UC Berkeley
Research Reports

Title

Identification of High Collision Concentration Locations Under Wet Weather Conditions

Permalink

https://escholarship.org/uc/item/1xp3g5b4

Authors

Hwang, Taesung
Chung, Koohong
Ragland, David
et al.

Publication Date

2008-04-01

**Identification of High Collision Concentration Locations
Under Wet Weather Conditions**

Taesung Hwang, Traffic Safety Center;
Koohong Chung, California Department of Transportation;
David Ragland, Traffic Safety Center;
Ching-Yao Chan, California PATH

April 2008

Identification of High Collision Concencrtation Locations under Wet Weather Conditions

Submission Date: August 1, 2007

Word Count: 2,552 words + 9 figures and tables (250 words each) = 4,802

Taesung Hwang
Institute of Transportation Studies
University of California, Berkeley
Traffic Safety Center
2614 Dwight Way, Suite 7374
Berkeley, California 94720-7374, USA
Tel: (510) 642-0566; fax: (510) 643-9922; tshwang@berkeley.edu

Koohong Chung, Ph.D.
California Department of Transportation
Highway Operations Special Studies
111 Grand Avenue
Oakland, California 94623-0660, USA
Tel: (510) 622-5429; fax: (510) 286-4561; koohong_chung@dot.ca.gov

David R. Ragland, Ph.D., MPH*
Director, Traffic Safety Center
University of California, Berkeley
2614 Dwight Way, Suite 7374
Berkeley, California 94720-7374, USA
Tel: (510) 642-0655; fax: (510) 643-9922; davidr@berkeley.edu

Ching-Yao Chan, Ph.D., P.E.
California PATH, Headquarters
Institute of Transportation Studies
University of California, Berkeley
Richmond Field Station, Bldg. 452, 1357 S. 46th Street
Richmond, California 94804, USA
Tel: (510) 665-3621; fax: (510) 665-3757; cychan@path.berkeley.edu

* corresponding author

ABSTRACT
This paper focuses on identifying roadway locations that display high collision rates only under wet pavement condition. A unique approach of screening and identifying such locations, called the continuous risk profile (CRP) method, was utilized for this analysis. The CRP method was applied to over 380 miles of freeways in the San Francisco Bay Area to identify sites that display high collision rates only under wet pavement condition. Twelve of the identified sites were then further investigated to determine if there are any common geometric, topographic, or site conditions that may contribute to the high collision rates under wet pavement conditions.

INTRODUCTION
Improving the safety of the roadway has been a priority for the California Department of Transportation (Caltrans), and to this end, Caltrans has been monitoring the traffic collisions on freeways and identifying list of sites that need to be investigated for further safety improvements. The identified sites were listed in quarterly reports, referred to as Table-C and Wet Table-C, and used as references for safety investigation. Many freeway sites have already been improved due to such effort. However, the department continuously strives to improve the current procedure for selecting high collision concentration locations.

In 2002, Caltrans conducted a survey among 44 of its safety engineers and the survey responses from the participants provided inputs and suggestions to improve the site-screening process. For instance, it was pointed out that high collision concentration locations related to wet pavement condition in Wet Table-C should be systematically filtered so that there would be few or no repeated appearance in the list of sites identified for dry pavement condition in Table-C *(1)*. The investigators strongly indicated that they would like to see for the implementation of a robust and reliable method of identifying the list of sites that display high collision rates only under wet pavement condition.

