (% of cracks)	Yes
14	DIGOUT	Asphalt pavement has been dug out and replaced					N/A	N/A		F, SR, C	% of WP	yes
15	FAULTING	Rigid pavement slabs faulted (tilted)					S(Severe), L(Light)	Difference in elevation at the joint (mm)	Height of faults	R	Heights of Faults (Mean and STD); can be extracted from profilometer?	yes
18	JOINT SEALED	Joints sealed					N/A	N/A	Sealed or not sealed	R	% OF JOINT SEALED	yes
	CRC CRACK SPACING										TO BE DEFINED	yes, later
	CRC PUNCHOUTS										TO BE DEFINED	yes, later
	CRC CRACK SEALED										TO BE DEFINED	yes, later
21	LONG. EXTENT UP/DOWN	Longitudinal cracks displaced up or down extents (CONSTRUC-TION JOINT LONGIT.)		<1/4;>1/4			Recorded in 2 separate fields: Severity 1-4 for crack size in 1/4" and Extent as	Flexible pvmts. Severity: Recomm. To combine Alligator and Longit. Cracking in WP.		F,SR,C		yes, out of wheelpath

Current Caltrans Condition Survey Method							**Comparison of Methods**					**PMS Recommend.**
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recom-mendations**	**Recommend for use in PMS**
							L,M,H					
40	SHOULDER EDGE CRACKING	Shoulder pavement has edge cracking					N/A	N/A		F, SR	EXTENT: METERS; SEVERITY >1/4IN; <1/4IN	no
24	PATCHING	Patched pavement in this location	FT	F;G;P;C	1	200	% ; Separate field recording PATCH CONDITION	NOT CRITICAL. % area of segment		F, R, SR,C	% OF SLABS FOR R; % OF WP FOR F,C,SR	yes
25	SHOULDER EDGE LOSS	Flexible pavement breaking off edge					N/A	NOT CRITICAL. Define: Edge raveling, Edge Patching, Lane <10ft		F		no
26	POTHOLES	Potholes	CNT	<6;6TO12;>12	1		N/A	NOT CRITICAL.Severity: S,M,L; Extent: no. of potholes in a segment		F,SR,C		no
27	PUMPING	Water and subsurface material pumping thru cracks					N/A	NOT CRITICAL Severity: L,M,H; Extend: % of the no. of joints and cracks that exhibit pumping)	Location:transverse, longitudinal,shoulder/slab joint and/or crack; % joints within section where distress occurred	R,SR,C,F		no
28	RAVEL	Asphalt surface shows raveling	C,F				F or C plus %	NOT CRITICAL. Severity: L,M,H; Extent: % of the surface area of the segment.		F,SR,C	F or C plus % OF WP-CAUSED BY TRAFFIC	no

Current Caltrans Condition Survey Method							**Comparison of Methods**					**PMS Recommend.**
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recommendations**	**Recommend for use in PMS**
30	RE-OPENED CRACKS	Sealed cracks have reopened					N/A	N/A		F,R,SR,C		no
31	RE-OPENED JOINTS	Sealed joints have reopened.					N/A	N/A		R		no
32	RUTTING	Rutting in wheelpaths					%	Avg. rut depth in WP. Recomm. Min 5 sensors	Rut depth in the wheelpaths	F	MM,MEAN, STD	yes
33	SETTLEMENT	Surface settlement has occurred.					N/A	N/A		F,R,C,SR		no
34	SETTLEMENT CRACK	Settlement cracking. chk_crk_sttlmnt.					N/A	N/A		F,R,C,SR		no
35	SEV MULTIPLE CRACK SPALLING	Over 25% of third stage crack spall >1-1/2 inches					N/A	see CRACK SPALLING (10)	Overall rated in Rigid Cracking (Longit, Transv., Corner)	R	Where 2 or more types of cracking (LONGIT,TRANSV,CORNER) % of slabs	no
37	SHOULDER CONDITION	Shoulder condition: good,fair, poor or missing.		FAIR; GOOD; MISSING;POOR			FAIR; GOOD; MISSING; POOR	N/A	Drains present or not, drains properly functioning.	F,R,C,SR		no
38	SHOULDER DISPLACEMNT	Shoulder displaced: up or down		D;U			N/A	N/A		R		no
39	SHOULDER DROP OFF	Shoulder drops from pavement					N/A	N/A		F,R,SR,C		no
41	SHOULDER JOINT SEALD	Shoulder joint sealed					N/A	N/A		F,R,SR,C		yes
43	SHOULDER SEPARATION	Shoulder joint separation					N/A	N/A				no

Current Caltrans Condition Survey Method							Comparison of Methods					PMS Recommend.
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recom-mendations**	**Recommend for use in PMS**
45	SHOVING	Flexible pavement surface shoving.					N/A	NOT CRITICAL. Size of the area in a segment.		F,SR,C	YES/NO	no
46	SLAB SPALLING (SCALING)	Surface spalling found					N/A	Severity:L,M,H;extent:% of spall cracks out of total no of cracks in the segment	Yes/no - flag to core later (reffers to slab spalling)	R	YES/NO; % OF SLABS	yes
47	TRANS. EXTENT UPDOWN	Transverse cracking displaced up or down		<1/4; >1/4			no unit	Flexible pvmts. Severity:crack width; extent: % section length with no cracking,% section length w/ cracking and distribution of crack spacing.	Flexible pvmts. Recomm. to identify as Thermal or Reflective	F,SR	No upper limit on count; composite covered under REFL. CRACKING	yes, but as recommended under UC proposed
48	WEATHERING	Surface weathered					N/A	N/A		F,SR,C	% of total area (non-traffic caused)	no
670	CHECKING	checking					N/A	N/A		F,R,C,SR		no
680	CORNER REFL. CRK	Corner Reflection Cracking (AC/PCC or AC/CTB)	N/A				N/A	Severity (width) and Extent (cracks/100m)		C		yes
730	LONG. REFLECTION CRK	Longitudinal Reflection Cracking (AC/PC or AC/CTB)	N/A				N/A	Severity (width) and Extent: length		C,SR		yes
810	TRANS.REFLECTION CRK	Transverse Reflection Cracking (AC/PC or AC/CTB)	N/A				N/A	Severity (width) and extent (cracks/100m)	See note from cond. id 47 (trans extent up down)	C,SR		yes
690	CORRUGA-TION	Corrugation	N/A				N/A	NOT CRITICAL; L,M,H and % of segment length affected		F,C,SR		no

Current Caltrans Condition Survey Method							**Comparison of Methods**					**PMS Recommend.**
Condition ID	**Condition Code**	**Condition Description**	**Unit Code**	**Severity**	**Extent Low**	**CND Extent High**	**Collection Method: Old PMS**	**UCPRC Recommended Variables Required for Development of Performance Models**	**Additional Notes on Collection Method UCPRC Proposed**	**Pavement Type**	**Notes and Recom-mendations**	**Recommend for use in PMS**
700	DELAMINATION	Delamination /slippage cracking	N/A				N/A	NOT CRITICAL; Record the number and location in the segment.		F,C,SR		no
790	SEGREGATION	Segregation	N/A				N/A	N/A				no
820	BLOCK CRACKING	Block cracking	N/A				%	NOT CRITICAL. Block size: L,M,H; crack size: L,M,H		F,C,SR	% of area, distinguish from reflection cracking by spacing less than 2 m	yes