RESEARCH

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Utah Department of Transportation - Research Division

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SKID CORRECTION PROGRAM USER'S MANUAL

Prepared For:

Utah Department of Transportation
Research Division

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16. Abstract

This document outlines methods for use by UDOT personnel to address pavements with unacceptable skid numbers. The program involves coordination between Safety, Pavement Management, Region, and Maintenance managers. A process has been recommended using a skid number history, crash history, and other information to make decisions concerning these pavements.

This manual provides flow charts, templates and examples to facilitate implementation. The program requires very limited manpower in decision-making and delivery of information to UDOT stakeholders. Implementation of this manual should result in enhanced analysis methods and better communication between UDOT divisions and regions.

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Purpose and Scope

The goal of this program is to help the Utah Department of Transportation (UDOT) address sections of highway with unacceptable levels of skid resistance with a formal and coordinated approach. An organized endeavor is needed between the Planning Statistics Section, the Region Offices, Central Maintenance, and the Division of Traffic & Safety to make the program function effectively.

The stopping distance of vehicles is directly impacted by the skid number of the pavement surface. Low skid numbers can result in an excessive increase in stopping distance resulting in the potential for an increase in crashes. This problem is amplified during conditions when the pavement surface is wet.

The concept behind UDOT's Skid Correction Program is to identify and reduce the negative safety impacts associated with unacceptable levels of skid resistance on pavement surfaces. An effective program must identify the extent of the problem, establish a priority for correction, and recommend appropriate actions. These tasks should be based on the available skid numbers, traffic characteristics, and the overall pavement condition.

Skid Correction Process

The steps described in Table 1 are recommended to analyze and address the skid resistance deficiencies of pavement surfaces in Utah. Included for each step is a target timetable aimed at completing the task in a reasonable amount of time. It is important to keep the time expended for each step to a minimum to allow UDOT personnel to implement actions in a prompt manner for highway sections with safety concerns.

A flow chart is included in Figure 1 to illustrate the process used identifying the appropriate stakeholders and what deliverables they will be required to produce. This flow chart provides a visual description of the steps needed in the process. It is crucial that the data and decision-making take place effectively between the Planning Statistics Section, the Traffic & Safety Division, and the Region Offices.

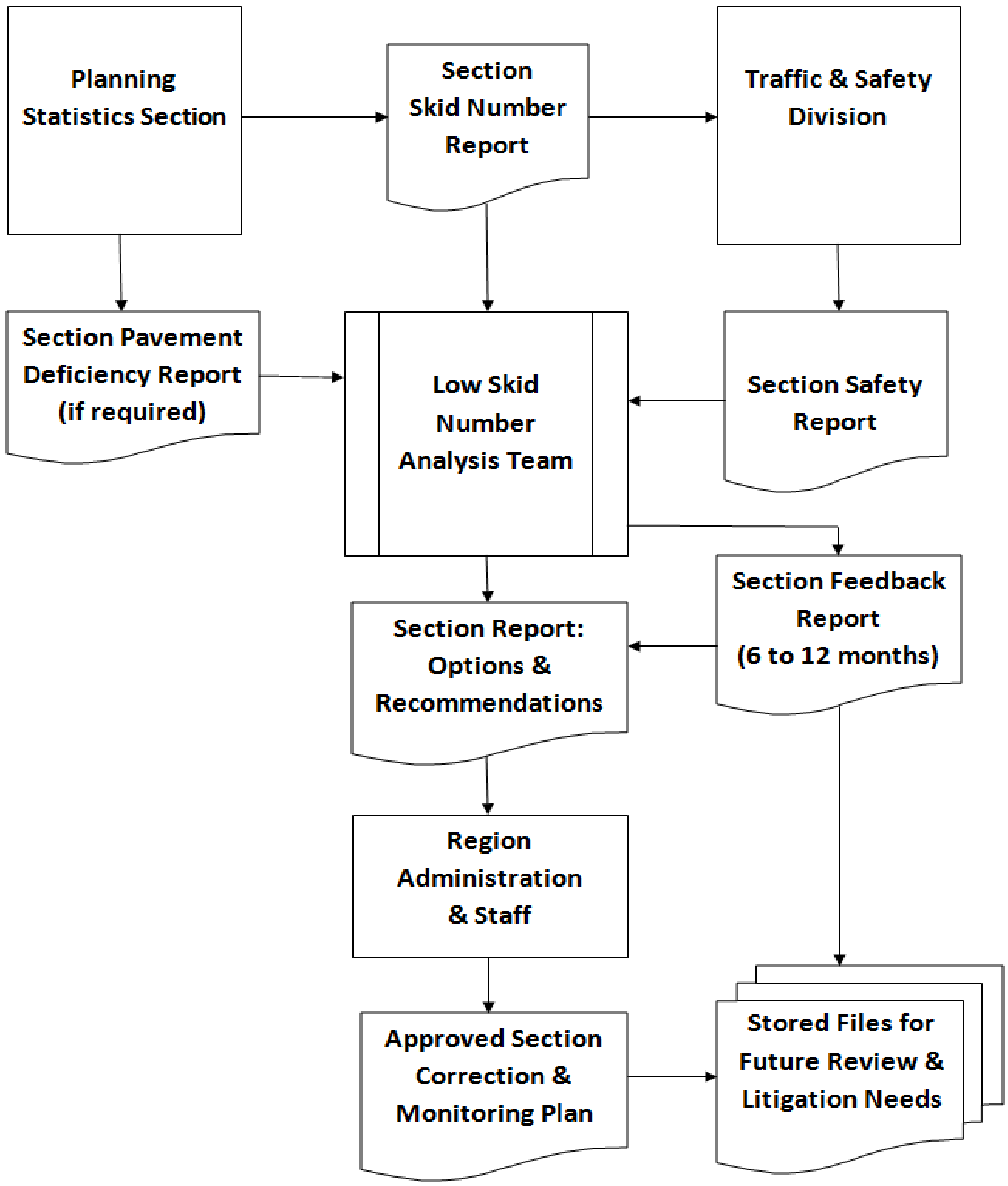
This process can be made more manageable to the stakeholders by using the UDOT uPlan system. Each responsible division, section and region could post the information on uPlan entry. The data entered will be password protected and for use by authorized personnel only.