A continuous risk profile (CRP) *(2)* approach has been applied in this study to screen for locations that uniquely show high collision rates under wet pavement condition. Results showed that by comparing risk profiles of collisions that occurred under dry and wet pavement conditions separately, unique wet-pavement-related collision concentration locations can be identified.
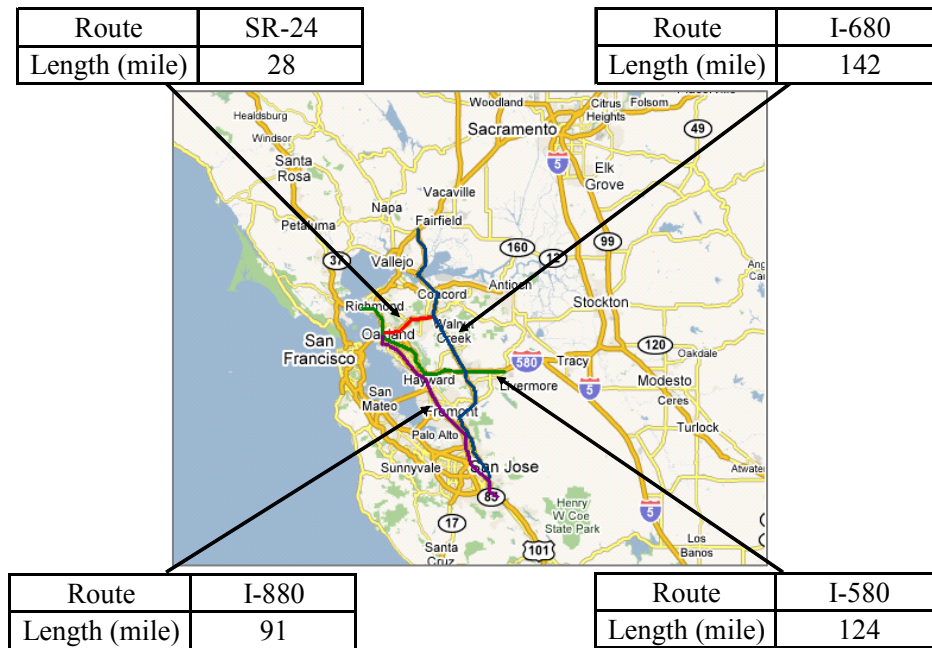
Several previous studies have investigated the relationship between wet pavement conditions and collisions on roadways. Andrey, J. et al. *(3)* showed that inclement weather increased travel risk in six mid-sized Canadian cities and induced a chronic danger for travelers in Canada. They found that generally, precipitation is related to an increase in traffic collisions and an increase in related injuries. Black and Jackson *(4)* elaborated on several scenarios related to wet weather collision. Kokkalis and Panagouli *(5)* used mathematical regression equations to explore the characteristics of skid resistance for dried and wetted pavement conditions.

Twelve of the sites located by the proposed method were further investigated in an effort to identify common site characteristics that may contribute to the high collision rates.

STUDY ROUTES
More than 380 miles of freeways in San Francisco, California were investigated in this study (see Figure 1). These freeway corridors were selected based on the diversity of their topographic and geometric features and their proximal, convenient locations—which allowed timely site

inspection during periods of wet weather conditions. The length of each of the four freeway routes including both directions are shown in Figure 1. These four routes are all divided freeways, and collision data for both directions are included in the study.

Route	SR-24
Length (mile)	28

Route	I-680
Length (mile)	142

Route	I-880
Length (mile)	91

Route	I-580
Length (mile)	124

FIGURE 1 Map of study site (source: http://maps.google.com).

Twelve study locations were subsequently determined through the continuous risk profile (CRP) method for detailed study.

SOURCE COLLISION DATA

Collision data from years between 1994 and 2003 were used in this study. These data were extracted from the Traffic Accident Surveillance and Analysis System (TASAS), which is a collision database maintained by the California Department of Transportation (Caltrans). The database contains collision records documented by the California Highway Patrol for the California State Highway system. There are two major categories of data in TASAS: one is a collision database that contains detailed information on each reported collision, the other is a highway database that contains geometric and location attributes for highways, ramps, and intersections.

Collision locations in the TASAS can be distinguished in three sections: 1) beyond shoulder drivers left; 2) within traveling lanes; and 3) beyond shoulder drivers right. Figure 2 shows how the collision locations are coded in the database. Table 1 shows the breakdown of collisions based on pavement condition and collision locations for the four study routes.