Table 1
Skid Correction Program Steps

Skid Correction Program Steps	Complete by	Stakeholder	Person-Hours
1-Identify the problem using the Locked-Wheel Trailer testing as a trigger	Day 10	Pavement Condition Engineer, Planning Statistics Section	2 hrs
2-Determine the highway section boundaries using the results from the skid testing	Day 10	Pavement Condition Engineer, Planning Statistics Section	2 hrs
3-Produce a skid number history using data collected over the most recent 6 to 8 years	Day 10	Pavement Condition Engineer, Planning Statistics Section	4 hrs
4-Develop a crash history for the road section	Day 30	Crash Studies Engineer, Traffic & Safety Division	8 hrs
5-Gather information related to the severity of the crashes occurring on the section	Day 30	Crash Studies Engineer, Traffic & Safety Division	4 hrs
6-Calculate the number and percentage of wet weather crashes	Day 30	Crash Studies Engineer, Traffic & Safety Division	2 hrs
7-Identify other pavement deficiencies existing on the highway section for use in strategy selection	Day 40	Pavement Condition Engineer, Planning Statistics Section	4 hrs
8-Use sound pavement management techniques to recommend practical solutions	Day 60	Region Operations, Materials, and Traffic Operations Engineers	4 hrs
9-Select a corrective or mitigation strategy including the timing of the action and file the plan into program records	Day 70	Region Operations, Materials, and Traffic Operations Engineers	6 hrs
10-Monitor the roadway section over time to determine the effectiveness of the strategy and file the results	1 Year	Pavement Condition Engineer, Planning Statistics Section	2 hrs
11-Select a new strategy if needed based on the new information and the data from previous years	1 Year	Region Operations, Materials, and Traffic Operations Engineers	2 hrs

Figure 1

Low Skid Number Section Process Flow Chart



Skid Number Data and Analysis

The key trigger for the program is when a section of highway is tested below the minimum acceptable value for a significant length. Analysis of a pavement section should be triggered when the observed skid numbers are in the unacceptable range. The section length defines the study segment where all data will be analyzed. Ranges corresponding to unacceptable, marginal, or acceptable skid numbers are shown in Table 2.

Table 2
Skid Number Trigger Values

Functional Class	Unacceptable	Marginal	Acceptable
Interstate Highways	Less than 30	30 to 40	Greater than 40
Non-Interstate Highways	Less than 35	35 to 45	Greater than 45

These values are based on extensive studies related to crash frequencies on Utah's highway system over many years. The crash frequency has been shown to begin to increase within the marginal range, and rise significantly in the unacceptable range. This trend is also significant for wet-weather crashes. Examples are provided in Appendix A.

In a typical year, skid numbers for one to two percent of Utah's Highway system fall within the unacceptable range. Values in the marginal range may trigger an analysis if the section is in a high volume corridor or safety issues have been observed in the area. <u>The analysis process should be put into motion within ten days of observing unacceptable skid numbers on a pavement section.</u>

For the analysis, a skid history is needed to determine how rapid the problem has developed and to indicate how the issue has impacted safety in the past. An example skid history is provided in Figure 2.

Safety issues are often made worse by loss of skid resistance over time. Loss of skid resistance is associated with increased stopping distance. Increased stopping distance may result in an increase in both crash frequency and crash severity. It cannot be overstated how important the work done by members of the Division of Traffic & Safety is in providing accurate crash data for use in enhancing safety related decisions made in UDOT programs. The use of this information in reducing the risk to the traveling public is of utmost importance.

Gradual Loss Skid Number History

An example of a gradual loss in skid number is illustrated in Figure 2. This trend typically indicates that the loss in skid resistance is due to traffic wear or environmental degradation.

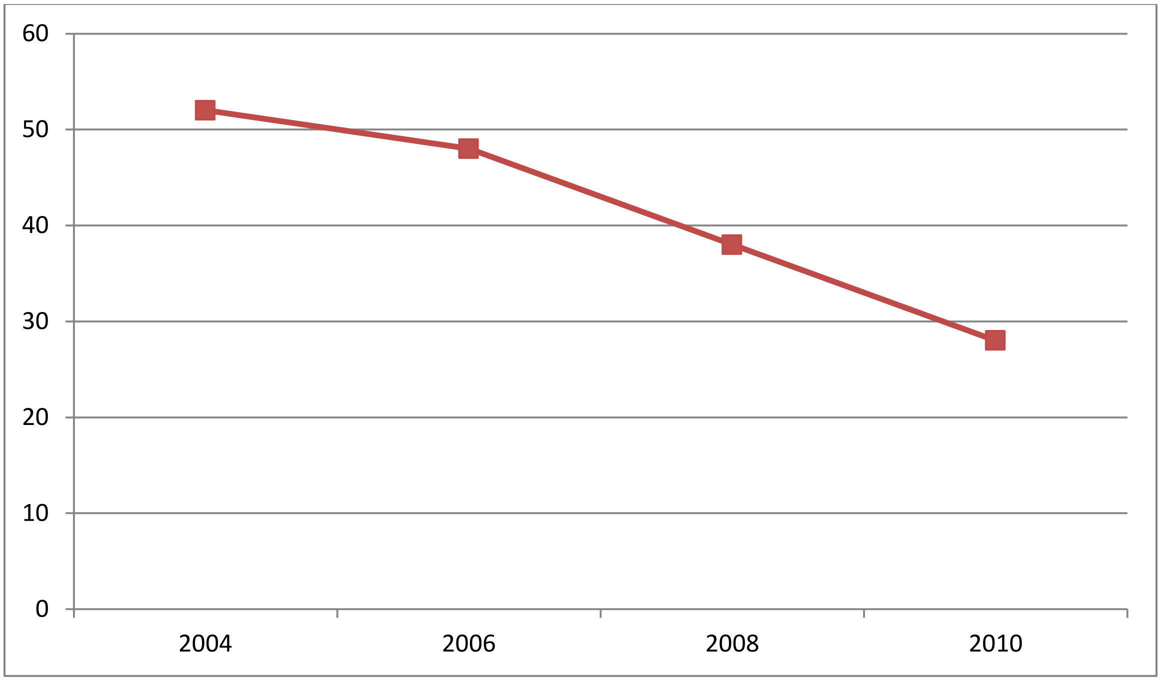


Figure 2- Gradual Loss of Skid Resistance

Causes of Gradual Loss of Skid Resistance on Asphalt Concrete (AC) Pavements:

Polishing aggregate- As a pavement surface receives traffic loading or weathering the resistance to skidding is reduced if the micro-texture of the aggregate or macro-texture of the pavement surface is inadequate. This is the friction between a vehicle tires and the large and medium aggregates on the surface of the pavement. Some aggregate sources polish under traffic where the micro-surface is removed. Other aggregate sources are naturally polished prior to being mixed with the asphalt binder due to wearing actions at the aggregate source.

Certain laboratory testing prior to mixing the pavement can limit the use of these polishing aggregates. However, there is not a direct, reliable relationship between the laboratory test results and performance in the field. For this reason, some polishing aggregates are inadvertently used in asphalt pavement mixes on occasion.

The best way to treat polishing aggregates on an asphaltic concrete pavement is to place a new surface on top of the existing pavement or to remove and replace the existing surface.

Bleeding surface- Under traffic loading, asphalt binder can be pushed to the surface of a pavement. Also some pavement treatments can increase the asphalt binder at the surface. This may result in a reduction of the macro-texture of the pavement known as bleeding.

Bleeding surfaces can be treated using a milling operation or treating the surface with sand. Natural weathering will sometimes eliminate the problem, so monitoring of locations with surfaces that have low skid resistance due to bleeding may be useful. However, if the roadway section is a high crash area, action should be taken within a reasonable time period. This decision should be a team decision made at the Region level with input from other stakeholders.

Causes of Gradual Loss of Skid Resistance on Portland Cement Concrete (PCC) Pavements:

Loss of macro-texture- New concrete pavement surfaces have textures applied using brooms, transverse tining, longitudinal tining, or other methods. Traffic and weathering can wear off this macro-texture, leaving a smoother surface with lower skid numbers. Texture wear is a factor of aggregate hardness, traffic volumes, and depth of the applied texture. When surface wear occurs on concrete pavements, friction between vehicle tires and the pavement surface relies on the micro-texture of the large aggregates. Aggregates with good properties will provide acceptable resistance to skidding for many years.

When low skid numbers result from loss of texture, a new surface should be considered. Options include diamond grinding operations and steel shot treatments. Diamond grinding applications leave a high skid resistant surface on concrete pavements. Steel shot treatments can be used to apply improved textures to concrete pavements with low skid numbers. Thin bonded surfaces can also be used to apply aggregates with sharp angles and good skid properties. Diamond grinding operations, steel shot treatments, and thin bonded surfaces are most often justified on bridge decks or other short problem areas.

Polishing aggregate- Over time the texture of any PCC pavement surface will show wear. As noted above, resistance to skidding relies more on the micro-texture of the aggregates in the PCC mix when the surface is worn. Aggregates with high micro-texture properties may provide resistance to skidding. Aggregates that show a tendency to polish will ultimately result in low skid numbers on PCC pavements.

The best way to treat polishing aggregates is to place a new surface on the pavement. New textures will increase the skid numbers. As the texture wears the skid numbers will return to the values allowed by the micro-texture of the aggregate.

Skid histories are valuable in estimating the life of a new surface for a given road segment. Unless traffic changes significantly the life of the new texture will be similar to the life of the previous surface. Where hard aggregates show extended texture life, a new texture will be more economical than resurfacing if no other major deficiencies exist on the pavement.

Buildup of cement dust on surface- Cement dust (known as laitance) caused by surface wear can build up on PCC pavements. This is common when dry periods prevent rain from washing this material off of the surface. Dry states like Utah experience this problem more often than regions that receive rainfall more frequently. Skid numbers that are 5 to 10 numbers lower than normal are observed on concrete surfaces following dry periods of more than 3 or 4 weeks. The problem occurs when rain mixes with this dust after a dry period, causing friction loss at the pavement-tire interface. This has been observed in Utah during dry summer months on certain concrete pavements.

This factor may be important when making decisions to address low skid numbers on certain road segments. Skid numbers taken during various seasons can be useful in determining how a cement dust issue may be affecting friction on high traffic road segments with PCC pavements.

Rapid Loss Skid Number History

An example of a rapid loss in skid numbers is illustrated in Figure 3. One problematic issue with rapid loss of skid resistance is that crash histories at these sites may not show how the loss of skid resistance affected safety since the loss is recent. However, a crash history is still very much needed under these circumstances. If safety issues existed prior to the skid number reduction, they may be aggravated by the loss of skid resistance.

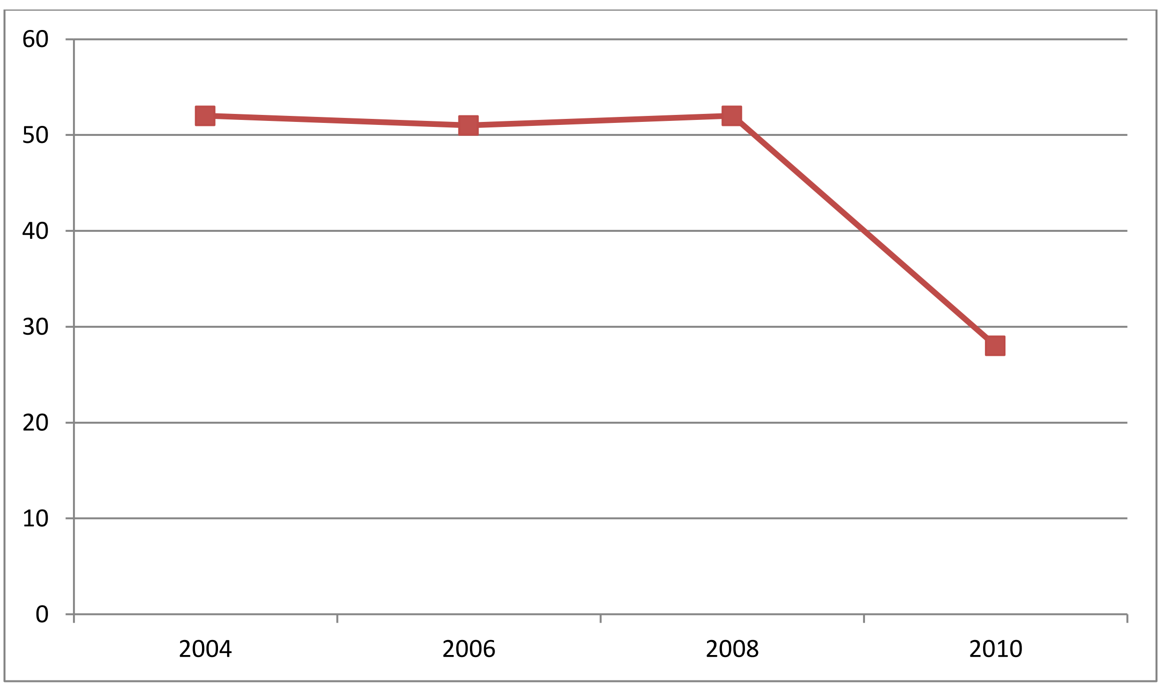


Figure 3- Rapid Loss of Skid Resistance

Causes of Rapid Loss of Skid Resistance on Pavements:

Rejuvenating agents or flush coats- Use of rejuvenating materials have been shown to result in a rapid reduction in skid numbers by 10 to 15. The skid numbers do recover over time as the treated surface cures and weathers. The time needed for this return to an acceptable skid number depends on the application rate, time of year treated, traffic loading, and other factors. The use of rejuvenating agents is not recommended on pavements with skid numbers below 45 on Interstate highways and 50 on non-interstate sections.

Road segments where low skid numbers result from rejuvenators or flush coats can be treated with sand or monitored for traffic wear if the section is not a high crash area. More aggressive methods should be considered to address the issue where safety concerns are expressed by the Region staff or Traffic and Safety personnel.

Concrete Sealers- Some agencies utilize concrete sealers to protect PCC pavements from deterioration. Certain concrete sealers have been shown to lower skid numbers. An Experimental Project was conducted in Utah to determine which concrete sealers could be safely used on pavements, and which ones should be restricted to vertical surfaces. The results of this project are reflected in the Utah New Products Approved Listing. When horizontal surfaces that will support traffic are scheduled for a concrete sealer, this list should be used to select an appropriate material that will not result in skid numbers in the unacceptable range.

Crash History

A thorough review of the crash history of a road segment with low skid numbers is very important. The number of crashes, the crash frequency, and the severity of the crashes should be reviewed. Also, the analysis should focus on the types of crashes and the primary contributing factors in the crash records.

Crash Trend Follows Skid Reduction:

The crash history often shows a corresponding increase in crash frequency as the skid number drops into the unacceptable range. This usually occurs on highway sections with high traffic volumes and/or areas with significant points of conflict such as areas with congestion or driveways. Certain geometric elements such as horizontal curves and steep grades may influence crash trends when skid numbers are low. Experts should be consulted to determine if these trends are within crash numbers expected for the highway functional class and volumes. If it is determined that action is justified, an analysis to select a strategy should be conducted.

If both skid numbers and crash history are at unacceptable levels, a high priority should be given to the correction strategy. Rapid solutions may include moving scheduled preventive surface treatments to the current year. An example crash history with significant increases in the rate is shown in Figure 4.

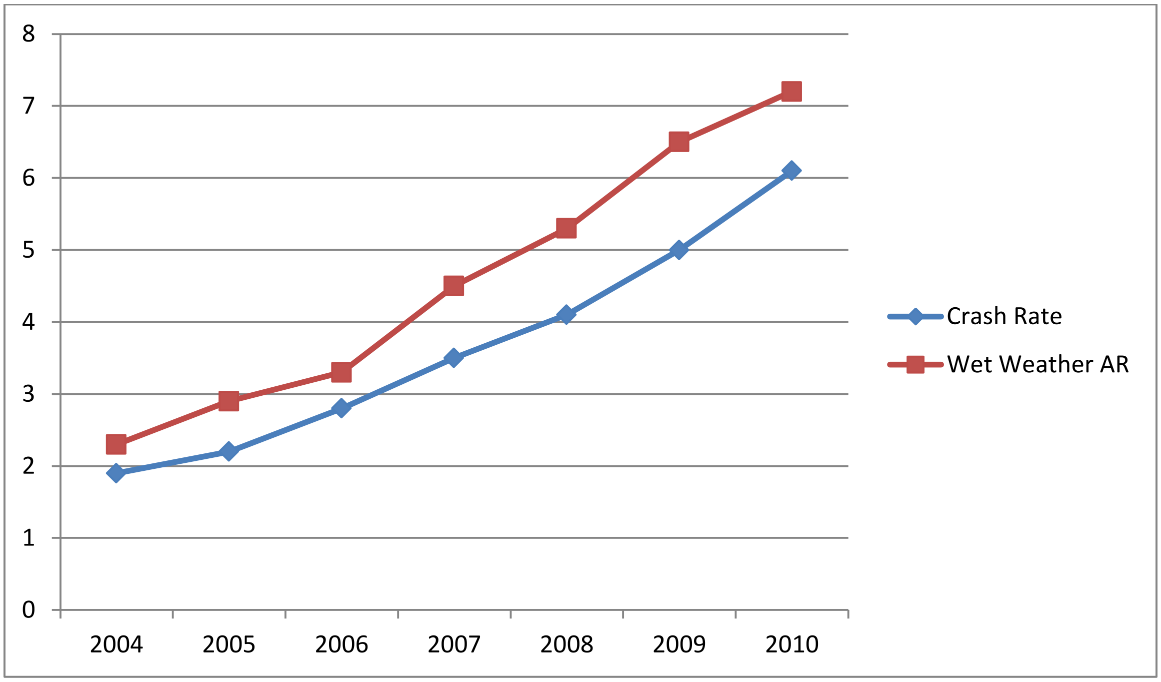


Figure 4 – Crash Rate Increases with Loss of Skid Resistance

Crash Trend Not Affected by Skid Reduction:

Low skid numbers have been shown to have a minimal safety impact on certain road segments. An example is illustrated in Figure 5. Longer stopping distances are tolerable in some low volume areas with few conflict points and straight, flat geometric elements. In these areas, the timing of the corrective activity may not be as critical as in higher risk areas.