TABLE 1 Collision Rate Based on Pavement Condition and Collision Location

Collision Location / Pavement Condition	Beyond Shoulder Drivers Left	Traveling Lanes (Left, Right, and Interior Lanes)	Beyond Shoulder Drivers Right
Dry	9%	85%	6%
Wet	22%	66%	12%
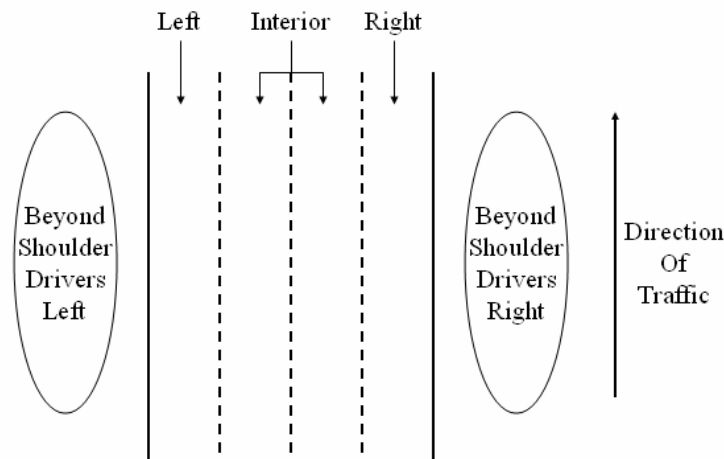
FIGURE 2 Description of freeway lanes in TASAS.

METHODOLOGY

The continuous risk profile (CRP) method was applied to the four freeway routes to determine sites that display high collision rate only under wet pavement condition. Detailed description of the method can be found in Chung and Ragland *(2)*. Brief description of the CRP method is provided next.

Continuous Risk Profile (CRP)

The continuous risk profile can be constructed first by cumulatively plotting collisions, *A(d)*, with respect to distance, *d*. Then by rescaling it by a reference risk, $B(d - d_0)$, determined by the user, one can visually identify extended segment of the freeways with higher collision rates (see Figure 3). Similar rescaling techniques have been used in studying the propagation of kinematic waves *(6, 7)*. The rescaled cumulative collision count curve amplifies the changes in the slope of the curve and makes it easier to observe how risk changes continuously with respect to the distance (i.e., number of collisions observed at a given postmile). In this example, the average collision count per unit distance observed over a 10-year period was used as the rescaling factor. The plot for the I-880 freeway segment in year 2003 is shown in Figure 3. The positive slope in

the figure indicates that the risk in the corresponding segment is higher than $B(d - d_0)$ and negative slope indicates lower risk: Such plot can enable the reader to instantly identify extended section of freeway segments with high collision counts.
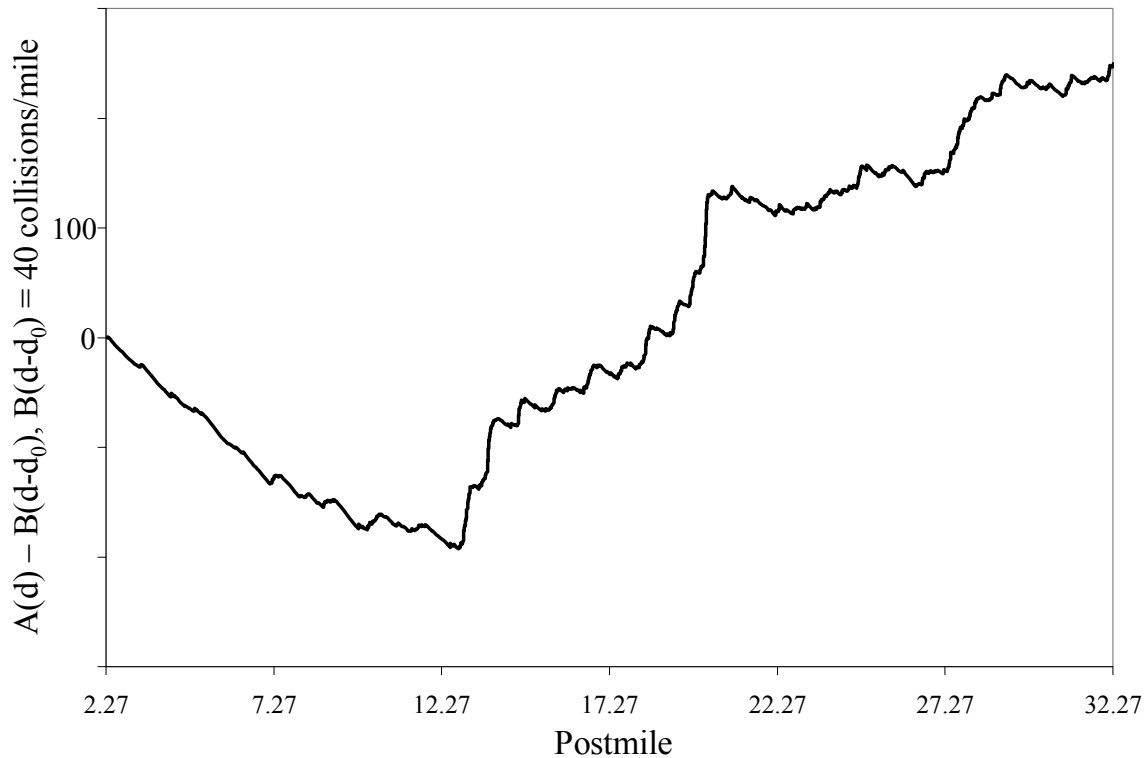
FIGURE 3 Rescaled cumulative collision count curve (I-880 northbound, Alameda County, California, 2003).

Some of the fluctuations shown in rescaled cumulative collision counts (see Figure 3) are due to statistical variations and these variations can be pre-filtered *(8)* by using a moving average as shown in equation (1).

$$M(d) = \frac{\sum_{i=-\min(L/l,(d-d_0)/l)}^{\min(L/l,(d_{end}-d)/l)} f(d+i\times l)}{\min(L/l,(d_{end}-d)/l) + \min(L/l,(d-d_0)/l)+1} \tag{1}$$

For

$$d = d_0 + k \times l \text{ and } k = 1,2,...\frac{d_{end}-d_0}{l}$$

Where

$$f(d) = k(d) - B(d - d_0)$$

d_0 = beginning postmile
d_{end} = ending postmile
$D_{start} < D_{end}$

l = increment
$2L$ = size of the moving average
k, $\dfrac{L}{l}$ and $\dfrac{d_{end} - d_0}{l}$ are integers

Since we are only interested in high collision concentration locations, we can then apply equation (2) to identify the positive portion of the rescaled smoothed cumulative curve:

$$K(d) = Max\left(\frac{M(d+l) - M(d)}{l}, 0 \right) \qquad (2)$$

Note that in equation (2), $K(d)$ will not only identify high risk locations, but also show the excess risk that the segment has compared to the reference risk, $B(d - d_0)$. This will allow us to determine where the risk started to increase and decrease as well as locations of the localized peaks in risk.

Application of Continuous Risk Profile Method to Selected Sites
Figures 4a-4c show the $K(d)$ plot for the northbound direction on I-880. Figure 4a shows the CRP plotted using collisions that occurred along a 45-mile segment of northbound I-880 in year 2003 under dry pavement conditions. Figure 4b shows a similar plot for the collisions that occurred while the pavement condition was wet.
        In Figures 4a-4c, the x-axis is the postmile and the y-axis shows excess collision rates compared to $B(d - d_0)$. The y-axis represents the excess collision rate (number of collisions per mile) compared to the reference risk. The average collision rates in year 2003 for dry and wet pavement related were used as the reference risk for Figures 4a and 4b respectively. The x-axis shows the increase in postmile with respect to a reference location in the direction the vehicle is traveling.
        Many locations that displayed high collision rates, marked by peaks in Figure 4a, also displayed high collision rates in Figure 4b. An example of such is shown in Figures 4a and 4b by the peaks inscribed in a dotted circle annotated by D_1 and W_1. The reappearance of these peaks in both wet and dry weather intuitively makes sense, since a site that displays high collision rates under dry pavement conditions will not become any safer under wet pavement conditions.
        Figure 4c is the result of filtering out the redundant peaks in Figure 4a and Figure 4b. As a result, the peaks in Figure 4c identify the locations that display high collision rates only under wet pavement conditions. (Note that the scales of the y-axis in Figure 4a is about four times larger than those in Figures 4b and 4c to allow better assessment of relative heights of peaks.) Following the same procedure, the unique collision concentration locations related to wet pavement conditions are identified from the selected routes and given in Table 2.
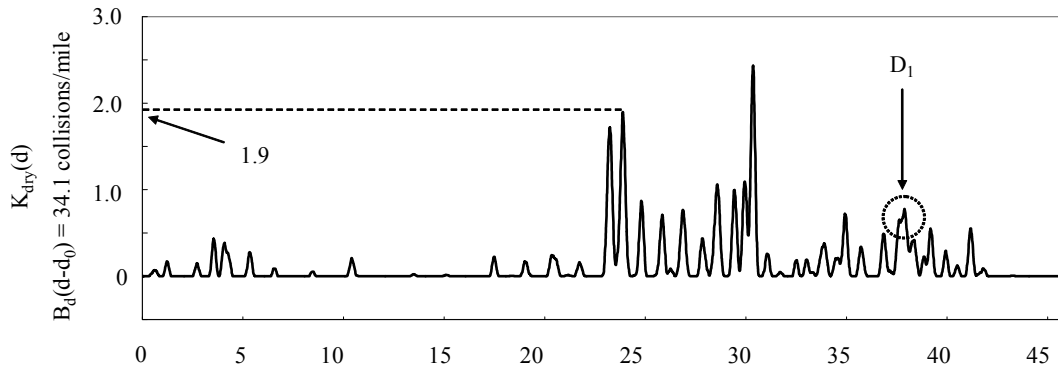
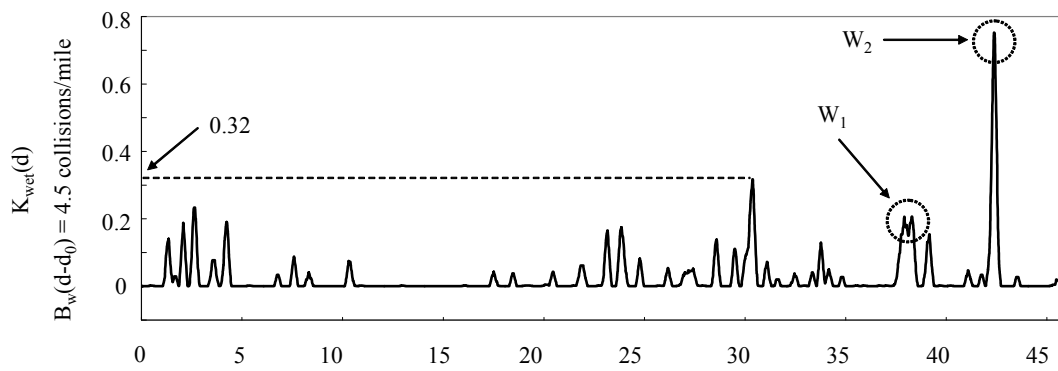FIGURE 4a Dry continuous risk profile.
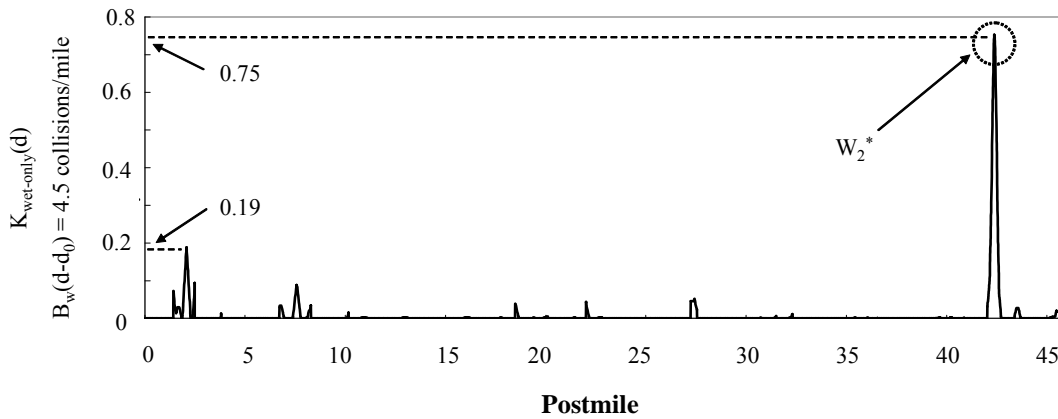

FIGURE 4b Wet continuous risk profile.

FIGURE 4c Wet-only continuous risk profile.

**FIGURES 4a-4c Procedure for identifying wet-only study sites.**

TABLE 2 List of Study Sites Displaying High Collision Rates Only Under Wet Pavement Condition (1999 to 2003 data)

Route	Site ID	County	Nearby Cross Street	No. of Wet-Accident/Year
24E	1	Contra Costa	Camino Pablo Ave.	11
	2	Contra Costa	Acalanes Rd.	7
24W	3	Contra Costa	Fish Ranch Rd.	16
580E	4	Alameda	Eden Canyon Rd.	11
580W	5	Alameda	Off-ramp to Castro Valley Blvd.	6
	6	Alameda	Fontaine Ovps	10
	7	Alameda	13th Ave.	26
880N	8	Alameda	Tennyson Rd.	20
	9	Alameda	Grove Shafter Freeway	9
880S	10	Santa Clara	Tasman Dr./Great Mall Pky.	6
	11	Alameda	Winton Ave.	14
	12	Alameda	On-ramp from Broadway	29

Field Investigations

After determining the locations that display high collision rate only under wet pavement condition, as listed in Table 2, field inspections were made to these sites. The field investigations were generally conducted under wet weather conditions. Observations from these field trips were combined with the CRP plots to investigate the particular attributes of the identified sites. SR-24 is used in the following section to explain the investigation process and findings.

Analysis Based on GPS Data and Site Visits
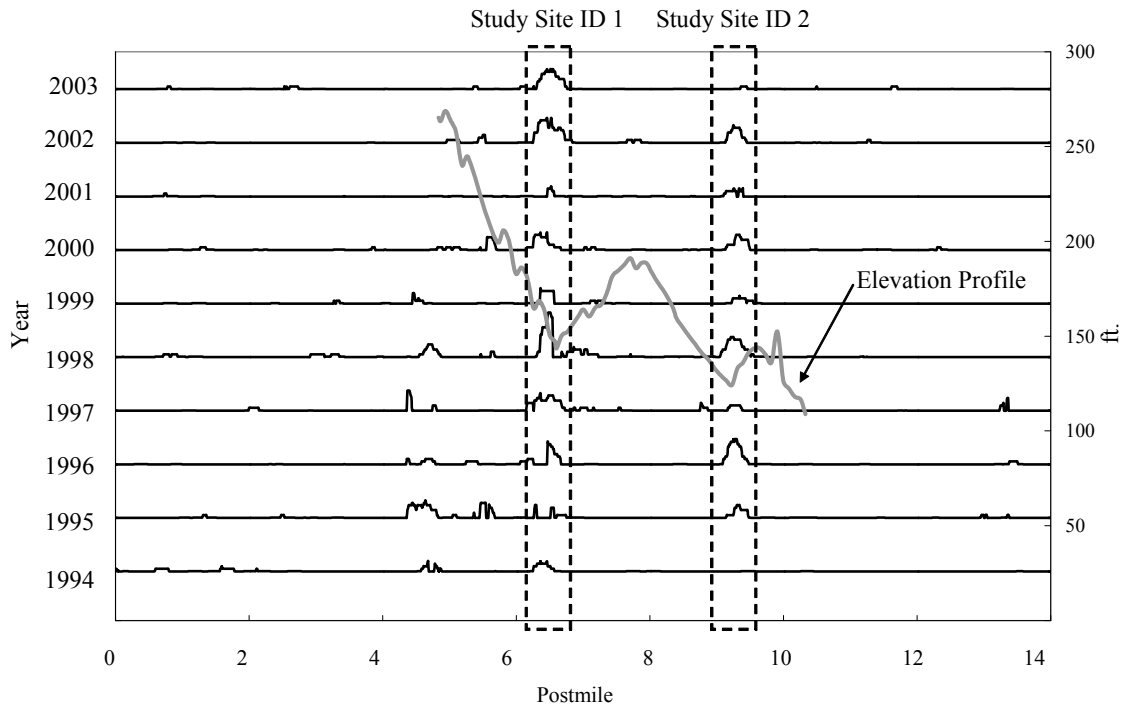
FIGURE 5 Wet-only continuous risk profile and elevation profile (SR 24 East, 1994-2003).

Figure 5 shows the wet-only CRP plots along 14 miles of eastbound SR-24 for the years between 1994 and 2003. The plot illustrates how the collision rate varied over the corridor in each of the ten years. Two sites that displayed high collision rates only under wet pavement conditions are marked by dotted boxes in Figure 5. The yearly CRP plots are shown together in Figure 5 to demonstrate how the plots are reproducible over the years and average collision count per unit distance over the ten years was used for the reference risk for each year.

   During the field trips, a global positioning system (GPS) was used to record altitude data along the freeway. The elevation profile of the corridor is shown in the figure by the solid grey line, with the altitude indicated by the right vertical axis. Locations of the two sites that showed high collision rates (site ID 1 and 2) matched with the locations of vertical sags on the highway.

   Field investigations were conducted in first quarter of year 2007 to all twelve study sites. The study sites were found at or in the vicinity of vertical sags and horizontal curves. One other common site condition at some of these locations is the presence of heavy vegetation, which can potentially clog the drainage during the rainy season (from November to April in the San Francisco Bay Area).

Collision Distributions under Dry and Wet Pavement Conditions
Detailed analysis of collision patterns at the identified locations were carried out to evaluate the differences in collision distribution and primary collision causative factor under different pavement conditions. Figure 6 shows collision distribution at site ID-1. At this location, 28 collisions occurred under dry pavement conditions, while 105 collisions occurred while pavement condition was wet years between 1994 and 2003. The black bars indicate the distribution of collisions related to wet pavement, while the grey bars show collisions related to dry pavement. Pronounced increase on collision distribution on the "beyond shoulder drivers left" was observed under wet conditions.
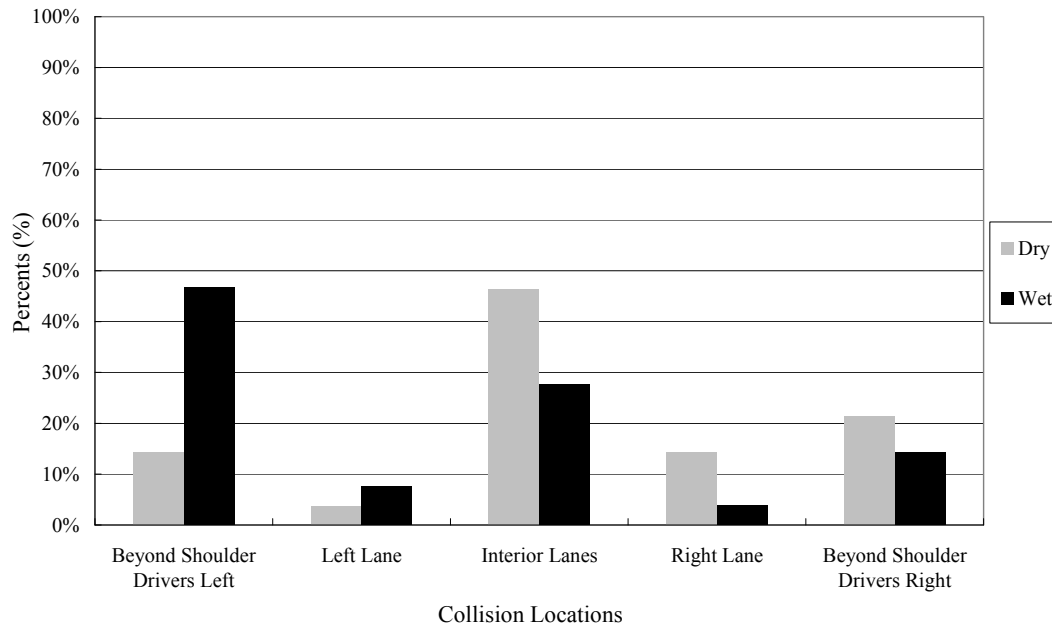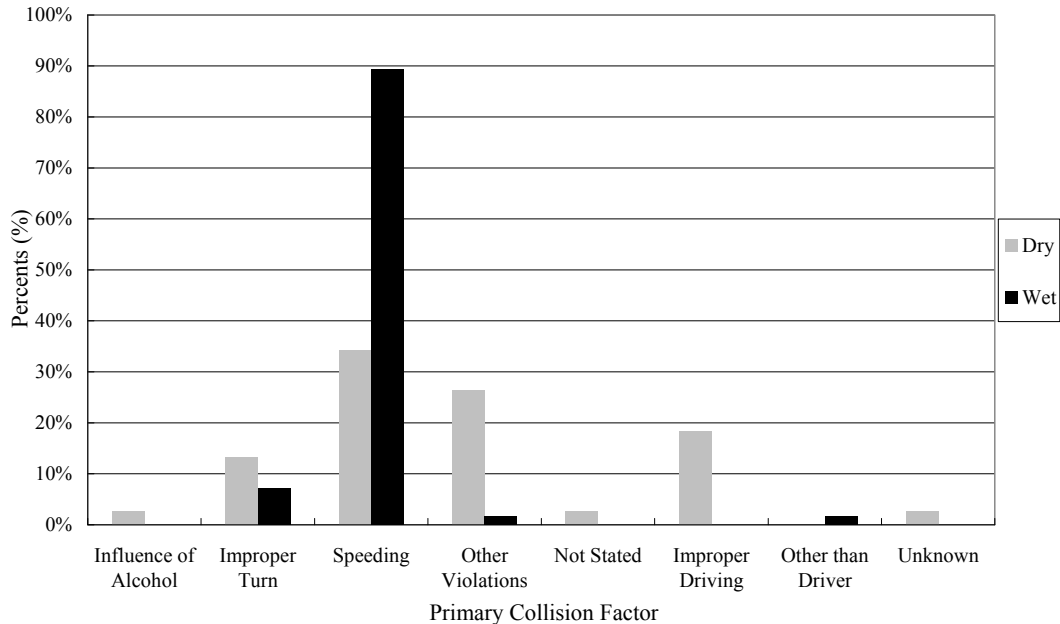

FIGURE 6 Collision Location of Site ID-1

   Analysis of collision data at other sites also shows a notable shift in collision distributions

to one side or both sides of roadways.

   Speeding became more dominant primary causative factor among the collisions that occurred under wet pavement condition and this is illustrated in Figure 7. The figure compares primary collision factors under different pavement conditions at site ID-1. It can be seen that the effect of speeding is amplified by the wet pavement conditions.

FIGURE 7 Primary collision factor of site ID-1

CONCLUSION

This paper documented findings from investigating freeway sites that displayed high collision rates only under wet pavement conditions. These locations were selected by constructing the continuous risk profile (CRP) plots and brief description of the CRP approach was presented in the methodology part.

   Investigation of the collisions that occurred under wet pavement condition at the twelve sites revealed marked shift in collision distributions. The general trend was increase in collision frequencies in one side or both sides of freeways. Speeding becomes more dominant collision causative factor. These sites were located at or in the vicinity of vertical sags or horizontal curves. Heavy vegetations were also often found at these sites.

   For a systematic identification of wet-only collision concentration locations, the continuous risk profile method was applied to 380 mile of freeway. The screening for sites that uniquely show high collision rate under wet pavement condition based on this approach can also be compared to other methods for further evaluation of different methodologies. The continuous risk profile method shows promise for use in evaluating the potential effectiveness of safety countermeasures.

ACKNOWLEDGEMENTS

REFERENCES
1   California Department of Transportation. *Table C Task Force: Summary Report of Task Force's Findings and Recommendations.* Caltrans, 2002
2   Chung, K., and Ragland, D.R. A Method for Generating a Continuous Risk Profile for Highway Collisions. *Transportation Research Board Annual Meeting 2007*, Paper #07-0668.
3   Andrey, J., Mills, B., Leahy, M., and Suggett, J. Weather as a Chronic Hazard for Road Transportation in Canadian Cities. *Natural Hazards*, Vol. 28, 2003, pp. 319-343.
4   Black, G.W. Jr., and Jackson L.E. Pavement Surface Water Phenomena and Traffic Safety. *Institute of Transportation Engineers. ITE Journal*, Vol. 70, No. 2, 2000, pp. 32-37.
5   Kokkalis, A.G., and Panagouli, O.K. Fractal Evaluation of Pavement Skid Resistance Variations. I: Surface Wetting, *Chaos, Solitons & Fractals*, Vol. 9, No. 11, 1998, pp. 1875-1890.
6   Cassidy, M.J., and J.R. Windover. Methodology for Assessing Dynamics of Freeway Traffic Flow. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1484, TRB, National Research Council, Washington, D.C., 1995, pp. 73-79.
7   Chung, K., and M.J. Cassidy. Test Of Theory of Driver Behavior on Homogeneous Freeways. In *Transportation Research Record: Journal of the Transportation Research Board*, No.1883, TRB, National Research Council, Washington, D.C., 2004, pp. 14-20.
8   Ljung, L. *System Identification - Theory for the User.* Prentice-Hall, Upper Saddle River, New Jersey, 1999.