Funding for maintenance is limited and often does not meet all of the needs of the transportation system. For this reason priority should be given to locations where the safety problems are more significant as shown by this analysis. Low-cost solutions such as posting "Slippery When Wet" signs and monitoring at the lower risk sites may be appropriate in the situation where there are not enough funds to fix all problem areas.

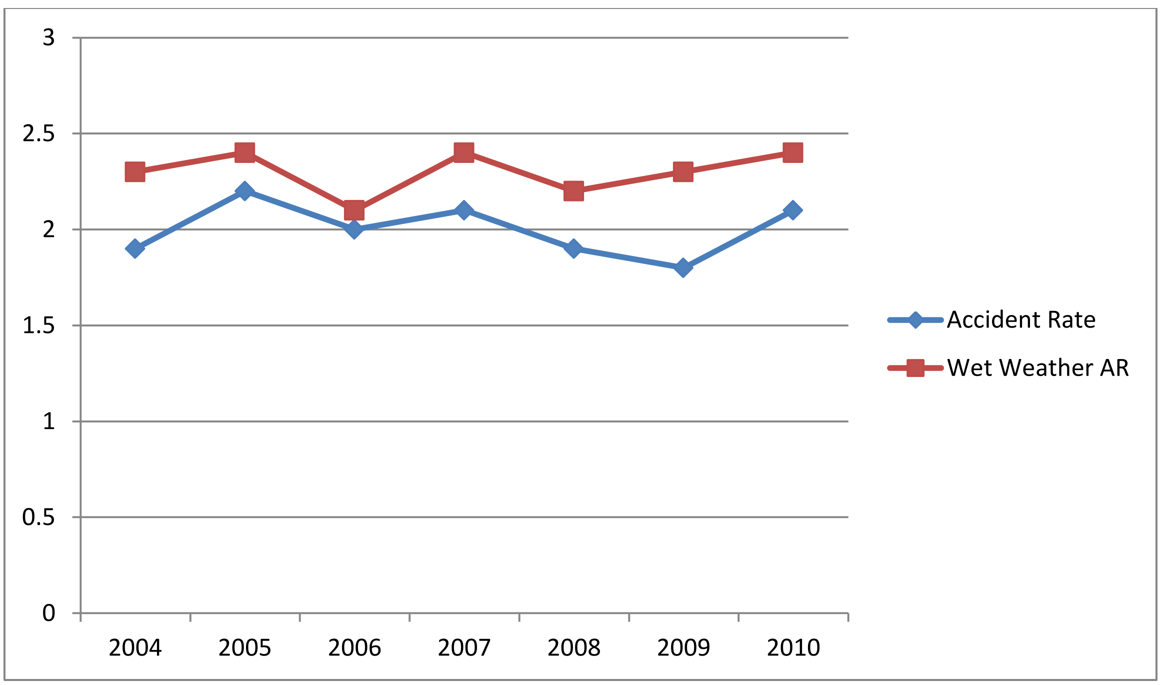


Figure 5 – Crash Rate Not Affected by Loss of Skid Resistance

Wet Weather Crashes:

The number of wet weather crashes and the percentage of the wet weather crashes compared to the total are very useful for analysis. These numbers can be used to determine if unacceptable or marginal skid numbers are impacting safety in wet weather conditions. Under normal pavement conditions, the stopping distance increases by 25 to 30% when a pavement is wet compared to dry conditions. When skid numbers are low, the increased stopping distance is increased even further due to the wet pavement surface.

Utah is the second driest state in the country. If significant numbers of wet weather accidents occur on a road segment, it should be a concern to UDOT managers and officials. In addition to low skid numbers, wet weather crashes may be significant due to other factors. These factors include drainage problems, water accumulating in ruts, icing of bridge decks, or loss of visibility due to spray. For this reason, the Traffic and Safety Division should identify any wet weather related crash clusters statewide. These sites may be different than the locations with low skid numbers but should be analyzed and prioritized using the same process described earlier in this document.

A template for entering the information for use is included in Appendix C. This template facilitates the input of the needed data, and aids in the accumulation of a complete set of information. In this way all of the information supplied by multiple stakeholders in compiled in one place.

Other Pavement Deficiencies

Pavement deficiencies existing on the pavement section should be considered in addition to the low skid number when selecting a correction strategy. This includes factors such as pavement roughness, cracking, rutting, and drainage.

An appraisal of all of the pavement deficiencies should be considered when selecting a correction method for the pavement to ensure that a cost-effective solution will be programmed. Funding for strategies that correct the surface texture only may be less efficient if strategies such as overlays and other measures are implemented in just a few years.

Good pavement management techniques are crucial in this step to compile all of the available data and engineering knowledge into the process. The region staff should take the lead on this step and utilize expertise from other sources as needed.

Skid Correction Strategies

Correction strategies can range from aggressive solutions to those where monitoring can be the best action. The following strategies are typical actions that may be taken to address a highway segment with low skid numbers:

- Schedule a surface treatment during the next construction season
- Schedule an overlay to correct the low skid numbers and other deficiencies on the roadway segment
- Mill the pavement surface if bleeding is observed
- Treat the pavement with blotter sand if a rejuvenator or flush seal is present and causing potential safety problems
- Diamond grind the surface of PCC pavement if an acceptable treatment life is predicted
- Apply a steel shot texture on PCC pavement
- Post "Slippery When Wet" signs and monitor the segment over time until acceptable skid numbers are restored

Establishing an appropriate priority for the strategy is a very important aspect of the plan. UDOT engineers and managers are responsible to maintain all highway segments in an acceptable condition for the traveling public. Notice of a deficiency to UDOT personnel is considered the time for a decision to apply one of the following time-lines to the issue:

1. Act immediately with a solution to correct the low skid numbers
2. Schedule a correction in the near future, or
3. Monitor the skid numbers and accident history over time.

Highway segments with skid numbers that fall into the unacceptable range should be of major concern and receive a high priority if any of the following safety issues exist:

- A high number of crashes are observed
- The crash rate is above the expected level
- The crash severity is above the expect level
- The wet weather crashes exceed 30% of the total number

Legal Considerations

All UDOT programs that have a direct impact on the safety of the traveling public should take into consideration the legal aspects of the program activities. If a request is submitted through the Government Records Access and Management Act (GRAMA) or if any formal legal action is taken related to the program, the following information will be a necessity and will reduce UDOT's liability for safety issues:

- A formal process is in place to address highway segments that have measured or suspected skid resistance issues
- Documentation that the process has been followed including analysis and the correction of safety deficiencies
- Complete files of the data and other information used
- A description of the analysis done including the criteria used
- The actions taken based on the analysis
- The reasons the strategy was selected including any budget limitations
- A description of why the priority for the action was given compared to other road segments with safety concerns
- The results of any performance measures and feedback information assembled for the site

Record Keeping:

Maintaining formal files with the information listed above will be of significant benefit to UDOT. These files indicate a commitment to safety and display an understanding of what is needed to succeed in addressing deficiencies. Most judges understand that UDOT does not have unlimited funding to deal with these issues, but has dealt with the deficient sections appropriately based on available time and resources.

Although this seems like a time-consuming activity, the cost and labor related to this can be minimized using creative forms and filing techniques. Time spent will be recovered through more efficient information generation during court ordered data submittals and GRAMA requests.

Constructive Notice:

In legal actions, “constructive notice” of a highway safety issue is considered just as valid as “actual notice”. Constructive notice is in play if any UDOT employee is aware of an issue. Under the law all UDOT employees have notice of the deficiency and must act accordingly. This adds to the need for formal interact between the various stakeholders within UDOT.

Lawsuits against highway agencies are more often dismissed when it can be demonstrated that good data was compiled, an effective strategy selected, an appropriate priority set, and the strategy was implemented. Priorities are crucial to show that deficiencies are analyzed and corrected based on sound data and policies. It is also important to show that projects that did not receive high priorities did not carry sufficient urgency compared to other issues based on the limited program funding.

Performance Measures and Feedback Information

It is essential that the UDOT follow-through with feedback information to evaluate the effectiveness of the actions taken on locations with low skid numbers. This information should be filed for use if needed during any litigation taken against the Department. Also the measured success of implemented actions is valuable in future decision-making and pavement management programs.

Feedback Testing:

When the surface of a pavement is treated to improve the skid number, special testing of the site may be appropriate. Personnel in the Division of Planning, Pavement Management Section can provide this testing upon request. It is crucial to archive data showing that the deficiency was corrected in a timely manner related to the physical abilities of the staff and the budget limitations of the Department.

In cases where no action was taken, this feedback process may necessitate long-term monitoring of the highway segments. Once the surface is replaced due to the normal pavement maintenance program and the skid number has been returned to an acceptable level, the monitoring can be terminated. All feedback information should be maintained until the statute of limitations has expired.

Aggregate Source Analysis to Improve Skid Resistance:

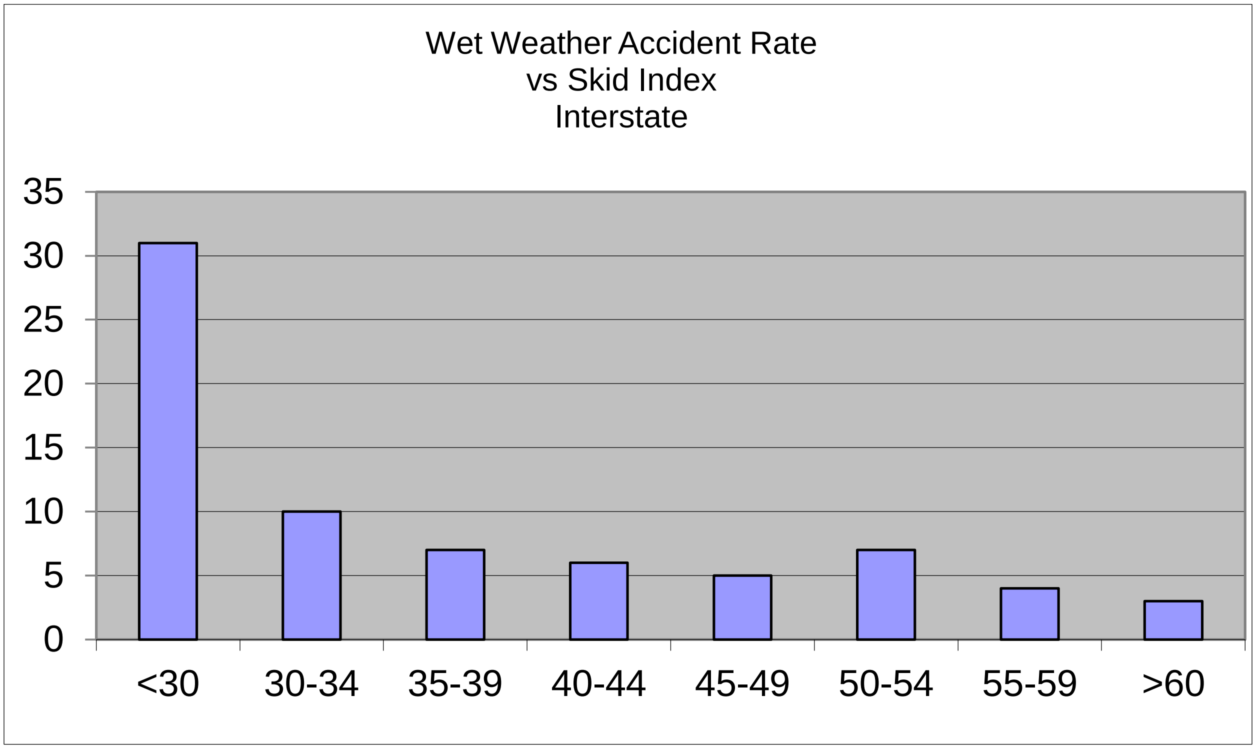
Over the years UDOT materials engineers have observed certain aggregate sources that have poor skid resistance characteristics. These aggregates demonstrate unacceptable microtexture when used as a pavement surfacing material. Often the skid numbers measured are not satisfactory during the initial skid measurements or shortly after minimal traffic loading.

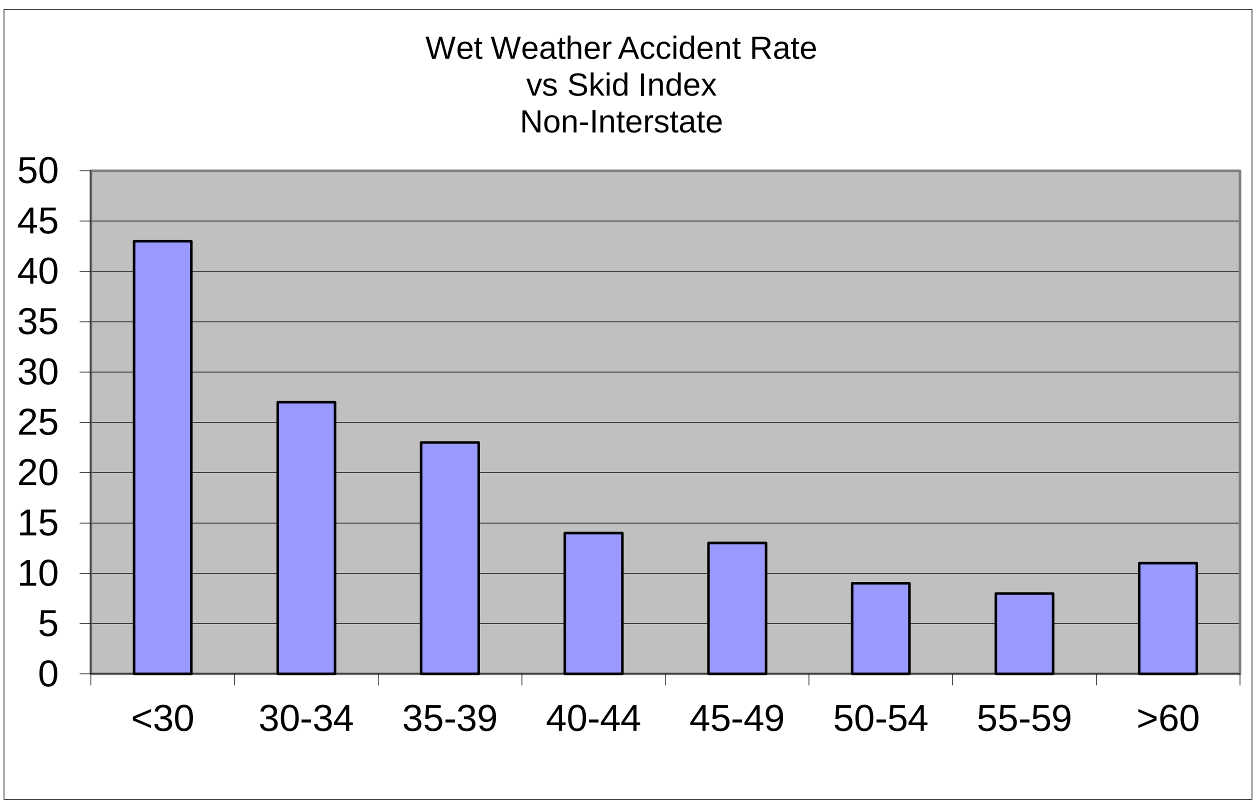
A study to evaluate the microtexture and polishing characteristics of aggregates around the state is recommended. Data gathered from the skid correction program is natural input to the aggregate source analysis.

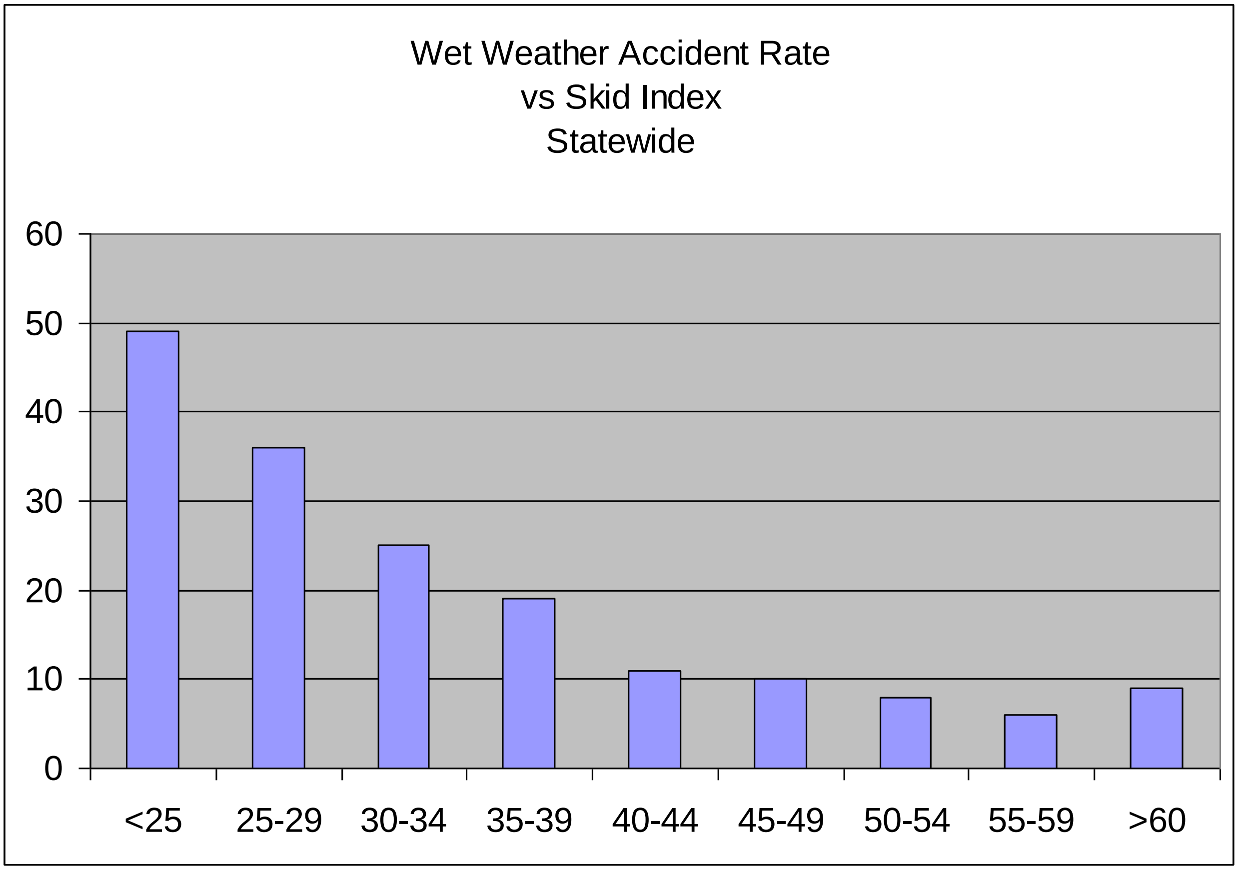
Correlations between low skid numbers and aggregate sources are needed on a routine basis. As new aggregate pits are opened around the state it is important to evaluate their skid resistance properties in the field.

Appendix A

Skid Numbers vs. Crashes






Wet Weather Accident Rate
vs Skid Index
Statewide
60
50
40
30
20
10
0
<25
25-29
30-34
35-39
40-44
45-49
50-54
55-59
>60

Appendix B

FHWA Criteria for Low Skid Numbers

Crash Problem

Crashes that occur when the pavement is wet on approaches with speed limits of 45 mph or more may be attributed to increased stopping distances due to low skid numbers and/or severe rutting in the wheel paths that might induce hydroplaning.

Countermeasures

The low-cost countermeasure for intersections with higher frequencies of wet pavement crashes and above average wet/total crash rates include increasing the friction characteristics on intersection approaches which have low skid numbers and eliminating any severe wheel path rutting.

One way transportation officials can increase pavement friction beyond what is attainable through traditional techniques is by using new high-friction surfacing systems. These systems are a combination of resins and polymers (usually urethane, silicon, or epoxy) and a binder topped with a natural or synthetic hard aggregate. Micro-texture, macro-texture, and the durability of that texture distinguish these overlays from standard asphalt and concrete pavement surfaces. High-friction surfacing systems typically use much smaller and harder aggregates, such as calcined bauxite, slag, or other synthetic aggregates. These aggregates are generally less than 6.0 mm (0.23 inch) in diameter and have high skid resistance. The small and hard aggregate makes the overlay much more resistant to wear and polishing. The resin or polymer binder combination locks the aggregate firmly in place, creating an extremely rough, hard, durable surface capable of withstanding everyday roadway demands such as heavy braking and snowplowing. The rougher texture and greater surface area increase the pavement's friction.

The length of approach to apply skid resistance surfaces is variable dependent on approach speeds, sight distance, and expected queue lengths at signalized intersections. A minimum 300 feet of approach is recommended for through high-speed approaches to stop-controlled intersections. In addition, significant wheel rutting (2 inches in depth or greater) should be eliminated before applying any skid resistant surface.

Countermeasure Crash Reduction Factors, Threshold Levels, Additional Implementation Factors, and Estimated Cost Ranges

Crash reduction factors for skid-resistant surfaces on high-speed (i.e., 45 mph or greater) intersection approaches with a high frequency and rate of wet pavement crashes and either (1) a ribbed tire skid number of 30 or less, (2) wheel path rutting of at least 2 inches in depth, or (3) both, is 50 percent of wet pavement crashes (*The FHWA Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer*).

Typical threshold crash levels for considering friction countermeasures on high-speed approaches to intersections are provided in Table B.

Table B: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Skid Resistance Countermeasures at Intersections with High Rates of Low-Friction Crashes

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Implementation Cost Range per Intersection
Skid resistance surface	50% (wet pavement crashes only)	8 wet pavement crashes in 5 years, a wet /total crash ratio above the statewide average wet/total crashes for intersections	8 wet pavement crashes in 5 years, a wet /total crash ratio above the statewide average wet/total crashes for intersections	High-speed approaches (45mph or greater) and a ribbed tire skid number of about 30 or less.	$20,000 to $50,000

Appendix C

Low Skid Number
Section Analysis
-Template-

Section Information:

Route No.___________ Region ______Station No.__________

Milepoint___________to___________

Skid Number History:

	Average	Minimum
2011	_______	_______
2010	_______	_______
2009	_______	_______
2008	_______	_______
2007	_______	_______

Skid Number Graph:

Crash History:

Average crashes per year	_______	Average wet weather	_______	_______%
2011	_______		_______	
2010	_______		_______	
2009	_______		_______	
2008	_______		_______	
2007	_______		_______	
Accident Rate	_______	Expected AR	_______	

Crashes per Year Graph:

Severity of crashes:

	01_____	_______%
	02_____	_______%
	03_____	_______%
	04_____	_______%
	05_____	_______%

Possible Correction Strategies (check all that apply):

- Post "Slippery When Wet" signs
- Chip seal
- Open-graded surface course
- Plant mix seal coat
- Overlay
- Treat with blotter sand to correct rejuvenator or flush seal
- Mill surface to correct bleeding
- Diamond grinding (concrete)

Strategy Timing (check one):

- ASAP
- Swap with another section
- Next Rehab Cycle

Region Approval and Work Order:

Recommended strategy:

Approved timing:

Feedback Information:

Skid Numbers: Date tested:

Crashes per Year: Date: